DRAFT REPORT

ASSESSMENT OF CONTAMINATED AREAS DUE TO PAST WASTE DISPOSAL PRACTICES AT EIIL, BHOPAL

SPONSOR

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BHOPAL

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EXECUTIVE SUMMARY

* M/s. Everyday Industries India Limited (EIIL)(Formerly M/s. Union Carbide India Limited) was manufacturing Carbamate type pesticides between 1977 and 1984 at their Bhopal plant. The plant was closed down since December 1984 due to leakage of MIC

* Solid and tarry wastes, falling under waste categories 15, 17 and 11 under Hazardous Wastes (Management and Handling) Rules 1989, generated during the manufacture of pesticides were dumped in open areas within the plant premises

* The above mentioned past disposal activities would have resulted in contamination of land and water environment. The dumped materials, and contaminated land and water if present, have to be remediated to restore the environmental quality of the plant premises

* EIIL retained National Environmental Engineering Research Institute, Nagpur to assess the environmental status within the plant premises in March 1994

* The study area is within the facility premises of EIIL, Bhopal and this includes only waste disposal areas, spilled areas and open area. In addition, open land on the north adjacent to EIIL plant premises has also been included in the study area

* Tarry residues generated from Sevin and Naphthol units which are classified as hazardous wastes are stored in drums. Separate studies are in progress at NEERI and IICT on the treatment and disposal of these residues and these are not included in the present study

* The off specification products were disposed in open areas within the plant premises. The tarry residues generated from sevin and temik units are mostly stored in drums and other containers. However, six pits were made to store/dispose tarry residues. The neutralized temik waste was pumped to two solar evaporation ponds constructed within the plant premises. An incinerator was used to combust trashes. The ash from incinerator was disposed on open land near incinerator. The burnt and unburnt residues (Waste Category 17) which arose from the fire accident in naphthalene godown is stored in underground pit

Dump Materials

* The disposal area is divided into three zones covering about 7 hectares (11% of total area). The maximum sevin content in dump was recorded as high as 520003 mg/kg. About 20% of the samples are having sevin more than 1000 mg/kg. Maximum number of samples (37%) have sevin content between 100 and 500 mg/kg. The concentrations of temik in dump materials vary widely from BDL to 7876 mg/kg. Temik was either BDL or not detected in 37% of

samples. Alpha naphthol was recorded between 500 and 10000 mg/kg only in 7 samples out of 64. Lindane was in traces in 50% samples and not detected in the remaining 50%. Naphthalene was not detected in any samples. The volatile organics of concern was not detected in any sample. However presence of other organics is not ruled out as the chromotographs have recorded other peaks which could not be identified.

* The unburnt and burnt residues of naphthalene which was buried in an underground pit has naphthalene content of 33%.

Soil Quality

* In Disposal Area I (DA I), the maximum concentration of sevin and temik were 356.32 mg/kg and 74.36 mg/kg respectively. Alpha Naphthol was not detected in any sample in DAI. However Lindane was present almost in all samples recording between 0.5 mg/kg and 201.4 mg/kg

* In Disposal Area II (DA II), the maximum areal extent and maximum quantity of wastes dumped, sevin concentration is 7218 mg/kg. Alpha naphthol concentration varied between 19.83 mg/kg and 1194.6 mg/kg in nearly 50% of the samples. Lindane is between o.34 mg/kg and 2.8 mg/kg in 13 samples out of 36 samples

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* In the remaining area (Rest of area), in general, the semi volatiles are below detection limits. However, in two sites, temik is recorded as 78.36 mg/kg and 102.4 mg/kg. Lindane, alpha naphthol and naphthalene are not detected in any sample

* Among the heavy metals, manganese is present between in high concentration (388 to 978 mg/kg) in six site

* Samples collected near target and spill areas did not show the presence of contaminants except in traces in a few sites. Thus the impact due to material handling in target/spill areas is minimum. Poly chlorinated Biphenyls (PCBs) and asbestos are not detected

* Soil samples collected along the wastewater drain indicated the increased presence of chloride at higher depths. However the increased level of chloride is within the limit

Ground water

* Seventeen ground water samples collected in and around EIIL did not show the presence of semi volatiles, organics, heavy metals and inorganics. The water meets the drinking water quality criteria. This indicates that the contaminants have not reached the water table till now. In general, the soil in the area is clayey soil with more than 45% clay content. This clayey soil is highly impermeable and would travel approximately at

the rate of 36 cm/year at the permeability rate of $1x10^{-5}$ cm/sec. i.e. it would take many decades for the contaminants to reach the ground water table provided the leachate does not find a channel to migrate at a faster rate. This could be reason for the water in not getting contaminated

Geoelectrical Investigation

* The geoelectrical investigations carried out by National Geophysical Research Institute, Hyderabad revealed that the soil strata is predominated with black cotton soil and the absence of any fault and fissures. The profiling studies do indicate the soil resistivity changes in disposal areas

Conclusion

* In order to evaluate the soil quality and to designate as contaminated areas, risk based soil quality criteria is adopted. The risk based quality criteria for soil and ground water given by Region III of US EPA has been considered. The soil has been considered as contaminated wherever the soil quality exceeds the criteria level

* Accordingly, it is concluded that the entire Disposal Area I (0.3 ha to a depth of 60 cm) and a few identified contaminated zone in Disposal Area II (0.32 ha to a depth of 30 cm) and at two sites in rest of

area (0.08 ha to a depth of 30 cm) is designated as contaminated area and require decontamination

Dump materials and naphthalene residues do need treatment and disposal in view of their hazard potential

* The tarry residues present in the pits and also present in the disposal areas are required to be decontaminated alongwith the tarry residues stored in drums. Studies are in progress at NEERI, Nagpur and IICT, Hyderabad to determine the treatment and disposal methods for these tarry residues in an environmentally friendly manner

* Treatability studies are required to determine the remediation measures for contaminated soil and treatment and disposal methods for dump materials. Based on the treatability studies, design criteria can be developed. The purpose of the treatability studies is to restore contaminated sites located within the the entire plant premises

* At one sampling point (23 - Table 3.13) in Disposal Area II, near incinerator, waste material was stored 15 cm below ground level. This material has to be excavated and characterized before treatment and/or disposal of the same

1.0 PREAMBLE

1.1 Introduction

M/s. Eveready Industries India Limited (EIIL)(Formerly M/s. Union Carbide India Limited) was manufacturing Carbamate type pesticides between 1977 and 1984 at their Bhopal plant. The plant was closed down since December 1984 due to leakage of Methyl Iso Cyanate (MIC). Solid and tarry wastes generated during the manufacture of pesticides were dumped in open areas within the plant premises. As is common in chemical manufacturing operations, particularly in batch process, spillages (of chemicals, solvents and products) might have occurred during handling, storage and transportation inside the plant. The above mentioned past disposal activities would have resulted in contamination of land and water environment. The dumped materials, and contaminated land and water if present, have to be remediated to restore the environmental quality of the plant premises. NEERI is retained by EIIL in March 1994 to investigate the present status of dump materials and their impact on land and water environment.

1.2 Aims and Objectives

* The overall objective of the study is to prepare a baseline status of dump materials, impacted land and water environment within plant premises of EIIL, Bhopal due to the past hazardous waste disposal activities.

1.3 Scope of the Project

* Collection and collation of data on the raw materials

and products handled during facility operation in order to develop an increased understanding of material's chemical and physical properties

* Identification of dump areas and spill sites

* Collection of representative samples from dumps, known impacted land, suspected unimpacted land, and ground water for chemical analysis

* Investigation of geological and hydrogeological features of the plant areas

* Specifications for proposed monitoring test bore wells in the facility premises, if required

* Assessment of air quality during the construction of test borewells, if necessary

* Preparation of baseline status report and remedial measures plans

1.4 Study Area

* The study area is within the facility premises of EIIL, Bhopal and this includes only waste disposal areas, spilled areas and open areas. In addition, open land on the north adjacent to EIIL plant premises has also been included in the study area

* The study area does not include the office buildings, inside of sheds and workshops located in the facility premises

* Soil samples and ground water are to be analyzed from sources outside EIIL, Bhopal facility to assess the possibility of contaminant migration associated with former facility operation

* The approximate landuse pattern of the facility premises is as follows :

Buildings	....	15.8 ha
Waste Disposal Area	....	6.9 ha
Roads and open area	....	7.8 ha
Total	....	30.5 ha

* Tarry residues generated from Sevin and Naphthol units are stored in drums. These are not included in this study

1.5 Methodology

* Reconnaissance survey was carried out to identify the disposal areas in the plant premises, and to obtain the

type of wastes disposed

* A Standard Operating Procedure (SOP) was prepared on sampling and analytical procedures to be adopted in this study to assist the scientists in conducting high quality assessment of impacted site. This was prepared in consultation with M/s. Arthur D. Little Inc., Cambridge, USA who was consultant to EIIL

* Field Sampling, sample preservation, and analysis were carried out as per SOP

* All precautions were taken to collect representative samples and Personnel Protection Equipments (PPEs) were used during sample collection

1.6 Manufacturing Process

1.6.1 Methyl Iso Cyanate (MIC)

Methyl isocyanate (MIC), an intermediate in the production of carbaryl, is synthesized from phosgene ($COCl_2$) and monomethyl amine (CH_3NH_2). The process 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 vapor phase leads to the formation of methyl carbamoyl chloride (MCC).

$$CH_3NH_2 + COCl_2 \text{------>} CH_3NHCOCl + HCl$$

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 neutralization in a lime pit.

The overall reaction is as follows :

$$CH_3NH_2 + COCl_2 \longrightarrow CH_3N=C=O + 2\,HCl$$

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.

1.6.2 Sevin (Carbaryl)

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

$$RN = C = O + ArOH \longrightarrow \underset{\text{Carbaryl}}{RNH - C}\begin{matrix} \diagup O \\ \diagdown OAr \end{matrix}$$

Isocyanate is gradually added upon stirring to an excess of alpha Naphthol in carbon tetra chloride solvent at 60 - 80^{o}C in presence of catalyst. The reaction is exothermic. The yield of product is more than 95%.

1.6.3 Alpha Naphthol

Crushed naphthalene (25% be weight) is dissolved in orthodichlorobenzene (ODCB) at 35^{o}C. Sulphonation is carried out by reacting naphthalene solution with chlorosulphonic acid (CSC) at 16 to 20 ^{o}C. HCl vapors evolved is absorbed. Naphthalene sulphonic acid produced after sulphonation is dissolved in water at 40°C. The resulting mass NSA solution and ODCB is continuously transferred to a decanter. The top layer being 40% NSA solution is neutralized with 40% caustic solution and the bottom ODCB is taken to crude ODCB tank. SNS formed in the neutralizer is crystallized and filtered. The wet SNS cake is fed to preheaters for drying. The fused mass is dissolved in water to obtain sodium naphtholate solution (SN). The SN solution reacts with HCl in an acidulator and the reaction mass is pumped to a naphthol decanter where crude naphthol layer settles at the bottom while salt layer being lighter floats at top and is transferred to hot pit. Crude naphthol is washed in hot water to reduce salt concentration. The solution is evaporated and the solid residues are removed by vacuum distillation.

1.6.4 Temik (Aldicarb)

The raw materials required to manufacture temik include MIC, TMA and CH_2Cl_2. These raw materials are taken to a reactor. HCl gases are scrubbed in alkali scrubber. The reacted product is taken to a charge pot where nitrogen is passed before it is filtered. The resulting solution is temik. The temik solution is taken to a granualtor. The temik solution gets coated in the granules. The granulated temik is sized in a sieve shaker. The oversize and undersize are rejected. The solvents are distilled.

1.7 Sources of Wastes

During the manufacturing of MIC, acidic wastewater containing HCl (15 - 20%) was generated. After neutralization, the treated wastewater was stored in solar evaporation ponds (SEPs). These ponds are located outside the plant premises. Based on the earlier studies carried out by NEERI in 1990 and 1992 at SEPs, remedial measures have been recommended and the same is being implemented by EIIL.

The other major source is tarry residues. These tarry residues were from the distillation units of Sevin and Naphthol units. Most of the tarry wastes are stored in drums and other containers and these are not included in this study. However, a portion of the tarry residues are disposed in pits and on open land within the plant premises.

In addition to these process wastes, solid wastes mostly consist of off-specification products were generated during the manufacture of both technical and formulation grade pesticides. During manufacture of temik, the oversized and undersized granules are rejected. The rejected granules were decontaminated with 5% caustic soda solution and the liquid (slurry) was pumped to temik solar evaporation ponds. As the plant was closed suddenly after the gas leakage in December 1984, residues were left in the temik neutralization pits. The residues are dried and this is categorized as solid waste for this study. The other major source of solid waste is from the sevin units mainly of off-specification products. It is reported that no solid waste was generated from the process. These solid wastes are disposed within the plant premises.

Further, there was a fire accident in naphthalene godown and the burnt and unburnt residues were disposed in an underground pit which also constitute as solid waste.

1.8 Solid Waste Handling

The off specification products were disposed in open areas within the plant premises. The tarry residues generated from sevin and alpha naphthol units are mostly stored in drums and other containers. However, six pits were made to store/dispose tarry residues. The neutralized temik waste was pumped to two solar evaporation ponds constructed within the plant premises. An incinerator was used to combust trashes. The ash from incinerator was disposed on open land near incinerator. The burnt and unburnt residues arised from the fire accident in naphthalene godown is stored in underground pit.

1.9 Standard Operating Procedures (SOPs)

In view of the many activities involved in evaluating the present status of dump materials, and environment in and around EIIL plant premises, it was felt that there is need to develop a Standard Operating Procedure (SOP). It is a written document to be followed during sampling and analysis of samples. It is essential that the SOP be documented, controlled, maintained and followed without exception unless authorised. Such standardization procedure assures that no matter who performing the work, the information provided will be reproducable.

