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GROUNDWATER QUALITY EVALUATION IN AND AROUND KAKINADA, ANDHRA PRADESH FOR THE YEAR 1995

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PREFACE

Water quality, one of several aspects within the discipline of chemical hydrogeology, is concerned with the chemical description of water, geographic distribution of various constituents and specific usability of water for manufacturing, agriculture, municipal and domestic supplies. The importance of the groundwater becomes still prominent not only of the quantity, but also the quality where urban areas are nearer to the sea coast. Water quality and salinity intrusion problems are another major phenomenon having negative effects on the deltaic water resources. Particularly the intrusion of saline waters into the groundwater resources can develop irreversible damages to the groundwater resources. Deltaic lowlands are also exposed to the spread of diseases originating from stagnant waters after the cyclonic events. Therefore a careful monitoring of the saline and polluted water is a very initial step in taking preventive measures.

As the water quality monitoring is costly and soon or later it may require financial assistance. However, the Deltaic Regional centre, National Institute of Hydrology, Kakinada has taken up a study programme to monitor the groundwater quality in and around Kakinada. As a part of it, total 87 samples were collected during the year 1995 from 29 observation wells scattered all over the city. In the present report a detailed investigations have been carried out to understand the variation of groundwater levels and the chemical characteristics of groundwater of this region. The study titled Groundwater Quality Evaluation in and around Kakinada, Andhra Pradesh for the year 1995 ' has been carried out jointly by Deltaic Regional Centre, Kakinada and Environmental Division of NIH, Roorkee.

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ABSTRACT

The groundwater levels variation and quality evaluation study has been carried out in and around Kakinada, East Godavari Dist. Andhra Pradesh. Total 87 samples were collected from 29 observation wells scattered all over the city for groundwater quality evaluation purposes for the year 1995. Well hydrographs showed that the trend of groundwater level fluctuations are similar in most of the observation wells. The comparison of groundwater level contour maps of pre monsoon and post monsoon periods indicated that the ground water storage has been recharged from pre monsoon to post monsoon period. Further high water levels have been observed near Sea, salt water creek and Kakinada Lock.

Samples are analysed at DRC Laboratory for various parameters viz. pH, Conductance, TDS, Alkalinity, Hardness, Chloride, Sulphate, Nitrate, Sodium, Potassium, Calcium and Magneseum. The analysis results shows that most of the wells were exceeded the ISI desirable limits of drinking water standards. especially E.C.values. The percentage of Sodium and SAR in the observation wells indicated that the groundwater quality is under low sodium hazards. The TDS contours showed that the groundwater quality has been diluted from pre monsoon to post monsoon periods. The ground water quality deterioration trend has been observed clearly during pre monsoon period (Apr.95). But the trend has been changed slightly during post monsoon (Dec.95) period.

Stiff classification shows that most of the wells are under NaHCO3 during pre monsoon and CaHCO3 during post monsoon periods. Only eleven groundwater samples were maintained the same type of water. Piper Trilinear diagrams grouped all samples into four hydrochemical facies namely $Ca+Mg+Cl+SO_4$, $Na+cl+K+SO_4$, $Na+K+CO_3+HCO_3$ and $Ca+Mg+CO_3+HCO_3$. Further the spatial analysis of these facies indicated that the discharge area is more during post monsoon than pre monsoon period.

The US Salinity Laboratory classification shows that the groundwater quality in most of wells are under C3-S1 type (high salinity and low SAR) which is fit for irrigation purpose in general, but may cause some problem where the soil permeability is very poor. In general, the significant changes in groundwater level and groundwater quality have been observed from pre monsoon to post monsoon periods in the study area. Hence groundwater levels and its quality monitoring study on long run may provide some useful information for groundwater management or policies.

1.0 INTRODUCTION

1.1. General

Water is one of the most important natural resources for the development of agriculture, industries, urbanisation, navigation etc. Rapid development of human society, and improvement of scientific and technological development change the environment in which water resources play a crucial role. The rate of replenishment of the groundwater reservoirs varies with the pattern of precipitation, surface runoff and stream flow. In the world as a whole 98.4% of all sweet water resources that exists at any point of time are in the form of soil moisture and groundwater, only the remaining 1.6% is found in the form of rivers, lakes and swamps.

The quality of groundwater reflects the mineral composition of the aquifer. During the slow movement of water through an aquifer, its composition will gradually change and this change will reflect the composition of the rocks through which the water has passed. Groundwater geo-chemistry depends on the distribution and mobility of elements, and compounds between water and aquifer material of the earth's surface, and also with the environment resulting from the interaction of the hydrosphere, atmosphere, lithosphere and biosphere.

The importance of the groundwater becomes still prominent not only of the quantity, but also the quality especially when urban areas are concerned nearby Sea coast. Groundwater under urbanised terrains can be subjected to quality threats such as overland seepage, bacterial contamination, saline water intrusion etc.

1.2 Chemical composition of natural waters

Natural groundwater and surface water contains many chemical species in the dissolved state. The occurence of these species results from many physical and chemical weathering processes on geologic formations and from many chemical reactions in the atmosphere. Consequently, these natural waters achieve definite concentrations of the several dissolved substances that are controlled, in turn, by equilibrium conditions of the weathering process. This is commonly given the description of water quality. The dissolved constituents in water are concentrated at the interface between solid and solution. They are said to be adsorbed on the solid. Adsorption means that the attachment of compounds of ionic parts of salts to a surface of another phase. Nutrients in solution (ions) carrying a positive charge become attached to (absorbed by) negatively charged soil particles. Such surface phenomenon are of particular relevance in groundwater chemistry.

Water quality in any specific area is a function of various environmental factors and variables. These include, but are not limited to geology, topography, climate, surface hydrology, hydrogeology and man. All factors are relatively constant in any given area. Man creats the greatest impact because he introduces abrupt changes to the environment by urbanisation.

1.3 Review

Due to rapid industrialisation and urbanisation groundwater resources are observed to be depleting and consequent threat of water pollution. Especially in coastal areas the quantity of groundwater is replenishing during monsoon but the quality is deteriorating year to year. Hence there is always a need for monitoring of water levels and its quality of water in urban areas. Sometimes overpumping of groundwater may invite Sea water into the aquifer.

Keeping in view of the importance of water resources in urban areas it is always a need to concern over the protection and management of groundwater quality. In this context, in India, the Central Ground Water Board (CGWB) and some of the State Groundwater departments are monitoring the water quality and quantity of the country. Further many authors have carried out the different case studies in the important cities and coastal areas.

DJaeni, et al (1986) studied the groundwater situation of the Jakarta where conservation measures were already needed due to the over exploitation of the aquifer system. Brackish groundwater is found in the aquifer between 0 m to 60m as far as 5 km inland while salinization exist in deep aquifers below 200m and near the coast between 0 to 100m. The water quality of the shallow aquifer is highly endangered by man made pollution in the densely populated and highly developed city area.

Salomomanurung (1987) studied the hydrochemistry of North Madras coastal aquifer by analysing 229 water samples. The composition of water chemistry changed with space and time. The major ion concentration increase from west to eastern direction towards the sea in the study area. The hydrochemical analysis reveal that Sodium and Chloride ions are the most prevalent cation-anion pair in the water samples and the dominant type of water is sodium chloride.

Kakar (1988), reports natural causes (cyclones, floods) can also be a source of ground water pollution. Salinity of groundwater is a major problem in north and western India, parts of Rajasthan, Southern Punjab, Southern Haryana and Gujarat.

Adaikala Jayaraj (1990) studied groundwater quality of Madras and stated that areas around the North Buckinghum canal and distal part of the river Cooum has raised serious concern for the groundwater quality.

Many authors i.e Govardhan (1990), Narayana (1989) and Das (1989) have attempted similar studies at Nalgonda district (Andhra Pradesh), Mangalore (Karnataka) and Arunachal Pradesh respectively.

Muralikrishna and Sumalatha (1992) have studied the groundwater quality of Kakinada town and reported that the quality of groundwater is exceeding the limits of drinking water standards. They also highlighted the need of monitoring the groundwater quality in and around Kakinada .

1.4 Scope of the Study

Due to rapid urbanisation and industrialisation in Kakinada town the quality of groundwater may deteriorate year to year. The existing municipal water supply scheme is not able to satisfy the drinking and domestic needs. People are going for pumping from groundwater storage. This phenomena of overpumping of groundwater may change the quality of groundwater in the town through salt water intrusion. Further the quality may also change due to natural calamities i.e. floods, cyclones etc.

Keeping in view of above circumstances 29 observation wells have been selected in and around Kakinada town to monitor the groundwater level and its quality variations. In this report the variation of groundwater levels and chemical analysis of groundwater samples collected during April 95, August 95 and December 95 are presented. The main objectives of the study is as follows:

1. The spatial distribution of groundwater levels and its quality in and around Kakinada town.
2. The suitability of groundwater for drinking and irrigation purposes.
3. Analysis of groundwater samples for sodium hazards.
4. Groundwater quality parameters variation with time and quality at different distances from Sea.
5. Classification of groundwater samples using Stiff and Piper Trilinear diagrams.

2.0 STUDY AREA

2.1 Location

Kakinada is the capital of East Godavari District in Andhra Pradesh and is situated on the East coast of India. Kakinada town lies between 82^{o} N to $82^{o}20'$ N latitude and $16^{o}45'$ E to $17^{o}5'$ E longitude. The area of the city is around 31 sq.km. The location map is shown in Fig.1.

2.2 Hydrogeology

The area is covered with coastal alluvium of recent origins, consists of fine to medium grain sands with clay and beach sands. Few medium and minor drains in the city are draining the waste water into Bay of Bengal through salt water creek. The depth of groundwater level varies between 0.6m to 3.5m with respect to ground level. The main recharge of groundwater is of monsoon rainfall during July to October. High tides in Bay of Bengal resisted by Hope island and it results low tides reaching part of Kakinada coast. High tides were observed at Vakalapudi area, north east of Kakinada town. The general groundwater quality in Kakinada varies potable to saline. Further the quality varies with space and time. The hydrogeomorphological features of Kakinada and nearby areas are shown in Fig.2.

2.3 Drainage and water supply

Major drains in Kakinada, namely, Upputeru (Saltwater creek), Gaderu, Cheedila pora and Yeleru drains are draining the waste water and storm water into Bay of Bengal through salt water creek (Fig. 3). The salt water creek at Jagannadhapuram is acting as main cargo handling of the ships. Due to mild slope of sea coast so far there is no planned drainage network in the city. Most of the residential buildings allowing sewage disposal on land and making obstruction to the natural drainage by forming the new roads and colonies.

The main drinking water supply is from Godavari river through Dowleswaram Barrage. The Samalkot branch canal is feeding water to the summer

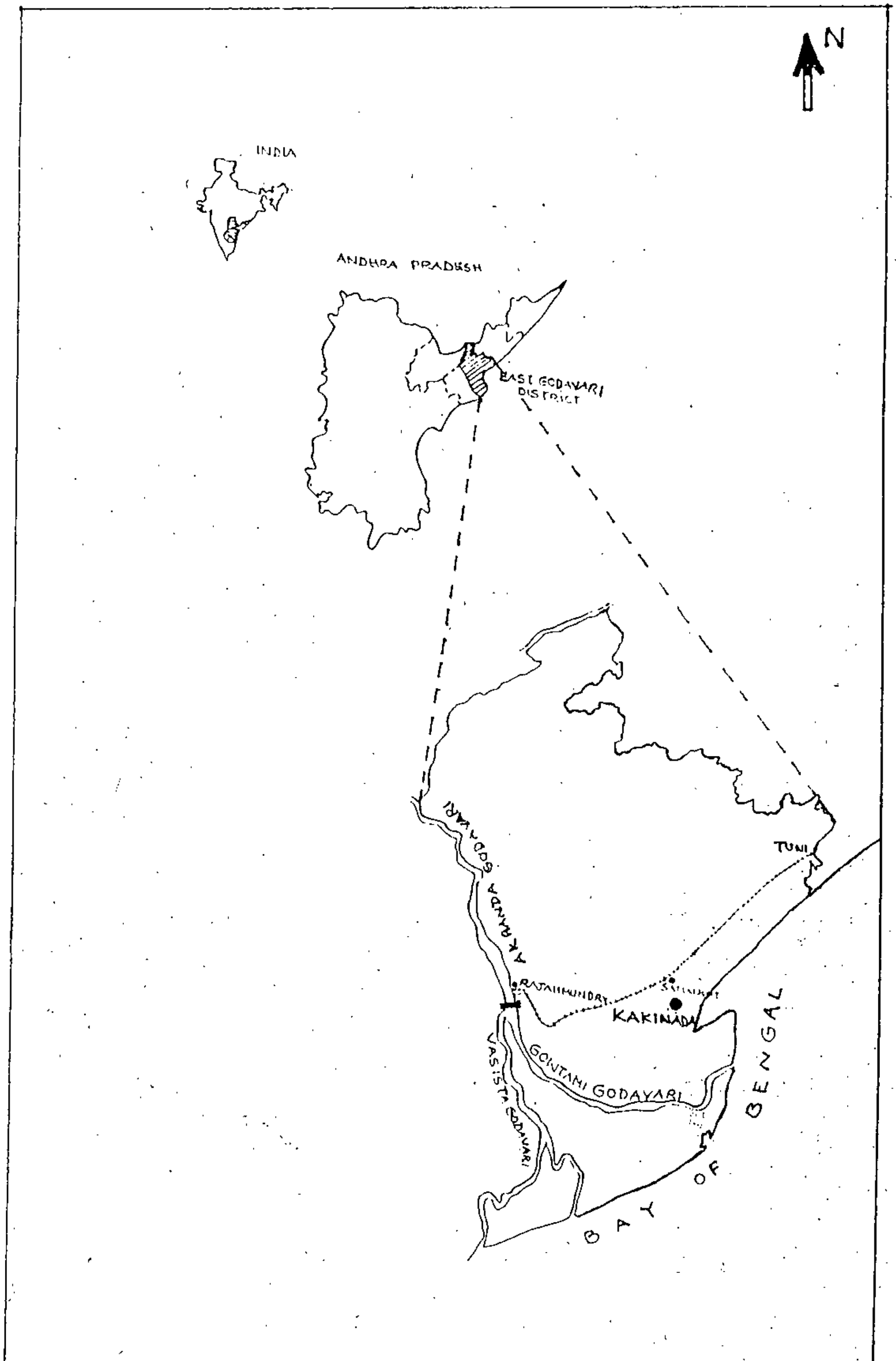


FIG.1. LOCATION MAP OF KAKINADA

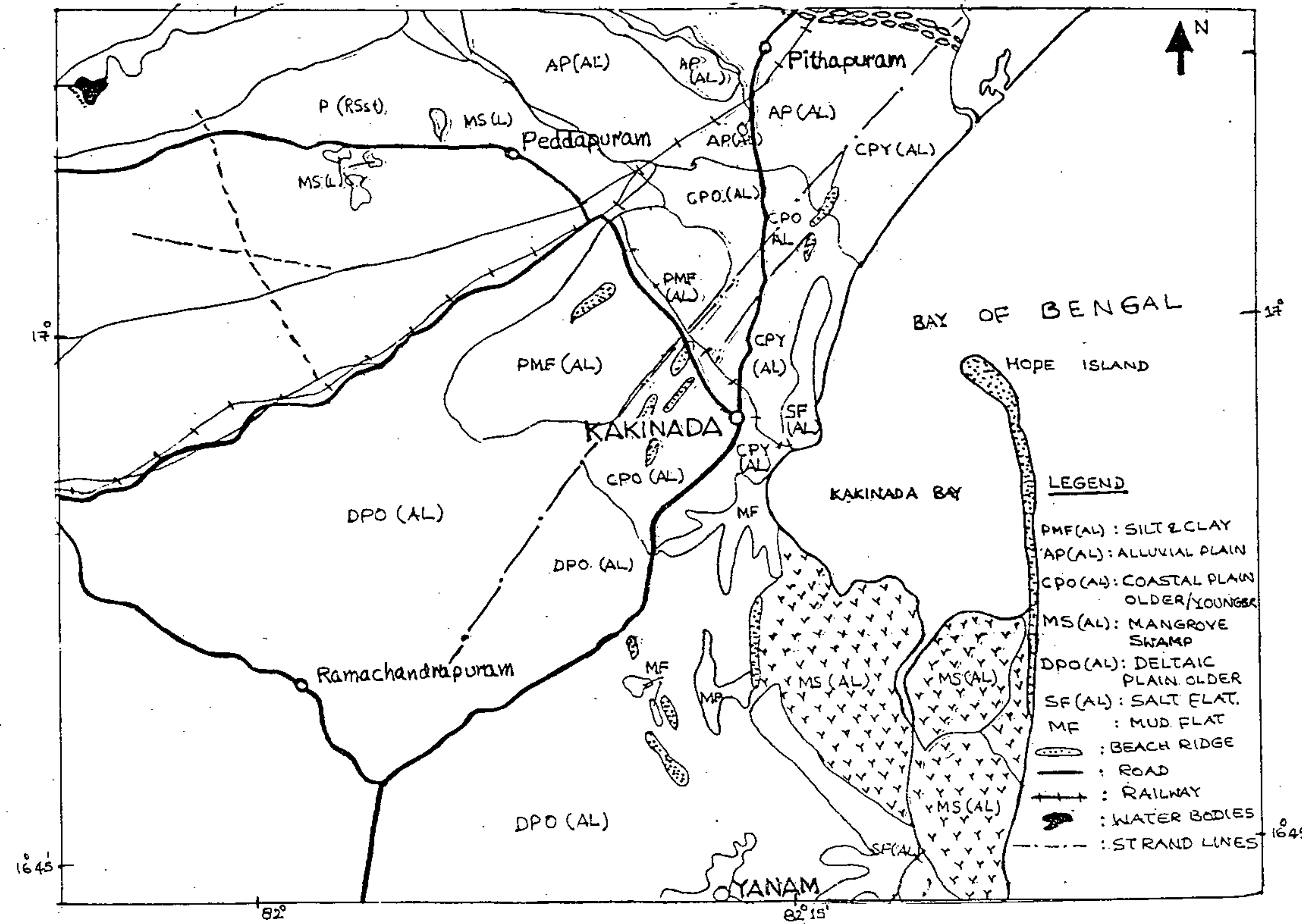


FIG.2. HYDROGEOMORPHOLOGICAL MAP OF KAKINADA AND NEARBY AREAS.

