ASSESSMENT OF POLLUTION DAMAGE DUE TO SOLAR EVAPORATION PONDS AT UCIL, BHOPAL

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Sponsor
Madhya Pradesh Pradushan Niwaran Mandal, Bhopal

National Environmental
Engineering Research Institute, Nagpur-440 020
APRIL 1990

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SPONSOR:
MADHYA PRADESH PRADUSHAN NIWARAN MANDAL, BHOPAL

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
NAGPUR - 440 020

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FOREWORD

M/s. Union Carbide India Limited were manufacturing carbaryl, a carbamate pesticide, at their Bhopal plant from 1977 to 1984. The plant stopped its production since December 1984 consequent to MIC gas episode. Acidic wastewater generated in the plant was neutralised and stored in three solar evaporation ponds(SEP) located about 800 m north of the plant. The major pollutants are chloride and sulphate of calcium and sodium with traces of organics.

The Government of Madhya Pradesh retained NEERI in 1989-90 to investigate the possible damage to land and water environment caused by waste disposal activities at SEP and to suggest decontamination procedures for pond contents and surrounding soil if necessary, before SEP area is used for establishing a proposed industry.

Investigations revealed that the land and water environment have not been contaminated due to the provision of flexible membrane liner in the pond and presence of low permeable plastic clay below SEP. The low levels of inorganics in ground water and soil near SEP and also the absence of contamination profile as measured by electrical resistivity substantiated the above findings. Inorganic salts are the main pollutants, and a material balance on the input of chloride and the chloride content remaining in pond water and sediments revealed that seepage had not occurred.

Treatment methods such as land farming, and water extraction of the sediment are not practicable due to large requirements for land and water. Containment of the sediments in a secure landfill is the preferred choice. Pond III can be converted into a secure landfill to contain the sediments and contaminated soil leaving 11 hectares of SEP area for reuse.

The cooperation and assistance rendered by Madhya Pradesh Pradushan Niwaran Mandal and UCIL management in the completion of this study are gratefully acknowledged.

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P.V.R. SUBRAHMANYAM

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SUMMARY

- M/s Union Carbide India Limited, were producing carbaryl, a carbamate pesticide, in their Bhopal plant between 1977 and 1984. The plant was closed since December 1984 consequent to MIC gas leak episode. During its operation acidic wastewater containing 15 to 20% HCl was generated and, after neutralisation, stored in three solar evaporation ponds (SEP) located 800 m north of the plant.

- The Government of Madhya Pradesh is considering to reclaim the land occupied by SEP covering an area of 14 hectares for estabilshing an industry as a part of rehabilitation programme for gas victims.

- As a consequence of the proposal, the Government of MP retained NEERI, Nagpur, to investigate the extent of contamination of soil and ground water near SEP and suggest decontamination of pond contents and contaminated soils and water.

- Studies carried out by NEERI include geological and hydrogeological settings, of the study area assessment of land and water quality around SEP and treatability of the pond sediments and soils.

- The Landsat Imagery of the area indicated distinct geological formations namely Deccan Trap and Vindhyan Sandstone overlain with Alluvium. SEP is located over Deccan Basalt, while the adjacent areas are over Vindhyan

Sandstone. Black cotton soil forms the top soil cover in the area.

* Ground water flow direction is from south to north in general, with an average velocity of 0.6 m/km in the area. Chola and Patra nallas flowing near UCIL act as influent during monsoon and as effluent in other seasons to the ground water. The depth to ground water varies from 2.9 to 14.2 m BGL in Basalt whereas it varies from 2.41 to 9.55 m BGL in Vindhyans.

* The study area falls under the climatic zone of dry subhumid region, temperature varying from 7°C (winter) to 43.3 °C (summer). The prevailing wind direction is north to northwest with a velocity of 4.3 to 13.2 kmph. The average annual rainfall is about 1000 mm. The net evaporation rate is 7.22 mm per day.

* Vertical electrical soundings (VES) conducted at 18 points within 2.5 km radius of SEP confirmed the presence of black cotton soil upto a depth of 2.0 m and presence of clay, mostly plastic in nature, with <u>kankar</u> below upto a depth of 20-30 m. Ground water is also obtained within 25 m BGL in an unconfined condition.

* Electrical resistivity profile (ERP) studies near SEP revealed that ground water flow is towards northeast as reported by Central Grouund Water Board (CGWB). Based on ERP data no contamination was observed around SEP except

for a small stretch within the fence west of Pond III near Piezometer 3, where very low resistivity vis a vis high electrical conductivity was recorded. Soil samples near Piezometer 3 also contained high concentration of salts which confirm the above observation and is possibly due to spillage/seepage from Pond III and/or Pond I

* In general crop yield in the study area is higher compared to the All India average values. Enquiries with farmers near SEP revealed that there is no substantial variation in the crop yield since 1979.

* The SEPs were provided with a flexible membrane liner (FML) at the bottom and sides to prevent seepage of the stored wastewater. Ponds I and II were generally used for storing the wastewater and Pond III whenever need arose. The depth of wastewater in the ponds was maintained around 2m.

* Wastewater samples from Pond I and II contained very high dissolved solids consisting of chloride and sulphate of calcium and sodium. The chloride concentration was as high as 214-260 g/l in Pond water samples collected in June 1989 indicating concentration of dissolved solids due to evaporation during storage. Heavy metals such as lead, cadmium and chromium were either present in very low concentration or below detection limits.

* Organic pollution in pond waters measured as COD (6100-7200 mg/l) was low compared to inorganics. The organics

are not readily biodegradable.

* HPLC analysis of pond waters, however, did not indicate the presence of carbaryl. Alpha naphthol, methylamine, chloroform and carbon tetrachloride were absent in pond water samples.

* Pond III water was less contaminated as chloride (9100 mg/l) and COD (161 mg/l) values were lower compared to Ponds I and II.

* Wastewater from Ponds I and II exerted acute toxicity to fish at 10% dilution and the toxicity was due to presence of inorganic salts in the wastewaters (20% TDS).

* Total dissolved salts in sediments from Ponds I and II ranged from 14 to 15% . Chloride and sulphate of calcium and sodium accounted for most part of the inorganics. Total organic carbon was 3.64 percent in Pond I sediment and the corresponding values for sediments from Ponds II and III were 2.08 and 0.37 percent, respectively. This data show that Pond III was not used to the same extent as Ponds I and II.

* Appreciable variation was observed in the chemical composition of the sediments from top and bottom layers. In bottom sediment layer, the chloride level was 41 percent of the value observed in the top layer and the corresponding value for organic carbon was 19 percent which indicate that the salts and organics from

wastewater were deposited mostly in the top portion of the sediment.

* Piezometers located on the periphery of SEP were dry during the study period except for a few days in September 1989. Chemical analysis of piezometer water samples indicated relatively higher chloride content in Piezometers (3,4 & 5). These are located to the west and north of Pond III. This observation coupled with the low resistivity values of the soil in this area and its chemical composition confirmed that the soil between Pond III embankment and fence on the west of SEP was contaminated. However, soils within a radius of 2.5 km from SEP, particularly where test bore wells are constructed, were not contaminated

* No change in the chemical quality of waters was observed in the Upper and Lower lakes and dug wells regularly monitored by CGWB during the period 1984-1989. Contamination of the lakes by SEP is not possible as the lakes are located at a higher elevation.

* Based on the geological setting around SEP, topography, hydrogeology, quality of water in the existing dug wells and electrical resistivity profiling studies, 11 test bore wells (TBW) within a radius of 2.5 km from SEP were constructed to monitor the subsurface water quality in the northeastern direction of SEP following the prevailing ground water flow direction and also in the

upgradient direction.

* In addition to the test bore wells, 82 wells which are in regular use and located within a radius of 10 km from SEP were selected for monitoring water quality

* In general, water from test bore wells had low calcium, sulphate and nitrate. Chloride in 10 out of 11 wells was less than 100 mg/l. Sodium was upto 150 mg/l Although slight variations were observed in the anions and cations in the TBW waters, they are well within the drinking water standards. Further no appreciable difference in water quality was observed in wells located in the SEP area.

* The absence of high chloride, calcium and sodium in all test bore wells (TBW) and tube wells (TW) located within a radius of 1.0 km from SEP clearly indicated no contamination from the impounded wastewater in the ponds.

* Very high chloride, calcium and sodium levels in waters from wells near ice factory, which is a t a distance of 1.1 km and SSE of SEP, were likely due to the reported use of calcium and sodium chlorides in the factory.

* A few TW and dug wells (DW) located close to Central Warehouse Corporation (CWC)contained high chloride. Investigation revealed that the activities of CWC and the use of the area close to CWC for municipal refuse disposal in the past are responsible for poor water

quality in the wells. Similarly high chloride in DW close to nallas is due to seepage from nallas. On the whole all the wells situated within 2.5 km radius of SEP did not indicate contamination from SEP.

* Similarly variation in cations and anion in the wells located within 5 and 10 km radius of SEP were due to local activities such as agriculture as could be seen from high nitrate in the well waters.

* The water quality in the TWB, TW and DW situated within 10 km radius from SEP clearly indicates that no contamination had taken place due to the waste disposal activities at SEP by UCIL factory.

* Estimates revealed that SEPs contain about 8850 m³ of impounded water and 26,200 m³ of sediment (18610 MT) containing very high levels of soluble salts of calcium and sodium as chloride and sulphate besides a little amount of organic matter.

* Toxicity characteristic leaching procedure (TCLP) test as prescribed by USEPA on sediment samples did not show heavy metals, carbaryl, chloroform and carbon tetrachloride to designate the sediments as hazardous. However as per the Hazardous Waste Management and Handling Rules of 1989, framed by GOI, the sediments fall under hazardous waste as these are derived from the manufacture of pesticide. In view of the above the

sediment samples require treatment or containment so that they will not cause present or future damage to the environemnt.

* Treatment of the sediment samples with water washing to remove dissolved salts would require 150,000-200,000 m^3 of water to reduce the chloride lefvel to that present in the soils around SEP. Resulting water extract requires treament/dilution to meet the regulatory requirements for disposal into the nearby nallas particularly for meeting TDS limits.

* Studies on land farming/treatment of the sediments indicated that normal soil physico-chemical and microbiological properties are affected when sediemnt concentration in soil was at one percent level. To keep the soil salinity around the existing value, an application rate of 5.6 MT sediment per hectare is needed. This method of treatment/disposal would need 3400 hectares of land only for the pond sediments.

* The total volume of sediment, residue resulting from evaporation of remaining pond wastewater and the contaminated soil near Pond III is estimated to be 31,100 m^3. Pond sediments, residue and contaminated soil should be excavated and disposed off in a secure landfill to contain it permanently either on a suitable off-site or in Pond III, the volume of which is adequate for containment.

- Methods of converting Pond III into a secure landfill have been out lined.
- Use of Pond III for containment of the sediments leaves nearly 11 hectares of SEP area for reclamation and reuse.
- The overall conclusion of the study is that no contamination of soils and ground water was observed due to the impoundment of wastewater in solar evaporation ponds. The pond contents are to be removed and contained in a secure landfill prior to establishment of an industry in the area occupied by SEP.

RECOMMENDATIONS

1. Wastewater in the ponds should be spread out within the ponds for enhancing the evaporation which helps in subsequent handling alongwith the sediments.
2. **Land farming/treatment** is recommended if 4000 hectares of land is available as it would provide a one time solution without creating pollution problems. This treatment should be done under supervision by regulatory agency to prevent dumping the material in heaps.
3. Alternately, the sediment, residue and contaminated soil should be exacavated and contained in a **Secure Landfill** either on a site specified by regulatory agency or in Pond III. The landfill site should not be used for any activity at present or in future and should be under surveillance by regulatory agency.

1.0 INTRODUCTION

1.1 PREAMBLE

M/s Union Carbide India Limited (UCIL) were operating a pesticide plant at Bhopal producing carbaryl (Sevin) from 1977 to 1984. The plant consisted of various sections producing intermediates and other chemicals required in the manufacture. Solvents and other ingredients were also used during the manufacture and pesticide formulation activities. The acidic wastewater generated during manufacture of methyl isocyanate, an intermediate in the manufacture of Sevin, was neutralised with limestone before pumping into the solar evaporation ponds (SEP). The ponds were not receiving the wastewater since the closure of the plant in December 1984. The ponds are located about 800 m north of the plant across the Bhopal-Indore railway line.

The Government of Madhya Pradesh is considering to utilize the area occupied by the solar evaporation ponds for setting up an industrial complex as a part of rehabilitation programme for gas victims. NEERI was requested by the Government of M.P. to investigate the possible impacts due to past waste disposal at SEP on the land and water environments in the surrounding area and to recommend remedial actions for decontaminating the pond contents and the surrounding area if required.

1.2 PROJECT SETTING

Bhopal, the capital city of the state of Madhya Pradesh lies between 77°23' and 77°25' latitude, and 23° 15' and 23° 17' longitude and spreads over an area of 190 sq km within the municipal limits. The population of the city was 6.71 lakhs as per 1981 census and is estimated to be around 9 lakhs at present. The city is surrounded by hills and has a rolling terrain. There are two lakes within the city - the upper and the lower lakes. The upper lake is formed by impounding water from Kolan river by a massive earthen bund which also links the old city with the developing new colonies. Upper lake serves as the main source of water supply to the city.

There were no major industries located within the city limits except a straw board mill, a textile mill and a forging unit till the establishment of the UCIL. All these industries are located in the old city. Union Carbide India Limited established the pesticide manufacturing unit at Bhopal about 1.5 km NW of Bhopal railway station. However, the major industrial unit in the vicinity of the city of Bhopal include Bharat Heavy Electricals Limited about 12 km on the east and the industrial estate at Mandideep about 20 km on the south.

M/s. Union Carbide India Limited (UCIL) were manufacturing carbaryl (Sevin), a carbamate class of pesticide, using methyl isocyanate (MIC) and alpha naphthol from 1977 to 1984 at their Bhopal unit. In the initial stages (1977-79) the factory was importing MIC till its manufacturing unit established in the plant premises became operational in early 1980. The installed capacity of the plant was to produce 5000 MT per annum of carbaryl. The plant has not been functioning since December 1984 after MIC gas leakage tragedy.

The plant, spread over an area of 30 hectares, is bounded by Bhopal-Indore railway line on the north, Chola nalla on the south, Vidisha road on the east and Berasia road on the west. Solar evaporation ponds (SEP) used for storing the neutralised wastewater from the plant are located across the Bhopal-Indore railway line on the north. The location of the plant and the SEP are shown in Figure 1.1 and Plate 1 1.

1.3 SCOPE OF THE STUDY

The scope of the study is to characterise the pond sediment and water, to assess the contamination of ground water and soil around SEP and to suggest decontamination methods for reclaiming the area for establishing an industrial complex.

1.4 METHODOLOGIES FOR STUDY

I. Collection of general information relating to

- Past waste disposal activity
- Physico-chemical and hydrogeological aspects of the study area

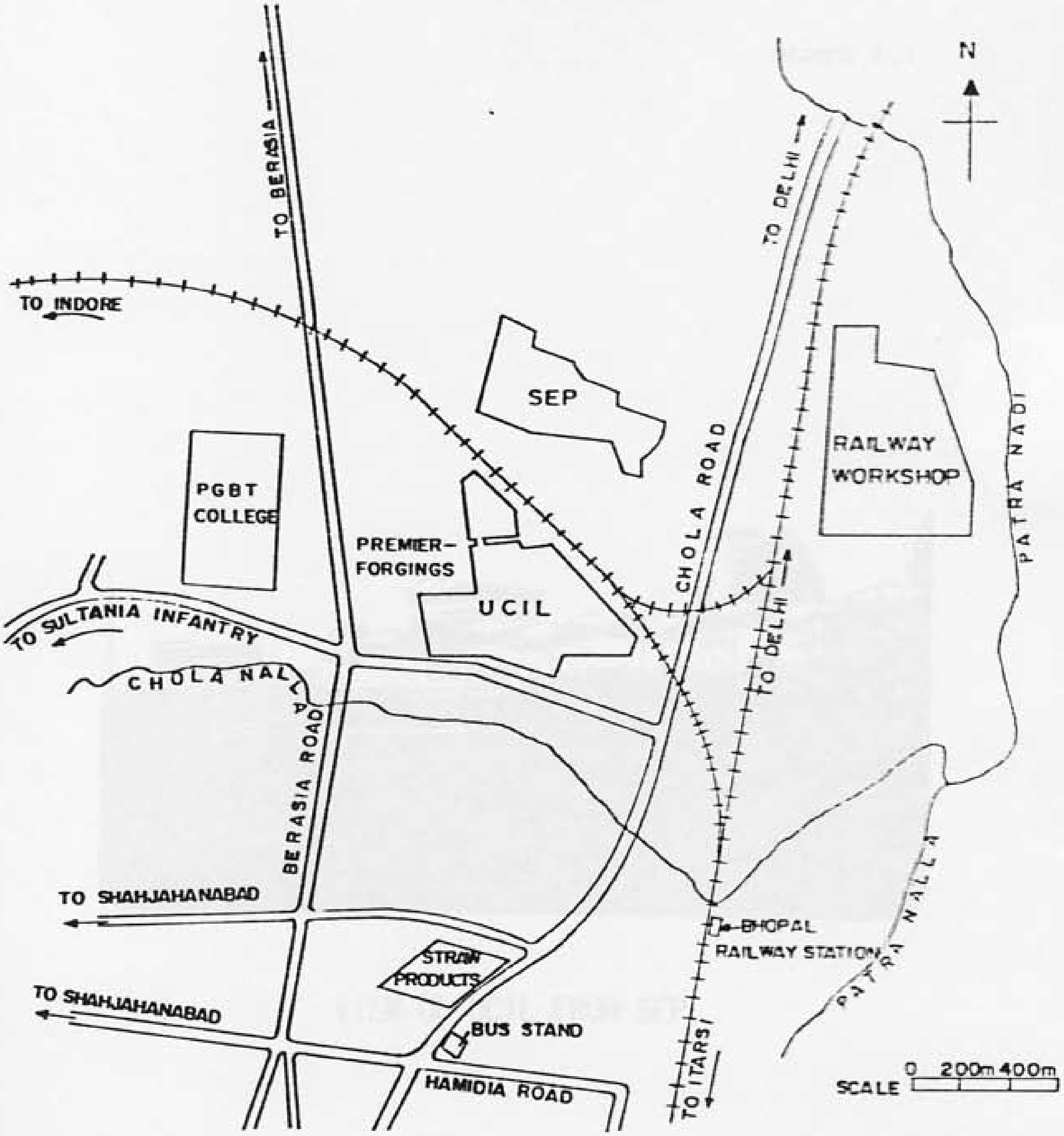
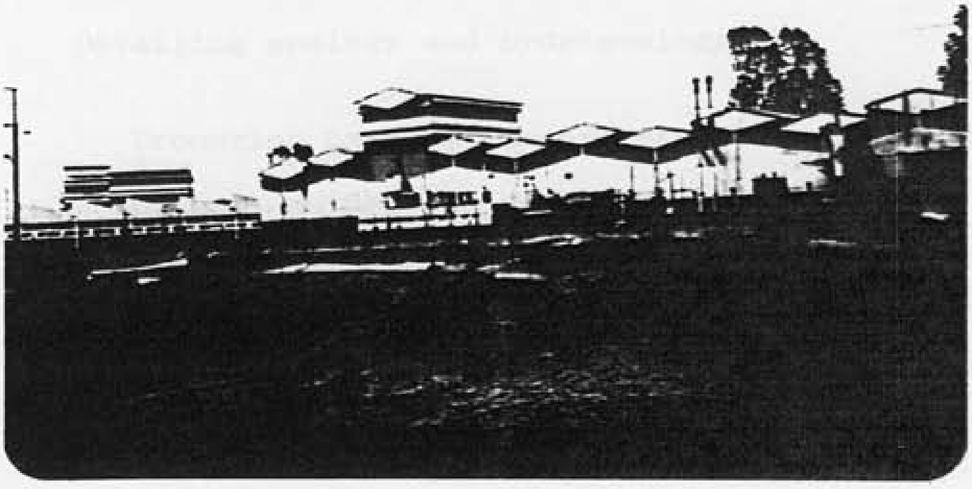


FIG. 1·1 LOCATION OF UCIL, BHOPAL

PLATE 1.1



VIEW OF UCIL FROM SEP

II. Characterisation of pond water and sediment

- Collection of sediment samples above liners at different locations from each pond
- Analysis of the individual and composite sediment samples collected from different depths
- Collection of pond water from each pond and analysis besides recording water level and water spread area in each pond at the time of sampling

III. Detailing geology and hydrogeology

- Procuring Landsat imagery maps from Madhya Pradesh Council on Science and Technology (MAPCOST)
- Collecting ground water contour maps. from Central Ground Water Board (CGWB) to design monitoring test bore wells
- Conducting vertical electrical surroundings (VES) to define the soil texture
- Conducting soil resistivity profile tests around SEP to determine the ground water flow direction and to locate any contamination profile

IV. Assessment of potential ground water contamination

- Designing of network of monitoring wells
- Construction of test bore wells

V. Assessment of potential soil contamination

- Collecting and analysing soil samples around SEP
- Analysing the soil samples from test bore wells

VI. Remedial action

- Conducting probing studies on the treatment of sediments and pond water samples for suggesting suitable treatment and/or disposal methods

1.5 MANUFACTURING PROCESS

Methyl isocyanate (MIC), an intermediate in the production of carbaryl, is synthesised from phosgene ($COCl_2$) and monomethyl amine (CH_3NH_2). The process is carried out with equimolar ratios of phosgene to amine or even with an excess of phosgene in a solution of chloroform.

The reaction of phosgene with monomethyl amine in vapour phase leads to the formation of methyl carbamoyl chloride (MCC).

$$CH_3NH_2 + COCl_2 \text{ -----> } CH_3NHCOCl + HCl. \quad \text{(i)}$$

The reaction products are quenched in chloroform and then fed to phosgene stripping still to remove the unreacted phosgene for recycle. The bottoms from the stripper are fed to a pyrolyser where MCC is broken to MIC and HCl which are further separated. The pyrolyser condenser feeds the MIC refining still (MRS) where MIC is separated from the chloroform in the upper part and is led directly into a storage tanker. The bottoms of MRS are recycled to the process. The HCl formed is scrubbed with chloroform and extracted with water to produce aqueous HCl which is disposed off by neutralisation in a lime pit.

The overall reaction is as follows:

$$CH_3NH_2 + COCl_2 \text{ -----> } CH_3N{=}C{=}O + 2HCl \qquad \text{(ii)}$$

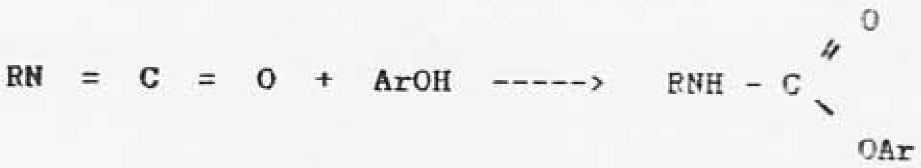
Phosgene required for MIC synthesis is prepared from carbon monoxide, obtained by passing air over red hot coke in a controlled manner and then reacting with chlorine gas.

$$2C + O_2 \text{ ------> } 2CO$$

$$CO + Cl_2 \text{ ------> } COCl_2$$

Carbaryl is manufactured by the reaction of slight excess of alpha naphthol with MIC in the following manner:

i)



$$RN = C = O + ArOH \text{ -----> } RNH - C\overset{O}{\underset{OAr}{\Big\langle}}$$

Carbaryl

Isocyanate is gradually added upon stirring to an excess of alpha naphthol in carbon tetrachloride solvent at 60-80°C in presence of a catalyst. The reaction is exothermic. The yield of product is more than 95% . Data on the production of Sevin and MIC from 1977-84 are presented in Table 1.1.

TABLE 1.1 : PRODUCTION OF SEVIN AND MIC AT UCIL, BHOPAL

(MT/year)

Year	Sevin	MIC
1977	321	--
1978	367	--
1979	1468	--
1980	1534	374
1981	2658	864
1982	2271	623
1983	1727	535
1984	1101	313
TOTAL	**11447**	**2709**

Data Provided by M/s. UCIL, Bhopal

1.6 SOURCES OF WASTEWATER

The wastewater streams in the plant are classified as under:

- acid waste
- process sewer waste
- sanitary waste
- sullage

Acid Waste : The major source of wastewater was from MIC manufacturing unit which contains 15-20 % hydrochloric acid. The wastewater was taken to a neutralisation pit where it was introduced at the bottom and allowed to flow upward through a bed of limestone. The neutralised wastewater was subsequently mixed with the overflow of process sewer alkaline wastewater before being pumped to the solar evaporation ponds (SEP). Based on mass balance, one mole of MIC produces two moles of hydrochloric acid equivalent to 1.28 MT of 100 percent HCl per MT of MIC. From the production data given in Table 1.1 for MIC, it was computed that about 3479 MT of HCl should have been generated during 1980 to 1984. As the concentration of HCl in the wastewater was reported to be of the order of 15 to 20%, the volume of acid wastewater generated must have been in the range of 17,340 to 23,120 m^3 during the operation of the plant. Actual data on the volume of wastewater generated and its characteristics could not be ascertained from UCIL as all their records were sealed by the investigating agency after the gas leak incident.

Process Sewer Waste: All other non acidic process wastewaters alongwith floor and equipment washings were collected in tubs provided in all units within battery limits. These wastes were routed to skimmer pits where oil was skimmed off periodically and incinerated. The lower aqueous layer being alkaline was carried through the process sewer and pumped into the overflow compartment of the neutralisation pit for secondary neutralisation of acidic wastewater. Data on the volume of the wastewater were not available.

Sanitary Waste : The wastewater from toilets was taken through septic tanks and the overflow was disposed off in soakage pits within the factory premises and any overflow joined the open surface drains leading to Patra nalla.

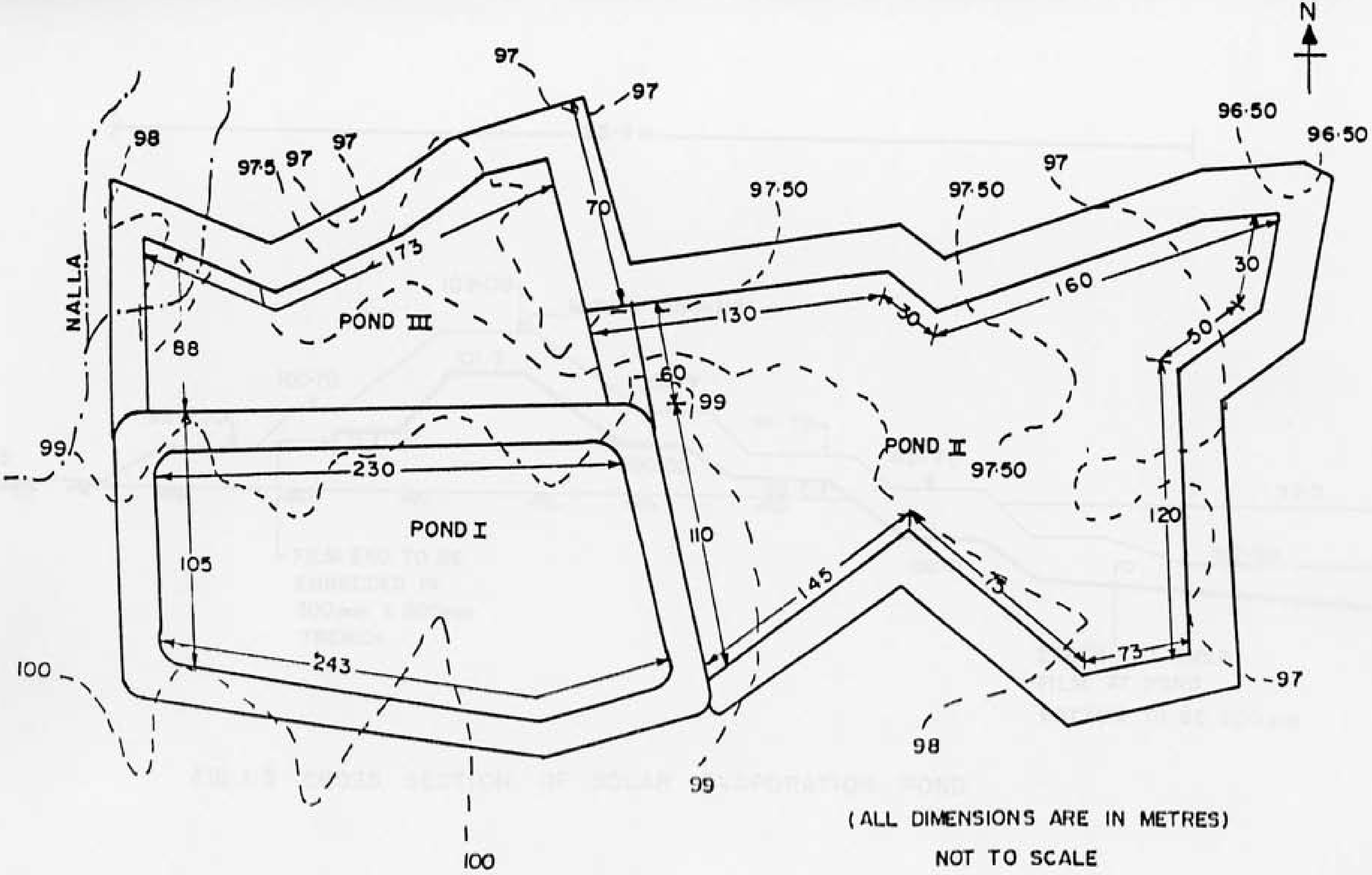
Sullage : All other wastewaters consisting of sullage, filter backwash water, steam condensates, boiler blow downs, and floor washings from non-process unit areas were taken through stormwater drain and discharged into Chola nalla flowing south of the plant.

1.7 TREATMENT AND DISPOSAL UNITS

Skimmer Pits: The skimmer pits have a total hold up capacity of 125 m³. The pit consists of a concrete basin with baffles where the organic matter lighter than water rises to the top and was skimmed off periodically into a sump. The aqueous alkaline layer was pumped to the overflow compartment of the neutralisation pits as already indicated.

Neutralisation Pits : These are tanks made of concrete and lined with acid-alkali resistant bricks and tiles. There are two pits each having two compartments, viz primary for reaction and secondary for collection. In the reaction compartment, the acidic waste was allowed to flow upwards through a bed of limestone and the neutralised waste overflowed into the second compartment where it was mixed with the alkaline waste from the skimmer pits. The total liquid holdup capacity of each pit is 60 m^3.

Solar Evaporation Ponds (SEP) : There are three solar evaporation ponds covering an area of 14 hectares. The plan and cross sectional details of the ponds are given in Fig.1.2 and 1.3, respectively. These ponds were built by taking out 20 cm of top soil and constructing bunds by using the excavated soil and also soil obtained from nearby area. A special grade low density black polyethylene sheet as liner was laid on all sides including bottom of the ponds to prevent any seepage of liquid from the ponds. The ends of the sheets were thermally sealed. Clay was spread over the top of the liner to a thickness of 20 cm for effective retention of the liner in position as well as additional barrier for seepage. The depth of the ponds when built ranged from 3.3 to 5.6 m from top upto the liner. It was reported that a maximum water depth of about 2 m was provided during their operation leaving a free board of about 1.3 to 3.6 m.



(ALL DIMENSIONS ARE IN METRES)

NOT TO SCALE

FIG. 1·2. DETAILED PLAN OF SOLAR EVAPORATION PONDS

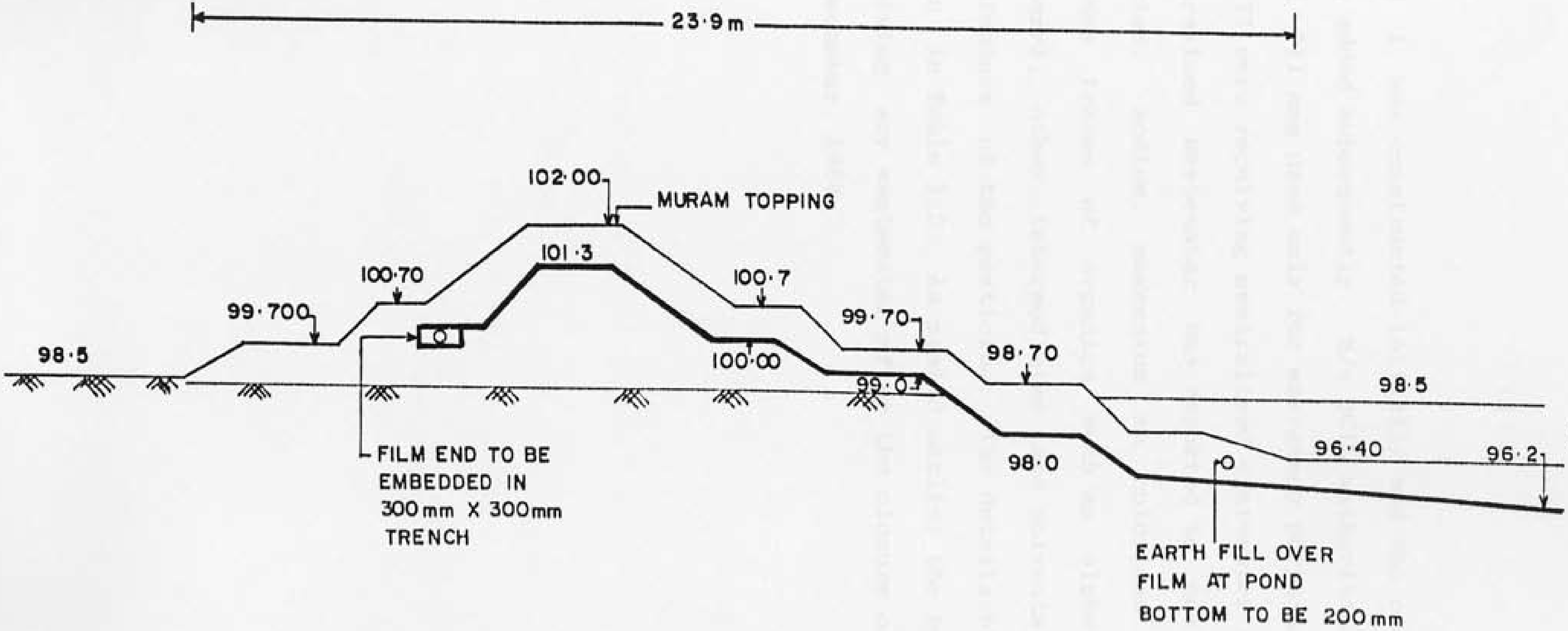


FIG 1·3 CROSS SECTION OF SOLAR EVAPORATION POND

Pond I was constructed initially and the other two ponds were added subsequently. M/s UCIL authorities reported that Pond III was used only for emergency purposes while ponds I and II were receiving neutralised wastewater regularly. The neutralised wastewater was reported to contain salts of calcium, sodium, magnesium as chlorides and sulphates besides traces of organics such as alpha naphthol and carbaryl, other intermediates and solvents used in the manufacture of the pesticide. The details of the ponds are given in Table 1.2. As stated earlier the ponds were not receiving any wastewater after the closure of UCIL factory in December, 1984.

TABLE 1.2 : DETAILS OF SOLAR EVAPORATION PONDS

	Pond Nos.		
	I	II	III
Hold up capacity (m^3)	116,800	155,180	45,000
Pond depth (m)	5.5	5.6	3.3
Total pond area	14 hectares		

Specifications of Liner used:

. Melt Index (ASTM D1238)	.. 0.25 - 0.45 dg/min
. Density (ASTM D1505)	.. 0.926 - 0.940 g/ml
. Carbon content (ASTM D1603)	.. 2.5 ±0.5%
. Volatiles (ASTM D1203)	.. < 0 1%
. Ash content	.. < 20 ppm
. Molecular weight	.. 20000 - 35000
. Tensile strength(ASTM D882)	. 1500 - 3000 psi
. Elongation (ASTM D882)	.. 100 - 700 %
. Tensile elastic modulus (ASTM D1004)	.. 0.14 - 0.38 x 10^5 psi
. Hardness (ASTM D1004)	.. R 10
. Tear strength (ASTM D1004)	.. 65-575 lbs/mil
. Tear strength (Propagation ASTM D1922)	.. 100 - 500 lbs/mil
. Water vapour permeability (ASTM E-96)	.. 0.512 g/m^2. 24 hrs @ 25 °C

(As furnished by M/s. UCIL , Bhopal)

2.0 GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

2.1 INTRODUCTION

Migration of pollutants from SEP to ground water mainly depends on the geological and hydrogeological features of the area. Hence a detailed investigation on the geology and hydrogeology of the area was carried out covering an area of 10 km radius from SEP. Necessary information was collected from MAPCOST, Geological Survey of India (GSI), Central Ground Water Board (CGWB) and MP State Ground Water Board at Bhopal.

2.2 GEOLOGY

The geological features of the study area as recorded by Landsat Thematic Imagery, are shown in Figure 2.1. The imagery indicates that the study area, in a broader perspective, is underlain by three distinct rock formations, viz.

i. Alluvium / colluvium (Recent times)	Clay mixed with gravel of basalt or sandstone
ii. Upper Deccan Traps (Cretaceo - Eocene age)	Alternate flows of hard,compact, fine grained and vesicular basalt together with red boles and intertrappean beds
iii. Upper Vindhyans (Pre-Cambrian age)	Sandstone becoming quartzitic at places, flagstone and shale

In addition to these, Recent unconsolidated deposits (alluvium/colluvium) overlie all these deposits, with or

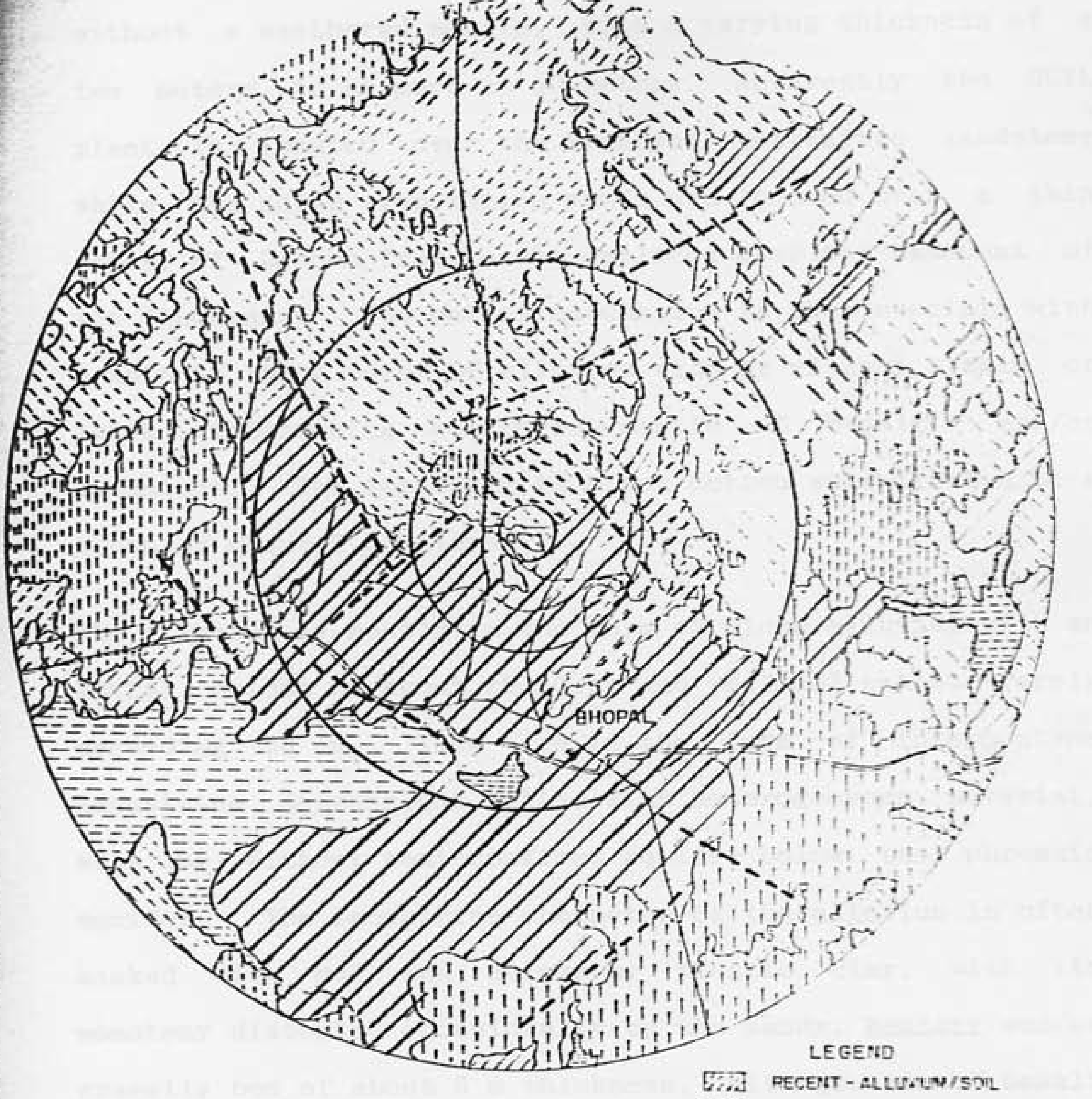


FIG. 2-1 GEOLOGICAL MAP OF STUDY AREA

without a weathered mantle, with a varying thickness of a few meters to as much as 60 meters. Apparently the UCIL plant is located over the Vindhyan quartzitic sandstone while the solar evaporation ponds are located over a thin cover of Deccan Trap basalt emplaced over the basement of the Vindhyans. The entire succession is then overlain with a thin to thick cover of alluvium with or without a thin or thick intervening weathered mantle of basalt and/or sandstone. The top layer is black cotton soil limited to a depth of about 2.5 meters.

The alluvium is mostly in the form of micro-alluvium with an aerial extent of about 25 sq.km and vertical extent rarely exceeding 30 m. They are in the form of intermontane lacustrine depressions filled with heterogeneous material, with or without semi-confined aquifer below the phreatic aquifer. The lacustrine character of the alluvium is often masked with mud and sticky or plastic clay, with its monotony disturbed occasionally by the sandy, kankary and/or gravelly bed of about 6 m thickness, with gravels of basalt or Vindhyan sandstone.

Over the geological setting came to be established a newer topography of Recent times immediately after the great episode of glacial/pluvial activity in Pleistocene times, when the depressions were occupied by lakes. Earlier sediments were derived mostly from the Vindhyan sandstone. With the activity of the Pleistocene times the lakes were partly silted and shallowed and occupied more extensive area, with the source of sediments derived from the Deccan Trap basalts. With this, the clay base became typically black with all attributes of stickiness and plasticity, enclosing eroded pieces of basalt. In very Recent times, lime got segregated below the soil cover to give rise to gravels of kankar in the Older Alluvium to occur along with those of basalt. This thick black clay of the Older Alluvium along with the cover of black soil occurring underneath the SEP is of particular significance, as it forms a fool-proof seal of impermeable natural blanket.