SOP was prepared after preliminary reconnaissance survey and based on the inputs from M/S. Arthur.D.Lttle Inc., SOP was made available to the study team members involved both in sampling and analysis. SOP was addressed at the following :

* Sample control including sampling locations, sample collection, sample preservation, sample storage and transportation
* Analytical methods
* Quality control programme during sampling and analysis
* Safety and Health Plans including type of Personnel Protection Equipments (PPEs)

1.10 Pollutant Pathways

It is essential to determine the pathway of the pollutant from the source to the receptors. The plant was closed in December 1996 and hence no activity since then. The wastes that were disposed within the plant premises are in the form of solids and tarry residues. The wastes contain mainly semivolatile matters such as sevin, temik, alpha naphthol, lindane and naphthalene. However organic compounds used in the process as raw materials can be expected to be present in the waste. The wastes were expected to contain heavy metals also. The main pathway of pollutant migration from the disposal sites is mainly through ground water. This is possible due to rain. The water soluble portion present in the waste may get dissolved and travel through the soil before joining water table. The earlier studies carried out by NEERI in 1990 and 1992 indicated that the subsurface soil around EIIL facility is of clayey soil having a very low permeability. The volatile organic compounds (VOCs) release from the dumps is not ruled out. However, the fugitive emission from these dumps due to VOCs is expected to be low as these wastes are lying since December 1984. The VOCs would have already got vaporized. It is assumed that there could an impact on the soil and water environment. Thus it is concluded that the ground water could be the major pathway. In view of this, emphasis is given in this study to evaluate the status of soil and ground water both within the plant premises and also in the neighbourhood of the plant premises. However air quality during sampling would be assessed in order to measure the VOCs trapped in the soil.

1.11 Parameters of Concern

The information collected during the reconnaissance survey indicated that the disposed materials are mainly belong to off-specification category. As stated earlier, these wastes are expected to be predominant with semivolatiles and partly with organics and heavy metals. In this study, semi volatiles such as sevin, temik, alpha naphthol, lindane and naphthalene are considered as primary pollutants. The organics includes Chloroform, Formaldehyde, Methylene Chloride, 1-2- Dichlorobenzene, Toluene, Monomethylamine, Carbon tetra Chloride, and TMA. Heavy metals such as manganese, copper, zinc, chromium, cadmium, lead and nickel are considered.

2.0 SAMPLING PROCEDURES

2.1 Study Area Details

The study area is mainly within the facility premises excluding the sheds. Studies were concentrated on the open land to assess the impact due to past disposal activities. The study area within the facility premises is divided into five major areas based on the location, possible impacted area, and suspected impacted area, and disposal practices. They are as under :

* Disposal Area I
* Disposal Area II
* Disposal Area III
* Target Area
* Rest of the area

The waste materials mainly include the off specification products from Sevin and Temik plants. These solid wastes are disposed as heaps inside the plant premises. Another major source is tarry residues and are partly disposed mainly in pits except a few above the ground. The third major solid waste buried below the ground level is burnt and unburnt naphthalene. In addition, the dried neutralized temik waste in neutralization tank, and evaporated waste material present in temik solar evaporation ponds constitute solid waste. As happen in any industry, trash materials are also seen in many waste disposal heaps. It is reported that no waste was reported to have been disposed outside the plant premises. The total disposal area is about 6.9 ha.

2.2 Disposal Areas

The wastes that were dumped/disposed include sevin dust, temik granules, tarry residues from sevin and naphthol plants, and off quality products. Reconnaissance survey carried out in February 1994 revealed that the wastes including off quality products (pesticides) were dumped mainly in three areas inside the facility premises. These are designated as Disposal Areas I to III for this study (Fig 2.1)

The wastes from temik plant and formulation unit located on the northern end of the facility were expected to have been disposed in Disposal Area I due to close proximity. They were mainly dumped on open land above the ground. The temik neutralization tanks are also located in this disposal area. It was reported that the waste from Temik plant was taken to two underground tanks (adjacent to Temik plant) for neutralization. The underground tanks have dried waste materials.

Most of the wastes generated from other process units such as CO, Sevin, Naphthol, and MIC were expected to have been disposed in Disposal Area II which is the largest in areal extent. The solid waste were dumped above the ground and tarry residues were partly disposed in pits.

The neutralized temik waste was pumped into solar evaporation ponds having lime bed. It has been reported that the neutralized waste was discharged into only one solar evaporation pond while another solar evaporation pond was constructed as standby. These ponds are located in Disposal Area II.

There was a fire accident in naphthalene godown and the burnt residues were stored below the ground level. In addition, there are two open pits where some fire residues were appeared to have been dumped. This constitutes the Disposal Area III (Fig 2.2).

In addition to the defined three disposal areas, spillage, material handling arising from various units/sections would have resulted contamination of land and water environment. Such areas are covered as Target Areas(Fig 2.3).

The remaining area within the facility premises excluding the sheds is termed as Rest of Area.

2.3 Sampling Methods for Dump Materials

2.3.1 Dump Material (Above Ground)

Most of the dumpsites located within the known disposal areas are small (< 20 m^3 in volume) and consist of different waste materials such as solid wastes, tarry residues and trashes.

Initially, the dump materials were excavated from each dumpsite (heap) above the ground level and segregated into solid waste, tarry waste (if any) and trash.

Trash materials such as plastic containers, papers etc., which do not form as waste materials were removed. Since the trash materials have been in close contact with hazardous materials, these were considered as hazardous materials. Such items were stored separately in a bag.

Composite samples were then collected to obtain a near representative sample of the waste materials dumped. During such excavation sampling, air quality was monitored keeping one sampler each in upwind and down wind of each heap. This investigation was carried out initially at five disposal sites. The SPM levels were far below the allowable limit for Sevin (5 mg/m^3). It was assumed that SPM contains only Sevin (as worst case scenario). This indicated that the impact due to dump material excavation is insignificant.

The bags containing different waste materials were counted and weighed. The bags were subsequently transferred to shed for storage by EIIL. All information was logged.

However, the sampling (after removal of dumps) was discontinued. Subsequently, samples from each heap at different points and from different depths were collected and composited.

The implements after sampling each heap was decontaminated. Necessary personnel protection equipments (PPE) were used both by the labors and supervising staff.

2.3.2 Sampling from pits

It is observed during the preliminary visit that only tarry residues were disposed in the pits located in Disposal Area II (Fig 2.1). There are six pits each of about 3 m x 3 m in size. Four pits were partly filled with tarry residues while two pits appear to have not received the waste.

In addition to the four pits in Disposal Area II, there two pits in Disposal Area III adjacent to the naphthalene underground storage. These pits were reported to have been constructed to store excess naphthalene residues. These pits were observed to be with solid wastes and tarry residues for a depth not more than about 15 cm. The waste disposed is therefore is very less.

One composite sample from each pit was collected for characterisation using cup.

2.3.3 Sampling of Ponds

There are two solar evaporation ponds having lime bed. It is reported that Pond I on the extreme eastern end had received neutralized waste from Temik plant while Pond II to the west of Pond I has been reported to have been unused. However samples upto 30 cm depths were collected from five locations of each pond.

The samples were composited at 15 and 30 cms depths pondwise. The samples of Pond I was not mixed with Pond II.

2.3.4 Sampling of Buried Materials

Residues (both burnt and unburnt) arised from fire accident of naphthalene godown buried under the ground is the only identified buried dump below ground level.

The top soil at the centre of the buried dump was removed. Sample at 60 cm depth from the top surface of waste material was collected for characterisation.

During sampling at Sample ID No. 23 in Disposal Area II (Fig 2.4), near incinerator, waste material was observed to have been buried below the ground level(15 cm below ground level). A random sample was collected for characterisation.

It is to be stated that none of the buried waste material was removed from the site for storage. They are still present in the site.

2.3.5 Sampling of Temik Neutralization Tank

Initially it was planned to remove the sediments present in the ponds, and then the soil present (above liner if provided) were to be collected for characterisation. This could not be carried out in order to comply with the 'minimum sampling' suggested by the Hon'ble Session Court, Bhopal.

There are two underground tanks where the waste from temik plant was taken for neutralization with alkali. It has been observed that the tanks contain waste material. As the contents were in dry condition, samples at different depths and from different points from each tank were collected and composited tankwise for characterisation.

2.4 Soil Sampling

2.4.1 Site Description

The plant premises of EIIL, Bhopal is classified into five zones for soil sampling to delineate the extent of impact due to past facility operations. They are as follows:

- Disposal Area I near Formulation plant on the north east of the plant premises
- Disposal Area II on the eastern side of the plant
- Spill and target areas
- Underground wastewater drains and pipelines
- Rest of the area not covered in the above categories including the outside plant premises area on the north adjacent to the plant

2.4.2 Sampling Locations

Disposal Area I (Fig 2.4)

It was informed during the reconnaissance survey that most of the waste materials from Temik plant and other formulation units were reported to have been dumped along the road sides and to a little extent in the inner area. In view of this, the Disposal Area I is divided into two zones viz., 20 m width from the road sides as outer periphery (Zone A) and the rest of the inner area as inner Periphery (Zone B). In addition, there is a very small disposal area to the east of the Disposal Area I.

* In Zone I (outer periphery), soil samples were collected from seven locations spaced at equal distance
* In Zone II, the area was divided into seven grid points and the soil samples were collected from the centre of these grids
* Soil samples from three locations from the small area adjacent to main disposal area were collected

Disposal Area II (Fig 2.5)

It was observed that most of the materials were dumped along the roadside to a distance of less than 20 m. However there are small dumps away from the road. Hence a width of 20 m from the edge of the road and along the road was considered as the width of this dump area.

The area was divided into grids of 40 m x 40 m and the samples were collected at the centre of each grid.

Disposal Area III (Fig 2.2)

Initially, it was planned to collect soil samples around the naphthalene residue disposal site. However, as the study was in progress and after in-depth field investigation, it was decided to include the sampling location under rest of the Area. Hence no soil sampling location is discussed in this report under Disposal Area III.

2.5 Spill Area / Target Area

In addition to the disposal areas where solid wastes and tarry residues were dumped as briefed earlier, it is also anticipated that the land and water environment would also be affected due to other activities including handling of raw materials and products, spillages near storage tanks and their transfer points, and spillages near the major process units.

The identified sources and sampling location for each source are detailed in Table 2.1.

Plants/Sheds: The main process units where spillages of raw materials or products or intermediates may have occurred include Sevin, Temik, MIC, and naphthol. The sampling locations are within 1 m from the fence.

Storage Tanks : The raw materials (chemicals) were pumped into the tanks directly from the trucks and were subsequently pumped to the process units. It is therefore expected that the spillages could occur near the pumps/ transfer points.

Soil samples from four points within 1 m from each pumps/ transfer points were collected.

PCB Sources : Spillages are anticipated in electricity substations, workshops, diesel generator sets etc., where the oils might have spilled during handling. These are identified as possible sources of PCBs. Soil samples (outside the building) from about 4 to 6 points from each target sites were collected.

2.6 Along Wastewater Drain (Fig 2.6)

The acidic wastewater generated from MIC unit was taken to the neutralization unit through underground drain. The drain was about 1 m below groundlevel. The wastewater contained mainly chloride. In order to assess whether there was any leakage of wastewater, soil samples at six locations along the drain (Fig 2.6) were collected.

2.7 Rest of the area (Fig 2.7)

The above mentioned sampling locations would give a scenario of the quality of land at and/or near the identified dumps which are potential sources of contamination. The contaminants may have traveled and affected the quality in other areas within the plant premises. It is also anticipated that pesticides would have become airborne during handling operation and would have deposited in other areas within the plant premises. In order to evaluate the impact of past activities, soil samples from the rest of the area of the plant premises were also collected. The area was divided into grids of 40 m x 40m. Soil samples at the nodes as shown in the Figure 2.7 were collected.

In addition, soil samples were also collected from the open land adjacent to the facility boundary wall on the north.

Background Samples

In order to compare the soil quality within the facility premises, soil samples away from facility premises are required to be collected. The data collected from such locations would present back ground level. Soil samples from three locations about 500 m outside the plant premises were also collected to obtain back ground level.

2.8 Sampling Methods

2.8.1 General

It has been observed during the reconnaissance survey that vegetation growth was predominant in the facility premises in spite of disposal of hazardous waste materials. The vegetation was removed before fixing the sampling location. This also aided in locating additional disposal sites. Initially, the sampling location in each area was identified and located. A flag with serial number was fixed at each sampling location for future reference. Soil samples at predetermined depths were collected using crowbar and shoal as auguring is not possible. Volatile Organic Compounds (VOCs) using Organic Vapor Analyzer(OVA- Foxbourgh make) were monitored during sampling. Recorded the colour (Munsell color system), any odor, type of soil, UCS classification (using the chart provided) in the field data sheet (Annexure I) . The depths of soil sampling varied with the sites and the same is summarized in Table 2.2.

2.8.2 Disposal Areas

The soil samples at 15 cm and 30 cm depths were collected with stainless steel scoop and transferred the soil samples into plastic bags with ziplock facility. By taking samples at 15 cms and 30 cms and then mixed to obtain a better representation of sample status upto 30 cm. This is particularly true in this case because of the presence of low permeable top soil.

The excavation was continued upto 60 cm depth and collected soil samples.

SOIL SAMPLES OF 30 CM AND 60 CMS WERE NOT MIXED AND COLLECTED IN THE SAME PLASTIC BAG. THE SAMPLES FOR ORGANIC ANALYSIS AND SEMIVOLATILES WERE PRESERVED AT OR BELOW $4^{O}C$.

Collected duplicate soil samples at 30 cm and 60 cm depths once in TWENTYsample locations to meet the requirements of QC/QA.

2.8.3 Target Areas

Soil samples were collected at 15 and 30 cms from each identified location.

2.8.4 Rest of Area

In general, the top and subsurface soils are of low to moderate permeable type. It is anticipated that contamination would have been confined to the top layer.

Based on this assumption, soil samples were collected at 15 and 30 cm. The samples are then composited for each site.

Field duplicate soil samples were collected once in every Twenty samples to meet the requirements of QC/QA.

2.9 Compositing of Samples

2.9.1 Samples to be composited

Disposal Area I

There are three zones in this area and samples collected were as follows:

- 7 samples from outer periphery
- 7 samples from inner periphery and
- 3 samples from small area adjacent to main disposal area

Samples collected from sites of each zone were composited separately and depthwise. i.e. one composite sample each of 30 cm and 60 cm from each zone. However during excavation, dump material was obtained in Sample DAI 04 and this sample was preserved seprately and was not considered for compositing.

Disposal Area II

Samples collected at 15 cm and 30 cm depths at each site was composited in the field to represent as one sample representing the entire 30 cm depth. Samples of 30 cm and 60 cms were not be composited. Thus two samples viz., 30 cm and 60 cms were collected for analysis.

Target/Spill Area

Samples collected from each target/spill area were composited as shown in Table 2.1.

Along the Drain

No compositing of soil samples was adopted for samples collected along the wastewater drain.

Rest of the Area

No compositing of samples was made in the rest of the area collected under Grid pattern at the site. In view of possible low concentration in this area, a few samples have been composited in the laboratory.