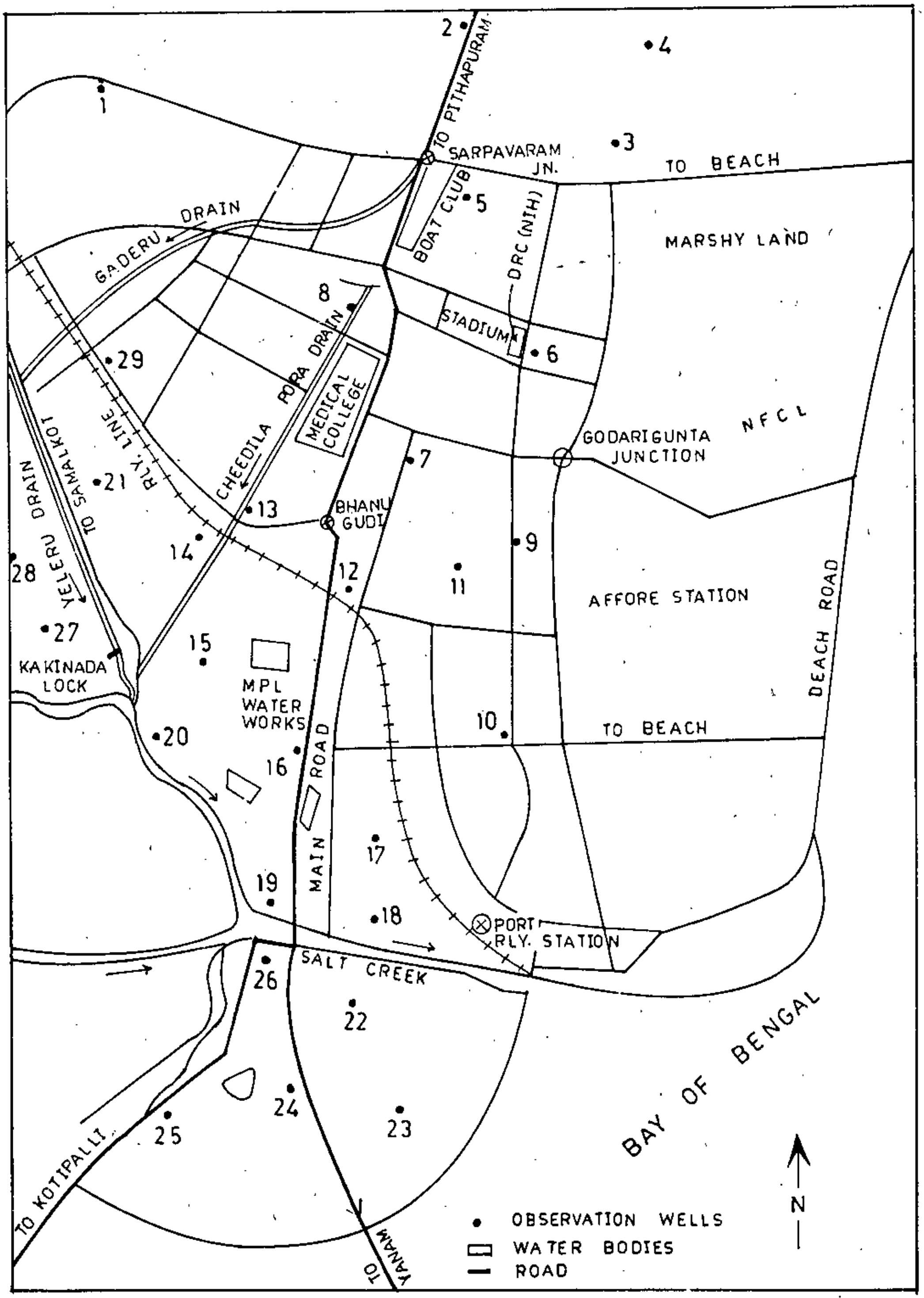


FIG. 3 LOCATION MAP OF OBSERVATION WELLS

storage tank at Samalkot, which is main surface water storage to the city. From this reservoir water is drawn by gravity to the Victoria water works and there, water is filtered, treated and supplied to the city through municipal water taps.

2.4 Climate

Kakinada coast is under tropical climate and frequently effected by cyclonic storms and depressions in Bay of Bengal. Sometimes thunderstorms also bring rainfall to Kakinada during the summer season. The city is very warm in April to June with a maximum temperature of $40^{o}C$ and winter months are December to January having minimum temperature of $20^{o}C$. High percentage of humidity upto 75% to 80 % observed during the summer months. The average evaporation rate varies from 2.5 to 9 mm/day.

2.5 Rainfall

Kakinada receives two distinct monsoons, the south west monsoon from June to September and the north east monsoon from October to December. More than half of the annual rainfall is brought by the southwest monsoon. The annual normal rainfall in Kakinada is 1095mm. The monthly rainfall for the year 1995 is given in the following Table 1.

Table.1: Total monthly rainfall (mm) at Kakinada for the year 1995

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
43.8	0.0	0.0	0.0	547.6	87.2	185.6	156.6	98.0	489.0	15.4	0.0

The highest rainfall had been observed in the month of May due to cyclonic storm.

2.6 Groundwater level fluctuations

Groundwater levels in 29 observation wells have been measured from ground level(using water level recorder) in the month of Oct. 94, Dec. 94, Apr. 95, Aug.95 and Dec.95. The location of all observation wells spread in and around Kakinada is shown in Fig. 3. The observed groundwater levels in 29 observation wells are given in Table2.

Table 2: Groundwater levels(mts) in the observation wells measured from ground level

W.No.	Well location	Groundwater level (mts)				
		Oct.94	Dec.94	Apr.95	Aug.95	Dec. 95
1	Sarpavaram	1.51	1.57	2.27	0.89	1.32
2.	Balaji nagar	1.84	1.83	2.36	1.36	1.56
3.	Valasapakalu	0.75	1.36	2.11	0.81	1.36
4	Vakalapudi	0.62	1.23	2.00	0.60	1.20
5	Ramanayya peta	1.39	1.67	2.22	1.12	1.42
6	R.R.Nagar	0.96	1.69	2.24	1.04	1.74
7	Madhav nagar	0.75	1.07	1.20	0.45	0.95
8	Nagamallithota	1.43	1.50	2.18	0.98	1.33
9	Godarigunta	1.85	1.28	1.83	0.73	1.18
10	Sambamurthynagar	0.31	1.42	2.12	0.87	1.12
11	Shantinagar	0.56	0.83	1.18	0.43	0.68
12	Perraju peta	0.56	0.96	1.51	0.71	0.81
13	Kondayya palem	1.85	1.65	2.35	1.50	1.60
14	Gandhi nagar	1.03	1.41	1.91	1.11	1.31
15	Rama Rao peta	2.99	1.97	2.87	1.67	1.87
16	Surya Rao peta	1.24	1.46	2.39	0.94	1.14

Contd..

17	Suryanarayanapuram	0.79	0.96	1.31	0.86	0.86
18	Budam Peta	0.46	1.20	2.40	0.85	1.10
19	Temple Street	0.24	1.53	1.78	0.58	0.73
20	Frazer Peta	1.90	1.63	2.23	1.33	1.43
21	Pratap nagar	0.86	0.96	1.36	1.06	1.06
22	Revenue colony	0.64	1.20	1.80	0.80	1.05
23	Gogudanayya Peta	0.18	0.49	0.94	0.34	0.64
24	M S N Charties	1.15	1.60	2.25	1.35	1.75
25	Turangi	0.97	1.71	2.46	1.36	1.56
26	Paradesamma peta	1.43	1.79	1.89	1.49	1.14
27	Indra Palem	2.07	2.23	2.73	1.79	1.53
28	Chidiga	2.73	2.81	3.06	2.31	1.81
29	Madhura nagar	1.40	1.49	1.99	0.99	1.19

During the year 1995 groundwater levels in all observation wells are high in the month of August i.e during monsoon period and low in the month of April i.e. pre monsoon period. The water levels from Oct. 94 to Dec. 95 are used to plot the well hydrographs in the study area. The well hydrographs of few wells are shown in Fig. 4. It is being observed that the trend of groundwater levels fluctuation are similar in all wells. It may be due to local aquifer conditions i.e. shallow water table condition. The spatial distribution of groundwater levels in the study area during pre monsoon and post monsoon periods has been studied through groundwater level contour maps, which are shown in Fig 5 & 6 respectively. The comparison of Fig. 5 and 6 shows that the ground water storage has been recharged from pre monsoon to post monsoon period. Further high water table levels have been observed at well Nos 21, 15, 11, 17, and 25.

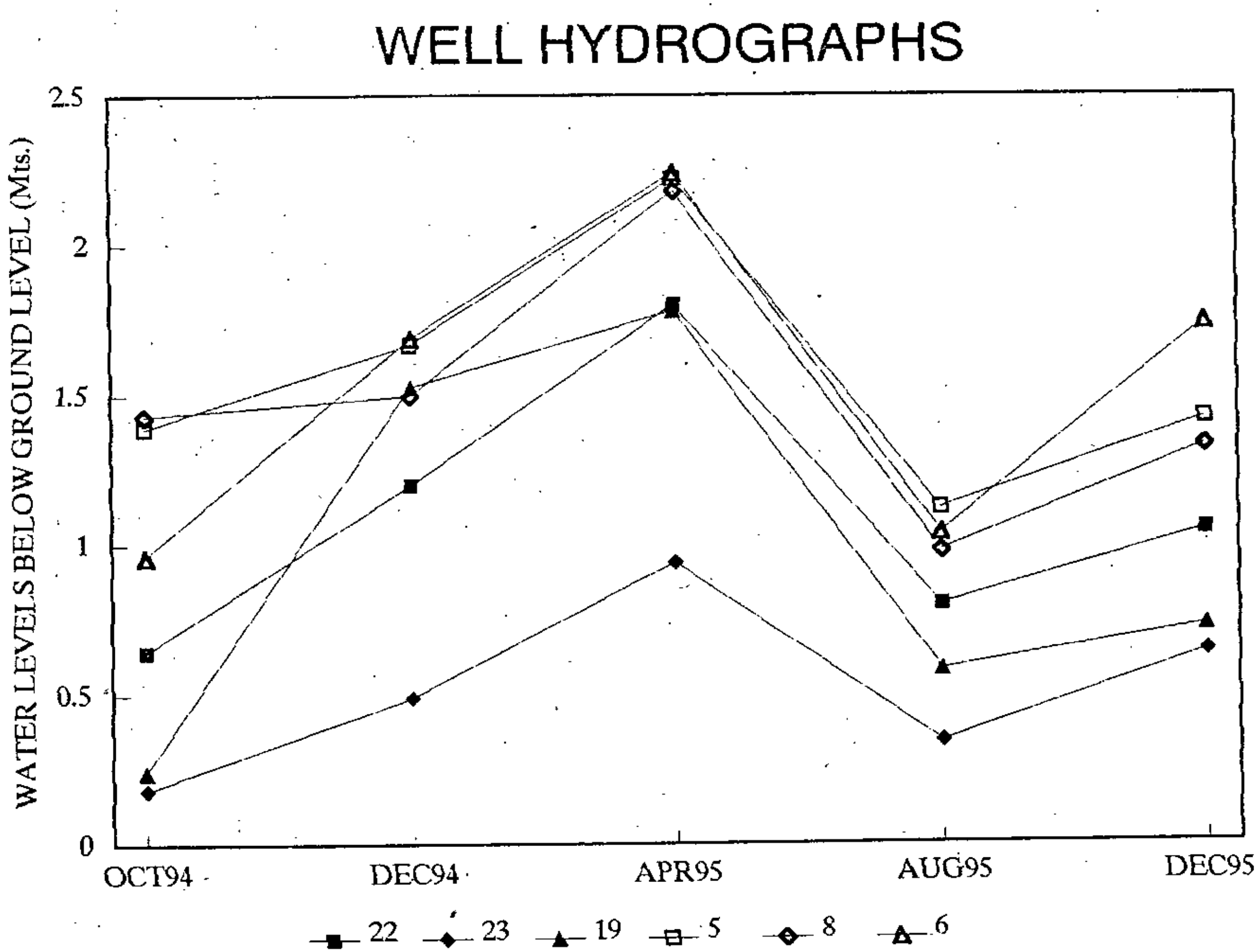


FIG. 4 WELL HYDROGRAPHS IN THE STUDY AREA

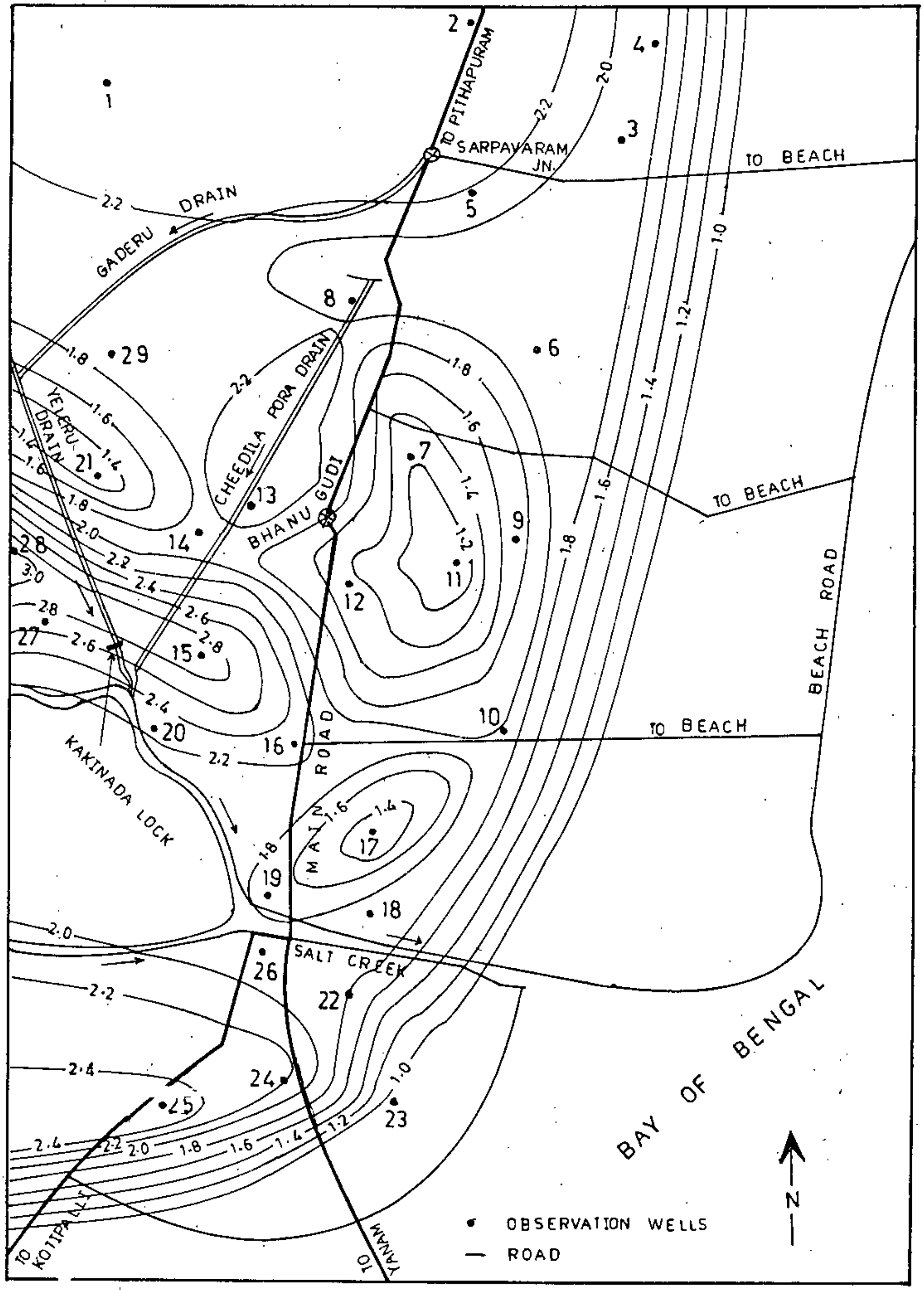


FIG. 5 GROUNDWATER LEVEL CONTOURS DURING PRE MONSOON PERIOD (APR-95)

