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**GROUND WATER QUALITY MONITORING AND
EVALUATION IN AND AROUND GREATER
GUWAHATI (ASSAM)**

PART - I : PRELIMINARY



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PREFACE

The sources of ground water pollution are mostly disposals from industries, domestic sewages, insecticides applied in agricultural practices and so on. Quality monitoring of ground water is very essential since it is the source of domestic supply for millions in the country both in rural and urban areas. Ground water pollution is much more dangerous than surface water pollution as the former once polluted, can not be recovered very easily and is remains unusable for a very long time. While surface water pollution is visible and can be directly approached ground water pollution problems can not be so easily handled.

The main objective of the study is of preliminary nature to see the suitability of water for various designated uses in the study area. An analysis of physical properties of water quality parameters are given in this report. The determination of physical parameters from time to time is very important for appraisal of pollution hazards. The work includes determination of such parameters like pH, temperature, % light transitivity, oxidation reduction potential, conductivity, total dissolved solids etc. determined by laboratory and field tests on the water quality samples seasonally collected from a network of selected dug wells in the study area. This study is expected to continue for different other water quality aspects like chemical, bacteriological, radiological and tracer elements.

Guwahati is a fast growing city regarded as the gateway of the north eastern region. With the growth of population and industries there is adverse impact on its ground water reserve which has been source of drinking water for more than half of its citizens. It was therefore proposed to undertake initially ground water quality monitoring and evaluation in the Greater Guwahati.

The study has been carried out jointly by North Eastern Regional Centre, Guwahati and Environmental Hydrology Division, NIH, Roorkee under guidance of Dr. K. K. S. Bhatia, Scientist 'F' and Co-ordinator NERC, NIH, Guwahati.

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ABSTRACT

The quality of ground water varies from place to place and from time to time. Good quality water drawn from a particular strata at a particular time of the year may be unsuitable drawn at other time due to various factors. The quality of water depends on a large number of individual, hydrological, physical, chemical and biological factors. Some parameters are of special importance and deserve frequent attention and observation, while others (like physical parameters) give a rough picture of water body and its quality status.

Ground water quality variation problem can be understood only by the regular monitoring of quality of water. In Greater Guwahati rapid industrial and population growth has taken place during the last decade. The adverse effect on water quality because of this urbanisation has been the concern of the people. Therefore, it was proposed to study ground water quality in and around Greater Guwahati. Samples from twenty three dug wells, representing the shallow unconfined aquifer, were collected in pre and post monsoon season of 1994 and 1995 and analysed for various physical parameters, viz., temperature, pH, conductivity, % light transmission, oxygen reduction potential, total dissolved solids etc. The findings of the water quality tests on the representative time variant samples should be useful to have a first hand knowledge about the quality standards of ground water which is the source of drinking water for a vast population of elite citizens of the locality.

1.0 INTRODUCTION

Water quality has been one of the important water resources issues since 1970s. With the population explosion and rapid industrialisation there is continuous adverse effects on the sources of water and hence on its quality. It is global phenomena that due to human influence and ever increasing pressure on the resources for fulfilling demands, the quality of water is deteriorating day by day. Polluted and unpotable water has been creating many health hazards to the living beings and often cause many water born diseases in the country. Oflate, scientists, technocrats and planners have engaged serious attention to the water quality problems. The water quality study has therefore been presently regarded as one of the trust areas in the water resources sector as envisaged in the national water policy that "*..Both surface and ground water should be regularly monitored. A phased programme should be undertaken for improvements of water quality*".

Ground water is one of the major sources for meeting the domestic needs for the people. So ground water quality studies are not only essential for critical evaluation of its standards for the purposes such as domestic, agricultural and industrial supplies etc. but also required in many cases to ascertain geological history of the area where it occurs.

For proper utilisation of water for various purposes, understanding geo-chemical controls on it and the extent of pollution, it is of paramount importance to carry out systematic monitoring of ground water quality to suggest suitable remedial measures.

The Guwahati city which has been selected for ground water quality study saw its first phase of expansion during the period 1960-1965 with the setting up of the oil refinery, the New Guwahati Goods Yard, the Army Cantonment and the Oil India Campus. The second phase of expansion in 1972 was when the State Capital was shifted to Dispur on the south-eastern strip of the city. Then added

with time where population growth, urbanisation etc. giving rise to great demand for quality water for drinking and allied purposes. The water supply system had to be extended but only to serve less than one fourth of its population. The rest of the people continued to depend on ground water only.

Keeping this in view, the North Eastern Regional Centre of National Institute of Hydrology undertook the study of ground water quality monitoring in and around Guwahati city. The main objective of the study is to see the suitability of water for various designated uses like regional variation in the quality of shallow ground water, the seasonal variation in the ground water quality, delineation of bad water quality zones and so on. For the purpose, water samples from a selected network of dug wells covering the study area were collected from time to time initially for a period of two years (1994 & 1995). The samples were subjected to various laboratory and field tests for physical parameters like temperature, pH, conductivity, % light transmission, oxygen reduction potential, total dissolved solids etc. The study is expected to continue for different other water quality aspects like chemical, bacteriological, radiological and tracer elements in due course.

2.0 REVIEW

2.1 General

History reveals that the beginning of civilization always took place near the water sources. The people of ancient times seemed to be curious about the quality of water which is abode for life. A quotation from Yajurveda tells that "*..Anything we try to identify requires water and depends parasitically on water, to this unique indispensable part of our life we pray*".

Marsh(1907) examined the impact of industrial wastes on fish, while Shelford (1917) experimentally studied various effects, caused by gas waste on fishes with reference to stream pollution. Richardson (1921) reported various changes in the composition of bottom and shore fauna of Illinois river and its connecting lakes, due to sewage pollution. Kitrell (1969) experienced that when man alters the nature for his own good, he often produces unanticipated results. Kemp (1971) studied the chemistry of waters and gave a classification. Duran and Haffty(1971) examined the selected minor elements in water. Stumm and Bilinski(1973) studied the trace metals in natural water. Golterman (1973) worked with Phosphate. Kunkla(1974) described that water quality often depends on the forest. Horned (1982) analyzed the water quality in terms of variability, pollution loads and long term trends.

During the latter part of nineteenth century for chemical analysis of water, the relative concentration of ammonia nitrogen, nitrate nitrogen, nitrite and allu-minoid nitrogen were used to indicate the presence of pollutants. Today, the chemical analysis involves various important factors i.e. salts, metals, nutrients, radioactivity etc. No definite standard of water quality other than general clarity or palatability was recorded by ancient civilization. In 1921, very first standard criterion for drinking water was reported in the literature when United States published USPH standard for drinking water specifying only bacteriological parameters.

In India, many scientists have valuable contributions in the area of water quality. Hora in 1942 published a short note on the pollution of streams and its likely effect on fisheries. Ganpati and Chacko(1951) made an investigation and examined the effects of paper mill pollution at Rajmundry. Chakrabarty et al. (1959) studied the physico-chemical condition and planktonic population at Allaha-bad between 1954-55. Mahatre et al. (1980) studied the effects of industrial pollution on the aquatic ecosystem . Sharma (1981) investigated the pollution and its effect on drinking water supply of Agra city. Olaniya and Saxena (1977) observed pollution effects in well waters upto a distance of 450 meters in sandy [soils of Jaipur, Rajasthan due to refuse dumps. Similarly pollution of ground water has been observed in M.P., Gujarat, U.P. and Delhi (Kaushik et al., 1963, Kaushik and Prasad, 1964, Aboo et al. 1968, Thapliyal et al. 1972, Rajgopalan et al, 1972 and Sastry et al. 1972, perri Subbea and Venkat Rao (1973).

The first manual for the examination of industrial water in the country was published by ISI. National Environmental Engineering Education and Research Institute (NEERI), Nagpur published a manual of water and waste water analysis in 1979. Mathur (1982) published a laboratory manual for water and waste water testing. In the year 1984, Trivedy and Goel published a book on chemical and biological methods for water pollution studies. In 1988. Jain and Bhatia, National Institute of Hydrology, Roorkee published a user's manual on Physico-chemical Analysis of Water and Waste Water.

All India Institute of Hygiene and Public Health, Calcutta and Indian Council of Medical Research, New Delhi carried out several surveys for detection of water pollution in the critically affected industrial and urban areas of West Bengal, Bihar and Uttar Pradesh. During recent years National Environmental Engineer- ing Research Institute (NEERI) at Nagpur, various Universities and other Institu- tions have also started working on these problems. Uttar Pradesh is the first state in the country to establish an Effluent Board (1955). In 1970, Maharashtra introduced a Comprehensive Water Pollution Prevention Act and in 1974, Parlia-

ment passed the National Act to provide effective prevention and control of water pollution. Recently a Central Board for the Prevention and Control of Water Pollution has been formed by Central Government at New Delhi.

The water quality study has since been one of the thrust areas in the water resources sector as envisaged in the National Water Policy. As a result government departments, academic institutes and research organizations have created infrastructures for thorough examination and monitoring of water quality throughout the country.

2.2 Water Pollution

Water Pollution may be defined as the adverse change in composition or condition of the water such that it becomes less suitable for the purpose for which it would be suitable in its natural state. The changes include, physical changes, and biological changes. Water pollution now a days is considered not only in terms of public health but also in terms of conservation, aesthetics and preservation of natural beauty and resources.

Types of pollution :

(a) Physical pollution : This refers to the physical quality of water like colour, odour, temperature, turbidity, suspended matter, radio activity, foams in the form of gas etc.

(b) Chemical pollution : This refers to the chemical elements of water like acids, alkaline, toxic inorganic compounds, dissolved inorganic substances, suspended inorganic substances and so on.

(c) Bacteriological pollution : This refers to the constituents of water like domestic sewage, industrial wastes, solids excreta from human bodies, decomposable organic matter etc.

2.3 Water Quality Characteristics

2.3.1 Conductivity

Most of the salts dissolved in water are in ionic forms by which water is

capable to conduct electricity. The capacity of water to conduct electric current is known as conductivity. The conductivity of distilled water ranges between 1-5 micro mho/cm. Generally, natural waters possess low conductivity but contamination increases its level.

Conductivity is a convenient, rapid method of estimating the amount of dissolved solids. It is a numerical expression of the ability of an aqueous solution to convey an electric current. This property is related to the total concentration of ionized substances and their respective concentrations, mobility, and valence and to the temperature at which the measurement is made. Solutions of most inorganic acids and bases are relatively good conductors. Organic compounds that do not dissociate in aqueous solutions are not good conductors.

Conductivity measurement is also used to indicate the concentration of total dissolved solids. Total dissolved solids (mg/L) is equal to the conductivity multiplied by a factor between 0.55 and 0.9 depending on the soluble constituents in a specific water.

2.3.2 Turbidity

It is principally caused by the presence of coliform or very finely divided suspended matter. The main causes of turbidity are silt, clay, sand, microscopic biota, organic matter etc. The higher amount of turbidity produces water unfit for domestic use. It also causes profound adverse effect on the biota of natural water as it blocks the gills of fish and reduces the penetration of light which in turn minimize the primary productivity.

The term turbid is applied to waters containing suspended matter that interferes with the passage of light through the water or in which the visual depth is restricted. In lake or other waters existing under relatively quiescent conditions, most of the turbidity will be due to colloidal and extremely fine dispersions. In rivers under flood conditions, most of the turbidity will be due to relatively coarse dispersions.

Turbidity is an important consideration in public water supplies for three major reasons.

(a) Aesthetic : Consumers of public water supplies expect and have a right to demand turbidity free water. Laymen are aware that domestic waste water is highly turbid. Any turbidity in the drinking water is automatically associated with possible waste water pollution and the health hazards occasioned by it. This fear has a sound basis historically, as anyone knows who is familiar with the water borne epidemics that formally plagued the water works industry.

(b) Filterability : Filtration of water is more difficult and costly when turbidity increases. The use of slow sand filters has become impractical in most areas because high turbidity shortens filter runs and increases cleaning costs. Satisfactory operation of rapid sand filters depends upon effective removal of turbidity by chemical coagulation before the water is admitted to the filters. Failure to do so results in short filter runs and production of an inferior quality water, unless filters of special construction are used.

(c) Disinfection : Disinfection of public water supplies is usually accomplished by means of chlorine or ozone. To be effective, there must be contact between the agent and the organisms that the disinfectant is to kill.

In turbid waters, most of the harmful organisms are exposed to the action of the disinfectant. However, in cases in which turbidity is caused by sewage solids, many of the pathogenic organisms may be encased in the particles and protected from the disinfectant. For this and aesthetic reasons the U.S. Environmental Protection Agency has placed in limit of 1 unit of turbidity as the maximum amount allowable in public water supplies.

2.3.3 Oxidation-Reduction Reactions.

Oxidation-reduction reactions are among the most important characteristic with which the environmental engineer deals. Many reactions of interest in waste water treatment such as organic oxidation and methane fermentation, nitrification, and denitrification, are of this type and are mediated by bacteria. Oxidation-

reduction reactions are important in the solubilization and precipitation of iron and manganese. Oxidants such as chlorine and ozone are added to water and waste water to bring about desired inorganic transformations as well as to disaffect. The fate of materials introduced into the environment frequently depends upon the redox environment to which they become subjected. Also, many analytical tests used by the environmental engineer depend upon oxidation-reduction reactions.

(a) Oxidation-Reduction Potential (ORP) : Chemical substance is oxidized by losing its electrons while a substance which acquires electrons is reduced. Both the processes always occur simultaneously. When any solution contains chemical substance in more than one state of oxidation or reduction, a particular potential is associated with each state. But the potential of any solution is the net of all these reactions and known Redox Potential of that solution (or water).

The redox potential is an indication of the energy state of water system, governed by the presence of oxidized and reduced chemical substances or their biological activities as the oxidation and reduction reactions are accompanied by the transference of electron. The oxidized or reduced energy can be estimated by measuring emf capable of regulating this movement by electrons. The Redox potential can be quickly observed and is, therefore a valuable index to measure the conditions of water body.

(b) Oxidation Reduction Index (rH) : It is also an efficient indicator of Redox conditions of water system and always associated with the ORP and pH.

$$rH = (ORP / 0.029) + 2pH$$

2.3.4 Temperature

Temperature of surface and ground water varies with the climate and the season. Its measurement is useful to indicate the trend of various chemical and biological activities. A rise in water temperature lead to the faster chemical and biochemical reactions. Biological activity is also enhanced by higher temperature

upto 60 degree centigrade. Kinetics of BOD is also regulated to some extent by water temperature. It may also affect some other characteristics of water like dissolution of gases, pH, conductivity etc.

Temperature relation of water controls the structure and function of aquatic ecosystem in a significant way. The sun is the source of heat by which most water is warmed.

2.3.5 pH

pH is a term used rather universally to express the intensity of the acid or alkaline condition of a solution. It is a way of expressing the hydrogen-ion concentration, or more precisely, the hydrogen-ion activity. It is important in almost every phase of environmental engineering practice. In the field of water supplies, it is a factor that must be considered in chemical coagulation, disinfection, water softening, and corrosion control. In waste water treatment employing biological processes, pH must be controlled within a range favorable to the particular organisms involved. Chemical process used to coagulate waste waters, dewater sludges, or oxidize certain substances, such as cyanide ion, require that the pH be controlled within rather narrow limits. For these reasons and because of the fundamental relationships that exist between pH, acidity and alkalinity, it is very important to understand the theoretical as well as the practical aspects of pH.

The measurement of pH is of great importance as many chemical and biochemical reactions take place at a particular pH or within a very narrow range.

pH value is generally determined by calorimetric method or electrometric method. In calorimetric method some indicator is added (Table 2.1) in the sample of water and colour so formed is compared with standard colour solution. This method gives a range of pH of the sample. For accurate measurement pH meter is used.

Table 2.1

Common Indicator for Determining pH Values

Sl.No.	Name of the Indicator	pH range	Original Colour of indicator	Final colour
1.	Methyl Red	4.4 - 6.2	Red	Yellow
2.	Phenol Red	6.8 - 8.4	Yellow	Red
3.	Cresol Red	7.2 - 8.8	Yellow	Red
4.	Thymol Red	1.2 - 2.8	Red	Yellow
5.	Methyl Orange	2.8 - 4.4	Red	Yellow
6.	Brown Thymol Blue	6.0 - 7.6	Yellow	Blue
7.	Phenolphthaline Red	8.6 - 10.3	Yellow	Red
8.	Polyl Red	10.0 - 11.6	Red	Yellow
9.	Thymol Blue	8.0 - 9.6	Yellow	Blue
10.	Bromocresol Green	3.8 - 5.4	Yellow	Blue
11.	Bromophenol Blue	3.0 - 4.6	Yellow	Blue
12.	Chlorophenol Red	5.4 - 6.8	Yellow	Red

2.3.6 Colour

Pure water has no significant colour but natural water shows a pale green-blue tint in large volumes, which may occur due to many dissolved substances i.e. humic acid, fulvic acid, metallic ions etc. and their micro-biota i.e. phytoplankton. On the ground of aestheticity water with dark colour is objectionable for the public water supply.

Many surface and ground waters, particularly those emanating from swampy areas, are often coloured to the extent that they are not acceptable for domestic or some industrial uses without treatment to remove the color. The coloring material results from contact of the water with organic debris, such as leaves, needles of conifers, and wood, all in various stages of decomposition.

Natural color exists in water primarily as negatively charged colloidal particles. Because of this fact, its removal can usually be readily accomplished by coagulation with the aid of a salt having a trivalent metallic ion, such as aluminum or iron.

In water analysis it is important to differentiate between apparent and true color. Color intensity generally increases with increase in pH. For this reason recording pH along with color is advised.

Many industrial processes also require the use of color-free water. Removal of color is expensive when capital investment and operating costs are considered. Therefore the water engineer, when developing for new supplies look for a suitable source with a color low enough so that chemical treatment is not required.

2.3.7 Dissolved and Undissolved Solids

(a) Total Solid (TS): Total solids is a measure of dissolved and suspended impurities of water. In natural water many minerals, salts and organic substances are present in dissolved form, known as dissolved solids. While silts, sand, clay etc present in suspended form, are known as suspended solids. Higher TS concentrations are much harmful to the biota of the water body and also its users. An increase in the values of total solids shows an increase in the pollution, may be physical or chemical.

The total solids content for potable waters usually ranges from 20 to 1000 mg/l, and as a rule, hardness increases with total solids. In all other liquid materials, the amounts of undissolved colloidal and suspended matter increase with the degree of pollution.

(b) Volatile and Fixed Solids: One of the major objectives of performing solids determinations upon domestic wastes, industrial wastes, and sludge samples is to obtain a measure of the amount of organic matter present. This test is accomplished by a combustion procedure in which organic matter is converted to carbon dioxide and water, while the temperature is controlled to prevent decomposition and volatilization of inorganic substances as much as is consistent with complete oxidation of the organic matter. The loss in weight is interpreted in terms of organic matter.

(c) Settlable Solids: The term settlable solids is applied to solids in suspension that will settle, under quiescent conditions, because of the influence of gravity. Only the coarser suspended solids with a specific gravity greater than that of water will settle. Sludges are accumulations of settlable solids. Their measurements is important in engineering practice to determine the need for sedimentation units and the physical behavior of waste streams entering natural bodies of water.

2.3.7.1 Environmental Significance of Solids Determinations

The amount of dissolved solids present in water is a consideration in its suitability for domestic use. In general, waters with a total solids content of less than 500 mg/l are most desirable for such purposes. In many areas, it is impossible to find natural waters with solids content under 500 mg/l; consequently it is impossible to meet this desired level without some form of treatment. Standards generally recommended an upper limit of 1000 mg/l on potable waters.

2.3.7.2 Applications in Environmental Engineering Practice

In public and industrial water supplies, the total-solids determination is of unique importance. It is used to determine the suitability of potential supplies for development. In cases where water softening is needed, the type of softening procedure used may be dictated by the total-solids content. Corrosion control is frequently accomplished by the production of stabilized waters through pH adjustment. The pH at stabilization depends to some extent upon the total solids present as well as the alkalinity and temperature.

The settlable-solids determination has two very important applications. First, it is used extensively in the analysis of industrial wastes to determine the need for and design of primary settling tanks in plants employing biological treatment processes. The test is also widely used in waste-treatment-plant operation to determine the efficiency of sedimentation units. It is fully as important in the operation of large treatment plants as in the smaller.