2.9.2 Compositing Procedure

A stainless steel container having less surface area but with more depth was used for compositing which was carried out in the field. Equal volume of soil sample from each sample bag was taken and mixed gently to obtain a composite and homogeneous sample. Transferred about 500 gms into each of three sample bags. One sample bag was preserved in ice container as a prerequisite for organic compound analysis.

2.10 Sample Preservation

Samples were collected and preserved in the ice box for semi volatiles and organics as per SOP at the site. The samples were then transferred to deep fridge available in the EIIL laboratory. The samples were again kept in the ice box for transportation to Nagpur. On reaching NEERI, the samples were kept again in deep fridge. Care was taken to prevent any cross contamination while handling the samples.

2.11 Decontamination

The implements before shifting to next depth, before shifting to the next site and after completion of day's work were decontaminated. Washed all the implements with water. After first washing with water, soap bath was given. Then rinsed with water and dried. All implements were inspected for any apparent residue prior to reuse.

Collected 'Equipment Blank' samples to meet QC/QA at regular interval.

2.12 Ground Water Sampling

2.12.1 Preamble

The past waste disposal activities at EIIL, Bhopal would have resulted in contaminating groundwater by seepage through soil media. Studies were therefore carried out to evaluate the possible impact on the ground water due to past disposal activities. The sources of ground water wells are of two types viz. monitoring wells, and production wells based on the purpose for which they were constructed.

Monitoring wells : Wells constructed within and outside the facility premises only for monitoring water quality

Production wells : Wells constructed for routine use for drinking or for any other purpose and which are in constant use. These are located both inside the plant as well outside the plant premises of EIIL. The production wells inside the EIIL premises have electric pump while public production wells have hand pumps

2.12.2 Well Locations

The identified wells for monitoring the water quality are shown in Fig 2.8.

2.12.3 Sampling Procedures

2.12.4 Monitoring Wells

There are two deep bore wells within the plant premises and these wells have not been in constant use. In view of this, purging method was adopted. Samples were collected following SOP and are outlined below :

* Removed the pump and other fittings.
* Monitored the head space immediately for volatile organic compounds (VOC) with Organic vapor analyzer (OVA). This was done by placing the instrument probe at the opening of the well and recorded the reading in the field sheet (Annexure II)
* Measured and recorded the depth to water and depth to well bottom from the ground level using a decontaminated rope.
* Tied a weight to one end of the rope and slowly introduced into the well. After the weight touched the well bottom, marked the ground level on the rope. Measured the total well depth and the wet portion on the rope. The length of wet portion gives the water column. The diameter of the well was also noted. All data were recorded in the Ground Water Monitoring Sheet.

* Computed the unit purge volume.

* After replacing the handpump, purging with bailer was carried out. As soon as water came out of the well, water quality was tested at the site for temperature, pH, conductivity and dissolved oxygen with the portable water test kit.

* Purging was continued and the water quality at 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 and 5.0 purge volumes was monitored. and recorded the data in the field data sheet. The water quality parameters were considered to have been stabilized when the following criteria were reached for two successive purge volumes:

  - Temperature ± 0.5 ^{o}C
  - pH ± 0.5 units
  - Conductivity ± 10 %
  - DO ± 1 ppm

  Turbidity readings were recorded after all parameters have been stabilized and prior before sample collection.

* The presence of chlorine was checked by dipping a piece of KI starch paper into a water sample.

* Recorded the information on unique odors, colour and suspended matter content.

* The required preservatives were added to the sample containers as described in Table 2.3 just before sampling

* Rinsed the sampling bailer once with water drawn directly from the well prior to sample collection. The rinsed water was discarded.

* Collected the required amount of water to fill the sample bottles taking caution to minimize the distribution of the well water.

* Initially samples were collected for organics and semivolatiles in the respective sample containers.

* All samples for semi volatiles and organics will be preserved at 4^{o}C.

2.12.5 Production wells

The wells identified under this category are located adjacent to EIIL (within 500 m) and these wells are in constant use by the public. As these wells are in constant use, purging method was not adopted. Water was collected and immediately tested for pH, temperature, conductivity and DO using portable water test kit. The presence of chlorine was tested in the field. Recorded the information such as unique odors, colour and suspended matter content if any in the field data sheet.

The required preservatives were added to the sample containers as described in Table 2.3 just before sampling.

Initially samples were collected for organics and semivolatiles in the respective sample containers. Water samples were collected in separate containers for other analysis

2.13 Chain of Custody

The samples were labelled properly to facilitate proper identification of samples. All samples were preserved as per SOP and transported to Nagpur for analysis. Recorded all information pertinent to the field survey in the field log book. After inspection of sample containers for possible damage during transit and any other discrepancies, samples were analyzed.