It is, therefore, apparent that the Vindhyan basement is covered by a fairly thick alluvium of about 30 m below a thin soil cover of about a meter as evident from the lithology of the operating tube wells in the UCIL area.

Lineaments in the area are primarily aligned in i) NW-SE, ii) ENE-WSW, iii) E-W or WNW-ESE and iv) NNW-SSE directions as shown in Fig.2.1 and they are very much responsible for controlling the direction of flow of both Chola nalla and Patra nalla in the area.

Except for these lineaments along with a ubiquitous horizontal bedding joint, the Vindhyan basement is a compact formation with a set of joints and fractures underneath the alluvium extending to another 20 to 30 m or more in depth.

Deccan trap occurs as one or more flows, which are generally thinner along the fringes. They are in the form of Simple flows with always vesicular/zeolitic unit towards the top.

Black cotton soil which forms the top soil cover in the area, is light along the fringes and forms a typical product of weathering from the basic rocks of the type of Deccan Trap. They are sticky and due to shrinkage develop deep cracks in summer. They are generally classified as montmorillonite type of clays.

There are thus three important geological formations with Vindhyan quartzitic sandstone serving as the apparent basement of the Bhopal area. Over this, were emplaced in successive spells the Deccan basalts of Simple type in this fringe area, and over the weathered topography were deposited first yellow clay of Vindhyan origin and later black clay of basaltic origin interspersed with gravels of identical formation with or without <u>kankar</u>. The whole succession is then masked with a thin layer of black cotton soil, with clays and soil being the products of very Recent date.

2.3 HYDROGEOLOGY

The high ground, with an altitude of about 505.75 m in the west, has a gentle gradient of about 1 in 200 to 1 in 450 towards east and eastsoutheast. The overflow from the Lower lake in the heart of Bhopal city gives rise to Patra nalla in the south, which continues to flow northerly. Chola nalla originating about 5 km west of the UCIL plant flows eastsoutheasterly along the southern boundary of the UCIL plant. The two nallas join about 2 km east of UCIL plant and flow northwards as Patra Nadi which finally joins Halali river, a tributary to river Betwa.

The study area is located in the southern part of the Betwa river basin. The altitude of the water table ranges from 485-500 m. Ground water flows towards the Betwa river following the surface drainage of the basin. Locally, the flow of ground water is towards nalla courses and regionally from south to north with an average gradient of 0.62 m/km. The depth to water in most of the dug wells in the study region is within the range of 3 to 9 m below ground level (BGL). Both Chola and Patra nallas are influent after the setting of monsoon to recharge the water table body of the area, but with the recession of monsoon the nallas become effluent to get recharged from the water table.

The depth to water level varies from 2.93 to 14.18m BGL in basalts, whereas in Vindhyans, it varies from 2.41 to 9 55 m BGL. The water table is nearest to the land surface towards the end of August but starts receeding from October end to reach the lowest level in June.

Two types of aquifers are encountered in the study area, viz. i) Shallow (Unconfined) and ii) Deep (Semi confined to Confined).

2.3.1 Shallow aquifers (Unconfined)

Aquifer, occurring above the first confining layer of massive basalt, normally encountered about a few meters to about 30 m BGL is considered as phreatic or unconfined aquifer. It comprises black or yellow clay (2-4 m) followed by weathered (3-10 m) and jointed basalt (>10m). Massive basalt in most of the cases forms the impermeable base of the shallow aquifer. Vindhyan sandstones also form weathered mantle as seen in the unlined well sections east of the Bhopal-Delhi railway line. However, occasional moderate yields are reported because of joints and location of the wells along the convergence of flow lines. In all older formations of the Purana group of hard rocks, shallow groundwater occurs in thick weathered and fractured profiles with larger potential in the area apparently forming part of a hydraulic trough.

2.3.2 Deep aquifers (Semi-confined to confined)

Aquifers occurring below the first confining layer of upper massive basalt are considered as relatively deeper aquifers, and they occur under semi-confined to confined condition, depending upon their relation with the water table body. When the deeper aquifer body is partly in contact with the phreatic body, the aquifer is said to be semi-confined which may be due to interconnection through joints, fractures, etc. With lack of interconnection in the immediate vicinity the aquifer body becomes confined.

Water table data from a large number of dug wells and hand pumps located within 3 km of the solar evaporation ponds have been collected. The data facilitated close comparison of ground water depth contours with those already drawn in the area by agencies like Central and State Groundwater Boards. Based on the information collected and through physical, investigation of the area, groundwater flowlines were drawn. The water table contours and flowlines are shown in Figure 2.2. It can be interpreted from Figure 2.2 that the phreatic surface has a gentle hydraulic gradient towards east and/or east-south-east towards Chola and Patra nallas. However, general gradient in the area is northerly to north-easterly.

Here, while the depth of water level varies from 2 5 to 14.0 m BGL the altitude of the water table ranges from 485-500 m with a gentle northerly gradient of 0.6 m/km. The ground water occurs mostly under phreatic condition with only occasional tendency to semi-confined condition. In this area both the wells and hand pumps are capable of yielding higher potential; but due to lack of development and lack of penetration in the coarser, gravelly, pebbly or weathered mantle discharges are poor to problematic due to a persistent blanket of yellow/black clay. So also the quality of water is good, or at best of calcium-bicarbonate type, when extraneous influence is lacking.

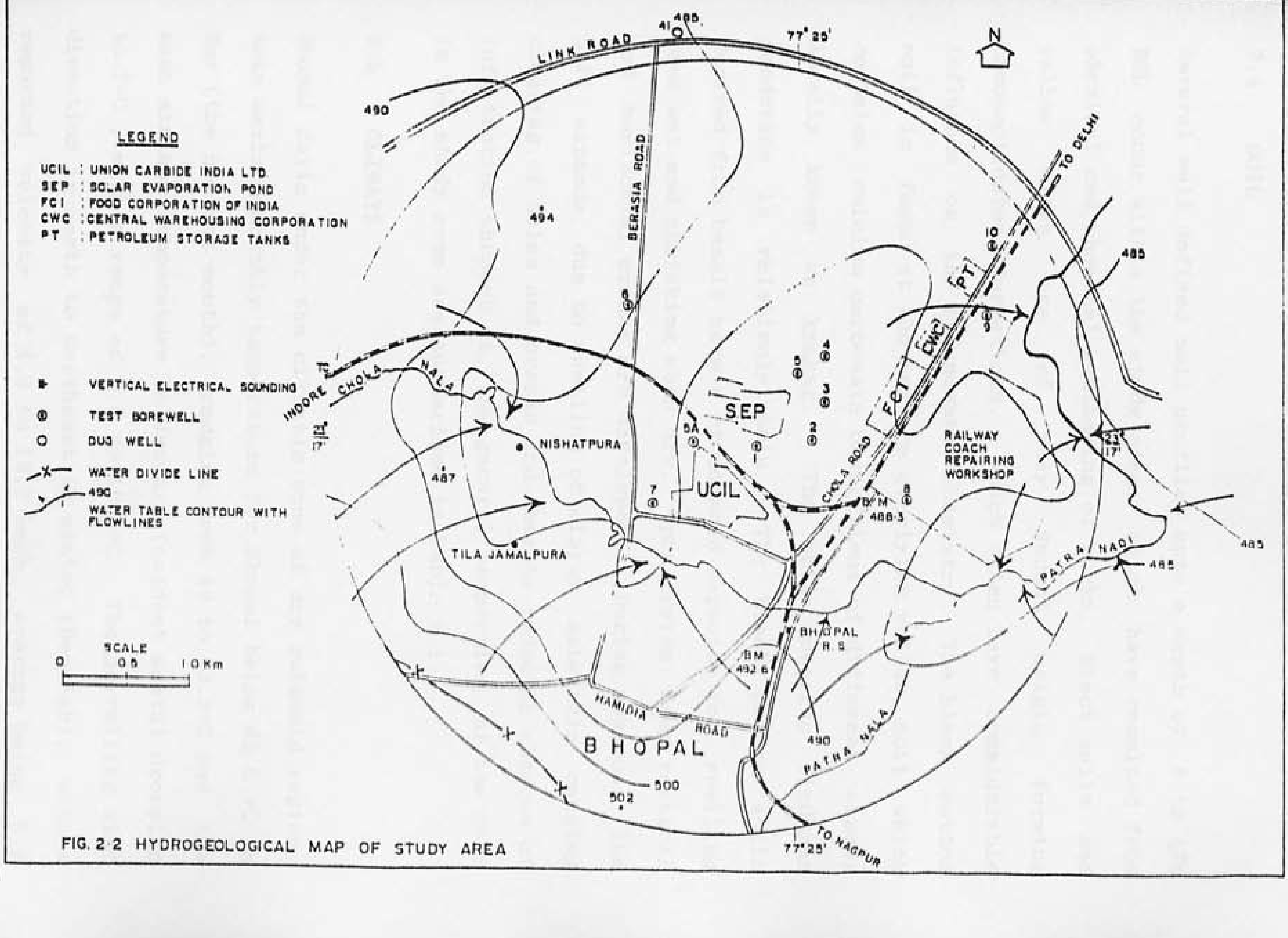


FIG. 2.2 HYDROGEOLOGICAL MAP OF STUDY AREA

2.4 SOIL

Several well defined soil profiles upto a depth of 5 to 12m BGL occur within the study area, which have resulted from physical and chemical weathering of rocks. Black soils and yellow clays are of very Recent origin forming unconsolidated formations, which often have considerable influence on the groundwater chemistry. The black cotton soil is found at the surface overlying yellow soil which contains calcium carbonate concretions of different sizes, locally known as <u>kankar</u>. The soil covering Vindhyan sandstone is relatively thin. The black cotton soils derived from basalt have a pronounced capacity for swelling when wet and shrinking when dry. Upon drying, deep vertical and horizontal cracks are developed. During monsoon, the soil expands due to swelling of clayey materials causing clogging of holes and cracks and thereby reducing chances of infiltration through it. The general properties of the soil in the study area are summarised in Table 2.1.

2.5 CLIMATE

Bhopal falls under the climatic zone of dry subhumid region, mean maximum monthly temperature for Bhopal being 42.8 °C in May (the hottest month), ranging from 40 to 43.3°C and the mean minimum temperature in January (coldest month) dropping to 7°C , with a range of 3.8 to 10.4°C. The prevailing wind direction is north to northeast in winter (Dec-Feb), with a reported velocity of 4.3 to 13.2 kmph, average being 8.3

TABLE 2.1 : SOIL PROPERTIES OF STUDY AREA

Bulk density	1.53 g/cc
Specific gravity	2.57
Total porosity	41.9%
Hydraulic conductivity (wet)	< 1.0 mm/hr
Percolation rate	0.3 mm
Water holding capacity	37.0 %
Void ratio	0.69
Safe bearing capacity	11.0 MT/m^2
Liquid limit	48.6%
Plastic limit	23.9%
Clay	54.7%
Silt	30.5%
Fine sand	13.0%
Coarse sand	1.8%
Calcium carbonate	2.83%
Organic carbon	0.48%
Cation exchange capacity	49.2 meq/100 g
Predominant clay mineral	Montmorillonite

Source: Data obtained from Institute of Agriculture Engineering (ICAR), Bhopal, 1989 kmph. In summer (March - May) and monsoon (June - Sep) seasons the prevailing wind directions are westnorthwest (WNW) and west (W) respectively. The evaporation rate varies from 3.5-16.7 mm/d with an average of 7.2 mm/d.

3.0 GEOPHYSICAL METHODS FOR INVESTIGATION

3.1 INTRODUCTION

The geological and hydrogeological features presented in the previous chapter were mainly based on the Landsat Imagery and information collected from State and Central Ground Water Boards located at Bhopal. The information provides general features of the study area but does not necessarily detail the area around SEP. In order to confirm the findings in SEP area, further investigation was necessary. Geophysical methods, which are indirect, are reported to be successful in exploration work and are cost effective Among the available geophysical methods, electrical resistivity measurement was selected as it meets the objectives. Electrical resistivity (ER) studies are mainly carried out to define the texture of the formation through soundings, and to determine ground water direction and contamination through resistivity profiling.

3.2 VERTICAL ELECTRICAL SOUNDINGS

The Landsat Imagery map (Fig 2.1) does not show details of the actual alluvium present in the area and also the minor variations in geological settings in SEP areas. Earlier studies carried out by GSI indicated the presence of alluvium over Deccan basalt and Vindhyan sandstone in Bhopal. In order to obtain actual texture of the formation near SEP area, vertical electrical soundings (VES) were conducted at 18 locations.

The soundings measure the resistivity of the formation. The method employs an artificial source of current which is introduced into the ground through point electrodes or long line contacts. The procedure then is to measure potentials at other electrodes placed in the vicinity of the current flow, which enables to determine an effective apparent resistivity of the subsurface. Various types of electrode configurations are employed of which Wenner and Schlumberger arrangements are common. The procedures adopted in this study are given in Annexure I. Schlumberger configuration was employed in this study to obtain subsurface geology at 18 points. Most of the VES points were located near SEP in all directions except for two, which were about 2 km from SEP in eastern and northeastern directions. The location of VES points are shown in Figures 3.1 & 3.1A.

In general the initial apparent resistivity varying from 3.5 to 5 ohm-m dipped down to about 2.0 to 2.5 ohm-m and then rose to the original value and increased upto 20-30 ohm-m. The resistivity almost became infinity as the depth increased. The apparent resistivity findings were plotted on semi-log paper and compared with sets of standard curves to obtain actual resistivity values which are shown in Figure 3.2. The actual resistiviy and depth for each VES point obtained from standard curves are presented in Table 3.1. Based on this, lithologs were prepared and are shown in

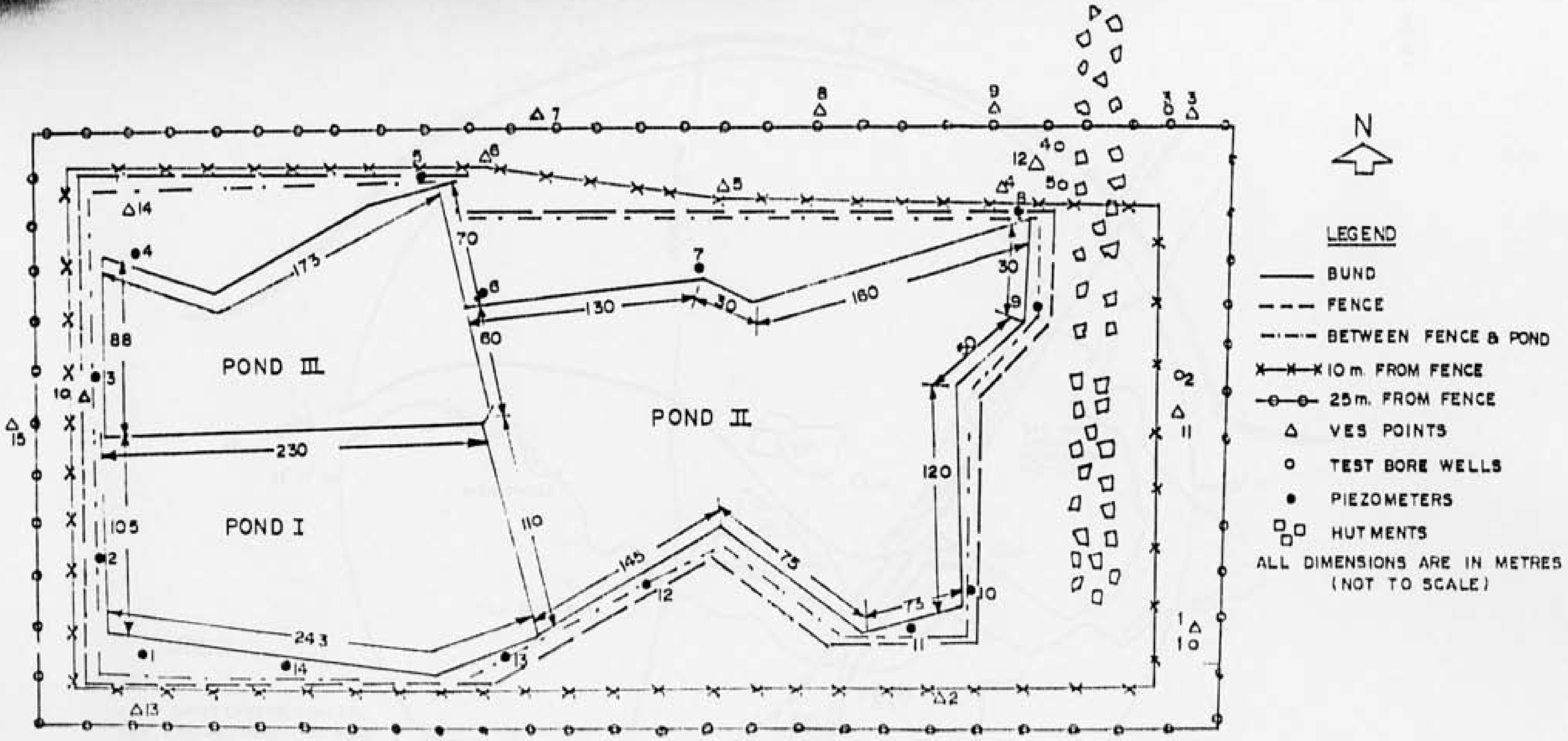


FIG. 3·1 LOCATION OF POINTS FOR VES AND ER MEASUREMENTS

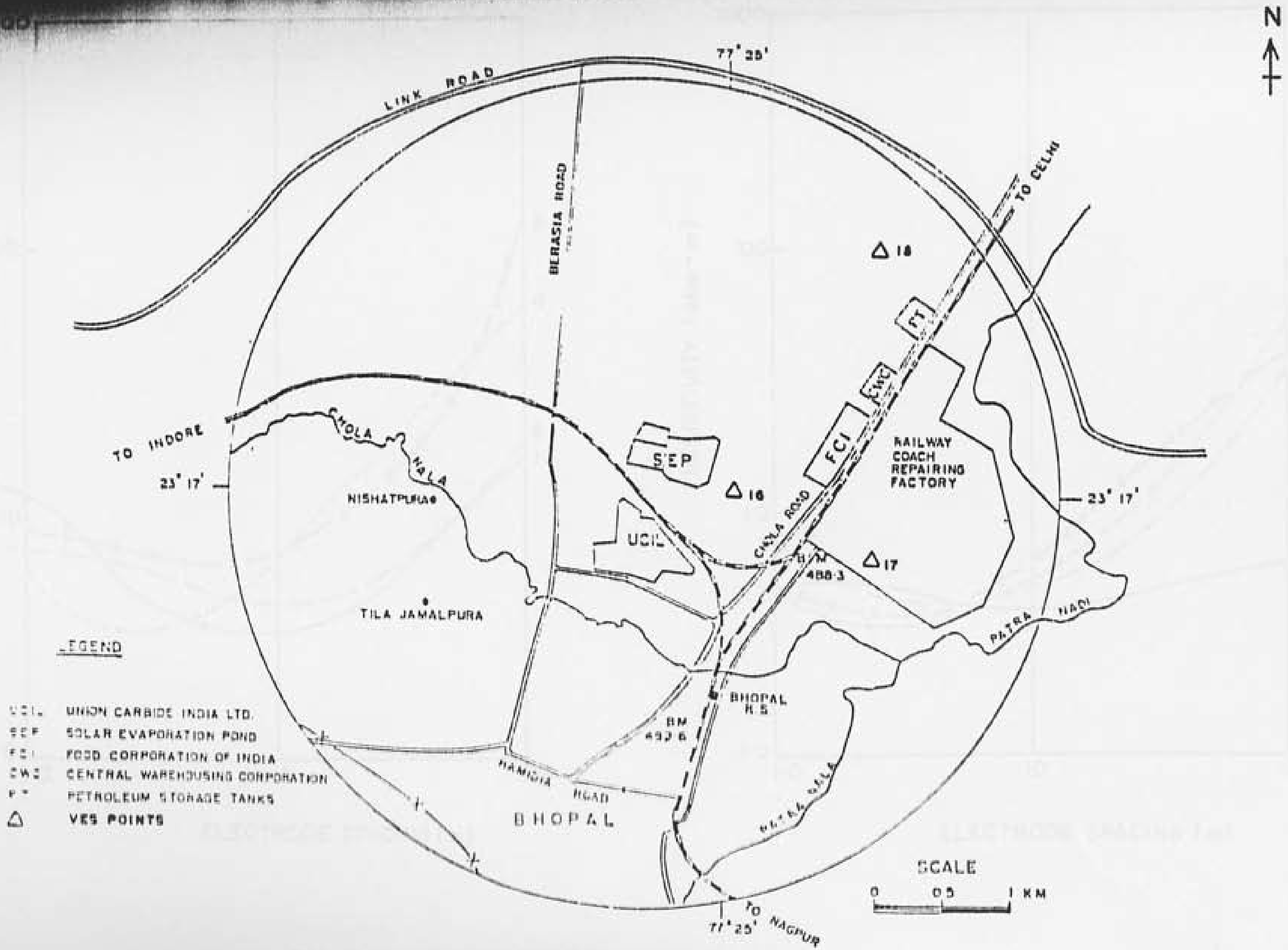


FIG. 3·1A LOCATION OF VES POINTS

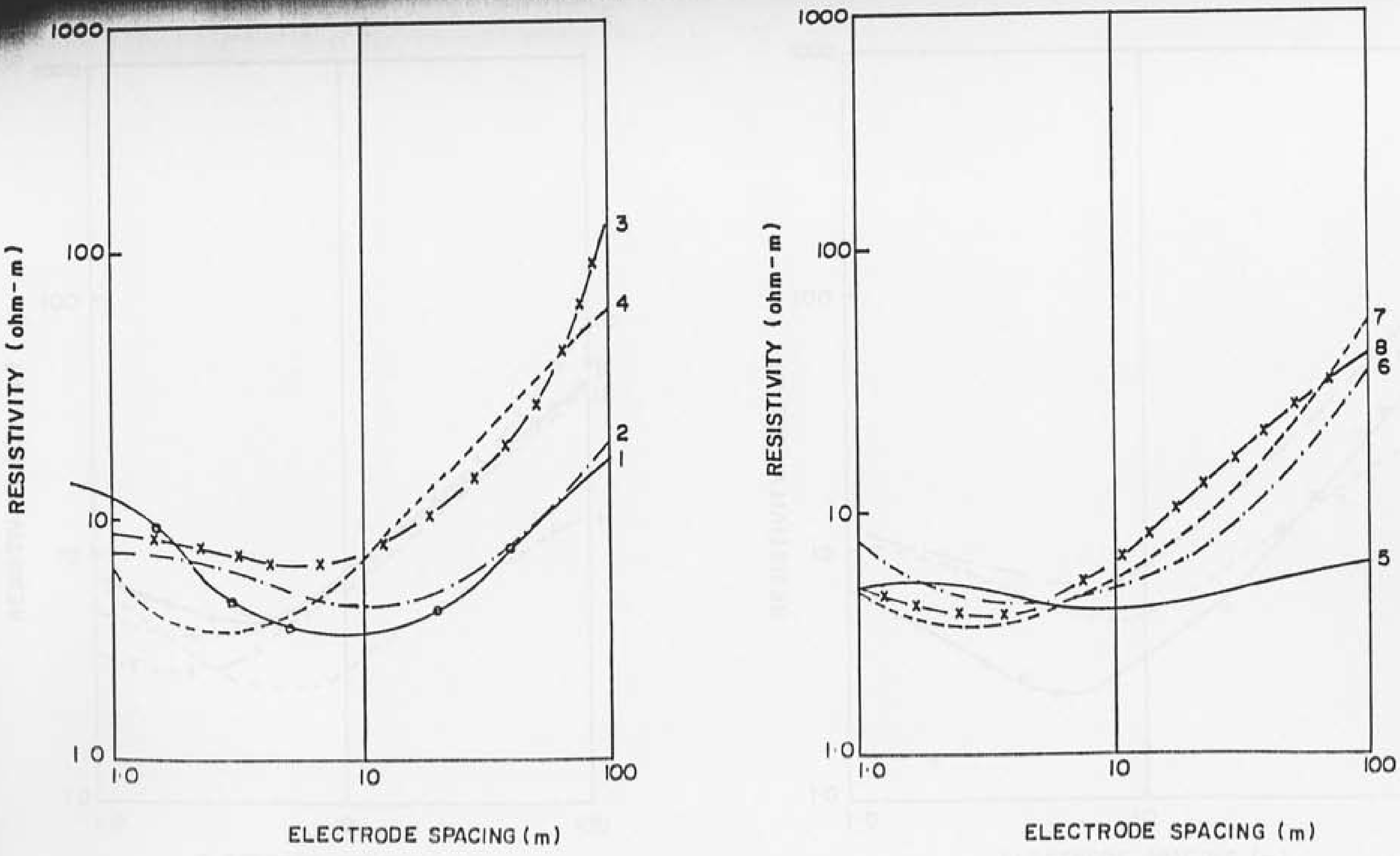


FIG. 3 2 RESISTIVITY CURVES AT VES POINTS

CONTD.

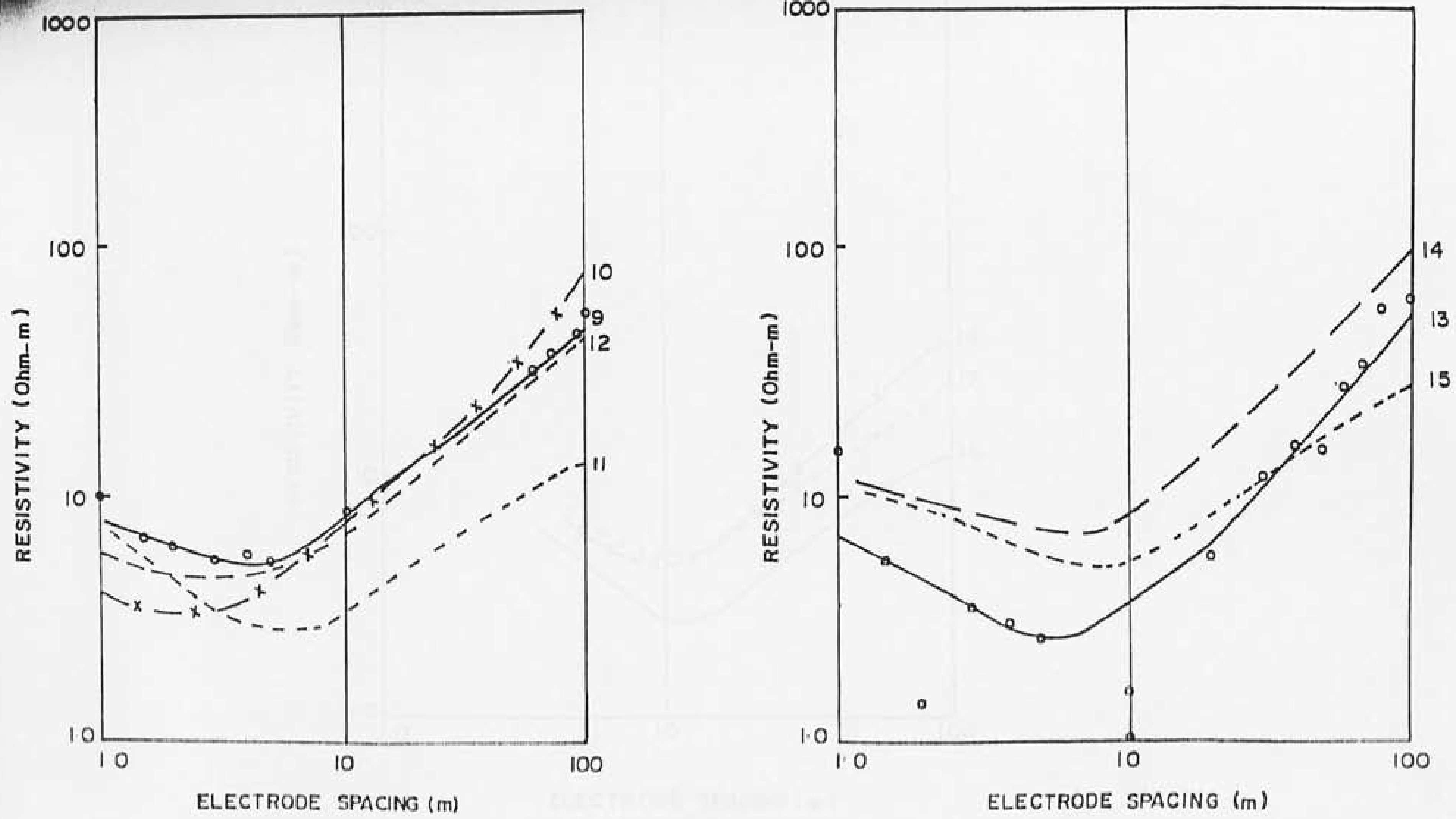


FIG.3·2(CONTD)

Contd.

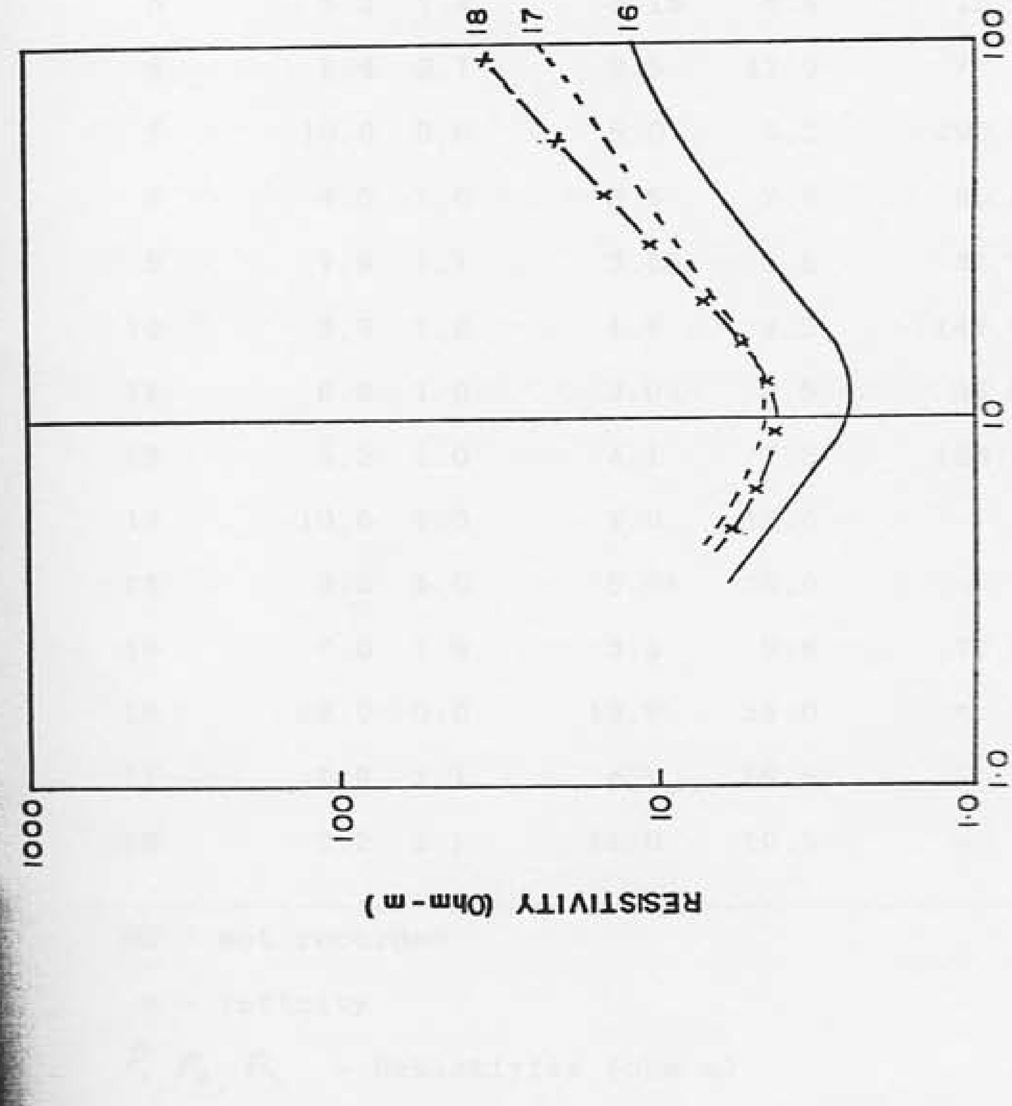

RESISTIVITY (Ohm-m)
1000
100
10
1.0
ELECTRODE SPACING (m)
1.0
10
100
16
17
18

FIG.3·2 (CONTD)

TABLE 3.1 : ACTUAL RESISTIVITY AT VES POINTS

VES Points	First ρ_1	Layer H_1	Second ρ_2	Layer H_2	Third ρ_3	Layer H_3
1	15.0	7.0	3.0	17.5	*	-
2	6.5	1.0	4.2	9.0	44.0	-
3	8.3	1.0	5.6	10.0	172.0	-
4	9.7	2.91	2.91	4.5	*	-
5	5.2	1.4	4.16	8.4	13.0	-
6	8.4	0.7	2.5	11.0	*	-
7	10.0	0.8	5.0	5 2	200.0	-
8	4.0	1.0	3 5	7.9	80.0	-
9	7.9	1.1	3 16	5.6	31 96	-
10	3.6	1.0	1.8	2 3	144 0	-
11	6.8	1.0	2.04	5.5	34.0	-
12	5.2	1.0	4.1	7.6	104 0	-
13	10.0	1.0	4 0	12 0	-	NR
14	9.0	1.0	5.95	10.0	-	NR
15	7.0	1.6	3.5	9.6	70 0	NR
16	28.0	0.0	19 8	25 0	*	NR
17	1.8	1.1	4 5	16.5	-	NR
18	2.2	2.1	11.0	10.5	-	NR

NR - Not recorded

* - Infinity

ρ_1, ρ_2, ρ_3 - Resistivity (ohm-m)

H_1, H_2, H_3 - Thickness of Layer (metres)

Figure 3.3

In general, the area is covered by black cotton soil and alluvial soil upto a depth of 1 to 1 5 m BGL. The thickness of yellowish soil with gravel below alluvium varies between 2 and 3.5 m. Weathered rock is present at a depth of 5 m BGL. Water table is expected to be very near the surface in an unconfined condition, within 25 m. Further the subsurface ground water yield is likely to be moderate.

3.3 RESISTIVITY PROFILES

The Electrical resistivity profiling (ERP) is employed as an indirect means, as opposed to the traditional drilling and water sampling, to assess the ground water contamination and to detect buried drums in abandoned hazardous waste dump sites. For ERP, Wenner configuration was used in which the electrode spacings were fixed at 5 m and 10 m to measure the resistivity at these electrode spacings over an area at fixed interval. This method is detailed in Annexure I In order to assess ground water contamination around SEP, three ER profiles were carried out, one between the pond embankment and fence and two at 10 m and 25 m outside the fence. However on the eastern side of SEP, ERP was carried out at 70 m and 100 m from fence because of obstruction from closeby hutments. Resistivity was measured at 5 m and 10 m electrode spacings at every 10 m intervals The apparent resistivity was plotted as shown in Figures 3.4 to 3.11.

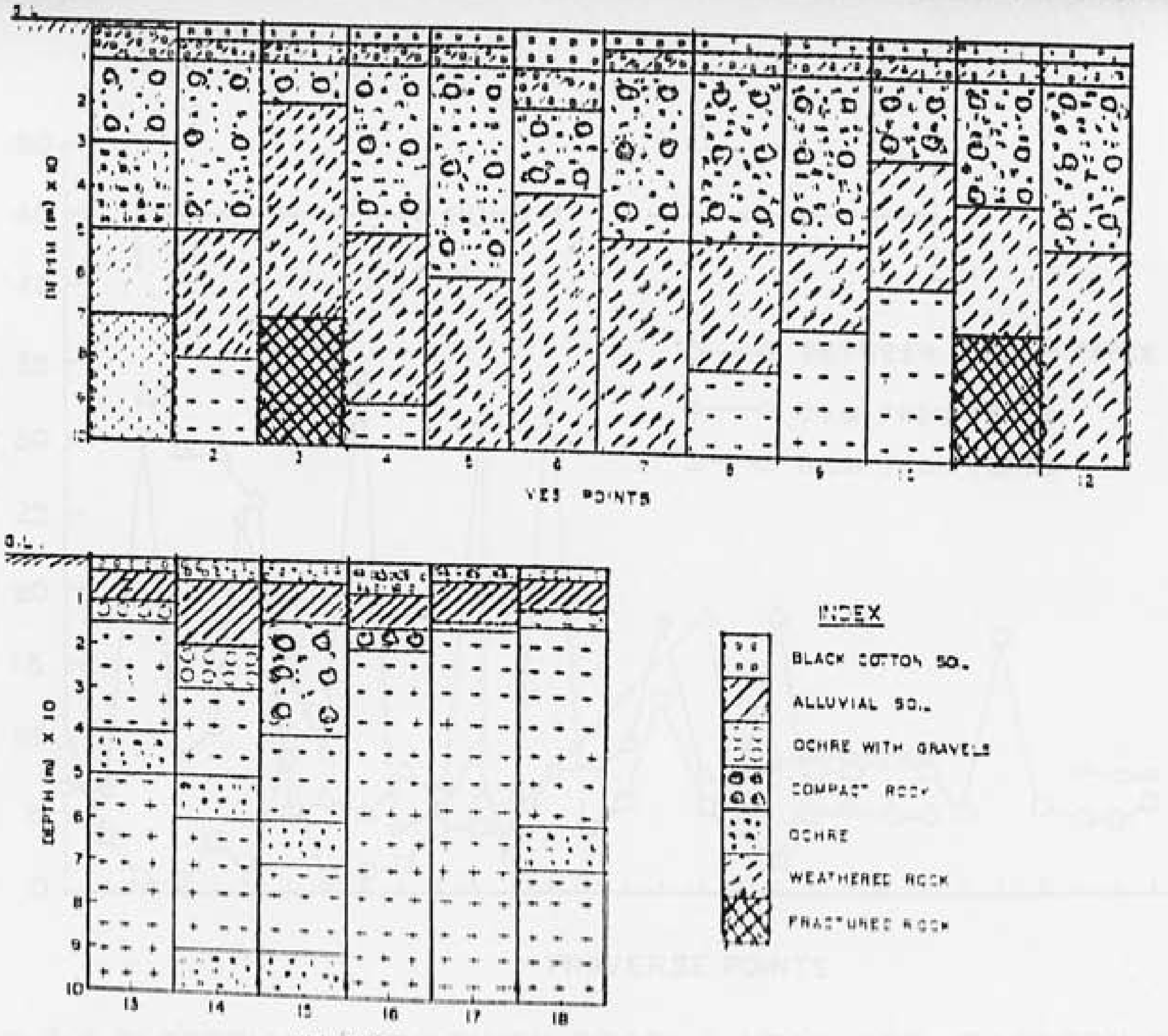


FIG. 3.3 LITHOLOGS BASED ON VES

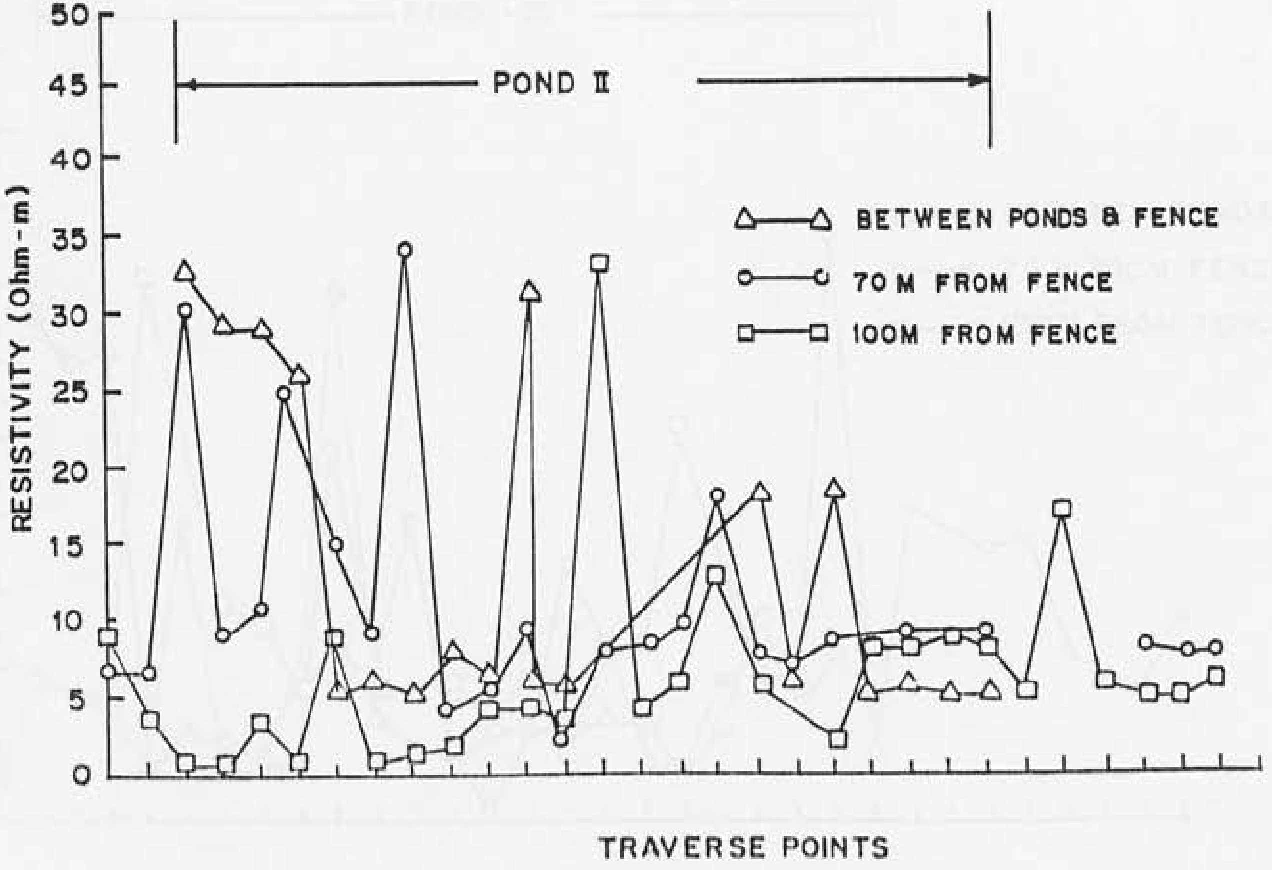


FIG 3·4 ELECTRICAL RESISTVITY PROFILE NEAR SEP -EASTERN SIDE (5m)