The total and volatile-solids tests are the only solids determinations normally applied to sludges. They are indispensable in the design and operation of sludge-digestion, vacuum-filter, and incineration units.

2.3.8 Dissolved Oxygen (DO)

Temperature has the greatest affect on the solubility of oxygen in water. The relationship between oxygen solubility and temperature is calculated using an empirical relationship (Churchill et al., 1957) :

$$C_s(t) = 14.652 - 0.41022T + 0.0079917T^2 - 0.000077774T^3$$

where $C_s(t)$ is the solubility of oxygen in water at a given temperature, $T(^{\circ}C)$. The relationship shows that temperature is inversely proportional to solubility, meaning that as water becomes warmer its ability to hold oxygen decreases.

All the atmospheric gases are soluble in water to some degree. Both nitrogen and oxygen are classed as poorly soluble, since they do not react with water chemically, their solubility is directly proportional to their partial pressure. The solubility of atmospheric oxygen in fresh waters ranges from 14.6 mg L^{-1} at $0^{\circ}C$ to about 7 mg L^{-1} at $35^{\circ}C$ under 1 atm of pressure. Since it is a poorly soluble gas, its solubility varies directly with the atmospheric pressure at any given temperature. This is an important consideration at higher altitudes.

DO measurement is meaningful only instantly at the sampling spot. The oxygen content of a sample of water can readily change after collection and thus must be chemically preserved and determined quickly. The development of electrodes for sensing dissolved oxygen has greatly simplified sampling and determination problems.

The low solubility of oxygen is the major factor that limits the purification capacity of natural waters and necessitates treatment of wastes to remove pollutional matters before discharging into receiving streams.

The solubility of oxygen is less in salty water than in clean water. For this reason the solubility for a given temperature decreases as one progresses from

fresh water to estuary water to the ocean.

2.3.8.1 Environmental Significance of Dissolved Oxygen

In liquid wastes, dissolved oxygen is the factor that determines, whether the biological changes are brought about by aerobic or by anaerobic organisms. The former uses free oxygen for oxidation of organic and inorganic matter and produces innocuous end products, whereas the latter brings about products like sulfates, and the end products are often very obnoxious. Since both types of organisms are ubiquitous in nature, it is highly important that conditions favorable to the aerobic organisms (aerobic conditions) be maintained; otherwise the anaerobic organisms will take over, and development of nuisance conditions will result. Thus dissolved-oxygen measurements are vital for maintaining aerobic treatment processes intended to purify domestic and industrial waste waters.

Dissolved-oxygen determinations are used for a wide variety of other purposes. In most instances involving the control of stream pollution, it is desirable to maintain conditions favorable for the growth and reproduction of a normal population of fish and other aquatic organisms. This condition require the maintenance of dissolved-oxygen levels that will support the desired aquatic life in a healthy condition at all times.

Oxygen is a significant factor in the corrosion of iron and steel, particularly in water distribution systems and in steam boilers. Removal of oxygen from boiler-fed waters by physical and chemical means is common practice in the power industry.

2.3.9 Taste and Odour

The presence of taste and odour in natural water show the presence of any toxic material or the decomposition of organic material by micro-organisms. Due to decomposition process a sharp increase in the number of micro-organisms takes place. Water with taste and odour is objectionable for the public water supply.

Industrial effluents containing chemical substances such as iron, free chlorine, and phenols impart characteristic and unpleasant tastes to water. According to Southgate (1948), phenol produces an inky taste when present in water to the extent of 7 ppm. When a water containing phenol is chlorinated, chlorophenols are formed which have a characteristic taste and odour. Manganese, synthetic detergents, oils, petroleum products, and hydrocarbons are the other substances reported to produce tastes in water. The decomposition of organic matter and algae fungi and filamentous bacteria imparts peculiar tastes. Unpleasant earthy or musty tastes and odours are produced by aquatic actinomycetes. The taste producing substances can be removed by conventional water purification processes such as chemical precipitation, chlorination and treatment with activated carbon.

Odour in water is one of its most important characteristics. It is caused both by chemical agents such as free chlorine, phenols, hydrogen sulfide and ammonia and by biological agents such as algae and micro organisms. The commonest form of objectionable odour in streams and other water bodies is attributed to the presence of small amounts of sulfides. The extent of odour depends upon the pH of water. The presence of inorganic and organic compounds of nitrogen, sulfur and phosphorus and the eutrophication of proteins and other organic materials present in sewage and in trade wastes are the causes for odour in polluted water. Many of the industrial effluents containing organic substances (e.g., phenols, alcohols, esters, aldehydes, ketones and sulfur compounds) possess characteristic odours.

The Royal Commission in Sewage Disposal, London, classified the smells from polluted water as follows :

1. Putrid smell (mainly due to hydrogen sulfide)
2. Fishy smell (probably due to organic amines)
3. Wormy smell (may be due to phosphorus amines)
4. Earthy smell (due to humus)

Odours in drinking water can be eliminated by the use of activated carbon. In addition to the removal of odour it also eliminates tastes. Aeration is another method of removal of odour. Chlorine, chlorine dioxide and ozon may also be used in the removal process. Chlorination is reported to be a useful method in controlling odours of some of the industrial effluents.

2.4 Water Quality Monitoring Programme

Important considerations for an effective water quality program primarily depend on its objectives. Broadly these include:

- (i) Objectives of the monitoring programme.
- (ii) Identification of the definite sources of pollution and other needs as for objective monitoring.
- (iii) Selection of sampling locations, so as to link the sampling locations to sites for other monitoring operation.
- (iv) Selection of the water quality constituents of sample.
- (v) Determination of the sampling frequencies.
- (vi) Decision upon the methods required to sample the selected water quality constituents.
- (vii) Selection of the equipment necessary for field and lab analysis.

2.4.1 Water Quality Sampling

Chemical elements in various forms are distributed throughout the hydrologic environment- in the atmosphere, precipitation, surface water, soil water and ground water. Measurements of these elements are made on the representative samples. The term "representative" means that the sample represents all possible samples within the population. To achieve representativeness for data it is necessary to minimize, or at least standardize, sampling bias as it relates to site selection, sampling frequency, sample collection, sampling devices and sample handling, preservation and identification. The major considerations for water quality sampling are as follows:

Selection of Sampling Sites : Sampling sites are located to meet the monitoring objectives. Sampling locations can be established as

-individual locations in a network

-a pair of locations above and below a suspected pollution location.

-one location for sampling before and after a pollution location.

The location can be concentrated in key sites, or the locations can be distributed throughout the entire watershed. It is often useful to select locations that are easily accessible and can be reached throughout the monitoring period, but in doing so it is imperative not to predicate the selection of locations that will contribute to a more representative.

Sampling Frequency : There is no definite answer for sampling frequency of ground water for water quality. The minimum no. of samples to be collected and the frequency of sample collection from a distribution system have been generally based on the size of the population served (Table 2.2).

Table 2.2

Sample Frequency Based on Population

Population Served Interval	Min. No. of Samples per Month	Min. Frequency of Sampling
up to 1000	2	twice per week
1001-100,000	10+1 per 1000 of population per month	once per week
over 100,000	100+1 per 10,000 of population per month	once per month

Sample Handling : Deteriorated samples negate all the efforts and cost expended in obtaining good samples. In general, the shorter the time that elapses between the collection of a sample and its analysis, the more reliable will be the analytical results. For certain constituents and physical values, immediate analysis in the

field is required in order to obtain reliable results to avoid possible change in the samples by the time it reaches from the site to the laboratory . However, some samples can be satisfactorily preserved by chilling or by adding suitable acid or germicide or by other special treatment. They may then be allowed to stand for a longer period of time till the specific tests are conducted on it.

Certain sensitive parameters like temperature, pH, specific conductance and dissolved gases should be tested at site. Samples for metal analysis can be preserved by the addition of nitric acid, samples for organic constituents can be preserved by chilling or freezing and samples for determination of biodegradable substances as nitrates, phosphates, and surfactants can be preserved by chilling the sample immediately and then storing it in the dark at a temperature just above freezing until the tests are conducted. Samples for determination of certain dissolved inorganic and organic elements must not be frozen unnecessarily since it is not always possible to reconstitute the original sample exactly as it was before freezing. Selection of preservatives however depends on the parameter to be examined and method of its analysis since some preservatives interfere with analytical measurements. However water samples should be analyzed as far as possible within the time limitations specified (Appendix - I).

2.5 Ground Water Quality Modelling

Traditionally ground water quality modelling has been based on distributed system representation of the ground water flow e.g. Maddaus and Aaronson (1972) used a computer based finite difference model of two dimensional aquifer flow to predict quality trends throughout a ground water basin. Lyons and Stewart (1973) developed a distributed two dimensional finite difference aquifer model coupled with a storage effect for the unsaturated zone to predict concentration distribution in an aquifer including the effects of hydrodynamic dispersion.

Konikow and Beredehoeft (1974) have demonstrated the application of a numerical model which includes dispersion to water quality simulation in an irrigated stream-aquifer system, but the model requires extensive field data. Elabo-

rate digital models have been used to evaluate the ground water quality hazards of the AEC Hanford Project (Cearlock, 1971). Lumped parameter models have been used in predicting the salinity of irrigation return flows (e.g. Hornsby, 1973, Thomas, Riley and Isralsen, 1972).

United States Geological Survey has developed number of generalized codes e.g. MOC, SUTRA and MOD-3D.

Ground water quality modelling is comparatively a new field and as such there is not much research work has been acknowledged in India. Anand Prakash (1982) developed simple analytical models to simulate ground water contamination due to point, line, plane or parallelepiped sources in a confined or unconfined aquifer. The effects of the upper and lower confining boundaries in an artesian aquifer are accounted for by the method of images. The same technique is used to model the contribution of a constant concentration boundary in the flow field like the one provided by a full penetrating perennial stream the number of images at which accuracy of the results is indicated. Uniform flow velocity has been assumed in the analysis.

Third symposium on Hydrology at Central Water and Power Research Station (CWPRS), Pune noticed the work of Pawar et. al. on effect of vibration in the quality of ground water in Bhairoba Basin, Pune and Patil et. al. on Geochemistry of ground water and its implications on the precipitation of Carbonates in the Saswad-Nira Area, Western Maharashtra.

3.0 GROUND WATER POLLUTION SOURCES

3.1 Pollution of Ground Water

The problem of pollution in ground water is much less than that in surface waters as the soil acts as an adsorbent retaining a large part of colloidal and soluble ions with a maximum of its cation exchange capacity. Still, ground waters are not absolutely free from the menace of pollution; however, they are likely to be the suspended solids.

The extent of ground water pollution depends upon several factors: (i) soil properties, viz texture, structure and the infiltration rate, (ii) depth of water table, (iii) rainfall pattern, (iv) distance from the source of contamination.

Only soluble effluents pollute the ground water and the extent of pollution is likely to be more in sandy soils, with high water table conditions, and in humid regions. Seepage from polluted lake, pond or stream can also pollute the well waters. The detergents being soluble can also pass through the soil and pollute the ground water. The infiltration of liquid from refuse dumps particularly in low lying areas, may cause pollution and more easily in sandy soils.

Some ground waters of high rainfall areas are polluted naturally by excessive iron. This problem has often been observed in the ground water of Assam, West Bengal, Orissa and Kerala. Iron in toxic amounts as high as 20 ppm exists in deep tubewells as ferrous iron and on taking out, it immediately changes to light yellow orange colour on oxidation and precipitate as ferric hydroxide. Such waters are very harmful for drinking purposes as the permissible limit is only 0.3 ppm.

The complexity of water pollution in surface and ground water is due to the various processes occurring simultaneously viz. (i) variation in the flow rate of water, (ii) nature of effluent, (iii) their chain of reactions (iv) their reaction products in water (v) biological activities therein and (vi) the extent of water quality modification with time and space.

3.2 Sources of Water Pollution

Most municipal sewages are reported to have no treatment before disposal. These in combination with industrial wastes produce many health hazards. With population growth the quantity of waste water is also increasing. All the sewage contain decomposable organic matter and they exert oxygen demand on water.

Next in order is the waste from agriculture practices. Drainage from silage and manure slurry from intensive husbandry is reported to cause serious pollutions in some water courses. Plant nutrients, insecticides and pesticides are also introduced into water courses by agricultural practices. Sediment from land erosion containing mostly inorganic materials are also pollutants.

Underground water pollution occurs by the substances leached through refuse and spoil heaps, from fertilizers spread over the land and from silage making. The pollution of water may also arise from the disposal of industrial wastes in unused mineshafts and quarries. Since saline waters are drawn on to the aquifer, overpumping in coastal areas is considered to cause ground water pollution.

3.3 Nature and Effects of Water Pollution

Based on the contaminants, water pollution may be divided into two types, (i) pollution caused by materials and (ii) pollution caused by biological organisms. The first category involves the following organic and inorganic contaminants. Acids, alkalis, carbohydrates, coal, dyes, fats, soaps, waxes, gases, toxic, metals, oils, proteinaceous matters, resins, rubber, synthetic detergents, and various other pollutants including radio-active materials and heated effluents that impart thermal loading on receiving waters. The second category includes biological organisms such as bacteria viruses, plants and animals.

Acids : Acids are considered to cause damage to metals or concrete structures, pumps etc. by their corrosive activity. More over, they produce hydrogen sulfide gas when they come into contact with the sludge and mud of the river.

The lower the pH value, the greater is the amount of hydrogen sulfide liberated leading to a higher degree of atmospheric pollution. Acidic pollutants, also destroy micro-organisms and thus inhibit self-purification of the stream.

Alkalis : Alkalis also cause damage to ground water by altering the pH values resulting in a break in the natural buffer system. Chemical manufacturing wastes, Kier liquors, wool scouring wastes, tannery wastes, cotton mercenising wastes raise the pH values even up to 12. Alkalis behave similarly as acids in destroying bacterial and other micro-organisms .

Dyes : Though the dyes are not harmful, they create aesthetic problems. Moreover they also add to the B.O.D. (Biochemical Oxygen Demand) of the water. In addition to the dye material, salts of chromium, aluminum and iron also are impart colour. The colours imparted to water may be removed by treatment with activated carbon or other chemical agent.

Fats : The higher fatty acids undergo decomposition to lower fatty acids when subjected to microbial action. These lower fatty acids produce unpleasant rancid odours.

Gaseous Pollutants : This category includes ammonia, free chlorine, hydrogen sulfide, ozone and phosphine. Ammonia is liberated during the manufacture of chemicals, fertilizers, gas and coke. Sewage and other nitrogenous organic matters contribute and increase the ammonia content to dangerous levels. Free chlorine results from the process of textile bleaching, paper mills and laundries. Hydrogen sulfide occurs by the bacterial action and pH alterations during the discharge of viscose rayon wastes, and sulfate and sulfate containing materials. Inhalation of considerable quantities of ammonia seems to be an internal poison to fish which gets into the body through the gills.

Pesticides : Pesticides have great value in the control of insect borne diseases affection in the protection of crops and livestock. They are used in homes, industries, shops and by farmers, gardeners and foresters. In agriculture, these chemicals are used to protect plants against disease and to treat seeds.

DDT is the most widespread man-made molecule in the environment. DDT, the archetypal pollutant is considered to be the most emotive and controversial of pollutants. DDT is partially soluble in water and it evaporates into air resulting in atmospheric pollution. Winds, rains and rivers are the carriers of DDT to all over the world. The DDT from air and water accumulate in animal tissue, humans, soil or mud in concentrations thousands of times higher than it is found in water through food chain. Man is also contaminated by DDT and other organochlorine pesticides residues. The levels of these insecticides in human fat is reported to be on the lower side.

The residues of DDT in soil disappears slowly and the period is estimated to be roughly about fifteen years. It is reported that DDT is continuously recycled in living systems. Other insecticides such as gammexane, aldrin, dieldrin, endosulfane and chlordane are also reported to be similar in causing effects to wild life and in changing the metabolic activities through the change in body chemistry.

Fertilizers and Farm Wastes : Modern agriculture practices introduce fertilizers into water. Now-a-days, the use of fertilizer is increased by a number of times. These fertilizers are generally retained in the soil and by the crops, but some nitrates are liable to be washed out due to the negligence in applying fertilizers to arable lands, particularly in a wet spring, these nitrates cause undesirable effects on water of nearby wells. Increase in the population of cattle and pigs has resulted in an increase in the numbers of cattle sheds. Poultryies have also increased considerably. Buildings in which cattle and pigs are housed are commonly hosed down with water for cleaning with the result that the manure is washed out and deposited as wet slurry on the land. This slurry deposited on soil may be washed or it may seep into drains and streams causing pollution in them. These manures are completely organic in nature. The quantity of organic material produced by cattle and pigs is high. Excess amounts of nitrates of conjunction with phosphates cause many unwanted nuisances.

Toxic Metals : Mining processes, discharge of industrial effluents containing metallic solutions, dumping of solid wastes which contain considerable amounts of heavy metals. The primary metals considered to be toxic are lead, arsenic, copper, cadmium, mercury and nickel.

These metallic solutions are toxic to living organisms and higher amounts of these metals may inhibit self-purification of waters. The metallic contaminants destroy bacteria and other organisms which act on water to purify it. In addition, aquatic plants and animals are also killed. Arsenic and lead particularly make the water dangerous to drink. These toxic materials are reported to cause chromosome damage and thus interfere with the process of heredity.

Oils : Replacement of coal by oil fuel has increased the problem of pollution. The presence of oil in a water course is undesirable since it creates aesthetic problems. It has a tendency to spread over the surface of water and the diffusion of oxygen into water is inhibited and reaeration of water is affected. The absorption of oxygen from air into water depends on the thickness of the film formed by oil.

Protein and Carbohydrates : Faces and household wastes in sewage are the principal tributors of proteins and carbohydrates to a water course. Carbohydrates are compounds of carbon, hydrogen and oxygen are distributed in plant and animal kingdom widely. Glucose, sucrose, starch, dextrin, cellulose, glycogen and alginic acid are some of the carbohydrates. Sugar factories, glucose factories, sweet manufacturing industries, dairies, breweries, wood processing industries, food processing industries and textile industries contribute sugars and starch. Proteins are a group of organic nitrogenous compounds of high molecular weight, distributed widely in plant life and animal kingdom. The main component of proteins are amino acids. Proteins vary in their nature according to the number of amino acids present, their order in the chain and the geometrical shape of the molecule. Apart from carbon, hydrogen oxygen and nitrogen, proteins also contain sulfur and phosphorus. Egg albumin, gelatin, casein keratin, glutenin are some of the examples of proteins. They undergo putrefaction by bacterial action to release

primarily sulfur and phosphorus compounds. The released sulfur compounds on further action by bacteria produce sulfurated gases such as hydrogen sulfide which in turn produces a putrid smell. Phosphorus compounds on the other hand causes mostly smell.

Mercury and Mercuric Compounds : In very recent years, a lot of attention has been given to the problems of mercury poisoning. Natural waters contain only a few parts per billion of mercury. Mercury enters the biosphere as a water product from a number of industrial activities. A major source is the production of chlorine where mercury is used as an electrode in the electrolysis of brine. Paper and pulp industries, oil refining industries, plastic industries and battery manufacturing industries also contribute to mercury pollution. Mercuric compounds are also used as fungicide to prevent seeds from and for the protection of various plants. But the use of mercuric compounds as fungicide and insecticide are declining due to the acute poisoning nature.

Biological Pollutants : Biological pollutants may conveniently be classified into two groups as primary pollutants and corollary pollutants. Primary pollutants comprise biota that are added to water directly as a result of man's activities e.g. pathogenic bacteria or viruses from sewage. Corollary pollutants are the indigenous living materials that interferes with the beneficial uses of water e.g. weeds in irrigation ditches. Corollary pollutants although not added directly to the water course by man, are attributable to human endeavor. While primary pollutants have very short life, corollary pollutants have a longer life. The organisms that constitute primary and corollary pollutants are numerous.

Viruses : Viruses are infectious agents of both plant and animal cells. They are ultramicroscopic, obligate intra-cellular parasites. their presence is manifested by the destruction or impairment of the host cells. They are devoid of any intrinsic metabolism and they have to depend only on the host cell for development and replication.