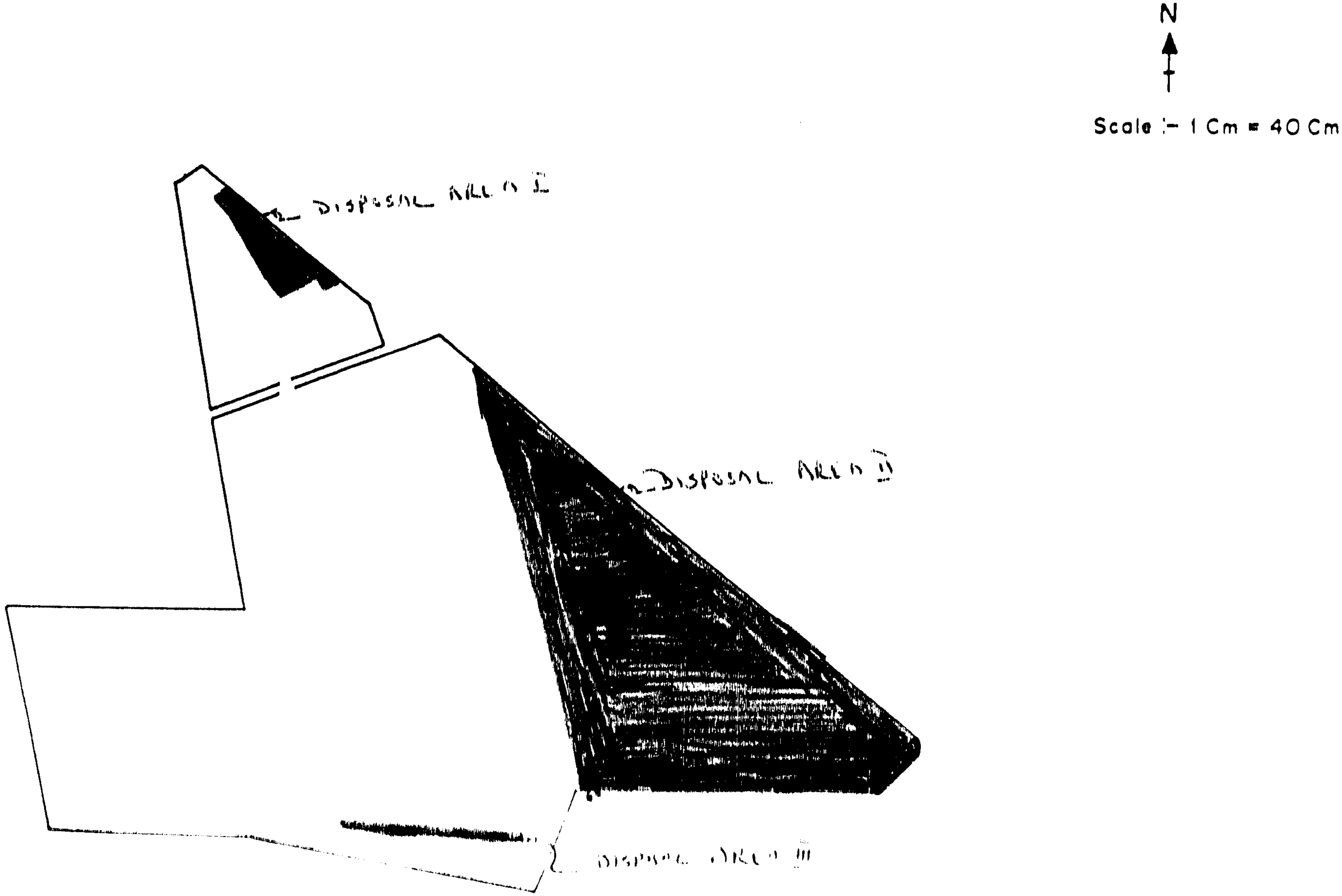


FIG 2.1 DISPOSAL AREAS AT EFIL, BHOPAL

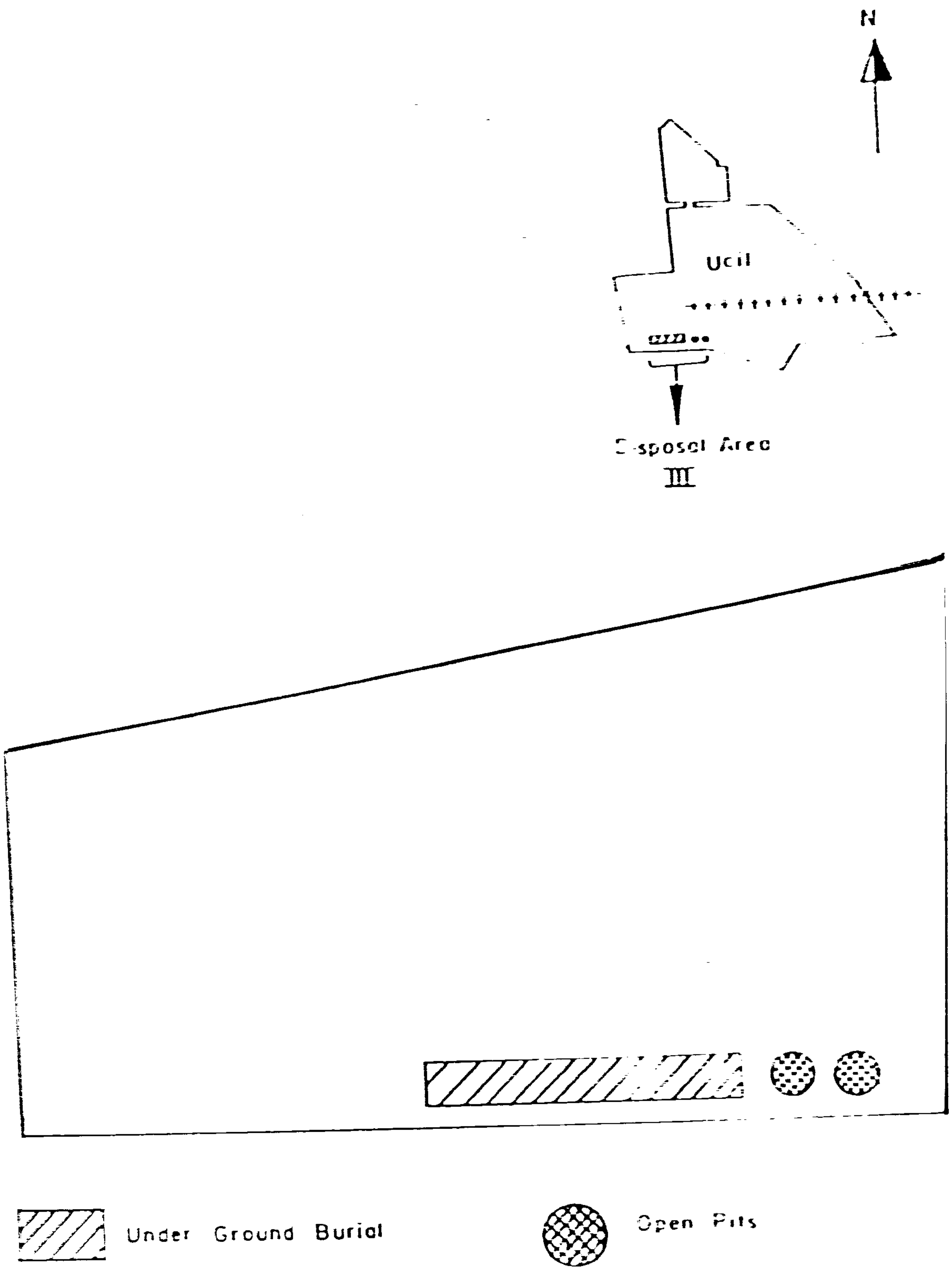


FIG 2.2 NAPHTHALENE DISPOSAL LOCATION

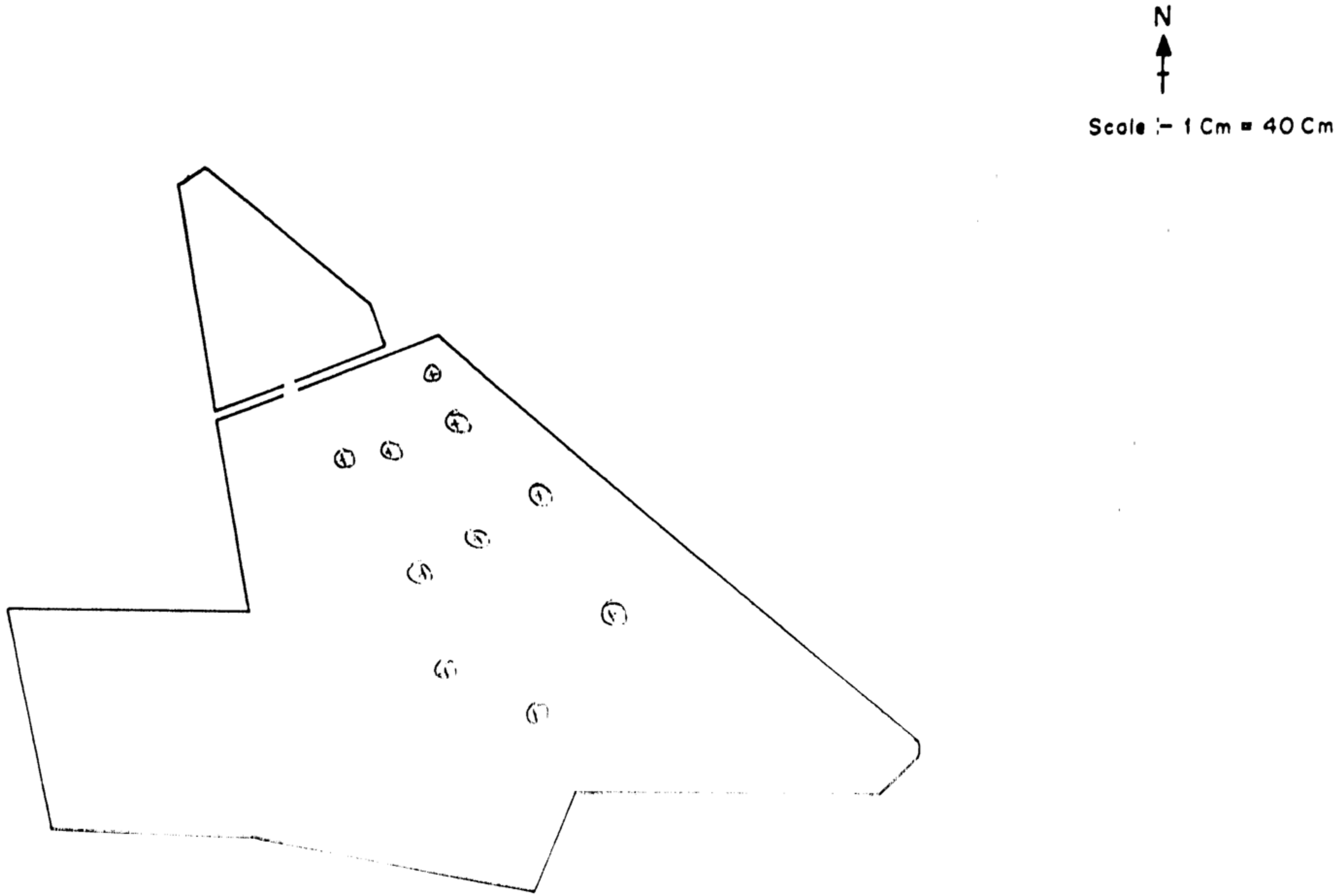


FIG 2.3 TARGET AREAS AT EIIL, BHOPAL

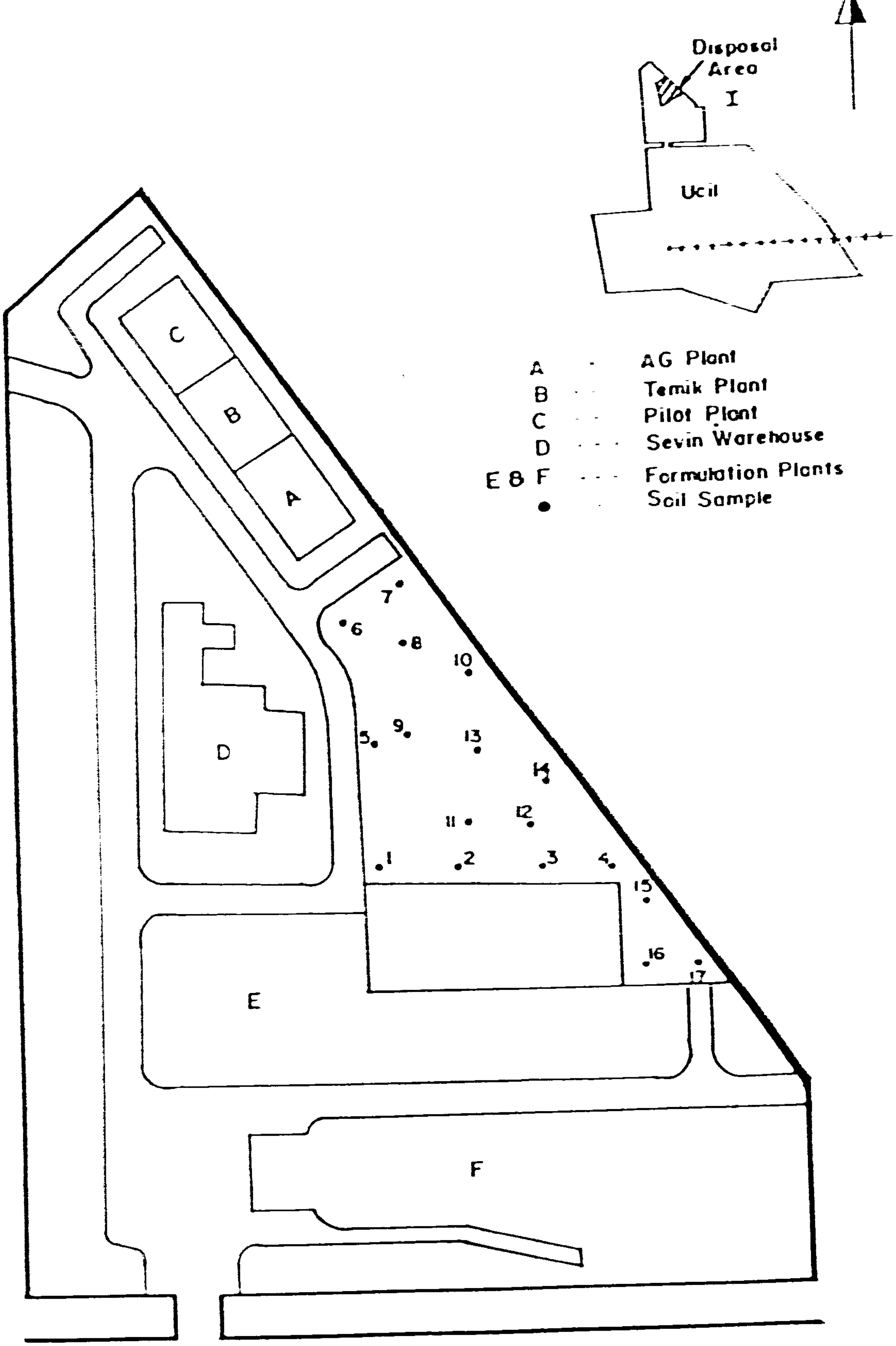


FIG 2.4 SOIL SAMPLING LOCATIONS AT DISPOSAL AREA I

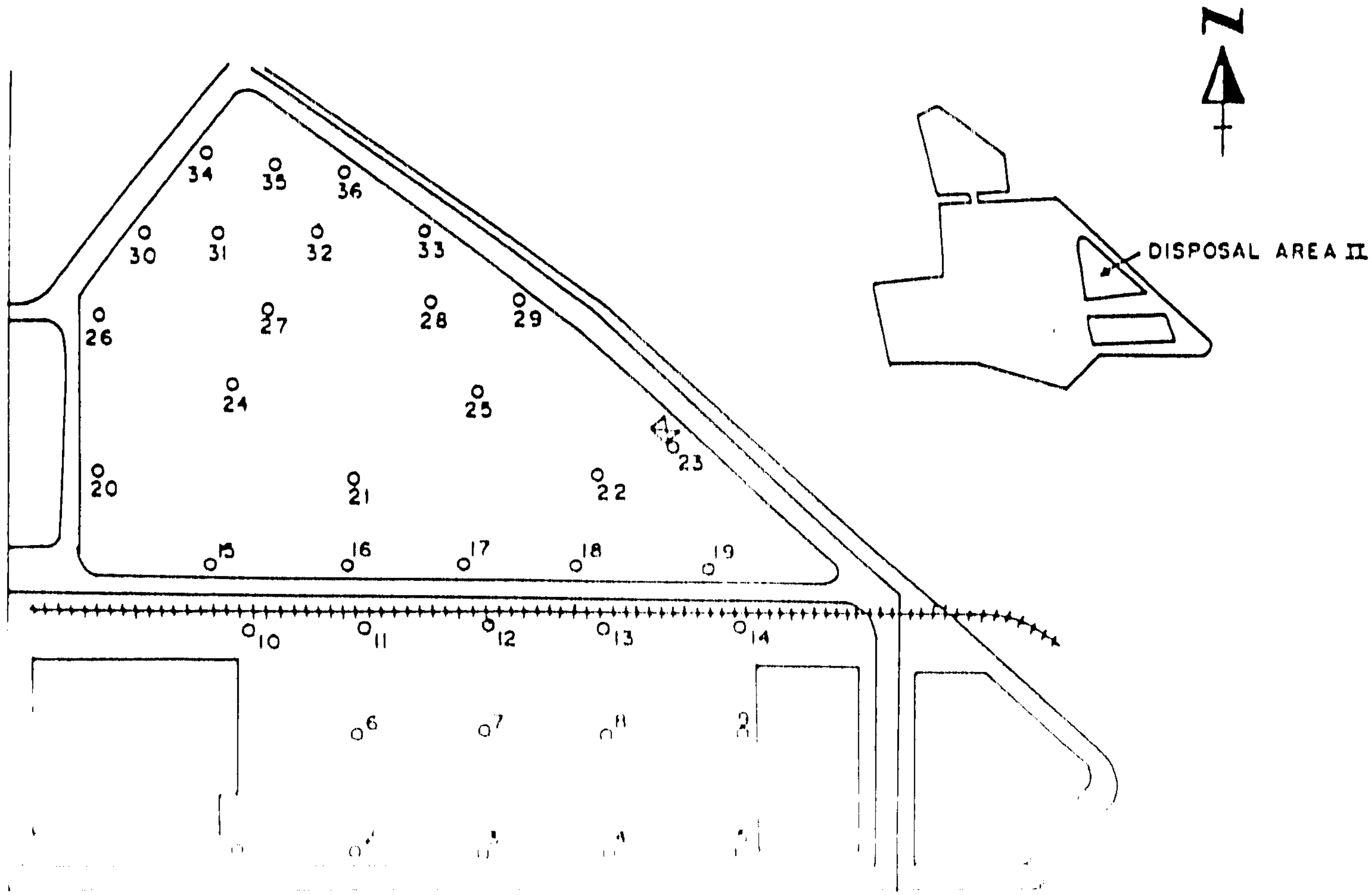
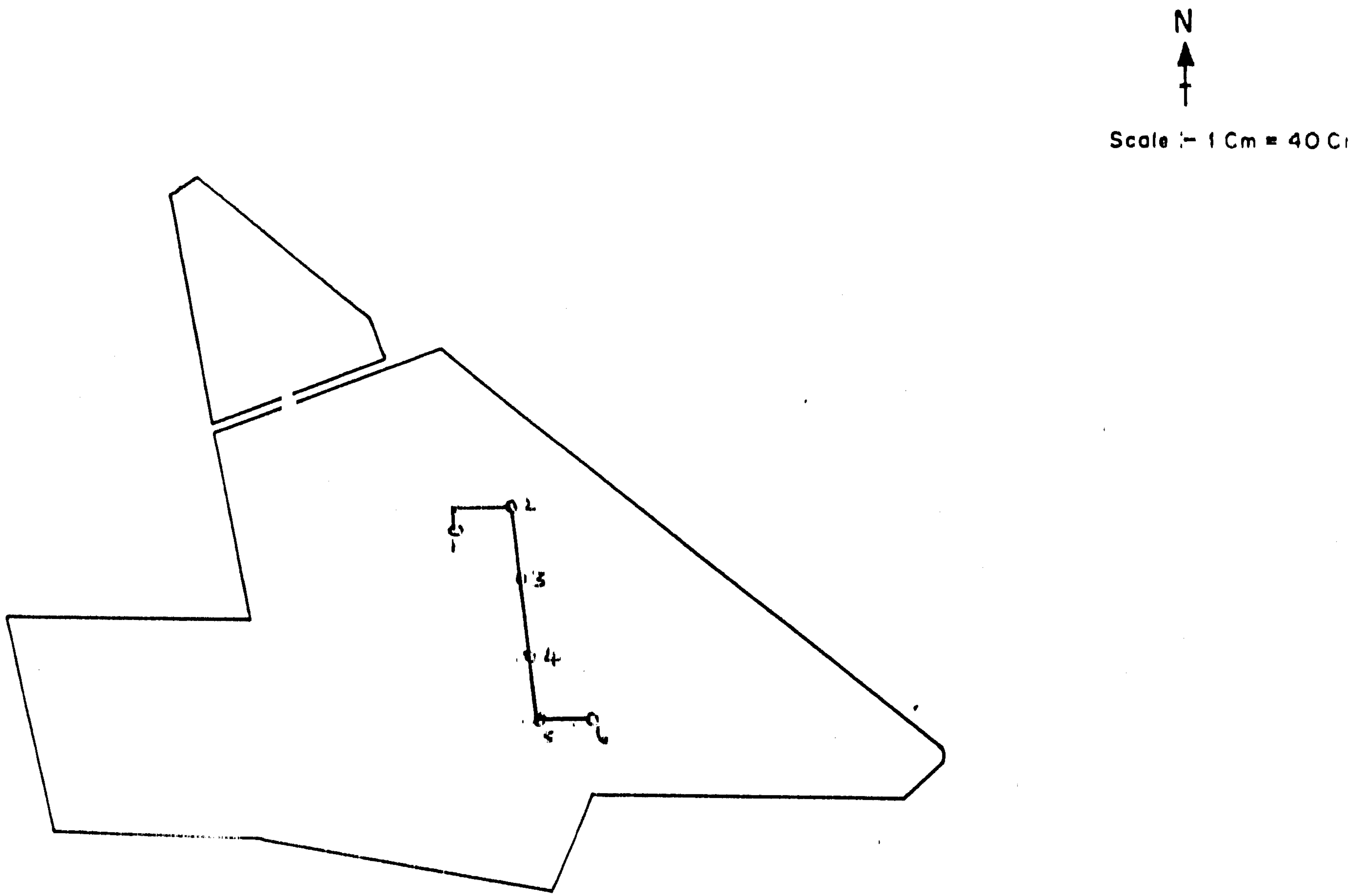


FIG 2.5 SOIL SAMPLING LOCATIONS AT DISPOSAL AREA II


N
Scale :- 1 Cm = 40 C
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4
5
6