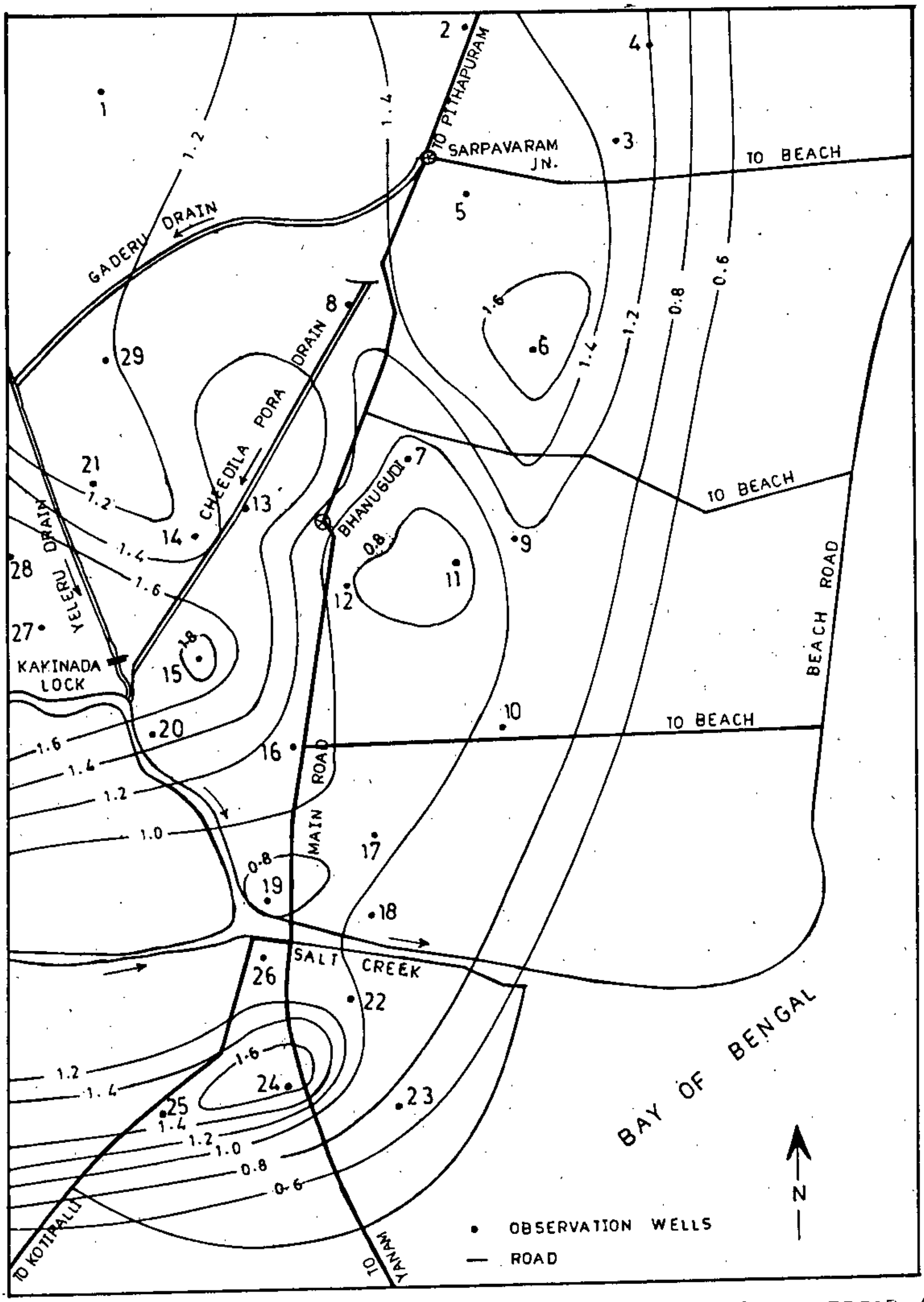


FIG. 6 GROUNDWATER LEVEL CONTOURS DURING POST MONSOON PERIOD (DEC.95)

2.7 Sources of pollution

In general, the major sources of pollution for groundwater are:

- Land disposal of solid wastes,
- sewage disposal on land
- agricultural activities
- petroleum leakage and spills
- deep well, disposal of liquid wastes
- and urban runoff and polluted surface water
- salt water intrusion

The main sources of pollution in study area are as follows:

1. There is no planned drainage network in the study area. The natural drainage system is being obstructed by laying of new roads and rapid development of colonies in the city.

2. Unconfined shallow water table in study area is being easily effected by stagnated water in surface water bodies, seepage from septic tanks and infiltration of waste water from residential building, hotels etc. The similar phenomena has been observed in Mylapore temple tank area in Madras city (Satyaji Rao,Y.R,1992)

3. During the high tides the sea water is flowing upto 2 to 3 kms through salt water creek which is in the middle of the city. The continuous flowing of sea water through this creek effect the nearby wells.

4. Even high tides are obstructed by Hope island near Kakinada coast, the salt water is inviting to aquifer through development of unplanned aquaculture and converting the paddy fields to fish or prawn ponds.

3.0 METHODOLOGY

3.1 Groundwater sampling

The purpose of regional geochemical studies is to identify the controlling chemical reactions in order to explain the observed chemical character of groundwater. Water sampling is one of the most important step for representing the various groundwaters for quality studies.

To obtain the local groundwater hydrochemistry of Kakinada, three sampling surveys were conducted in the month of April 1995, August 95 and Dec. 95. In each survey 29 samples were collected by lowering the sampler in the open wells at various locations in Kakinada. Further the groundwater level in each well was measured from ground level during the surveys. Physical parameters like PH, Temp, and Conductivity were measured with portable kits at the time of sample collection in the field. For other analysis i.e. major anions and cations, samples were collected in clean polyethylene bottles fitted with screw caps and brought to the laboratory. Further appropriate reagent is added to preserve the samples till the analysis is completed. The procedure for physico-chemical analysis of samples is adopted from Manual on 'Physico-chemical analysis of water and waste water' (NIH Report-UM-26).

3.2 Physical parameters

(a) Hydrogen ion concentration (pH)

PH value represents the concentration of hydrogen ions in water and is a measure of acidity and alkalinity of water. pH value below 7.0 indicates acidic character while pH greater than 7.0 is indicative of alkaline character of water. The pH values of the samples were measured using electrometric digital PH meter.

(b) Electrical Conductivity(EC)

Electrical conductivity is a measure of water's capacity for conveying electrical current and is directly related to the concentration of ionized substances in the water. Conductivity measurement is commonly used to determine the purity of demineralized water and total dissolved solids in irrigation and domestic waters. Wheatston bridge conductivity meter was used to measure Ec values of the water sample. The temperature of the sample is measured with thermometer.

3.3 Chemical Parameters

(a) Carbonate and Bicarbonate (Alkalinity)

Alkalinity refers to the capability of water to neautralise acids. The presence of carbonates, bicarbonates and hydroxides is the most common cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil. The carbonate and bicarbonate contents in the samples are calculated by standard titrimetric methods using phenolphthalein and methyl orange as indicators.

(b) Hardness(Ca+Mg)

The hardness of water was originally defined in terms of its ability to precipitate soap. Calcium and Magneseum ions are the principle causes although iron, alluminium, manganese and hydrogen ions are capable of producing the same effect. In general, total hardness is defined as characteristic of water which represents the total concentration of calcium and magneseum expressed as their calcium carbonate equavalent. Total hardness and calcium hardness were determined by EDTA titrimetric method.

$$\text{Total Hardness} = 2.497\ Ca + 4.115\ Mg$$

where, Ca and Mg contents are in ppm.

Temporary hardness is caused by the presence of bicarbonates of calcium and magneseum, whereas permanent hardness is mostly due to sulphate. If hardness is 0 to 75, water is soft and more than 150 is hard. The calcium and magneseum contents in the samples are calculated by standard titrimetric methods. Hardness causes intestinal troubles and need more fuel and more time to cook. There is loss of palatability of vegetables and meet cooked in it. The precipitate formed due to the hardness of waters adhers to the surface of tubs, sinks and utensils and stain clothes and dishes. The precipitate remains in the pores and the skin may feel rough and uncomfortable and may lose its texture. Soft waters, tend to be more acidic and may corrode steel pipes and boilers. Also they lead to heart attaks and affect the human cardiovascular systems.

(c)Chloride

Chloride is one of the major inorganic anion in water and waste water. It presents in all potable water supplies and in sewage, usually as a metallic salt. When sodium is present in drinking water, chlroide concentration in excess of 250 mg/lt gives a salty taste. The maximum allowable chloride concentration is 250 mg/lt in drinking water has been established for reasons of taste rather than as a safe guard against physical hazard. Chloride content in the sample is measured by silver nitrate method. Chloride is highly corrosive and eats away the reinforcement of RCC. It also corrode pipes and utensils. It causes permanent hardness which is difficult to remove.

(d)Sulphate

Sulphate appears in natural waters in a wide range of concentrations. Mine waters and industrial effluents frequently contain large amounts of sulphate from pyrite oxidation and the use of sulfuric acid. Sodium concentration above 250 mg/lt in potable water is objectionable. Sulphate content in the sample is measured by gravimetric method.

(e)Nitrogen

In water, the forms of nitrogen of greatest interest are in order of decreasing oxidation state, nitrate, nitrite, ammonia and organic nitrogen. Nitrate generally occurs in trace quantities in surface water but may attain high levels in groundwater. High levels of nitrate in water indicate the introduction of biological waste or contamination due to leaching from heavily fertilised fields. Drinking water containing excessive amounts of nitrate can cause infant methaemoglobinaemia (blue babies). For this reason a limit of 10 mg nitrate as nitrogen/lt has been established in public drinking water supplies. The nitrate- nitrogen of the sample is measured by UV-Absorbance Spectrophotometer.

(f)Phosphate

Phosphorous occurs in natural waters and in waste waters almost solely as phosphates. Phosphates are used widely in municipal and private water treatment systems. A certain amount of phosphate is essential to organisms in natural water and is often the limiting nutrient for growth. Too much phosphate can produce eutrophication or over fertilisation of receiving waters, especially if large amounts of nitrates are present. The phosphate content of the sample is measured by spectrophotometer using ascorbic acid.

(g)Sodium and Potassium

Sodium is a common element presents in nearly all natural waters. The levels may vary from less than 1 mg/lt to more than 500 mg/lt. Ratio of sodium to total cations is important in agriculture and human pathology.

Potassium ranks seventh among the elements in order of abundance, yet its concentration in most drinking waters seldom reaches 20 mg/lt. Potassium is less common in the groundwater.Sodium and Potassium contents of the sample are determined by Flame emission method using Flame Photometer.

(h)Calcium and Magneseum

Calcium is one of the principle cations in groundwater. In the sedimentary rocks, calcium occurs as carbonates and in alluvium it occurs as limestone. Calcium carbonate imparts the property of hardness to water together with sulphate, carbonates and bicarbonates.

After calcium, magneseum is the most important alkaline earth metal present in the groundwater. It is one of the important contributor to the hardness of water. The magneseum concentration in water may vary from practically zero to several hundred ppm, depending on the source of water. Calcium and magneseum contents in the samples are determined using Titrimetric Method.

3.4 Classification of waters

(a)Stiff Classification

The Stiff classification (Stiff, 1951) is to define the type of water based on the presence of dominant cations and dominant anions. The Stiff graphical method plots four major cations (Ca,Mg, Na+K,Fe) on the left side and four major anions (HCO3+CO3, SO4, Cl and NO3) on the right side. The original Stiff plot connects the points on the diagram and produces pattern which, when compared to another analysis, is useful in making comparisons of waters. In modified Stiff diagram the length of each line defines the concentrations of a particular cation and anion. Concentrations on the diagram are expressed in milliequivalents per liter.

(b)Pipers Trilinear Classification

Piper (1953) developed a form of Trilinear diagram which is an effective tool in segregating analysis data. Trilinear diagrams are used for analysing the water types. It consists of two triangles, on the left and one on the right side and central diamond shaped projection space.

Here, cations (in epm), expressed as percentages of total cations, are plotted as a single point on the left triangle, while anions similarly expressed as percentages of total anions appear as a point in the right triangle. Those two points are then projected upwards parallel to the sides of the triangles to give a point in the diamond. The water quality types can be identified quickly by the locations of the point in the different zones of diamond. The Pipers plots depicit not only the quality of ground waters but also provide possible pathways of freshwater and saline water movement and abstracted geochemical processes(Sukhija B.S et al, 1996). The Bicarbonate facies represents discharge area and choloride facies represents recharge area(Sikdar et al, 1993).

(c) U.S.Salinity Classification

Sodium concentration is an important criterion in irrigation water classification because sodium reacts with the soil to create sodium hazards by replacing other cations. The extent of this replacement is estimated by Sodium Adsorption Ratio (SAR).

$$SAR = \frac{Na}{[(Ca + Mg)/2]^{0.5}}$$

A diagram for use in studying the suitability of groundwater for irrigation purposes, names after Wilcox (1955) is based on the sodium adsorption ratio (SAR) and conductivity of water expressed in μs/cm.

4.0 RESULTS AND DISCUSSIONS

The hydrochemical analysis results of groundwater samples collected in and around Kakinada town during the month of April 95, August 95 and Dec 95 are presented in Table 3, 4 and 5 respectively. Each table contains the Well Nos., pH, Electrical Conductivity, Total dissolved solids, Total hardness, Major cations (Calcium, Magneseum, Sodium, Potassium) and major anions (Carbonate and Bicarbonate, Sulphate, Nitrate, Chloride, Phosphate).

4.1 Water Quality evaluation for domestic purpose

(a) pH

A pH range of 6.5 to 8.5 is normally acceptable as per the guidelines suggested by WHO (1984). The range of pH value during three surveys is 6.1 to 7.8 (Table 3,4, &5). The lowest pH value 6.1 has been observed in Well No.2 during April 95. However other wells in all three surveys are found to be within the limits of ISI Standards for drinking water.

(b) Electrical Conductance

It represents the total concentration of soluble salts in water. The range of conductivity values during April 95, Aug 95 and Dec 95 are 750 to 3830 μmhos/cm, 280 to 3640 μ mhos/cm and 500 to 3270 μ mhos/cm respectively. High Electrical conductance values have been observed during premonsoon period (April 95) than other periods i.e. during Aug 95 and Dec95. Total 21 wells have been exceeded the limit 1200 μmhos/cm during the month of April95.