A report by Derby et al. (1960) indicates that nearly seventy-six viruses

are pathogenic to man. Among them, Enteroviruses Adenoviruses, Polioviruses, Infectious Hepatitis viruses, and Coxsackie viruses are the most common viruses present in polluted waters and sewage. One of the most important and dreaded of virus diseases is poliomyelitis. It may cause paralysis of one or more parts of the body by the destruction of certain nerve cells controlling the muscles. The disease occurs all over the world.

Other Nuisance Organisms : Apart from bacteria, viruses, and algae there are numerous organisms which are a nuisance to man. Among them, parasitics are of considerable importance. Eggs of nematode worms and tapeworms are common in crude sewage. When such sewages are discharged in to water courses without treatment, contamination of water occurs with resultant danger to man and animals. Of the parasites that may be ingested, Entamoeba histolytica is the casual agent which causes both internal amoebiasis such as amoebic dysentery and extra-intestinal forms of the disease. The guinea worm, causes dracontiasis, is transmitted through open village wells and ponds infested with the copepod intermediate host. Intestinal helminths, such as Ascaris lumbricoides and Trichuristrichiura are also reported to be water-borne. Heavy chlorination is needed to destroy the eggs and cysts of these parasites.

Solid Waste : The disposal of solid waste poses many problems, depending upon both the type of waste and the disposal method employed. The majority of the waste classified as combustible - rubbish, garbage and sewage sludge- has been disposed of by one of three methods: incineration, using it as landfill, or disposal by ocean dumping. Incineration generally gives to air pollution; landfill operations or ocean dumping lead to water contamination. If landfill disposal is used the material, as it decomposes, will dissolve in or become suspended in the rainwater percolation into the ground and thus into subsurface aquifers. This tends to contaminate not only ground water but also surface water, since the two system are ultimately interconnected.

Septic Tanks : Septic tanks and cesspools contribute filtered sewage effluent

directly to the ground, and are the most frequently reported sources of ground water contamination, especially in rural, recreational and suburban areas. Poorly located septic tanks endanger water supplies. If the dispersal field is too close to a well or a local aquifer, and if the soil is too sandy, waste liquids from the tank may enter the local water supply before bacterial decomposition gets completed.

Radioactive Materials : Harmful radiation may result in water environments from the wastes of uranium and thorium mining and refining, from nuclear power plants; and from industrial, medical, and scientific utilization of radioactive materials. An important source of radioisotopes is nuclear weapons testing. The amount and variety of radioactive materials formed depends on the type of weapon tested. These materials reach the earth as radioactive fallout.

4.0 METHODOLOGY

4.1 Sampling

Water samples from twenty three observation wells (Fig 4.1) were collected initially for a period of two years during 1994 and 1995 in pre & post monsoon season and was subjected to various physical tests. Water samples collected were collected by dip (grab) sampling method. While collecting the samples, the depths of water in the wells were also measured. The samples were collected in clean polyethylene bottles fitted with screw caps. Some physical parameters like temperature, pH and conductance were measured at the spot by means of portable water testing kits.

4.2 Method and Equipment Used

For the measurements of some physical parameters such as pH, conductance and temperature, the portable water testing kit were used. The list of parameters and purpose of analysis, essential equipment used and methods of analyses are presented in Table 4.1.

Table 4.1

Analysis Methods and Equipments Used in the Study

Parameter	Equipments used
Temperature	Thermometer
pH	pH Meter
% Light Transmission	Sludge Blanket Detector
Conductivity	Conductivity Meter
Total Solids	From Conductivity Results
Oxygen Reduction Potential	pH Meter (with ORP Probe)

Details of procedures adopted procedure and instruments used for analysis of physical parameters are given below. Also a sample field record sheet to keep water quality related information during sampling is given in Appendix - II.

4.2.1 PORTABLE WATER TESTING KIT

This equipment can be used both in laboratory as well as in the field for

measurement of parameters such as pH, ORP, Conductivity, TDS for water samples. This can be operated electrically (mains) or by battery. Ranges of Measurement are :

pH range = 0 to 14 pH

Redox Potential = -1999 mV to 1999mV

Conductivity = 0 to (20 μ -mho, 200 μ -mho, 2 m-mho, 20 m-mho, & 200 m-mho)

TDS Range = 0 to 2000 mg/L

Calibration & Measurement

(i) pH Measurement

The pH electrode is connected to the input socket. The electrode is cleaned with distilled water and dried. The temperature of the buffer solution supplied along with is measured and the temperature knob is set to the temperature of the buffer solution. The electrode is dipped in a solution of known pH buffer solution and the display is adjusted to the pH value with the Cal knob, instrument is now calibrated. The electrode, is dried tissue paper may be used for drying the electrode. The temperature of the sample is measured and the temperature knob is to the measured value. The probe in the sample of unknown pH and the reading is noted after a steady rate is obtained, which is the value of pH of the sample. The probe may be dried and dipped in another sample for measurement. Random calibration can be made to avoid improper readings. The measurement of pH using a Portable Water Testing Kit and the Digital pH meter is same as mentioned above.

Maintenance of pH Electrode

For the pH electrode to work satisfactorily it should be kept immersed in distilled water when not in use. The level of the saturated KCl solution in the probe is to be maintained, this can be done by adding KCl solution in the tube by opening the small cap provided on the side of the electrode. When the buffers are damaged due to fungus, the buffer solution may be prepared freshly.

When the electrode becomes too slow, it may be kept dipped in N/10 HCl for some time and washed thoroughly before use.

(ii) ORP Measurement

The ORP electrode (special platinum electrode) is connected into the input socket. The electrode is cleaned with distilled water. The temperature of the 4.00 pH buffer solution is measured and the temperature knob is set to that of the buffer solution. The ORP switch is switched on and calibrated to the value according to the temperature of the solution as shown in the table below.

Temperature of the buffer in degree Centigrade	ORP in mV
20	268
25	263
30	258
35	253
40	248
45	243

The probe is dipped in the sample of unknown ORP and the reading is noted down after a steady state is obtained, which is the value of the ORP of the sample.

(iv) Measurement of Conductivity

Electrical conductivity is measured by passing the AC voltage through the solution. Measurement of resistance of the solution is made and is suitably converted to display the conductivity directly. The unit for electricity conductivity is mho.

Conductivity cell is to be connected into the input sockets provided. Then the cell is immersed in the solution whose specific conductivity is known (0.1N KCl solution). The conductivity switch is pressed and the range switch is brought to proper position in which maximum resolution is obtained. Reading is set after measuring the temperature of the solution as per the table given below. The measurement of conductivity using a Digital Conductivity meter is same as that of a portable Water Testing Kit as mentioned above.

Temp. in degree Centigrade	Specific Conductivity of 0.1 KCl solution	Salinity of 100 ppf	TDS of 0.1 KCl solution
10	9.33	7.20	5071
20	11.67	9.06	7469
21	11.91	9.25	7622
22	12.15	9.45	7776
23	12.39	9.66	7930
24	12.64	9.83	8090
25	13.88	10.00	8243
26	13.13	10.18	8403
27	13.37	10.36	8557
28	13.62	10.54	8717
29	14.87	10.73	8877
30	14.12	10.91	9037
31	14.12	11.10	9197
32	14.62	11.24	9357
33	14.88	11.43	9523
34	15.13	11.60	9683
35	15.59	11.79	9978

In some cases the conductivity of the sample may exceed the range of the instrument, in such cases the following procedure may be applied:

Dilute the water sample with deionized water to a final sample of known volume. Measure the conductivity of the sample.

$$\text{Conductivity (C)} = (100 (C_i - C_d (100 - V)) / V)$$

where C_i - Conductivity reading on instrument.

C_d - Conductivity of diluted sample

V - Volume of the sample

Maintenance of Conductivity Probe

Conductivity cell is thoroughly washed when it is being changed from one solution to another. Once the platinum coating on the cell is damaged after prolonged use it has to be deposited again chemically.

(iii) Temperature Measurement

The temperature probe is connected into the input sockets provided for. The probe is immersed in the solution whose temperature is to be measured. The Temperature switch is switched on and the temperature of solution/sample as required is measured when the reading becomes stable.

Maintenance of Temperature Probe

To ascertain that the temperature probe is working properly, the resistance of the probe has to be measured by an ohm meter. It is open (infinity) in one side and offers some resistance on the other side.

4.2.2 SLUDGE BLANKET DETECTOR (For % Light Transmission)

The sludge blanket detector is a simple instrument which can be used to establish the height of the sediment layer in case of settling sludge. The instrument consists of a detector unit which is a photo sensitive device connected to a measuring unit which is an analog meter. The detector unit consists of a photocell, filament lamp mounted on a water proof U shaped housing. The detector unit has a long cable marked in definite length and is designed to be lowered into the sedimentation tank. The filament lamp is fed by a separate 1.5 V battery.

Operating Instructions

The detector unit is connected to the socket of the measuring unit. The Range switch is set to position 1 from off position. Using the small plastic plate supplied with, the light falling on the photocell is blocked wholly to protect it from day light as well as from the lamp. The best way to achieve this is to hold the plate well pressed against the photocell window, potentiometer screw head marked zero/null is adjusted so that the meter shows zero % transmission. It is necessary to avoid any stray light, otherwise the zero adjustment may not correct. The detector unit is lowered into a container containing clear water, the potentiometer screw head marked Cal / 100 % is adjusted so that the meter reading shows 100 % transmission.

Measurement

When using the instrument for actual measurement, the detector unit is lowered slowly into the sedimentation tank/sample. The readings on the meter

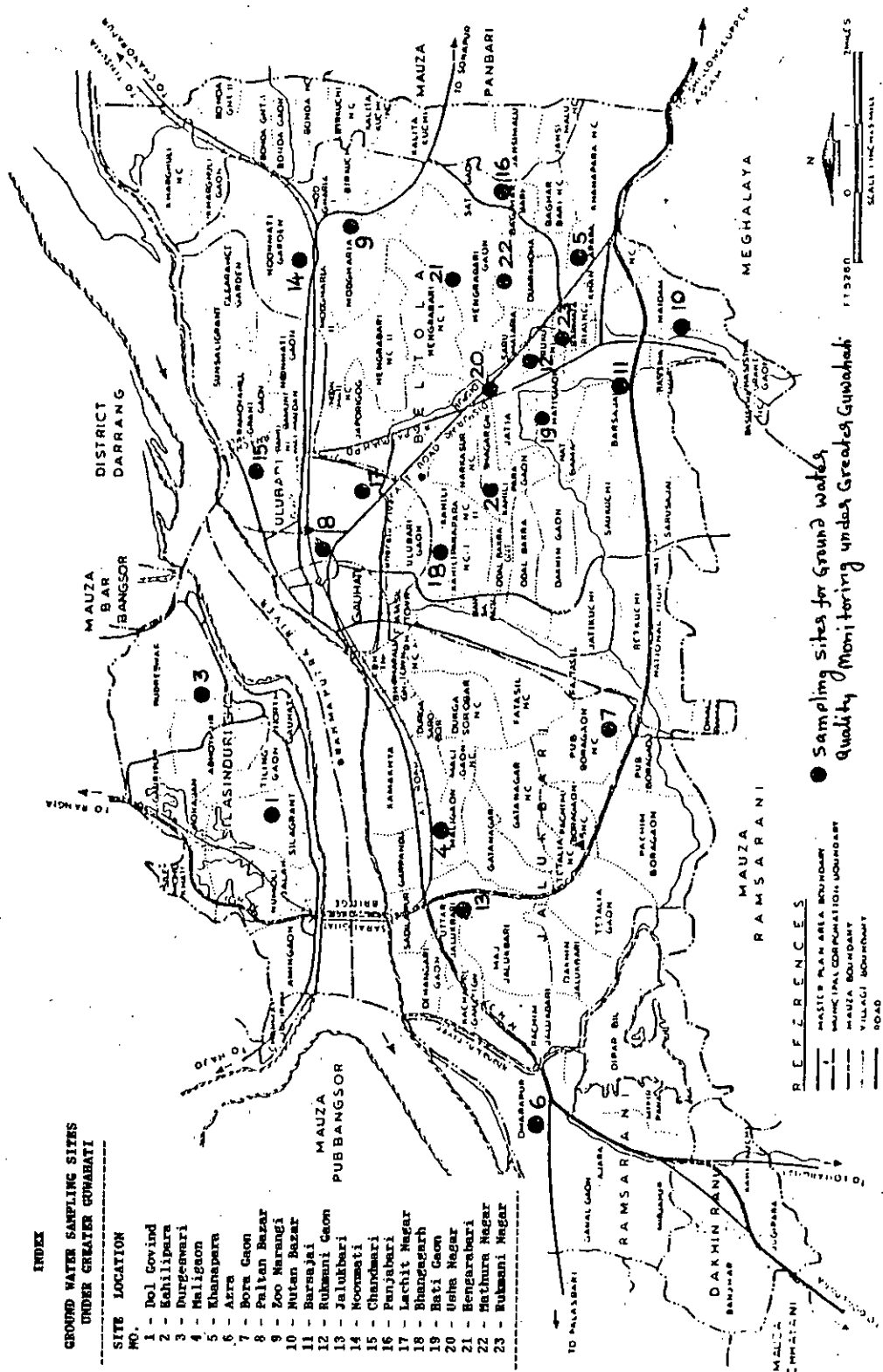
will go on decreasing as the fully sedimented zone is reached. A graph can also be plotted by noting meter readings and depth markings. In general the select switch is kept in position 1 only. When higher sensitivity is required, during cloudy surroundings, range switch is taken at position 2 and the calibration is repeated as mentioned above.

INDEX

GROUND WATER SAMPLING SITES UNDER GREATER GUWAHATI

SITE LOCATION

- 1 - Dol Cowind
- 2 - Kahilpara
- 3 - Nurgswari
- 4 - Maligon
- 5 - Khanapara
- 6 - Arxa
- 7 - Bora Gaon
- 8 - Paltan Bazar
- 9 - Zoo Narangí
- 10 - Nutan Bazar
- 11 - Barasajai
- 12 - Rukmani Gaon
- 13 - Jalukbari
- 14 - Moomasati
- 15 - Chandwari
- 16 - Panjabari
- 17 - Lachit Neger
- 18 - Bhangaagarh
- 19 - Bati Gaon
- 20 - Usha Nagar
- 21 - Bengarabari
- 22 - Mathura Nagar
- 23 - Rukmani Nagar



● Sampling sites for ground water
Quality Monitoring under Greater Guwahati

REFERENCES

- MASTER PLAN AREA BOUNDARY
- MUNICIPAL CORPORATION BOUNDARY
- MAUZA BOUNDARY
- VILLAGE BOUNDARY
- ROAD
- RAILWAY LINE
- RIVER
- BRIDGE
- INTER STATE BOUNDARY

FIG. 4.1 : GROUND WATER SAMPLING SITES UNDER GREATER GUWAHATI (MAP SOURCE - TOWN AND COUNTRY PLANNING ORGANIZATION, GUWAHATI)

5.0 STUDY AREA

The city of Guwahati is located at 26°11' N latitude and 91°45' E longitude. Structurally, the region is situated on a 50 meter thick alluvium bed of middle Brahmaputra valley underlain with granitic rocks of the Shillong Plateau, the outcrops of which may be seen in various parts of the city and neighbourhood. The area covered by the city is about 257.09 Sq.Km. with a population of about 5,77,591 according to 1991 census. The city is situated on an undulated plain area dotted with small hillocks altitude of 50-60 meters above mean sea level.

Towards the East, South and mid part of the City, there are scattered swamps and marshes. They are generally found in the Ulubari, Paltan Bazar and Kalapahar areas. The marshy lands are now gradually filled up for residential and other purposes. There are a number of small and big water supply tanks scattered through different parts of the city. The largest well-maintained tank is Dighali Pukhuri. A very big waterbody called Deepar Beel is on the outskirts of the city in the Western part. Other beels or natural water reservoirs which are not properly utilised are Solabeel and Silsako Beel. The main drainage channel of the city, Bharalu river passing through heart of the city is also being used for discharge of refinery waste. This has created serious problems of pollution endangering public health in the locality.

Major problems that are affecting the lives of the city dwellers are drinking water and water logging. These two problems prevail in each and every corner of the city under the governance of Guwahati Municipal Corporation.

According to the Master Plan of Guwahati, the lush green hillocks around the city were kept isolated from the preview of any developmental activity considering its ecological and environmental importance and impact on the town. But with the passage of time and increasing demand of housing, the people went on constructing residential quarters by felling trees on the hillock. And as a result of massive destruction of the green cover around the city, the water table dras-

tically dropped down. And this is the reason that ring wells in the areas like Birubari, Navagraha, Kalapahar, Chandmari, geetanagar, Kahilipara, Christian Basti, Ganeshguri etc. remain dry and face acute water crisis round the year bearing a few months of monsoon.

Due to wanton felling of trees and earth cutting, the hillocks surrounding Guwahati lost its capacity to hold rain water resulting in heavy soil erosion. A hilly area covered with trees holds 98 % of total water it receives from rain and releases only two percent but in case of denuded hillocks, it does just the reverse. And as a matter of fact during rainy season with full flow of water, it causes massive soil erosion which is carried down to the plains and blocks the outlets, chokes the drainage canals etc. resulting in water logging and flood.

Serious problem of water logging when a shower of rain even for a minute used to turn the low lying riverine areas and roads under knee deep water for hours, sometimes even for days.

A very basic human need is drinking water. This premier city of Assam, in this later part of the 20th century, provides piped drinking water to only 20% of its population, leaving the rest to fend for themselves with tube wells, shallow wells, ponds and so on.

Guwahati has no scientific sewage disposal system. Majority of the areas have individual septic tanks without any collective disposal of the effluents. Some areas are being served by that abomination called the service pit latrines. Garages are dumped on the streets and roads are littered with dosed disposals as the GMC does not have any effective system of garbage collection and disposal.

The acute shortage of land has resulted in overcrowding and many residential houses have been converted into shops and offices (government offices not excluded), thus adding to the chaotic conditions. The resultant pressures on land have led to encroachment of the e surrounding hills, thus further reducing the open space in the city. The hills around Guwahati are now bleeding and are the picture of ecological and environmental disaster.

Due to lack of proper drainage system rainwater gets flooded during monsoons. Even the water enters the house holds. Even the effluents discharged from the Noonmati refinery sometimes pollute the well water posing health hazards. Water logging problem is so serious that even a small rain for a brief period brings the low laying areas and roads under knee deep water (Plate-I).

6.0 RESULTS AND ANALYSIS

The results of physical properties in ground water of Greater Guwahati at different places (Fig. 4.1) in pre and post monsoon period of 1994 and 1995. The results of the physical analysis of ground water samples are presented in Table 6.1 to 6.12 and Figure 6.1 to 6.8 and are discussed below.

6.1 Water Temperature

Temperature is a standard physical characteristic that is important in the consideration of the chemical properties of water. In natural rivers also it is necessary to assess the effects of temperature on living organisms. The temperature of water depends on the season and the temperature of the ground with which it is in contact.

The temperature of Guwahati during the month of July 94 varied between 30 to 26.4°C with an average temperature of 28.7°C. The variance in temperature was found to be $\pm 1.8^\circ\text{C}$. Maximum temperature of 30°C was measured at Lachit Nagar and Panjabari and minimum of 26.4°C was measured at Maligoan.

During the month of December 1994 the temperature varied between 24 to 20°C with an average temperature of 21.7°C. The variance in temperature was found to be $\pm 2^\circ\text{C}$. Maximum temperature of 24°C was measured at Paltan Bazaar and Jalukbari and minimum temperature of 20°C was measured at Chandmari.

During the month of April 95 the temperature varied between 29.8 to 24.9°C with an average temperature of 28.4°C. The variance in temperature was found to be $\pm 2.5^\circ\text{C}$. Maximum temperature of 29.8°C was measured at Rukminigaon and a minimum of 24.9°C at Jalukbari.

During the month of October 1995 the temperature varied between 29.3 to 26°C with an average temperature of 28.1°C. The variance was found to be $\pm 1.7^\circ\text{C}$. Maximum temperature of 29.3°C was measured at Nutan Bazaar and a minimum temperature of 26.0°C measured at Maligoan.