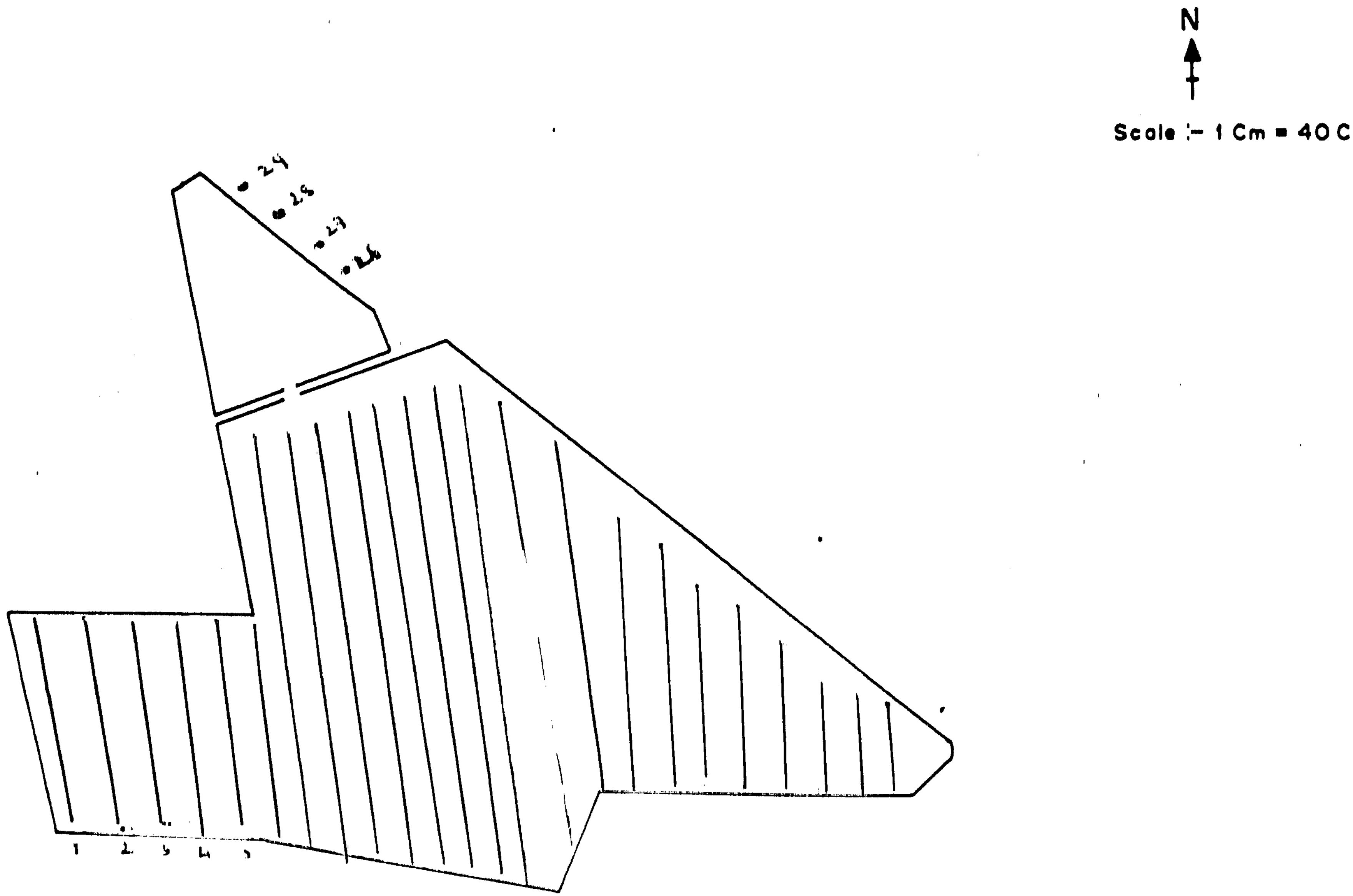

FIG 2.7 SOIL SAMPLING LOCATIONS AT REST OF AREA

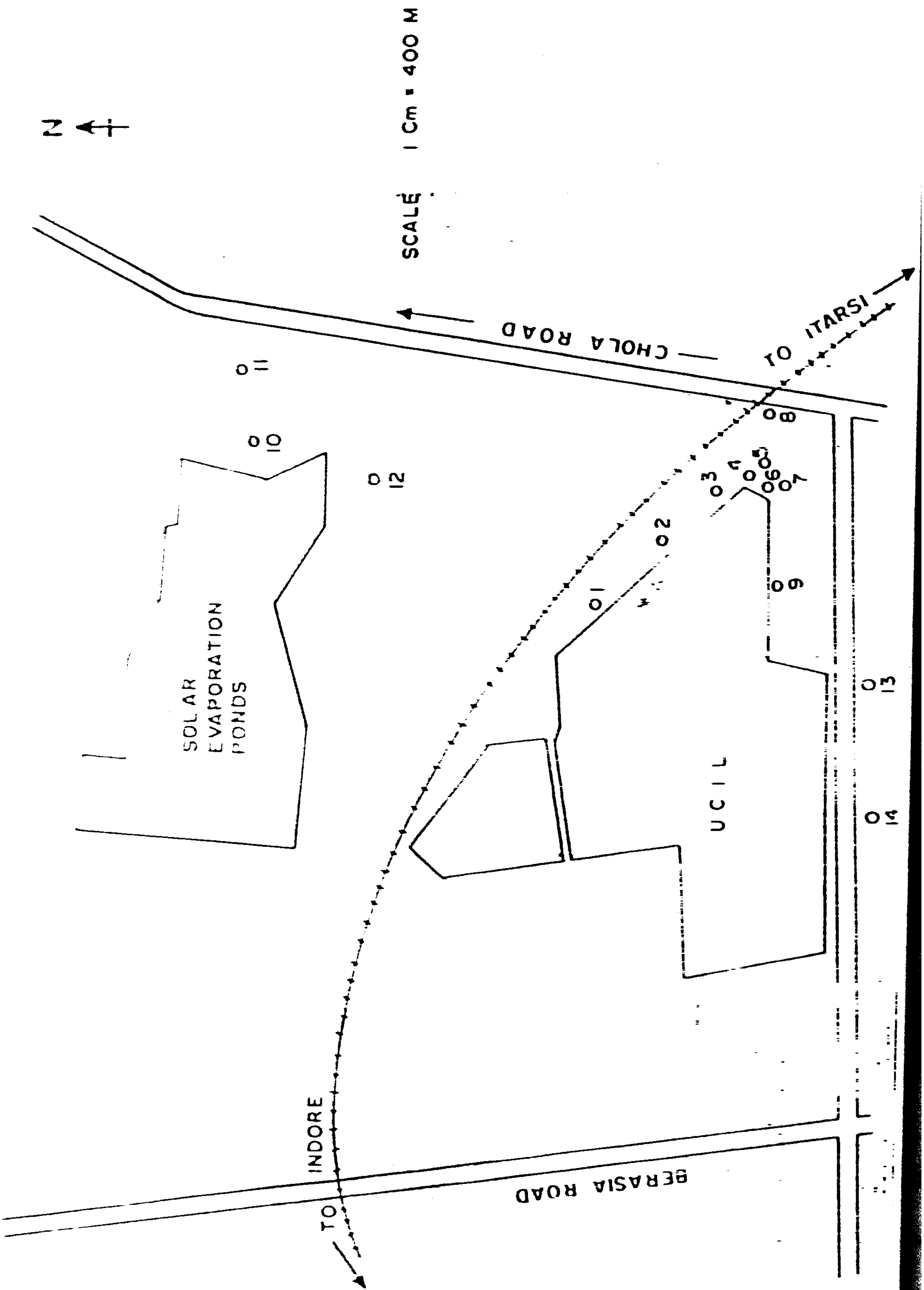
N
SCALE : 1 Cm = 400 M
CHOLA ROAD
TO ITARSI
SOLAR
EVAPORATION
PONDS
U C I L
TO INDORE
BERASIA ROAD
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TABLE 2.1

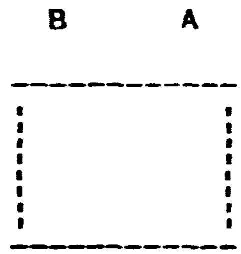
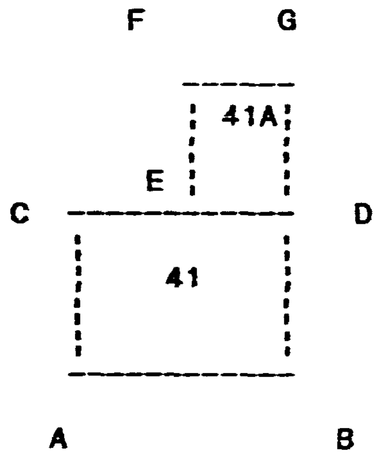
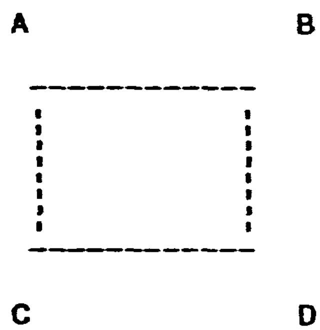
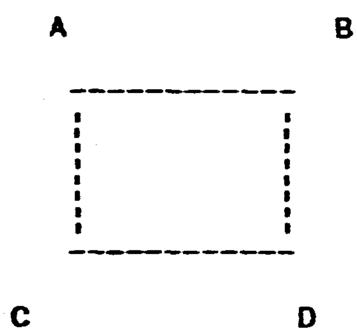
Soil Sampling Locations - Target/Spill Area

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Compos
Plant/ Sheds					
01	T 09	Weigh bridge (18 m^2)	A B / C D	15,30	A,B,C,& I
02	T 10	Storage shed (525 m^2)	A B / C D	15,30	A,B,C,& I
03	T 18 T 18A	CO plant (18 m^2)	A B / C D	15,30	i) A,B,C ii) D (18/
04	T 20	Coke Storage shed (1114 m^2)	A B / C D	15,30	A,B,C,& I

Contd ...

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Com[illegible]
05	T 27 T 27A	Boiler House (460 m^2)	A B C D	15,30	i) [illegible] ii) [illegible] (D - ash slurry di[illegible]
06	T 29 T 29A	Incinerator (60 m^2)	A B C D	15,30	i) [illegible] ii) [illegible] (D- ash [illegible]
07	T 32 T 32 A	Water treatment (202 m^2)	A B C D	15,30	i) [illegible] ii) [illegible] (D - Alum [illegible]
08	T 43	Salt recovery (63 m^2)	A B C D	15,30	A,B,[illegible]

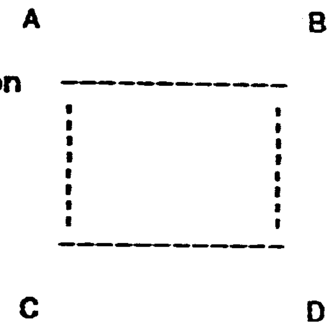
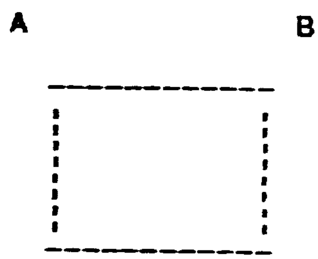
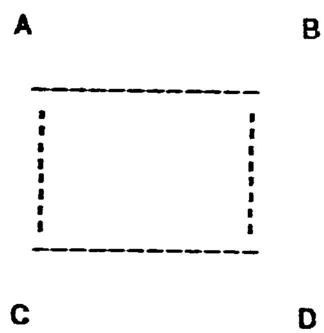
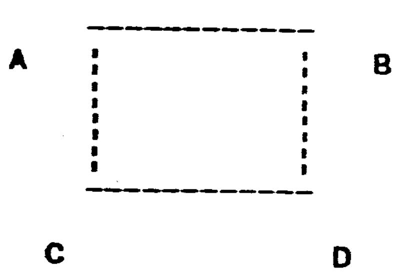
Contd ....

Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Composite
T 62 T 62A	Soapstone (813 m^2)		15,30	i) A (62) ii) B (62A) (A - Dump material heap)
T 41 & 41 A	Sevin (733 m^2)		15,30	i) A,B,C,& ii) E,F,G (
T 42	Naphthol (1508 m^2)		15,30	A,B,C,& D
T 42 A	Naphthol (525 m^2)		15,30	A,B,C,& D

Contd ....

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Composi
13	T 60	Formulation ($1627\ m^2$)	A B C D E F	15,30	A,B,C, E & F
14	T 61	Formulation ($3253\ m^2$)	A B C D E	15,30	A,B,C, E
15	T 63	Sevin warehouse ($1431\ m^2$)		15,30	A,B,C, E,F &
16	T 64,65 & 66	Temik & pilot plants ($1457\ m^2$)	A B C D E F	15,30	A,B,C, E & F

Contd ....

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Composite
PCB					
17	T 6	33 KV sub station (177 m^2)		15,30	A,B,C,& D
18	T 8A & 8B	M/c & Inst. (178 m^2)		15,30	A & B,
19	T 12	Fuel oil Storage (233 m^2)		15,30	A,B,C,& D
20	T 15	Kerosene Storage (133 m^2)		15,30	A,B,C,& D

Contd ....

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Compo
21	T 24	HSD Storage ($48\ m^2$)	A B C D	15,30	A,B,C
22	T 25	Diesel set ($200\ m^2$)	A B	15,30	A & B
23	T 26	Dewtherm Hot oil unit ($324\ m^2$)	A B C D	15,30	A,B,C
24	T 34	Substation ($170\ m^2$)	A B C D	15,30	A,B,C

Contd ....

S.No.	Sample ID No.	Description	Sampling Locations	Sampling Depth (cms)	Composi[t]
25	T 52 & 53	Boiler house (151 m^2)		15,30	A,B,C,D, E & F
Storage Tanks					
26	T 14	CSA	At the transfer point/valve;	15,30	A & B
27	T 16	NaOH			
28	T 17	HCl			
29	T 11	CTC			
30	T 13	Aromax			
31	T 36, 37, 37 A & 48	MIC			
32	T 38	MMA			
33	T 39	Chlorine			
34	T 55	LDO			

Note : S.Nos. given in Column 1 are the same as the serial numbers given in EIIL Site Plan (Drawing Number EB-4501-A-36/1)

TABLE 2.2

Sampling Depth Adopted At Different Stations

Sampling Area	Sampling Depths
Disposal Area I	15, 30 & 60 cm*
Disposal Area II	
- Identified dump along the road sides	15, 30 & 60.cm*
- Rest of the area within Disposal Area II	15, 30 & 60 cm*
Spill area/target area	15 cm & 30 cm
Rest of the area	30 cm
Along the Wastewater drain	90 cm and 120 cm

* .... Additional sampling at 90 cm and 120 cm was carried out at a few stations where contamination at deeper depth was anticipated.

TABLE 2.3

Sample Containers and Preservations

Parameters	Vol. water	Type of container	Preservation
Semi volatiles	40 ml	Glass	4°C
Volatile organics	40 ml	Glass	HCl ; 4°C
Heavy metals	1000 ml	Glass	2 ml HNO_3
Others	1000 ml	Glass	None

3.0 ANALYTICAL METHODS

3.1 Parameters

The industry was manufacturing carbarmate pesticides such as Carbaryl (Sevin) and Aldicarb (Temik). The off-specification products generated during the process, and tarry residues from distillation units of sevin and alpha naphthol units, and neutralized temik wastes were disposed within the facility premises on open land. The parameters selected in the present investgation for characterisation of wastes, soil quality and ground water quality are, therefore, based on the site specific activity. After reviewing the past process operations, it has been decided to identify final products such as Sevin and Temik as most of the wastes comprise of off-specification products. However, it is also possible that a few raw materials (volatile organics) might have entered in the off-specification products. In addition, heavy metals which are normally present in the raw materials have also been considered for analysis.