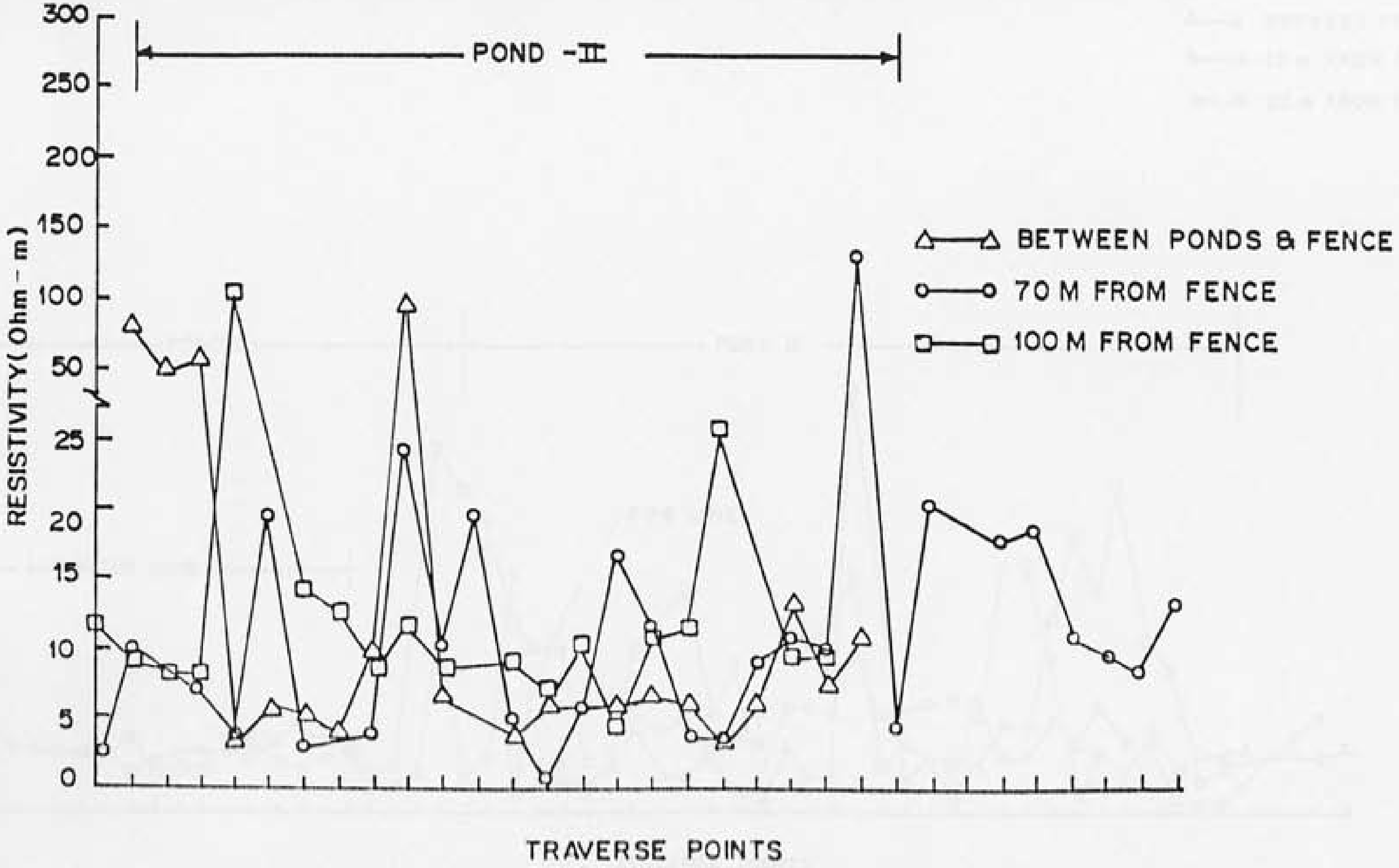


FIG.3·5 ELECTRICAL RESISTIVITY PROFILE NEAR SEP - EASTERN SIDE(10m)

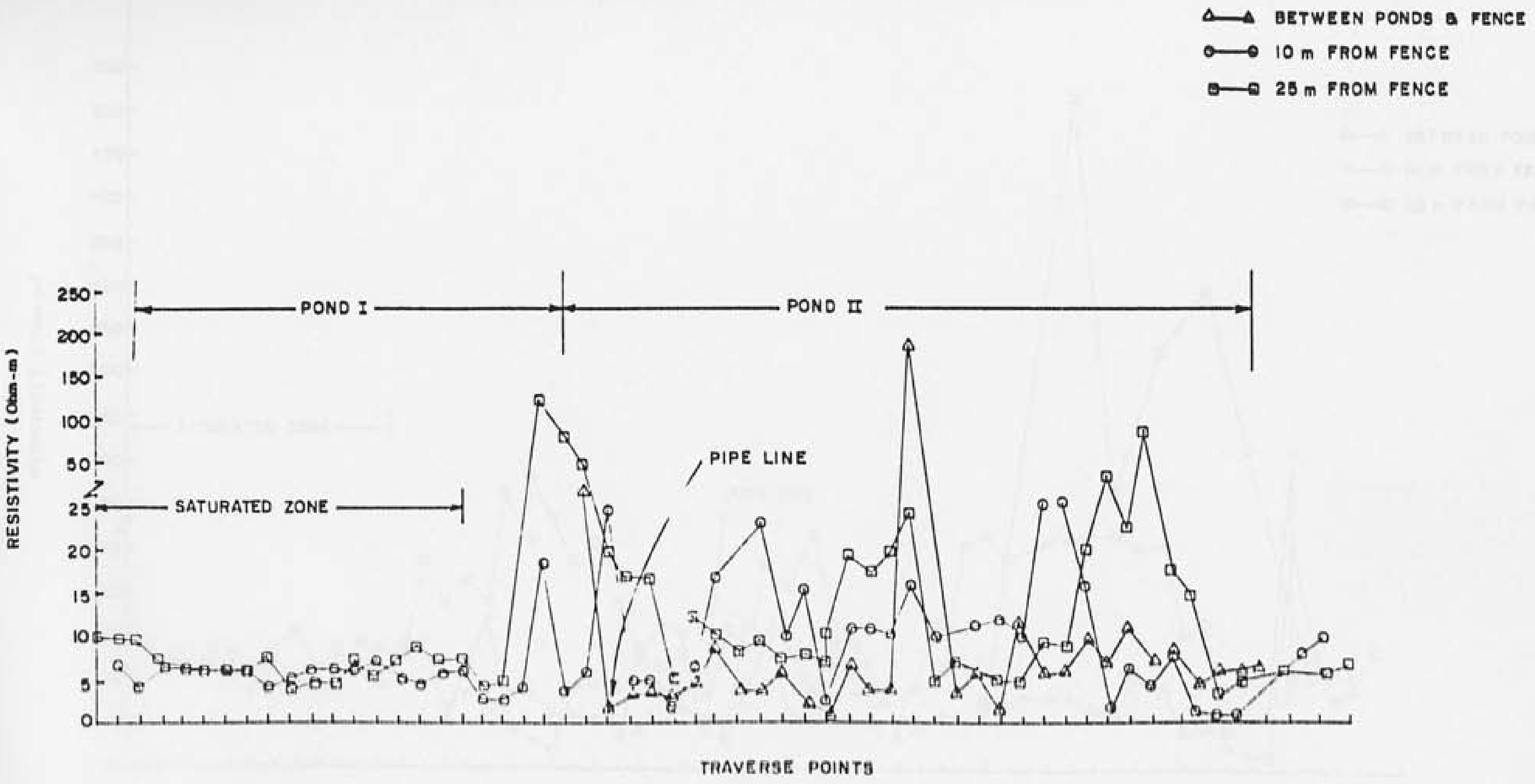


FIG. 3·6 ELECTRICAL RESISTIVITY PROFILE NEAR SEP - SOUTHERN SIDE (5 m)

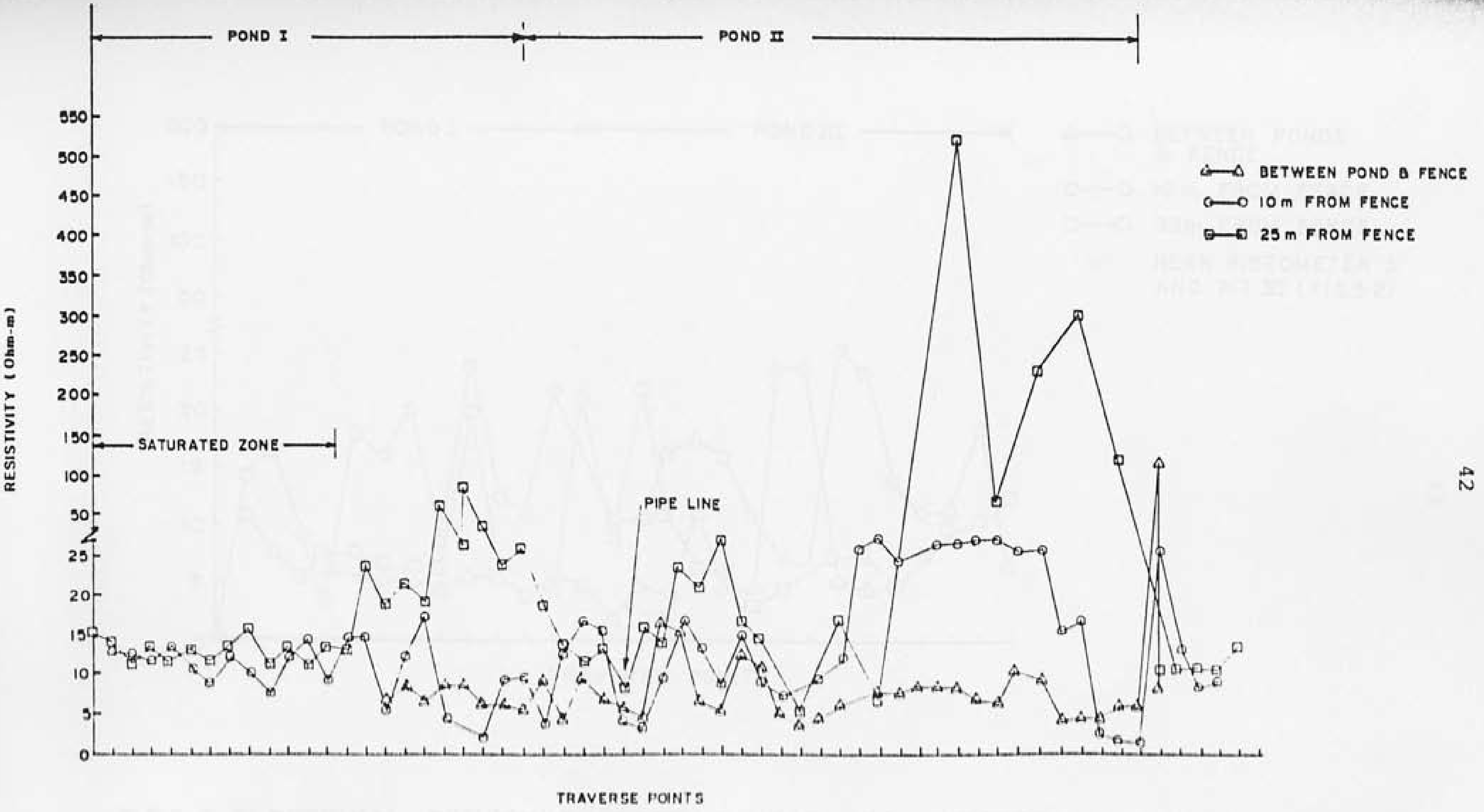


FIG.3.7 ELECTRICAL RESISTIVITY PROFILE NEAR SEP- SOUTHERN SIDE (10 m)

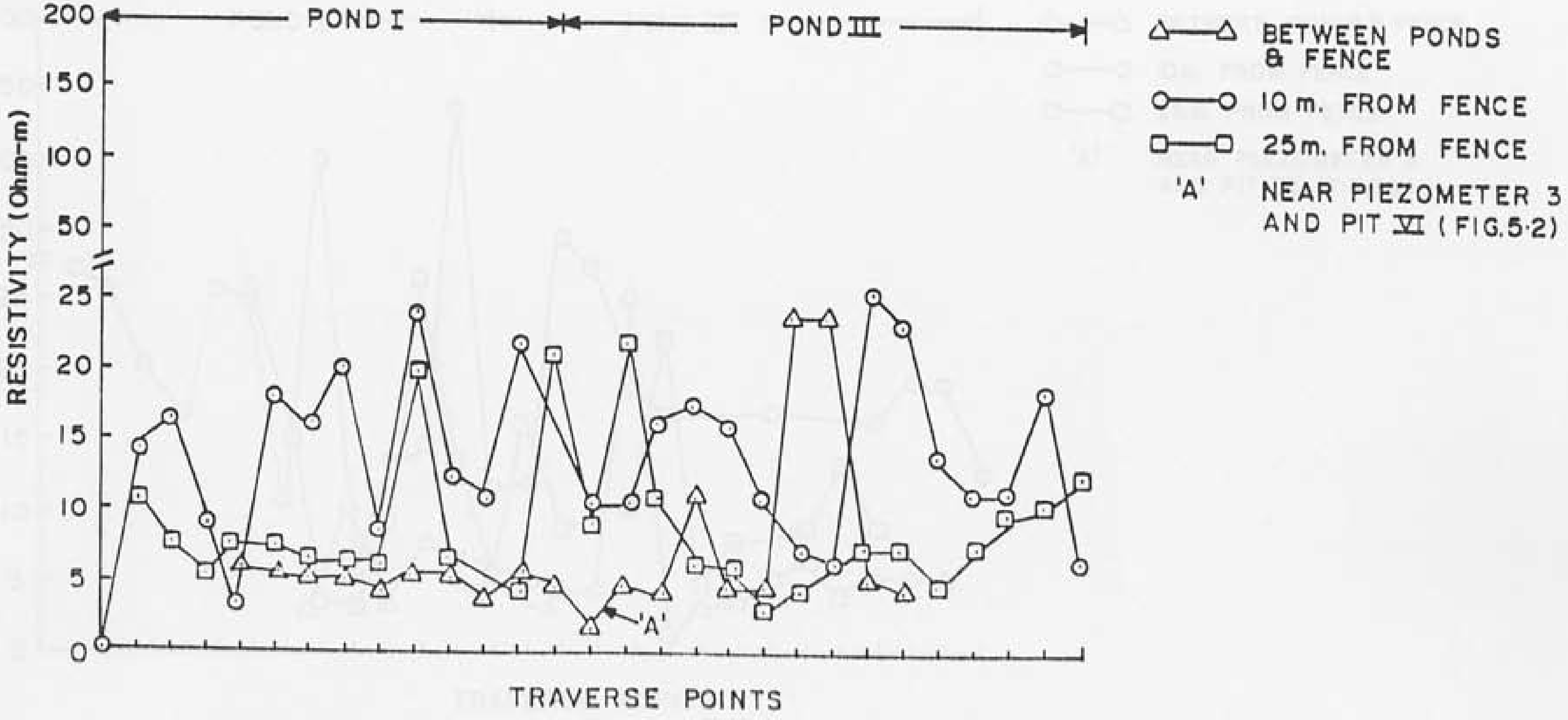


FIG.3·8 ELECTRICAL RESISTIVITY PROFILE NEAR SEP – WESTERN SIDE (5m.)

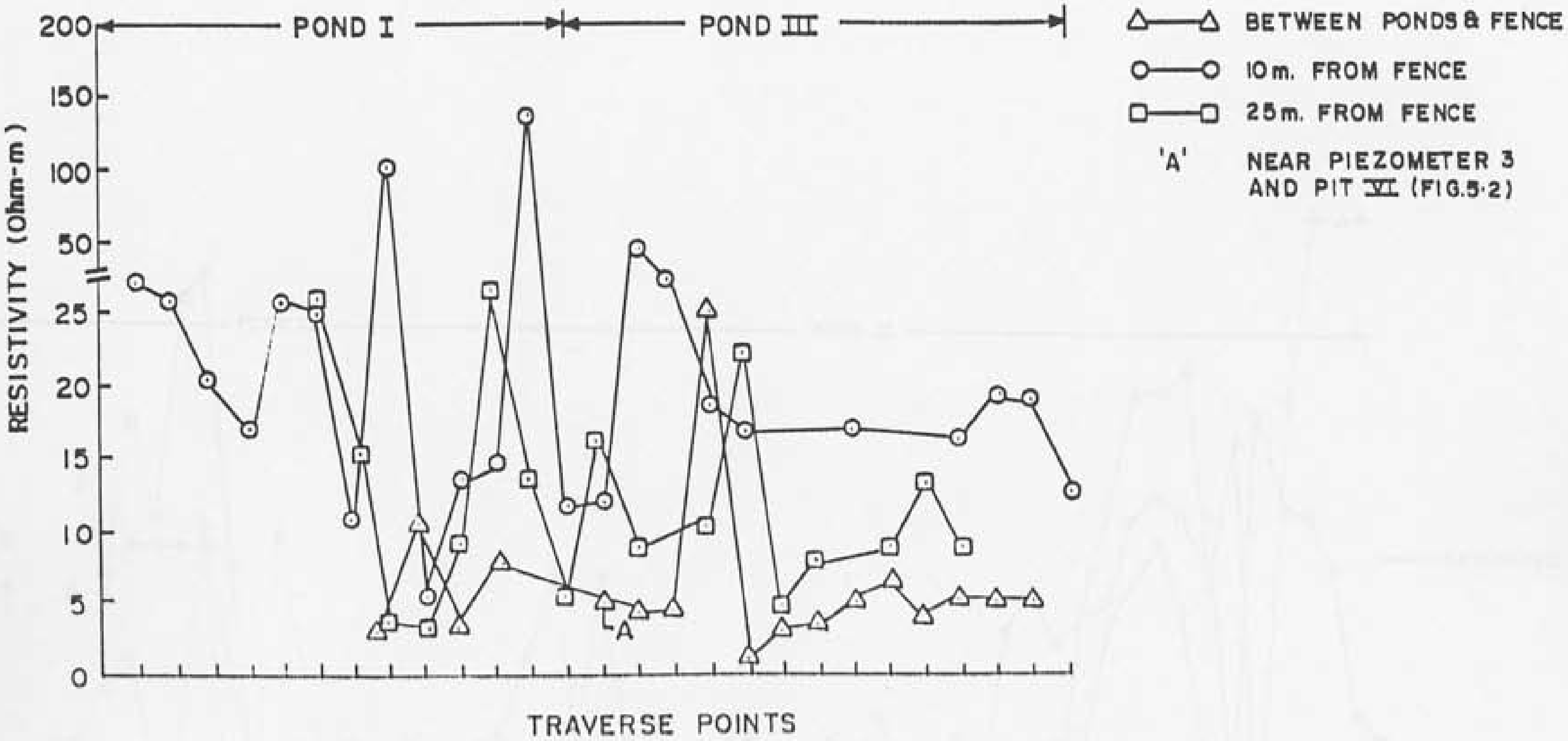


FIG.3·9 ELECTRICAL RESISTIVITY PROFILE NEAR SEP – WESTERN SIDE (10m)

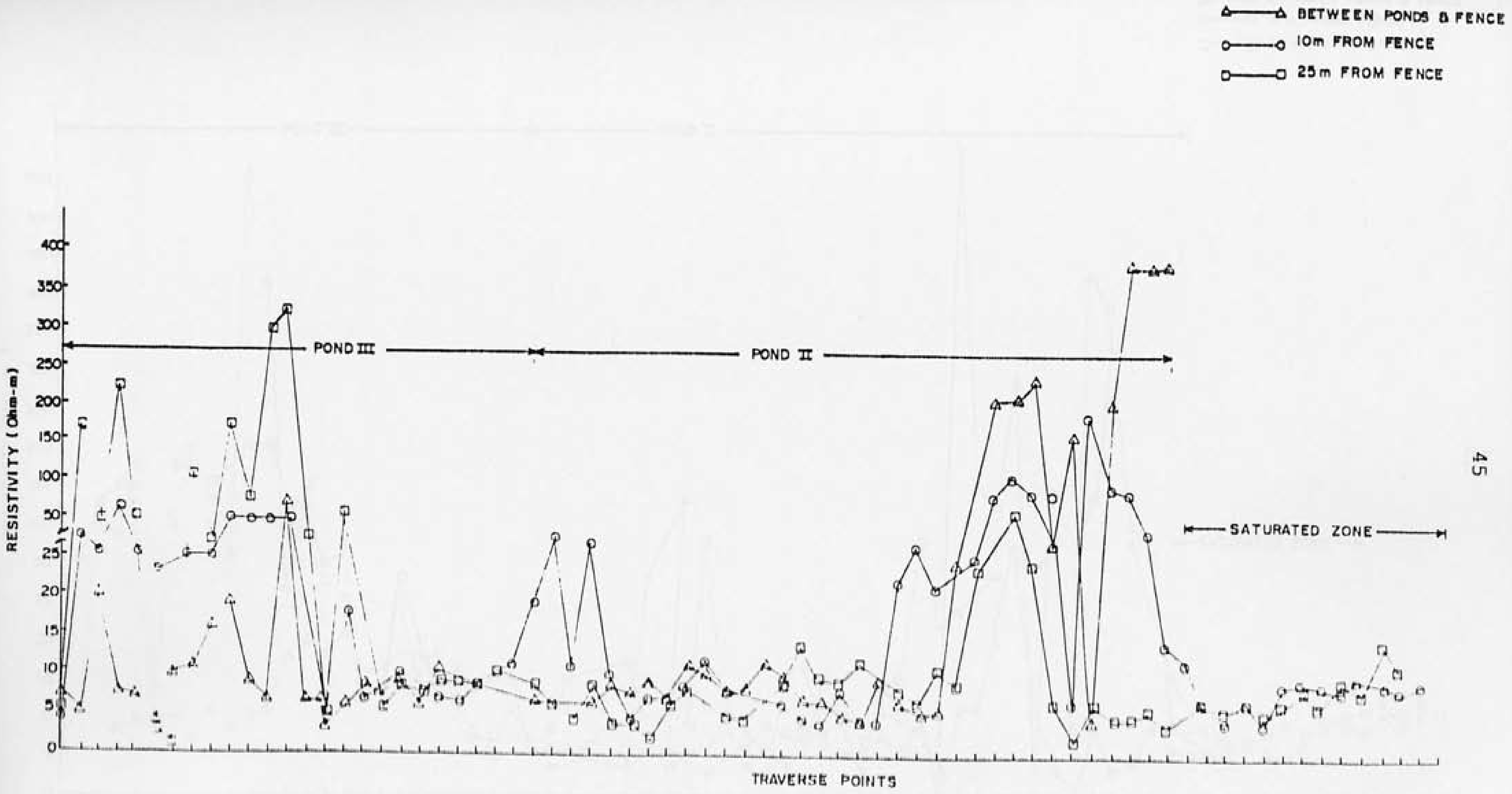


FIG.3.10 ELECTRICAL RESISTIVITY PROFILE NEAR SEP-NORTHERN SIDE (5m)

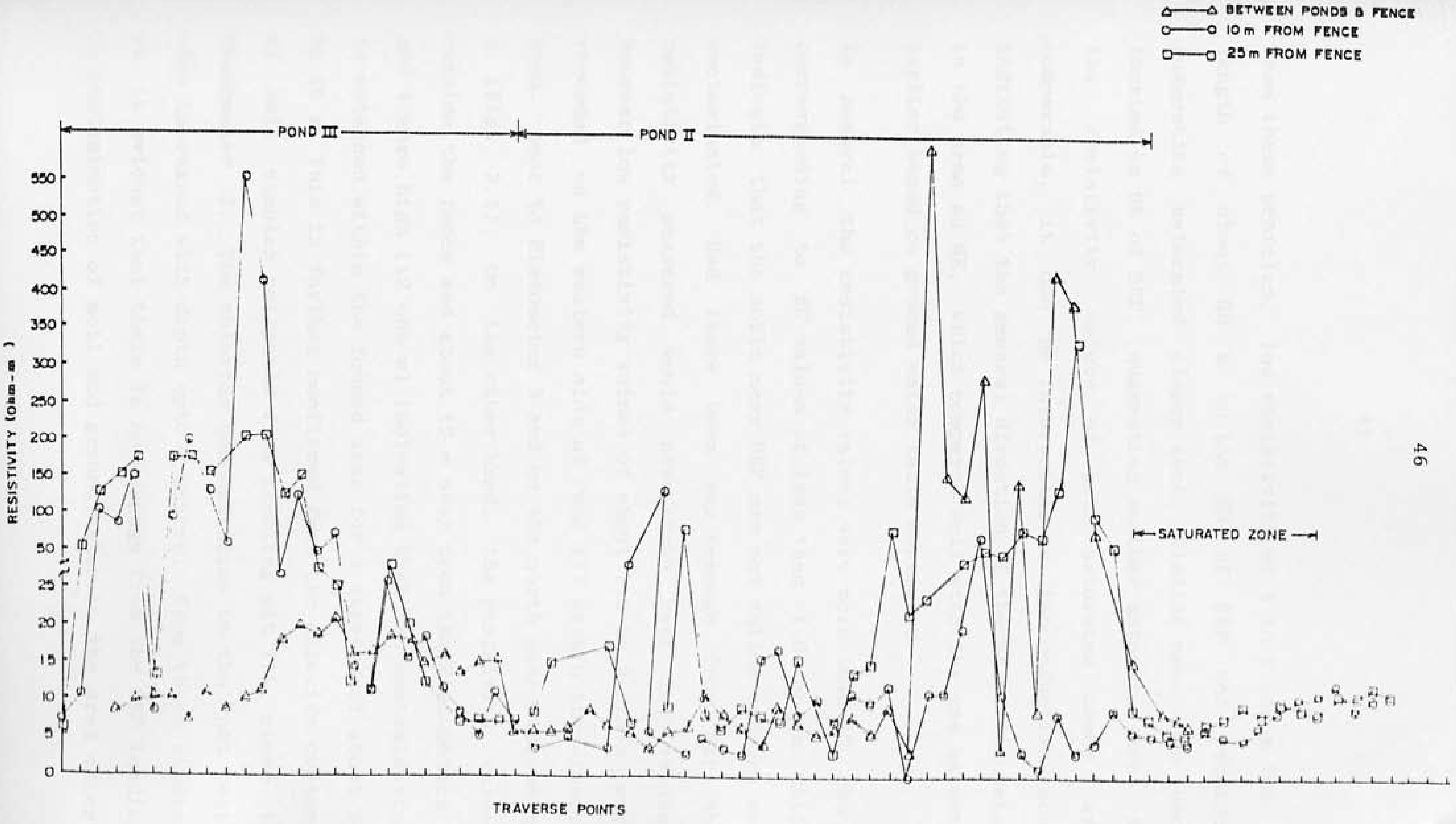


FIG 3.11 ELECTRICAL RESISTIVITY PROFILE NEAR SEP– NORTHERN SIDE (10m)

From these profiles, low resistivity of 4 to 5 ohm-m for a length of about 60 m on the SW of SEP was recorded suggesting saturated clayey zone. Similar zone has been located on NE of SEP, suggesting another saturated zone. As the resistivity values of both saturated zones are comparable, it can be interpreted as isoconductive zone indicating that the general direction of the phreatic water in the area as NE, which compares well with the one assumed earlier based on ground water table contours.

In general the resistivity values were more than 10 ohm-m corresponding to EC values of less than 1.0 mS/cm which indicate that the soils near SEP are not saline and are not contaminated. Had there been any seepage from SEP the resistivity measured would have shown very low values. However low resistivity values of about 1.5 to 2 ohm-m were recorded on the western side of Pond III within the fenced area, near to Piezometer 3 and on the north near Piezometer 4 (Fig. 3.1). On the other hand, the resisivity values outside the fence and about 10 m away from the Piezometers 3 and 4 were high (12 ohm-m) indicating that the contamination is retained within the fenced area for a stretch of about 30 to 40 m. This is further confirmed from the chloride content of soil samples collected from sampling pit VII close to Piezometer 3. The chloride concentration in the pit soil also increased with depth upto 2 meters From these studies it is evident that there is no seepage from the SEP leading to contamination of soil and ground water in the area except for the stretch mentioned above. The soil in this area has to be treated for decontamination

4.0 STUDIES ON SOLAR EVAPORATION PONDS

4.1 INTRODUCTION

Solar evaporation ponds were used for storing neutralised acidic wastewater generated in the factory There are three ponds covering an area of 14 hectares. These ponds were designed to retain the wastewater for evaporation Wastewater contained mostly inorganics consisting of primarily chloride of calcium and sodium which are highly soluble in water. The construction and other details of the ponds are described in Chapter 1.

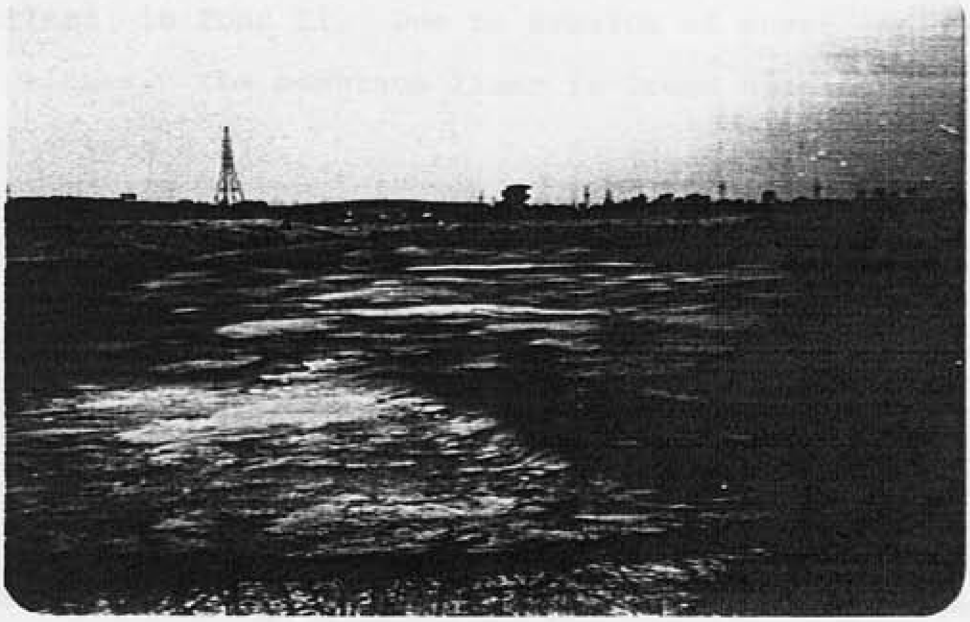
No wastewater was reported to have been generated and pumped into SEP since the closure of the plant in December 1984. While Ponds I and II were used regularly, Pond III was operated whenever a need arose. During the last five years the impounded wastewater (referred hereto as pond water) in SEP was undergoing evaporation during winter and summer months and dilution with rain water during monsoon months. Since there was no input of wastewater into the ponds from December 1984, evaporation played a major role as is evident from the appearance of white patches of salt on the pond slopes and dried-up bottom surface during summer months. A major portion of Ponds I and II was dry containing only a little impounded water covering an area of about 20-30% of bottom surface. Pond III was totally dry for most part of the year except for monsoon months (Plates 4.1 and 4.2).

PLATE 4.1

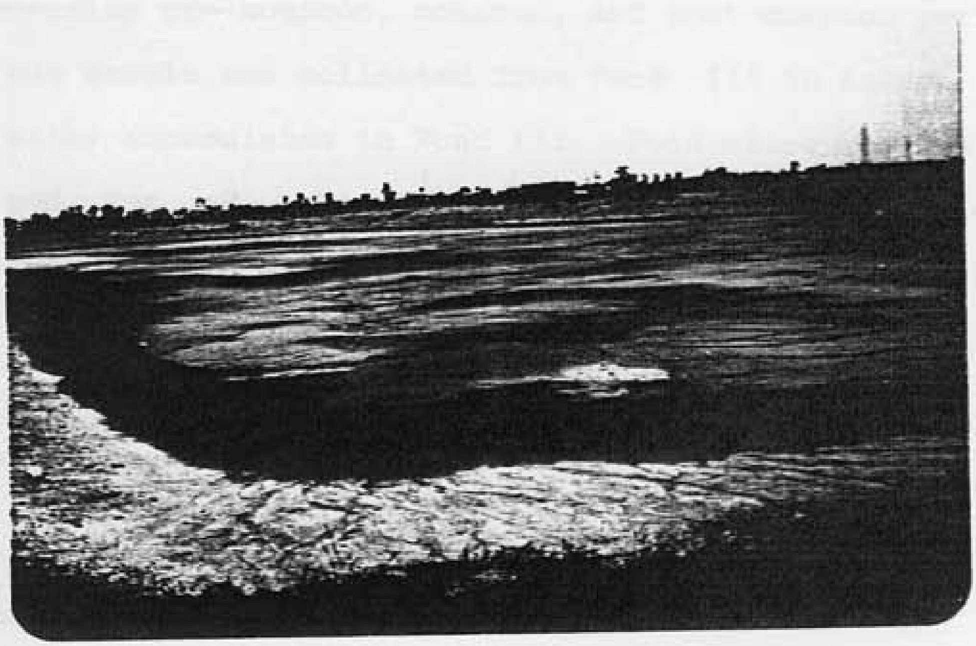
WASTEWATER INLET PIPE TO SEP

SOLAR EVAPORATION POND I

PLATE 4.2



SOLAR EVAPORATION POND II SHOWING
EXPOSED MEMBRANE LINER



SOLAR EVAPORATION POND III

The water from Pond I was dark brown in colour, while it was colourless in Pond II. Due to erosion of cover soil from pond slopes, the membrane liner is found exposed at a few places (Plate 4.3).

4.2 CHARACTERISTICS OF POND WATERS

Pond waters were collected and analysed to assess the nature of contaminants present in SEP. At the start of sampling in June 1989, Pond I and II had pools of water with varying depths and spreading upto 20-30 % of the total pond bottom surface. However Pond III was totally dry. Water samples were collected randomly from different points in each pond and composited (Plate 4.4). Water level at different points in each pond was recorded at the time of sampling and averaged. Samples were collected five times from ponds I and II, covering pre-monsoon, monsoon, and post-monsoon periods. Only one sample was collected from Pond III in August 1989 when water accumulated in Pond III. Pond water samples were analysed for pH, chloride, sulphate, nitrate, calcium, sodium, potassium and COD as per Standard Methods. Carbaryl and alpha naphthol were analysed colorimetrically as detailed in Annexure II. The analytical results are presented in Table 4.1 .

The pH of Ponds I and II waters ranged from 5.6 to 6.9 indicating slight acidic to neutral character. The high dissolved solids in pond waters are due to inorganic salts

PLATE 4.3

EXPOSED MEMBRANE LINERS ON THE POND BUND

PLATE 4.4

COLLECTION OF POND WATER SAMPLE

TABLE 4.1: CHEMICAL CHARACTERISTICS OF POND WATER

(All values except pH, carbaryl and alpha naphthol are expressed as mg/l)

Sample	pH	Calcium	Magnesium	Sodium	Potassium	Chloride	Nitrate-N	Sulphate	COD	Carbaryl ug/l	Alpha-naphthol ug/l
Pond I											
	6.5	15200	1196	94000	120	214000	4160	1525	7200	127.5	ND
	5.6	16800	1680	59700	80	137000	-	1300	4420	61.0	ND
	6.4	16000	720	50000	85	130000	2880	1400	1800	53.0	ND
	6.0	14400	960	36200	100	110000	1200	1600	1500	27.0	ND
	6.9	4680	576	12400	33	27470	270	930	998	-	-
Pond II											
	6.4	61200	1380	86000	200	260000	3420	1200	6100	ND	ND
	5.7	38000	2400	33200	100	127000	-	1250	2440	ND	ND
	6.2	52000	3600	30500	110	129000	2310	1100	1350	ND	ND
	6.1	28000	1920	19600	100	95000	1000	1250	1200	ND	ND
	6.6	9460	720	5600	27	67000	240	240	882	ND	ND
Pond III											
	7.4	696	96	400	6.4	9100	11.2	50	165	ND	ND

ND - Not detected

such as chloride and sulphate of calcium and sodium. Calcium content is higher in Pond II (9460-61200 mg/l) while Pond I has high sodium (12400-94,000 mg/l). This is due to the fact that the factory was reported to be using sodium carbonate/hydroxide in early stages to neutralise the acid wastewater and storing it in Pond I. Subsequently limestone was used for neutralisation. Chloride content is nearly the same in both the pond waters.

COD value of Ponds I and II ranged from 998-7200 mg/l and 882-6100 mg/l, respectively, indicating organic contamination. Due to dilution by rain water, both organic and inorganic levels in pond waters showed a decreasing trend in samples collected during monsoon months.

The characteristics of Pond III water, as compared to the other two ponds, clearly indicate that it received only small quantity of the impounded water from ponds I and II.

The factory was not using any heavy metals or their salts in the manufacturing processes or in the formulations. As such, the chances of their presence in the pond water are remote. However, the pond water samples collected in July 1989 were analysed for lead, cadmium and chromium and the results are as follows:

	Lead, ug/l	Cadmium, ug/l	Chromium, ug/l
Pond I - water	70	Below detection limit	45
Pond II - water	78	Below detection limit	22

Although lead and chromium are detected, they are in very low concentrations and are even below the guidelines prescribed for drinking water (Annexure III).

BOD tests carried out, using composite water from Pond I and II obtained by mixing all the five sets of samples, and sewage as seed indicated that the BOD to COD ratio was 0.25 to 0.30. This shows that the organics in the pond waters are not readily biodegradable. Attempts to develop acclimated activated sludge for preparing seed for BOD using pond water diluted with domestic sewage did not result in sludge build up. Using the effluent from this system as seed for BOD test, it was observed that there was no significant improvement in the biodegradability of the organics in the pond waters.

Of the two major organic compounds <u>viz.</u> carbaryl and alpha naphthol likely to be present in the wastewater from the factory, only carbaryl (0.12 mg/l) was present in Pond I water collected in June 89. Pond II and Pond III waters did not show these compounds. Although the method used for sevin is reported to be specific, interference due to other phenolics when present along with sevin cannot be totally ruled out. Solubility of sevin in water is 40 mg/l and the half life is only 1 to 5 days. Further the time required for 90% of added sevin to disappear from soil environment is reported to be 15 days. TLm 50 value for fish to sevin is 5-13 mg/l in water.

High Performance Liquid Chromatographic (HPLC) analysis was carried out to identify the organic compounds present in pond water as well as sediment samples. Conditions used for HPLC analysis are given in Annexure IV. From the results presented in Figure 4.1, it could be seen that two peaks were observed for Pond I and II water samples (using dioxan and water as mobile phase) at retention time of one and two minutes, respctively. First peak was prominent in Pond I whereas in Pond II it was not significant. The probable compounds present in pond samples are sevin, naphthol, intermediates or polymerised compounds. Of the many probable compounds injected for identification, peak 1 matched with that of standard benzene sulphonic acid (BSA) having a retention time of one minute. Other peak could not be identified.

HPLC analysis using acetonitrile and water as mobile phase showed the presence of four peaks each in pond waters I and II (Fig. 4.2). However, none of these peaks matched with that of either alpha-naphthol or sevin (Fig. 4.3). This confirms that pond water did not contain alpha-naphthol and sevin.