In general the maximum temperature varied between 29.3 to 30°C and a minimum temperature between 26 to 26.4°C. The variance in temperature was maximum at Panjabari and Bhangagarh with a value of $\pm 4.9^\circ\text{C}$ and minimum at Boragoan and Paltan Bazaar with a value of $\pm 2.4^\circ\text{C}$. During the sampling period maximum temperature of 30°C was measured at Panjabari and Lachit Nagar during July 94 and a minimum of 20°C was measured at Chandmari during December 94.

6.2 Conductivity

Electrical conductivity (EC) is a physical property of water that is dependent on the dissolved salts. Thus its measurements in $\mu\text{-mho per centimeter}$ gives a good estimate of the dissolved solids content of a sample. The conductivity of water depends upon the concentration of dissolved ions.

During July 1994 conductivity varied between 1198 to 720 $\mu\text{-mho/cm}$ with an average value of 1048 $\mu\text{-mho/cm}$. The variance was found to be $\pm 239 \mu\text{-mho/cm}$. Maximum conductivity of 1198 $\mu\text{-mho/cm}$ was measured at Rukmanigaon and a minimum of 720 $\mu\text{-mho/cm}$ at Kahilipara.

During the month of December 1994, the conductivity varied between 1148 to 651 $\mu\text{-mho/cm}$ with an average value of 998m. The variance was found to be $\pm 249 \mu\text{-mho/cm}$. Maximum conductivity of 1148 $\mu\text{-mho/cm}$ was measured at Jalukbari and a minimum conductivity of 651 $\mu\text{-mho/cm}$ was measured at Kahilipara.

During the month of April 1995 the conductivity varied between 1154 to 698 $\mu\text{-mho/cm}$ with an average value of 1000 $\mu\text{-mho/cm}$. The variance was found to be $\pm 228 \mu\text{-mho/cm}$. Maximum conductivity of 1154 $\mu\text{-mho/cm}$ was measured at Barsajai and a minimum of 698 $\mu\text{-mho/cm}$ was measured at Kahilipara.

During the month of October 1995, the conductivity varied between 1068 to 659 $\mu\text{-mho/cm}$ with an average value of 949 $\mu\text{-mho/cm}$ and the variance was found to be $\pm 205 \mu\text{-mho/cm}$. Maximum conductivity of 1068 $\mu\text{-mho/cm}$ was measured at Panjabari and a minimum of 659 $\mu\text{-mho/cm}$ measured at Kahilipara.

From the above it is found that the variance has a whole does not change much and the conductivity of Kahilipara, Noonmati, Jalukbari, and Rukmaninagar

almost remained same with a variance of $\pm 35 \mu\text{-mho/cm}$, $\pm 31 \mu\text{-mho/cm}$, $\pm 8 \mu\text{-mho/cm}$, $\pm 22 \mu\text{-mho/cm}$ respectively with negligible variance. The maximum variance was at Maligaon and Khanapara with a variance of $\pm 143 \mu\text{-mho/cm}$ and $\pm 144 \mu\text{-mho/cm}$ respectively. During the sampling period maximum conductivity of $1198 \mu\text{-mho/cm}$ was measured at Rukmanigoan during July 94 and a minimum of $651 \mu\text{-mho/cm}$ was measured at Kahilipara during December 1994.

6.3 % Light Transmission

The suspended particles - soil, silt particles, decomposed, or undecomposed organic matter, total dissolved solids as well as microscopic organisms etc. one the main source of turbidity in water, which always interferes with the penetration of light. Hence % light transmission can give a rough idea about level of turbidity in water surface. The % light transmission of ground water at Guwahati varied between 69 - 88 during the month of July 94, 74 - 88 during the month of Dec. 94, 75 - 88 during April 95 and 74-88 during the month of Oct. 95. The maximum % light transmission of ground water at Guwahati was 88 during the month of July 94, Dec. 94. April 95 for Nutan Bazar, Jalukbari and Zoo Narangi respectively. The minimum % light transmission of ground water at Guwahati was 74 during the month of Dec. 94 at Ajra.

6.4 Hydrogen Ion Concentration (pH)

pH is a measure of the concentration of hydrogen ions (H^+) and indicates the degree of acidity or alkalinity of the water. The permissible pH range for public water supplies is 6.5 to 8.5 (WHO). Lower pH cause tuberculation and corrosion while the higher value produce incrustation, sediment deposit, difficult in chlorination, certain physiological effects on human systems etc.

pH of Guwahati during the month of July 94 varied between 7.43 to 5.74 with an average value of 6.55 and the variance was found to be ± 0.85 . Maximum value of 7.43 was measured at Lachit Nagar and a minimum of 5.74 at Noonmati.

During the month of December 94 the pH varied between 7.38 to 5.24 with an average of 6.41 and the variance was found to be ± 1.07 . Maximum of 7.38 was measured at Maligoan and a minimum of 5.24 at Noonmati.

During the month of April 1995, the pH varied between 6.99 to 4.87 with an average value of 6.06 and variance was ± 1.06 . Maximum value of 6.99 was measured at Jalukbari and a minimum of 4.87 was measured at Noonmati.

During the month of October 1995, the pH varied between 7.03 to 5.47 with an average value of 6.38 and the variance was found to be ± 0.78 . Maximum value of 7.03 was measured at Maligaon and a minimum of 5.47 was measured at Noonmati.

From the results it is found that the pH of Noonmati almost remained the same compared to other sampling sites, pH varied between 4.87 to 5.74 with a lowest of 4.87 measured in the month of April 1995. From the values it is found that the water was slightly acidic. In other sites the pH values were within the normal range. During the sampling period maximum pH of 7.43 was measured at Lachit Nagar in July 94 and a minimum of 4.87 was measured at Noonmati in April 95.

6.5 Oxidation Reduction Potential (ORP)

Testing the value of ORP plays very important role in the factory and industrial water applications (chromium and cyanide concentration), fish farming & aquarium (water quality), swimming pools (sanitation level) etc. A typical ORP application is the destruction of cyanide in plating solution with the additions of chlorine. The process can be monitored and controlled by measuring the ORP of solution.

ORP of Guwahati during the month of July 94, varied between 221 mV to 145 mV with an average value of 179 mV. The variance was found to be ± 38 mV. Maximum value of 221 mV was measured at Ajra and a minimum of 145 mV was measured at Hatigoan.

During the month of December 94, ORP varied between 279 mV to 156 mV with an average value of 218 mV and the variance was ± 62 mV. Maximum value of 279 mV measured at Noonmati and a minimum of 156 mV was measured at Jalukbari.

During the month of April 95, ORP varied between 229 mV to 143 mV with an average value of 196 mV. The variance was found to be ± 43 mV. Maximum value of 229 mV measured at Hatigaon and a minimum of 143 mV at Usha Nagar and Mathura Nagar.

During the month of October 95, ORP varied between 231 mV to 165 mV with an average value of 198 mV. The variance was found to be ± 33 mV with a maximum value of 231 mV measured at Hengrabari and a minimum of 165 mV at Mathura Nagar. During the sampling period maximum ORP of 279 mV was measured at Noonmati and a minimum of 143 mV at Usha Nagar and Mathura Nagar.

6.6 Total Dissolved Solids

How much solids are dissolved in water (TDS) is a problem to be reckoned with. A high concentration could result in corrosion and scale deposits in industrial applications with extensive damage for aquatic flower & fish farming. Drinking water having TDS upto 500 ppm is the ideal (WHO).

During the month of July 94, TDS varied between 719 to 432 ppm with an average value of 629 ppm, the variance was found to be ± 143 ppm. Maximum TDS of 719 ppm was measured at Rukmanigoan and a minimum of 432 ppm was measured at Kahilipara.

During the month of Dec. 94, TDS varied between 689 to 391 ppm with an average value of 599 ppm, the variance was found to be ± 149 ppm. Maximum TDS of 689 ppm was measured at Jalukbari and a minimum of 391 ppm at Kahilipara.

During the month of April 95, TDS varied between 692 to 419 ppm with an average value of 600 ppm, variance was ± 137 . Maximum TDS of 692 ppm was measured at Boragoan and a minimum of 419 ppm was measured at Kahilipara.

During the month of October 95, TDS varied between 641 to 395 ppm with an average value of 569 ppm, the variance was found to be 123 ppm. Maximum TDS of 641 ppm was measured at Panjabari and minimum of 395 ppm was measured at Kahilipara.

During the sampling period maximum TDS of 719 ppm was measured during the period July 94 at Rukmanigoan and a minimum of 391 ppm during December 94 at Kahilipara. In general the TDS was higher at all the sampling sites except Kahilipara and Paltan Bazar.

6.7 Dissolved oxygen (DO)

Dissolved oxygen (DO) plays a large part in the assessment of water quality, since it is an essential ingredient for the sustenance of fish and all other forms of aquatic life. It also affects the taste of water, and a high concentration of dissolved oxygen in domestic supplies is encouraged by aeration. Values of dissolved oxygen are given in mg l^{-1} (O_2).

During the month of July 1994 DO varied between 8.8 ppm - 6.4 ppm with an average value of 7.51 ppm. The variance was found to be ± 1.2 ppm. Maximum value of 8.8 ppm was measured at Maligaon and a minimum of 6.4 ppm was measured at Lachit Nagar.

During the period of December 1994, the value of DO varied between 8.2 ppm to 4.8 ppm with an average value of 6.80 ppm. The variance was found to be ± 1.7 ppm. Maximum value of 8.2 ppm was measured at Khanapara and a minimum of 4.8 ppm was measured at Durgeswari.

During the period of April 1995 the value of DO varied between 7.5 ppm to 6.56 ppm with an average value of 5.82 ppm. The variance was found to be ± 0.84 . Maximum value of 7.5 ppm was measured at Durgeswari and a minimum of 5.82 ppm was measured at Zoo narangi.

During the period of October 1995, the value of DO varied between 8.14 ppm to 6.38 ppm with an average value of 7.044 ppm. The variance was found to be ± 0.88 ppm. Maximum value of 8.14 ppm was measured at Ajra and a minimum

of 6.38 ppm was measured at Durgeswari.

Maximum variation in DO was between 7.50 ppm to 8.80 ppm and a minimum was between 4.80 ppm to 6.38 ppm. the variance in DO was maximum at Maligoan, Zoo Narangi and Duregeswari with ± 1.45 ppm, ± 1.44 ppm, ± 1.35 ppm respectively. The minimum variance was ± 0.19 at Lachit Nagar. During the sampling period maximum DO was 8.80 ppm measured at Maligoan during April 94 and a minimum of 4.80 ppm was measured at Duregeswari during December 94.

6.8 Ground Water Table

In general the water table was high except at Paltan Bazar and Maligoan. During the month of July 94 the water table varied between 7.32 m (BGL) to 1.14 m (BGL) with an average value of 2.97 m (BGL), the variance was ± 3.09 m (BGL). Water table was low at Hengrabari and high at Nutun Bazar with 7.32 m (BGL) and 1.14 m (BGL) respectively.

During the month of Dec. 94 the water table varied between 9.70 m (BGL) to 1.13 m (BGL) with an average value of 3.62 m (BGL), the variance was found to be ± 4.29 m (BGL). Water table was low at Paltan Bazaar and high at Nutun Bazaar with 9.70 m (BGL) and 1.13 m (BGL).

During the month of April 95 the water table varied between 10.10 m (BGL) to 1.54 m (BGL) with an average value of 4.38 m (BGL), the variance was found to be ± 4.28 m (BGL). Water table was very low at Paltan Bazaar and high at Nutun Bazar with 10.10 m (BGL) and 1.54 m (BGL) respectively.

During the month of Oct. 95 the water table varied between 7.20 m (BGL) to 0.50 m (BGL) with an average value of 2.66 m (BGL), the variance was ± 3.35 m BGL. Water table was low at Paltan Bazar and very high at Noonmati with 7.20 m (BGL) and 0.50 m (BGL).

In general the water table was high at all places except at Paltan bazaar, which had a low water table throughout the sampling period. Maximum variance of ± 3.02 was found at Usha Nagar (Dispur) and a minimum of ± 0.19 at Barsajai.

6.9 Suitability of Irrigation Water

(a) On the basis of conductivity: In general, waters with conductivity values below 750 micro-mhos/cm are satisfactory for irrigation in so far salt content is concerned, although salt sensitive crops may be adversely affected by the use of irrigation waters having conductivity affected by the use of irrigation waters having conductivity values in the range 250 to 750 micro-mhos/cm are (USDA, 1954). Waters in the range of 750 to 2250 micro-mhos/cm are widely used, an satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of waters with conductivity values above 2250 micro-mhos/cm, is the exception. However, in this case the more salt tolerant crops can be grown with such waters, only if sub-soil drainage is good.

(b) On the basis of total dissolved solids: In addition, for best quality of irrigation water total dissolve solids should be below 800 mg/l (Jermer, 1987). In general water is good for irrigation, if total dissolved solids are below 1000 mg/l. However, this limit can be increased to 1700 mg/l, in case calcium forms 25% of the total bases ($K^+ + Na^+ + Ca^{++}$) in the irrigation water (Raghunath, 1982).

TABLE - 6.1 : PHYSICAL AND REDOX PARAMETERS IN GROUND WATER OF GREATER GUWAHATI
(JULY - 1994)

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	Temp °C	pH	ORP mV	DO ppm	Cond. μ -mho/cm	% Tr.	TDS ppm	WL (BGL) m
1	W- 1	Well	Dol Govind	26.8	6.67	195	7.40	874	78.0	612	1.50
2	W- 2	Well	Kahilipara	27.5	6.67	186	7.30	720	83.0	504	2.50
3	W- 3	Well	Durgeswari	28.8	5.87	190	7.10	878	84.0	615	1.87
4	W- 4	Well	Maligaon	26.4	7.20	203	8.80	1094	80.0	766	5.97
5	W- 5	Well	Khanapara	28.2	6.40	193	6.50	1172	84.0	820	2.05
6	W- 6	Well	Azra	28.1	6.20	221	8.50	1131	80.0	792	1.52
7	W- 7	Well	Bora Gaon	28.2	6.42	197	8.40	1172	75.0	820	1.75
8	W- 8	Well	Paltan Bazar	26.8	6.75	183	7.70	752	80.0	526	7.02
9	W- 9	Well	Zoo Narangi	27.7	6.10	190	8.70	1016	82.0	711	2.69
10	W-10	Well	Nutun Bazar	29.7	6.57	198	7.50	1178	88.0	825	1.14
11	W-11	Well	Barsajai	29.6	6.60	160	6.80	1094	81.0	766	1.26
12	W-12	Well	Rukmini Gaon	29.7	6.96	147	7.40	1198	80.0	839	—
13	W-13	Well	Jalukbari	29.8	7.18	200	7.70	1132	83.0	792	3.45
14	W-14	Well	Noonmati	29.2	5.74	204	8.00	1070	82.0	749	1.50
15	W-15	Well	Chandmari	29.4	6.73	160	7.70	1020	83.0	714	1.80
16	W-16	Well	Panjabari	30.0	6.32	160	7.10	1160	80.0	812	3.05
17	W-17	Well	Lachit Nagar	30.0	7.43	157	6.40	1152	78.0	806	4.57
18	W-18	Well	Bhangagarh	29.8	6.28	170	7.40	1056	84.0	739	—
19	W-19	Well	Hati Gaon	29.0	6.76	145	7.50	1086	82.0	760	3.20
20	W-20	Well	Usha Nagar	28.3	6.77	146	6.50	1058	69.0	741	1.39
21	W-21	Well	Hengrabari	28.8	6.02	156	8.30	912	80.0	638	7.32
22	W-22	Well	Mathura Nagar	28.5	6.48	184	6.60	1120	75.0	784	3.75
23	W-23	Well	Rukmani Nagar								
			MAX.	30.0	7.43	221	8.80	1198	88.0	839	7.32
			MIN.	26.4	5.74	145	6.40	720	69.0	504	1.14
			AVG.	28.7	6.55	179	7.51	1048	80.5	733	2.96
			VAR. \pm	1.8	0.84	38	1.20	239	9.5	167	3.09

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

Abbreviations :

ORP - Oxidation Reduction Potential
Tr. - % Light Transmission(at 1000 nm)
TDS - Total Dissolved Solids
pH - Hydrogen Ion Concentration
DO - Dissolved Oxygen

Cond. - Conductivity
Temp. - Temperature
WL - Water Table
BGL - Below Ground Level

TABLE - 6.2 : PHYSICAL AND REDOX PARAMETERS IN GROUND WATER OF GREATER GUWAHATI
(DECEMBER - 1994)

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	Temp °C	pH	ORP mV	DO ppm	Cond. μ -mho/cm	% Tr.	TDS ppm	WL (BGL) m
1	W-1	Well	Dol Govind	22.6	6.38	216	7.00	940	84.0	658	2.64
2	W-2	Well	Kahilipara	23.0	6.79	226	7.30	651	82.0	456	2.40
3	W-3	Well	Durgeswari	22.7	6.50	200	4.80	1130	82.0	791	2.15
4	W-4	Well	Maligaon	23.0	7.38	200	5.90	890	82.0	623	7.20
5	W-5	Well	Khanapara	23.2	6.64	204	8.20	884	84.0	619	3.25
6	W-6	Well	Azra	23.5	5.76	233	7.50	1038	74.0	727	3.90
7	W-7	Well	Bora Gaon	23.4	6.03	226	7.90	1020	82.0	714	1.45
8	W-8	Well	Paltan Bazar	24.0	6.57	221	6.20	810	82.0	567	9.70
9	W-9	Well	Zoo Narangi	23.1	7.04	208	7.90	1078	76.0	755	2.30
10	W-10	Well	Nutun Bazar	20.4	6.30	242	6.50	1092	83.0	764	1.13
11	W-11	Well	Barsajai	20.6	6.34	220	6.44	1058	81.0	741	1.59
12	W-12	Well	Rukmini Gaon	21.0	6.74	221	7.20	1097	83.0	768	-
13	W-13	Well	Jalukbari	24.0	6.98	156	6.24	1148	88.0	804	-
14	W-14	Well	Noonmati	21.0	5.24	279	7.80	1050	80.0	735	1.50
15	W-15	Well	Chandmari	20.0	6.11	205	6.80	949	86.0	664	4.20
16	W-16	Well	Panjabari	20.2	5.70	178	6.84	1154	83.0	808	4.20
17	W-17	Well	Lachit Nagar	20.8	6.15	238	6.20	1132	81.0	792	2.40
18	W-18	Well	Bhangagarh	20.1	5.54	274	6.30	879	82.0	615	6.80
19	W-19	Well	Hati Gaon	20.6	6.89	256	6.58	959	83.0	671	4.20
20	W-20	Well	Usha Nagar	20.1	6.29	168	6.10	1048	78.0	734	2.84
21	W-21	Well	Hengrabari	20.6	7.14	237	7.20	848	82.0	594	6.03
22	W-22	Well	Mathura Nagar	20.4	6.20	233	6.20	1056	81.0	739	2.53
23	W-23	Well	Rukmani Nagar	20.9	6.74	179	7.20	1049	76.0	734	
			MAX.	24.0	7.38	279	8.20	1154	88.0	808	9.70
			MIN.	20.0	5.24	156	4.80	651	74.0	456	1.13
			AVG.	21.7	6.41	218	6.80	998	81.5	688	3.62
			VAR.±	2.0	1.07	62	1.70	252	7.0	176	4.28

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

Abbreviations :

ORP - Oxidation Reduction Potential
Tr. - % Light Transmission (at 1000 nm)
TDS - Total Dissolved Solids
pH - Hydrogen Ion Concentration
DO - Dissolved Oxygen

Cond. - Conductivity
Temp. - Temperature
WL - Water Table
BGL - Below Ground Level

TABLE - 6.3 : PHYSICAL AND REDOX PARAMETERS IN GROUND WATER OF GREATER GUWAHATI
(APRIL - 1995)