(c) Alkalinity

The presence of carbonate, bicarbonate and hydroxides is the most common cause of alkalinity in natural waters. The minimum and maximum values of alkalinity during the months April 95, Aug 95 and Dec 95 are 150-1090, 130-802 and 192-860 mg/lt respectively. The highest value of alkalinity has been observed in well No.23 during premonsoon period i.e April 95, which is nearer to Bay of Bengal (Fig 3).

TABLE No.3 : GROUNDWATER QUALITY ANALYSIS DURING THE MONTH APRIL 1995

Well No.	Temp °C	PH	Conductivity (µ.mhos/cm)	Total Alkalinity (mg/lt)	Total Hardness (mg/lt)	TDS (mg/lt)	Sodium (mg/lt)	Potassium (mg/lt)	Calcium (mg/lt)	Magneseum (mg/lt)	Chloride (mg/lt)	Sulphate (mg/lt)	Phosphate (mg/lt)	Nitrate (mg/lt)
1	26	7.0	1200	264	640	768	108	40	168.40	53.46	176	140	0.266	178
2	25	6.1	750	140	220	480	60	11	64.16	14.58	136	53	0.102	NIL
3	27	7.2	3830	660	860	2451	564	272	160.40	111.78	726	300	0.112	204
4	26	7.1	1550	520	342	992	380	15	84.21	32.07	236	222	0.462	NIL
5	25	6.9	1280	260	420	819	100	47	108.27	36.45	166	85	0.704	122
6	27	7.5	1010	340	320	646	110	4	96.24	19.44	136	36	0.260	NIL
7	25	7.5	760	276	184	486	88	14	44.11	17.98	104	40	1.303	NIL
8	24	7.5	1800	440	600	1152	196	12	160.40	48.60	286	118	0.147	114
9	26	7.2	1700	310	400	1088	160	70	120.30	24.30	234	61	0.626	165
10	25	7.6	1410	540	410	902	184	6	75.38	53.95	118	128	0.178	3
11	26	7.5	1000	364	176	640	170	4	51.33	11.66	106	40	0.310	NIL
12	26	7.3	2100	580	430	1344	360	21	88.22	51.03	326	93	0.620	36
13	27	7.2	1710	340	304	1097	200	129	67.37	33.05	186	55	1.403	146
14	26	7.2	1530	500	484	979	200	26	131.53	37.91	214	55	0.188	11
15	24	7.3	1140	296	320	730	90	32	92.23	21.87	110	45	0.673	59
16	26	7.5	1990	666	474	1274	250	60	100.25	54.43	216	122	0.382	19
17	25	7.6	1530	540	240	979	270	96	72.18	14.58	148	99	0.883	NIL
18	27	7.7	1800	570	420	1152	230	117	92.23	46.17	236	90	0.206	20
19	27	7.3	2100	610	700	1344	185	82	240.60	24.30	204	200	0.437	12
20	25	7.4	1490	370	390	954	120	74	112.28	26.73	146	60	0.640	96
21	26	7.3	1700	460	460	1088	200	26	124.31	36.45	162	80	0.139	50
22	27	7.8	1800	790	250	1152	400	8	52.13	29.16	194	90	0.310	2
23	25	7.7	2800	1090	450	1792	476	90	100.25	48.60	336	169	1.445	NIL
24	26	7.8	500	196	120	320	65	26	36.09	7.29	46	32	0.075	NIL
25	27	7.4	2950	370	830	1888	270	9	212.53	72.90	606	78	0.105	134
26	25	7.4	3700	630	900	2368	450	98	176.44	111.78	666	203	0.359	266
27	26	7.3	3300	596	820	2112	440	132	176.44	92.34	696	210	1.150	84
28	25	7.3	1600	150	520	1024	130	13	140.35	41.31	264	90	1.208	186
29	25	7.2	870	204	310	557	60	3	88.22	21.87	66	50	0.015	98

TABLE No.4: GROUNDWATER QUALITY ANALYSIS DURING THE MONTH AUGUST 1995

Well No.	Temp °C	PH	Conductivity (μ.mhos/cm)	Total Alkalinity (mg/lt)	Total Hardness (mg/lt)	TDS (mg/lt)	Sodium (mg/lt)	Potassium (mg/lt)	Calcium (mg/lt)	Magneseum (mg/lt)	Chloride (mg/lt)	Sulphate (mg/lt)	Phosphate (mg/lt)	Nitrate (mg/lt)
1	22	6.9	1000	456	530	640	138	192	176.44	21.87	244	240	2.4	253
2	23	6.9	1190	426	170	762	142	26	48.12	12.15	188	65	0.6	6.2
3	23	7.2	2700	720	530	1728	528	156	164.41	29.16	524	335	0.3	135
4	24	7.1	1300	550	312	832	312	18	91.43	20.41	234	80	0.6	4.0
5	22	6.7	1100	280	330	704	94	50	81.80	30.62	160	125	0.9	115
6	23	7.6	550	284	260	352	62	6	68.17	21.87	58	40	0.4	0.9
7	21	7.1	730	396	214	467	120	10	72.18	8.26	54	40	0.2	8.4
8	22	7.3	1600	372	530	1024	216	11	116.29	58.32	274	210	0.3	109
9	23	7.2	850	324	312	544	201	25	96.24	17.49	210	75	2.8	100
10	24	7.0	1250	490	380	800	189	9	84.21	41.31	94	110	0.5	8.4
11	23	7.4	280	130	130	179	12	3	40.10	7.29	4	35	0.1	2.0
12	25	7.1	2090	600	430	1337	470	29	96.24	46.17	294	125	0.9	58
13	22	6.6	1380	346	292	883	175	99	71.38	27.70	156	110	2.0	118
14	21	6.8	1360	420	270	870	195	23	88.22	12.15	180	125	0.7	64
15	23	7.2	1100	340	250	704	115	28	68.17	19.44	104	75	1.4	62
16	24	6.8	1790	630	420	1146	170	55	104.26	38.88	194	125	1.4	38
17	22	7.2	1660	620	250	1062	240	82	80.20	12.15	234	120	1.1	3.1
18	21	7.1	1140	680	460	730	265	65	120.30	38.88	174	160	1.4	87
19	22	7.1	2870	640	720	1837	345	76	200.50	53.46	374	480	1.5	24
20	24	6.9	1430	400	370	915	160	51	100.25	29.16	136	108	1.2	93
21	23	6.6	1290	480	440	826	140	15	136.34	24.30	98	220	0.4	50
22	23	7.3	2480	802	440	1587	380	12	136.34	24.30	274	140	1.2	91
23	23	7.6	1220	460	240	781	175	20	52.13	26.73	88	65	2.0	6.2
24	23	7.6	560	230	176	358	40	25	41.70	17.49	38	17	0.2	4.9
25	22	7.3	3250	432	436	2080	435	4	160.40	8.75	674	220	0.4	231
26	24	7.1	3230	680	650	2067	400	89	132.33	77.76	484	235	0.7	22
27	24	6.9	3640	790	850	2329	500	70	340.85	133.65	644	445	1.6	115
28	23	6.6	1260	170	378	806	135	4	96.24	33.53	164	125	2.2	164
29	23	7.2	340	156	320	218	25	7	96.24	19.44	14	138	0.7	20

TABLE No.5: GROUNDWATER QUALITY ANALYSIS DURING THE MONTH DECEMBER 1995

Well No.	Temp °C	PH	Conductivity (µ.mhos/cm)	Total Alkalinity (mg/lt)	Total Hardness (mg/lt)	TDS (mg/lt)	Sodium (mg/lt)	Potassium (mg/lt)	Calcium (mg/lt)	Magneseum (mg/lt)	Chloride (mg/lt)	Sulphate (mg/lt)	Phosphate (mg/lt)	Nitrate (mg/lt)
1	20	6.6	1620	360	464	1100	60	14	105.86	48.6	166	73	2.9	176.0
2	21	7.04	900	352	344	540	39	22	86.61	31.1	108	35	0.2	9.7
3	20	6.57	2950	668	592	1720	352	230	86.6	91.37	408	150	0.3	132.0
4	21	6.85	1500	530	412	900	96	19	80.2	51.51	220	25	0.7	1.3
5	20	7.0	1460	360	460	920	44	90	101.0	50.54	126	100	1.3	154.0
6	19	7.53	950	354	380	500	45	5	88.22	38.88	106	20	0.4	0.5
7	21	7.27	740	380	320	520	33	17	67.37	36.93	60	18	1.2	5.7
8	19	7.33	1220	360	440	700	46	8	80.2	58.32	126	70	0.3	8.4
9	19	6.8	1390	374	352	800	40	32	75.4	39.85	210	30	2.2	35.0
10	20	7.3	1200	520	340	720	55	12	104.26	29.16	90	85	0.3	4.8
11	21	7.7	500	192	184	220	20	3	48.1	15.55	36	35	0.1	1.3
12	20	7.3	1300	330	448	960	52	30	101.0	47.63	176	55	0.6	118.0
13	19	7.1	1070	292	284	740	33	55	54.53	35.96	106	45	1.6	92.0
14	20	7.1	1330	354	420	800	80	25	89.82	47.63	154	85	0.4	70.0
15	19	7.1	920	320	296	540	47	40	83.41	21.38	76	25	1.4	61.0
16	19	6.7	2030	690	500	1240	126	68	117.0	50.54	236	90	1.2	57.0
17	20	6.5	2240	730	400	1340	98	98	77.0	50.54	326	50	1.3	1.3
18	20	6.8	1730	660	470	1160	112	93	120.3	41.31	230	90	0.6	35.0
19	19	6.8	2050	514	552	1312	130	99	112.3	66.0	246	230	1.1	70.0
20	20	6.98	1270	390	400	813	50	82	88.22	43.74	126	50	1.2	101.0
21	19	7.5	610	290	252	390	20	17	67.37	20.41	26	30	0.4	4.4
22	19	7.2	2260	860	408	1420	170	20	85.0	47.63	278	68	1.2	154.0
23	20	7.0	1430	642	370	910	120	34	76.19	43.74	146	24	4.0	1.8
24	21	7.3	1420	320	400	910	76	88	168.4	29.16	206	70	0.2	20.0
25	20	7.2	2780	474	780	1820	180	9	176.4	82.60	532	180	0.3	167.0
26	19	6.9	3270	792	730	2093	198	224	144.36	89.9	476	155	0.7	238.0
27	19	7.1	3110	694	660	1940	124	120	160.4	63.18	558	220	1.8	110.0
28	20	6.86	2450	434	576	1570	96	172	105.86	75.8	286	123	4.0	260.0
29	19	7.7	930	324	380	595	28	5	88.2	38.9	70	63	0.5	2157.0

(d) Total Dissolved Solids (TDS)

The total dissolved solids indicate the general nature of water quality or salinity. Water containing 500 mg/lt as the desirable limit for drinking water.The TDS values in grondwater samples varies from 320 to 2451 mg/lt during April 95, 218-2329 mg/lt during Aug 95 and from 220 to 2093 mg/lt during Dec 95. Well Nos. 3,25,26,27 have high TDS values i.e. more than 1500 mg/lt during April 95, Aug 95 and Dec 95. These four wells are located in marshy land, Kakinada lock and near Saltwater creek (Fig.3). These areas represents high salinity zones in Kakinada all over the year.

(e) Sodium

Sodium concentration more than 50 ppm makes the water unsuitable for domestic use. The sodium content in water samples collected during April 95, Aug 95, Dec 95 varies from 60 to 564 mg/lt, 12 to 528 mg/lt and 28 to 352 mg/lt respectively. Especially well No.3 located at Valasapakalu shows high sodium content in above three surveys. The water in well No.3 is not suitable for domestic purpose. High sodium content has been observed in most of the wells during pre monsoon period (April 95).

(f) Calcium, Magneseum, and Total Hardness

Calcium, Magneseum and total hardness in the water are interrelated. The range of calcium content in the groundwater samples collected during April95, Aug 95 and Dec 95 are 36.09 to 240.60 mg/lt, 41.7 to 340.85 mg/lt and 48.1 to 176 mg/lt respectively and theMagneseum content range is 7.29 to 111.28 mg/lt, 7.29 to 133.65 mg/lt and 15.55 to 91.37 mg/lt respectively.

Calcium and magneseum along with their carbonates, sulphates and chlorides makes the water hard, both temporarily and permanently. The total hardness as Ca CO3 ranges between 120 to 900 mg/lt during April 95, 130 to 850 mg/lt during August 95 and 1.84 to 780 mg/lt during Dec 95. The range of hardness 0 to 75 is to be soft water, 75 to 150 moderately hard, 150-300 hard and more than 300 is very hard. Three surveys shows that the groundwater quality in Kakinada varies from moderately hard to very hard. The similar high values in Kakinada were reported by MuraliKrishna and Sumalatha (1992).

(g) Chloride

Mainly chloride content is important for taste considerations. No adverse health effects on humans have been reported from intake of waters containing even higher content of chloride. The chloride content in groundwater samples collected during April95, Aug 95 and Dec 95 ranges from 46 to 726 mg/lt, 4 to 674 mg/lt and 26 to 558 mg/lt respectively. A desirable limit of chloride in drinking water is 250 mg/lt. It is being observed that the taste of groundwater in Kakinada is different from municipal water. Most of the people in Kakinada are prefering to drink municipal water.

(h) Sulphate

Sulphate content more than 150 mg/lt is objectionable for many domestic purposes. Water containing more than 500 ppm sulphate tastes bitter and beyond 1000 ppm, it has purgative effect. The sulphate content in groundwater samples collected during three surveys ranges from 18 to 480 mg/lt. Most of the wells are below the permissible value for domestic uses except few wells in marshy lands and near saltwater creek (Fig.3).

(i) Nitrate

Nitrate is effective plant nutrient and moderately toxic. Its concentration above 45 mg/lt in drinking water may prove detriment to human health. The maximum nitrate content of groundwater samples collected during April 95, Aug. 95 and Dec.95 are 266 mg/lt, 231 mg/lt and 260 mg/lt respectively. The wells located at Kakinada lock and Vakalapudi shows high values of nitrate contents.

The above chemical parameters are compared for Indian Standards of maximum permissible limits of drinking waters. Table No.6 shows the well numbers which have exceeded the drinking water limits during April 95, Aug. 95 and Dec. 95. The comparison shows that the wells located near salt watercreek, Kakinada Lock and nearby sea coast have exceeded the limit. The wells located nearby Bhanugudi Junction (Fig 3) shows the values are within the permisible limits. It is also observed from these three surveys the

Table 6 : Comparison of Water Quality Parameters with ISI Drinking Water Standards

Parameter	During 1995 Min	During 1995 Max	ISI Max. permissible Limits	Well Nos. in which limit exceeded April 95	Aug 95	Dec 95
pH	6.1	7.8	6.5-9.2	NIL	NIL	NIL
Ca (mg/lt)	36	340	200	19&25	27	NIL
Mg (mg/lt)	7.29	133.65	150	NIL	NIL	NIL
Cl (mg/lt)	4	726	1000	NIL	NIL	NIL
SO_4 (mg/lt)	18	480	400	NIL	19&27	NIL
T.H.(mg/lt)	120	900	600	1,3,19,25 26 & 27	19,26,27	25,26 &27
E.C (µS/cm)	280	3830	1200	3,4,5,8,9 10,12,13,14 16,17,18,19 20,21,22,23 25,26,27 & 28	3,4,8,10 12,13,14 16,17,19 20,21,23 25,26,27 & 28	1,3,4,5,8,9 12,14,16,17 18,19,20,22 23,24,25,26 27 & 28

general quality of groundwater is varying with respect to seasons. The high concentration of chemical parameters are observed during pre monsoon period i.e. April 95. Most of the wells are exceeding the permissible limit for drinking water Standards during the year 1995.

4.2 Water Quality evaluation for Irrigation Purpose

A good quality water has the potential to cause maximum yield under good soil and Irrigation management practices. However irrigated water quality refers to its suitability for agricultural use. The suitability of groundwater for irrigation in Kakinada has been evaluated based on total dissolved solids and relative proportion of sodium to other cations.

4.2.1 Total Dissolved solids

In general any water contains dissolved substances which, as a general collective term, are called salts. The appearence of salts in water may be weathering of rocks, soils and dissolving of lime, gypsum, and other salt sources as water passes over or percolated through them.

The total concentration of soluble salts in irrigation can thus be expressed for the purpose of classification of Irrigation water as follows:

Zone	TDS(mg/lt)	Conductivity(μs/cm)
low salinity zone	<200	<250
Medium salinity zone	200-500	250-750
High salinity zone	500-1500	750-2250
Very high salinity zone	1500-3000	2250-5000

TDS values in study area varies from 320 to 2451 mg/lt, 179 to 2329 mg/lt and 220 to 2093 mg/lt during April95, Aug.95 and Dec.95 respectively. The complete TDS values during three surveys are given in Tables 3 to 5.