Following parameters were analyzed in dump materials, soil and ground water samples :

Dump Material and Soil

Semi Volatiles	:	Sevin, Temik, alpha naphthol, Lindane, and Naphthalene
Volatile Organics	:	Carbon tetrachloride, Chloroform, Methylene Chloride, 1-2-Dichlorobenzene, Toluene, Formaldehyde,

Monomethylamine, Trimethylamine

Inorganics	:	pH, EC, Chloride, Sulphate, Na. K, Ca, Mg, Carbonate and Bicarbonate
Heavy metals	:	Lead, Chromium, Cadmium, Iron, Copper, Manganese, Zinc and Nickel

Ground Water

Volatile Organics	:	Carbon tetra chloride, Chloroform, Methylene Chloride, 1-2-Dichlorobenzene, Toluene, Formaldehyde, Monomethylamine, Trimethylamine(TMA)
Semi Volatiles	:	Naphthalene, Lindane, Sevin, Temik, and Alpha Naphthol
Inorganics	:	pH, EC, Hardness, Chloride, Sulfates, Sodium, Potassium & COD
Heavy metals	:	Lead, Chromium, Cadmium, Iron, Manganese, Zinc, Mercury, Nickel and Copper

3.2 Semi Volatiles

Analytical methods adopted for volatile and semi-volatile organics in soil and ground water are summarized in Table 3.1. Table 3.2 summarizes methods adopted for inorganics in soil. Ground water samples were analyzed for inorganics and heavy metals as per Standard Methods (1).

3.2.1 Sample Extraction

Soxhlet extraction was employed for the extraction of semi volatiles from dump materials and soils. 10 gms of dump materials / soils were extracted with methylene chloride in soxhlet extractor and concentrated in rotary vacuum evaporator. The extracts after vacuum evaporation and clean-up were subjected to GC /HPLC analysis depending on the compounds to be identified. The extract is cleaned up by florisil column (Method 3620) using chloroform as an elutring solvent. 50 ml of chlroform was passed thrice through the colum and eluate collected. Subsequently it is concentrated in rotary vacuum evaporator. Semi-volatiles in water were extracted with methylene chloride using separatory funnel extraction.

1 L of water sample was extracted with 60 ml of methylene chloride in separatory funnel and the extracts were collected. The extraction was repeated thrice using fresh solvent everytime and collecting the combined extracts. The extracts after filtration through anhydrous sodium sulfate was concentrated by rotary vacuum evaporator.

3.2.2 Analytical Procedure

Sevin, temik and alpha naphthol in all samples of dump materials/soils/water were analyzed by HPLC. The methylene chloride extract was concentrated in rotary vacuum evaporator and after cleanup. The solvent was exchanged with methanol and analyzed by HPLC (Waters Associates USA).

Naphthalene was analyzed by GC/FID. Lindane was analyzed by GC/ECD after clean-up of the methylene chloride extract by florisil (Method 3620) (2), and exchange with n - hexane.

The operating conditions of HPLC used were :

Mobile phase	=	40 % acetonitrile in water
Flow rate	=	1.5 ml/min
Wave length	=	222 nm (uv detector)
Temp	=	Ambient
Instrument	=	Waters Model 204

Retention time :

Sevin	..	2.05 min
Temik	..	3.20 min
Alpha naphthol	..	3.65 min
Detector	..	FID

The operating conditions of GC were as follows :

Instrument make	=	Perkin Elmer Sigma 3B
Oven Temp	=	180 °C
Injector Temp	=	250 °C
Detector Temp	=	250°C
Carrier Gas	=	Nitrogen (30 ml/min)

Oven Temp	=	120 °C
Injector temp	=	250 °C
Detector	=	250 °C
Nitrogen	=	40 ml/min
Detector	=	ECD

3.3 Volatile Organics

Head Space method was employed for the extraction of volatile organics and were analyzed by GC/FID.

The conditions of GC are as follows :

Instrument make	=	Perkin Elmer Sigma 3B
Oven Temp	=	80 °C
Injector Temp	=	200 °C
Detector Temp	=	200 °C

Carrier Gas = Nitrogen (40 ml/min)

The compounds were analyzed by comparing the retention time with peaks of standard chromatographs. Calibration curves were prepared for each analyte and analyzing different concentration of the analyte prepared by External Standard Methods (1).

3.4 Method Detection Limits

Method Detection Limits (MDLs) for the analytes were determined as per Standard Method (1).

3.5 Inorganics

Although most of the materials dumped at UCIL premises are of organic in nature, inorganic compounds and trace metals were also analyzed. However, as the inorganics are of not very much concern in this study, it was decided to analyze only for a few selected samples which showed considerable concentration of semi volatiles and volatile organics. The analytical procedures are summarized in Table 3.1 for soil and dump materials. Methodologies described under Standard Methods were adopted for analysis of ground water samples.

Heavy metals in dump materials, soil and water samples were acid digested and analyzed by Atomic Absorption Spectrophotometer as per Standard Methods (1) and SW-846 (2).

3.6 Immuno Assay for PCB

The analysis for PCB in soil samples were carried out for a selected target areas. few sites under target areas. Immuno Assay tests were carried out for detecting the presence of PCB in the soil samples where spillages due to transformer oil and hydraulic oil are anticipated. The target areas include electrical substation and workshops. Soil samples were collected near the target areas and tested for the presence of PCBs using Enviroguard Soil Test Kit for PCB (Millipore make).

Reference

1. Standard Methods for the Examination of Water and Wastewater, 17th Edition, 1989, APHA, AWWA & WPCF.

2. Test Methods for Evaluating Solid Wastes SW - 846, Sep.1986. US EPA

H. Ansan Moye . In Analysis of Pesticide Residue. Ed by H. Ansen Moye,John Wiley & Sons, 1981

TABLE : 3.1

Chromatographic Columns and Detection Limits for Semi Volatiles and Volatile Orga

Sr. No.	Name of the compound	Extraction Method		Column	Analytical methods	Detectio
		Dump material/ Soil	Water			Water (ug/L)
1.	Chloroform	3810	3810	10% FFAP on chromosoorb WHP 80/100	GC/FID	2.3
2.	Carbon tetrachloride	3810	3810		GC/FID	4.0
3.	Methylene chloride	3810	3810	or SP-1000 on Carbo-pack B 60/80	GC/FID	2.5
4.	1,2-Dichlorobenzene	3810	3810		GC/FID	1.0
5.	Toluene	3810	3810	-do-	GC/FID	0.5
6.	Formaldehyde	3810	3810	- do-	—	-
7.	Monomethyl amine	3810	3810	4% Carbo Wax 20 M/0.8% KOH on carbopack B 60/80	GC/FID	-
8	Trimethyl amine	3810	3810	—do—	GC/FID	-

Cont

Sr. No.	Name of the compound	Extraction Method		Column	Analytical methods	Detection Limi	
		Dump material/ Soil	Water			Water (ug/L)	Soil (mg/kg)
9.	Lindane	3540	3510	3% OV-101 on chromosorb WHP 100/120	GC/ECD	0.05	0.1
10.	Naphthalene	3540	3510	5% Dexsil 300 on chromosorb WAW-DHES 80/100	GC/FID	4	10
11.	Sevin	3540	3510	u Bondapack C-18	HPLC with	1.25	1
12.	Alpha Naphthol	3540	3510	Mobile phase 40% acetonitr-	UV detector 222nm	7.5	10
13.	Temik	3540	3510	ite and water		5	5

TABLE 3.2
Analytical Methods Adopted For Dump Materials and Soil Samples

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 25oC.	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.

Contd...

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 (CO3) and bicarbonate (HCO3), 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.

4.0 CHARACTERISATION OF DUMP MATERIALS

4.1 Results and Discussion

Originally samples were collected after removing each heap and after compositing the samples at the site. Twenty two samples were collected and these are coded as 'DA'. Subsequently samples were collected at different points and at different depths from each remaining heaps. These samples were coded as 'DM'. The dumps are shown in Fig 4.1.

The characteristics of dump materials in respect of semi volatiles such as sevin, temik, alpha naphthol lindane, and naphthalene are presented in Table 4.1. Table 4.2 presents the volatile organics and the heavy metal concentration is given in Table 4.3.

4.2 Disposal Area

All dump materials in Disposal Area I contain a moderate to high concentration of sevin, alpha naphthol and lindane. Four samples out of 12 recorded sevin more than 5928 mg/kg and other samples have sevin content between 164 mg/kg and 1276 mg/kg. Alpha naphthol in four samples out of 12 have values more than 1342 mg/kg and in traces in remaining samples. There is not much variation in lindane recording between 14 and 210 mg/kg. In general, the concentration of temik in all samples is not significant. A maximum concentration of 116 mg/kg of temik was observed in two samples and 5 samples out of 12 were below detection limit (BDL). Naphthalene was mostly below detection limit of 10 mg/kg.

In view of larger sample size, samples of a few heaps were composited and analysed. The details of compositing are given in Table 4.2. The organics are either BDL or not detected (Table 4.2) for the organics of initerest. However, the chromotograms show the presence of other organics which could not be identified.

Manganese, among the heavy metals analyzed, showed high concentration varying from 986 mg/kg to 2175 mg/kg (Table 4.3). Zinc ranged between 178 mg/kg and 460 mg/kg. All other heavy metals are low.

4.3 Disposal Area II

In general, in Disposal Area II, the concentration of semi volatiles varies very much from 15 mg/kg to 4162 mg/kg. Six samples out of 33 (nearly 20%) have sevin content between 1238 mg/kg and 4162 mg/kg. Sixteen samples (50%) have sevin concentration between 200 mg/kg and 1238 mg/kg. Twenty samples (60%) have sevin less than 200 mg/kg. The maximum concentration of temik in dump materials in the entire EIIL premises are present in this area in three locations (DM 18, DM 20 and DM 20A). Six samples have temik more than 1264 mg/kg with a maximum of 7876 mg/kg. However, the temik in remaining samples (about 80%) have moderately low content less than 786 mg/kg. Temik was below detection limit in about 52 % of the samples. The maximum content of alpha naphthol is 1024 mg/kg. About 20% of the samples have alpha naphthol more than 300 mg/kg. The lindane is observed to have low concentration in most of the samples. Nearly 90% of the sample do not contain lindane. Lindane was below detection limit in 27 samples out of 35 samples. Naphthalene was in traces in 20% Of the samples while it was not detected in the remaining samples.

The volatile organics of concern were not detected in any samples. However the chromotographs recorded other peaks. These peaks could not be identified and showed the presence of other organics.

Managanese continues to be the major heavy metal in dump material, recording from 678 mg/kg to 1672 mg/kg. Zinc was present in the range of 78 mg/kg to 378 mg/kg. All other heavy metals are in traces.

4.4 Disposal Area III

Two samples collected near the pits located near the place where naphthalene residues stored in southern end of the plant premises have only traces of semivolatiles. Sevin varies from 68 mg/kg to 462 mg/kg while temik and lindane are BDL. Alpha naphthol is in traces less than 58 mg/kg. Heavy metals in the dump materials are in low levels less than 688 mg/kg.

4.5 Tarry Residues

Tarry residues disposed in pits in Disposal Areas II and III have sevin content between 462 mg/kg and 949 mg/kg while alpha naphthol ranges from 169 mg/kg to 316 mg/kg. Temik is present in traces while lindane is not detected. The sources of tarry residues are from sevin and alpha naphthol units and the residues should contain only sevin and alpha naphthol. Temik was not detected in the samples collected from pits. However temik with a concentration of 264 mg/kg was present in one sample. This sample (DM X) was collected from a small heap near temik pond. The presence of temik, although in negligible concentration, could be due to cross contamination, probably arising out of material handling.

4.6 Temik Neutralization Ponds

The sediments present in both the temik neutralization pits recorded a moderate concentration of temik. The average concentration of temik is 5105 mg/kg in Pit I and 4411 mg/kg in Pit II. Sevin and alpha naphthol are in traces while lindane and naphthalene are not detected.

Organics are not detected from the residues of temik neutralization pits. Heavy metals are also in low concentration. Chromium is between 138 mg/kg and 185 mg/kg. The samples from temik neutralization pits have recorded the maximum concentration of chromium among all the waste materials sampled.

4.7 Naphthalene Residue

The naphthalene content in the burnt/unburnt residues buried below ground level is 395 mg/gm i.e. 39.5% by weight. Although the organics of interest were below detection limit, many peaks are present in the chromotagrams which could not be identified.

4.8 Temik Ponds

Samples collected at two depths (15 and 30 cms) from 5 locations from each temik ponds did not record high levels of temik. In Pond I which was reported to have been used registered only 140 mg/kg as temik that too in the top 15 cm depth. However the temik at 30 cms in Pond I and temik in Pond II are below 26 mg/kg. Sevin and lindane are in BDL. It is observed that lime bed was laid in the pond and white powder present in the pond may be attributed to this.

Organics are below detection limits. In general, the heavy metals are in very low levels (less than 16 mg/kg) except for managanese (1648 mg/kg to 2134 mg/kg).

The temik ponds receive the neutralized wastes from temik neutralized pits. Thus the characteristics of samples collected from these location should be nearly the same. Temik was recorded between 4411 mg/kg and 5105 mg/kg in the neutralization pits while temik was less than 140 mg/kg in the neutralization ponds. This indicated that the residues present in the neutralization tank have not undergone complete neutralization process. This could probably due to sudden closure of the plant in December 1984.