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	Temp °C	pH	ORP mV	DO ppm	Cond. μ -mho/cm	% Tr.	TDS ppm	WL (BGL) m	
1	W- 1	Well	Dol Govind	28.0	5.35	199	6.28	798	86.0	559	6.15	
2	W- 2	Well	Kahilipara	28.4	6.20	194	6.64	698	83.0	489	3.42	
3	W- 3	Well	Durgeswari	28.7	5.99	185	7.50	904	84.0	633	2.70	
4	W- 4	Well	Maligaon	28.6	6.94	204	7.40	1128	83.0	790	7.10	
5	W- 5	Well	Khanapara	28.7	6.20	184	5.89	1032	82.0	722	3.85	
6	W- 6	Well	Azra	29.0	5.42	224	7.20	998	86.0	699	6.20	
7	W- 7	Well	Bora Gaon	28.0	5.56	210	6.90	1154	83.0	808	2.00	
8	W- 8	Well	Paltan Bazar	28.8	5.93	198	6.24	824	84.0	577	10.1	
9	W- 9	Well	Zoo Narangi	27.9	4.96	228	5.82	852	88.0	596	3.42	
10	W-10	Well	Nutun Bazar	29.3	6.48	195	6.90	998	85.0	699	1.54	
11	W-11	Well	Barsajai	29.5	6.50	210	6.24	1054	82.0	738	1.65	
12	W-12	Well	Rukmini Gaon	29.8	6.66	218	6.70	1098	82.0	769	-	
13	W-13	Well	Jalukbari	24.9	6.99	148	6.19	1143	87.0	800	-	
14	W-14	Well	Noonmati	28.7	4.87	198	6.90	1112	86.0	778	1.60	
15	W-15	Well	Chandmari	27.3	6.30	178	6.58	928	80.0	650	3.95	
16	W-16	Well	Panjabari	28.9	5.48	178	6.58	1152	84.0	806	4.90	
17	W-17	Well	Lachit Nagar	28.6	6.00	224	6.20	1098	78.0	769	3.00	
18	W-18	Well	Bhangagarh	28.6	5.70	220	6.12	908	82.0	636	7.35	
19	W-19	Well	Hati Gaon	29.5	6.70	229	6.48	964	84.0	675	4.42	
20	W-20	Well	Usha Nagar	28.8	6.75	142	6.20	1152	80.0	806	3.24	
21	W-21	Well	Hengrabari	28.0	5.26	188	6.98	884	84.0	619	7.00	
22	W-22	Well	Mathura Nagar	27.4	6.53	143	6.38	1082	83.0	757	4.02	
23	W-23	Well	Rukmani Nagar	28.6	6.61	219	6.70	1092	75.0	764	-	
				MAX.	29.8	6.99	229	7.50	1154	88.0	808	10.1
				MIN.	24.9	4.87	142	5.82	698	75.0	489	1.54
				AVG.	28.4	6.06	196	6.57	1002	83.1	690	4.38
				VAR. \pm	2.5	1.06	44	0.84	228	6.5	160	4.28

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

Abbreviations :

ORP - Oxidation Reduction Potential
Tr. - % Light Transmission(at 1000 nm)
TDS - Total Dissolved Solids
pH - Hydrogen Ion Concentration
DO - Dissolved Oxygen

Cond. - Conductivity
Temp. - Temperature
WL - Water Table
BGL - Below Ground Level

TABLE - 6.4 : PHYSICAL AND REDOX PARAMETERS IN GROUND WATER OF GREATER GUWAHATI
(OCTOBER - 1995)

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	Temp °C	pH	ORP mV	DO ppm	Cond. μ -mho/cm	% Tr.	TDS ppm	WL (BGL) m
1	W- 1	Well	Dol Govind	26.2	6.22	193	6.94	984	80.0	689	1.75
2	W- 2	Well	Kahilipara	28.5	6.33	185	7.14	659	74.0	461	2.10
3	W- 3	Well	Durgeswari	26.7	6.45	195	6.38	969	80.0	678	1.00
4	W- 4	Well	Maligaon	26.0	7.03	201	7.58	842	86.0	589	4.15
5	W- 5	Well	Khanapara	28.7	6.18	191	7.54	924	81.0	647	1.50
6	W- 6	Well	Azra	28.5	6.22	208	8.14	949	78.0	664	1.84
7	W- 7	Well	Bora Gaon	27.0	6.01	215	7.18	988	85.0	692	1.35
8	W- 8	Well	Paltan Bazar	28.7	6.52	196	6.89	842	82.0	589	7.20
9	W- 9	Well	Zoo Narangi	28.6	5.58	221	6.43	969	84.0	678	1.80
10	W-10	Well	Nutun Bazar	29.3	6.91	191	7.10	984	82.0	689	1.10
11	W-11	Well	Barsajai	28.9	6.42	206	6.58	1003	81.0	702	1.38
12	W-12	Well	Rukmini Gaon	27.9	6.54	208	7.24	987	84.0	691	-
13	W-13	Well	Jalukbari	-	-	-	-	-	-	-	-
14	W-14	Well	Noonmati	28.7	5.47	204	7.82	1058	80.0	741	0.50
15	W-15	Well	Chandmari	28.6	6.59	168	7.49	936	81.0	655	2.90
16	W-16	Well	Panjabari	27.2	6.15	198	6.84	1068	88.0	748	3.69
17	W-17	Well	Lachit Nagar	28.7	6.88	174	6.59	1059	76.0	741	3.90
18	W-18	Well	Bhangagarh	28.8	6.44	181	7.10	923	80.0	646	3.30
19	W-19	Well	Hati Gaon	28.4	6.38	219	7.19	894	83.0	626	2.90
20	W-20	Well	Usha Nagar	28.6	6.43	209	6.85	1028	81.0	720	1.28
21	W-21	Well	Hengrabari	28.3	6.78	231	6.49	839	80.0	587	6.92
22	W-22	Well	Mathura Nagar	28.2	6.38	165	6.42	1018	81.0	713	2.56
23	W-23	Well	Rukmani Nagar								
			MAX.	29.3	7.03	231	8.14	1068	88.0	748	7.20
			MIN.	26.0	5.47	165	6.38	659	74.0	461	0.50
			AVG.	28.1	6.38	181	7.04	949	81.3	664	2.66
			VAR. \pm	1.7	0.78	33	0.88	205	7.0	143	3.35

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

Abbreviations :

ORP - Oxidation Reduction Potential
 Tr. - % Light Transmission (at 1000 nm)
 TDS - Total Dissolved Solids
 pH - Hydrogen Ion Concentration
 DO - Dissolved Oxygen
 Cond. - Conductivity
 Temp. - Temperature
 WL - Water Table
 BGL - Below Ground Level

TABLE - 6.5 : WATER TABLE (BGL) VARIATION IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	WATER TABLE (BGL); m (At Field)							
				YEAR-->		1995		MAX.	MIN.	AVG.	VAR.
				MONTH-->	DEC.	APRIL	OCT.				
1	W-1	Well	Dol Govind	1.50	2.64	6.15	1.75	6.15	1.50	3.01	2.33
2	W-2	Well	Kahilipara	2.50	2.40	3.42	2.10	3.42	2.10	2.61	0.66
3	W-3	Well	Durgeswari	1.87	2.15	2.70	1.00	2.70	1.00	1.93	0.85
4	W-4	Well	Maligaon	5.97	7.20	7.10	4.15	7.20	4.15	6.11	1.53
5	W-5	Well	Khanapara	2.05	3.25	3.85	1.50	3.85	1.50	2.66	1.18
6	W-6	Well	Azra	1.52	3.90	6.20	1.84	6.20	1.52	3.37	2.34
7	W-7	Well	Bora Gaon	1.75	1.45	2.00	1.35	2.00	1.35	1.64	0.32
8	W-8	Well	Paltan Bazar	7.02	9.70	10.10	7.20	10.10	7.02	8.50	1.54
9	W-9	Well	Zoo Narangi	2.69	2.30	3.42	1.80	3.42	1.80	2.55	0.81
10	W-10	Well	Nutan Bazar	1.14	1.13	1.54	1.10	1.54	1.10	1.23	0.22
11	W-11	Well	Barsajai	1.26	1.59	1.65	1.38	1.65	1.26	1.47	0.19
12	W-12	Well	Rukmani Gaon	-	-	-	-	-	-	-	-
13	W-13	Well	Jalukbari	3.45	-	-	-	-	-	3.45	-
14	W-14	Well	Noonmati	1.50	1.50	1.60	0.50	4.20	0.50	1.28	1.85
15	W-15	Well	Chandmari	1.80	4.20	3.95	2.90	4.90	1.80	3.21	1.55
16	W-16	Well	Panjabari	3.05	4.20	4.90	3.69	4.90	3.05	3.96	0.93
17	W-17	Well	Lachit Nagar	4.57	2.40	3.00	3.90	7.35	2.40	3.47	2.48
18	W-18	Well	Bhangagarh	-	6.80	7.35	3.30	7.35	3.30	5.82	2.03
19	W-19	Well	Hati Gaon	3.20	4.20	4.42	2.90	4.42	2.90	3.68	0.76
20	W-20	Well	Usha Nagar	1.39	2.84	3.24	1.28	7.32	1.28	2.19	3.02
21	W-21	Well	Hengarabari	7.32	6.03	7.00	6.92	7.32	6.03	6.82	0.65
22	W-22	Well	Mathura Nagar	3.75	2.53	4.02	2.56	4.02	2.53	3.22	0.74
23	W-23	Well	Rukmani Nagar	-	-	-	-	-	-	-	-
			MAX.	7.32	9.70	10.10	7.20	10.10	7.02	8.50	3.02
			MIN.	1.14	1.13	1.54	0.50	1.54	0.50	1.23	0.19
			AVG.	2.97	3.62	4.38	2.66	5.00	2.40	3.44	1.30
			VAR. ±	3.09	4.29	4.28	3.35	4.28	3.26	3.64	1.41

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.6 : VARIATION OF TEMPERATURE IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	TEMPERATURE ; °C (At Field)									
				YEAR-->		1994		1995		MAX.	MIN.	AVG.	VAR
				MONTH-->		JULY	DEC.	APRIL	OCT.				
1	W- 1	Well	Dol Govind	26.8	22.6	28.0	26.2	28.0	22.6	25.9	2.7		
2	W- 2	Well	Kahilipara	27.5	23.0	28.4	28.5	28.5	23.0	26.9	2.8		
3	W- 3	Well	Durgeswari	28.8	22.7	28.7	26.7	28.8	22.7	26.7	3.1		
4	W- 4	Well	Maligaon	26.4	23.0	28.6	26.0	28.6	23.0	26.0	2.8		
5	W- 5	Well	Khanapara	28.2	23.2	28.7	28.7	28.7	23.2	27.2	2.8		
6	W- 6	Well	Azra	28.1	23.5	29.0	28.5	29.0	23.5	27.3	2.8		
7	W- 7	Well	Bora Gaon	28.2	23.4	28.0	27.0	28.2	23.4	26.7	2.4		
8	W- 8	Well	Paltan Bazar	26.8	24.0	28.8	28.7	28.8	24.0	27.1	2.4		
9	W- 9	Well	Zoo Narangi	27.7	23.1	27.9	28.6	28.6	23.1	26.8	2.8		
10	W-10	Well	Nutan Bazar	29.7	20.4	29.3	29.3	29.7	20.4	27.2	4.7		
11	W-11	Well	Barsajai	29.6	20.6	29.5	28.9	29.6	20.6	27.2	4.5		
12	W-12	Well	Rukmani Gaon	29.7	21.0	29.8	27.9	29.8	21.0	27.1	4.4		
13	W-13	Well	Jalukbari	29.8	24.0	24.9	-	29.8	24.0	26.2	2.9		
14	W-14	Well	Noonmati	29.2	21.0	28.7	28.7	29.2	21.0	26.9	4.1		
15	W-15	Well	Chandmari	29.4	20.0	27.3	28.6	29.4	20.0	26.3	4.7		
16	W-16	Well	Panjabari	30.0	20.2	28.9	27.2	30.0	20.2	26.6	4.9		
17	W-17	Well	Lachit Nagar	30.0	20.8	28.6	28.7	30.0	20.8	27.0	4.6		
18	W-18	Well	Bhangagarh	29.8	20.1	28.6	28.8	29.8	20.1	26.8	4.9		
19	W-19	Well	Hati-Gaon	29.0	20.6	29.5	28.4	29.5	20.6	26.9	4.4		
20	W-20	Well	Usha Nagar	28.3	20.1	28.8	28.6	28.8	20.1	26.5	4.4		
21	W-21	Well	Hengarabari	28.8	20.6	28.0	28.3	28.8	20.6	26.4	4.1		
22	W-22	Well	Mathura Nagar	28.5	20.4	27.4	28.2	28.5	20.4	26.1	4.1		
23	W-23	Well	Rukmani Nagar	-	20.9	28.6	-	28.6	20.9	24.8	3.9		
			MAX.	30.0	24.0	29.8	29.3	30.0	24.0	27.3	4.9		
			MIN.	26.4	20.0	24.9	26.0	28.0	20.0	24.8	2.4		
			AVG.	28.7	21.7	28.4	28.1	29.1	21.7	26.6	3.7		
			VAR.±	1.8	2.0	2.5	1.7	1.0	2.0	1.3	1.3		

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.7 : VARIATION OF pH IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	pH VALUE (At Field)									
				YEAR---		1994		1995		MAX.	MIN.	AVG.	VAR.
				MONTH-->		JULY	DEC.	APRIL	OCT.				
1	W- 1	Well	Dol Govind	6.67	6.38	5.35	6.22	6.67	5.35	6.16	0.66		
2	W- 2	Well	Kahilipara	6.67	6.79	6.20	6.33	6.79	6.20	6.50	0.29		
3	W- 3	Well	Durgeswari	5.87	6.50	5.99	6.45	6.50	5.87	6.20	0.31		
4	W- 4	Well	Maligaon	7.20	7.38	6.94	7.03	7.38	6.94	7.14	0.22		
5	W- 5	Well	Khanapara	6.40	6.64	6.20	6.18	6.64	6.18	6.36	0.23		
6	W- 6	Well	Azra	6.20	5.76	5.42	6.22	6.22	5.42	5.90	0.40		
7	W- 7	Well	Bora Gaon	6.42	6.03	5.56	6.01	6.42	5.56	6.01	0.43		
8	W- 8	Well	Paltan Bazar	6.75	6.57	5.93	6.52	6.75	5.93	6.44	0.41		
9	W- 9	Well	Zoo Narangi	6.10	7.04	4.96	5.58	7.04	4.96	5.92	1.04		
10	W-10	Well	Nutan Bazar	6.57	6.30	6.48	6.91	6.91	6.30	6.57	0.31		
11	W-11	Well	Barsajai	6.60	6.34	6.50	6.42	6.60	6.34	6.47	0.13		
12	W-12	Well	Rukmani Gaon	6.96	6.74	6.66	6.54	6.96	6.54	6.73	0.21		
13	W-13	Well	Jalukbari	7.18	6.98	6.99	-	7.18	6.98	7.05	0.10		
14	W-14	Well	Noonmati	5.74	5.24	4.87	5.47	5.74	4.87	5.33	0.44		
15	W-15	Well	Chandmari	6.73	6.11	6.30	6.59	6.73	6.11	6.43	0.31		
16	W-16	Well	Panjabari	6.32	5.70	5.48	6.15	6.32	5.48	5.91	0.42		
17	W-17	Well	Lachit Nagar	7.43	6.15	6.00	6.88	7.43	6.00	6.62	0.71		
18	W-18	Well	Bhangagarh	6.28	5.54	5.70	6.44	6.44	5.54	5.99	0.45		
19	W-19	Well	Hati Gaon	6.76	6.89	6.70	6.38	6.89	6.38	6.68	0.25		
20	W-20	Well	Usha Nagar	6.77	6.29	6.75	6.43	6.77	6.29	6.56	0.24		
21	W-21	Well	Hengarabari	6.02	7.14	5.26	6.78	7.14	5.26	6.30	0.94		
22	W-22	Well	Mathura Nagar	6.48	6.20	6.53	6.38	6.53	6.20	6.40	0.17		
23	W-23	Well	Rukmani Nagar	-	6.74	6.61	-	6.74	6.61	6.68	0.06		
			MAX.	7.43	7.38	6.99	7.03	7.43	6.98	7.14	1.04		
			MIN.	5.74	5.24	4.87	5.47	5.74	4.87	5.33	0.06		
			AVG.	6.55	6.41	6.06	6.38	6.73	5.94	6.35	0.39		
			VAR.±	0.84	1.07	1.06	0.78	0.84	1.06	0.90	0.49		

NB : VAR = [(MAX - AVE.) + (AVE - MIN)] / 2

TABLE - 6.8 : VARIATION OF ORP IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	ORP ; mV (At Field)							
				YEAR-->		1995		MAX.	MIN.	AVG.	VAR.
				MONTH-->	JULY	DEC.	APRIL				
1	W- 1	Well	Dol Govind	195	216	199	193	216	193	201	12
2	W- 2	Well	Kahilipara	186	226	194	185	226	185	198	21
3	W- 3	Well	Durgeswari	190	200	185	195	200	185	193	8
4	W- 4	Well	Maligaon	203	200	204	201	204	200	202	2
5	W- 5	Well	Khanapara	193	204	184	191	204	184	193	10
6	W- 6	Well	Azra	221	233	224	208	233	208	222	13
7	W- 7	Well	Bora Gaon	197	226	210	215	226	197	212	15
8	W- 8	Well	Paltan Bazar	183	221	198	196	221	183	200	19
9	W- 9	Well	Zoo Narangi	190	208	228	221	228	190	212	19
10	W-10	Well	Nutan Bazar	198	242	195	191	242	191	207	26
11	W-11	Well	Barsajai	160	220	210	206	220	160	199	30
12	W-12	Well	Rukmani Gaon	147	221	218	208	221	147	199	37
13	W-13	Well	Jalukbari	200	156	148	—	200	148	168	26
14	W-14	Well	Noonmati	204	279	198	204	279	198	221	41
15	W-15	Well	Chandmari	160	205	178	168	279	160	178	60
16	W-16	Well	Panjabari	160	178	178	198	205	160	179	23
17	W-17	Well	Lachit Nagar	157	238	224	174	238	157	198	41
18	W-18	Well	Bhangagarh	170	274	220	181	274	170	211	52
19	W-19	Well	Hati Gaon	145	256	229	219	274	145	212	65
20	W-20	Well	Usha Nagar	146	168	143	209	256	143	167	57
21	W-21	Well	Hengarabari	156	237	188	231	237	156	203	41
22	W-22	Well	Mathura Nagar	184	233	143	165	237	143	181	47
23	W-23	Well	Rukmani Nagar	—	179	219	—	219	179	199	20
			MAX.	221	279	229	231	279	208	222	65
			MIN.	145	156	143	165	200	143	167	2
			AVG.	179	218	196	198	232	173	198	30
			VAR. ±	38	62	43	33	40	33	28	31

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.9 : VARIATION OF CONDUCTIVITY IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	CONDUCTIVITY ; μ -mho/cm (At Field)								
				YEAR-->	1994		1995		MAX.	MIN.	AVG.	VAR.
					MONTH-->	JULY	DEC.	APRIL				
1	W- 1	Well	Dol Govind		874	940	798	984	984	798	899	93
2	W- 2	Well	Kahilipara		720	551	698	659	720	651	682	35
3	W- 3	Well	Durgeswari		878	1130	904	969	1130	878	970	125
4	W- 4	Well	Maligaon		1094	390	1128	842	1128	842	989	143
5	W- 5	Well	Khanapara		1172	384	1032	924	1172	884	1003	144
6	W- 6	Well	Azra		1131	1038	998	949	1131	949	1029	91
7	W- 7	Well	Bora Gaon		1172	1020	1154	988	1172	988	1084	92
8	W- 8	Well	Paltan Bazar		752	810	824	842	842	752	807	45
9	W- 9	Well	Zoo Narangi		1016	1078	852	969	1078	852	979	113
10	W-10	Well	Nutan Bazar		1178	1092	998	984	1178	984	1063	97
11	W-11	Well	Barsajai		1094	1058	1054	1003	1094	1003	1052	46
12	W-12	Well	Rukmani Gaon		1198	1097	1046	987	1198	987	1083	106
13	W-13	Well	Jalukbari		1132	1148	1143	-	1148	1132	1141	8
14	W-14	Well	Noonmati		1070	1050	1112	1058	1112	1050	1073	31
15	W-15	Well	Chandmari		1020	949	928	936	1020	928	958	46
16	W-16	Well	Panjabari		1160	1145	1152	1068	1160	1068	1131	46
17	W-17	Well	Lachit Nagar		1152	1132	1098	1059	1152	1059	1110	47
18	W-18	Well	Bhangagarh		1056	879	908	923	1056	879	942	89
19	W-19	Well	Hati Gaon		1086	959	964	894	1086	894	976	96
20	W-20	Well	Usha Nagar		1058	1048	1152	1028	1152	1028	1072	62
21	W-21	Well	Hengarabari		912	848	884	839	912	839	871	36
22	W-22	Well	Mathura Nagar		1120	1056	1082	1018	1120	1018	1069	51
23	W-23	Well	Rukmani Nagar		-	1049	1092	-	1092	1049	1063	22
			MAX.		1198	1148	1154	1068	1198	1132	1141	144
			MIN.		720	651	698	659	720	651	682	35
			AVG.		1048	938	1000	949	1080	935	1002	72
			VAR. \pm		239	249	228	205	239	241	230	63