Gas chromatographic analysis was carried out to detect the presence of either chloroform or carbon tetrachloride which are used as solvents in the manufacturing process of sevin GC conditions and sample preparations are given in Annexure V. From Figure 4.4, it is seen that both these compounds are

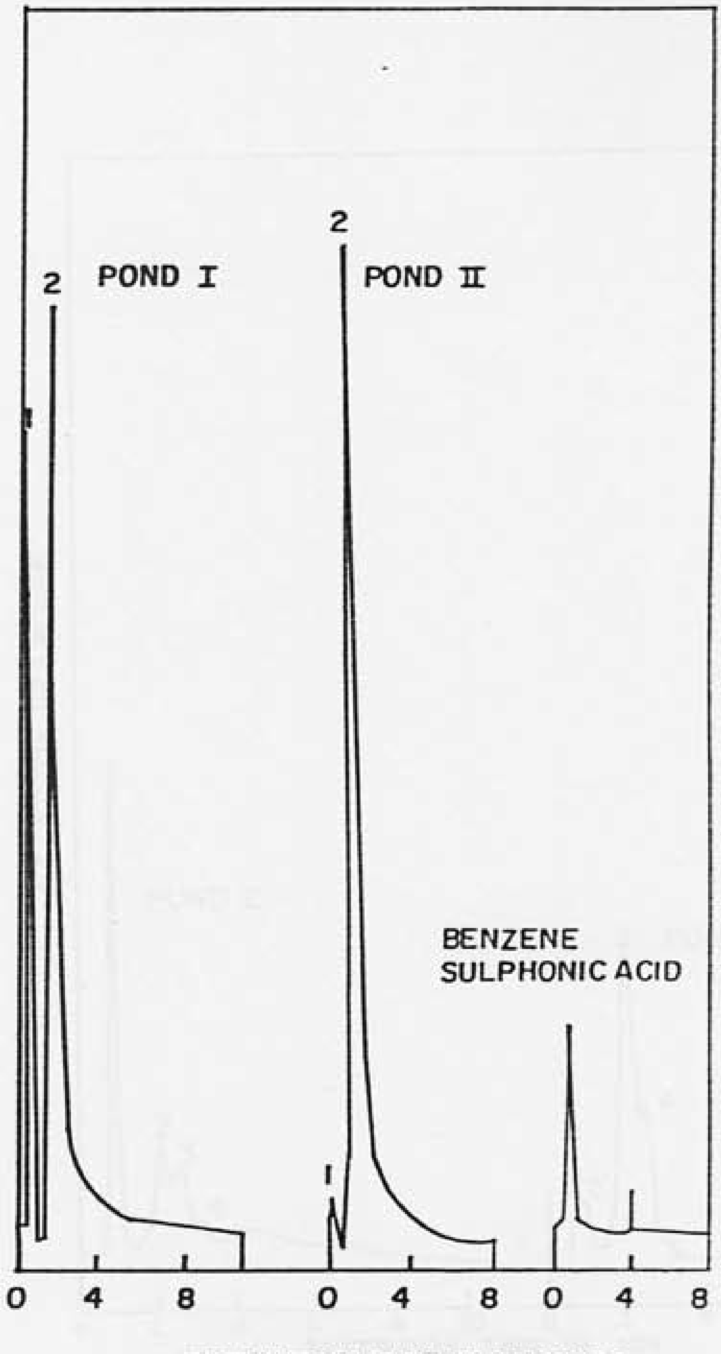


FIG.4·1. HIGH PERFORMANCE LIQUID CHROMATOGRAM OF POND I WATER, POND II WATER AND STANDARD BENZENE SULPHONIC ACID

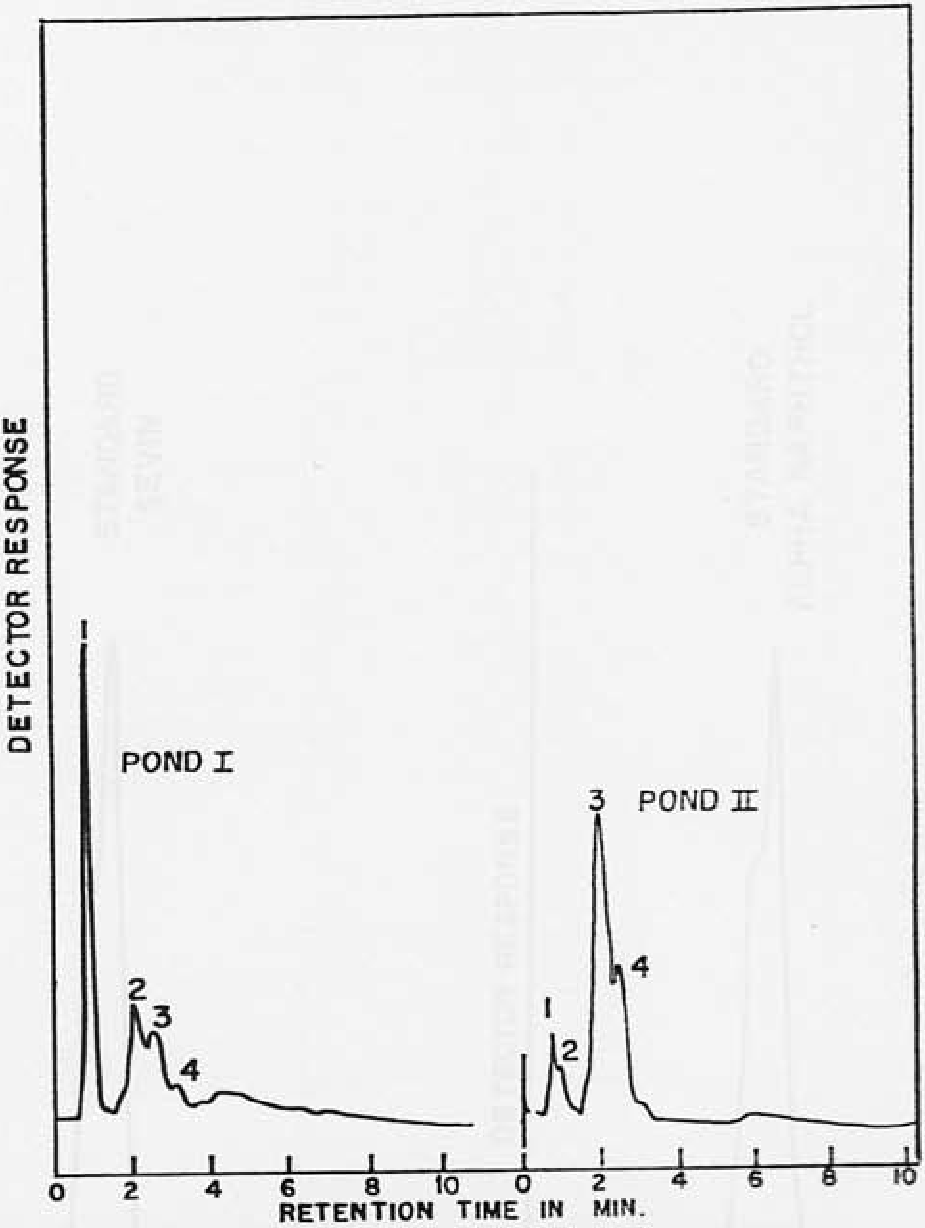
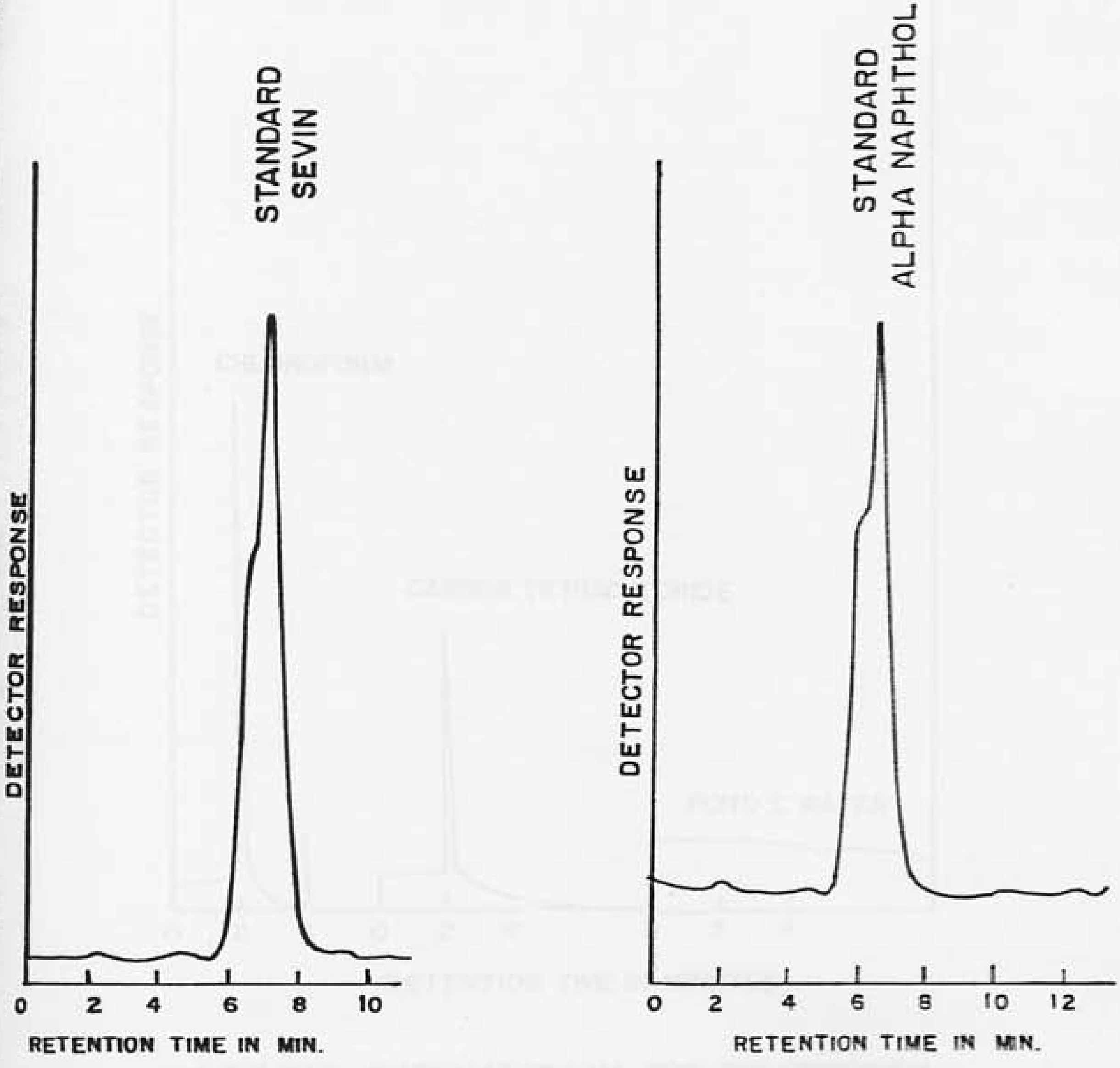


FIG. 4·2. HIGH PERFORMANCE LIQUID CHROMATOGRAM OF POND WATER



43.HIGH PERFORMANCE LIQUID CHROMATOGRAM FOR STANDARD SEVIN AND ALPHA NAPHTHOL

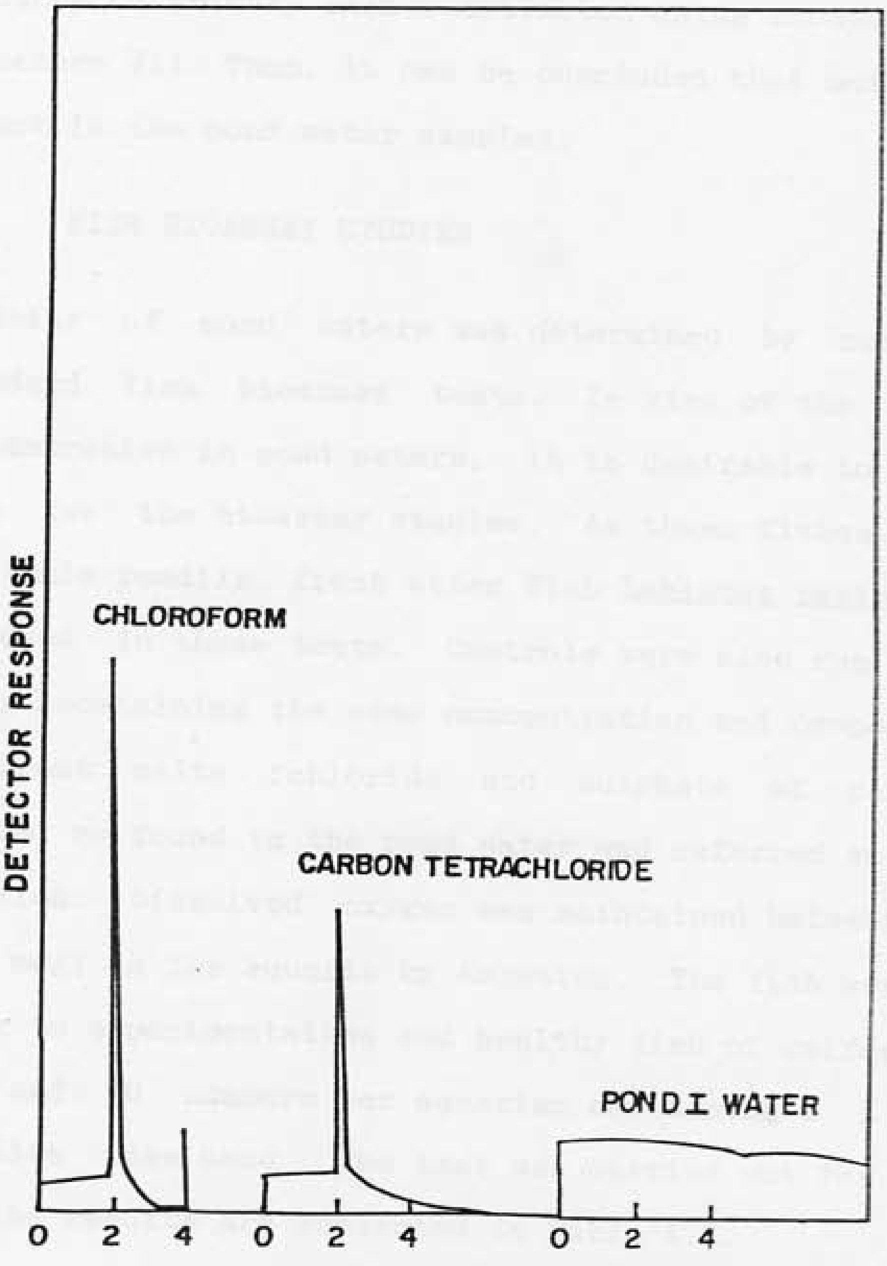


FIG. 4-4. GAS CHROMATOGRAM FOR CHLOROFORM, CARBON TETRACHLORIDE AND POND WATER

not present in pond water samples. Since they are highly volatile, they might have been lost due to prolonged storage (5 years) in SEP. Pond water samples also did not show the presence of primary amines estimated using ninhydrin method (Annexure VI). Thus, it can be concluded that methylamine is absent in the pond water samples.

4.3 FISH BIOASSAY STUDIES

Toxicity of pond waters was determined by carrying out standard fish bioassay tests. In view of the high salt concentration in pond waters, it is desirable to use marine fish for the bioassay studies. As these fishes were not available readily, fresh water fish Lebistes reticulatus was employed in these tests. Controls were also run with tap water containing the same concentration and proportions of different salts (chloride and sulphate of calcium and sodium) as found in the pond water and referred as synthetic solution. Dissolved oxygen was maintained between 6.5 and 7.0 mg/l in the aquaria by aeration. The fish were starved prior to experimentation and healthy fish of uniform size (2 cm) and 10 numbers per aquarium containing 5 l of test solution were used. The test was carried out for 96 hours and the results are presented in Table 4.2.

The data presented in Table 4.2 indicate that both pond waters exhibit acute toxicity at concentration of 10 % . Since the controls with synthetic solutions representing the salt concentration present in pond waters, also exhibited

TABLE 4.2 : FISH BIOASSAY TEST RESULTS

Concentration	Mortality Percent in hours			
	24	48	72	96
Control Tap Water	0	0	0	0
Pond I Water				
5 percent	0	0	0	20
10 percent	100	-	-	-
25 percent	100	-	-	-
Control Synthetic Solution				
5 percent	0	0	0	0
10 percent	100	-	-	-
25 percent	100	-	-	-
Pond II Water				
5 percent	0	0	0	0
10 percent	100	-	-	-
25 percent	100	-	-	-
Control Synthetic Solution				
5 percent	0	0	0	0
10 percent	100	-	-	-
25 percent	100	-	-	-

toxicity at the same dilution level it can be assumed that the toxicity in pond water to the test fish used is due to inorganic salts as these are present in high concentration (20 % TDS). It may also be concluded that the organics present in the pond waters do not seem to exert acute toxicity. Since the toxicity of pond water is due to inorganic salts, dilution of pond content decreases the toxicity. Thus samples collected in summer will have higher toxicity than those collected in monsoon.

If the pond waters are to be disposed of into the nearest nalla, they require a dilution of twenty times with fresh water when the TDS in the pond water is around 20% .

More over the pond water can be disposed only, after required treatment/dilution into the nallas which carry the fresh water.

From the characteristics of the water from Ponds I & II it can be concluded that they are highly saline and the major pollutants being chlorides of calcium and sodium. Sulphate present in the water must have been derived from the chlorosulphonic acid used for the manufacture of alpha naphthol through naphthalene sulphonic acid.

The organic pollutants as measured by COD and BOD tests indicate that they are not readily biodegradable. The presence of very high concentration of chloride even after five monsoon seasons since the closure of the factory, vis-a-vis discontinuation of use of the SEPs, indicates that the impounded wastewater had not leached causing contamination of ground water. In other words, the liner and the clay cover on the sides and bottom of the ponds besides naturally present thick plastic clay below the liner acted as a barrier for the seepage of the stored wastewater. It may also be mentioned that the hydraulic conductivity of the soils in the SEP area is less than 1.0 mm per hour.

4.4 POND SEDIMENTS

Sediments samples upto the depth of polyethylene liner were collected using a PVC cup sampler without causing damage to the liner. Small pits were also prepared to collect samples from different depths in places where PVC cup could not be used (Plate 4.5). Soil samples below liners were not collected as it would damage the liner creating conditions for seepage of pond water. In all seven samples from each of Ponds I and II and two samples from Pond III were randomly collected in June 1989 and analysed. Sediment samples were collected both from the dry and semi-dry zones in the ponds. On a few other occasions additional samples were also collected from Ponds I and II for conducting treatability studies. The sampling points are shown in Figure 4.5.

A portion of each sample was preserved separately and the remaining individual samples from each pond were mixed together to get a composite sediment sample. The individual and composite samples were analysed for pH, EC, Cl, HCO_3, Mg

PLATE 4.5

COLLECTION OF POND SEDIMENT SAMPLE

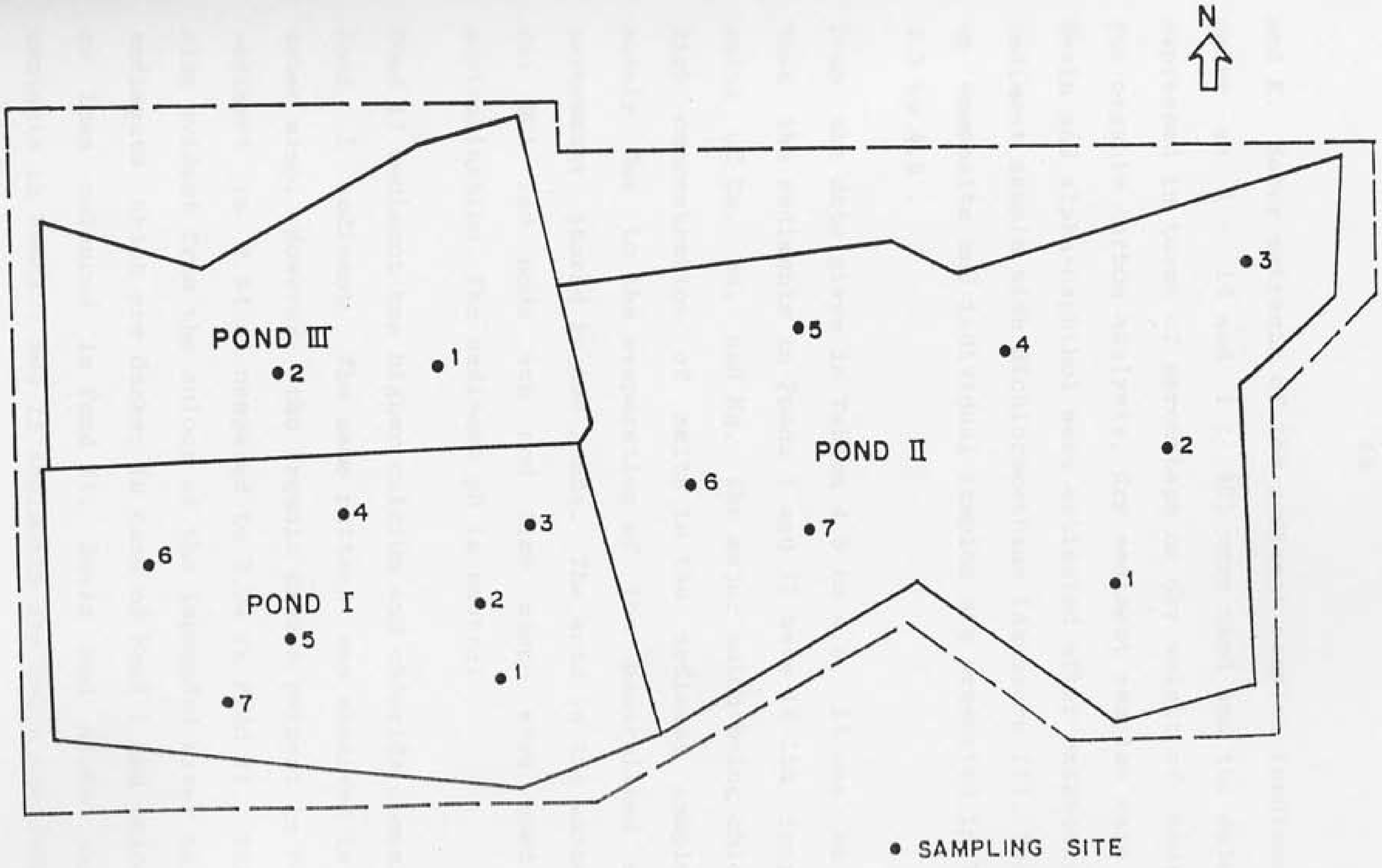


FIG.4·5 LOCATION OF SEDIMENT SAMPLING SITES INSIDE SEP and K. Water extracts of the sediment samples (sediment to water as 1 : 10 and 1 : 40) were used and the data are expressed in terms of percentage on dry weight of sediment. For organic carbon analysis, dry sediment samples were used. Sevin and alpha-naphthol were estimated after extracting the sediment sample with dichloromethane (Annexure II). The data on composite and individual samples are presented in Tables 4.3 to 4.5 .

From the data given in Tables 4.3 to 4.5, it can be seen that the sediments in Ponds I and II have 14-15% inorganic salts of Ca, Na, and Mg, the major anion being chloride. High concentration of salts in the sediment samples is mainly due to the evaporation of the neutralised acidic wastewater stored in the ponds. The acid in the wastewater was HCl and soda ash and lime stone were used for neutralisation. The sediment pH is neutral .

Pond II sediment has higher calcium and chloride compared to Pond I sediment. The same pattern was observed in pond water also. However, the organic carbon percent in Pond I sediment is 3.64 as compared to 2.08 in Pond II. This is also evident from the colour of the impounded water and the sediments which are darker in case of Pond I and colourless or less coloured in Pond II. Sevin and alpha naphthol contents in Ponds I and II sediments are below the detection limits.

HPLC analysis of pond sediments (Fig. 4.6) does not indicate

TABLE 4.3: CHEMICAL COMPOSITION OF COMPOSITE SEDIMENTS FROM SOLAR EVAPORATION PONDS
(All percentage values are on oven dry basis)

Parameters	Pond I	Pond II	Pond III
pH	6.9	7.0	6.6
EC mS/cm at 25 °C	22.15	23.70	1.86
Ca, %	2.14	3.03	0.22
Mg, %	0.12	0.28	0.04
Na, %	2.53	1.44	0.11
K, %	0.02	0.01	0.01
HCO_3, %	0.11	0.05	0.02
Cl, %	6.80	7.56	0.60
SO_4, %	1.20	0.34	0.05
Total dissolved salts, % (EC mS/cm x 0.640)	14.18	15.17	1.19
Organic carbon, %	3.64	2.08	0.37
Total organic matter, % Organic carbon % x 1.72	6.26	3.58	0.64

pH measured in saturated paste of the sediment.

All cations, anions and EC are determined in the water extract prepared by taking 1 g sediment and 10 g water shaken for 6 hours and filtered through Whatman No. 42. Organic carbon was estimated taking the air dried sediment

TABLE 4.4: CHEMICAL COMPOSITION OF SEDIMENTS FROM SOLAR EVAPORATION POND I

Sampling point	pH	EC ms/cm at 25°C	Percent Dry Weight of Sediment							Organic carbon %
			Ca	Mg	Na	K	HCO_3	Cl	SO_4	
1	6.40	6.23	4.64	0.19	3.00	0.20	0.05	7.65	8.32	4.69
1a*	7.20	2.40	0.80	0.09	1.40	0.15	0.04	3.12	0.58	0.89
2	7.00	6.02	3.20	0.24	3.60	0.22	0.04	7.37	-	4.66
2a*	6.70	2.57	0.88	0.08	2.00	0.15	0.05	3.12	0.58	1.05
3	6.60	6.35	3.84	0.29	3.40	0.19	0.06	6.50	3.75	5.42
4	6.10	11.25	4.24	0.52	8.00	0.39	0.08	9.64	6.64	4.71
5	6.90	8.46	5.20	0.28	6.40	0.24	0.05	11.06	7.68	5.44
6	6.60	7.63	4.96	0.24	5.40	0.22	0.05	9.35	7.84	4.99
7	6.60	6.70	2.72	0.24	4.40	0.26	0.05	9.64	1.64	2.53

* Bottom portion of the sediment samples at sampling point 1 and 2 were separately collected and analysed. All others are composite sample

pH is measured in saturated paste of the sediment. EC, cations and anions are estimated in water extract of 1 part sediment to 40 parts water. Organic carbon is estimated on air dry sample.

TABLE 4.5: CHEMICAL COMPOSITION OF SEDIMENTS FROM SOLAR EVAPORATION POND II

Samp-ling point	pH	EC ms/cm at 25°C	Percent Dry Weight of Sediment							Organic carbon %
			Ca	Mg	Na	K	HCO_3	Cl	SO_4	
1	6.5	5.66	4.32	0.19	1.80	0.27	0.04	9.79	1.54	2.19
2	6.9	2.59	1.56	0.14	0.50	0.16	0.05	3.74	0.17	1.32
3	6.6	6.91	4.64	0.14	2.00	0.27	0.05	11.40	0.55	2.15
4	6.8	7.45	5.92	0.19	3.80	0.26	0.05	13.49	0.61	2.82
5	6.6	8.28	6.56	0.38	3.60	0.31	0.04	15.03	0.58	1.34
6	6.6	8.21	6.32	0.34	4.80	0.29	0.06	14.57	-	3.05
7	6.6	6.23	4.50	0.56	1.68	0.54	0.10	10.04	0.20	2.21

pH is measured in saturated paste of the sediment. EC, cations and anions are estimated in water extract of 1 part sediment to 40 parts water. Organic carbon is estimated on air dry sample.

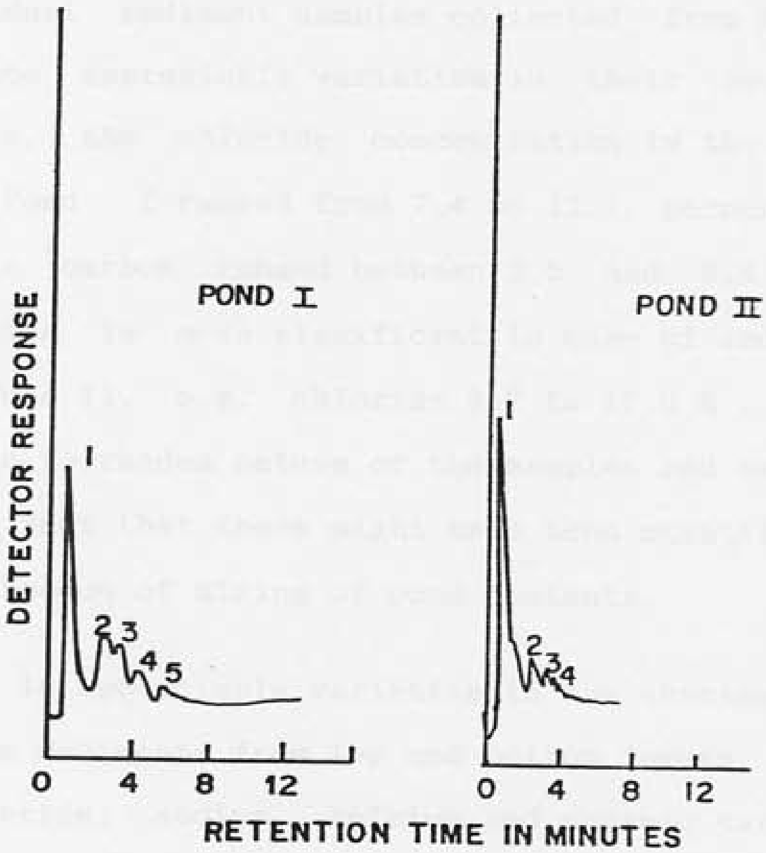


FIG. 4-6. HIGH PERFORMANCE LIQUID CHROMATOGRAM OF POND SEDIMENTS

the presence of sevin or alpha naphthol. Of the 5 peaks observed the peak 1 corresponds to benzene sulphonic acid. The other four peaks could not be identified. Data presented in Tables 4.4 and 4.5, on the chemical composition of individual sediment samples collected from Ponds I and II indicate appreciable variation in their composition. For example, the chloride concentration in the seven samples from Pond I ranged from 7.4 to 11.1 percent, while the organic carbon ranged between 2.5 and 5.4 percent. The variation is more significant in case of sediment samples from Pond II. e.g. chloride 3.7 to 15.0 % . This variation is due to random nature of the samples and may also be due to the fact that there might have been stratification due to near absence of mixing of pond contents.

There is appreciable variation in the chemical composition of the sediments from top and bottom layers. Concentration of chloride, sodium, calcium and organic carbon were lower in the bottom layer than in the top layer. For example in Pond I the bottom sediment layer at sampling points 1 and 2, the chloride level is 41 % of the value observed in the top layer. Similarly the corresponding organic carbon levels are 19 % and 23 % of the top layer, respectively. This indicates that the salts and organics present in the wastewater got deposited mostly in upper portion of the pond sediment and did not percolate into deeper layers. Had there been a percolation through sediment into the soil layer over the FML, or intermixing between layers, the chemical composition of the top and bottom layers should have been nearly same.

It was reported by UCIL management that water level in the ponds never exceeded 2 m from the bottom. The soil on the side slopes would have absorbed contaminants. In order to assess the contamination on the pond's inside slopes, random samples to a depth of 15 cm were collected 1m above the pond bottom and composited. Similarly another set of random samples were also collected about 1.5 m below from top and composited. The data are presented in Table 4.6.

In general, the chloride level in the sediments from pond slopes was low (3-130 mg/kg) and sediments close to the bottom showed higher chloride content compared to top portion of the pond slope.

4.5 PIEZOMETERS

Fourteen piezometers were prepared within the fenced area of SEP at the time of their construction as shown in Figure 4.7 to monitor possible seepage, if any, from the ponds. The piezometers consisted of a MS pipe of 150 mm diameter driven to a depth of 4 meters. The water quality in the piezometers was monitored by UCIL and it was reported that water collected only in monsoon months. Analytical data on piezometer samples are not available with the management for reasons already explained in Chapter 1. During the present investigation, water had collected in the piezometers in the month of September 1989 and samples were collected to assess

TABLE 4.6: CHEMICAL COMPOSITION OF SOIL SAMPLES FROM POND SLOPES

Sample Description	pH	ECe mS/cm	Cations and Anions, meq/l						
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate
Pond I									
Top	7.9	0.58	1.2 (1.10)	1.6 (0.9)	3.28 (3.40)	0.13 (0.24)	2.2 (6.3)	4.0 (5.7)	0.29 (0.57)
Bottom	7.6	8.1	20.2 (21)	8.4 (5.4)	50.17 (60.2)	0.11 (0.23)	3.2 (10.5)	68.0 (138.5)	7.27 (19.2)
Pond II									
Top	7.9	0.51	2.4 (2.2)	2.4 (1.3)	1.16 (1.2)	0.03 (0.06)	1.8 (5.2)	3.6 (6.9)	0.11 (0.24)
Bottom	7.5	4.66	22.5 (20.4)	7.5 (4.2)	17.39 (18.3)	0.14 (0.26)	1.5 (4.8)	45.0 (75.6)	0.06 (0.13)
Pond III									
Top	7.7	0.55	1.6 (1.7)	3.2 (2.1)	0.44 (0.5)	0.04 (0.07)	1.5 (5.2)	1.6 (3.1)	2.24 (5.9)
Bottom	7.5	3.70	18.4 (19.1)	4.4 (2.8)	16.09 (19.3)	0.07 (0.15)	1.2 (3.9)	34.4 (56.0)	0.50 (1.32)

ECe - Electrical Conductivity of Saturation Extract at 25°C

Values in parenthesis indicate mg/kg, on dry weight basis.

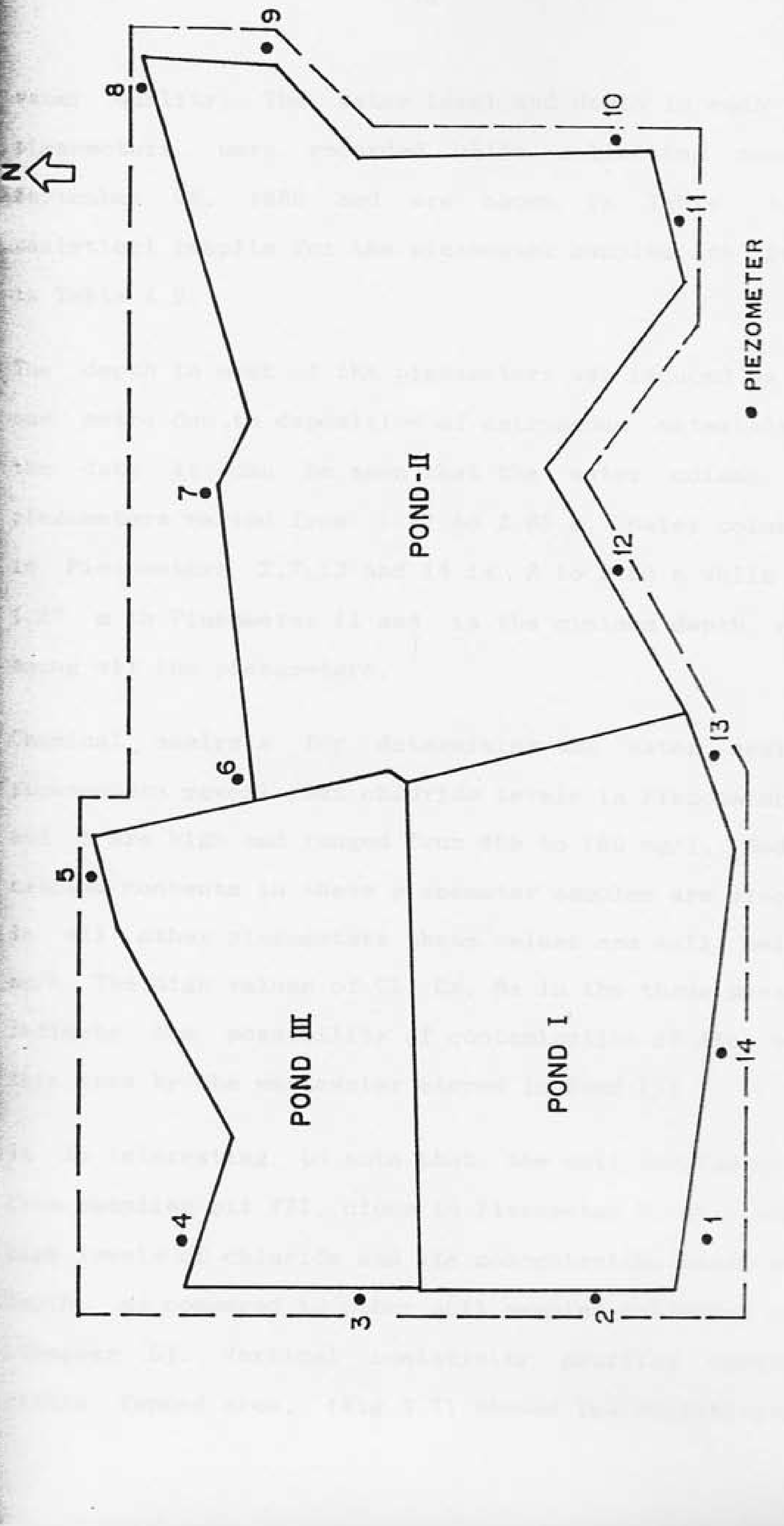


FIG.4.7: LOCATION OF PIEZOMETERS

water quality. The water level and depth in each of the piezometers were recorded while collecting samples on September 25, 1989 and are shown in Table 4.7. The analytical results for the piezometer samples are presented in Table 4.8.

The depth in most of the piezometers was reduced by nearly one metre due to deposition of extraneous materials. From the data it can be seen that the water column in the piezometers varied from 1.27 to 2.65 m. Water column depth in Piezometers 2,7,13 and 14 is 2 to 2.65 m while it is 1.27 m in Piezometer 11 and is the minimum depth recorded among all the piezometers.

Chemical analysis for determining the water quality in piezometers reveal that chloride levels in Piezometers 3, 4 and 5 are high and ranged from 605 to 780 mg/l. Sodium and calcium contents in these piezometer samples are also high. In all other piezometers these values are well below 100 mg/l. The high values of Cl, Ca, Na in the three piezometers indicate the possibility of contamination of the soil in this area by the wastewater stored in Pond III.

It is interesting to note that the soil samples collected from sampling pit VII, close to Piezometer 3, also contained high levels of chloride and its concentration increased with depth, as compared to other soil samples collected near SEP (Chapter 5). Vertical resistivity profiles carried out within fenced area, (Fig.3.7) showed low resistivity near

TABLE 4.7: WATER LEVELS IN PIEZOMETERS AS ON 25TH SEPT. 1989

Piezometer	Water level from bgl (cms)	Water column (cms)	Total depth (cms)
1	90	187	277
2	35	216	251
3	50	184	234
4	65	180	245
5	80	160	240
6	125	155	280
7	67	200	267
8	125	170	295
9	114	165	279
10	128	165	293
11	155	127	282
12	65	190	255
13	66	245	311
14	40	265	305

TABLE 4.8: CHARACTERISTICS OF WATER SAMPLES FROM PIEZOMETERS

(All Values Except pH & EC are in mg/l)

Piezometer	pH	EC uS/cm	Calcium	Magnesium	Sodium	Potassium	Chloride	Nitrate-N	Sulphate	COD
1	7.0	488	32	34	36	1.2	33	BDL	15	8
2	7.8	260	30	10	16	1.2	15	BDL	8	8
3	7.2	1930	92	86	184	1.6	780	2.7	21	24
4	6.9	1740	224	55	104	1.4	635	1.8	14	24
5	7.1	1655	140	60	136	1.6	605	1.7	17	40
6	7.3	440	24	37	24	1.4	6	BDL	4	10
7	7.7	515	21	33	48	1.6	52	BDL	2	16
8	7.5	688	16	35	64	1.4	14	BDL	9	-
9	7.3	455	14	43	34	1.4	5	BDL	5	-
10	7.5	458	29	29	32	1.2	6	BDL	9	16
11	7.5	400	27	29	16	1.2	53	BDL	11	16
12	8.0	400	11	35	26	1.6	12	BDL	16	8
13	7.6	368	16	33	16	1.4	8	BDL	7	16
14	7.5	428	10	45	24	1.6	28	BDL	14	12

BDL - Below Detection Limit

piezometer 3,4 and 5 which again indicates that the soil in this area has high conductivity due to inorganic salts present in the soil moisture.

Thus the results of electrical resistivity, soil chemical characteristics and water samples from piezometers reveal that the area near piezometer 3 to a stretch of 40-60 meters in length was contaminated due to spillage or seepage of wastewater from Pond I and/or Pond III when they were in operation. Similarly the high chloride levels in Piezometers 4 and 5 also suggest spillage/seepage from Pond III. The other possible explanation for high chloride in Piezometers 4 and 5 is that the subsurface water from the area of Piezometer 3 might have seeped into Piezometers 4 and 5 through the nalla which was existing in this area but now covered and cannot be seen on the surface of the soil.

Hence it is concluded that the soil within the fenced area on the western and northern sides of Pond III is contaminated by the pond water through spillage/seepage and requires treatment.

4.6 MIGRATION OF POLLUTANTS FROM SEP

The pollutants present in the ponds could escape through air, land and water environments. The volatile organic compounds that are likely to be present in the wastewater from the factory are chloroform and carbon tetrachloride, which were used as solvents for chemical reactions, besides methylamine used for making MIC. The chlorinated solvents are recovered and recycled in the processes. However some quantity might enter the wastewater stream and reach SEP. Similarly some quantity of methyl amine could also be present in the wastewater and reach the SEP. These compounds because of their high volatile nature can not remain for long duration and get released into the surrounding atmosphere. Analysis of pond water samples did not show the presence of the three organic compounds. Further enquiry from the people residing in nearly hutments revealed that there is no odour problem in the last five years. Hence no volatile organics are present in the pond leading to air pollution.

The other routes include overflow of pond contents onto surrounding land leading to contamination of soil and ground water. From the physical examination of the pond embankments it is clear that the pond water did not overflow, as a free board of 1.3 to 3.6 m was maintained. Spillage near SEP could occur when the contents of Ponds I and II were transferred to Pond III by pumping.

One of the major routes for pollutants migration from solar evaporation ponds into environment is through seepage into ground water. The major pollutants in the pond waters are inorganic salts, viz. chloride of calcium and sodium. These being highly soluble can reach ground water through seepage of pond water from points/places where the liner is damaged or not properly laid or jointed. The soil below the liner being plastic clay with the hydraulic conductivity less than 1.0 mm per hour, it acts as a barrier to the seepage from the ponds. However, any seepage would ultimately reach the unconfined aquifer below SEP and travel along with ground water flow and contaminate the wells in its flow path. The contamination of confined aquifer is not possible due to the presence of clay for a depth of nearly 20 m and the bed rock at more than 40 m depth. It is, therefore, decided to study the quality of ground water in the unconfined aquifer and soils near SEP to assess the extent of contamination due to storage of wastewater in solar evaporation ponds.

5.0 LAND ENVIRONMENT

5.1 INTRODUCTION

Studies were undertaken to characterise and describe the land environment and various components in terms of land use and cropping pattern, physical, chemical and microbiological properties of soils near SEP area. The land use pattern of the study area is shown in Fig.5.1. In general, the land use pattern in the study area is as follows:

Residential	25 to 30%
Irrigated land	35 to 40%
Fairly dense shrubs	25 to 30%
Barren land	4 to 5%
Lakes and nallas	3 to 4%

Nearly 70% of the population in the area live in Bhopal city and its suburbs. Higher population density is observed in the old city area and relatively low in the newly constructed townships such as TT nagar, Arera Colony, Shyamala hills, etc. While residential colonies are fast coming up in the southern side of the city there is relatively no construction activity on the northern side. Residential colonies are also coming up on the slopes of hillocks.