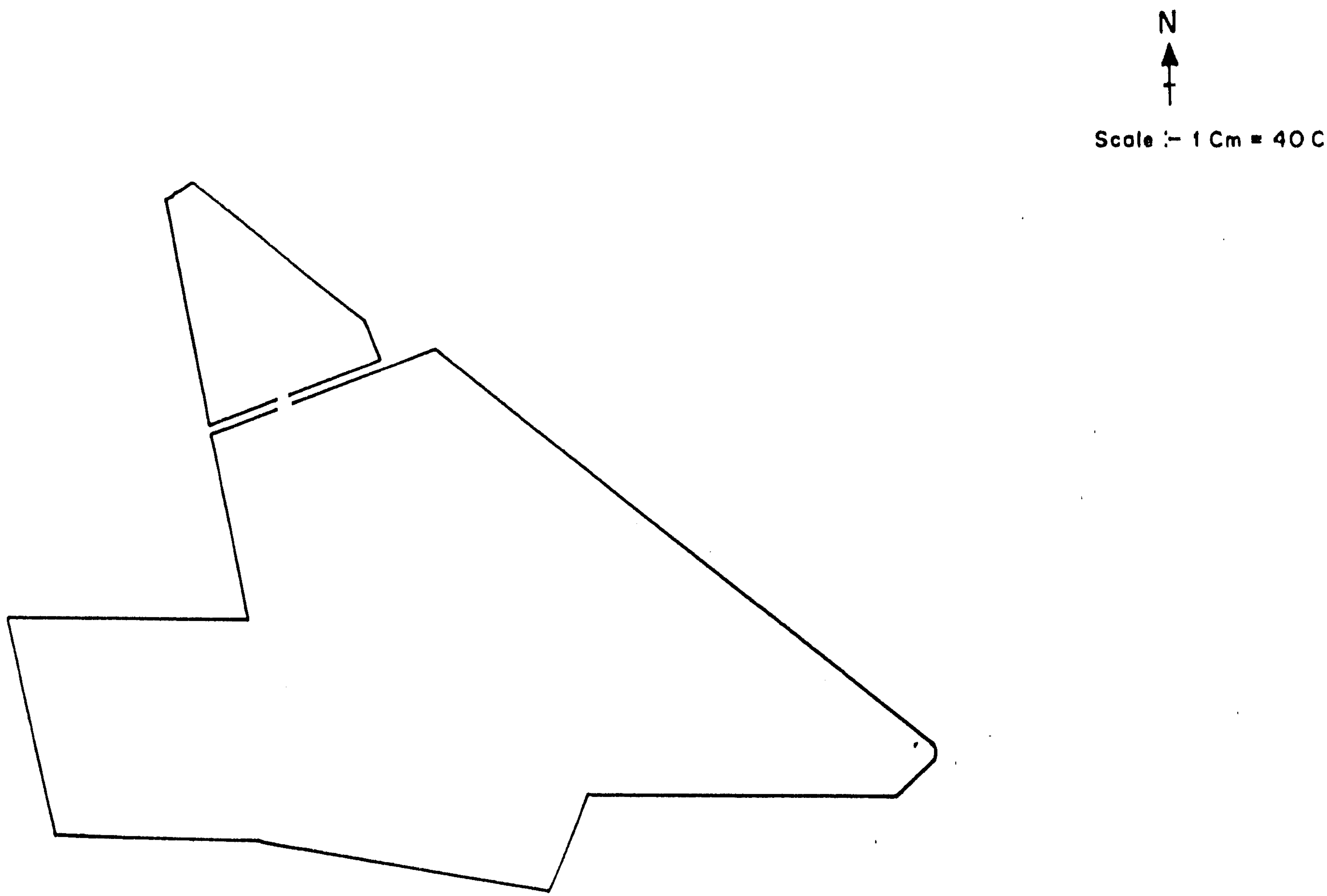

N
Scale :- 1 Cm = 40 Cr

TABLE 4.1

Characteristics of Dump Materials at EIIL, Bhopal

Semi volatiles
(mg/kg)

Sample ID No.		Sevin	Temik	Alpha-Naphthol	Lindane	Naphthalene
	DISPOSAL AREA I					
1.	DM21	51003	BDL	9914	76	BDL
2.	DM22	16256	13	2364	82	ND
3.	DM23	5928	56	1342	67	BDL
4.	DM24	12642	28	1846	126	BDL
5.	DM25	862	116	28	210	BDL
6.	DM26	216	14	11	59	BDL
7.	DM27	756	BDL	57	60	BDL
8.	DM28	164	BDL	18	126	BDL
9.	DM29	562	BDL	26	78	BDL
10.	DM30	1276	41	48	32	ND
11.	DM33	328	116	17	14	BDL
12.	DM36	426	BDL	24	BDL	ND
	DISPOSAL AREA II					
13.	DM1	822	BDL	233	46	BDL
14.	DM2	1264	BDL	348	62	BDL
15.	DM3	436	128	162	58	ND
16.	DM4	162	BDL	28	22	ND
17.	DM5	56	BDL	12	BDL	ND
18.	DM7	BDL	455	BDL	42	ND
19.	DM8	18	146	BDL	82	ND
20.	DM9	46	212	11	BDL	ND
21.	DM10	126	326	26	BDL	BDL
22.	DM11	BDL	678	BDL	BDL	ND
23.	DM12	BDL	396	BDL	BDL	ND
24.	DM13	216	424	51	BDL	BDL
25.	DM14	62	43	12	BDL	ND
26.	DM15	148	192	31	17	ND
27.	DM16	26	38	11	BDL	ND
28.	DM17	88	56	20	14	ND
29.	DM18	2868	BDL	256	26	ND
30.	DM19	4162	BDL	1024	10	ND
31.	DM20	3291	BDL	854	21	ND
32.	DM20 A	126	7876	32	BDL	ND
33.	DM35	21	20	16	BDL	ND
34.	DA1	216	BDL	13	BDL	ND
35.	DA2	68	32	41	BDL	ND

Contd...

Sample ID No.		Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
36.	DA3	176	28	41	BDL	ND
37.	DA4	463	ND	121	11	ND
38.	DA5	768	ND	142	BDL	ND
39.	DA6	396	ND	76	BDL	ND
40.	DA7	1238	26	306	14	ND
41.	DA8	246	BDL	58	BDL	ND
42.	DA9	416	BDL	96	BDL	ND
43.	DA10	126	2346	24	BDL	ND
44.	DA11	672	112	168	BDL	ND
45.	DA12	68	1264	15	BDL	BDL
46.	DA13	2672	62	671	22	ND
47.	DA14	226	2416	57	BDL	ND
48.	DA15	678	BDL	167	BDL	ND
49.	DA16	172	BDL	41	BDL	ND
50.	DA17	168	BDL	36	11	BDL
51.	DA18	276	BDL	67	BDL	ND
52.	DA19	786	21	192	BDL	ND
53.	DA20	2154	176	432	16	ND
54.	DA21	254	182	67	BDL	ND
55.	DA22	376	BDL	82	BDL	ND
	DISPOSAL AREA III					
56.	DM6	462	BDL	58	BDL	BDL
57.	P3	68	BDL	12	ND	BDL
	TARRY RESDIDUES					
58.	P4	722	BDL	246	ND	ND
59.	P5	946	BDL	316	ND	ND
60.	P2	686	ND	216	ND	ND
61.	P1	462	ND	158	ND	ND
62.	DM X (DA II)	516	264	169	ND	ND
	TEMIK NEUTRALIZATION PIT					
63.	DM31	53	5105	23	BDL	ND
64.	DM32	13	4411	ND	BDL	ND
	NAPHTHALENE RESIDUE					
65.	DA III			Naphthalene	395 mg/gm 395 gm/kg 39.5%	

Contd.

Sample ID No.		Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
	TEMIK PONDS					
66.	TPI (15)	BDL	140	1.5	ND	ND
67.	TPI (30)	BDL	26	BDL	ND	ND
68.	TPII (15)	BDL	73	BDL	ND	ND
69.	TPII (30)	BDL	12	BDL	ND	ND

Detection Limits (mg/kg) :

Sevin .... 1.0 Temik 5.0
Alpha Naphthol .... 10.0 Lindane 0.1
Naphthalene 10.0

BDL ..... Below Detection Limits
ND ..... Not Detected

(DA indicates the samples collected during May/June 1995 and DM indicates the samples collected during May 1996)

TABLE 4.2

Characteristics of Dump Materials at EIIL, Bhopal

Volatile Organics
(mg/kg)

Sample ID No.		Chloroform	Methylene Chloride	1-2- Di Chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbon tetra Chloride	TMA
DISPOSAL AREA I (Composited Samples)									
1.		ND	ND	ND	ND	ND	ND	ND	ND
2.		ND	ND	ND	ND	ND	ND	ND	ND
3.		ND	ND	ND	ND	ND	ND	ND	ND
DISPOSAL AREA II(Composited Samples)									
4.		ND	ND	ND	ND	ND	ND	ND	ND
5.		ND	ND	ND	ND	ND	ND	ND	ND
6.		ND	ND	ND	ND	ND	ND	ND	ND
7.		ND	ND	ND	ND	ND	ND	ND	ND
8.		ND	ND	ND	ND	ND	ND	ND	ND
9.		ND	ND	ND	ND	ND	ND	ND	ND
10.		ND	ND	ND	ND	ND	ND	ND	ND
11.		ND	ND	ND	ND	ND	ND	ND	ND
DISPOSAL AREA III									
12.	Sm6	ND	ND	ND	ND	ND	ND	ND	ND
13.	P3	ND	ND	ND	ND	ND	ND	ND	ND
TARRY RESIDUE									
14.	P4	ND	ND	ND	ND	ND	ND	ND	ND
15.	P5	ND	ND	ND	ND	ND	ND	ND	ND
16.	P2	ND	ND	ND	ND	ND	ND	ND	ND
17.	P1	ND	ND	ND	ND	ND	ND	ND	ND
18.	Sm (DA II)	ND	ND	ND	ND	ND	ND	ND	ND
TEMIK NEUTRALIZATION PONDS									
19.	SM31	ND	ND	ND	ND	ND	ND	ND	ND
20.	SM32	ND	ND	ND	ND	ND	ND	ND	ND

Contd ....

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di Chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbon tetra Chloride	TBA
NAPHTHALENE RESIDUE								
21. DA III	ND	ND	ND	ND	ND	ND	ND	ND

Detection Limits (mg/kg)

Chloroform	 50	Formaldehyde	....
Methylene Chloride	 20	1-2- Dichlorobenzene	 400
Toluene	 40	Monomethylamine	....
Carbon tetra Chloride	 100		

Note :

Since the concentration of all organics was either below BDL or ND, dump materials have been composited and the sample ID. No. in this table defines the composite sample number. The details of composting is stated as under :

1. Composite of DM 21 to DM 25 in Disposal Area I
2. Composite of DM 26 to DM 29 in Disposal Area I
3. Composite of DM 30 to DM 33 & DM 36 in Disposal Area I
4. Composite of DM 1 to DM 5 in Disposal Area II
5. Composite of DM 7 to DM 11 in Disposal Area II
6. Composite of DM 12 to DM 16 in Disposal Area II
7. Composite of DM 17 to DM 20A in Disposal Area II
8. Composite of DA 1 to DA 5 in Disposal Area II
9. Composite of DA 6 to DM 11 in Disposal Area II
10. Composite of DA 12 to DA 16 in Disposal Area II
11. Composite of DA 17 to DA 22 in Disposal Area II

TABLE 4.3

Characteristics of Dump Materials at EIIL, Bhopal

Heavy Metals
(mg/kg)

Sample ID No.		Mn	Zn	Cu	Ni	Pb	Cr	Cd
DISPOSAL AREA I(Composited Samples)								
1		2175	460	21	19	7	51	0.1
2		1976	280	12	8	11	48	0.1
3		986	178	16	7	9	61	0.2
DISPOSAL AREA II(Composited Samples)								
4		1672	146	12	11	8	36	0.1
5		978	122	14	9	7	43	0.2
6		878	208	18	7	9	54	0.1
7		678	154	20	8	6	43	0.2
8		1040	186	16	9	9	51	0.2
9		966	198	19	10	10	58	0.1
10		1566	378	20	14	9	61	0.1
11		786	78	10	7	6	28	0.2
DISPOSAL AREA III								
12	DM6	678	178	16	8	7	36	0.1
13	P3	286	88	6	5	5	28	0.1
TARRY RESIDUES								
14	P4	286	8	16	24	9	101	0.2
15	P5	186	12	20	17	11	86	0.1
16	P2	214	8	14	18	7	78	0.1
17	P1	164	10	12	26	6	61	0.2
18	DM	166	7	18	14	7	84	0.1
TEMIK NEUTRALISATION PITS								
19	DM31	978	9	8	5	6	138	BD
20	DM32	3265	4	30	35	7	185	0.2
NAPHTHALENE RESIDUE								
21		6155	700	12	4	ND	20	0.
TEMIK PONDS								
22	TPI	1648	10	12	6	8	98	BD
23	TPII	2134	12	16	10	6	76	BD

Note :

1. Composite of DM 21 to DM 25 in Disposal Area I
2. Composite of DM 26 to DM 29 in Disposal Area I
3. Composite of DM 30 to DM 33 & DM 36 in Disposal Area I
4. Composite of DM 1 to DM 5 in Disposal Area II
5. Composite of DM 7 to DM 11 in Disposal Area II
6. Composite of DM 12 to DM 16 in Disposal Area II
7. Composite of DM 17 to DM 20A in Disposal Area I
8. Composite of DA 1 to DA 5 in Disposal Area II
9. Composite of DA 6 to DM 11 in Disposal Area II
10. Composite of DA 12 to DA 16 in Disposal Area II
11. Composite of DA 17 to DA 22 in Disposal Area II

5.0 SOIL QUALITY

The number of soil samples collected are summarized in Table 5.1. The data on the soil quality within the plant premises are presented in Tables 5.1 to and discussed according to disposal areas. The soil quality data reported in this study are compared with this criteria to identify the contaminated areas which requires remediation.

5.1 Disposal Area I

In this area located on the northeast of Formulation units, waste materials are almost scattered over the entire open area. However maximum waste materials were dumped along the walls.

Initially the samples collected in this area were composited zonewise and the semivolatile constituents present in the composite samples are given in Table 5.2. Sevin varied from 32.28 mg/kg to 153.86 mg/kg. Temik was recorded between 6.39 mg/kg and 52.2 mg/kg. Lindane ranged widely from 0.25 mg/kg to 130.18 mg/kg. Alpha naphthol and Naphthalene were below detection limits. can be seen that the concentration of sevin, temik, alpha naphthol and lindane are present in marginal levels. Naphthalene was not detected in any sample. Subsequently, all samples were analyzed individually to obtain a well-defined picture of the soil status in detail , and the data are shown in Table 5.2. In general, the concentration recorded varied for sevin from mg/kg to mg/kg and temik varied from mg/kg to mg/kg. Alpha naphthol are below detection limit (BDL). The lindane concentration varies from 16.2 mg/kg to 36.24 mg/kg at 30 cm depth in all samples. It is reduced to BDL in a few samples and recorded a maximum of 38.46 mg/kg at 60 cm depth samples.