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.10 : VARIATION OF TOTAL DISSOLVED SOLIDS IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	TDS ; ppm							
				YEAR-->		1995		MAX.	MIN.	AVG.	VAR.
				MONTH-->	JULY	DEC.	APRIL				
1	W- 1	Well	Dol Govind	524	564	479	590	590	479	539	56
2	W- 2	Well	Kahilipara	432	391	419	395	432	391	409	21
3	W- 3	Well	Durgeswari	527	678	542	581	678	527	582	76
4	W- 4	Well	Maligaon	656	534	677	505	677	505	593	86
5	W- 5	Well	Khanapara	703	530	619	554	703	530	602	86
6	W- 6	Well	Azra	679	623	599	569	679	569	617	55
7	W- 7	Well	Bora Gaon	703	612	692	593	703	593	650	55
8	W- 8	Well	Paltan Bazar	451	486	494	505	505	451	484	27
9	W- 9	Well	Zoo Narangi	610	647	511	581	647	511	587	68
10	W-10	Well	Nutan Bazar	707	655	599	590	707	590	638	58
11	W-11	Well	Barsajai	656	635	632	602	656	602	631	27
12	W-12	Well	Rukmani Gaon	719	658	629	592	719	592	650	63
13	W-13	Well	Jalukbari	679	689	686	--	689	679	685	5
14	W-14	Well	Noonmati	642	630	667	635	667	630	644	19
15	W-15	Well	Chandmari	612	569	557	562	612	557	575	28
16	W-16	Well	Panjabari	696	687	691	641	696	641	679	28
17	W-17	Well	Lachit Nagar	691	679	659	635	691	635	666	28
18	W-18	Well	Bhangagarh	634	527	545	554	634	527	565	53
19	W-19	Well	Hati Gaon	652	575	578	536	652	536	585	58
20	W-20	Well	Usha Nagar	635	629	691	617	691	617	643	37
21	W-21	Well	Hengarabari	547	509	530	503	547	503	522	22
22	W-22	Well	Mathura Nagar	672	634	649	611	672	611	641	31
23	W-23	Well	Rukmani Nagar	--	629	655	--	655	629	638	13
			MAX.	719	689	692	641	719	679	685	86
			MIN.	432	391	419	395	432	391	409	5
			AVG.	629	599	600	569	648	561	601	43
			VAR. ±	143	149	137	123	143	144	138	41

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.11 : VARIATION OF % LIGHT TRANSMISSION IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	% TRANSMITTIVITY (At Field)							
				YEAR-->		1995		MAX.	MIN.	AVG.	VAR.
				MONTH-->	JULY	DEC.	APRIL				
1	W- 1	Well	Dol Govind	78.0	84.0	86.0	80.0	86.0	78.0	82.0	4.0
2	W- 2	Well	Kahilipara	83.0	82.0	83.0	74.0	83.0	74.0	80.5	4.5
3	W- 3	Well	Durgeswari	84.0	82.0	84.0	80.0	84.0	80.0	82.5	2.0
4	W- 4	Well	Maligaon	80.0	82.0	83.0	86.0	86.0	80.0	82.8	3.0
5	W- 5	Well	Khanapara	84.0	84.0	82.0	81.0	84.0	81.0	82.8	1.5
6	W- 6	Well	Azra	80.0	74.0	86.0	78.0	86.0	74.0	79.5	6.0
7	W- 7	Well	Bora Gaon	75.0	82.0	83.0	85.0	85.0	75.0	81.3	5.0
8	W- 8	Well	Paltan Bazar	80.0	82.0	84.0	82.0	84.0	80.0	82.0	2.0
9	W- 9	Well	Zoo Narangi	82.0	76.0	88.0	84.0	88.0	76.0	82.5	6.0
10	W-10	Well	Nutan Bazar	88.0	83.0	85.0	82.0	88.0	82.0	84.5	3.0
11	W-11	Well	Barsajai	81.0	81.0	82.0	81.0	82.0	81.0	81.3	0.5
12	W-12	Well	Rukmani Gaon	80.0	83.0	82.0	84.0	84.0	80.0	82.3	2.0
13	W-13	Well	Jalukbari	83.0	88.0	87.0	—	88.0	83.0	86.0	2.5
14	W-14	Well	Noonmati	82.0	80.0	86.0	80.0	86.0	80.0	82.0	3.0
15	W-15	Well	Chandmari	83.0	86.0	80.0	81.0	86.0	80.0	82.5	3.0
16	W-16	Well	Panjabari	80.0	83.0	84.0	88.0	88.0	80.0	83.8	4.0
17	W-17	Well	Lachit Nagar	78.0	81.0	78.0	76.0	81.0	76.0	78.3	2.5
18	W-18	Well	Bhangagarh	84.0	82.0	82.0	80.0	84.0	80.0	82.0	2.0
19	W-19	Well	Hati Gaon	82.0	83.0	84.0	83.0	84.0	82.0	83.0	1.0
20	W-20	Well	Usha Nagar	69.0	78.0	80.0	81.0	81.0	69.0	77.0	6.0
21	W-21	Well	Hengarabari	80.0	82.0	84.0	80.0	84.0	80.0	81.5	2.0
22	W-22	Well	Mathura Nagar	75.0	81.0	83.0	81.0	83.0	75.0	80.0	4.0
23	W-23	Well	Rukmani Nagar	—	76.0	75.0	—	76.0	75.0	75.5	0.5
			MAX.	88.0	88.0	88.0	88.0	88.0	83.0	86.0	6.0
			MIN.	69.0	74.0	75.0	74.0	76.0	69.0	75.5	0.5
			AVG.	80.5	81.5	83.1	81.3	84.4	78.3	81.5	3.0
			VAR. ±	9.5	7.0	6.5	7.0	6.0	7.0	5.3	2.8

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

TABLE - 6.12 : VARIATION OF DISSOLVED OXYGEN IN GROUND WATER OF GREATER GUWAHATI

S. NO.	SITE NO.	SAMP-LING SOURCE	LOCATION	DISSOLVED OXYGEN ; ppm (At Field)								
				YEAR-->	1994		1995		MAX.	MIN.	AVG.	VAR.
					MONTH-->	JULY	DEC.	APRIL				
1	W- 1	Well	Dol Govind		7.40	7.00	6.28	6.94	7.40	6.28	6.91	0.56
2	W- 2	Well	Kahilipara		7.30	7.30	6.64	7.14	7.30	6.64	7.10	0.33
3	W- 3	Well	Durgeswari		7.10	4.80	7.50	6.38	7.50	4.80	6.45	1.35
4	W- 4	Well	Maligaon		8.80	5.90	7.40	7.58	8.80	5.90	7.42	1.45
5	W- 5	Well	Khanapara		6.50	8.20	5.89	7.54	8.20	5.89	7.03	1.15
6	W- 6	Well	Azra		8.50	7.50	7.20	8.14	8.50	7.20	7.84	0.65
7	W- 7	Well	Bora Gaon		8.40	7.90	6.90	7.18	8.40	6.90	7.60	0.75
8	W- 8	Well	Paltan Bazar		7.70	6.20	6.24	6.89	7.70	6.20	6.76	0.75
9	W- 9	Well	Zoo Narangi		8.70	7.90	5.82	6.43	8.70	5.82	7.21	1.44
10	W-10	Well	Nutan Bazar		7.50	6.50	6.90	7.10	7.50	6.50	7.00	0.50
11	W-11	Well	Barsajai		6.80	6.44	6.24	6.58	6.80	6.24	6.52	0.28
12	W-12	Well	Rukmani Gaon		7.40	7.20	6.70	7.24	7.40	6.70	7.14	0.35
13	W-13	Well	Jalukbari		7.70	6.24	6.19	-	7.70	6.19	6.71	0.75
14	W-14	Well	Noonmati		8.00	7.80	6.90	7.82	8.00	6.90	7.63	0.55
15	W-15	Well	Chandmari		7.70	6.80	6.58	7.49	7.70	6.58	7.14	0.56
16	W-16	Well	Panjabari		7.10	6.84	6.58	6.84	7.10	6.58	6.84	0.26
17	W-17	Well	Lachit Nagar		6.40	6.20	6.20	6.59	6.59	6.20	6.35	0.19
18	W-18	Well	Bhangagarh		7.40	6.30	6.12	7.10	7.40	6.12	6.73	0.64
19	W-19	Well	Hati Gaon		7.50	6.58	6.43	7.19	7.50	6.43	6.93	0.54
20	W-20	Well	Usha Nagar		6.50	6.10	6.20	6.85	6.85	6.10	6.41	0.38
21	W-21	Well	Hengarabari		8.30	7.20	6.98	6.49	8.30	6.49	7.24	0.91
22	W-22	Well	Mathura Nagar		6.60	6.20	6.38	6.42	6.60	6.20	6.40	0.20
23	W-23	Well	Rukmani Nagar		-	7.20	6.70	-	7.20	6.70	6.95	0.25
			MAX.		8.80	8.20	7.50	8.14	8.80	7.20	7.84	1.45
			MIN.		6.40	4.80	5.82	6.38	6.59	4.80	6.35	0.19
			AVG.		7.51	6.80	6.56	7.04	7.61	6.31	6.97	0.64
			VAR.		1.20	1.70	0.84	0.88	1.11	1.20	0.74	0.63

NB : VAR = [(MAX - AVE) + (AVE - MIN)] / 2

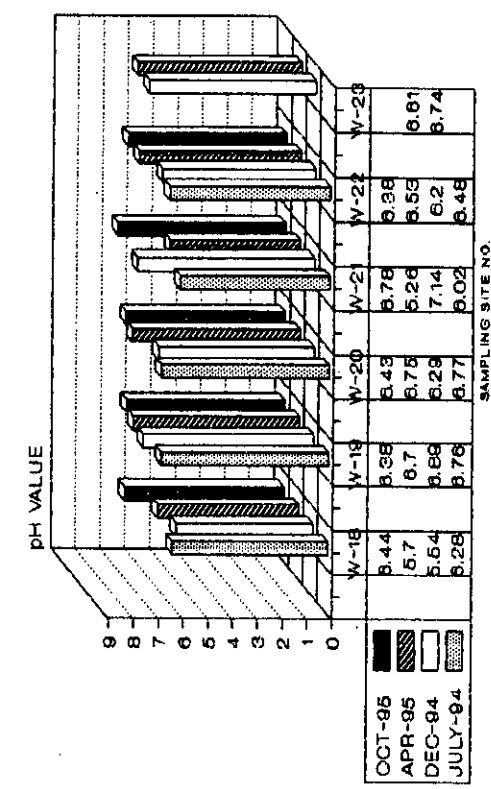
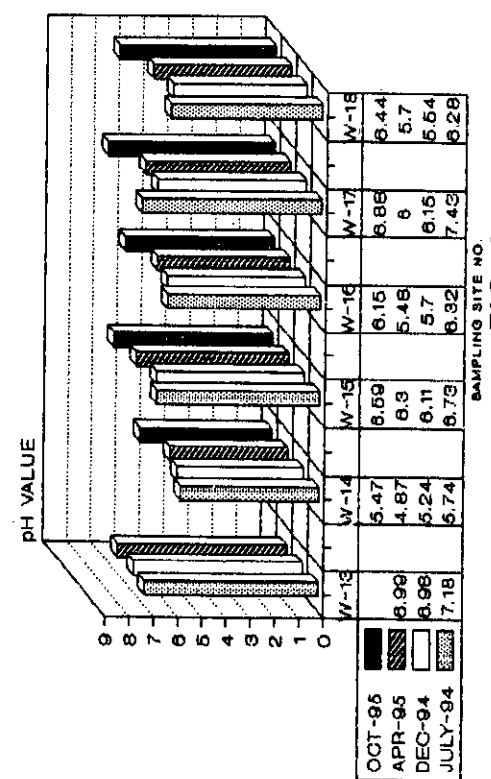
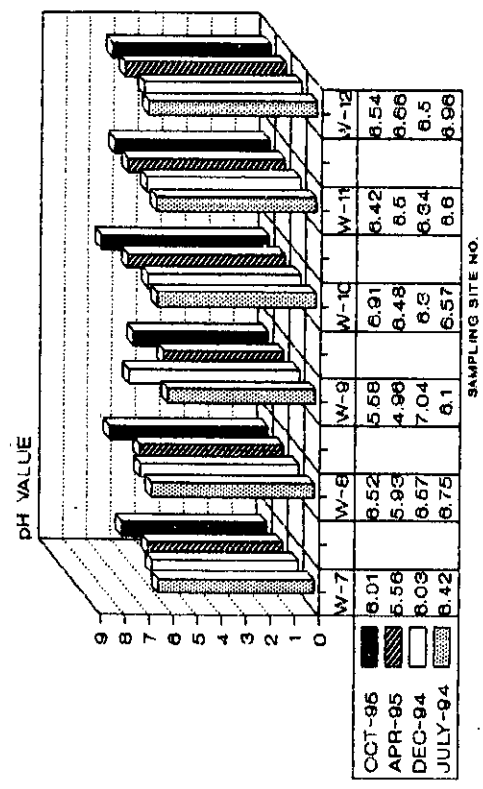
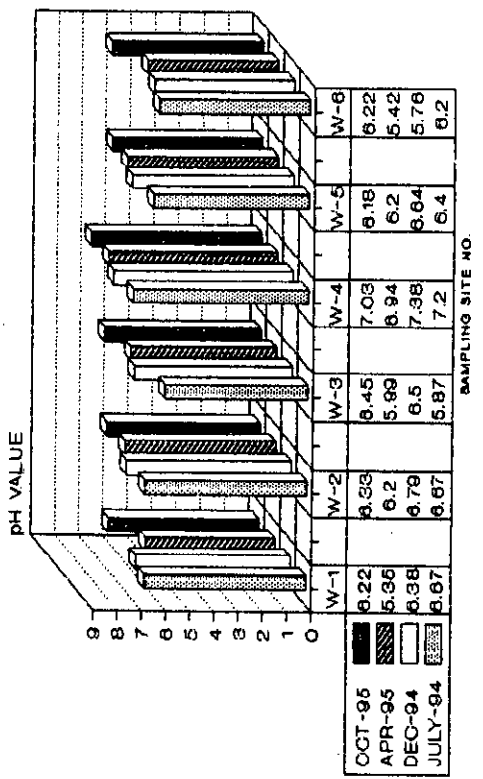


FIG. 6.1 : VARIATION OF pH IN GROUND WATER

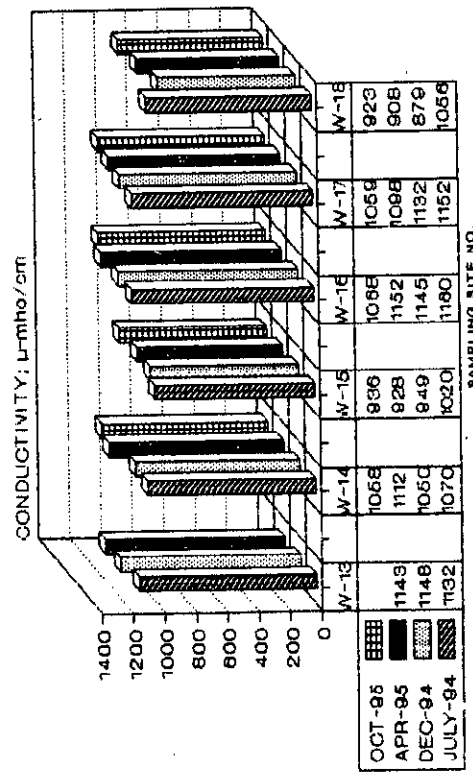
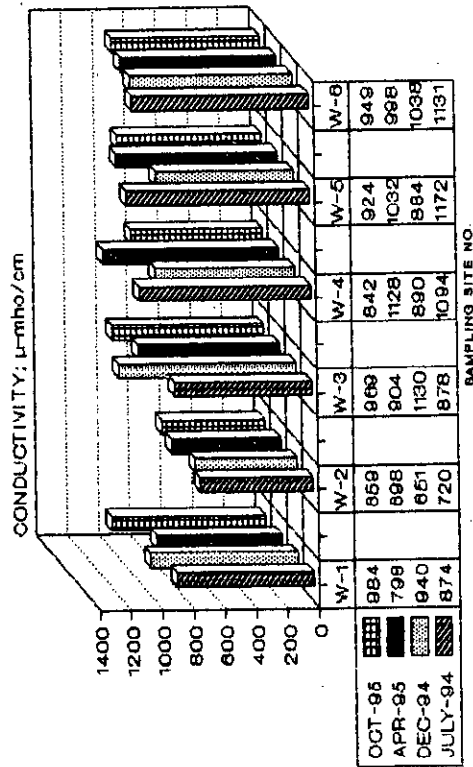
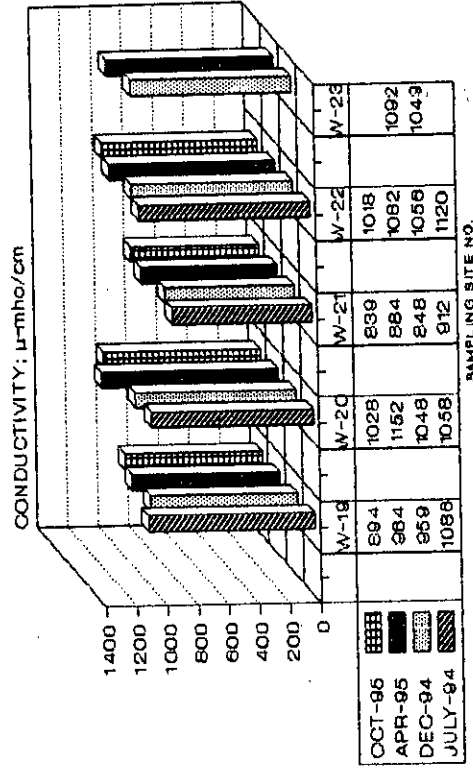
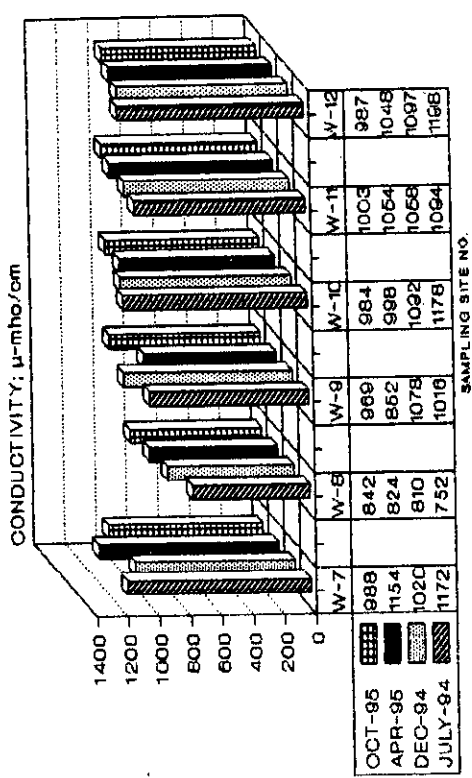