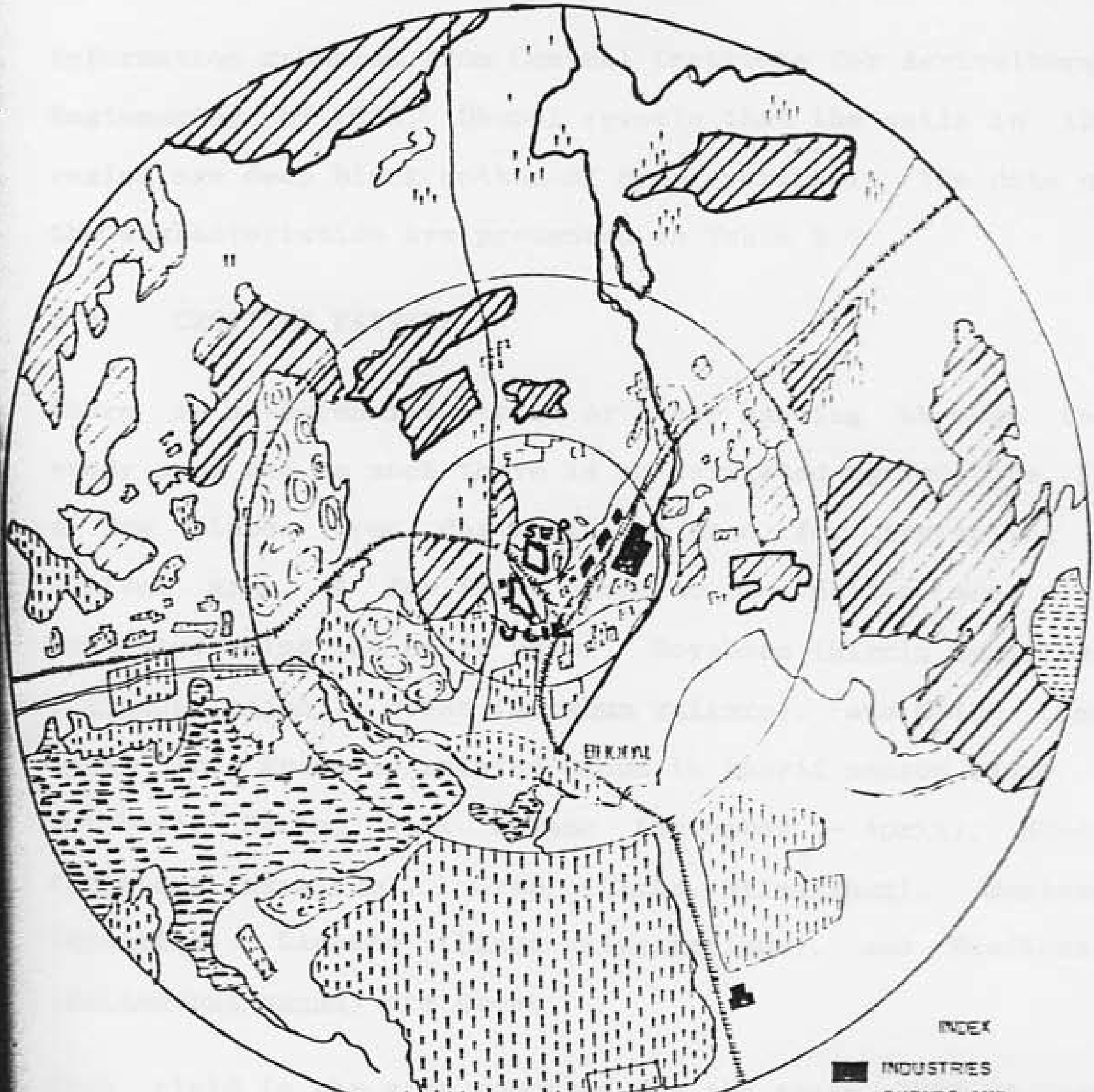


FIG. 5·1 LAND USE PATTERN OF STUDY AREA

5.2 PHYSICO-CHEMICAL SOIL CHARACTERISTICS

Information gathered from Central Institute for Agricultural Engineering of ICAR, Bhopal reveals that the soils in the region are deep black cotton of order vertisol. The data on the characteristics are presented in Table 2.1.

5.3 CROPPING PATTERN

There is no perennial stream or river passing through the study area and as such there is no irrigated agriculture. In a few places open dug wells are used for irrigating a limited area. A few farms close to the nallas are also irrigated using the nalla water. Soyabean (Glycin max), Pea (Cajanus cajan), Jowar (Sorghum vulgare), and Maize (Zea mays) are grown as rainfed crops in kharif season (June - October). During rabi season (November - April), Wheat (Triticum aestivum), Gram (Cicer arientinum), Mustard (Brassica), Linseed (Linun usitatissimum), and Sunflower (Helianthus annus) are grown.

Crop yield in the area reported for the years 1982-83 and 1984-85 is presented in Table 5.1 and compared with the All India average yield for the crops. The yield data for different crops in the region were much higher than the All India average values showing that there were no adverse effects on the growth of crops even when UCIL was in operation. During the study period, enquiries made with the farmers near SEP area also revealed that there was no change in the cropping pattern and yield either when UCIL was in operation or after its closure in 1984. It is also observed that all the agricultural lands near SEP during 1989 kharif season were lush green.

TABLE 5.1 : CROP YIELD IN THE STUDY AREA
(Kg/ha)

Crop	Bhopal		All India Average	
	1982-83	1984-85	1982-83	1983-84
Wheat	889	1113	663	635
Maize	1012	1358	122	142
Jowar	1034	1418	271	273
Soyabean	598	763	-	-
Mustard	420	604	-	-
Gram	602	785	126	114
Tur	621	970	-	-

5.4 LAND QUALITY NEAR SEP

The Solar Evaporation Ponds are about 800 m away from the factory on the north and the area is fenced by a wall made of concrete slabs to prevent intrusion from outside. The area is even now guarded and the entry is restricted. The neutralised wastewater was pumped through an underground HDP pipe from the factory and let into Ponds I and II directly. It was reported that Pond III was used, whenever need arose, by pumping water from Ponds I or II. The total fenced area of SEP is nearly 14 hectares.

Studies on SEP indicated that chances for seepage from ponds are very remote. However, seepage from ponds if occurred or spills during pumping of water from Ponds I and II into Pond III, could contaminate soil near SEP. In order to evaluate the extent of land pollution, if any, due to waste disposal activities at SEP, soil samples from the area between the pond embankment and the fence, outside the fence and from test borewells were collected for physico-chemical analysis. The location of sampling pits is shown in Figure 5.2.

5.4.1 Soil Sampling

Pits of 1m x 1m x 1.2 m were dug to collect profile samples. Four pits (I to IV) about 10-15 m away from and outside the fence and three pits (V-VII) between the pond embankment and fence were prepared and samples collected at every 30 cms depth. A low resistivity of 1.5-2 ohm-m was recorded near Piezometer 3 on the western side of Pond III within the fenced area. This was anticipated due to the spillages of pond contents near Piezometer 3 when pond contents of I or II are pumped for storage in Pond III. Soil samples from Pit VII provide the necessary information to verify the findings reported in Chapter 3. Soil samples from different depths collected during drilling of the test bore wells are used for determining the lithology of the area as well as the chemical characteristics of the soil.

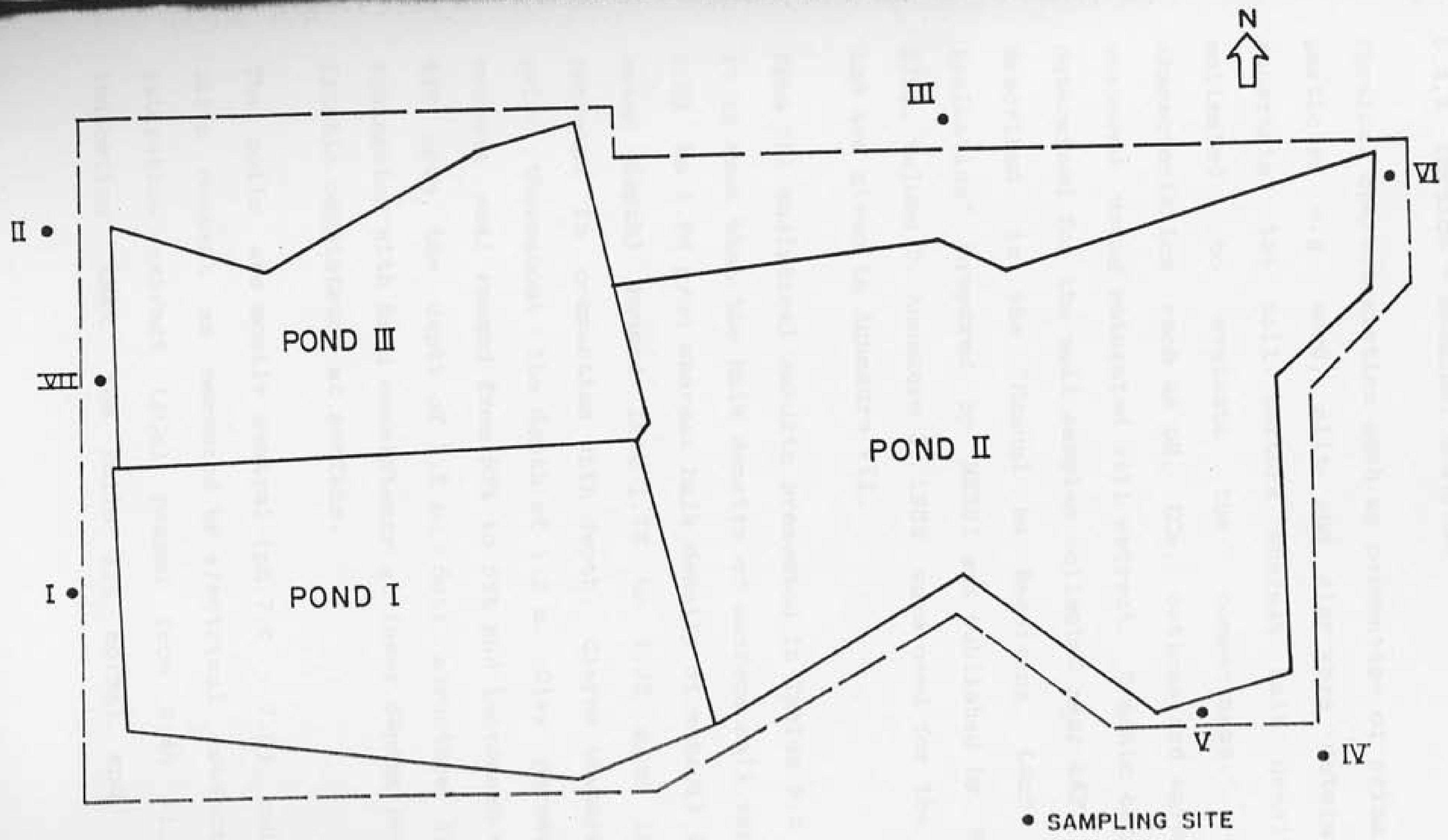


FIG.5·2 LOCATION OF SOIL SAMPLING SITE AROUND SEP

5.4.2 Physico - chemical Analysis

Physical characteristics such as percentage of primary soil particles e.g. sand, silt and clay were determined to ascertain the soil texture whereas bulk density was estimated to evaluate the compactness. Chemical characteristics such as pH, ECe, cations and anions were measured using saturated soil extract. Organic carbon was determined for the soil samples collected near SEP. Methods described in the "Manual on Receiving Land Quality Evaluation" prepared by NEERI and published by UNEP and SIDA, Volume 2, Annexure 3, 1989 were used for the analysis and are given in Annexure VII.

From the analytical results presented in Tables 5.2 to 5.5, it is seen that the bulk density of surface soil varied from 1.58 to 1.68 g/cc whereas bulk density of subsoil (at 1-1.2 meter depth) ranged from 1.78 to 1.92 g/cc indicating increase in compaction with depth. Clayey textured soils exist throughout the depth of 1.2 m. Clay percentage in surface soil ranged from 53% to 55% and increased to 57% - 64% upto the depth of 1.2 m. Soil structure is blocky subangular with hard consistency at lower depths compared to friable consistency at surface.

The soils are mostly neutral (pH 7.0 - 7.6) and soluble salts content as measured by electrical conductivity of saturation extract (ECe) ranged from 0.46 -1.2 mS/cm, indicating that the soils are normal and are not

TABLE 5.2 : PHYSICAL PROPERTIES OF SOIL AROUND SOLAR EVAPORATION POND AT UCIL

Soil depth, cm	Sand %	Silt %	Clay %	Textural class	Bulk density g/cm^3
Pit I					
0-22	18.25	24.37	51.80	clay	1.62
22-45	18.10	23.60	53.70	clay	1.68
45-98	16.40	22.80	58.10	clay	1.73
98-123	17.10	23.15	58.60	clay	1.78
Pit II					
0-23	14.60	28.90	51.25	clay	1.58
23-68	16.45	27.20	51.85	clay	1.58
68-103	15.45	26.15	54.05	clay	1.76
103-127	18.12	21.45	63.85	clay	1.81
Pit III					
0-22	18.40	24.65	54.40	clay	1.61
22-51	14.60	28.45	51.30	clay	1.67
51-93	16.40	23.85	56.25	clay	1.83
93-112	19.40	21.62	57.12	clay	1.82
Pit IV					
0-20	13.76	26.15	54.85	clay	1.68
22-60	15.80	24.85	57.10	clay	1.80
60-103	14.30	29.45	55.15	clay	1.80
103-124	14.40	26.80	58.70	clay	1.92

TABLE 5.3 : CHEMICAL COMPOSITION OF SOILS OUTSIDE SIP FENCE

(All values except pH, ECe, and Organic carbon are in meq/l)

Soil depth, cm, bgl	pH	ECe (mS/cm)	Saturation Extract							Organic carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate	
Plot I										
0-22	7.0	0.572	4 (38.0)	1 (5.7)	0.4655 (5.1)	0.145 (1.3)	0.5 (14.5)	3 (50.5)	2.3 (52.0)	0.56
22-65	7.1	0.463	4 (32.0)	0 -	0.4238 (3.9)	0.079 (0.6)	1.5 (36.6)	3 (42.5)	0.3 (6.5)	0.36
65-98	7.0	0.597	4 (32.0)	1 4.8)	0.8260 (7.6)	0.1053 ((0.8)	1.5 (36.6)	4 (56.7)	0.5 (9.6)	0.36
98-123	7.1	0.565	3 (24.0)	1 (4.8)	1.4565 (13.4)	0.0658 (0.5)	1.5 (36.6)	4 (56.7)	0.4 (7.7)	0.31
Plot II										
0-23	7.1	0.613	3 (24.0)	2 (9.6)	0.9238 (8.5)	0.171 (1.3)	1.0 (24.4)	5 (70.9)	0.24 (4.0)	0.57
23-60	7.1	0.485	3 (24.0)	1 (4.8)	0.3805 (3.5)	0.0658 (0.5)	1.5 (36.6)	3 (42.5)	0.3 (6.5)	0.37
60-103	7.1	0.505	3 (24.0)	2 (9.6)	0.633 (6.1)	0.092 (0.7)	1.5 (36.6)	2 (28.3)	2.1 (40.3)	0.31
103-127	7.1	0.720	3 (24.0)	3 (14.4)	1.1088 (10.2)	0.0658 (0.5)	1.5 (36.6)	5 (70.9)	0.4 (7.7)	0.30

Contd.

pth, bgl	pH	ECe (mS/cm)	Saturation Extract Calcium	Magnesium	Sodium	Potassium	Bicarb-onate	Chloride	Sulphate	Organic carbon %
III										
-22	7.6	1.202	9 (99.0)	1 (6.6)	1.1822 (14.9)	0.211 (2.2)	1.5 (50.3)	8 (113.4)	1.3 (34.3)	0.43
22-51	7.0	0.875	6 (48.0)	0.8 (3.8)	1.4348 (13.0)	0.092 (0.7)	1.0 (24.4)	6.1 (86.0)	0.3 (5.8)	0.35
51-83	7.2	0.738	3 (24.0)	2 (9.6)	2.1088 (19.4)	0.0528 (0.4)	1.5 (36.6)	5 (70.9)	1.0 (19.2)	0.30
-112	7.1	1.126	7 (56.0)	2 (9.6)	1.4047 (12.9)	0.1406 (1.3)	1.3 (35.7)	9 (128.0)	0.9 (17.3)	0.30
IV										
-22	7.6	0.565	3 (30.0)	2 (12.0)	0.3368 (3.8)	0.092 (0.9)	1.5 (45.3)	3 (53.1)	0.8 (19.0)	0.57
22-60	7.3	0.574	3 (24.0)	1 (4.8)	0.9020 (8.2)	0.0832 (0.6)	1.5 (36.6)	4 (56.7)	0.5 (9.6)	0.40
-103	7.2	0.640	4 (32.0)	1 (4.8)	1.0435 (9.6)	0.0788 (0.5)	1.5 (36.6)	4 (56.7)	0.8 (15.4)	0.35
-124	7.1	0.515	3 (24.0)	1 (4.8)	0.9020 (8.2)	0.0788 (0.5)	1.5 (36.6)	4 (56.7)	0.2 (3.8)	0.30

- Electrical Conductiavity of Saturation extract at 25°C

- below ground level

in parenthesis indicate mg/kg on dry weight basis

TABLE 5.4 : CHEMICAL COMPOSITION OF SOILS INSIDE SEP FENCE

(All values except pH, ECe and Organic Carbon are in meq/l)

	pH	ECe (mS/cm)	Saturation Extract							Organic Carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate	
	7.0	1.480	6 (60.0)	5 (30.0)	2.696 (31.0)	0.0282 (0.55)	1 (30)	13 (230)	0.5200 (124)	0.54
	7.0	0.447	3 (27)	1 (5.4)	0.8044 (8.3)	0.0077 (0.134)	1 (27)	3 (47)	0.2038 (4.5)	0.34
	7.0	0.471	3 (56)	1 (4.8)	0.674 (6.2)	0.0154 (0124)	1 (24)	4 (57)	0.1562 (0.5)	0.32
	6.7	0.462	3 (27)	1 5.4)	0.6394 (6.5)	0.0128 (0.23)	1 (27)	3 (47)	0.1041 (2.2)	0.51
	6.8	0.471	3 (24)	1 (4.8)	0.8044 (7.4)	0.0154 (0.24)	1 (24)	4 (57)	0.1562 (0.5)	0.32
	6.9	0.589	3 (30)	2 (12)	1 (11.5)	0.0205 (0.4)	1 (30)	4 (71)	0.5200 (124.9)	0.32

Contd.

[illegible]	pH	ECe (mS/cm)	Saturation Extract							Organic Carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate	
VII										
[illegible]	6.9	1.365	5 (45)	2 (10.8)	6 62.1)	0.0179 (0.31)	1 (27)	11 (175)	0.1041 (2.2)	0.59
[illegible]	6.8	2.265	7 (70)	6 (36)	7.91 (90.9)	0.0256 ().5)	2 (61)	20 (354)	0.1562 (3.7)	0.40
[illegible]	6.8	2.490	5 (40)	7 (33.6)	10.24 94.2)	0.0307 (0.48)	2 (48)	22 (312)	0.7812 (14.9)	0.30
[illegible]	7.6	3.436	7.6 (74)	4.6 (27)	19.912 (224)	0.3076 (6)	1.2 (37)	32 (576)	0.521 (12.9)	
[illegible]	7.8	3.706	6.8 (62)	6.6 (37)	21.56 (226)	0.205 (4)	0.8 (243)	32.8 (551)	0.417 (9.6)	
[illegible]	7.9	3.140	3.6 (42)	5.2 (37)	20.956 (283)	0.512 (1.2)	1.2 (37)	29.6 (633)	0.625 (18.5)	

in parenthesis indicate in mg/kg on dry weight basis

- Electrical Conductivity of Saturation extract

- below ground level

TABLE 5.5 : CHEMICAL COMPOSITION OF SOILS FROM TEST BORE WELLS

(All Values except pH, ECe, and Organic Carbon are in meq/l)

pth, bgl	pH	ECe (mS/cm)	Saturation Extract							
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate	Organic Carbon %
well 1										
1	7.2	0.495	1.5 (9)	1.3 (6.2)	2.05 (18.8)	0.0312 (0.7)	1.25 (30.5)	3.5 (62.1)	0.03 (0.72)	0.45
3	7.6	0.430	1.2 (7.2)	1.0 (3.3)	2.10 (19.3)	0.0432 (0.97)	0.65 (17.8)	2.8 (49.7)	0.8 (19.2)	0.34
5	7.5	0.590	2.0 (12.0)	1.5 (7.2)	2.32 (21.3)	0.0206 (0.45)	1.55 (45.7)	4.0 (70.9)	0.104 (2.5)	0.24
6	7.4	0.560	1.8 (10.0)	1.5 (7.2)	2.21 (20.2)	0.0641 (1.4)	0.80 (21.3)	3.5 (62.1)	1.4 (26.8)	0.30
Well 2										
1	7.6	0.540	1.5 (9.0)	1.2 (5.7)	2.54 (23.3)	0.0312 ((0.7)	1.25 (30.5)	3.8 (67.4)	0.5 (12.0)	0.42
	7.8	0.570	1.8 (10.8)	1.2 (5.7)	2.54 (23.3)	0.0845 (1.9)	1.05 (32.0)	3.5 (62.1)	1.2 (28.8)	0.32
	7.8	0.470	1.3 (7.8)	1.1 (5.3)	2.21 (20.2)	0.0206 (4.5)	0.80 (21.3)	2.5 (44.3)	1.5 (12.0)	0.27
	7.9	0.560	1.6 (9.6)	1.4 (6.7)	2.54 (23.3)	0.0432 (0.97)	0.80 (21.3)	3.5 (62.1)	1.2 (28.8)	0.30
Well 3										
	7.4	0.460	1.5 (9.0)	1.0 (3.3)	2.0 (18.36)	0.0512 (1.15)	1.05 (32.0)	3.5 (62.1)	0.5 (12.0)	-
	7.3	0.510	1.8 (10.8)	1.0 (3.3)	2.05 (18.8)	0.0832 (1.9)	1.05 (32.0)	4.0 (70.9)	0.52 (12.5)	-
	7.6	0.520	1.8 (10.8)	1.0 (3.3)	2.54 (23.3)	0.0432 (0.97)	1.0 (24.4)	4.0 (70.9)	0.3 (7.2)	-
	7.7	0.540	2.0 (12.0)	1.0 (3.3)	2.32 (21.3)	0.0614 (1.4)	1.00 (24.4)	4.0 (70.9)	0.3 (8.4)	-

Contd..

	pH	ECe (mS/cm)	Saturation Extract							Organic Carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarb-onate	Chloride	Sulphate	
Well 4										
1	7.4	0.697	2.0 (12.0)	2.0 (9.6)	1.64 (15.1)	-	1.25 (30.5)	3.0 (53.9)	1.3 (24.9)	0.48
2	7.3	0.950	5.0 (40.0)	3.0 (14.4)	1.10 (10.1)	-	1.00 (24.4)	7.0 (99.3)	1.2 (23.0)	0.28
3	7.4	0.712	2.5 (20.0)	1.5 (7.2)	2.73 (25.1)	-	1.25 (30.5)	4.0 (56.7)	1.5 (28.8)	0.30
4	7.4	0.675	3.0 (24.0)	1.0 (48.0)	1.94 (17.8)	-	1.0 (24.4)	4.5 (63.8)	0.8 (15.8)	0.28
Well 5										
1	7.6	0.400	1.0 (10.0)	2.0 (12.0)	0.9348 (10.7)	0.0192 (0.4)	1.0 (30.5)	2.5 (44.0)	0.5 (12.0)	0.50
2	7.8	0.960	2.0 (12.0)	2.0 (9.6)	4.02 (37.0)	-	1.00 (24.4)	6.0 (85.1)	1.3 (24.9)	0.30
3	7.2	1.065	3.5 (28.0)	4.5 (21.6)	1.34 (12.3)	-	1.5 (36.6)	7.5 (103.6)	0.8 (15.3)	0.40
4	7.6	1.115	4.0 (32.0)	2.0 (9.6)	4.73 (43.5)	-	1.25 (30.5)	8.0 (113.4)	1.3 (24.9)	0.32
Well 6										
1	8.0	0.660	3.5 (42.0)	-	2.891 (39.9)	0.0705 (1.6)	3.0 (109.8)	3.0 (63.9)	0.6 (17.3)	0.47
[illegible]	8.2	0.667	0.2 (26.0)	1.0 (3.3)	3.3696 (50.3)	0.0897 (2.3)	1.5 (59.4)	5.0 (15.0)	0.5 (15.5)	0.30
[illegible]	8.4	0.710	3.0 (51.0)	-	3.0896 (60.4)	0.1538 (5.1)	2.0 (103.7)	5.0 (151.0)	1.0 (40.8)	0.34
[illegible]	8.3	0.840	6.0 (114.0)	-	2.4348 (5.3)	0.0513 (1.9)	2.0 (115.9)	6.0 (202.0)	0.4 (18.2)	0.30

Contd..

	pH	ECe (mS/cm)	Saturation Extract							Organic Carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate	
Well 7										
	7.6	0.581	3.0 (30.0)	1.7 (10.2)	0.8427 (9.6)	0.041 (0.8)	1.5 (45.7)	3.5 (62.1)	0.6 (14.4)	-
	7.3	0.887	4.0 (32.0)	3.0 (14.4)	1.3 (10.1)	-	1.5 (24.4)	7.0 (99.3)	0.2 (3.0)	-
	7.6	0.534	3.0 (30.0)	1.5 (9.0)	0.5978 (6.8)	0.0320 (0.6)	2.0 (61.0)	2.0 (35.5)	0.8 (19.2)	-
	7.8	0.322	2.0 (20.0)	0.5 (3.0)	0.6304 (7.2)	0.0513 (1.0)	1.0 (30.5)	1.5 (26.6)	1.0 (24.0)	-
Well 8										
	7.8	0.465	3.5 (35.0)	-	0.4674 (5.3)	0.0641 (1.2)	1.5 (24.0)	3.3 (58.0)	0.2 (4.8)	0.50
	7.8	0.690	3.0 (36.0)	2.0 (14.0)	1.5217 (21.0)	0.0513 ((1.2)	2.0 (73.2)	3.5 (74.0)	1.0 (28.0)	0.38
	7.8	0.558	2.5 (25.0)	1.8 (10.8)	0.9945 (11.4)	0.0545 (1.1)	1.5 (45.7)	3.2 (56.8)	0.9 (21.6)	0.30
	7.7	0.426	2.0 (22.0)	1.5 (9.9)	0.4674 (5.9)	0.0577 (1.2)	1.0 (33.5)	3.0 (58.0)	0.7 (18.5)	0.30
Well 9										
	7.9	0.538	4.5 (54.0)	-	1.4456 (19.9)	0.0513 (1.9)	1.5 (54.9)	3.5 (74.0)	0.8 (23.0)	-
	7.1	0.950	5.0 (40.0)	4.0 (19.2)	1.02 (9.4)	-	1.0 (24.4)	7.0 (99.3)	1.4 (26.0)	-
	7.1	0.743	3.5 (28.0)	4.0 (19.2)	0.07 (0.6)	-	0.75 (18.3)	6.0 (85.1)	0.6 (11.5)	-
	7.8	0.465	3.0 (33.0)	0.5 (3.3)	0.5543 (7.0)	0.0448 (0.9)	1.5 (50.0)	3.0 (58.0)	0.3 (7.9)	-

Contd..

	pH	ECe (mS/cm)	Saturation Extract							Organic Carbon %
			Calcium	Magnesium	Sodium	Potassium	Bicarb-onate	Chloride	Sulphate	
ll 10										
	7.7	0.735	4.0 (44.0)	2.0 (13.0)	1.522 (14.6)	0.1842 (1.9)	2.0 (67.0)	5.0 (97.0)	0.24 (6.3)	0.44
	7.6	0.750	6.0 (66.0)	-	1.5 (18.9)	0.1182 (1.2)	2.5 (83.3)	3.5 (68.0)	1.4 (36.9)	0.40
	7.7	0.640	3.5 (38.0)	2.0 (13.0)	1.1304 (14.3)	0.1182 (1.2)	1.5 (50.0)	5.0 (97.0)	0.5 (13.2)	0.30
	7.9	0.735	2.0 (24.0)	3.5 (25.0)	1.891 (26.1)	0.1361 (1.5)	2.5 (91.5)	4.5 (96.0)	0.6 (17.3)	0.30

-Electrical Conductivity of Saturation Extract at 25°C

-below ground level

in parenthesis indicate mg/kg on dry weight basis contaminated with inorganic pollutants. Concentration of sodium (0.38-2.11 meq/l) and chloride (2.0-9 meq/l) in the soils further confirmed that the soils are not contaminated.

Data on organic carbon content of soil profile samples around SEP area indicate that it decreased with depth (surface to 1.2 m depth - 0.57% to 0.30%). The organic carbon content in pit soils from inside and outside the SEP fenced area did not show appreciable variation except that surface sample from Pit VII was slightly high i.e 0.59% as compared to 0.51 to 0.54% in other samples. The variation in percent organic carbon in different types of soils is shown below:

Type	Percent Organic Carbon
Uncultivated soil	0.25 - 0.50
Cultivated soil without heavy organic manure	0.50 - 0.80
Forest soil	1.50 - 3.00

(Organic matter is computed by multiplying organic carbon with a factor of 1.72).

The organic carbon percentage in the soils from SEP area compare well with that of uncultivated soil which supports that the soils in this area are not contaminated from the wastewater impounded in SEP.

The results presented in Table 5.4, for soils collected from inside the fenced area of SEP show that they are slightly acidic to neutral in pH (pH 6.7 - 7.0). Soluble salts in soils from Pits V and VI compare well with the corresponding values for soil outside the fence. However, the soil from Pit VII located close to the bund separating Ponds I and III on the west of SEP and Piezometer 3 showed high concentration of soluble salts; sodium (6.00 - 10.24 meq/l) and chloride (11.0 - 22.00 meq/l) upto the depth of 1.0 m. As the concentration of inorganics was increasing with depth, soils samples upto a depth of 2.0 m from Pit VII were collected and analysed. The data showed an increase in salt content as measured by (ECe 3.14 - 3.71 mS/cm), Na (19.91 - 21.56 meq/l), and Cl (29.6 - 32.8 meq/l). This observation indicates that there might have been some spillage of the pond water from Pond I while being transferred to Pond III or some seepage might have occurred from Pond I in this area. The resistivity study also revealed that about 40-60 m stretch between the fence and pond bund on the western side of Ponds I and III seemed to have been contaminated due to past activities at SEP. Since there was no evidence of increase in conductivity in the other surrounding areas it is concluded that this area alone should have been contaminated by spillage/seepage.

From the data given in Fig. 5.3, it is evident that the chloride concentration of soils at different depths from test bore wells is varying and show peaks with depth indicating homogenization of chloride by dispersion within the soil environment has probably not taken place. Similar findings are reported in a study on hydrogeochemistry of

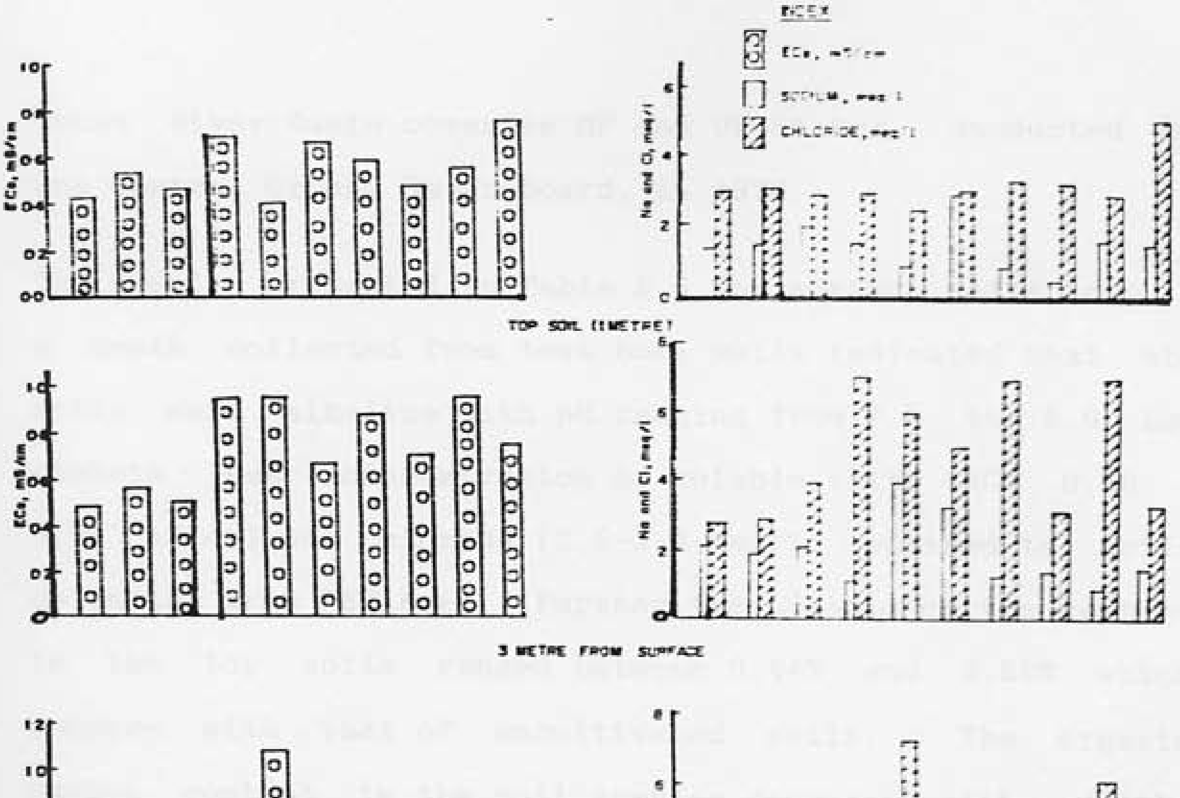


FIG. 5-3 CHEMICAL CHARACTERISTICS OF PROFILE SOIL SAMPLES FROM TEST BORE WELLS

Betwa River Basin covering MP and UP States, conducted by the Central Ground Water Board, in 1976.

The results presented in Table 5.5 for surface soils upto 1 m depth collected from test bore wells indicated that the soils were alkaline with pH ranging from 7.2 to 8.0 and contain lower concentration of soluble salts (ECe 0.40 - 0.74 mS/cm) and chloride (2.5-3.8 meq/l) compared to soils collected from SEP area. Further the organic carbon content in the top soils ranged between 0.44% and 0.50% which compare with that of uncultivated soils. The organic carbon content in the soil samples decreased with depth. These observations show that the soils within a radius of 2.5 kms particularly in the area where test bore wells are located are not contaminated by SEP.

ECe, sodium and chloride levels in surface soils collected from out side and inside of the SEP fenced area and test bore wells are shown in Figure 5.4 A comparison of the results indicated that all the surface soils except from Pit VII did not indicate any contamination due to impounded wastewater in SEP. As stated earlier the higher values of chloride in the top and subsoil around Pit VII appeared to have been due to spillage or through seepage from Pond I. It was also observed from the electrical resistivity data that the contamination was confined to a limited area between the Pond III embankment and fence on the west for a length of about 40-60 m.

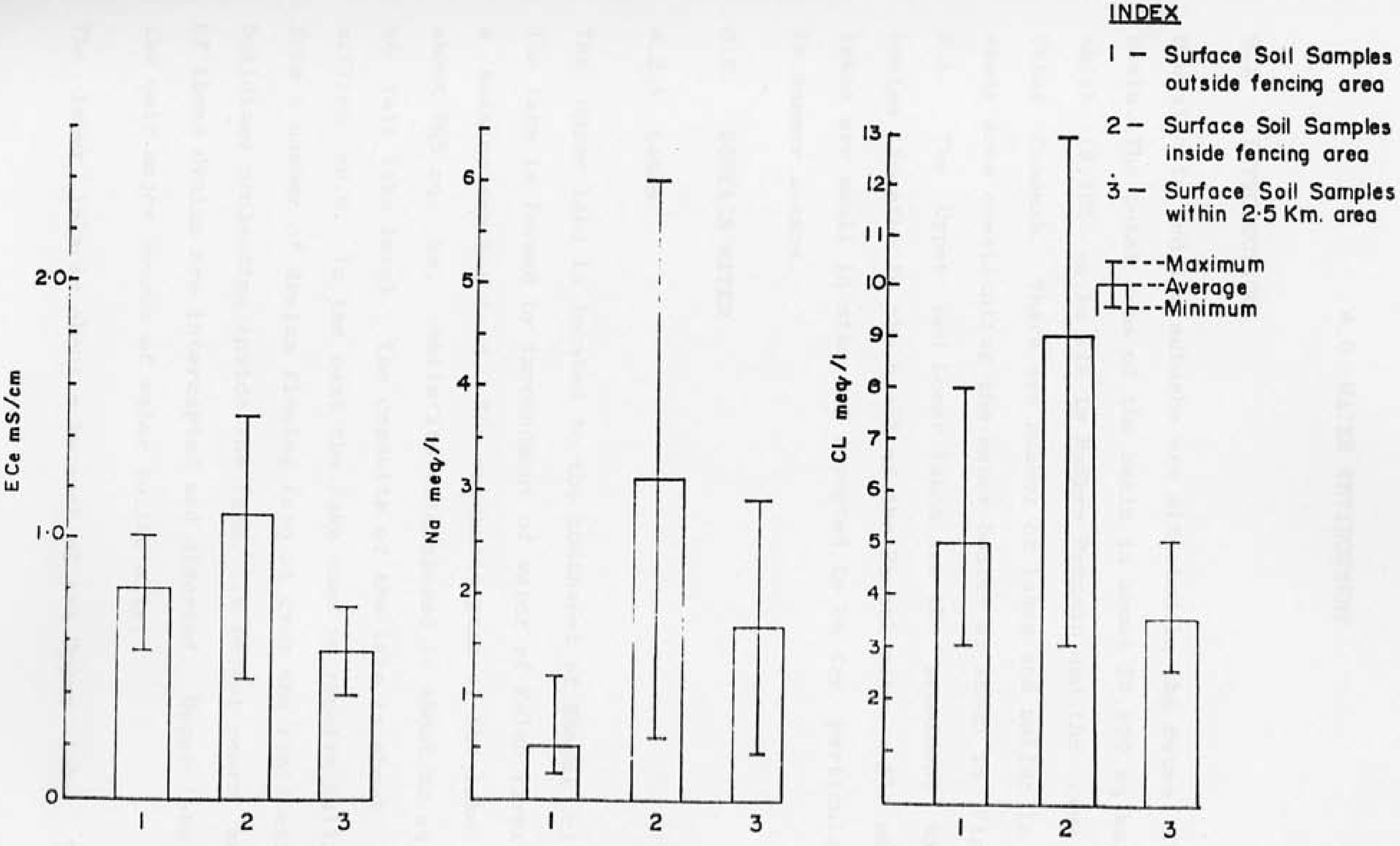


FIG. 5·4 CHEMICAL COMPOSITION OF SURFACE SOILS WITHIN 2·5 KM. RADIUS

6.0 WATER ENVIRONMENT

6.1 INTRODUCTION

Bhopal city and its suburbs are situated in the Betwa River basin. The total area of the basin is about 20,600 sq km, of which 19,425 sq.km lie in Madhya Pradesh and the rest in Uttar Pradesh. There are number of lakes and nallas in the study area constituting the water bodies as shown in Figure 6.1. The Upper and Lower lakes are the prominent water bodies located in the heart of the Bhopal city. All other lakes are small in size and reported to be dry particularly in summer season.

6.2 SURFACE WATER

6.2.1 Lakes

The upper lake is located to the southwest of Bhopal city. The lake is formed by impoundment of water of Kolan river by a massive earthen bund. The catchment area of the lake is about 365 sq. km, while its waterspread is about 32 sq.km at full lake level. The capacity of the lake is about 100 million cu.m. In the past the lake used to receive sullage from a number of drains flowing into it from the residential buildings projecting inside the lake. In recent years most of these drains are intercepted and diverted. Upper lake is the only major source of water to the city.

The lower lake is about a km east of the Upper lake. The

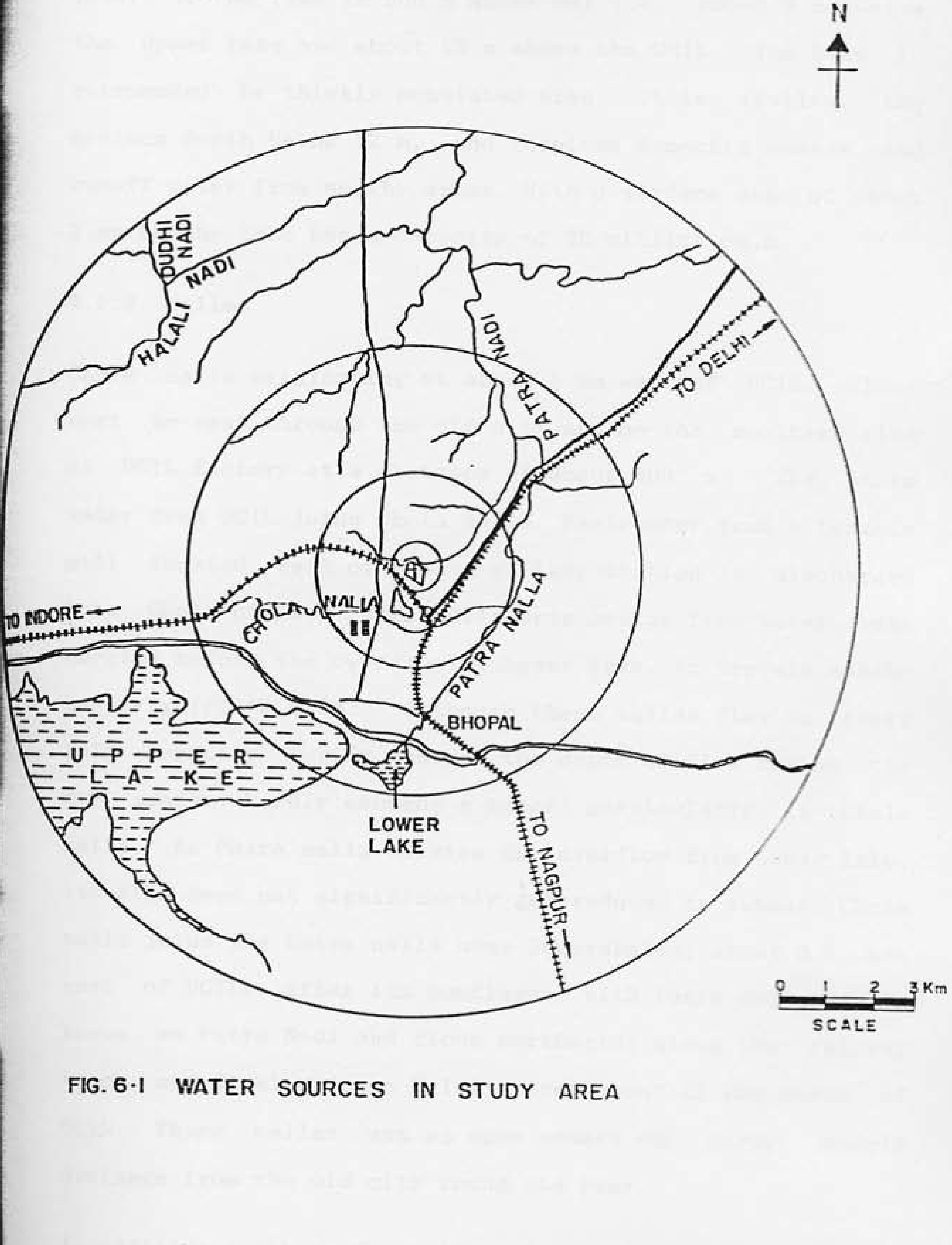


FIG. 6·1 WATER SOURCES IN STUDY AREA

level of the lake is 503 m above msl i.e. about 9 m below the Upper lake and about 15 m above the UCIL. The lake is surrounded by thickly populated area. It is shallow, the maximum depth being 12 m, and receives domestic sewage and runoff water from nearby areas. With a surface area of about 1 sq.km the lake has a capacity of 20 million cu.m.