Well Nos. 3,19,22,23,25,26 and 27 showing very high salinity values during the study period. These wells are located at marshy land, Kakinada lock and near by salt water creek. In the study area 65% of wells are showing high salinity vaues, 18% of wells fall under very high salinity zones and 17% of wells are under medium to low salinity zone. High salinity waters can not be used directly for irrigation.

4.2.2 Relative proportion of Sodium to other Cations

The Sodium or alkali hazard in the use of a water for irrigation is determined by the obsolute and relative concentration of cations and is expressed in terms of Sodium Adsorption Ratio (SAR). A simple method of evaluating the range of high-sodium water is the Sodium Adsorption Ratio (Richards, 1954).

$$SAR = \frac{Na}{[(Ca^{+} + Mg^{+})/2]^{0.5}}$$

The sodium percentage is calculated as:

$$Na\ \% = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100$$

where all ionic concentrations are expressed in milliequivalent per litre.

Calculation of SAR for a given water sample provides a useful index of the sodium hazard of that water for soils and crops.

The sodium hazard in water sample based on SAR values are as follows:

SAR Range	Remarks
2-10	little danger from sodium
7-18	medium hazards
11-26	high hazards
> 26	very high hazards

TABLE. 7 : SODIUM ADSORPTION RATIOS AND SODIUM PERCENTAGES

W.No.	LOCATION	April 95 SAR	April 95 Na%	August 95 SAR	August 95 Na %	December 95 SAR	December 95 Na %
1	Sarpavaram	1.85	30.88	2.61	50.72	1.21	24.23
2	Balaji Nagar	1.76	39.65	4.74	66.79	0.91	24.72
3	Valasapakalu	8.36	64.67	9.97	71.77	6.29	64.16
4	Vakalapudi	8.94	71.20	7.68	69.21	2.06	36.13
5	Ramanayya peta	2.12	39.79	2.25	44.84	0.89	31.43
6	R.R.Nagar	2.67	43.29	1.67	35.40	1.00	21.52
7	Madhav Nagar	2.82	53.21	3.57	56.12	0.80	22.61
8	Nagamalli thota	3.48	42.39	4.08	47.72	0.95	20.04
9	Godarigunta	3.48	52.23	4.95	60.05	0.93	22.65
10	Sambamurthy nagar	3.95	49.86	4.22	52.65	1.23	26.20
11	Shanti nagar	5.57	68.04	0.46	18.71	0.64	20.46
12	Perraju Peta	7.55	65.31	9.86	71.12	1.07	25.27
13	Kondayya palem	4.99	66.36	4.45	63.46	0.85	33.35
14	Gandhi Nagar	3.95	49.16	5.16	62.67	1.70	32.89
15	Rama Rao Peta	2.19	42.51	3.16	53.34	1.19	34.12
16	Surya rao Peta	4.99	56.69	3.61	51.16	2.45	41.93
17	Suryanarayanapuram	7.58	74.73	6.60	71.48	2.13	45.83
18	Budam Peta	4.88	60.74	5.37	58.90	2.25	43.54
19	Temple Street	3.04	42.00	5.59	54.06	2.41	42.59
20	Frazer Peta	2.64	47.69	3.62	52.75	1.09	34.81
21	Pratap Nagar	4.05	50.43	2.90	42.37	0.55	20.56
22	Revenue colony	11.00	77.88	7.88	65.66	3.66	49.21
23	Gogudanayya Peta	9.76	71.88	4.91	62.85	2.71	45.14
24	MSN Charties	2.58	59.26	1.31	40.33	1.42	33.96
25	Turangi	4.07	41.90	9.06	68.56	2.80	34.06
26	Paradesamma Peta	6.52	55.09	6.82	60.21	3.19	49.55
27	Indra Palem	6.68	57.85	5.81	45.67	2.10	39.06
28	Chidiga	2.48	36.53	3.02	44.14	1.74	42.67
29	Madhura Nagar	1.48	30.22	0.61	16.51	0.62	15.04

The SAR values in groundwater samples collected in the study area ranges from 1.48 to 11, 1.31 to 9.97 and 0.55 to 6.29 during April 95, Aug 95 and Dec.95 respectively. TheSARvalues andsodium percentagesinthe observation. wells are given in Table 7. Most of the groundwater samples collected during the year 1995 falls under the category of low sodium hazards, which reveals that the groundwater in the study area is to be monitored for sodium hazard.

The sodium percentage in the study area is found to be varied from 30.22 to 77.88%, 16.51 to 71.77% and 15.04 to 64.16% during April 95, Aug 95 and Dec 95 respectively. The lowest values of sodium percentage were observed in the month of Dec 95 and high values in the month of April 95. The high sodium saturation in the water samples directly causes calcium deficiency.

4.3 Spatial Distribution of Total Dissolved Solids (TDS)

The spatial distribution of TDS values in the study area during pre monsoon and post monsoon periods are shown in Fig. 7 & 8 respectively. High TDS contours have been observed along the coast in both periods. Mainly highest TDS values have been observed in well Nos. 26 & 27. This is due to the salt water creek influence at well No.26 and the combined influence of salt water creek and Yeleru drain at well No.27. Further these contour maps shows that the concentration of TDS has been diluted from pre monsoon to post monsoon period. Low TDS values have been observed in both periods at well No.7 and nearby area, which is free from local polluted water bodies.

4.4 Variation of Groundwater Quality Parameters with Time

An attempt has been made to observe the change in water quality parameters in the observation wells. Well Nos.7, 8 and 29 have choosen in the middle of the city and well Nos.19,26 and 27 are at salt water creek. The variations of chloride, Alkalinity, Sodium and Potassium are shown in Fig. 9. The variation in these parameters is not followed any specific trend. With the available data it is very difficult to predict the reasons for these changes. Long term data may provide some useful information for these changes. The analysis

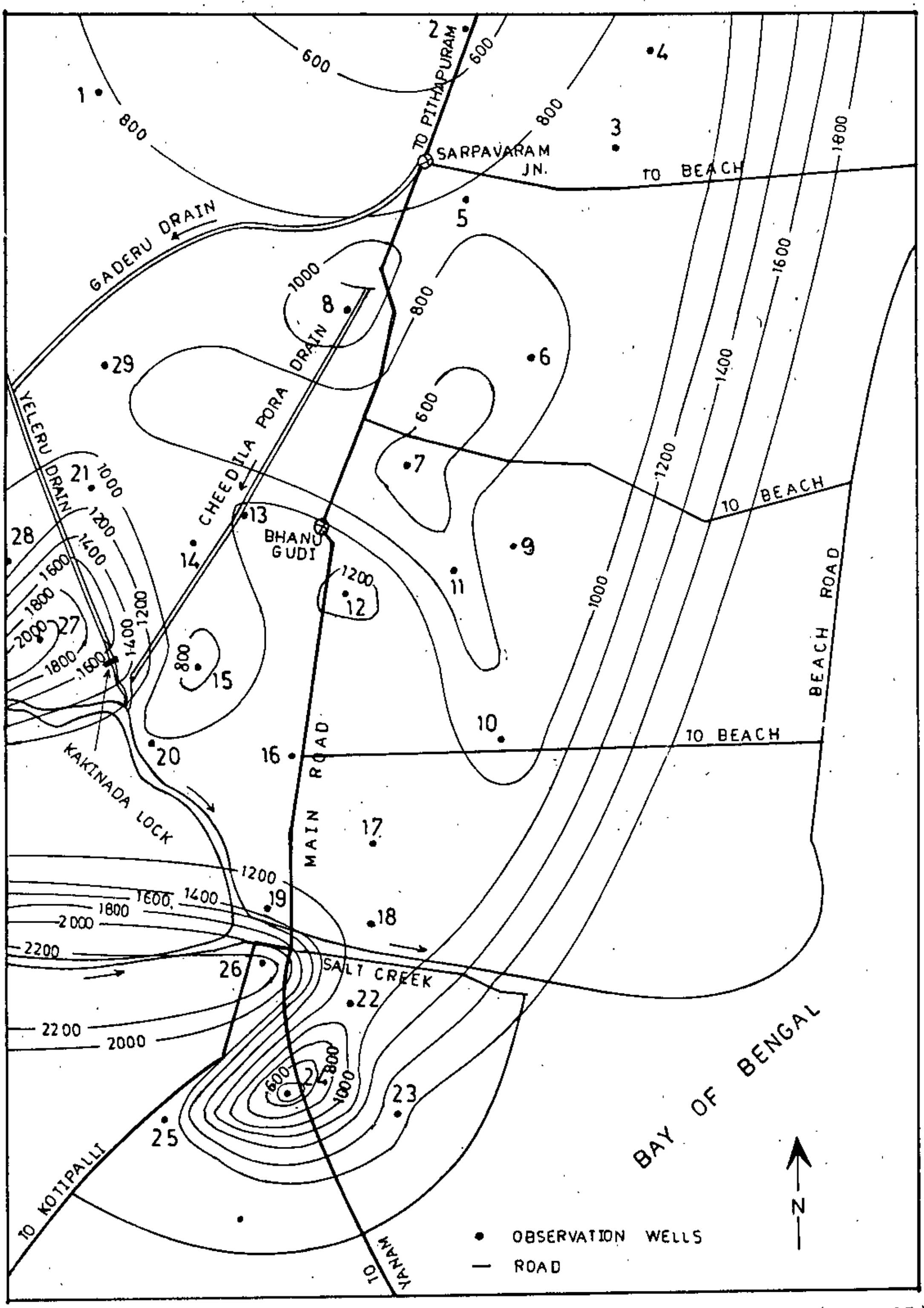


FIG. 7 TDS CONTOURS DURING PRE MONSOON PERIOD (APR 95)

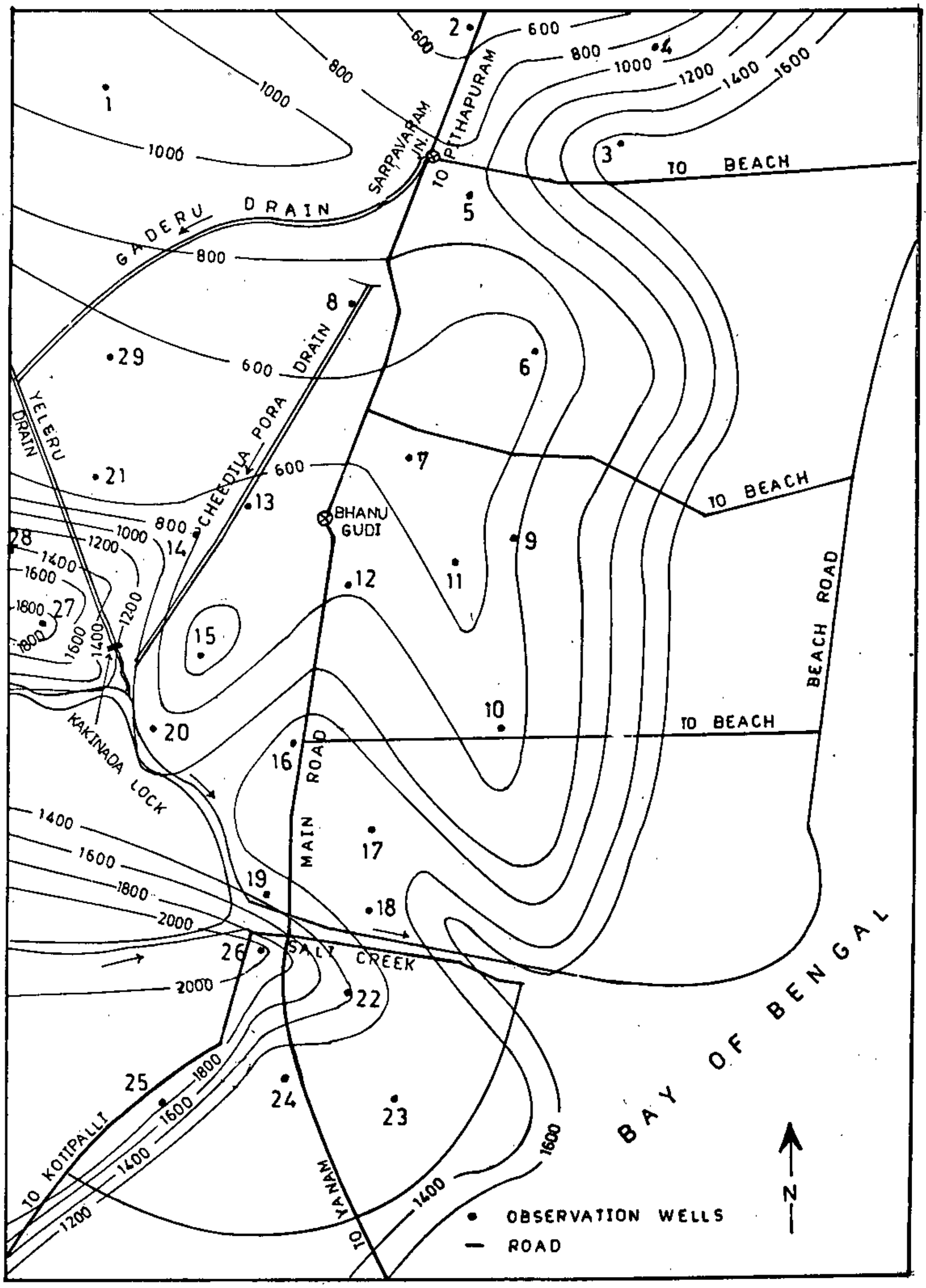


FIG.8 TDS CONTOURS DURING POST MONSOON PERIOD (DEC. 95)

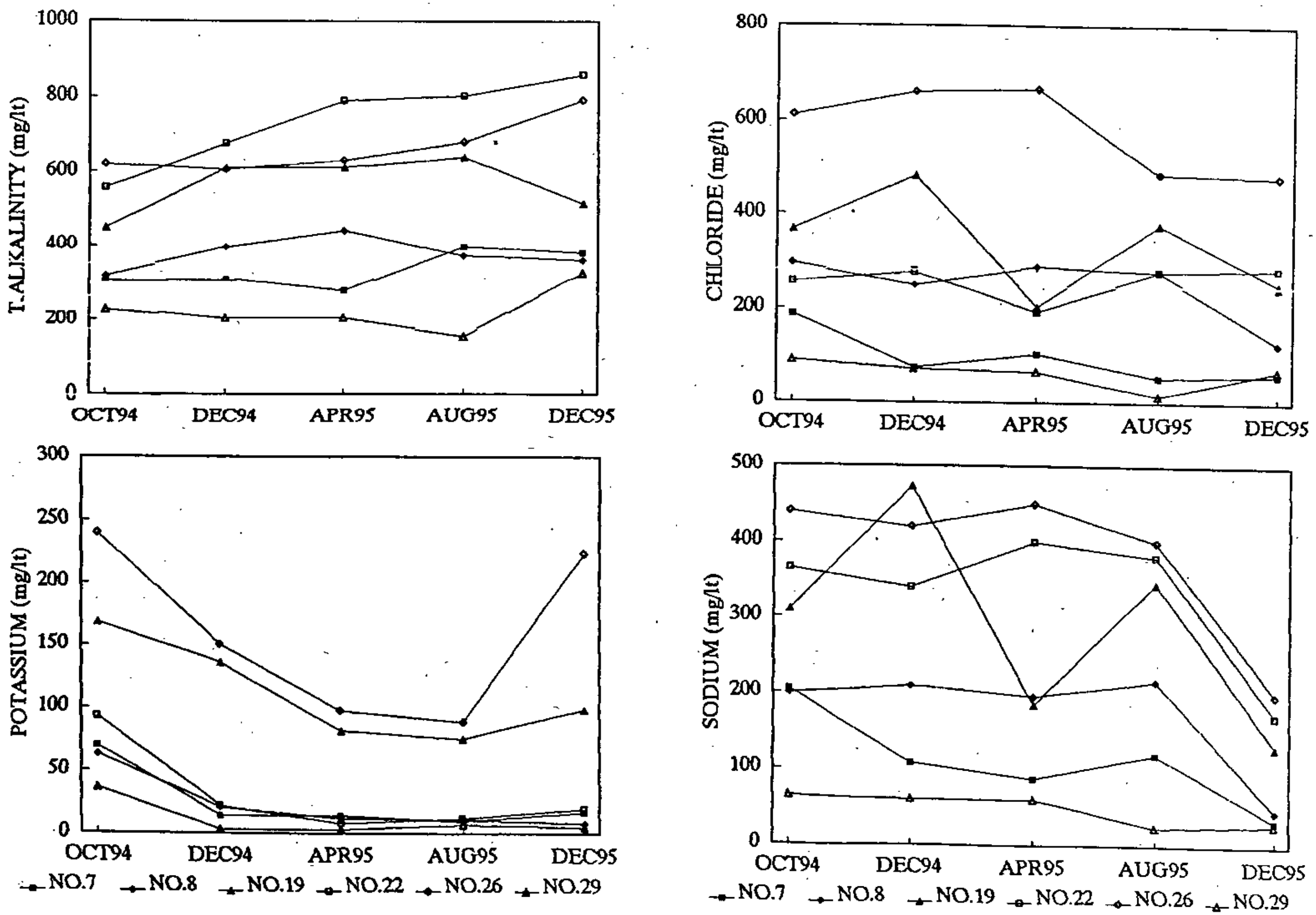


FIG. 9 VARIATION OF GROUNDWATER QUALITY PARAMETERS IN THE OBSERVATION WELLS

results during Oct.94 and Dec.94 are taken from NIH, CS-175 report.