FIG. 6.2 : VARIATION OF CONDUCTIVITY IN GROUND WATER

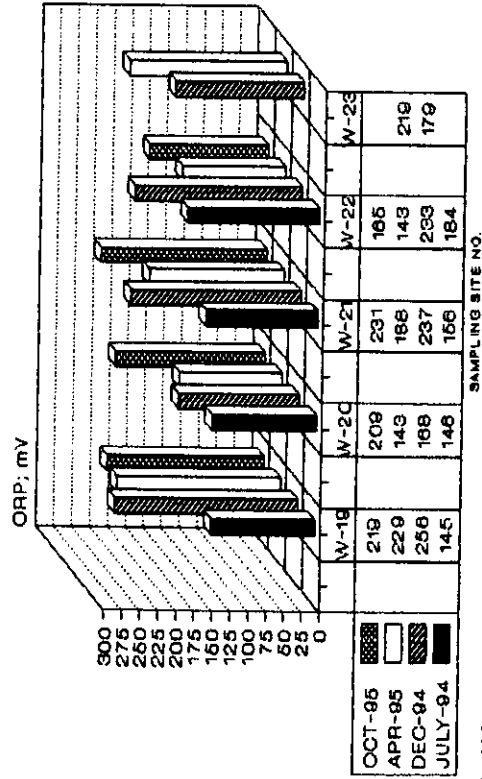
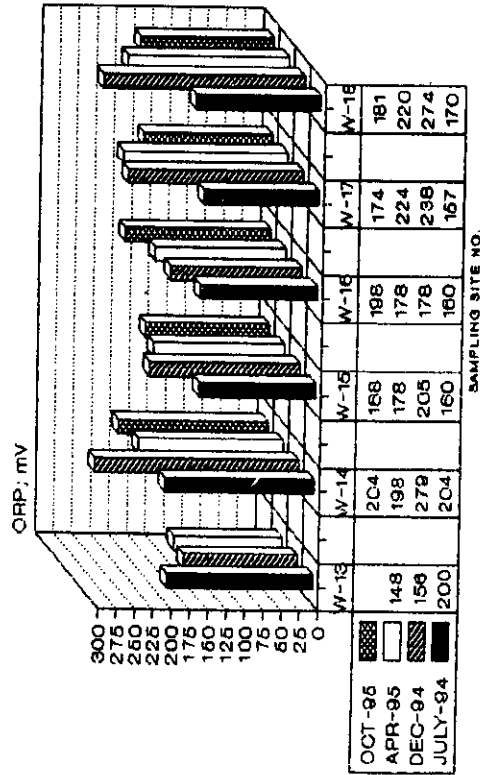
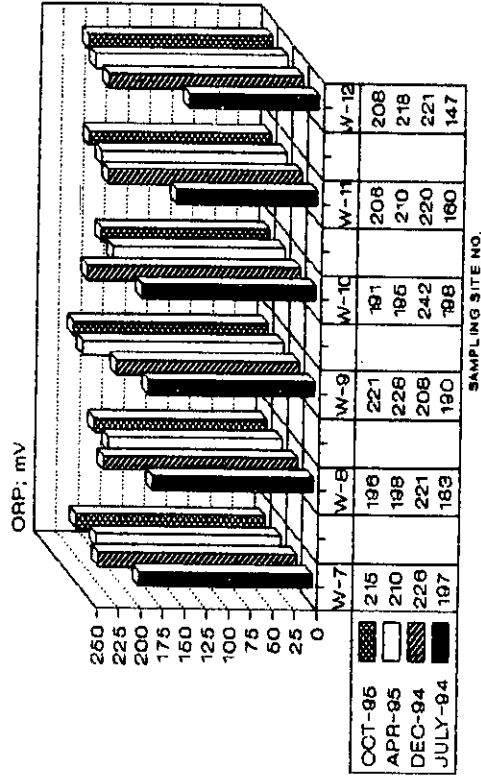
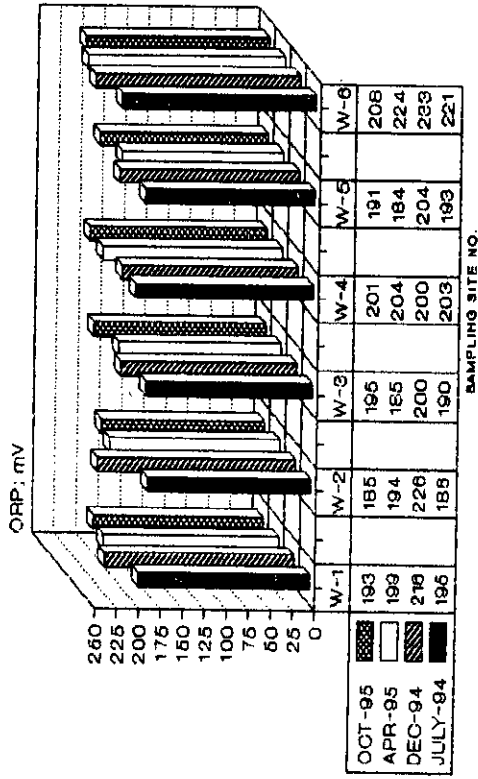


FIG. 6.3 : VARIATION OF ORP IN GROUND WATER

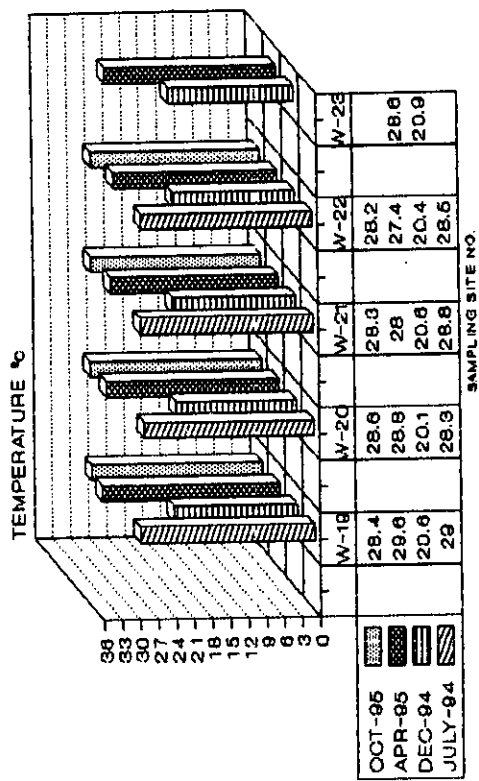
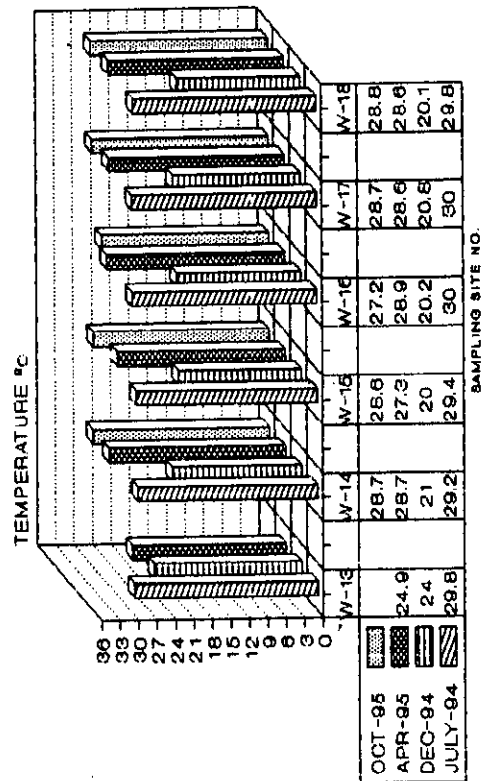
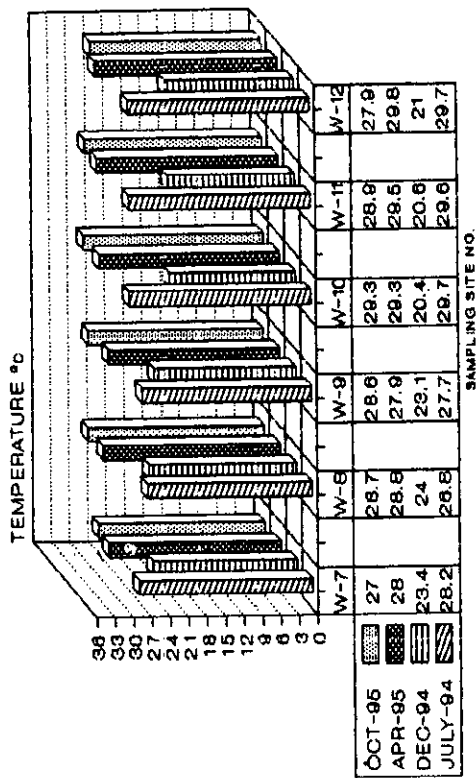
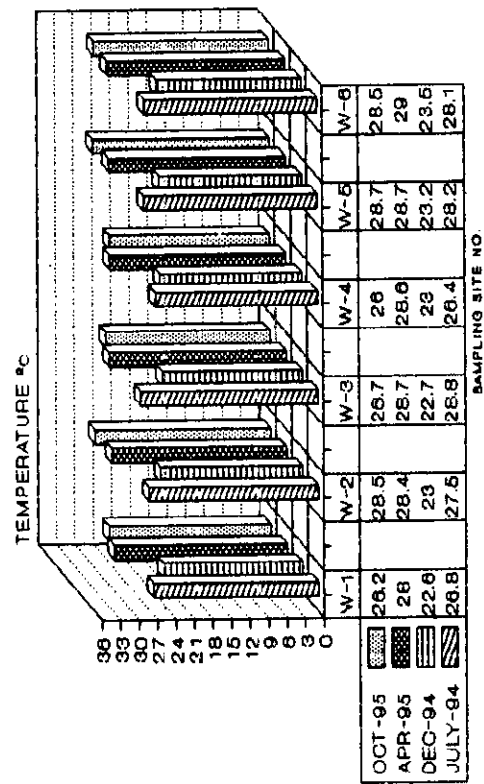


FIG. 6.4 : VARIATION OF TEMPERATURE IN GROUND WATER

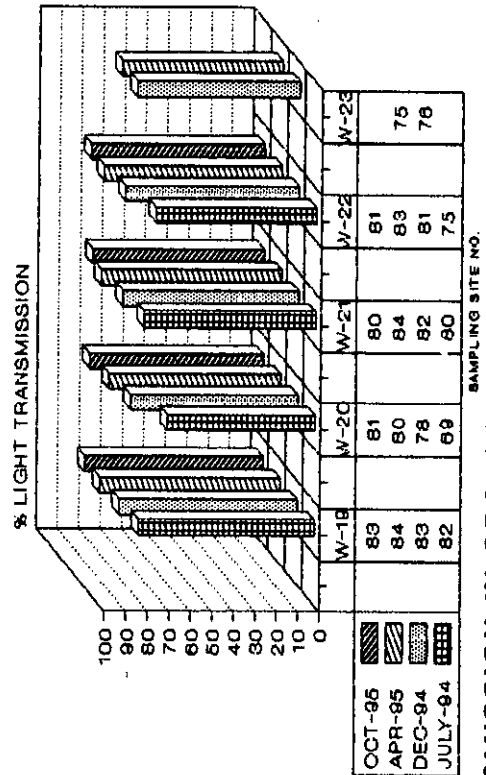
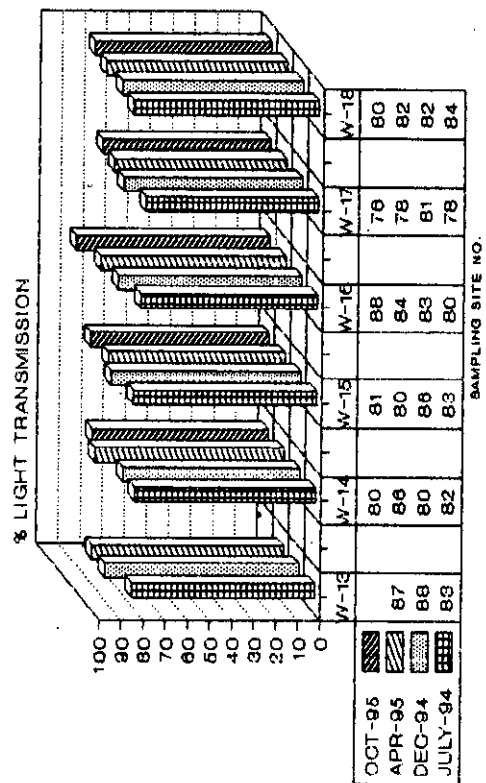
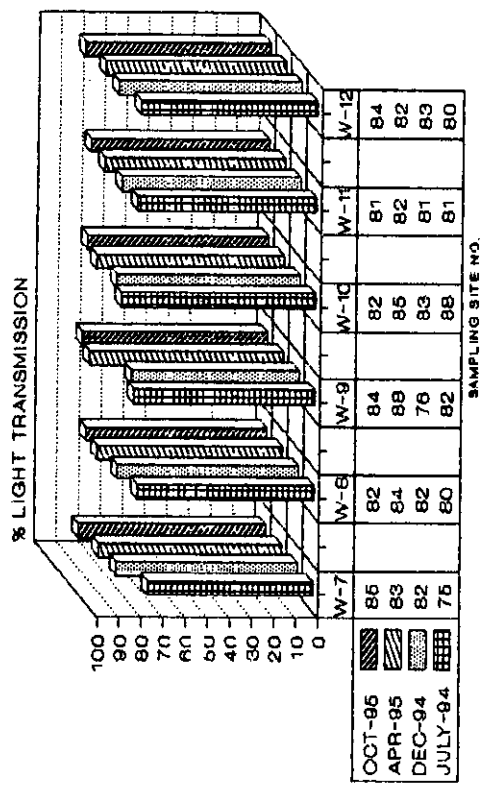
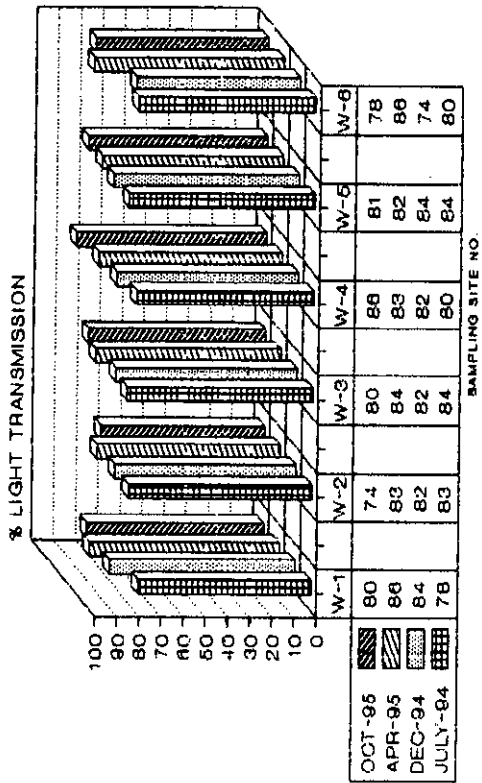


FIG. 6.5 : VARIATION OF %LIGHT TRANSMISSION IN GROUND WATER

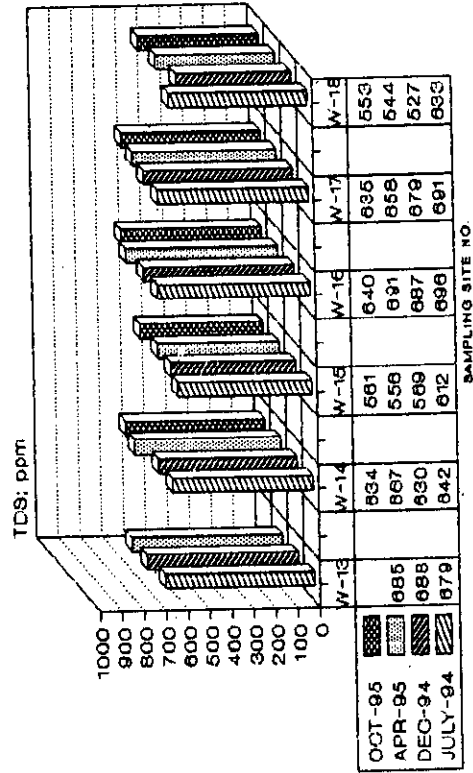
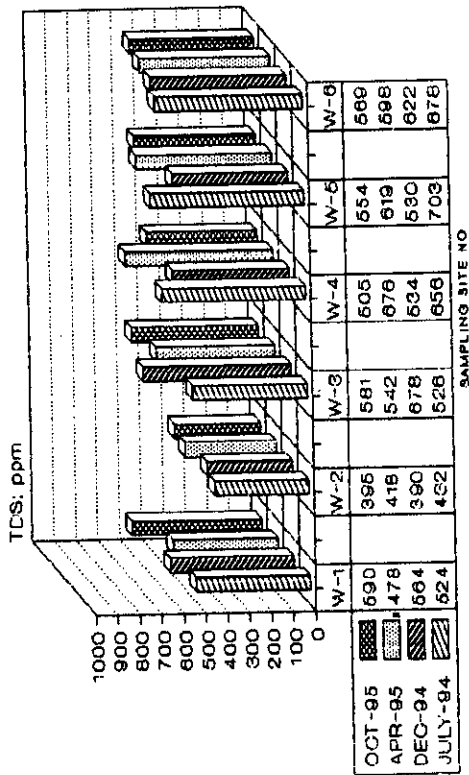
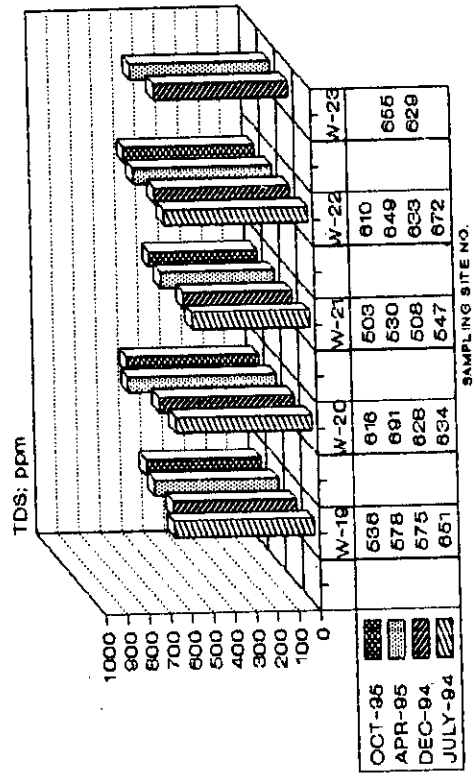
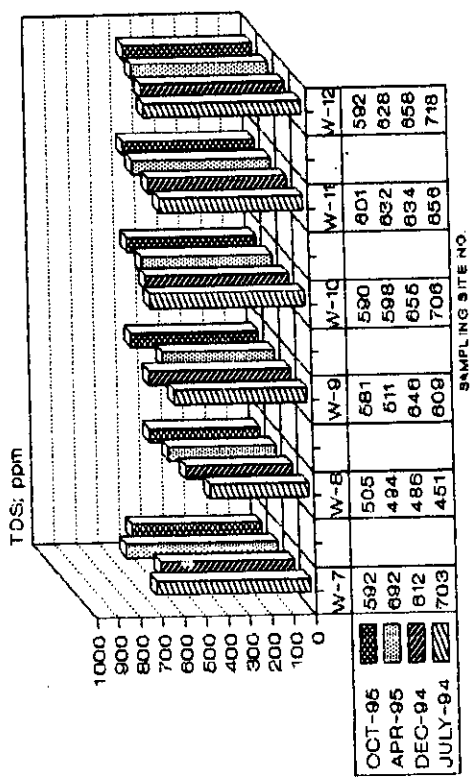
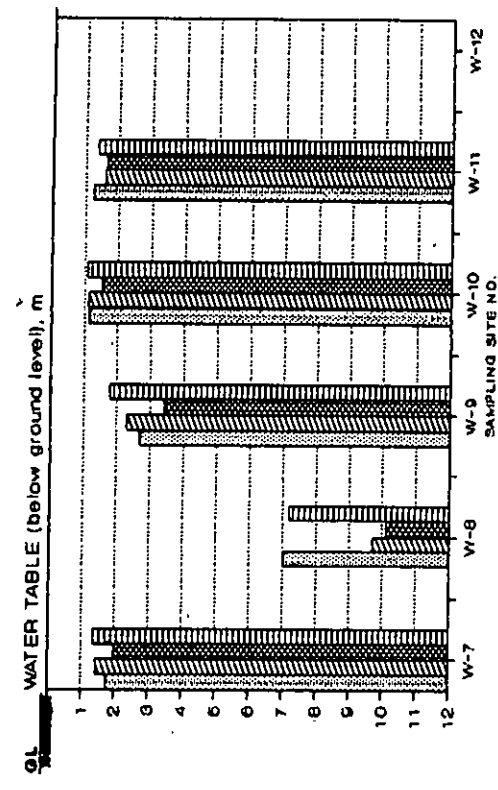
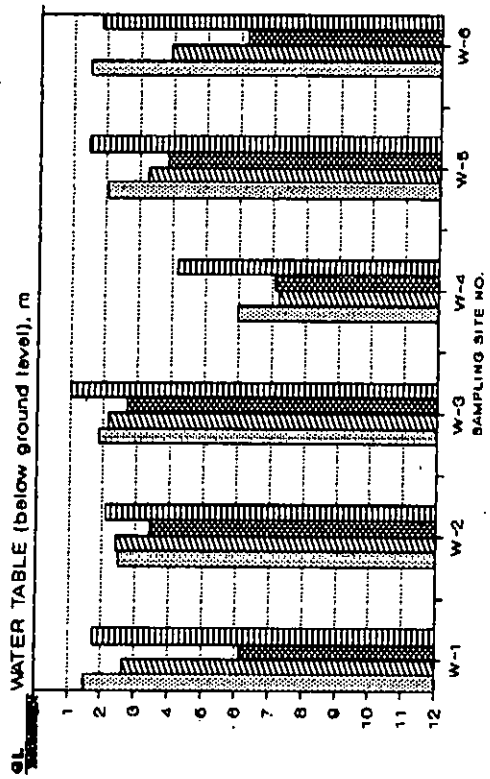