6.2.2 Nallas

Chola nalla originating at about 5 km west of UCIL, flows west to east through the old city and on the southern side of UCIL factory at a distance of about 300 m. The storm water from UCIL joins Chola nalla. Wastewater from a textile mill located east of Bhopal railway station is discharged into Chola nalla. Patra nalla originating from Lower lake carries mainly the overflow of Lower lake. It travels north-easterly (Plate 6.1). Although these nallas flow to their full capacity during monsoon the depth of flow during the dry season hardly exceeds a meter particularly in Chola nalla. As Patra nalla carries the overflow from Lower lake, its flow does not significantly get reduced in summer. Chola nalla joins the Patra nalla near Semarakalan, about 2.5 kms east of UCIL. After its confluence with Patra nalla it is known as Patra Nadi and flows northwards along the railway track and finally joins Halali river about 12 kms north of UCIL. These nallas act as open sewers and carry mainly drainage from the old city round the year.

In addition to these two nallas, there are many small nallas

PLATE 6.1

PATRA NALLA

which are almost dry throughout the year except for a few days during rainy season. The nalla near SEP could hardly been seen except for a small stretch. This nalla joins wih Patra nadi at about 5 km N of SEP. Water samples from both the lakes and the two nallas were collected on a few occasions and analysed for physico-chemical parameters. The analytical results collected during the present study and the data collected earlier in December 1984 are presented in Table 6.1. The results show that there is no appreciable change in the water quality of the two lakes between December 1984 and July 1989. The concentration of chlorides, calcium and sodium in Chola nalla is nearly 2.5 times of Patra nalla. As both Upper and Lower lakes in the city are at an higher elevation (15 to 24 m above UCIL) compared to the UCIL area and the two nallas, any polluted water from the nallas or that from UCIL cannot reach the lakes. Further Chola nalla acts as a barrier between UCIL and the lakes. Thus contamination of the lake waters by the past waste dispoal activities of UCIL at SEP, is therefore, ruled out.

6.3 GROUND WATER

There are three important formations, namely, Vindhyans in the form of quartzites with their weathered mantle, Simple basaltic flows with massive unit overlain with highly porous vesicular unit and an alluvial cover of about 30-45 m overlying either of the rock formations. In this, the last formation is significant only in its bottom horizon with well defined weathered mantle of heterogeneous rock

TABLE 6.1: CHEMICAL QUALITY OF SURFACE WATER SOURCES IN BHOPAL

(All values except pH & EC are in mg/l)

Source	pH	EC mS/cm 25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Nitrate-N	Sulphate	TOC
Upper Lake										
December 1984*	8.0	190	24	5	7	2	8.0	0.5	6.0	1.3*
July 1989	8.8	145	18	11	5	1	9.0	2.6	0.8	4.5
Lower Lake										
December 1984	7.5	265	29	6	15	6	17	1.2	8.0	2.7•
July 1989	9.1	240	48	8.5	10	2	32.5	7.4	4.5	20
Chola nalla										
June 1989	5.8	-	137	59	101	49	328	12	43	40
Patra nalla										
June 1989	7.0	-	82	20	45	1.8	155	8.0	6.0	45

* Samples analysed in the first week of December 1984

• 4-hr permanganate value

Carbaryl and alpha naphthol in all samples collected in 1989 were below detection limits fragments with large voids, as the upper portion of it is in the form of a very poorly permeable membrane, although given a chance yellow clay may prove to be relatively better water carrier than the black clay.

Except for the occurrence of an impermeable massive unit encountered as a chance at any place the ground water is mostly of phreatic type, but the occurrence of confined or semi-confined condition under ideal situation cannot be ruled out. However, potential horizon lies in tapping either of the three formations with the weathered mantle in a hydraulic trough, and in case of basalt with the vesicular unit with or without a possible intertrappean bed to obtain maximum yield. In fact, hand pumps in the area are more or less tapping the same horizon with muscle power, but without tapping the full potential of the same. The clayey impermeable mantle in its Upper layer is poor to very poor and problematic in this particular area, because of its being of typical lacustrine origin.

Dug wells or power tube wells tapping the weathered mantle are capable of yielding 50-150 m^3/d even with poor construction, provided they are adequately developed. However, when exclusively confined to its upper mantle the yield is poor to problematic as the permeability is then reduced to its all time insignificantly low level of less than one mm/d.

The quality of water in the Vindhyans is generally good, but in the Deccan trap it is mostly of bicarbonates of calcium and sodium type; and this is also true of the alluvium/colluvium/clay zone, unless it is influenced with extraneous sources.

6.3.1 Ground Water Monitoring

In order to determine the extent of contamination of ground water due to seepage of impounded water in SEP, it is necessary to establish a network of monitoring wells. A properly designed network helps to compare the quality of well waters located on the up gradient and down gradient directions. The following aspects were taken into consideration while designing the monitoring network near SEP.

- geological setting around SEP
- topography
- hydrogeological framework
- electrical resistivity profiles
- quality of water from nearby dug and tube wells

There is considerable variation in the geological setting of the terrain. While the Vindhyan sandstone forms the hard base south of the Bhopal-Indore railway line, the emplacement of Deccan basalts are noticed in the SEP area with a notable fringe effect. The whole sequence has undergone weathering before coarser, pebbly, gravelly sediments could be overlain, which later gave rise to a blanket of yellow and/or black clay in a lacustrine deposition, interspread with gravels of identical composition with or without kankar. This aspect is picked up by the vertical electrical soundings (Chapter 3). The whole succession is then topped with a thin cover of black cotton soil of 1-2 m thickness.

Locally the ground surface has a gentle gradient from west to east on the western side of the SEP but generally speaking towards north and northeast.

The ground water table contours prepared by CGWB, Bhopal and discussions with the hydrogeologists suggest that the regional ground water flow is towards northeast. The electrical resistivity profile studies inside and outside the fenced area of SEP, indicated isoconductive zones aligned in north-easterly direction which incidentally coincide with the general regional hydraulic gradient of the area.

The whole top succession forms an effective membrane near SEP due to occurrence of a blanket of thick plastic clay overlain with a thin layer of black cotton soil with or without gravels of basalt and/or kankar. Hence there could hardly be any contamination to occur due to seepage of SEP contents. However, the monitoritng wells are still needed to determine the effects of any seepage especially in the prevailing ground water flow direction northeast, should it be of any consequence whatsoever.

As already explained in chapter 3, the geophysical investigations through electrical resistivity profile studies around SEP did not show any contamination of soils. Most of the existing wells within 2.5 kms radius of SEP are in the south and a few in the northeastern direction. Only two wells are located on the eastern side within 500 m of SEP. Initially, water samples were collected from these two wells and observed to be free from contamination by chlorides, calcium and sodium. The chloride level in the well waters to the northeast (1.5 km from SEP) also did not show any significant increase compared to the ground water quality in the region. The wells located on the south were not likely to get affected by SEP as these wells are upgradient to the prevailing ground water flow direction. Hence monitoring of existing wells did not as such reflect the impact due to any seepage from SEP. Further, no systematic data are available on the quality of water in and around Bhopal city, except for the dug wells monitored by the CGWB and the results are presented in Table 6.2 .

The results in Table 6.2 relate to samples collected in January, 1985 and 1987. The chemical characteristics of the water from the 10 wells were varying and wherever chlorides were high calcium levels were also generally high. The pH value of the well waters was in most cases below 7.0 which was expected for ground waters. No correlation was seen between sodium and chloride values. Nitrates were high in seven well waters suggesting pollution due to proximity

TABLE 6.2: DATA ON CHEMICAL CHARACTERISTICS OF DUG WELL WATERS WITHIN A RADIUS OF 4 KM FROM UCIL

(All values except pH and EC are in mg/l)

[illegible]	Distance from UCIL	pH	EC, mS/cm 25°C	Calcium	Magnesium	Sodium	Potassium	Total alkalinity	Chloride	Nitrate-N	Sulphate	Soil/Rock type
[illegible]	1.5 km WSW	6.8 (6.9)	230 (265)	24	6.1	13	2.5	67	25 (25)	6.2	9.6	Vindhyan sand stone
[illegible]	3.0 km	7.6 (7.4)	900 (940)	58	45	61	0.9	433	46 (67)	-	-	Deccan trap
[illegible]	1.5 km WSW	6.6 (6.9)	740 (845)	60	16	40	2.0	262	60 (74)	6.0	34	Vindhyan sand stone
[illegible]	4.0 km E	8.0 (7.1)	1130 (1250)	112	44	62	0.7	494	110 (131)	31	24	Shallow alluvium over Deccan trap
[illegible]	3.0 km ESE	6.7 (6.9)	1180 (1190)	128	46	60	0.7	433	113 (145)	28	58	Shallow alluvium over Vindhyan sandstone
colony	2.0 km SE	6.4 (6.8)	1235 (1250)	146	40	46	1.5	421	142 (128)	43	43	- do -
gate	2.5 km ESE	6.9 (6.8)	1285 (1250)	142	48	63	1.1	409	152 (149)	62	43	- do -
[illegible]	3.0 km NE	7.1 (7.0)	1480 (1070)	162	47	58	2.5	390	234 (128)	37	38	Vindhyan sandstone
camp	0.5 km S	6.4 (6.6)	1745 (1380)	186	56	66	1.2	342	337 (209)	43	34	- do -
[illegible] mill	1.5 km S	6.1 (7.4)	1560 (690)	158	49	115	0.9	494	206 (223)	105	48	- do -

in parenthesis are for the year 1987 and all others are for the year 1985.

of the two nallas. Further , there was apparently no correlation in the chemical quality of waters among the wells located in the same geological formation as the overlying alluvium is the main controlling factor.

In present study, samples could be collected in June 1989 only from four out of the ten dug wells monitored by CGWB, since four wells were dry and two wells could not be located. The chemical analysis data are presented in Table 6.3 . A comparison of the data presented in Tables 6.2 and 6.3 indicate that the chemical composition had not appreciably changed over five years but for slight increase in chloride and calcium in three wells. The increase could be due to the fact that the water samples collected in the present study were in summer (June), while the samples collected by CGWB were in winter (January). However chemical quality of well waters located in the same geological formations overlain with a blanket of alluvium had shown appreciable differences.

6.3.2 Monitoring Network

Considering the above situation, it was felt necessary to monitor the subsurface water in the northeastern direction of SEP following the prevailing ground water flow direction and also in the upgradient direction for obtaining background data. Initially three wells on the east and northeast, one each on the southeast and south of SEP within 500 m were constructed. One well was constructed

TABLE 6.3: CHARACTERISTICS OF DUG WELL WATERS WITHIN A RADIUS OF 4 KM FROM UCIL
(All Values Except pH and EC are in mg/l)

Location	pH	EC, mS/cm 25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Nitrate-N	Sulphate	TOC
Semrakalan	6.7	-	157	24	90	0.8	320	11	43	34
Railway colony	6.8	-	176	6	49	3.3	260	28	59	12
Bhanpura	6.5	1200	116	78	32	2.7	240	17	28	13
Kazi camp	6.4	1500	216	26	59	1.8	295	20	23	10

Samples collected in June 1989

about 750 m NW of SEP on the upgradient of the prevaling ground water flow direction to act as a control well. The network was subsequently expanded by adding two wells on the northeast, one on the east and one on the southwest aligned in such a way that these are downgradient to the wells located near SEP. One more well was also constructed in the middle of the study to collect data from the SW direction. The location of the test bore wells (TBW) totalling 11, is shown in Figure 6.2. Test bore wells could not be constructed on the northern and western direction to SEP as the area was under cultivation at the time of the study. However, electrical resistivity studies were carried out in this area.

In addition to these test bore wells, existing bore wells and dug wells were also identified in all directions for regular monitoring within 2.5 kms distance from SEP. The well locations are shown in Figure 6.3. In order to obtain background levels on water quality, monitoring of a few wells located in the area between 2.5 and 10 kms from SEP were also considered (Fig. 6.4). Thus a total of 93 wells including the test bore wells, were chosen for sample collection and analysis in the study.

6.3.3 Test Bore Wells Construction

The construction of test bore wells was undertaken through a professional contractor. The drilling equipments were thoroughly cleaned before construction of each well to avoid

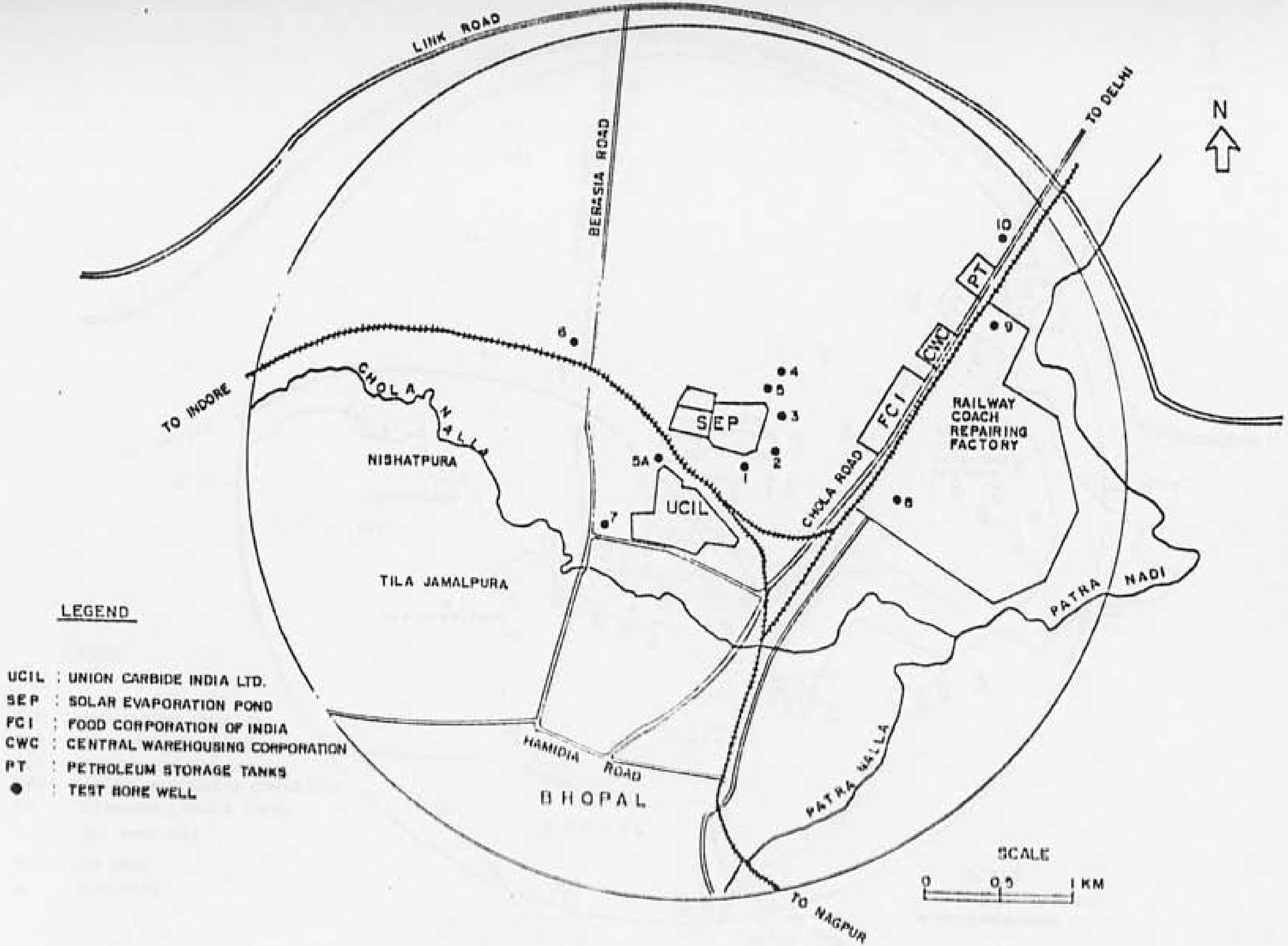


FIG. 6.2 LOCATION OF TEST BORE WELLS

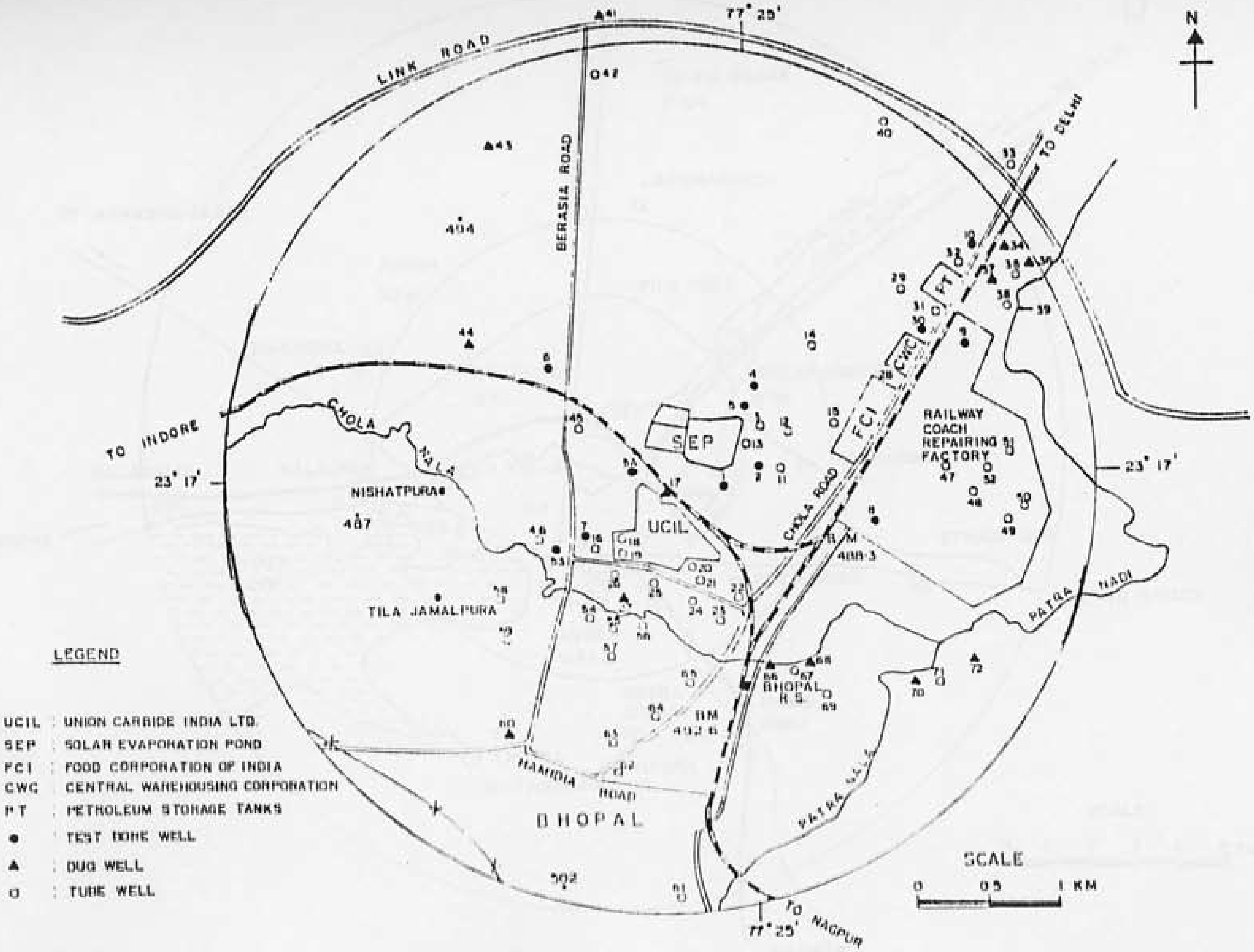


FIG. 6·3 · LOCATION OF MONITORING WELLS WITHIN 2·5 Km. RADIUS

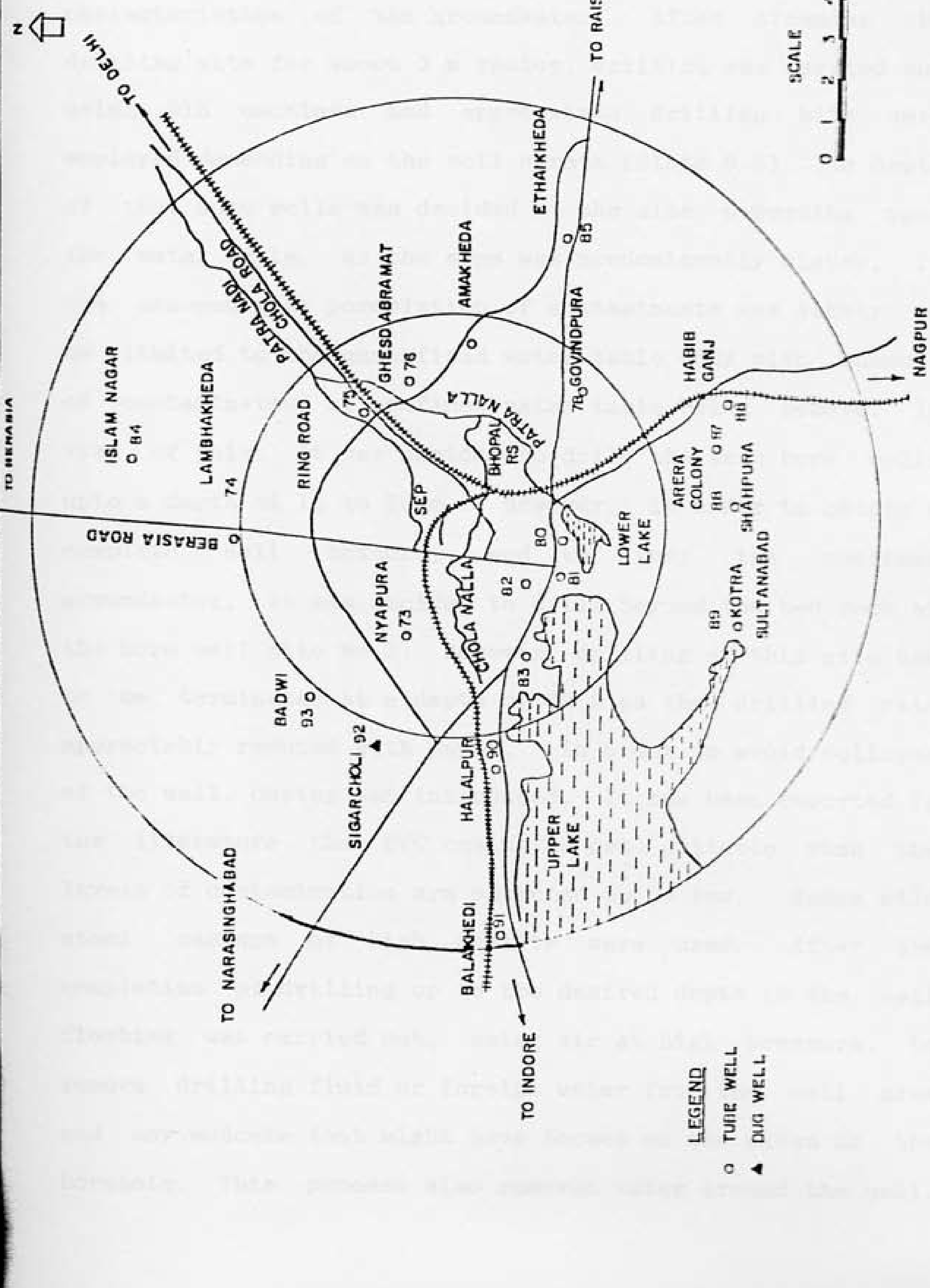
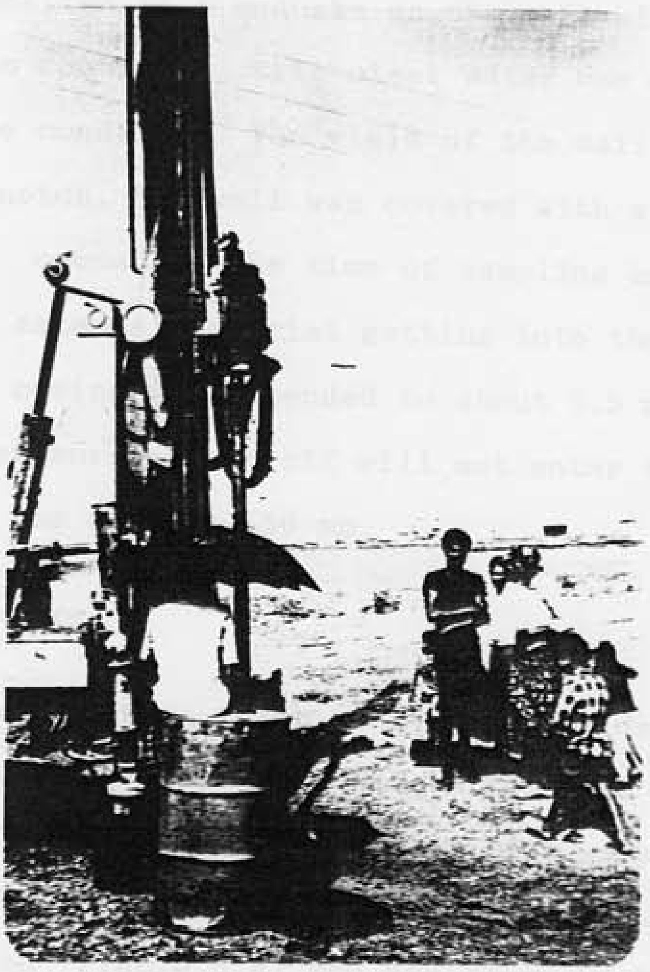


FIG. 6·4 LOCATION OF MONITORING WELLS BETWEEN 2·5 Km AND 10 Km any possible contamination. Care was taken to avoid introducing materials which may alter the chemical characteristics of the groundwater. After cleaning the drilling site for about 3 m radius, drilling was carried out using DTH machines and appropriate drilling bits were employed depending on the soil strata (Plate 6.2). The depth of test bore wells was decided at the site depending upon the water table. As the area was predominently clayey, it was assumed that percolation of contaminants was likely to be limited to the unconfined water table body with chances of contamination of confined water table being remote. In view of this, it was decided to drill the test bore wells upto a depth of 15 to 20 m. However, in order to obtain a complete soil texture, and to study the confined groundwater, it was decided to drill beyond the bed rock at the bore well site No.2. However, drilling at this site had to be terminated at a depth of 32 m as the drilling rate appreciably reduced with depth. In order to avoid collapse of the well, casing was introduced. It has been reported in the literature that PVC casing is not suitable when the levels of contamination are expected to be low. Hence mild steel casings of high quality were used. After the completion of drilling up to the desired depth in the well flushing was carried out, using air at high pressure, to remove drilling fluid or foreign water from the well area and any mudcake that might have formed on the sides of the borehole. This process also removed water around the well,

PLATE 6.2



DRILLING OF A TEST BORE WELL

to be replaced by water from larger surroundings of the well. This water was hopefully not influenced by drilling activites, and was representative of the undisturbed aquifer in the vicinity of the well. This process helped in developing the well by removing fine detritus material that may be clogging intragranular space in the formation or that may be deposited as a mudcake on the wall of the borehole. Flushing was continued till clear water was obtained under steady state condition. The yield of the well was determined by using V-notch. The well was covered with a MS cup so that it can be opened at the time of sampling and as also to prevent any external material getting into the wells. The top of the casing was extended to about 1.5 m above ground level so that surface run off will not enter the well. The diameter of the well is 150 mm.

6.3.4 Lithologs

Formation samples were taken at every meter depth to prepare lithologs at the test bore hole sites and for chemical analysis of selected soil samples for characterisation. Based on the formation samples collected, lithologs have been prepared (Table 6.4) and are shown in Figure 6.5 and the detailed lithologs are given in Annexure VIII. It can be seen that the top soil cover is of black cotton type varying in depth from 1 to 2 m. Clay is encountered below black cotton soil. Clay is mostly of plastic nature. The static water level in the test borewells in June, August and September, 1989 along with the yield data are presented in

TABLE 6.4: SUMMARY OF LITHOLOGS OF BOREWELLS

Lithology	Well Numbers										
	1	2	3	4	5	6	7	8	9	10	51
	Thickness (m)										
Black cotton soil	1	1	1	1	1	1	1	1	1	1	2
Clay, dark grey, plastic with association of medium to coarse sand of basalt and occasional grains of <u>kankar</u>	5	9	8	5	5	6	6.5	5	5	8	2
Clay, dark grey plastic with association of basaltic gravel of size 3.5 mm.	--	--	--	--	--	--	1.5	--	--	--	5
Clay, light grey, with decreasing plasticity and association of coarse sand and gravel of <u>kankar</u>, upto about 15 %	4	2	3	6	6	5	3	3	3	5	3
Clay light grey plastic with association of coarse sand of basalt.	--	--	--	--	--	--	3	9	8	--	3
Clay, yellowish, mixed with gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	6.8	7	7.81	7.81	6.3	7.8	1.15	--	--	4.3	--
Clay, yellow, sticky	--	6	--	--	--	--	--	--	--	--	--
Clay, yellow, mixed with coarse-grained flattened gravel of Vindhyan sandstone and ending in the same bed rock	--	7	--	--	--	--	--	7.9	5.8	--	--

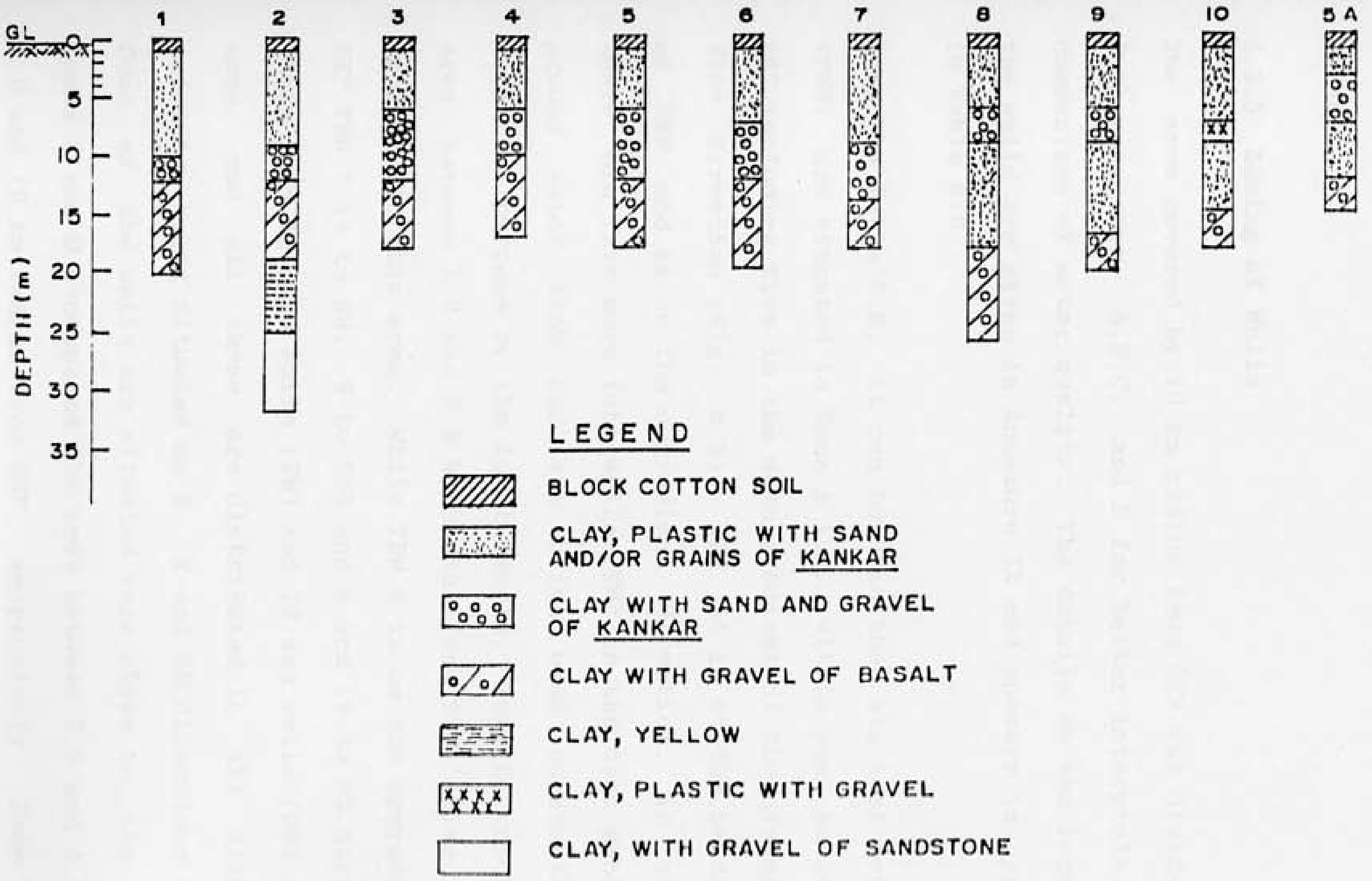


FIG.6·5 LITHOLOGS OF THE TEST BOREWELLS NEAR SEP AREA

Table 6.5. The data revealed that the yield potential of the wells during the present study varied from 0.2 m^3 to 5.0 m^3/hr.

6.3.5 Zoning of Wells

The area covered by 10 km radius from SEP was divided into four zones viz. A,B,C, and D for better interpretation and comparison of water quality. The details on the location of the wells are given in Annexure IX and summary is presented in Table 6.6 .

From the Table 6.6, it can be seen that six test bore wells (TBW) are situated in Zone A i.e. within one km radius of SEP including five in the down gradient of the ground water flow direction (Fig. 6.2). TBW 5A is on the SW direction of SEP and is on the upgradient direction. In addition, there are five more tube wells (TW) in the down gradient to ground water flow and are being used constantly for domestic purpose by the local people. Zone B covered the area between 1.0 and 2.5 km radius from SEP. Five TBW are located in this area. While TBW 6 is on the upgradient to SEP TBW 7 is to SW, 8 to ESE and 9 and 10 to NE directions. There are 44 tube wells (TW) and 12 dug wells (DW) in this zone, and all these are distributed in all directions, majority being situated on S, E and NE directions to SEP. Some of the wells are situated very close to the nallas. Zones C and D encompased the area between 2.5 and 5.0 km and 5.0 and 10 km radius from SEP, respectively. Zone C has 11

TABLE 6.5 : STATIC WATER LEVELS IN TEST BOREWELLS
(Values are in meters below ground level)

Well No.	June '89	Aug '89	Sep '89	Yield (m^3/hr)
1	4.1	3.9	3.6	0.2
2	6.0	5.8	5.7	1.8
3	4.2	3.9	3.7	0.4
4	4.5	4.1	3.9	2.0
5	3.8	3.4	3.2	1.5
6	9.0	8.8	8.6	0.2
7	5.0	4.8	4.7	0.2
8	6.0	5.6	5.3	2.2
9	4.0	3.7	3.4	5.0
10	4.0	3.8	3.5	1.9
5A	-	-	4.2	0.4

TABLE 6.6 : LOCATION AND TYPE OF MONITORING WELLS

Description of Wells	Zone			
	A	B	C	D
Distance from SEP,km	< 1.0	1.0-2.5	2.5-5.0	5.0-10.0
Well Type	Numbers			
Test bore well	6	5	-	-
Existing tube well	5	44	10	9
Dry well	-	12	1	1

wells of which one is DW while Zone D had 10 wells including one DW. No test bore well was constructed in Zones C and D.

It may be mentioned that DW 17 was only a pit, close to the UCIL compound wall and used by the hutment dwellers to collect seepage water for washing clothes. However it was filled up subsequently and hence not included for study.

6.3.6 Sample Collection and Analysis

Water samples were collected from all the 93 wells chosen for monitoring, in summer and during & after monsoon periods of 1989. Three to five sets of samples were collected in wells located in Zones A & B . Test borewell No. 5 A was monitored once since it was constructed only in September 1989. Samples were collected for analysis from other Zones C & D once or twice since these wells were considered only to provide background water quality within 10 km radius of SEP.

Water samples were anlaysed for pH, EC, calcium, magnesium, sodium, potassium, chloride, sulphate and nitrate as per Standard Methods for the Analysis of Water and Wastewater (1985). Test bore well water samples were also analysed for heavy metals particularly for Cd, Cr and Pb in addition to other parameters. Test bore well water samples were tested for sevin and alpha naphthol. Analytical results giving minimum, maximum and average are presented in Annexure X. Range values for parameters like calcium, sodium, and chloride which are the major pollutants present in pond water and sediments, besides sulphate and nitrate are presented zone wise giving the number of wells that fall in each range in Tables 6.7 to 6.11. The data are interpreted among the test bore wells, between TBW and others, and also zone wise and these are discussed in the following section.

6.3.7 Discussion

6.3.7.1 Test bore wells : The analytical data for the samples collected from TBW are presented in Table 6.7 and discussed below.

* In general, water from TBW had low calcium, sulphate and nitrate. Chloride concentration in 10 out of 11 wells was less than 100 mg/l. Sodium was upto 150 mg/l. The values indicate that the test bore well waters are of good quality.

* Although there was variation in the chemical quality of water among the TBW, the concentrations of anions and cations such as Cl, NO_3, Ca, and Mg, were within the standards for drinking water quality. Heavy metals such a cadmium (absent), chromium (0-50 ug/l) and lead (10-70 ug/l) in test bore wells were also below drinking water standards. Bacteriological quality of well waters was not studied.

* Compared to other TBW, water from TBW 6, which is on the upgradient to ground water flow, showed low Ca, Mg, and chloride but Na concentration was high and averaged 106

TABLE 6.7: DISTRIBUTION OF CATIONS AND ANIONS IN TEST BORE WELLS

Parameters	Calcium	Sodium	Chloride	Sulphate	Nitrate-N
Range, mg/l	Number of wells				
< 25	3	-	-	9	9
25 - 50	5	2	2	2	2
50 - 100	3	4	8	-	-
100 - 150	-	5	1	-	-
150 - 200	-	-	-	-	-
200 - 250	-	-	-	-	-
>250	-	-	-	-	-

mg/l which was the highest among the TBW waters. Water from TBW 6 & 7, equidistant from SEP but in different direction, had the same sodium concentration while Ca and Cl values were higher in TBW 7.

* Waters from TBW 1 to 5 and 5A which are located less than 500 meters from SEP had not shown any appreciable variation in the concentration of calcium (23-38 mg/l) while sodium and chloride values showed variation Na (38-148 mg/l) and chloride (43-105 mg/l) among themselves.

* Waters from TBW 8, 9 and 10 located E and NE of SEP respectively showed on an average calcium, 57-99 mg/l; sodium, 47-54 mg/l; and chloride, 79-88 mg/l. As compared to other TBW, calcium was appreciably high in these wells while Na and Cl were relatively low. This could be due to the local activities arising out of Central Warehouse Corporation (CWC), a transit store for a variety of chemicals.

* Sulphate and nitrate values in all the TBW were low indicating that the waters had appreciable bicarbonate concentration.

6.3.7.2 Zone A: The water quality data are presented in Table 6.8 for the six TBW and five TW located in Zone A.

* The water quality in the existing TW indicated that both cations and anions were low and within the drinking water standards.

TABLE 6.8: DISTRIBUTION OF CATIONS AND ANIONS IN WELL WATERS
ZONE A (< 1.0 km)

Parameters	Calcium	Sodium	Chloride	Sulphate	Nitrate-N
Range, mg/l	Number of wells				
< 25	- (2)	1 (-)	- (-)	3 (4)	4 (6)
25 - 50	1 (4)	1 (1)	1 (1)	2 (2)	1 (-)
50 - 100	2	1 (2)	2 (4)	- -	- -
100 - 150	2	2 (3)	2 (1)	-	-
150 - 200	-	-	-	-	-
200 - 250	-	-	-	-	-
>250	-	-	-	-	-

TBW = 6; TW = 5 ; Total 11 ; Numbers in parenthesis are TBW

TABLE 6.9: DISTRIBUTION OF CATIONS AND ANIONS IN WELL WATERS
ZONE B (1 - 2.5 km)

Parameters	Calcium	Sodium	Chloride	Sulphate	Nitrate-N
Range, mg/l	Number of wells				
< 25	1 (1)	4 (-)	2 (-)	41 (5)	33 (3)
25 - 50	6 (1)	30 (1)	3 (1)	11 (-)	16 (2)
50 - 100	15 (3)	17 (2)	11 (4)	4 (-)	6
100 - 150	20 (-)	3 (2)	10 (-)	-	1
150 - 200	7 (-)	-	9	-	-
200 - 250	5 (-)	-	8	-	-
>250	2 (-)	2	13	-	-

TBW = 5; TW = 51; DW = 5; Total 61; Numbers in parenthesis are TBW

- The absence of high chloride, calcium and sodium in all the TBW and TW located in this zone of one km from SEP clearly indicates the absence of contamination from the pond waters.

6.3.7.3 Zone B: This zone had the largest number of monitoring wells (5 TBW, 44 TW and 12 DW). The water quality data are presented in Table 6.9.

- Calcium content in twenty well waters is in the range of 101 to 150 mg/l and higher than 250 mg/l in two other wells. Sodium was present above 250 mg/l in one well (TW 20).

- Thirteen out of 56 wells showed chloride greater than 250 mg/l besides six wells had sulphate in the range of 51-100 mg/l.

- High chloride levels are particularly observed in wells 20,21 27 to 30,36 53,54,56,58,60 and 72. Wells 27,36 and 72 are DW and the remaining are TW. TW 20 located between UCIL and the ice factory and on the south of SEP, showed the highest concentration of chloride (3670 mg/l). However, TW 21 and 22 which are very close to well 20 showed relatively low chloride levels, 549 and 200 mg/l, respectively compared to TW 20. The ground water gradient in the area is towards E and/or ESE towards Patra and Chola nallas. Hence it is unlikely that seepage from SEP, if any could be the cause for high chloride in these well waters. Had the seepage been towards TW 20, TBW 1 which is close to SEP should have shown higher chloride, calcium and sodium than TW 20 . The reason for high Cl, Ca and Na in well 20 and 21 was likely due to the reported use of calcium and sodium chlorides in ice factory which is close to these wells besides the proximity of waste dumpsites within the factory premises of UCIL.

* Wells 28,29 and 30 are situated in the area where FCI and Central Warehouse Corporation (CWC) godowns were located. CWC handles a variety of chemicals and materials as a transit store. Floor sweepings of spills and washings are led into an open drain carrying sullage from the nearby hutments. The drain flows only during monsoon but rest of the year the water gets collected into pools. Enquiries from the local public revealed that the area close to CWC was a municipal refuse dump site of Bhopal Municipal Corporation several years ago. The past activity could be one of the reasons for the occurrence of high chloride and other ions in these well waters.

* Wells 58 and 60 are located on the right bank of Chola nalla and the possibility of SEP seepage reaching these wells was ruled out by the fact that SEP is located on the right side of Chola nalla at a distance of more than a kilometer. The high level of chloride could be due to other local conditions and seepage of nalla water.