4.5 Variation of groundwater Quality from Sea

Well No.23, 16, 14, 29 and 1 have been identified to study the impact of Sea on each well. These wells are approximately located at a distance of1, 2, 4, 6 and 7 kms., respectively from Sea. Few chemical constituents which are influenced by Sea such as TDS, Chloride, and other parameters i.e Sodium, Potassium etc., concentrations are plotted for above observation wells. The variation in these water quality parameters during pre monsoon (Apr.95) and post monsoon (Dec.95) periods are shown in Fig.10. During pre monsoon period it has been clearly observed that the quality of water is deteriorating towards Sea. However, slight increased values have been observed at well No.1, even it is far away from sea. This may be due to location of well i.e at irrigated land. During post monsoon period the concentration of above chemical constituents are obeserved to be less than pre monsoon period. But the quality deterioration trend in above observation wells have been changed from pre monsoon to post monsoon period. Especially well No.16 has showed slightly high values. It may conclude that the area nearby well No.16 has influenced by local pollution. Further the effect of sea water ingress in post monsoon period is less than the pre monsoon period.

4.6 Classification of waters

4.6.1 Stiff classification

The classification results of 29 samples collected during April 95, August 95 and Dec 95 are given in Table 8. During the study period mainly 4 types of water samples have been observed in the study area. They are sodium bicarbonate, sodium chloride, calcium bicarbonate and calcium chloride. Sample surveys in Table.8 shows that lot of mixing has taken place in the groundwater with respect to seasonal variations. It has also observed that the type of waters is varying from place to place in the study area. Well Nos. 3 and 26 are represented NaCl type of water throughout the year. These

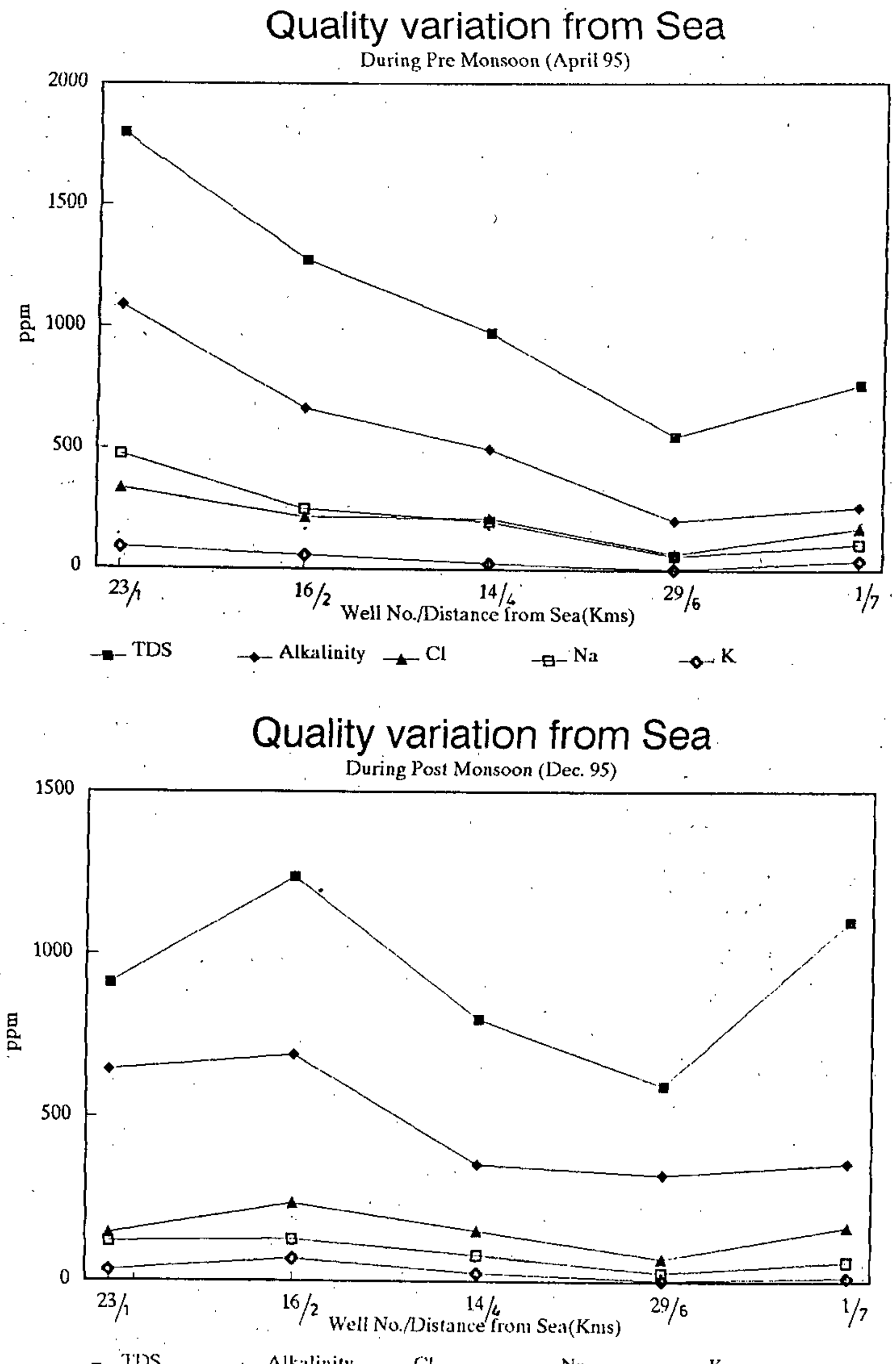


FIG. 10 GROUNDWATER QUALITY VARIATION FROM SEA

TABLE. 8 : STIFF CLASSIFICATION OF WATER SAMPLES

W. No.	Location	April 95	Aug 95	Dec. 95
1	Sarpavaram	$CaCl_2$	$CaHCO_3$	$CaHCO_3$
2	Balaji Nagar	$CaCl_2$	$NaHCO_3$	$CaHCO_3$
3	Valasapakalu	NaCl	NaCl	NaCl
4	Vakalapudi	$NaHCO_3$	$NaHCO_3$	$MgHCO_3$
5	Ramanayya peta	$CaCl_2$	$NaHCO_3$	$CaHCO_3$
6	R. R. Nagar	$CaHCO_3$	$CaHCO_3$	$CaHCO_3$
7	Madhav Nagar	$NaHCO_3$	$NaHCO_3$	$CaHCO_3$
8	Nagamalli thota	NaCl	NaCl	$MgHCO_3$
9	Godarigunta	NaCl	NaCl	$CaHCO_3$
10	Sambamurthy nagar	$NaHCO_3$	$NaHCO_3$	$CaHCO_3$
11	Shanti nagar	$NaHCO_3$	$CaHCO_3$	$CaHCO_3$
12	Perraju Peta	$NaHCO_3$	$NaHCO_3$	$CaHCO_3$
13	Kondayya palem	$NaHCO_3$	$NaHCO_3$	$MgHCO_3$
14	Gandhi Nagar	$KHCO_3$	$NaHCO_3$	$CaHCO_3$
15	Rama Rao Peta	$CaHCO_3$	$NaHCO_3$	$CaHCO_3$
16	Surya rao Peta	$NaHCO_3$	$NaHCO_3$	$CaHCO_3$
17	Suryanarayanapuram	$NaHCO_3$	$NaHCO_3$	$NaHCO_3$
18	Budam Peta	$NaHCO_3$	$NaHCO_3$	$CaHCO_3$
19	Temple Street	$CaHCO_3$	NaCl	$NaHCO_3$
20	Frazer Peta	$CaHCO_3$	$NaHCO_3$	$CaHCO_3$
21	Pratap Nagar	$NaHCO_3$	$CaHCO_3$	$CaHCO_3$
22	Revenue colony	$NaHCO_3$	$NaHCO_3$	$NaHCO_3$
23	Gogudanayya Peta	$NaHCO_3$	$NaHCO_3$	$NaHCO_3$
24	MSN Charties	$NaHCO_3$	$CaHCO_3$	$CaCl_2$
25	Turangi	NaCl	NaCl	$CaCl_2$
26	Paradesamma Peta	NaCl	NaCl	NaCl
27	Indra Palem	NaCl	NaCl	$CaCl_2$
28	Chidiga	$CaCl_2$	NaCl	$MgCl_2$
29	Madhura Nagar	$CaHCO_3$	$CaSO_4$	$CaHCO_3$

wells are located nearby Sea and Yeleru drain respectively. These two sources of polution are strongly dominated nearby ground water quality.

4.6.2 Pipers Trilinear Classification

The trilinear diagrams of samples collected during April 95, Aug 95 and Dec. 95 are shown in Fig. 11, 12 and 13 respectively. The hydrochemical facies inferred from these trilinear diagrams are given in Table 9. During the study period 4 facies have been observed in the study area. They are...

(I) = Ca+Mg+cl+SO4

(II) = Na + Cl + K + SO4

(III) = Na + K + CO3 + HCO3 and

(IV) = Ca +Mg + CO3 + HCO3

The spatial distribution of above facies during premonsoon(April 95) and post monsoon(Dec.95) are shown in Fig.14. The distribution of HCO3 facies (III & IV) represents discharge area and Cl facies (I & II) are recharge areas. Thecomparison in Fig.14 reveals that the change in groundwater quality is very much significant from pre monsoon to post monsoon period. Further, the discharge area has been increased from pre monsoon to post monsoon period.

The shift in the quality of observation wells could be seen clearly in central diamond shape of Piper Trilinear Diagrams prepared for the month of Apr.95, Aug. 95 and Dec. 95 (Fig 11, 12 & 13).

4.6.3 U.S Salinity Laboratory Classification

The chemical analysis of samples collected during April 95, Aug 95 and Dec 95 are plotted on Wilcox diagrams and shown in Fig. 15, 16 and 17 respectively. The results inferred from each diagram are given in Table 10. Depending on the water types, the information related to suitability of water for irrigation could be obtained. The following water types represent the classification of water.

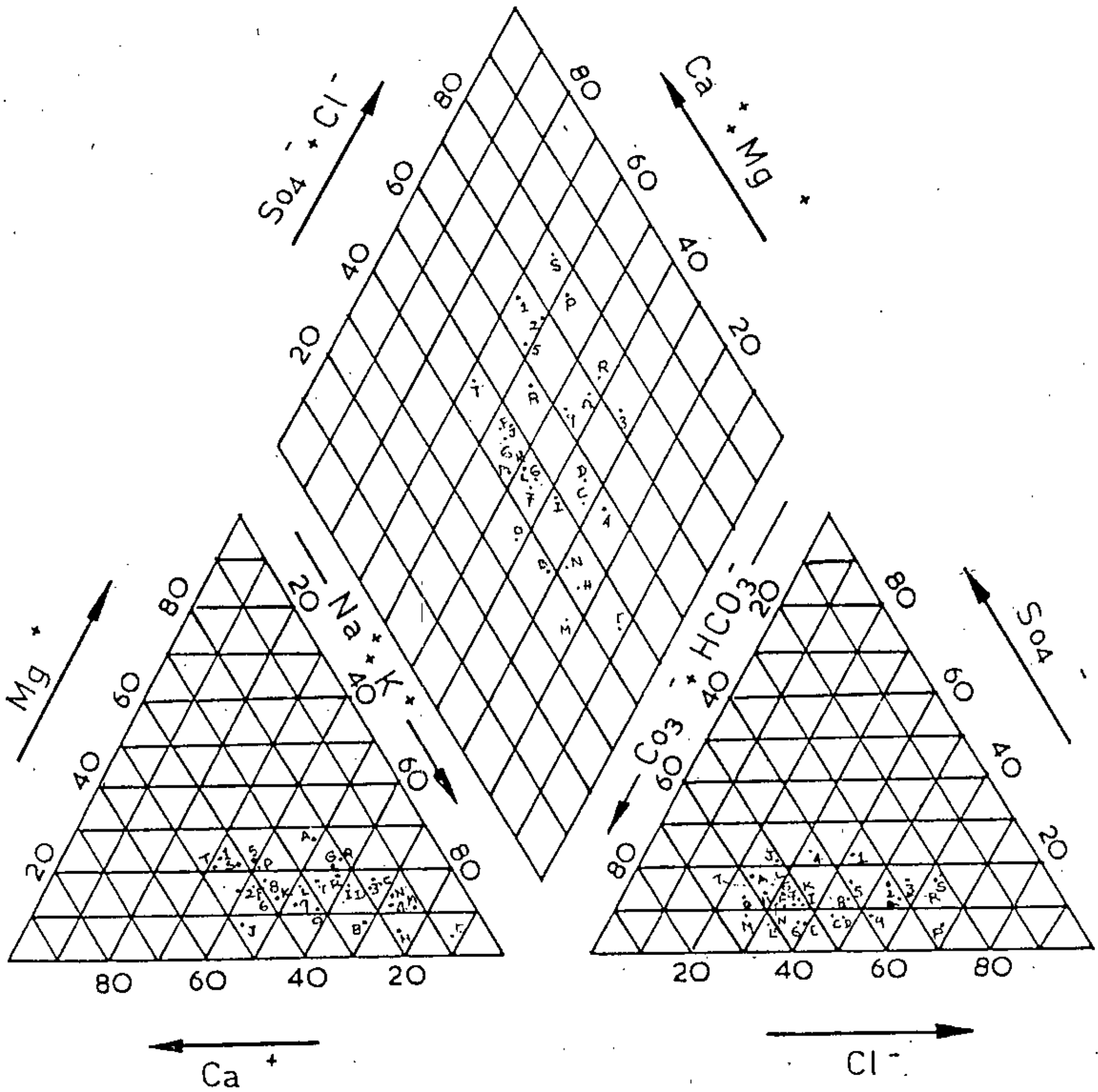


Fig. 11 PIPERS TRILINEAR DIAGRAM REPRESENTING CHEMICAL CHARACTER OF GROUND WATER SAMPLES COLLECTED DURING APRIL 1995.