FIG. 6.6 : VARIATION OF TDS IN GROUND WATER



JULY-94 DEC-94 APR-96 OCT-96

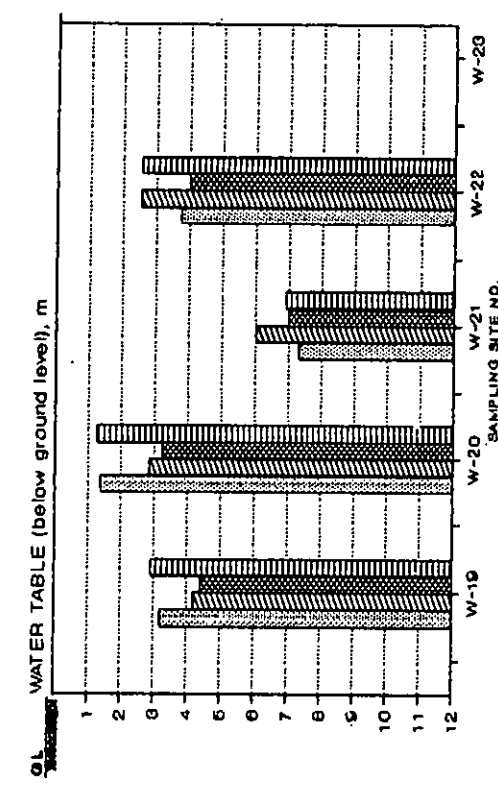
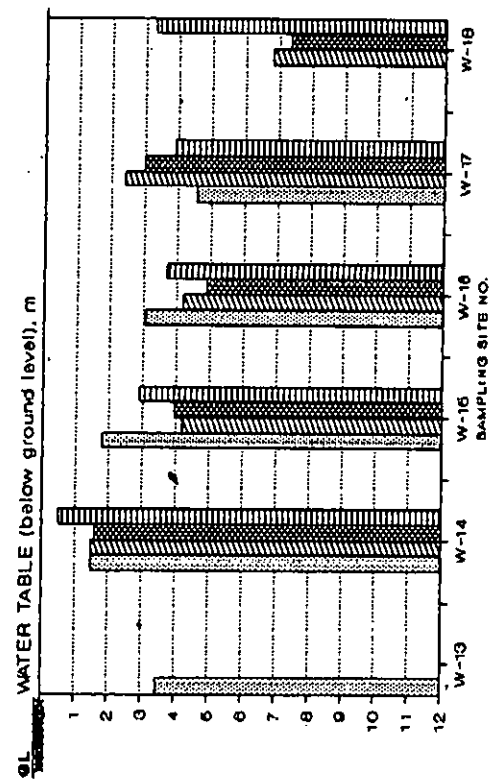


FIG. 6.7 : VARIATION OF GROUND WATER TABLE

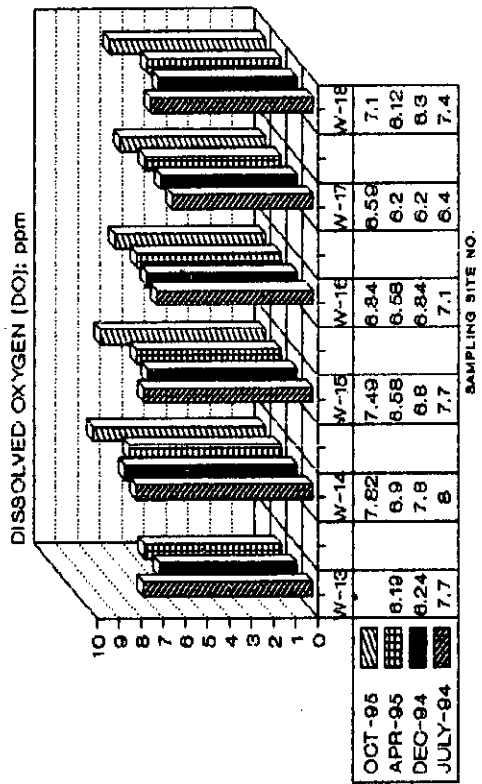
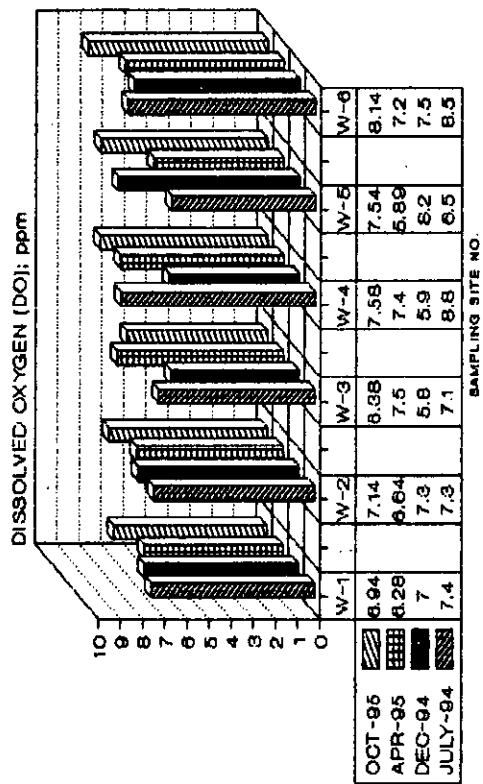
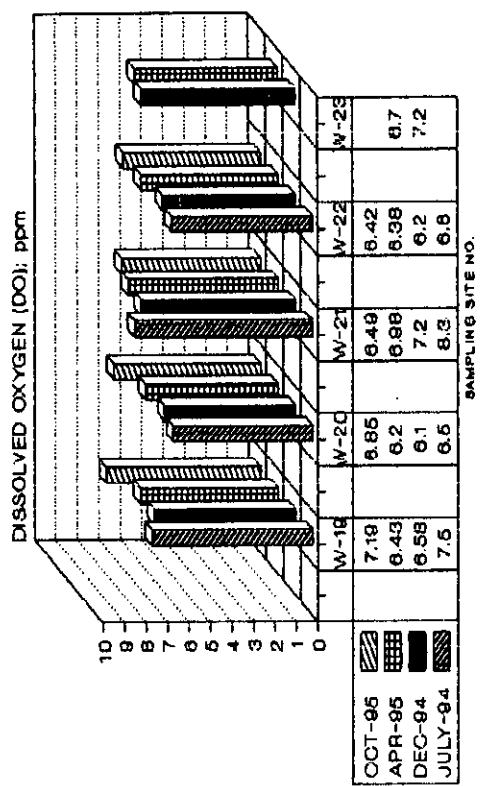
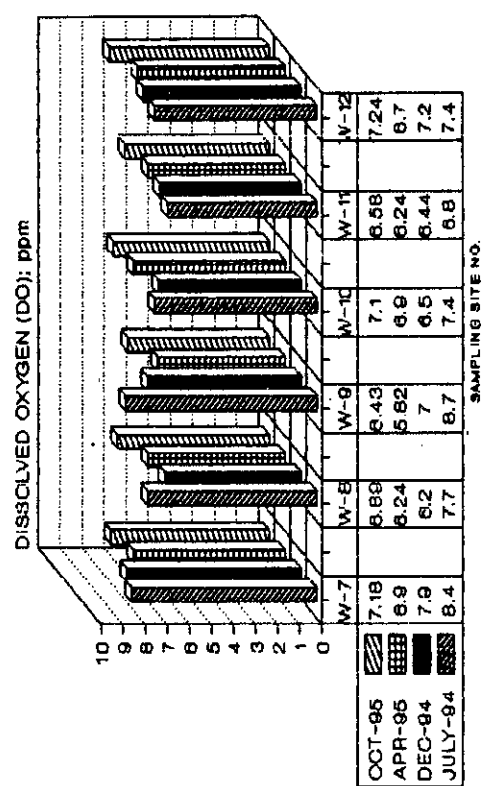


FIG. 6.8 : VARIATION OF DO IN GROUND WATER

7.0 CONCLUSIONS

Water pollution in surface water bodies unlike ground water is visible and hence the reaction of the public and policy makers is instant and vociferous. Once the ground water is polluted it gets lost almost for few decades, if not for ever. Then, curative and pollution control measures as well as monitoring of ground water pollution is much more difficult than that of surface water.

Physical tests do not directly indicate the safety of a water supply system. However, they do give an indication of its acceptability. In the present report, the results of the analysis of physical parameters in ground water samples from the selected open wells of Greater Guwahati have been presented. The main use of these wells is for domestic purposes. Therefore, suitability of water for drinking purpose has been tested with reference to available standards on the basis of physical parameters. There is not much variation in the quality of water in pre-monsoon and post-monsoon seasons.

Various physical constituents present in the water samples like pH, total dissolved solids, temperature, ORP, conductivity, % light transmission etc. were tested at sites as well as in the water quality laboratory. Further, temporal variation of ground water quality at these 23 specified locations were also marked and analysed.

On the basis of the present work, following points emerged indicating broadly the physical aspects of ground water quality:

1. The lowering of electrical conductivity in the post-monsoon season, in general, reflects the dilution of ions in ground water because conductivity is a characteristics which is mainly associated with the dissolved material and solute concentration present in the water.
2. ORP : The ORP data showed its higher values in pre-monsoon season of 1994 while lower values during winters. But in 1995 most of the sites showing reverse phenomena i.e. ORP is lower in summer and higher in winter. Low values

indicated the presence of slightly higher amount of organic matter.

3. Temperature : Due to high water table in whole Guwahati region the temperature of ground water is under direct influence of the air temperature. The average water temperature is more than 20 °C.

4. % Light Transmission : In general light transmission is more than 69%. This indicates the medium turbidity in the water samples.

5. TDS : TDS is much more than the acceptable limit and this indicates the water should be used after proper treatment. This is because of dissolved iron and shallow water table problem in whole city.

6. Water table : Overall ground water table range is showing that the all Guwahati is low laying area and this is the main cause of water logging problem.

7. DO : In general DO value found lower in pre monsoon and higher in post monsoon season.

DO value is below the permissible level at Durgeswari and Noonmati in the month of December 94 and April 95 respectively.

8. The average electrical conductivity values in the ground water were slightly higher than the limit for satisfactory quality of irrigation water (i.e. above 750 μ -mhos/cm, USDA, 1954) during all sampling periods. Further TDS were also within 800 ppm, the limit for best quality of irrigation water (Jermar, 1987). Therefore the ground water under present study is good for irrigation purpose under suitable sub-soil drainage condition.

7.1 Scope for Further Studies

Most of the physical parameters were determined at site by portable testing kits. To find out the significance level of pollution in any site it is necessary to find out chemical parameters also but these can not be found at site. Determination of chemical parameters needs systematic laboratory test in a fullfledge water quality laboratory. The effect of change of chemical parameters reflect the physical properties also. It is possible to find out the proper co-relationships between physical & chemical parameters upto some extent. We can apprise the people in

the vicinity the danger level of water pollution on the basis of physical testing also. In extension of the work and to draw vital conclusions on the water quality problems on the areas the other tests like chemical, Isotopes, Radiological, Bacteriological are also to be done as long term studies.

REFERENCES :

1. Agarwal, S. K., *Pollution Ecology*, Himanshu Publications.
2. Bhatia, K. K. S., *Water Quality and Sediment Modelling in Surface Waters*, SR-3, NIH, Roorkee, 1983-84.
3. Bhatia, K. K. S. and R. Jaiswal, *Water Quality Conservation and Need for Public Awareness*, Proc. of Seminar/workshop on Water Conservation and Public Awareness, Sept. 25-26, 1992, Inst. of Engineers (India), Roorkee, pp. 276-280.
4. Ffolliott, P. F. (1990), *Manual on Watershed Instruments and Measurements*, a publication of Asean-US Watershed Project, pp. 105-137.
5. Gautam, A., *Ecology and Pollution of Mountain Waters*, Ashish Publishing House, New Delhi.
6. Goel, M. K., *Remote Sensing Applications in Hydrology*, SR-32, NIH, Roorkee, 1992-93.
7. Hartigan, J. A., (1975), "Clustering Algorithms", John Wiley and Sons, New York.
8. Jain, C. K. and K. K. S. Bhatia, *Water Quality Modelling of Rivers*, TR-6, NIH, Roorkee, 1986-87.
9. Jain, C. K. and K. K. S. Bhatia, *Physico-Chemical Analysis of water and Waste Water*, UM-26, NIH, Roorkee, 1987-88.
10. Jal Vigyan Sameeksha, (Hydrology Review), Theme Water Quality, Publication of High Level Technical Committee on Hydrology, NIH, Roorkee, June 1988.
11. Majumdar, P. K., *Ground Water Quality Modelling*, SR-33, NIH Publication, 1992-93, pp. 63-64,
12. Manivasakam, N., *Environmental Pollution*, National Book Trust, India.
13. Master, G. M., (1974), *Introduction to Environmental Science and Technology*, John Wiley and Sons, New York. National Water Policy, Govt. of India, Ministry of Water Resources, New Delhi, September, 1987.
14. "Modified Final Master Plan & Zoning Regulation for Guwahati", Town & Country Planning Organisation, Govt. of Assam (1987), pp.1-3, 53-54.
15. Sarma, C. and S. K. Sarma (1988), *A Study of Physico-Chemical Qualities of the of the Water of Three Ring Wells and Two Ponds in Guwahati Area*, Journal of the Assam Science Society, Vol. 31, No. 1, Dec. 1988, pp.33-42.
16. Sawyer, N. C. and P. L. Mc-carty, *Chemistry for Environmental Engineering*. Third Edition, McGraw Hill International.
17. Sinha, A. K., R. Boojh and Viswanathan P. N., *Water Pollution (Conservation and Management)*, Gyanodaya Prakashan, Nainital.

18. Stednick, J. D., (1993), *Wildland Water Quality Sampling and Analysis*, Academic Press, INC, Harcourt Brace Jovanovich, Publishers, San diego.
19. Swarup, R., Mishra S. N. and Jauhari V. P., *Encyclopedia of Ecology, Environment and Pollution Control (Environment Water Pollution and its Control*, Mittal Publications, New Delhi.
20. Tripathi, A. K., and Pandey S. N., *Water Pollution* , Ashish Publishing House, New Delhi.
21. Trivedy, R. K., *River Pollution in India*, Ashish Publishing House, New Delhi.
22. Tyagi, A., *Automatic Water Quality Monitoring*, TN-66, NIH., Roorkee. 1989-90.
23. Varshney C. K., *Water Pollution and Management*, Wiley Eastern Ltd.

SAMPLE PRESERVATION METHODS FOR SPECIFIC PARAMETERS IN WATER QUALITY SAMPLES

Parameter	Preservative	Maximum Holding Period
Acidity-Alkalinity	Refrigeration at 4°C	24 hours
Biochemical oxygen demand	Refrigeration at 4°C	6 hours
Chemical oxygen demand	2 mL H ₂ SO ₄ per liter	7 days
Chloride	None required	7 days
Color	4°C	24 hours
Cyanide	NaOH to pH 10	24 hours
Dissolved-oxygen holding	Determine on site	No
Fluoride	None required	7 days
Hardness	None required	7 days
Metals, total	5 mL HNO ₃ per liter	6 months
Metals, dissolved	Filtrate: 3 ml 1:1 HNO ₃ per lit.	6 months
Nitrogen, ammonia	0.8 mL H ₂ SO ₄ per liter - 4°C	7 days
Nitrogen, Kjeldahl	0.8 mL H ₂ SO ₄ per liter -4°C	Unstable
Nitrogen, nitrate-nitrate	0.8 mL H ₂ SO ₄ per liter -4°C	7 days
Oil and grease	2 mL H ₂ SO ₄ per liter - 4°C	24 hours
Organic carbon	2 mL H ₂ SO ₄ per liter (pH2)	7 days
pH holding	Determine on site	No
Phenolics	1.0g CuSO ₄ per L+H ₃ PO ₄ to pH 4.0-4°C	24 hours
Orthophosphorus	40 mg HgCl ₂ per liter-4°C	7 days
Total phosphorus	2 mL H ₂ SO ₄ per liter	7 days
Solids	4°C	7 days
Specific conductance	4°C	7 days
Sulfate	4°C	7 days
Sulfide	2 mL Zn acetate per liter	7 days
Threshold odor	4°C	24 hours
Turbidity	None available	7 days
Total coliform	4°C	6 hours
Fecal coliform	4°C	6 hours

FIELD RECORD SHEET TO KEEP WATER QUALITY RELATED INFORMATION

STUDY NAME : _____

SAMPLING SITE : _____ MAP'S REFERENCE NO. : _____ DATE : _____

WELL KNOWN NEARBY LOCATION : _____

PLACE : _____				
DISTRICT : _____	bottle capacity	depth(bgl)	SAMPLING RECORD	
STATE : _____	1000 ml		bottle no.	preserved by/not
ELEVATION : _____	500 ml			purpose
SEASON / MONTH : _____	250 ml			
SAMPLING SOURCES : _____	125 ml			
(well,river,lake,tube well,pond, rain,effluent,beal,spring etc.)	20 ml			

PUBLIC USE INFORMATION : _____
(drinking, washing, agricultural etc.)

SURROUNDING ENVIRONMENT : _____
(like industrial activities, public interference etc.)

SOURCE OF POLLUTION : _____
(if observed any)

FIELD TESTING RECORD (time from _____ to _____)	LAB TESTING RECORD (date (time from _____ to _____)	INSTRUMENT USED
--	---	-----------------

APPEARANCE _____

COLOUR _____

ODOUR _____

WATER LEVEL
(BGL); m _____

AIR TEMP.
(°C) _____

depth
WATER TEMP.;
(°C) _____

pH _____

ORP; mV _____

DO; ppm _____

CONDUCTIVITY;
(m-mho/cm) _____

TDS; ppm _____

LIGHT TRANSMISSION
(%) _____

TURBIDITY _____

SALINITY; ppt _____

LAB SAMPLE NO _____

DATE OF RECEIPT AT NERC WQ LAB _____ COLLECTED BY _____

SOIL SURFACE AND SUBSURFACE INFORMATION (IF ANY) : _____

LOCAL GEOLOGICAL INFORMATION (IF ANY) : _____

REMARKS IF ANY : _____



PLATE - I : WATER LOGGING PROBLEM AT ZOO ROAD IN GUWAHATI



PLATE - II : SAMPLING & FIELD TESTING AT ZOO NARANGI SITE



PLATE - III : SAMPLING & FIELD TESTING AT DURGESWARI SITE

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