- Except for the abnormal levels of Cl, Ca, and Na in a few wells, the reasons for which are stated above, the well waters in this zone did not indicate contamination from SEP as the concentration of cations and anions were low and compared well with those in Zone A.

6.3.7.4 Zone C: This zone covers the area between 2.5 and 5.0 km radius from SEP with no test bore well. Out of eleven wells located one is dug well. Table 6.10 represents the water quality of wells in Zone C.

- All the well waters had chloride and calcium less than 150 mg/l and compared well with the water quality of wells located in Zones A and B.

- There were no chances of contamination of ground water in this zone from SEP and the observed variations were due to local influences.

6.3.7.5 Zone D: No test bore well is located in this zone covering an area between 5 and 10 km radius from SEP. Nine TW and one DW were considered for water quality assessment. Table 6.11 summarises the water quality for the wells monitored in this zone.

- All the well waters in this zone had chloride less than 150 mg/l except in two wells (91 & 91) where the value was upto 240 mg/l. Calcium was relatively high while sodium was less than 50 mg/l in 8 out of 10 wells. Nitrate nitrogen in the waters was high (35-40 mg/l) and

TABLE 6.10: DISTRIBUTION OF CATIONS AND ANIONS IN WELL WATERS ZONE C (2.5 - 5.0 km)

Parameters	Calcium	Sodium	Chloride	Sulphate	Nitrate-N
Range, mg/l	Number of wells				
< 25	-	3	3	11	7
25 - 50	5	6	-	-	4
50 - 100	5	2	6	-	-
100 - 150	1	-	2	-	-
150 - 200	-	-	-	-	-
200 - 250	-	-	-	-	-
>250	-	-	-	-	-

TW = 10; DW = 1; Total 11

TABLE 6.11: DISTRIBUTION OF CATIONS AND ANIONS IN WELL WATERS ZONE D (5.0- 10 km)

Parameters	Calcium	Sodium	Chloride	Sulphate	Nitrate-N
Range , mg/l	Number of wells				
< 25	-	3	1	8	5
25 - 50	2	5	2	2	5
50 - 100	3	2	1	-	-
100 - 150	5	-	4	-	-
150 - 200	-	-	-	-	-
200 - 250	-	-	2	-	-
>250	-	-	-	-	-

TW = 9; DW = 1; Total 10

was due to the agricultural activity in this zone.

6.4 CONCLUSION

The water quality from monitoring wells located within a radius of 10 km from SEP was compared with the data already presented in land environment and solar evaporation ponds to draw the following conclusions.

The water quality in the Upper and Lower lakes is not affected due to the activities of UCIL in view of high elevation difference and Chola nalla acting as a barrier between the lakes and UCIL. The water in the nallas is unfit for domestic use.

The water quality in the monitoring wells within 500 m from SEP and located in the area, did not show high levels of chlorides, calcium and sodium which are the main pollutants in SEP water and sediments. Further, carbaryl and alpha napthol were also below detection limits.

The presence of high concentration of chloride in the well (TW 20) south of UCIL plant premises, is not due to the impact of impounded water in SEP but due to other sources such as ice factory. This needs further investigation to find out the contributing source(s) other than ice factory.

In general, the water quality in the wells located very close to nallas is affected by the seepage from the nallas which carry sullage water for most part of the year.

Hence, it is concluded that the wastewater impounded in SEP had not led to contamination of water environment within the area under the study.

7.0 TREATMENT OF SOLAR EVAPORATION PONDS SEDIMENTS

7.1 INTRODUCTION

Solar evaporation ponds contained some amount of impounded wastewater and sediment consisting of the residue formed by the evaporation of impounded wastewater along with the soil used as cover over the polyethylene membrane liner provided in the ponds. A rough estimate indicated that the SEPs contained 26200 m^3 of sediment equivalent to about 18610 MT and 8850 m^3 of impounded water. The water and sediment samples contained high concentration of inorganic salts of calcium and sodium primarily as chloride besides small amounts of organic matter. Details on the estimates of pond sediment and water and the chloride content in SEP are given in Anexure XI.

Sediment samples were subjected to toxicity characteristic leaching procedure (TCLP) as prescribed by USEPA (Annexure XII) and the leachate analysed for heavy metals, carbaryl and other organic constituents which are used in the manufacture of carbaryl. The results indicated that the leachate samples did not show any of the 8 heavy metals, carbaryl, chloroform and carbon tetrachloride to designate the sediment as hazardous.

Pond water samples, and sediment samples extracted with water and methylene chloride were subjected to HPLC analysis. The data are presented in Chapter 4. The results show that a few peaks were observed in the chromatograms and one of the peaks corresponds to benzene sulphonic acid. This compound does not find a place in the list of organic compounds (Annexure XII.1) considered in defining the toxicity of a waste to classify it as hazardous. It may also be pointed out that the HPLC chromatograms of the pond water and sediments (Fig 4.1 to 4.3 and 4.6) did not indicate the presence of carbaryl and alpha-naphthol although colorimetric estimation indicated very low concentration of carbaryl. The method adopted although specific to these two compounds, can also measure phenolics and are calculated as carbaryl.

The Hazardous Waste Management and Handling Rules of 1989 framed by GOI identify wastes from manufacture of pesticides and herbicides and residues from pesticides and herbicides formulation as hazardous. The regulatory quantity prescribed is 200 kg per year calculated as pesticide or herbicide or its degradation products (Category 15) (Annexure XIII). Although the sediment falls under hazardous waste because of its origin from a pesticide manufacturing unit, presently it does not contain the pesticide. However, there are a few organic compounds which could not be identified and hence the sediment cannot be ruled out to be non hazardous. It is already reported (Chapter 4) that the pond water is not toxic to fresh water fish at 5% dilution and toxicity observed at higher concentrations is attributed to the high salt content in the wastewater. This evidence also points out to the fact that the organics in wastewater or the sediment are not likely to exert any acute toxicity to aquatic life. At the same time, as stated earlier, the pond sediment samples contain large amounts of inorganics besides organic matter 3-4 times the concentration found in the soils around SEP. In view of this it becomes necessary to treat/contain the material so that the inorganic and organic contaminants are removed or retained permanently and thus do not create any pollution problem when the land is reused for industrial activity.

7.2 TREATMENT METHODS

Methods generally adopted for clean up of contaminated soil are broadly classified into two categories:

* those aimed at removing or destroying the contaminants
* those aimed at preventing or restricting the dispersion of contaminants

The removal methods are further divided into two types, viz.

- excavation of the soil and cleaning it on offsite
- onsite or in situ cleaning of the soil without prior excavation

Steps for preventing/restricting the dispersion of contaminants include:

- excavation of the soil and its transportation to a permanent or temporary storage site

- restriction of the dispersion of contamination by installing vertical and horizontal barriers (bitumen membrane, plastic sheets, bentonite-cement walls, steel sheeting, etc.)
- restriction of the dispersion of the contamination by means of physical/chemical fixation techniques, (treatment with chemicals like lime, cement, water glass, urea formaldehyde in such a way that the contaminants in the soil are immobilised to a large extent).

In the present investigation experiments were carried out to study the feasibility of treatment and/or disposal of the sediment samples, as such and after extraction/washing with water, on land. The available methods for disposal of the pond water and the water extract of the pond sediments, and containment of the sediment samples in situ or excavation and retaining them in a permanent secure landfill are presented and approaches to be adopted in the present case outlined.

7.3 LAND TREATMENT

Land treatment is a waste treatment and disposal process whereby a waste is mixed with and incorporated into the surface soil and is degraded, transformed and immobilized through physico-bio-chemical processes. Synonyms include land cultivation, landfarming, land application and sludge spreading. Because of the potentially lower liabilities and relatively low initial and operating costs, land treatment has received serious attention as an ultimate disposal alternative for certain wastes. Land treatment utilises surface soil as medium for aerobic decomposition of organic hazardous waste constitutents. Proper management of the treatment zone and monitoring of the unsaturated zone are keys to the effectiveness of land treatment and protection of air and water resources.

In USA, a survey conducted during 1980 revealed that 197 land treatment facilities were in operation and over 50% of these facilities were at petroleum refineries and about 15% were associated with chemical production. Biodegradable wastes are suitable for land treatment. Radioactive waste, highly volatile, reactive and flammable liquids, and inorganic wastes such as heavy metals, acids and bases, cyanide, and ammonia are not considered candidates for land treatment.

Laboratory investigations were carried out to study the feasibility of land treatment of sediments from solar evaporation ponds. For this purpose the sediment sample was mixed at 1%, 5% and 10% level with virgin black cotton soil of clayey texture (clay 52.4%). The experimental and control soils were incubated at 27°C for 7 days. The moisture content in soil was maintained at 50% of water holding capacity. These soils were then analysed for chemical characteristics, viz. pH, EC, cations and anions. The samples were also tested for total viable bacterial and azotobacter counts.

Data on the changes in soluble salts in soil, due to mixing of pond sediments are given in Table 7.1 and changes in soil salinity are depicted in Fig 7.1 . It is observed from the results that even at 1% sediment concentration the resulting soil tended to become saline (ECe > 4.0 mS/cm). The salinity level increased further with 5% and 10% sediments. The concentration of chloride also showed appreciable increase from 3.2 in the control soil to 42.4-48.0 meq/litre of saturation extract of soil at 1 % sediment concentration. The increase in soluble salts and chloride in treated soil is due to the presence of high concentration of soluble inorganic salts in SEP sediments.

Microbiological analysis results presented in Table 7.2 for untreated and treated soils for total viable and azotobacter counts show 21% and 1% inhibition, respectively, at 1% sediment concentration in case of SEP I. The corresponding reduction for SEP II are 23% and 25%. The activity of azotobacter ceased completely at 10% sediment concentration whereas total viable count is inhibited by 57% and 62%, respectively, for SEP sediment I and II. The inhibition can be attributed mostly due to high concentration of soluble inorganic salts.

The soils in and around SEP are clayey textured black cotton soil and are sensitive to build up of soluble salts.

TABLE 7.1 : EFFECT OF ADDITION OF DIFFERENT LEVELS OF SOLAR EVAPORATION POND SEDIMENTS ON SOIL
(Saturation Extract Analysis)
(All Values except pH & ECe are in m eq/1)

Levels of SEP	pH	ECe mS/cm	Saturation Extract						
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate
Control Soil	7.6	0.37	2.4 (0.0024)	0.8 (0.0048)	0.42 (0.00048)	Nil	0.45 (0.0014)	3.2 (0.0057)	0.14 (0.00034)
SEP I	6.5	285.60	1404 (1.404)	216.0 (0.129)	1182.0 (1.359)	7.69 (0.015)	30.15 (0.092)	2780.0 (4.928)	26.04 (0.063)
SEP I 1 %	7.4	4.65	32.4 (0.032)	2.8 (0.0017)	10.04 (0.012)	0.05 (0.00009)	0.40 (0.0012)	42.4 (0.075)	0.66 (0.0016)
SEP I 5 %	7.0	16.81	104.8 (0.105)	10.4 (0.0062)	51.74 (0.059)	0.05 (0.00009)	0.50 (0.0015)	160.4 (0.2843)	1.13 (0.0027)
SEP I 10 %	7.0	27.52	156.8 (0.157)	18.8 (0.0113)	107.83 (0.124)	1.00 (0.002)	0.80 (0.0024)	279.0 (0.496)	2.40 (0.0058)

Contd.

Levels of SEP	pH	ECe mS/cm	Saturation Extract						
			Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulphate
SEP II	6.5	351.00	2502.0 (2.502)	24.0 (0.014)	973.91 (1.119)	10.26 (0.020)	24.00 (0.073)	3456.0 (6.126)	10.42 (0.025)
SEP II 1 %	7.5	5.02	37.0 (0.037)	5.6 (0.0034)	7.39 (0.0085)	0.04 (0.00008)	0.60 (0.0018)	48.0 (0.085)	0.39 (0.00094)
SEP II 5 %	7.0	20.48	151.2 (0.151)	16.8 (0.010)	40.00 (0.046)	0.05 (0.000097)	0.60 (0.0018)	205.0 (0.3634)	1.20 (0.0029)
SEP II 10 %	6.9	36.94	267.6 (0.268)	25.6 (0.015)	80.80 (0.093)	0.80 (0.0016)	0.40 (0.0012)	370.8 (0.657)	1.42 (0.0034)

Values in the parenthesis indicate percentage on dry weight basis

ECe - electrical conductivity of saturation extract in mS/cm at 25°C

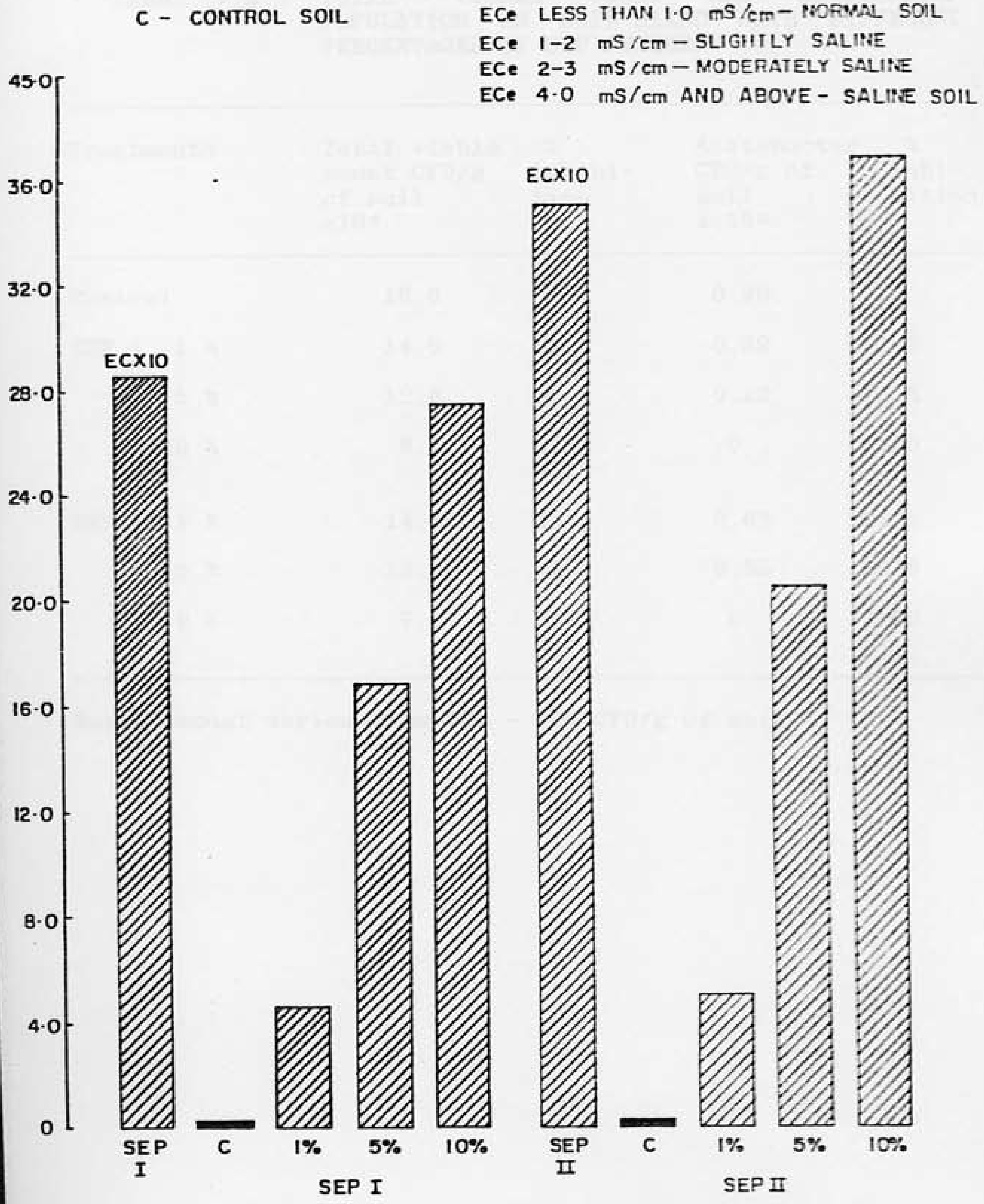


FIG. 7·1 STATUS OF SOIL SALINITY DUE TO MIXING OF SEP SEDIMENTS

TABLE 7.2 : TOTAL VIABLE COUNT AND AZOTOBACTER POPULATION IN SOIL MIXED WITH DIFFERENT PERCENTAGES OF SEP SEDIMENT

Treatments	Total viable count CFU/g of soil $\times 10^4$	% inhibition	Azatobacter CFU/g of soil $\times 10^2$	% inhibition
Control	18.8		0.90	
SEP I 1 %	14.9	21	0.89	1.2
5 %	12.8	32	0.22	75.6
10 %	8.1	57	0	100
SEP II 1 %	14.4	23	0.68	24.5
5 %	12.5	34	0.55	39.0
10 %	7.2	62	0	100

Normal count varies from 10^4 - 10^6 CFU/g of soil.

Presence of high clay content tended to buildup salinity and cause toxicity to plants. The permissible ECe for these soils is less than 1.5 mS/cm to grow crops of sensitive to moderately sensitive nature without reduction in yield.

Although the sediment samples did not show appreciable adverse effect on total viable and azotobactor counts at 1% concentration, the physico-chemical properties of the soil in respect of salinity in general and chloride in particular appreciably increased compared to normal soil in the area. If land treatment is to be considered for disposal of SEP sediments, they can be applied and mixed with virgin soil at 0.2-0.25 % level so that the physico-bio-chemical properties of the virgin soil do not get altered and will not be inimical to crop growth. At this application rate the area required to dispose of the total pond sediment worked out to 3400 hectares at an application rate of 5.6 MT sediment per hectare.

7.4 EXTRACTION

Extraction (soil washing) is one of the techniques applied to remove contamination in soil/sediment. In this process the contaminated soil is mixed thoroughly with extracting agent. The contaminants adsorbed or attached to the soil particles are dissolved in the extraction agent. The washed or extracted soil is separated and the extraction fluid is treated for removal of the contaminants after which reused. The extraction agent can be either water or organic solvents. Some chelating agents and other chemicals are also added during extraction depending on the contaminants requiring removal. Soil washing is used to decontaminate the soil containing cyanide, aliphatic and aromatic hydrocarbons and related compounds, heavy metals, mineral oil, phenol, toluene, benzene and pesticides. The choice of extracting/washing agent depends on the type of contaminants encountered.

From the characteristics of pond water and sediments, it is evident that chlorides of calcium and sodium are the major contaminants in SEP. Since these salts are highly soluble in water, extraction of pond sediments with water was tried. Water was also chosen as an extracting agent due to the following reasons:

* ease of use and safety of the extracting agent for personnel and environment
* natural presence of water in soil
* prevention of additional ground water and air pollution
* cost of extracting agent

Extraction/washing experiments were carried out on pond sediments with water at sediment to water ratio of 1:10. Accordingly, weighed quantities of air dried sediment was mixed with required amount of water and extracted on a shaker for one hour. The suspension was filtered and the filtrate was analysed for chloride. It was observed that over 98% of chloride was removed in first washing. The same filtrate when reused with fresh quantity of soil was able to extract 97% chloride from the added sample. This indicated that the filtrate after two extractions can be used for further extraction of salts from sediment samples. In order to find out the minimum volume of water required for maximum extraction of salts, the filtrate was used repeatedly for eight extractions. The filtrate, after eight extractions, was analysed for pH, COD and chloride. The sediment residues left after each extraction were mixed together, air dried and analysed for inorganics and organic carbon (Table 7.3). The pH of the filtrate was recorded as 8.1 for Pond I and 7.8 for Pond II.

It was observed that chloride content in the filtrate after eighth extraction was 45,500 mg/l in case of Pond I sediment and 48,000 mg/l in Pond II. Corresponding COD values were 2200 mg/l and 1278 mg/l, respectively. The chloride content in the residue was observed to be 1.3% in Pond I and 1.2% in Pond II as against the original chloride content of 6.1% in pond I and 6.0% in Pond II sediment samples used in the study.

The soils around SEP have a chloride content of 0.05%. The chloride content of the pond sediments can be brought down to this level by water extraction/washing at a ratio of sediment to water as 1:10 to 12.5 whereby over 98% of chloride vis-a-vis dissolved salts, from the sediment can be removed. Although the water can be reused for extracting fresh batches of sediment the chloride remaining in the residue increases making the sediment unfit for land disposal directly. In other words the land requirement will increase proportionately. To make the sediment chloride content equal to that of normal soil, a removal of 99% of chloride becomes necessary. Hence, a once through system of water washing is to be adopted. This treatment demands water to the tune of 150,000 - 200,000 m^3 besides treatment of this volume of extract to meet the regulatory standards before final disposal into nearby nallas. Hence, this method may not prove feasible in the present case.

7.5 CONTAINMENT

Land treatment and water washing/extraction methods described earlier will demand large area (3400 ha) and huge volume of water (150,000-200,000 m^3), respectively. The water extract along with the reamining impounded water requires to be treated to meet the regulatory standards for disposal into the existing nallas. In view of the limitations and that the pond sediments do not strictly fall under hazardous waste category as per the existing legal provisions, it is preferable to contain them in a manner to ensure present and long-term environmental protection.

Physical/chemical fixation or solidification techniques used for restricting the dispersion of pollutants from contaminated soils include treatment of the soil with cement, lime, fly ash, bitumen, urea-formaldehyde resin etc.

As the pond sediments contain fairly appreciable percentage of soluble salts e.g. chlorides of Ca and Na the solidification techniques given in Annexure XIV are reported to be not feasible for adoption except treatment with urea-formaldehyde resin. The solidified mass also requires to be contained in a secure landfill site. Studies on the use of urea-formaldehyde resin could not be carried out as the resin was not readily available.

The other alternatives for containment are: to provide vertical and horizontal barriers in situ to prevent seepage and to excavate the sediments from the ponds and transport to a permanent storage site. Site selection for permanent storage (secure landfill) should be based on environmental impact assessment (EIA). Since SEP area is being considered for reclamation and reuse, in situ containment is not desirable as the land will not be available for reuse. Hence excavation of the pond contents and retaining them in secure land fill is the preferred choice. Alternately, pond sediments from I and II are to be excavated and stored in Pond III as the available volume in Pond III is adequate to contain all the material. This approach facilitates to reclaim nearly 11 hectares of land occupied by SEP.

The pond water should be dried and the residue should be mixed with the sediment before landfill. For enhancing evaporation, it is recommended to spread the pond water into a thin layer in the dried sections of the ponds.

The total volume of sediment, residue resulting from evaporation of pond water and the contaminated soil to be handled for disposal is estimated to be as follows:

Sediment from Ponds I, II and III	26,200 m^3
Residue after pond water evaporation	4,500 m^3
Contaminated soil on the western side of Pond III	400 m^3
Total	31,100 m^3

Thus the total contaminated sediment and soil is 31,100 m^3. As Pond III has a volumetric capacity of 43,000 m^3, it can easily contain the total quantity of the contaminated sediment and soil.

As the geological and hydrogeological factors at the SEP site preclude leachate migration to ground and surface waters, it is preferable to utilise Pond III to contain the sediments after converting it into a secure landfill site.

The liner and sediment from Pond III should be removed before reconstruction. The sediments can be stored temporarily in Pond I and/or II. The bottom should be recompacted. Although the soil is of plastic clay a flexible membrane liner (FML) should be laid over the compacted clay bottom and also on the pond sides with the ends properly jointed. A clay soil cover of 20 cm thickness over the FML should be placed to retain the FML in postion as well as to act as an additional liner. After clearing the vegetation around the pond, the embakments should be reconstructed to provide a slope of 3:1 horizontal to vertical having a width of about 1.5 m with a 3 to 5% slope towards outside to promote run-off for rain water.

Since the Pond III sediment and soils from pond bund slopes contain relatively less contaminants they should be placed at the bottom of the landfill and compacted, over which another FML with clay cover should be placed. Subsequently sediments from Pond I followed by Pond II should be placed in the landfill by separating them with layer of FML and clay cover. Leachate collection system is not suggested since in the present case the waste does not strictly fall under hazardous waste category and the hydrogeological setting at SEP site precludes leachate migration to ground or surface water. To reduce the leachate generation it is recommended to place a low permeability membrane cap over the landfill. The cap should have a permeability less than or equal to the permeability of the bottom liner system. A thick clay cover is finally provided as cover cap with a gentle slope to drain out rain water. The entire area of the landfill site should have adequate drainage facilities. The area should be protected from any form of encroachment and should not be used for any activity at present or in future. Piezometers should be constructed around the landfill site for leachate monitoring. Necessary protective measures for the workers should be provided during excavation of pond sediments and construction of the secure landfill. Design details and construction procedures should be worked out after deciding the exact site location for landfill site.

ANNEXURE I

ELECTRICAL RESISTIVITY SURVEYS

INTRODUCTION

The electrical resistivity (ER) method applies current to the ground through electrodes and depends for its operation on the fact that any subsurface variation in conductivity alters the form of the current flow within the earth. Therefore, the distribution of electrical potential is affected. The degree to which the potential measured at the surface is affected depends on the size, shape, location, and ER of the subsurface mass. It is therefore, possible to obtain information about the subsurface distribution of various bodies at the surface.

The electrical resistivity of any medium is the resistance offered by a unit cube of it when a unit current passes normal to the surface of cross-sectional area A. It is given by Ohm's law

$$\rho = R \frac{A}{L}$$

where, ρ = resistivity (ohm-m)

R = resistance offered by the medium of length L and

A = cross sectional area

In ER surveys, current (I) is introduced into the surface through a pair of current electrodes A and B, and the potential difference (ΔV) produced in the medium is measured using another pair of electrodes M and N (Fig. A1.A). The resistivity of the medium is then computed by

$$ = K \frac{\Delta V}{I}$$

where. K is the factor depending on the electrodes array

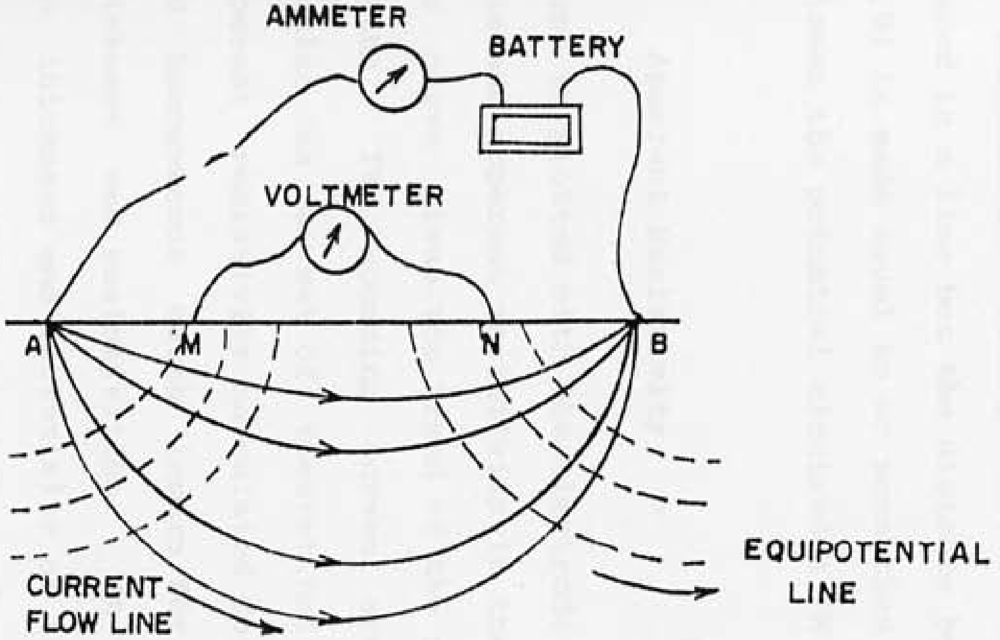
$$K = \frac{2}{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}}$$

The resistivity obtained is only apparent resistivity in view of anistropic formation. The apparent resistivity value depends on several variables like electrode spacing, geometry of electrode array, and other features of underlying formations such as layer thickness, dip and anisotropic properties.

Among the various electrode configurations employed, Schlumberger and Wenner arrangements are the most commonly used. In this project, Schlumberger method was adopted for vertical electrical soundings (VES) and Wenner array was employed for resistivity profiles (RP).

VERTICAL ELECTRICAL SOUNDINGS (VES)

This was carried out at 18 points, using Schlumberger electrode array (Figs. 3.1 & 3.1A). In this the place of observation is constant and by changing the electrode



A. SCHEMATIC ELECTRICAL CIRCUIT

C. WENNER

B. SCHLUMBERGER

FIG. AI. ELECTRODES ARRAY FOR RESISTIVITY SURVEY spacings, a set of apparent resistivity values for various depths are recorded. The current electrode spacings (AB/2) are increased.

In Schlumberger configuration, all four electrodes are placed in a line but the distance between current electrodes (A,B) is made equal to or more than five times the distance between the potential electrodes (M,N) (Fig. A1.B)

$$\text{Apparent Resistivity} = \frac{(L/2)^2 - (b/2)^2}{b} \Delta V/I$$

Graph is plotted with the electrode separation (AB/2) in the axis and apparent resistivity in the abscissa. The shape of the curve gives the trend of the resistivity at different depths. The sounding curves are prepared in the same modulus as a set of theoretical master-type curves of apparent resistivity calculated for horizontal, isotropic and homogeneous earth layers for various combination of thickness and resistivities. At the "best fit" position, the thickness and resistivity of the first layer are read from the master-curve chart. The thickness and resistivty of the second, third, fourth layers, as the case may be, are determined from ρ_2/ρ_1, ρ_3/ρ_1, ρ_4/ρ_1 and h_2/h_1, h_3/h_1, h_4/h_1 ratio given on the type of the curve.

Once the resistivities and thickness of the different layers are known, the data may be used to prepare a geoelectric section of VES spot. In this study, the maximum current electrode separation was kept at 200 m i.e AB/2 is 100 m. It has been reported in literature that the depth of penetration is about one-third of the AB/2 which means the present survey would indicate the soil texture upto a maximum depth of about 35 m.

RESISTIVITY PROFILING

In this study, Wenner array was employed to determine the ground water flow direction and contamination near SEP area. The electrode array is shown in Fig A1.C. In this method the electrode spacings are kept constant and shift the array to preselected stations along a section where the profile is to be carried out. The electrode spacings can be increased and the electrode array is shifted to the monitoring stations. By measuring the apparent resistivity along the same profile with different electrode spacings, lateral as well as vertical changes in apparent resistivity can be assessed.

Two potential elecrodes M and N are placed in a line with the current electrodes A and B, all four being situated equidistant from one another and disposed symmetrically with respect to a central point O, i.e. AM = MN = NB = a. The apparent resistivity is computed from

$$\rho = 2\pi a \frac{\Delta V}{I}$$

The depth of investigation can be approximated to the distance between any two electrodes.

In this study, electrode spacings (a) were fixed at 5 m and 10 m. Resistivity measurements were made at 10 m interval around SEP. Three profiles, viz. one within fenced area, two outside fence at 10 m and 25 m from the fence were carried out.

ANNEXURE II

SPECTROPHOTOMETRIC DETERMINATION OF CARBARYL AND ALPHA NAPHTHOL

Principle

Carbaryl is hydrolysed with sodium hydroxide to alpha naphthol which couples with p.nitrobenzene diazonium fluoborate to produce a colour that has a maximum absorbance at 475 nm.

Reagents

(a) Methylene chloride, redistilled
(b) Acetone, reagent grade
(c) Acetic acid, glacial, reagent grade
(d) Sodium sulphate, anhydrous
(e) Potassium hydroxide, 0.1 N, in methanol A.R.
(f) Coagulating solution : Dissolve 0.5 gm of ammonium chloride in 433 ml water containing 1.0 ml of 85 percent phosphoric acid
(g) Colour reagent : Dissolve 25 mg of p-nitrobenzene diazonium fluoborate in 5 ml methanol in a 25 ml volumetric flask. Dilute to 25 ml with glacial acetic acid and mix. Prepare fresh reagent prior to use.
(h) Diethylene glycol solution : Dissolve 1 ml diethylene glycol in 100 ml of methylene chloride

Extraction

Take 500 ml of water sample in a separatory funnel. Add 50 ml methylene chloride. Shake the contents thoroughly and allow the layers to separate. After clear separation, drain the lower layer containing solvent into a 250 ml flask through a bed of anhydrous sodium sulphate contained in a funnel fitted with a cotton plug. Repeat the extraction 5 times, adding 50 ml fresh methylene chloride every time. Collect the lower layer of solvent in the same flask. Rinse the funnel finally with methylene chloride. Add 1 ml diethylene glycol solution. Concentrate the residue in rotary vacuum flask evaporator at a temperature less than 40°C. Run the reagent blank with distilled water.

Cleanup

Using a pipette add 5ml of acetone into the flask from previous section and dissolve the residue. Add 50 ml coagulating solution to the flask. Swirl to mix and let stand for 30 minutes. Filter the contents of the flask through Whatman No.42. Wash the flask with 50 ml of 10 percent methanol in distilled water and filter through the same funnel. Transfer the filtrate to a separating funnel. Add 50 ml methylene chloride and shake vigorously. Let the layers separate completely. After clean separation drain the lower layer into a 250 ml round bottom flask through a bed of anhydrous sodium sulphate contained in a funnel fitted with cotton plug. Repeat the extraction using fresh 40 ml portions of methylene chloride twice and drain the lower layer each time through the same bed of sodium sulphate. Wash the sodium sulphate with 20 ml of methylene chloride.

Determination of Sevin

Depending upon the sevin concentrations transfer the desired fraction of the extract into 250 ml round bottom flask and concentrate in rotary vacuum flash evaporator adding 1 ml diethylene glycol solution at a temperature of less than 40°C. Dissolve the residue in 1 ml of acetone. Add 2 ml of 0.1 N methanolic potassium hydroxide solution. Allow the contents to stand at room temperature for 5 minutes. Add 17 ml of glacial acitic acid. Add 1 ml of colour reagent into the flask with constant stirring. Allow it to stand at room temperature for exactly one minute from the time of colour reagent additions. Transfer a portion of the sample in 1 cm cell of spectrophotometer and obtain the absorbance of the sample at a wavelength of 475 nanometer based on zero reading for blank. Determine the microgram of sevin from the calibration graph prepared. For the determination of alpha naphthol, the same procedure is adopted for extractions and clean up and samples are analysed without performing hydrolysis.

Extractions of Sediment

Transfer the representative weighed sample to a blender containing 100 ml methylene chloride. Blend the contents for one-two minutes. Allow the slurry to separate for 2-3 minutes. Filter the methylene chloride layer with Whatman 1 into a 500 ml flask. Repeat the extraction of sediment with fresh methylene chloride 4 times. Concentrate the filtrate in rotary vacuum evaporator and proceed further to clean up as described for water and develop colour. The concentration of sevin in sediments are expressed as ug/g of soil.

Preparation of Calibration graph for Sevin

Prepare the stock solution of sevin by weighing 10 mg of Sevin to 100 ml volumetric flask. Add acetone and mix thoroughly and dilute to the mark. Dilute the stock solution with acetone and prepare standard solutions of 1 ml = 10 ug. Prepare a series of standards having concentrations ranging from 0.5 ug to 20 ug and develop the colour by carrying out the hydrolysis. Prepare standard graph by plotting absorbance versus concentration of sevin. Find out the percentage recovery by adding known quantities of standard to samples and follow the procedure as given for samples. Calculate the percentage recovery by the following equation:

$$P = \frac{100\ Z}{T}$$

where, P = Percentage recovery

T = True value of added standard

Z = Experimentally determined value.

The sensitivity of the method is 0.1-0.2 ppm. However, even microgram concentrations of sevin can be measured by extracting large volume of water samples and concentration as low as 2 ug/l also can be measured. Percent recovery of this method is observed to be 92-105.

ANNEXURE III

DRINKING WATER STANDARDS

Parameter	ICMR		ISI		WHO	
	OBJ	MAC	OBJ	MAC	OBJ	MAC
Aluminium as Al, mg/l	-	-	-	-	0.2	-
Calcium as Ca, mg/l	75	200	75	200	-	-
Chloride as Cl, mg/l	200	1000	250	1000	250	-
Colour as platinum cobalt scale, Hazen units	5	25	10	50	15	15
Copper as Cu, mg/l	0.05	1.5	0.05	1.5	1	-
Hardness as $CaCO_3$, mg/l	300	600	300	600	500	-
Iron as Fe, mg/l	0.1	1.0	0.3	1.0	0.3	-
Manganese as Mn, mg/l	0.1	0.5	0.1	0.5	0.1	-
Magnesium as Mg, mg/l	50	100	30	100	-	-
pH	7.0-8.5	6.5-9.2	6.5-8.5	6.5-9.2	6.5-8.5	-
Sodium as Na, mg/l	-	-	-	-	200	-
TDS, mg/l	500	1500	500	3000	1000	-
Sulphate as SO_4, mg/l	200	400	150	400	400	-
Turbidity, NTU	5	25	10	25	5	-

Contd

Parameter	ICMR		ISI		WHO	
	OBJ	MAC	OBJ	MAC	OBJ	MAC
Zinc as Zn, mg/l	-	-	5	15	5.0	-
Fluoride as F, mg/l	1.0	1.5	0.6-1.2	1.5	1.5	-
Nitrate as N, mg/l	20.0	-	10.0	-	10.0	-
Arsenic as As, mg/l	-	0.05	0.05	NR	0.05	-
Cadmium as Cd, mg/l	-	0.01	0.01	NR	0.005	-
Chromium as Cr. mg/l	-	-	0.05	NR	0.05	-
Cyanide as CN. mg/l	-	0.05	0.05	NR	0.1	-
Lead as Pb. mg/l	-	0.1	0.1	NR	0.05	-
Mercury as Hg. mg/l		0.001	0.021	NR	0.001	-
Selenium as Se. mg/l	-	0.01	0.01	NR	0.01	-
DDT, ug/l (Total isomer)	-	-	-	-	1	-
Aldrin and Dieldrin, ug/l	-	-	-	-	0.03	-
Chlordane, ug/l	-	-	-	-	0.3	-
Heptachlor & Heptachlorepioxide, ug/l	-	-	-	-	0.1	-
Lindane, ug/l	-	-	-	-	3	-

Contd

Parameter	ICMR		ISI		WHO	
	OBJ	MAC	OBJ	MAC	OBJ	MAC
Methoxychlor, ug/l	-	-	-	-	30	-
2,4-D,ug/l	-	-	-	-	100	-
Pesticides, mg/l	-	-	Absent		-	-

ICMR: Indian Council of Medical Research, Manual of Standards of Quality for Drinking Water Supplies, 1975

ISI : Indian Standards Institution, Specifications for Drinking Water , IS:10500,1983

WHO : World Health Organisation, Guidelines for Drinking Water Quality, Vol. I, Recommendations, 1984

OBJ : Objectionable

MAC : Maximum Allowable Concentration

TDS : Total Dissolved Solids

NR : No Relaxation

ANNEXURE IV

HIGH PERFORMANCE LIQUID CHROMATOGRAPHIC ANALYSIS

Pond water samples were filtered through membrane filter and subjected to HPLC analysis.

Sediment samples were extracted with methylene chloride in soxhlet extractor and concentrated in rotary vacuum evaporator. The residue was dissolved in known volume 1:4 dioxan water and analysed by HPLC (Waters Associates, USA).

UV absorbance detector and Microbondapack C-18 chromatographic column were used for identification. Two solvent systems Dioxan : Water and Acetonitrile : Water were tried for identification of organics.

Operating Conditions:

1.	Acetonitrile and water	1:10
	Wave length	280 nm
	Flow rate	2 ml/min
	Pressure	105 ksc
	Chart speed	0.5 cm/min
2.	Dioxan and water	1:4
	Wave length	254 nm
	Flow rate	2 ml/min
	Pressure	105 ksc
	Chart speed	0.25 cm/min

GAS CHROMATOGRAPHIC ANALYSIS OF CHLOROFORM AND CARBON TETRACHLORIDE

Pinciple

The method is based on extraction into an organic solvent and measurement by gas chromatograph using electron capture detector. The lower detection limit is less than 0.1 ug/l.

Reagents

Stock solutions containing 10 mg/ml chloroform and carbon tetrachloride each were prepared in spectrographic grade redistilled benzene. Dilutions were made as necessary. Blank of solvents and water were analysed to insure their purity.

Analysis was performed using a gas chromatograph (Perkin - Elmer Model F-17) with linear Ni 63 electron capture detector.

Chromatographic Conditions

Column	Dexsil -400 on chromosorb W-AW 80 -100 mesh, $1\frac{1}{8}$ O.D. 2 m S.S
Oven temperature	60°C
Injector temperature	100°C
Detector temperature	100°C
Carrier gas flow	Ar + CH_4 - 25 ml/min

Sample preparation:

Fill up to the mark a 100 ml glass stoppered volumetric flask with sample.

Pipette 2.0 ml of hexane into the flask and cap tightly. Shake the sample vigorously for 2 min, and allow it to stand for 10 min before analysing the organic phase by removing the stopper and withdrawing a measured amount for injection into the gas chromatograph.

ANNEXURE VI

DETERMINATION OF METHYL AMINE IN WATER SAMPLES

Apparatus

Spectrophotometer: Spectronic-21 equipped with 1 cm path-length cells.

Water bath: Thermostat for constant heating arrangement at 85 °C.

Reagents

Ninhydrin reagent: Prepare a 0.2 % (w/w) solution of ninhydrin in isopropanol (0.16 gm dissolved in 100 ml isopropanol). This reagent is stable for 2 weeks if kept in a brown bottle.

Absorbing solution: Dilute one volume of conc. HCl to 100 volumes with isopropanol.

Reagent Grade Pyridine

n-Butylamine Stock Solution: (500 ug/ml) Weigh 0.250 gm of n-butylamine in a weighing bottle and dilute to 500 ml with absorbing solution.

n-Butylamine calibrating solution: Prepare a series of standards containing 2 to 100 ug/ml n-butylamine by diluting 0.4 to 20 ml of n-butylamine stock solution to 100 ml with absorbing solution. Take 1 ml of each solution and follow the analytical procedure.

Analytical Procedure

- Take 3 ml of the sample from the absorbing solution (1 ml of n-butylamine calibrating solution and dilute to 3 ml) in the heating tubes.
- To each of the tubes add 5 ml pyridine and then add 2 ml ninhydrin solution and mix.
- Place the tubes in water bath at 85°C for 7 minutes.
- Remove the tubes from the water bath and immerse them in cold water for 10 minutes.
- Transfer the solution to measuring cells and read the absorbance against that of the blank in the spectrophotometer set at 575 nm.
- Plot the absorbance of the calibrating solution as the ordinate versus the concentration as the abscissa on a linear graph paper.