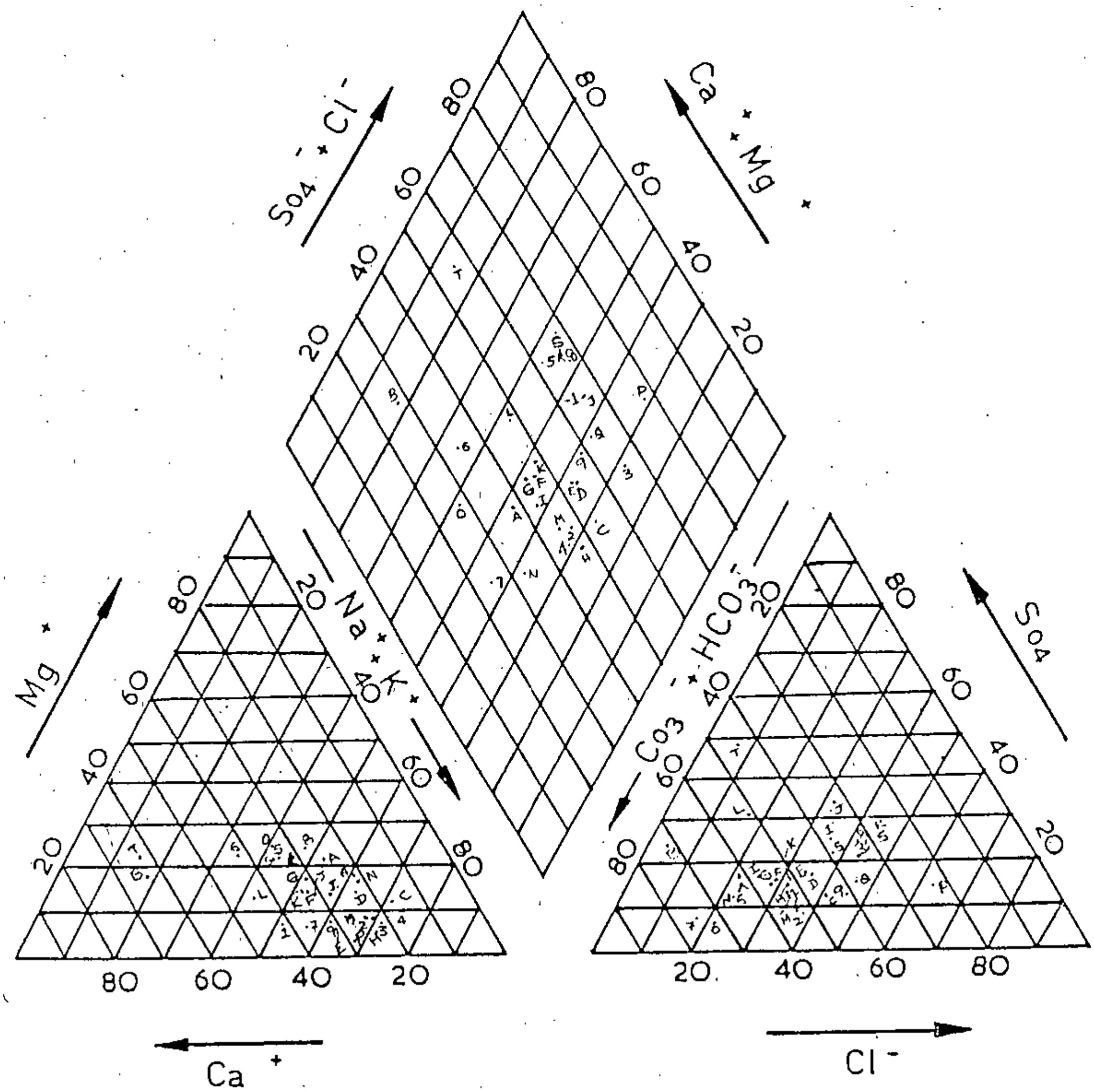


FIG. 12 PIPERS TR ILINEAR DIAGRAM REPRESENTING CHEMICAL CHARACTER OF GROUND WATER SAMPLES COLLECTED DURING AUGUST 1995.

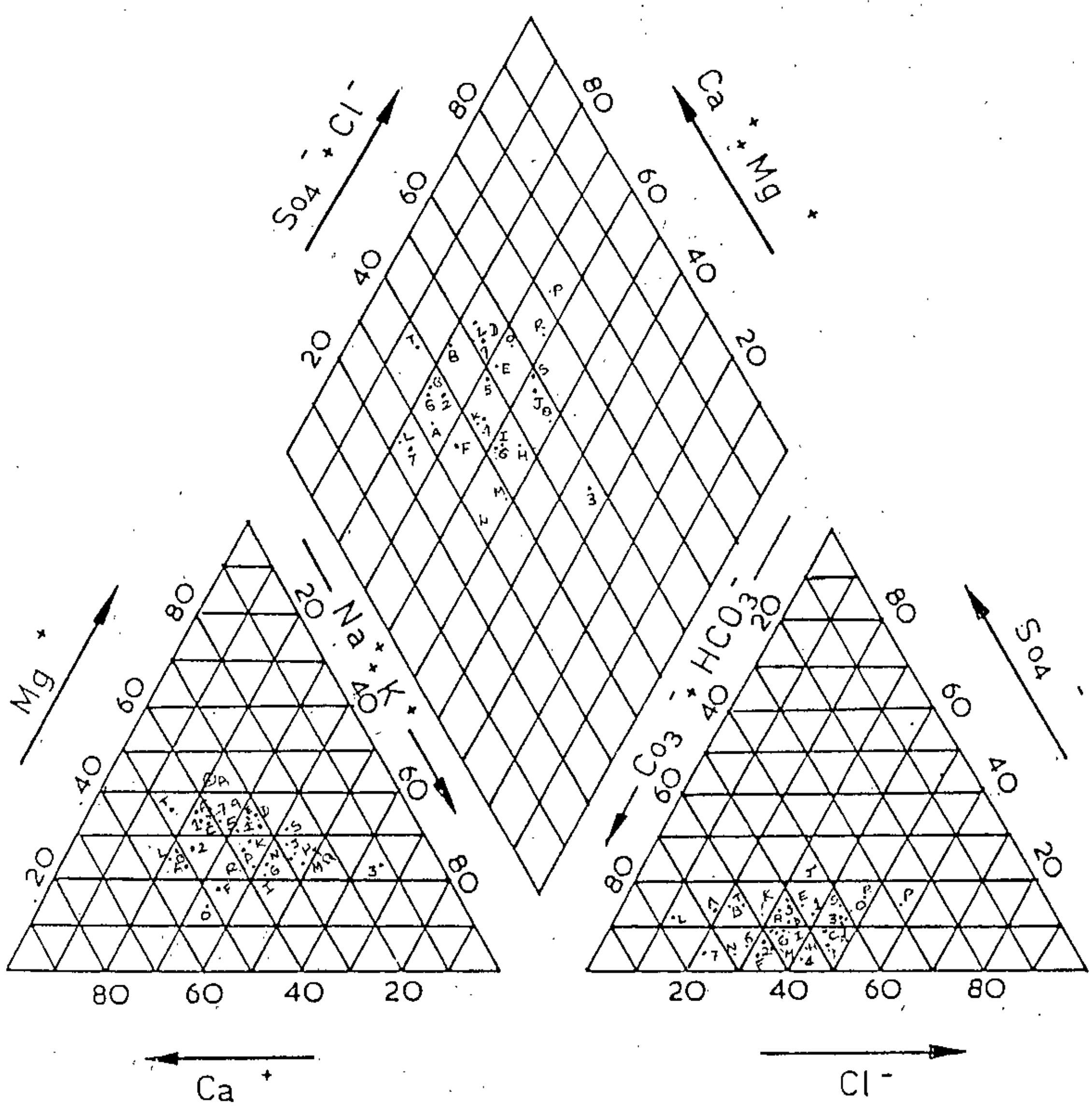
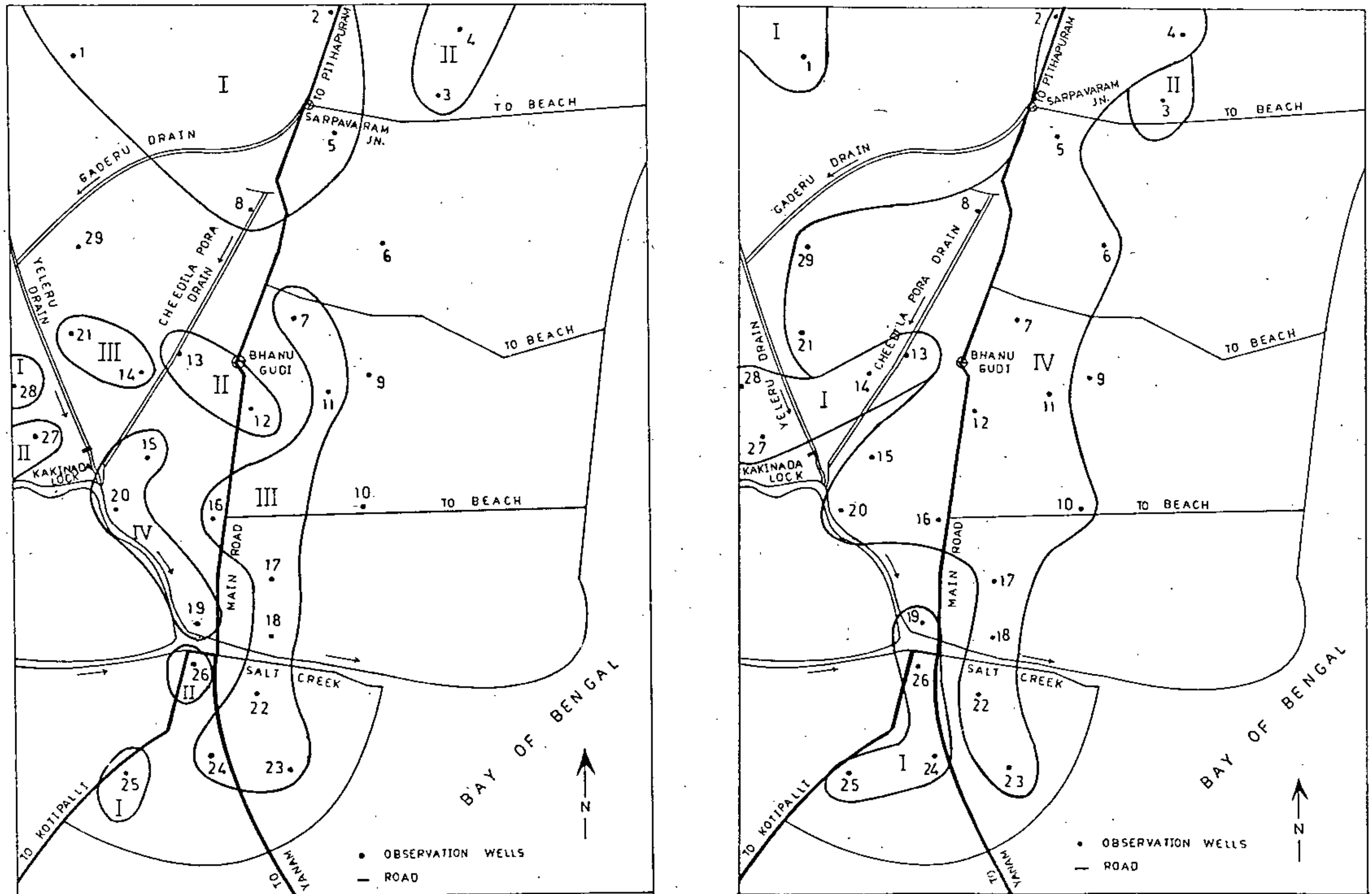


FIG. 13 PIPERS TR ILINEAR DIAGRAM REPRESENTING CHEMICAL CHARACTER OF GROUNDWATER SAMPLES COLLECTED DURING DECEMBER 1995.

TABLE 9: PIPERS CLASSIFICATION OF WATER SAMPLES

W.No	Location (LABEL)	April 95	Aug. 95	Dec. 95
1	Sarpavaram (1)	I	II	I
2	Balaji Nagar (2)	I	III	IV
3	Valasapakalu (3)	II	II	II
4	Vakalapudi (4)	II	III	IV
5	Ramanayya peta (5)	I	I	IV
6	R.R.Nagar (6)	IV	IV	IV
7	Madhav Nagar (7)	III	III	IV
8	Nagamalli thota (8)	I	I	IV
9	Godarigunta (9)	II	II	I
10	Sambamurthy nagar (A)	IV	III	IV
11	Shanti nagar (B)	III	IV	IV
12	Perraju Peta (C)	II	II	IV
13	Kondayya palem (D)	II	II	I
14	Gandhi Nagar (E)	III	II	I
15	Rama Rao Peta (F)	IV	III	IV
16	Surya rao Peta (G)	III	III	IV
17	Suryanarayanapuram (H)	III	III	IV
18	Budam Peta (I)	III	III	IV
19	Temple Street (J)	IV	II	I
20	Frazer Peta (K)	IV	III	IV
21	Pratap Nagar (L)	III	IV	IV
22	Revenue colony (M)	III	III	IV
23	Gogudanayya Peta (N)	III	III	IV
24	MSN Charties (O)	III	IV	I
25	Turangi (P)	I	II	I
26	Paradesamma Peta (Q)	II	II	I
27	Indra Palem (R)	II	I	I
28	Chidiga (S)	I	I	I
29	Madhura Nagar (T)	IV	I	IV

I = $Ca + Mg + Cl + SO_4$, II = $Na + K + Cl + SO_4$ III = $Na + K + CO_3 + HCO_3$ IV = $Ca + Mg + CO_3 + HCO_3$



DURING PRE MONSOON PERIOD (APRIL 95) DURING POST MONSOON PERIOD (DEC. 95)

FIG. 14 SPATIAL DISTRIBUTION OF HYDRO-CHEMICAL FACIES

C2-S1 = medium salinity low SAR

C3-S1 = high salinity low SAR

C3-S2 = high salinity and medium SAR

C4-S2 = very high salinity and medium SAR

C4-S4 = very high salinity and very high SAR

During the study period 10 wells have showed same type of water(C3-S1) which is fit for irrigation purpose in general, but may cause some problem where the soil permeability is very poor. Water types in other wells are changing with respect to time. In general C2-S1 type is suitable for irrigation purpose, C3-S2 type can not be used on soils with restricted drainage, C4-S2 type is not suitable for irrigation under ordinary conditions, and C4-S4 type is not at all suitable for irrigation purposes. Most of the study area falling between high salinity low SAR to Very High Salinity Medium SAR. From the Table.10 it has been observed that the suitability of groundwater for irrigation is changing with time. Very high salinity of groundwater (C4-S2) has been observed at salt water creek and near Kakinada Lock.

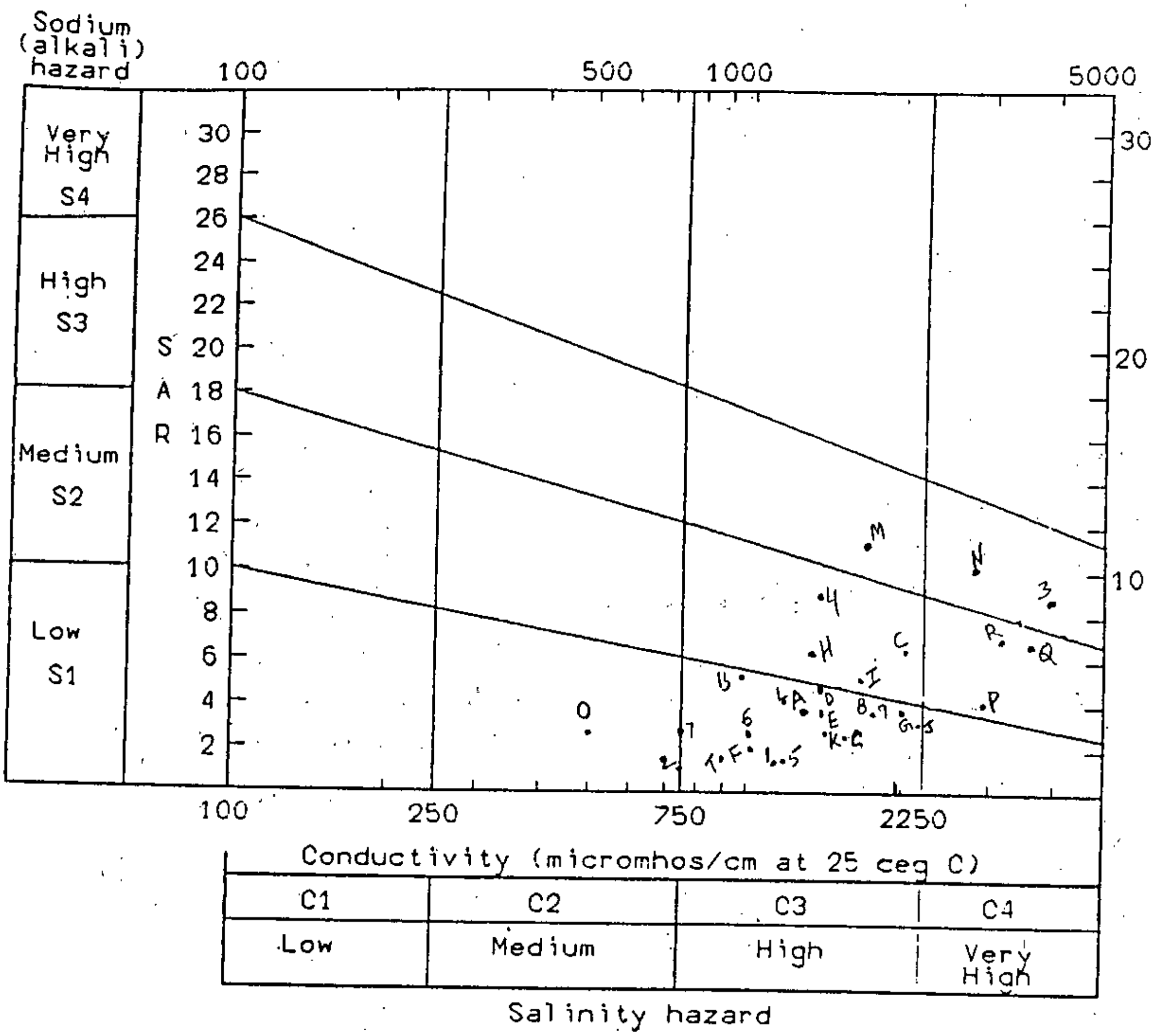


FIG.15 US SALINITY LABORATORY CLASSIFICATION OF SAMPLES COLLECTED DURING APRIL 1995.