Preparation of Water Samples

A 250 ml of water sample was transferred to a 500 ml separatory funnel. 5 ml of 4 N NaOH was added to it and the contents were shaken for one minute. It was allowed to remain as such for 5 minutes. A 25 ml aliquot of carbon tetrachloride was added and the contents were shaken for 2 minutes. The layers were allowed to separate. The organic layer was saved. Carbon tetrachloride extraction was repeated on the aqueous portion in the same way. The two carbon tetrachloride extracts were taken in a separatory funnel to which a 5 ml portion of 4 N hydrochloric acid was added. The contents were shaken vigorously for 2 minutes. The layers were allowed to separate. Organic layer was discarded and acidic aqueous portion was preserved for the determination of methylamine.

Determination of Methylamine

The 5 ml acid extract was mixed well with 5 ml of isopropanol. A 3 ml portion of this mixture was taken and subjected to the Ninhydrin reaction as described in the foregoing paragraph. A blank containing hydrochloric acid - isopropanol and standards containing various amounts of methyl amines in acid - isopropanol solution were similarly run. Absorbance of blue colour developed was recorded at 575 nm. Results were computed after subtracting the absorbance of the blank from the samples.

RECOMMENDED ANALYTICAL METHODS FOR SOILS

Measurements	Sample volume/ weight	Type of sample	Methodology	Reference
Physical				
Particle size analysis	20 g	Air dried and sieved	International pipette method	Methods of Soil Analysis C.A.Black, American Society of Agronomy Inc., Publisher Madison Wisconsin, USA, 1965.
Bulk density	-	Undisturbed soil core	Core or Clod method	Methods of Soil Analysis C.A.Black, American Society of Agronomy Inc., Publisher Madison, Wisconsin,USA, 1965.
Chemical				
pH of saturated soil paste	250 to 1000 g	Air dried and sieved	pH measurement	Diagnosis and Improvement of Saline and Alkali Soil, USDA Handbook No.60, 1954.
Electrical conductivity of saturation extract (ECe) mS/cm at 25°C.	250 to 1000 g	Saturation extract	Conductivity measurement	Diagnosis and Improvement of Saline and Alkali Soil, USDA Handbook No. 60, 1954.
Calcium (Ca), meq/l	20 ml	Saturation extract	EDTA Titration method	Diagnosis and Improvement of Saline and Alkali Soil, USDA,Handbook No.60, 1954.

Measurements	Sample volume/ weight	Type of sample	Methodology	Reference
Magnesium (Mg), meq/l	20 ml	Saturation extract	EDTA Titration method	Diagnosis and Improvement of Saline and Alkali Soil, USDA, Handbook No.60, 1954.
Sodium (Na), meq/l	20 ml	Saturation extract	Flame photometer method	Diagnosis and Improvement of Saline and Alkali Soil, USDA, Handbook No.60, 1954.
Carbonate (CO_3) and bicarbonate (HCO_3), meq/l	20 ml	Saturation extract	Titration method/ Potentiometric method	Diagnosis and Improvement of Saline and Alkali Soil, USDA, Handbook No.60, 1954.
Chloride (Cl), meq/l	20 ml	Saturation extract	Titration method	Diagnosis and Improvement of Saline and Alkali Soil, USDA, Handbook No.60, 1954.
Organic carbon (C) percent	0.5 to 2 g	Air dried 0.2 mm sieved	Wet digestion Walkey and Black method	Soil and Plant Testing as a Basis of Fertilizer Recommendations, FAO Soils Bulletin, 38/2, 1980.

ANNEXURE VIII

LITHOLOGS OF THE TEST BORE WELLS DRILLED IN UCIL-SEP AREA

Test Borewell No. 1

Location : 80 m S of SEP
Static water level : 4 m BGL
Discharge : 0.2 m^3/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic with association of coarse sand of basalt and occasional grains of gravel	1-6	5
Clay, light grey, with decreasing plasticity, and association of coarse sand and gravel of kankar, upto about 15 %	6-10	4
Clay, yellowish with increasing association of coarse gravel in depth of size 2.5-10 mm of vesicular/amygdaloidal/massive basalt	10-16.8	6.8

Contd..

Test Borewell No. 2

Location : 100 m ESE of SEP
Static water level : 6 m below ground level (BGL)
Discharge : 1.5 m^3/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic with association of medium to coarse sand of basalt and occasional grains of <u>kankar</u>	1-10	9
Clay, light grey, with decreasing plasticity and association of coarse sand and gravel of <u>kankar</u>, upto about 15 %	10-12	2
Clay, yellowish, mixed with gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	12-19	7
Clay, yellow, sticky	19-25	6
Clay, yellow, mixed with coarse-grained flattened gravel of Vindhyan sandstone and ending in the same bed rock	25-32	7

Contd..

Test Borewell No. 3

Location : 100 m ENE of SEP
Static water level : 4 m BGL
Discharge : 0.2 m^3/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic with association of medium to coarse sand of basalt and occasional grains of kankar	1-9	8
Clay, light grey with decreasing plasticity and association of coarse sand and gravel of kankar, upto about 15 %	9-12	3
Clay, yellowish, mixed with gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	12-19.81	7.81

Contd..

Test Borewell No. 4

Location : 180 m NE of SEP
Static water level : 4.5 m BGL
Discharge : 0.5 m³/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic, with association of medium to coarse sand of basalt, with or without smaller nodules of <u>kankar</u>	1-6	5
Clay, light grey, with decreasing plasticity, and association of coarse sand and gravel of <u>kankar</u>, upto about 15 %	6-12	6
Clay, yellowish, mixed with coarse sand and increasing association of gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	12-19.81	7.81

Contd..

Test Borewell No. 5

Location : 60 m NE of SEP
Static water level : 3.8 m BGL
Discharge : 1.5 m³/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic, with association of medium to coarse sand of basalt	1-6	5
Clay, light grey, with decreasing plasticity, and association of sand and kankar, fine to coarse	6-12	6
Clay, yellowish, with increasing association of gravel in depth of size 2.5-10 mm of vesicular/amygdaloidal/massive basalt	12-18.3	6.3

Contd..

Test Borewell No. 6

Location : 750 m NW of SEP (Berasia road)
Static water level : 9 m BGL
Discharge : $0.2\ m^3/hr$

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic, with association of coarse sand of basalt	1-7	6
Clay, light grey, with decreasing plasticity, and association of coarse sand and gravel of <u>kankar</u>, upto about 15 %	7-12	5
Clay, yellowish, mixed with gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	12-19.8	7.8

Contd..

Test Borewell No. 7

Location : 850 m SW of SEP (Premier Forging Co.)
Static water level : 5 m BGL
Discharge : 0.2 m³/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic with association of medium to coarse sand of basalt	1-7.5	6.5
Clay, dark grey, plastic with association of basaltic gravel of size 3-5 mm	7.5-9	1.5
Clay, light grey, plastic with association of grains of <u>kankar</u>	9-12	3
Clay, light grey, plastic with association of coarse sand of basalt	12-15	3
Clay, yellowish, with increasing association of coarse gravel in depth of size 2.5-10 mm of vesicular/amygdaloidal/massive basalt	15-16.15	1.15

Contd..

Test Borewell No. 8

Location : 1.75 kms E of SEP
Static water level : 6 m BGL
Discharge : 1.5 m^3/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic, with occasional grains of kankar	1-6	5
Clay, yellowish grey, plastic, with association of coarse sand and gravel of kankar of size 2.5-5 mm	6-9	3
Clay, yellowish, plastic, with association of medium to coarse sand	9-18	9
Gravel, flattened, of Vindhyan sandstone of size 50-150 mm, and ending in the same as bed rock	18-25.9	7.9

Contd..

Test Borewell No. 9

Location : 1.75 kms. NE of SEP
Static water level : 4 m BGL
Discharge : 5 m³/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, dark grey, plastic with occasional grains of <u>kankar</u>	1-6	5
Clay, dark grey, plastic with association of coarse sand and gravel of <u>kankar</u> of size 2.5-5 mm	6-9	3
Clay, light grey, plastic with association of medium to coarse sand	9-17	8
Gravel, flattened of Vindhyan sandstone of size 50-150 mm, and ending in the same as bed rock	17-22.9	5.9

Contd..

Test Borewell No. 10

Location : 2.4 kms NE of SEP (Chola Road)
Static water level : 4 m BGL
Discharge : 1.5 m³/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-1	1
Clay, light grey to yellowish with association of medium to coarse sand and occasional grains of <u>kankar</u>	1-9	8
Clay, yellowish with association of coarse sand and gravel of <u>kankar</u>	9-14	5
Clay, yellow with increasing association of gravel of vesicular/amygdaloidal/massive basalt of size 2.5-10 mm	14-18.3	4.3

Contd..

Test Borewell No. 5A

Location : 500 m SW of SEP (Near UCIL gate)
Static water level : 4.2 m BGL
Discharge : 0.35 m^3/hr

Lithology	Depth range (m)	Thickness (m)
Black cotton soil	0-2	2
Clay, dark grey, plastic with association of medium to coarse sand of basalt	2-4	2
Clay, dark grey, plastic with association of basaltic gravel of size 3-5 mm	4-9	5
Clay, light grey, plastic with association of grains of <u>kankar</u>	9-12	3
Clay, light grey, plastic with association of coarse sand of basalt	12-15	3
Clay, yellowish, with increasing association of coarse gravel in depth of size 2.5-10 mm of vesicular/amygdaloidal/massive basalt		

ANNEXURE IX

LOCATION OF MONITORING WELLS

S.NO.	Location	Distance m	Bearing	Depth m
Zone A : Less than 1 km from SEP				
1 TBW	NEAR SEP	365	S	16.80
2 TBW	NEAR SEP	350	ESE	32.00
3 TBW	NEAR SEP	360	ENE	19.81
4 TBW	NEAR SEP	500	NE	19.81
5 TBW	NEAR SEP	380	NE	18.30
5A TBW	NEAR UCIL	600	SSW	15.00
11 TW	GARIB NAGAR	460	ESE	38.00
12 TW	GARIB NAGAR	460	ENE	38.00
13 TW	GARIB NAGAR	300	E	---
15 TW	NEAR FCI	1000	E	---
45 TW	BERASIA ROAD (KAROD KALAN)	800	W	---
Zone B : 1 to 2.5 kms from SEP				
6 TBW	BERASIA ROAD	1050	NW	19.80
7 TBW	NEAR UCIL	1100	SW	16.15
8 TBW	RLY.WORKSHOP	1500	NE	25.90
9 TBW	RLY.WORKSHOP	2000	NE	22.90
10 TBW	CHOLA ROAD	2400	NE	18.30
14 TW	NISHATPURA	1100	NE	---
16 TW	PREMIER FORGING LTD.	1100	SW	---

Contd..

S.NO.		Location	Distance m	Bearing	Depth m
17	DW	SLUM BETWEEN UCIL AND RLY. LINE(ALMOST DRY)	500	S	---
18	TW	UCIL CAMPUS	1020	SSW	---
19	TW	UCIL CAMPUS	1020	SSW	---
20	TW	BETWEEN ICE FACTORY AND UCIL	1100	SSE	---
21	TW	EASTEREN AIR PRODUCTS.	1100	SSE	---
22	TW	JUNCTION OF CHOLA ROAD AND LINK ROAD.	1250	SSE	23
23	TW	JP NAGAR	1250	SSE	---
24	TW	JP NAGAR	1250	S	67
25	TW	KAZI CAMP	1200	SSW	---
26	TW	JP NAGAR	1200	SW	36
27	DW	KAZIPEN DIWAN DAULAT	1400	SSW	---
28	TW	CHOLA ROAD (BETWEEN CWC AND FCI)	1500	NE	---
29	TW	CWC	1750	ENE	---
30	TW	CWC GODOWN IN CHOLA ROAD	1600	NE	20
31	TW	CHOLA ROAD	1800	NE	---
32	TW	CHOLA ROAD (NEAR TEST BORE WELL 7T)	2300	NE	---

Contd..

S.NO.		Location	Distance m	Bearing	Depth m
33	TW	JUNCTION OF RING AND CHOLA ROAD.	2500	NE	---
34	DW	BHANPURA VILLAGE	2500	NE	---
35	TW	BHANPURA VILLAGE	2500	NE	43
36	DW	BHANPURA VILLAGE (A.G.LAND)	2500	NE	---
37	DW	BHANPURA VILLAGE NEAR PATRA NADI	2500	NE	---
38	TW	BHANPURA VILLAGE NEAR HANUMAN TEMPLE	2500	NE	38
39		NALLA WATER	2500	NE	---
40	TW	H.M.PLANT	2500	NE	---
41	DW	NABI BAGH (JUNCTION OF RING ROAD AND BARASIA ROAD)	2500	NNW	---
42	TW	BERASIA ROAD	2500	NNW	---
43	DW	BERASIA ROAD	2300	NW	---
44	DW	BERASIA ROAD (NEAR TEST BORE WELL 6T)	1300	WNW	---
46	TW	NEAR JN HOSPITAL	1200	SW	---
47	TW	RLY.WORKSHOP	2000	E	---
48	TW	RLY.WORKSHOP	2000	E	---

Contd..

S.NO.		Location	Distance m	Bearing	Depth m
49	TW	RLY.WORKSHOP	2000	E	---
50	TW	RLY.WORKSHOP	2000	E	---
51	TW	RLY.WORKSHOP	2000	E	---
52	TW	RLY.WORKSHOP	2000	E	---
53	TW	JUNCTION OF BARASIA ROAD AND LINK ROAD	1500	SW	46
54	TW	BAFRA COLONY	1400	SW	59
55	TW	KAZI CAMP	1500	SSW	---
56	TW	KAZI CAMP	1500	SSW	34
57	TW	BAFRIA COLONY	1700	SSW	43
58	TW	KAZI CAMP	1750	SW	---
59	TW	JAMALPURA	2000	SW	---
60	DW	RAILWAY COLONY	2000	SW	---
61	TW	SHAJAHANABAD BAJARA	2500	S	---
62	TW	HAMEDIA ROAD	2500	SSW	---
63	TW	CHOLA ROAD	2300	SSW	58
64	TW	CHOLA ROAD	2200	S	24
65	TW	CHOLA ROAD	2000	S	21
66	DW	BHOPAL RLY. COLONY	1750	SSE	---
67	TW	CHANDBAD	1800	SE	---
68	DW	KHAJANCHI BAGH	1750	SE	---
69	TW	RLY.COLONY	2250	SE	---

Contd..

S.NO.		Location	Distance m	Bearing	Depth m
70	DW	SAMRA GATE	2400	SE	---
71	TW	NEAR SAMRA GATE	2400	SE	---
72	DW	SAMRA KHALAN VILLAGE	2500	SE	---
Zone C : 2.5 to 5.0 km from SEP					
73	TW	NARIKEDA	3200	NW	---
74	TW	LAMBHAKEDA	5000	N	---
75	DW	VIDISHA ROAD	3500	NE	---
76	TW	GHESDABRAMAT	3500	ENE	---
77	TW	DHAMKHEDA	4500	E	---
78	TW	GOVINDAPURA (BHEL 13)	4500	SE	---
79	TW	JEHANGIRABAD	3500	S	---
80	TW	NOORMAHAL ROAD	3100	SSW	---
81	TW	EBRAHIMPURA	3600	SW	---
82	TW	SHAHJAHANABAD	3500	SSW	---
83	TW	AHMEDABAD	4000	SW	---
Zone D : 5.0 to 10.0 km from SEP					
84	TW	ISLAM NAGAR	8000	NNE	---
85	TW	ETHAIKHEDA	7500	ESE	---
86	TW	ARERA COLONY (OPP. E3/5)	7500	SSE	---

Contd..

S.NO.		Location	Distance m	Bearing	Depth m
87	TW	ARERA COLONY (NEAR MPPNM)	7500	SSE	---
88	TW	SHAHPURA	7000	S	---
89	TW	KOTRA SULTANABAD	8000	SSW	---
90	TW	HALDPURA	6500	WSW	---
91	TW	BAISAKHEDI	10000	WSW	---
92	TW	SIGARCHOLI	6000	WNW	---
93	DW	BADWARI	5200	NW	---

T ... Test borewells
D ... Dug wells
Others ... Tube wells constructed by state PHE dept for domestic purpose.

CHEMICAL QUALITY OF WELL WATERS

(All values except pH and EC are in mg/l)

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
Zone A Less Than 1 km from SEP									
1.	7.0 - 7.5	421 - 590 (519)	25 - 40 (30)	12 - 29 (19)	48 - 112 (78)	0.7 - 2.8 (1.5)	37 - 93 (71)	1.3 - 26 (11)	4 - 33 (14)
2.	7.1 - 8.5	560 - 828 (653)	10 - 56 (32)	10 - 45 (20)	55 - 188 (120)	0.9 - 2.4 (1.4)	60 - 94 (71)	9 - 15 (11)	4.4 - 11 (8)
3.	7.3 - 8.1	320 - 590 (457)	5 - 34 (23)	12 - 24 (19)	51 - 116 (73)	0.6 -2.9 (1.6)	15 - 63 (43)	2 - 8 (6)	3.1 -56 (17)
4.	7.3 -7.7	305-1285 (950)	10 - 42 (27)	2 - 22 (14)	55 - 318 (148)	0.5 -4 (1.4)	29 - 73 (56)	9 - 44 (26)	1.9 -30 (11)
5.	7.2 -7.4	450-1150 (833)	32 - 44 (38)	1 -19 (10)	75 - 210 (126)	1 - 2.8 (1.5)	40 -150 (105)	24 - 42 (32)	2.7 -54 (18)
5A.	7.2 - -	200 - -	24 - -	27 - -	38 - -	2.2 - -	58 - -	11 - -	2 - -
11.	6.4 -6.8	990 - -	98 -148 (125)	29 - 41 (37)	36 - 118 (67)	0.9 -1.3 (1.1)	135 -170 (151)	9 - 65 (28)	15 - 22 (12)
12.	6.8 -7.4	824 -880 (847)	46 - 88 (66)	4 - 42 (21)	91 - 128 (109)	0.9 -2.0 (1.2)	60- 89 (74)	4 - 22 (11)	7 - 39 (19)

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
83.	5.9- -	- - -	76 - -	16 - -	39 - -	11 - -	70 - -	18 - -	34 - -
Zone D 5 to 10 km from SEP									
84.	6.8- 7.1	- - -	122 - 124.2 (123)	34- 38.4 (36)	28.2 - 31 (30)	5 - 7.5 (6.2)	95- 108 (102)	13 - 25 (19)	4 - -
85.	8.7- -	- - -	134 - -	52 - -	33 - -	0.5 -	133- -	21 - -	3 - -
86.	7.2- -	- - -	102 - -	67 - -	35 - -	1.8- -	120 - -	18 - -	44 - -
87.	6.7- -	- - -	78 - -	22 - -	15 - -	0.4 - -	40 - -	10 - -	11 - -
88.	6.3- -	- - -	40 - -	8 - -	15 - -	0.4- -	125 --	19 - -	47 - -
89.	6.8- -	- - -	48 - -	14 - -	51 - -	0.6 --	63 - -	8 - -	44 - -
90.	6.7 -7.1	- - -	144- 154 (149)	76 - 86.4 (81.2)	48.8-85 (67)	0.5- 1.4 (0.9)	238 - 250 (244)	28 - 30 (29)	33 - -
91.	6.6- -	- - -	172 - -	48 - -	41 -	5.5 -	210-	32 - -	35 - -
92.	7.0 -7.1	- - -	64 - 87 (76)	35 - 36 (36)	20 - 21.4 (21)	1 - 2 (2)	6 - 18 (12)	1 - 3 (2)	3 - 10 (7)
93.	7.1 -7.1	- - -	56 - 73 (65)	25 - 74.8 (50)	27 - 34.6 (31)	1.5 -4 (3)	25 - 25 (25)	2 - - (2)	13 - 21 (17)

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
13.	6.5 -6.9	1080-1185 (1132)	69- 124 (88)	16 - 28 (21)	116 - 156 (142)	0.7 -1.0 (1.0)	110 -120 (113)	9 - 26 (18)	8 - 10 (9)
15.	7.1 -7.1	398 - -	108- 141 (124)	12 - 31 (22)	36 - 40 (38)	2.0 -2.0 (2.0)	68 - 129 (99)	25 - 35 (30)	40 - 56 (48)
45.	7.1 - -	845 - -	50 - -	19 - -	24 - -	0.7 - -	33 - -	4 - -	10 - -
Zone B 1 TO 2.5 kms from SKP									
6.	8.9 -9.3	870 -1020 (945)	4 - 12 (8)	0.5- 23 (8.1)	62- 150 (106)	0.6 -0.9 (0.8)	20 - 38 (31)	8 - 16 (12)	12- 65 (39)
7.	7.7-10.1	410 -623 (538)	18 - 53 (33)	4 -20 (10.6)	96 - 136 (113)	0.9 2.4 (1.5)	83 - 88 (85)	14 - 27 (21)	4.2 - 7 (5.6)
8.	6.8 7.7	272 620 (494)	26 -200 (99)	13 48 (30)	26 93 (54)	0.8 2.2 (1.3)	66 98 (79)	14 - 24 (17)	1.9 5 (3.4)
9.	6.8 -7.4	413 460 (431)	48 -146 (75)	14 - 31 (21)	28 - 93 (47)	1.9 3.5 (2.6)	48 -190 (85)	8 22 (15)	2.2 16 (7.4)
10.	7.0 -7.3	263- 480 (252)	46 - 84 (57)	10 - 42 (25)	17 - 115 (51)	1.3 2.8 (1.9)	27 -158 (88)	5 - 13 (8.8)	1.4- 73 (26)

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
14.	6.9 -7.3	745 -845 (797)	62 - 84 (75)	20 - 96 (43)	51 - 84 (73)	0.7 -3.0 (1.5)	57 - 160 (89)	9 - 26 (18)	10 - 31 (19)
16.	6.5 -7.0	890 - -	42 - 97 (60)	20 -59 (46)	37 - 72 (49)	0.7 -1.0 (0.9)	100 -103 (101)	1 - 1 (1)	15 - 32 (26)
17.	6.8 - -	- - -	182 - -	325 - -	- - -	3.6 - -	1535 - -	40 - -	36 - -
18.	6.4 -6.9	876 -958 (917)	98 -126 (109)	15 - 46 (33)	37 - 47 (43)	0.6- 2 (1.0)	115 -260 (157)	11 - 34 (20)	14 - 51 (30)
19.	6.5 -7.0	755 - -	65 -115 (89)	16 - 37 (25)	39 - 78 (57)	0.7 -4 (1.6)	35 - 235 (107)	12 - 24 (19)	5 - 64 (27)
20.	6.4 -6.7	7680 - 8360 (8020)	478 -914 (675)	182 -364 (263)	91 -588 (343)	1.6 -3.5 (2.6)	3600 -3700 (3667)	22 - 86 (47)	58 -78 (68)
21.	6.6- 7.3	1869-2140 (2000)	38- 318 (208)	8 - 150 (75)	96 -133 (112)	1 - 2 (1.4)	540 -560 (549)	8 - 33 (18)	12 - 28 (20)
22.	6.4- 7.2	1297-1400 (1349)	40 -150 (132)	48 - 61 (55)	49 - 67 (56)	5.5 -8.1 (7.1)	175- 228 (200)	26 - 76 (57)	24 - 46 (35)
23.	6.4 -6.8	1260 - - (1260)	50 -122 (85)	53 -110 (82)	53 - 54 (54)	6.8 -9.4 (8.1)	158- 170 (164)	43 - 75 (59)	36 - - (36)
24.	6.4 -7.0	1240- 1174 (1207)	20 -150 (138)	30 - 43 (42)	48 - 62 (53)	1.3 -3.0 (1.9)	175- 210 (196)	21 - 48 (35)	22 - 69 (39)

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
25.	7.2 - -	- - -	86 - -	32 - -	104 - -	0.8 - -	83 - -	13 - -	26 - -
26.	6.4 -7.0	1150- 1190 (1170)	134 -178 (152)	40 - 56 (47)	43 - 47 (47)	0.4 -0.9 (0.7)	83 - 215 (211)	13 - 33 (28)	16 - 32 (24)
27.	6.3- 6.4	1500 - -	216 - -	26 - -	59 - -	1.8 - -	295 - -	29 - -	36 - -
28.	6.6 -7.0	850 -2370 (1793)	76 -296 (188)	21 - 170 (173)	40 - 97 (80)	0.7 -1.4 (1.0)	107- 683 (534)	4 - 30 (14)	11 - 28 (20)
29.	6.7- 7.0	1500 -2120 (1810)	208 -309 (252)	36 - 67 (55)	33- 104 (47)	1.0 -3.0 (1.8)	260- 698 (464)	18 - 23 (20)	25 - 84 (55)
30.	6.7 -7.2	860 -1920 (1496)	118- 246 (202)	36 - 73 (63)	36 - 69 (56)	1.0 - 4.0 (1.7)	203- 418 (292)	16 - 42 (25)	23- 156 (83)
31.	6.9 -7.0	580 -630 (605)	86 - 98 (94)	20 - 31 (26)	16 - 24 (21)	0.4 - 1.2 (0.7)	11 - 33 (19)	2 - 10 (5.3)	14 - -
32.	6.7- 6.8	1049 - -	33 - 180 (117)	16 - 98 (56)	32 - 55 (44)	0.7 - 0.9 (0.8)	155- 188 (174)	8 - 22 (15)	13 - 30 (22)
33.	6.8- 7.1	790 -830 (810)	104 - 130 (118)	18 - 52 (32)	28 - 36 (33)	0.6 - 1.4 (0.9)	93 - 111 (101)	7 - 21 (13)	24 - -
34.	6.5 -7.4	1200 - -	78 - 152 (115)	40 - 116 (78)	38 - 42 (40)	8.6 -10 (9.3)	223- 240 (232)	20 -24 (22)	17 - -

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
35.	6.6 -7.1	1080 - -	128- 132 (129)	35 - 55 (44)	39 - 45 (42)	0.9 -4.1 (10.6)	163- 175 (204)	11 - 28 (17)	16 - 59 (38)
36.	6.9 -7.6	- - -	138- 162 (150)	73 - 82 (78)	55 - 61 (58)	2.6 -3.0 (2.8)	273- 280 (277)	20 - 24 (22)	55 - 59 (57)
37.	6.8 -7.2	950 - - (950)	107- 118 (113)	16 -108 (62)	20 - 60 (40)	1.2 - 1.7 (1.7)	123 -290 (207)	11 - 12 (12)	8 - -
38.	6.8- -	670 - -	124 -141 (78)	18 - 44 (31)	17 - 40 (28)	0.8- 1.7 (1.4)	133- 275 (204)	11 - 22 (17)	12 - -
39.	7.0- -	- - -	82 - - (82)	20 - - (20)	46 - - (46)	1.8 - - (1.8)	155- - (155)	6 - - (6)	8 - - (8)
40.	7.3- 6.9	780 -843 (812)	20 - 44 (34)	22 - 49 (33)	24 - 132 (84)	0.4 -1.8 (1.1)	28 - 35 (32)	7 - 33 (18)	10 - - (10)
41.	7.2 - 7.9	665 - 710 (688)	44 - 61 (50)	27 - 38 (34	16 - 80 (57)	0.5 - 3 (1.5)	28 - 50 (38)	1 - 16 (8)	11 - 51 (31)
42.	7.1 -7.6	1050 -	66 - 86 (76)	36 - 41 (39)	21 - 85 (53)	0.6 - 1.2 (0.9)	132- 135 (134)	8 - 13 (11)	22
43.	6.6- 7.3	- -	44 - 90 (67)	20 - 45 (33)	17 - 69 (43)	0.4 -1.1 (0.8)	118- 168 (143)	14 - 22 (18)	21 -
44.	7.2- 7.4	940 - -	28 - 34 (31)	17 - 17 (17)	30 - 34 (32)	1.6 -4 (2.8)	15 - 23 (19)	6 - 18 (12)	22 - -

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
46.	6.8 - -	- - -	122- -	34 - -	31 - -	5 - -	95 - -	13 - -	10 - -
47.	6.9 - -	- - -	208- -	7 - -	30 - -	3 - -	168- -	5 - -	75 - -
48.	7.1 - -	- - -	114- -	37 - -	42 - -	2 - -	95 - -	8 - -	28 - -
49.	6.7- -	- - -	136- -	46 - -	35 - -	2 - -	133 - -	- - -	37 - -
50.	7.2 - -	- - -	66 - -	40 - -	30 - -	2 - -	135 - -	1 - -	4.1- -
51.	6.9 - -	- - -	152- -	55 - -	45 - -	2 - -	208 - -	2 - -	10
52.	7.1		104	32	32 - -	6 - -	88	5	8
53.	6.8 - 7.0	- -	134 - 139 (137)	52 - 65 (59)	93 - 109 (101)	87 - 11.1 (4.9)	220 - 435 (328)	41 - 56 (49)	6 - 17 (12)
54.	6.4 - 6.5	- - -	101 - 244 (123)	13 - 44 (29)	37 - 68 (53)	0.9 - 1.9 (1.4)	240 - 470 (355)	31 - 33 (32)	17 - 49 (33)
55.	6.2- -	- - -	84 - -	19 - -	39 - -	1.9 - -	128- -	30 - -	32 - -

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
56.	6.7- 7.0	- - -	99 -242 (171)	49 - 95 (72)	31 - 90 (61)	5 - 5 (5)	220- 820 (520)	48 - 79 (88)	59 - 78 (69)
57.	6.8- -	- - -	62 - -	22 - -	31 - -	2 - -	205- -	25 - -	19 - -
58.	6.7- -	- - -	150- -	89 - -	66 - -	12 - -	260- -	21 - -	26 - -
59.	5.5- -	- - -	4 - -	30- -	21 - -	2.5 --	93- -	3 - -	10 - -
60.	6.7- -	- - -	32 - -	109 - -	90 - -	0.9 - -	400- -	17 - -	19 - -
61.	7.2 --	- - -	18 - -	12 - -	45 - -	1.5 --	68 - -	13 - -	17 - -
62.	6.8	40	10 - -	50 - -	2	70	10 -	10 -	- - -
63.	6.3- 6.3	- - -	46 -46 (46)	9 -31 (20)	18 - 23 (21)	3.1 3.3 (3.2)	55 100 (78)	11 11 (11)	15 - 17 (16)
64.	6.7- 6.9	- - -	84 -102 (93)	31 - 35 (33)	29 - 35 (32)	1 - 4.1 (2.6)	68 -150 (109)	40 - 61 (51)	17 - 18 (18)

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
65.	6.8- -	- - -	123- -	41 - -	45 - -	13 - -	225- -	25 - -	9 - -
66.	6.8- 6.8	- - -	144- 176 (110)	5.7- 34 (20)	39 - 49 (44)	1.5- 3.3 (2.4)	120- 260 (190)	30 - 59 (45)	28 - 41 (35)
67.	6.9- -	- - -	80 - -	17 - -	25 - -	0.6 - -	63 - -	21 - -	102 - -
68.	6.4- 6.5	- - -	86 -144 (115)	16 - 34 (25)	44 - 50 (47)	1.9- 10 (6)	88 - 115 (102)	2 - -	5 - 33 (19)
69.	6.6- -	- - -	224- -	41 - -	16 - -	3.8- -	70 - -	30 - -	11 - -
70.	6.5- -	- - -	146- -	24 - -	86 - -	14 - -	225- -	63 - -	16 - -
71.	6.8 - -	- - -	160	25 - -	35 - -	3 - -	65 - -	5 - -	14
72.	6.7 - -	- - -	157 - -	26 - -	31 - -	17 - -	320 - -	43 - -	9
Zone C 2.5 to 5 km from SKP									
73.	7.2 - -	940 - -	28 - -	17 - -	30 - -	1.6 - -	15 - -	6 - -	1.6 - -

Contd..

Well No.	pH	EC mS/cm,25°C	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate-N
74.	6.9 -7.0	- - -	48 - 56 (52)	14 - 36 (25)	22 - 26 (24)	1.3 - 2 (1.6)	13 - 23 (18)	8 - -	2.5- 27 (15)
75.	7.1- 9.6	- - -	12 - 60 (36)	7.2- 10 (8.6)	32 - 51 (42)	7.2- 25 (16)	35- 115 (75)	8 - 18 (13)	6 - 10 (8)
76.	7.0 -7.3	- - -	76- 132 (104)	19 -52.8 (36)	44- 35.4 (40)	13 - 17 (15)	65 -138 (102)	14 -29 (22)	35- - (35)
77.	7.2- -	- - -	72 - -	34 - -	32 - -	6.5 - -	80 - -	2 - -	30 - -
78.	7.1- -	- - -	44 - -	4 - -	16 - -	3.8 - -	210 - -	5 - -	- - -
79.	7.0- -	- - -	80 - -	12 - -	55 - -	18 - -	75 - -	18 - -	21 - -
80.	6.5- -	- - -	34 - -	8 - -	51 - -	0.6	65 -	8	40
81.	7.2- -	- - -	30 - -	8 - -	13 - -	4 - -	23 - -	8 - -	25 -
82.	6.1- -	- - -	76 - -	19	41 - -	9 - -	65 - -	13	22

Contd..

ANNEXURE XI

COMPUTATION OF TOTAL CHLORIDE IN POND

An attempt was made to compute the total quantity of sediment and water present in the pond as on June 1989 which require treatment and/or disposal.

The length and breadth of water spread were measured to determine its area in Ponds I and II. Pond III was totally dry during June 89. The depth of water column, about 3m from water edge, was also measured at different points from where samples were collected and averaged. The water spread multiplied by the depth provided an approximate volume of pond water. Total chloride in pond waters was then calculated from the chloride contents in the respective waters.

The depth of sediment upto the liner at different locations in each pond was measured and averaged. This was done randomly taking 10-25 points to cover the total pond bottom. Pond bottom dimensions were also measured. Volume of sediment was then estimated from the area and the average depth of sediment.

The moisture content of the sediment samples ranged from 20-40% depending on the degree of dryness of the sediment at different points. Average of 30% moisture was assumed for calculating the dry weight of the sediment. The density of the sediment was assumed as 1.1 MT/m^3. From the actual values of chloride measured in the composite sediment samples from each pond, the total weight of chloride in the sediments was estimated.

The chloride input into the pond, through neutralised wastewater was also worked out based on the total MIC produced since its manufacture. The data on the chloride in pond water and sediments are presented in Table XI. 1. The volume of sediment was computed as 26170 m^3 having a total chloride content of 1123 MT. The total chloride in pond water worked out to be about 2163 MT and thus the total chloride in SEP is 3286 MT.

Assuming that chloride input into SEP was only through the neutralised acid wastewater the ponds should have received a total chloride of about 3400 MT which is nearly equal to the total chloride present in the pond water and the sediments. This further supports the view that there was no seepage of the impounded water from SEPs into the ground water and soil.

TABLE XI.1 : TOTAL CHLORIDE IN PONDS

(As on June 1989)

Pond No.	Volume m^3	Dry Weight MT	Chloride %	Total Chloride MT
Pond Sediment				
I	7920	5540	6.80	377
II	14000	9800	7.56	726
III	4250	3270	0.60	20
Total	**26170**	**18610**		**1123**
Pond Water				
I	3000		214	642
II	5850		260	1521
III	No Water		--	--
Total	**8850**		--	**2163**

Total Chloride in the ponds	**3286 MT**
MIC Production	**2709 MT**
HCl Produced as Wastewater	**2709 x 1.2842**
	3479 MT as HCl
Total Chloride Input	**3382 MT**

ANNEXURE XII

TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP)

TCLP involves a leaching procedure used to simulate the aqueous leaching of a toxic chemical when the waste is land disposed. Any waste that exceeds the toxicity threshold limits (Table XII.1) is considered hazardous. In this test a known quantity of waste is mixed with 20 times its weight of extraction fluid (Acetic acid - NaOH - pH 4.93± 0.02, or Acetic acid 2.08 ± 0.02) and shaken in a rotary shaker for 18 hours, after which it is filtered through 0.6-0.8 u GFC. The filtrate is analysed for heavy metals, pesticides, herbicides and organics. For volatiles and semi volatiles the samples are to be estimated in a zero head space extractor. Details of the test procedure is described in Federal Register (Vol. 51, No. 216, 1986/Rules and Regulations).

TABLE XII.1 : CONTAMINANTS PROPOSED FOR TESTING WITH THE TCLP AND PROPOSED REGULATORY LEVELS

Contaminant	Regulatory level, mg/l
Acrylonitrile	5.0
Arsenic	5.0
Barium	100.0
Benzene	0.07
bis(2-Chloroethyl) ether	0.05
Cadmium	1.0
Carbon disulfide	14.4
Carbon tetrachloride	0.07
Chlordane	0.03
Chlorobenzene	1.4
Chloroform	0.07
Chromium	5.0
o-Cresol	10.0
m-Cresol	10.0
p-Cresol	10.0
2,4-D	1.4
1,2-Dichlorobenzene	4.3
1,4-Dichlorobenzene	10.8
1,2-Dichloroethane	0.40
1,1-Dichloroethylene	0.1
2,4-Dinitrotoluene	0.13
Endrin	0.003
Heptachlor	0.001
Hexachlorobenzene	0.13
Hexachlorobutadiene	0.72
Hexachloroethane	4.3
Isobutanol	36.0
Lead	[illegible]
Lindane	0.06
Mercury	0.2
Methoxychlor	1.4
Methylene chloride	8.6
Methyl ethyl ketone	7.2
Nitrobenzene	0.13
Pentachlorophenol	3.6
Phenol	14.4
Pyridine	5.0
Selenium	1.0
Silver	5.0
1,1,1,2-Tetrachloroethane	10.0
1,1,2,2-Tetrachloroethane	1.3
Tetrachloroethane	0.1
2,3,4,6-Tetrachlorophenol	1.5

Contd.

Contaminant	Regulatory level, mg/l
Toluene	14.4
Toxaphene	0.07
1,1,1-Trichloroethane	30.0
1,1,2-Trichloroethane	1.2
Trichloroethane	0.07
2,4,5-Trichlorophenol	5.8
2,4,6-Trichlorophenol	0.30
2,4,5-TP (Silvex)	0.14
Vinyl chloride	0.05

Source: Freeman, H.M (ed); "Standard Handbook of Hazardous Wastes Treatment and Disposal"; McGraw Hill Inc., N.Y.,1988

ANNEXURE XIII

CATEGORIES OF HAZARDOUS WASTES

Waste Categories	Type of wastes	Regulatory Quantities
Waste Category No. 1	Cyanide Wastes	1 Kilograms per year calculated as cyanide
Waste Category No. 2	Metal Finishing Wastes	10 Kilograms per year the sum of the specified substance calculated as pure metal
Waste Category No. 3	Waste containing water soluble chemical compounds of lead, copper, zinc, chromium, nickel, selenium, barium and antimony	10 Kilograms per year the sum of the specified substance calculated as pure metal
Waste Category No. 4	Mercury, Arsenic, Thallium and Cadmium bearing wastes	5 Kilograms per year the sum of the specified substance calculated as pure metal
Waste Category No. 5	Non-halogenated hydrocarbons including solvents	200 Kilograms per year calculated as non-halogenated hydrocarbons
Waste Category No. 6	Halogenated hydrocarbon including solvents	50 Kilograms per year calculated as halogenated hydrocarbons
Waste Category No. 7	Wastes from paints, pigments, glue, varnish and printing ink	250 Kilograms per year calculated as oil or oil emulsions
Waste Category No. 8	Wastes from Dyes and Dye intermediate containing inorganic chemical compounds	200 Kilograms per year calculated as inorganic chemicals
Waste Category No. 9	Wastes from Dyes and Dye intermediate containing organic chemical compounds	50 Kilograms per year calculated as organic chemicals
Waste Category No. 10	Waste oil and emulsions	1000 Kilograms per year calculated as oil and oil emulsions
Waste Category No. 11	Tarry wastes from refining and tar residues from distillation or pyrolytic treatment	200 Kilograms per year calculated as tar
Waste Category No. 12	Sludges arising from treatment of wastewaters containing heavy metals, toxic organics, oils, emulsions and spent chemicals and incineration ash	Irrespective of any quantity

Contd.

Waste Categories	Type of wastes	Regulatory Quantities
Waste Category No. 13	Phenols	5 Kilograms per year calculated as phenols
Waste Category No. 14	Asbestos	200 Kilograms per year calculated as asbestos
Waste Category No. 15	Wastes from manufacturing of pesticides and herbicides and residues from pesticides and herbicides formulation units	200 Kilograms per year calculated as pesticides and their intermediate products
Waste Category No. 16	Acid/alkaline/slurry wastes	200 Kilograms per year calculated as acids/ Alkalies
Waste Category No. 17	Off-specification and discarded products	Irrespective of any quantity
Waste Category No. 18	Discarded containers and container liners of hazardous and toxic wastes	Irrespective of any quantity

Source : Gazette of India, Extraordinary; Part II, Section 3- Subsection (ii), July 28, 1989

ANNEXURE XIV

COMPATIBILITY OF SELECTED WASTE CATEGORIES WITH WASTE SOLIDIFICATION AND STABILIZATION TECHNIQUES

Waste Categories	S/S Treatment Type			
	Cement-based	Lime-based	Thermoplastic solidification	Organic polymer (UF)+
Organics				
Organic solvents and oils	Many impede setting, may escape as vapour	Many impede setting, may escape as vapour	Organics may vaporize on heating	May retard setting of polymers
Solid organics (e.g., plastics, resins, tars)	Good - often increases durability	Good - often increases durability	Possible use as binding agent	May retard setting of polymers
Inorganics				
Acid wastes	Cement will neutralize acids	Compatible	Can be neutralized before incorporation	Compatible
Oxidizers	Compatible	Compatible	May cause matrix breakdown, fire	May cause matrix breakdown
Sulfates	May retard setting and cause spalling unless special cement is used	Compatible	May dehydrate and rehydrate causing splitting	Compatible

Contd.

Waste Categories	S/S Treatment Type			
	Cement-based	Lime-based	Thermoplastic Solidification	Organic Polymer (UF)†
Halides	Easily leached from cement; may retard setting	May retard setting; most are easily leached	May dehydrate	Compatible
Heavy metals	Compatible	Compatible	Compatible	Acid pH solubilizes metal hydroxides
Radioactive materials	Compatible	Compatible	Compatible	Compatible

Compatible indicates that the S/S process can be successfully applied to the indicated waste component. Exceptions to this may arise dependent upon regulatory and situation specific factors

†UF : urea formaldehyde resin

Source: Freeman, H.M (ed), "Standard Handbook of Hazardous Wastes Treatment and Disposal"; McGraw Hill Inc., N.Y.,1988