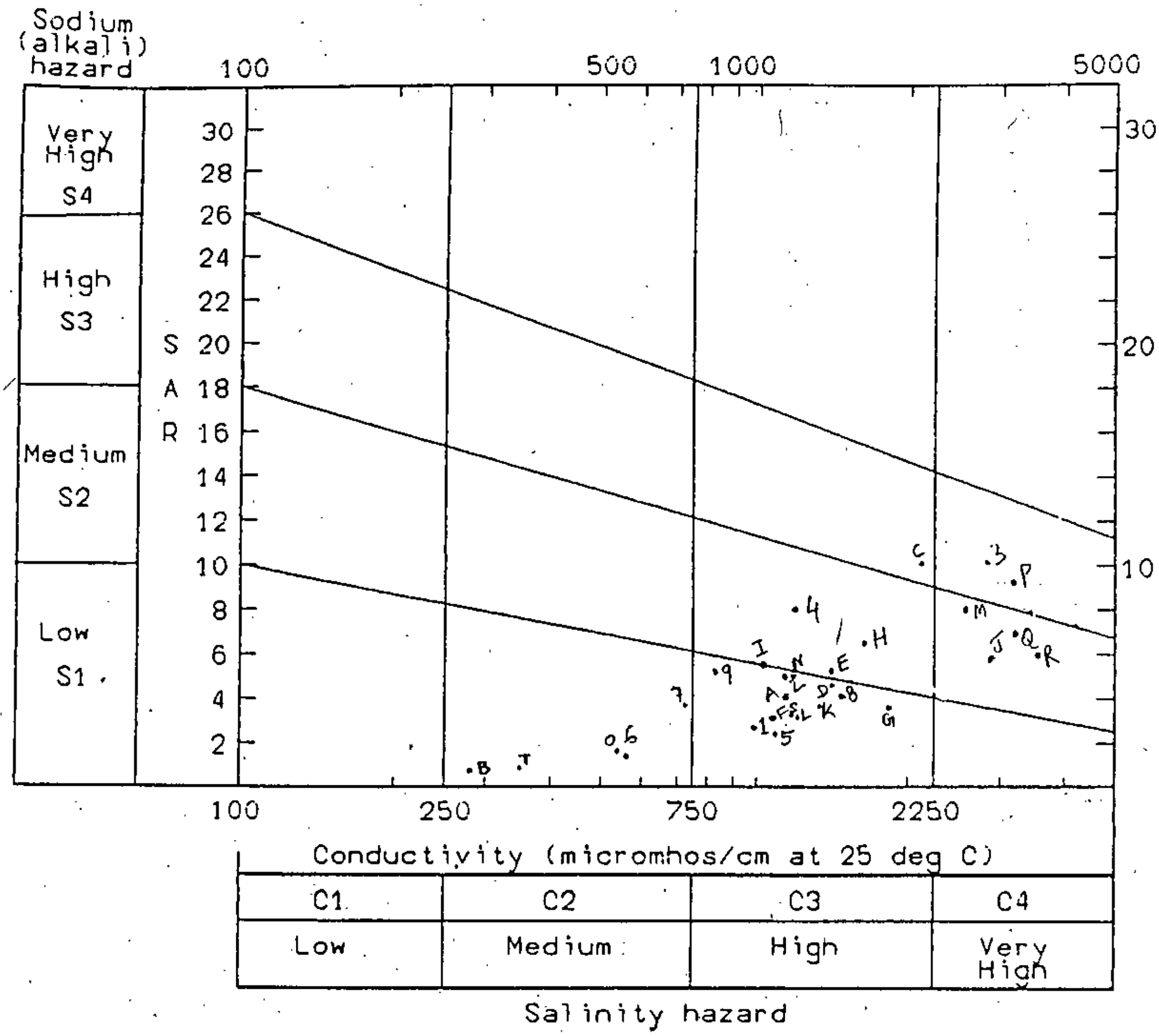


FIG. 16 US SALINITY LABORATORY CLASSIFICATION OF SAMPLES COLLECTED DURING AUGUST 1995

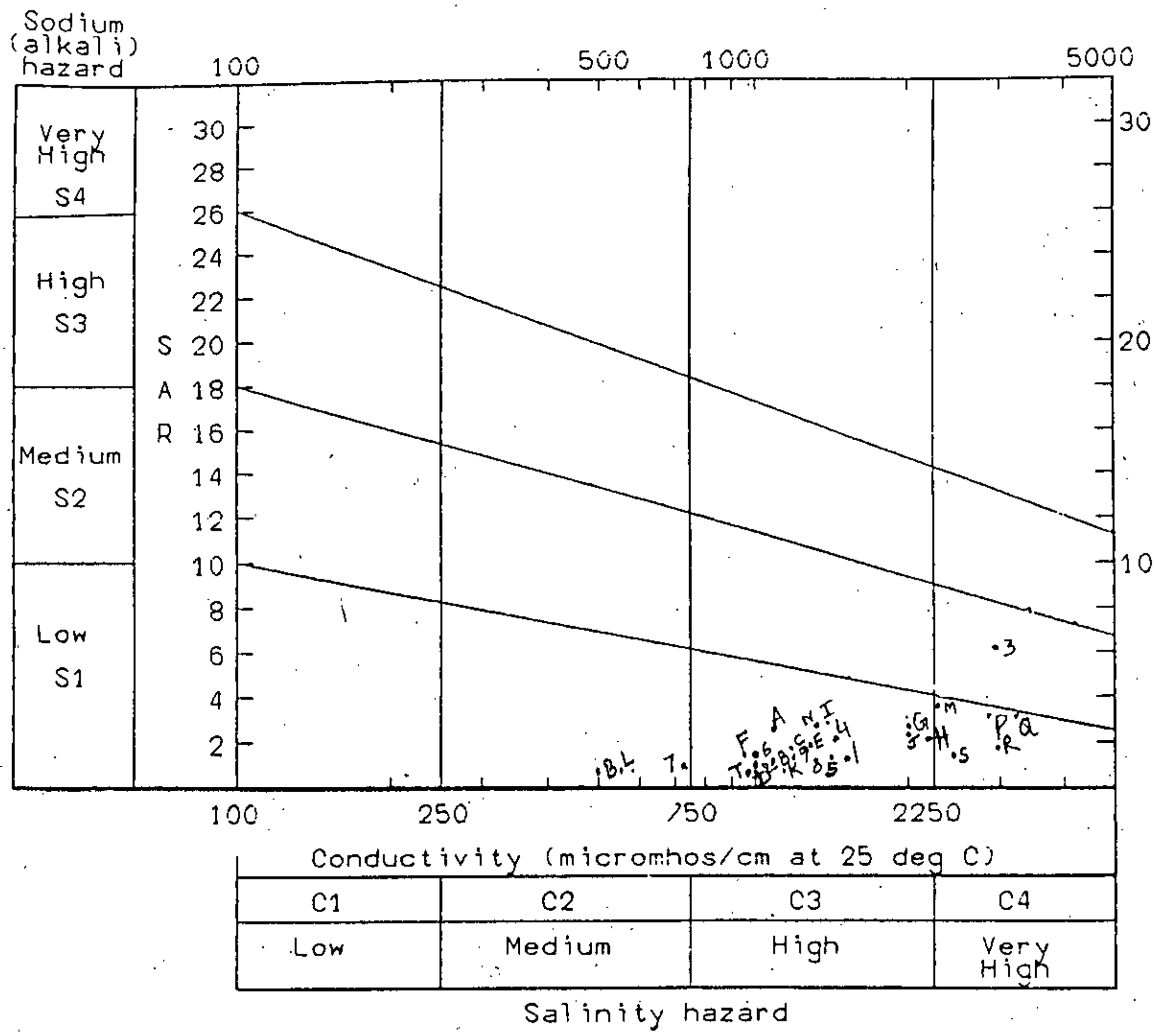


Fig. 17 US SALINITY LABORATORY CLASSIFICATION OF SAMPLES COLLECTED DURING DECEMBER 1995.

TABLE.10 : U.S.SALINITY LABORATORY CLASSIFICATION OF WATER SAMPLES

W.No.	LOCATION (LABEL)	APR.95	AUG. 95	DEC.95
1	Sarpavaram(1)	C3-S1	C3-S1	C3-S1
2	Balaji Nagar(2)	C3-S1	C3-S1	C3-S1
3	Valasapakalu(3)	C4-S3	C4-S3	C4-S2
4	Vakalapudi (4)	C3-S2	C3-S2	C3-S1
5	Ramanayya peta(5)	C3-S1	C3-S1	C3-S1
6	R.R.Nagar (6)	C3-S1	C2-S1	C3-S1
7	Madhav Nagar(7)	C3-S1	C2-S1	C2-S1
8	Nagamalli thota(8)	C3-S1	C3-S1	C3-S1
9	Godarigunta(9)	C3-S1	C3-S1	C3-S1
10	Sambamurthy nagar (A)	C3-S1	C3-S1	C3-S1
11	Shanti nagar(B)	C3-S1	C2-S1	C2-S1
12	Perraju Peta(C)	C3-S2	C3-S3	C3-S1
13	Kondayya palem(D)	C3-S1	C3-S1	C3-S1
14	Gandhi Nagar(E)	C3-S1	C3-S2	C3-S1
15	Rama Rao Peta (F)	C3-S1	C3-S1	C3-S1
16	Surya rao Peta(G)	C3-S1	C3-S1	C3-S1
17	Suryanarayanapuram(H)	C3-S2	C3-S2	C3-S1
18	Budam Peta(I)	C3-S2	C3-S2	C3-S1
19	Temple Street(J)	C3-S1	C4-S2	C3-S1
20	Frazer Peta (K)	C3-S1	C3-S1	C3-S1
21	Pratap Nagar (L)	C3-S1	C3-S1	C2-S1
22	Revenue colony (M)	C3-S3	C4-S2	C4-S1
23	Gogudanayya Peta (N)	C4-S3	C3-S1	C3-S1
24	MSN Charties(O)	C2-S1	C2-S1	C3-S1
25	Turangi (P)	C4-S2	C4-S2	C4-S1
26	Paradesamma Peta(Q)	C4-S2	C4-S2	C4-S1
27	Indra Palem (R)	C4-S2	C4-S2	C4-S1
28	Chidiga (S)	C3-S1	C3-S1	C4-S1
29	Madhura Nagar (T)	C3-S1	C2-S1	C3-S1

5.0 CONCLUSIONS

The groundwater level variations and its quality have been studied for the year 1995. Total 87 groundwater samples have been collected during Apr.95, Aug.95 & Dec.95 and are being analysed.

Few well hydrographs in study area shows that the trend of change in groundwater level in each observation well is similar. The wells located at salt water creek (Well Nos.22, 23, 19) shows high water table conditions than well Nos 5, 8, 6 (Fig.4). The water table contours during pre monsoon and post monsoon periods showed that the entire aquifer or groundwater storage is being recharged in post monsoon period. Thusit is confirming the unconfined water table condition in the study area.

The comparison of water quality parameters with ISI Drinking water standards indicated that the wells located near salt water creek, Kakinada Lock and nearby sea coast are exceeding the desirable limits. However, the Electrical Conductivity values are exceeded the maximum allowable limit in all wells except well Nos. 2, 6, 15 & 29. The percentage of Sodium in each observation well is calculated. The percentage of sodium is between 15 to 78% in the study area. The medium sodium hazard has been observed in the city, which reveals the monitoring of sodium hazard is essential in future.

Groundwater quality parameters variation in observation wells have not followed any specific trend. However the TDS contour maps of premonsoon and postmonsoon periods indicated that the dilution in TDS had taken place in the study area. High TDS values have been observed at Sea coast, salt creek and kakinada Lock. The ground water quality is deteriorating towards sea especially during pre monsoon than post monsoon periods.

Stiff Classification shows that only 4 types of water have been observed in the study area. They are sodium bi carbonate, sodium chloride, calcium bicarbonate and calcium chloride. The dominant cation and anions in most of the wells are observed to change with respect to season. The phenomena indicates mixing of shallow groundwater in the study area. Only Well Nos.3 &

26 have maintained Sodium chloride type throughout the year. This is due to the sea water interaction of nearby wells.

Piper Trilinear classification shows that four types of hydrochemical facies have been observed in the study area. The spatial distribution of these facies shows that the discharge area in pre monsoon is less than the post monsoon period. The US Salinity Laboratory classification indicated that most of the study area is under high salinity-low SAR (C3-S1) to very high salinity-medium SAR (C4-S2). It is also observed that the suitability of groundwater for irrigation purpose is changing with respect time.

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REFERENCES

1. Adaikala Jayaraj, A. (1990), Groundwater quality of Madras M.E.Thesis, Anna University
2. Das, A.B. et al (1989), ' Potability of waters of five districts of Arunachal Pradesh', Journal IWMA, pp 188-190.
3. Djaeni A. et al (1986), 'Hydrological investigation in the greater Jakartha area', Indonesia, Abstracts of 9th Saltwater intrusion Meeting Delft, The Netherlands pp. 26-29.
4. Govardhan, V. (1990), 'Groundwater pollution hazards to human life - A case study of Nalgonda district, Indian Journal on Environmental Protection,10.
5. Jain ,C.K.,.Bhatia KKS and T Vijay (1994)' Groundwater quality monitoring and evaluation in and around Kakinada, Andhra Pradesh, NIH Report, CS(AR)172.
6. Kakar Y.P.(1988), 'Groundwater Quality monitoring in India', Jalvigyan Sameeksha, a publication of High Level committee on Hydrology, Vol. III.No.1
7. Muralikrishna, KVSG and Sumalatha,V.(1992)' Groundwater quality in Kakinada', All India seminar on Groundwater Management in coastal areas, 5-6th June, 1992, Visakhapatnam.
8. Narayana, A.C. and Suresh G.C. (1989), Chemical quality of groundwater of Mangalore city, Karnataka, Indian Journal of Environmental Health, 31, 228-236.
9. Piper,A.M. (1953), ' A graphical procedure in the geochemical interpretation of water analysis, US.Geological Survey, Groundwater Note 12
10. Ramji Satyaji Rao, Y.(1992), ' Groundwater Hydrochemistry of Mylapore Temple Tank area - a case study, M.E. Thesis, Anna University.
11. Richards, L.A. (1954), 'Diagnosis and Improvement of saline and Alkali soil, U.S.Dept of Agriculture, Agriculture Hand book 60.

12.Salomonanurag (1987), 'Hydrochemistry of North Madras Coastal aquifers M.E.Thesis, Anna University.

13.Sikdar P.K., Sarkar, S.S and Dasgupta. S (1993), Compositional structure of groundwater in and around Gangajalgati, Bankura District, West Bengal, Ind.Jour Earth Sciences. Vol.20,No.1,pp.17-27 (12).

14.Sukhija B.S., V.N.Varma, P.Nagabhushanam, D V Reddy (1996).'Differential paleomarine and modern seawater intruded salinities in coastal groundwaters (of Karaikal and Tanjavur, India) based on inorganic chemistry, organic biomarker fingerprints and radiocarbon dating, Journal of Hydrology, Vol.174, pp.173-201.

15.WHO (1984), 'Guidelines for drinking water quality', Vol.1, Recommendations, World Health Organisation, Geneva, 1-130.

16.Wilcox,L.V. (1955), Classification and use of Irrigation water, U.S. Dept of Agricultural Circular 969.

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