As the concentration of sevin, temik and lindane are in significant quantities in composite samples, analysis were then carried out in individual samples. The data are presented in Table 5.3 It can be seen from Tables 5.3 that the concentration of sevin and temik was observed to be increasing with depth at six locations. In order to study the levels at higher depths, fresh samples were again collected at two locations very close to the two stations (S.No. 2 and 3) already sampled. The samples were collected upto 120 cms. The data are presented in Table 5.4. The concentration was increasing upto 60 cms and showed downward trends after 60 cms indicating the maximum contamination is confined upto 60 cms.

It was observed during sampling that in a few stations dump materials are present at 30 to 60 cms. The increase in concentration in such stations could be due to the presence of dump materials. Further the soil in the plant premises, in general, has higher clay content (45%) below 30 cms which may not allow the percolation of contaminants.

The volatile organic compounds are either below detection limits or not detected (Table 5.5). Among the various heavy metals, the maximum concentration is recorded is for manganese (Table 5.6). Manganese varied from 403 mg/kg to 978 mg/kg, and is closely followed by Chromium (60 mg/kg to 870 mg/kg) and Zinc (110 mg/kg to 230 mg/kg). The predominant inorganic compounds appear to be sulfate and the cation exchange capacity (CEC) varies from 33.2 meq/100 gm to 48.75 meq.100 gm (Table 5.7). In general, the soil in this disposal area contains about 42 to 43% as clay with hydraulic conductivity of 0.6 cm/hour indicating that the soil is moderately impervious (Table 5.8).

5.2 Disposal Area II

This is the major disposal area in the plant premises of EIIL. There are many heaps of waste materials (mainly off specification products) dumped along the roads, storage of tarry residues in pits, disposal of neutralized temik wastes in solar evaporation ponds.

The semi volatiles of 36 soil samples collected in this disposal area are given in Table 5.9. The maximum concentration of sevin was recorded as 7218 mg/kg at DAII 01. Temik in the same station (DAII 01) recorded between 36,9 mg/kg and 92.34 mg/kg. All other stations registered sevin less than 397.11 mg/kg. Five stations recorded sevin between 126.64 mg/kg and 397.11 mg/kg. Sevin was either below detection limit or not detected in 18 stations (50%). Temik levels were from 5.81 mg/kg to 30.3 mg/kg at 8 stations (22.2%). The temik at other remaining stations were below detection limit of 5 mg/kg. Lindane varied from 0.1 to 2.8 mg/kg at 10 stations (27.8%) and were below detection limit of 0.1 mg/kg at remaining stations. Naphthalene, like Disposal Area I, is not detected in any sample.

At station DAII 18, sevin is observed to be increasing with depth while samples collected at other stations showed decreasing levels with depth. Therefore, additional fresh sampling was done upto 120 cms at DAII 18 and the data are given in Table 5.10. It was observed that higher concentrations are upto 60 cms only and the concentration below 60 cms becomes insignificant. Alpha naphthol was also decreasing with depth. This showed that semi Volatiles are present only at subsurface level.

The volatile organic compounds as given in Table 5.11 are reported to be either below detection limit or not detected (ND). The heavy metals and inorganics are shown in Tables 5.12 and 5.13 respectively, and they are insignificant. The manganese appears to be present in moderate level(72 to 231 mg/kg). According to Table 5.14 , the soil in this disposal area continues to be dominated by clay with hydraulic conductivity similar to Disposal Area I.

5.3 Rest of Area

In addition to the two main disposal areas, soil samples from 97 stations spread out in the remaining part of the plant premises were collected. In addition, samples from four stations adjacent to the plant premises on the northern side were collected to assess the impact due to past disposal activities. This area is fenced and there is no encroachment by public. During reconnaissance survey, no open dumps were identified in this area. As this area is anticipated with low levels of contaminants, 4 to 5 samples at each stretch was composited and the details are presented in Table 5.15. According to Table 5.16, semi volatile concentration in most of the samples were BDL except in trace levels (2.4 mg/kg to 8.65 mg/kg) at three composited samples. Temik is also below detection limits in most of the samples except at one composite sample of RA 23. This sample is composite sample of four stations viz., G 87 to G 90. The four samples were subsequently analyzed for temik and the data are presented as Table 5.16 A . The concentration at these four sites were between 10.56 mg/kg to 102.4 mg/kg. The volatile organic compounds (Table 5.17) are recorded as BDL.

The cation exchange capacity of the soil samples continues to be in the order of 45 to 48 meq/100 gm (Table 5.18) with no significant contribution from inorganics. The heavy metals except for manganese are appear to be insignificant (Table 5.19).As per Table 5.20, the soil contains an average clay content of 42% with hydraulic conductivity of 0.45 cm/hr.

5.4 Target Areas

It is anticipated that there could be spillages around various process units due to material handling leading to contamination of soil samples around these units. Such units are termed as Target Areas. It is assumed that the contamination would be localized and may not be spread out. In order to evaluate the impact due to such past activities, soil samples were collected near all identified units. Analysis were carried out for specific parameters depending on the activities of each unit. Semi volatiles concentration near sevin, temik and naphthol plants are very low (Table 5.21), and the volatile organic compounds are BDL at all stations (Table 5.22). The heavy metal concentration presented in Table 5.23 and inorganics in Table 5.24 indicate that the stations are not impacted. The poly chlorinated Biphenyls (PCBs) expected from transformer oil and other oils used during the plant operation period are reported to be absent in the soil samples collected (Table 5.25) from the units where PCBs might have been used.

5.5 Asbestos

Another important contaminant considered was asbestos. This is expected because of use of sandstone during the formulation of Temik. A sample of sandstone was analyzed for determining the presence of asbestos. The analysis of sandstone sample carried out at National Geophysical Research Institute (NGRI), Hyderabad revealed the presence of asbestos. However, the soil samples collected near the sandstone storage yard (DAI) did not show the presence of asbestos.

5.6 Along the Wastewater Drain

Six samples at two depths (90 and 120 cms) were collected from six locations along the waste water drain. The drain is reported to carry the acidic wastewater containing about 15 to 20 % HCl from units like naphthol, MIC and Sevin. Chloride was considered as tracer contaminant. Samples were analyzed for chloride content. The chloride content (Table 5.26) varies from 987 mg/kg to 2686 mg/kg. Samples collected at Stations D2 to D5 showed relatively higher values of chloride (2268 mg/kg to 2686 mg/kg) than D1 (1487 mg/kg to 1986 mg/kg). Samples at D6 showed the lowest concentration of chloride (987 mg/kg to 1736 mg/kg). The soil samples collected at three stations to record background level have also similar chloride concentration.

One sample (D2) which highest chloride level was analyzed for semi volatiles. Semi volatiles are below detection limits. This indicated that the soil along the drain is not contaminated with semi volatiles.

Had there been any seepage from the drain, the chloride content would have gone up. In the absence of any increased concentration of chloride, it appears that no seepage had taken place from the drain. The heavy metals are also less.

5.7 Control Samples

Soil samples from three locations outside the plant (about 500 m away from EIIL) were collected and the data are presented in Tables 5.27 to 5.31. All samples do not contain semi volatiles and volatile organic compounds which are the main contaminants expected from the past activities of EIIL at their Bhopal plant. The soil appears to have an average clay content of 42% (Table 5.31) slightly less than the soil within plant premises. The manganese in these samples also very high indicating that the back ground level of manganese is rather high in this region. Chloride was from 0.4 meq/L to 12.0 meq/L.

5.8 Geoelectrical Investigations

Geoelectrical soundings (VES) were carried out (Fig 5.1) in the area to delineate sub-surface hydrogeological features in the plant premises. Geoelectrical profiling was carried out along eleven traverses (Fig 5.2). It was presumed that sufficient electrical resistivity contrast existed between sites containing dumped material and host rock.

Electrical profiling, with a constant electrode separation is used for location of lateral inhomogeneities. The procedure of multi-electrode spacing profiling is used to probe horizons at different depths. The depth of probing, is in general, regards the same as the inter-electrode spacing. The electrical sounding is used to delineate variations of resistivity with depth at a point. It consists of a succession of apparent resistivity measurements obtained by gradually increasing the electrode separation. Schlumberger configuration is used for soundings because of number of advantages as regards field operation and less sensitivity to near surface lateral inhogogenetics. Wenner soundings were adopted where surface resistivities are low and potential differences thus generated were small.

5.8.1 Geoelectrical Soundings

In the present study carried out by National Geophysical Research Institute (NGRI), Hyderabad eight resistivity soundings were made using Schlumberger electrode configuration with half current electrode separation (A/2) as 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 15.0, 20.0, 25.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, and 100.0 m. One sounding (VES 4) was carried out near the existing well for which lithologs were available with EIIL with a view to correlate geoelectrical measurements with lithologs and used this information for the interpretation of sounding data at other locations. The apparent resistivity values were plotted against AB/2 to generate a sounding curve. Whenever MN/2 values were increased to obtain a higher signal, there was shift in the field curve for the same AB/2 values.

and basement as hard sandstone. The constrained VES data interpretation indicates hard sandstone has resistivity of about 150 ohm-m while the soft/fractured sandstone shows a resistivity of only about 15 ohm-m. The saturated weathered sandstone and black cotton soil, of course, have much lower resistivities.

The combined thickness of black cotton soil, hard sandy soil and yellow sandy soil varies in the area from 15.3 m to 58.9 m, being least near sounding VES-7 and maximum near sounding VES-2. The depth to the hard sandstone in the area varies between 16.9 m and 69.6 m. No liner features like faults or dikes could be delineated.

5.8.2 Geoelectrical Profiling

Geoelectrical profiling using Wenner electrode configuration with a station interval of 5 meters and inter-electrode spacing of 2m, 5m and 10m were carried out along eleven traverses (marked A to K in Fig 5.2). The extent and bearing of these traverses are listed in Table 5.34.

The dumped materials, mostly organics and to a little extent with inorganics, is expected to produce contamination which may effectively change the resistivity of the host rock. The magnitude of the anomaly depends upon the size of the affected region and the extent of increase in the electrical resistivity of the host matrix. Out of eleven geoelectrical traverses laid in the area, five traverses (Traverses D, E, G, H and I) were laid over expected dump materials and remaining six traverses (Traverses A,B,C,F,J &K) were laid in the area where no dump materials is known to occur. The resistivity profiles are presented in Figures 5.14 to 5.16.

No appreciable resistivity anomaly has been observed along four traverses (Traverses A,I,F and K).Traverse D,E,G,H, and J showed resistivity anomaly only with 2 m inter-electrode spacing. Soil samples collected in this area also showed the presence of sevin and/or temik. The concentration, however, within the criteria level. At one point in each Traverses at B and C also exhibited a slight change in increased resistivity. However soil samples collected in these areas did not show the presence of any semi volatiles or volatiles. Thus the increased electrical resistivity could be a natural localized phenomenon.

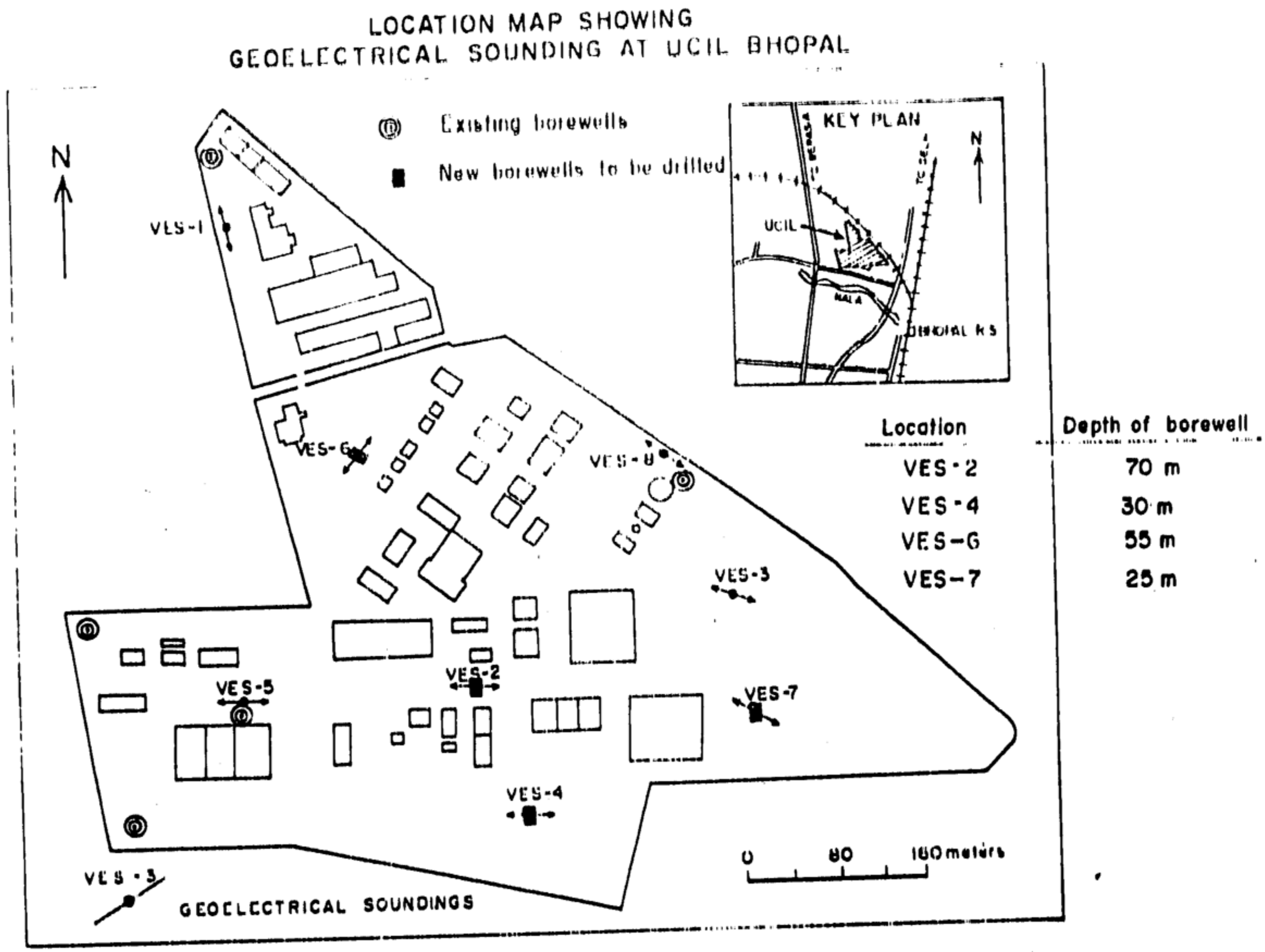


FIG 5.5 LOCATION OF VERTICAL SOUNDINGS

LOCATION MAP SHOWING
GEOELECTRICAL PROFILING AT UCIL BHOPAL

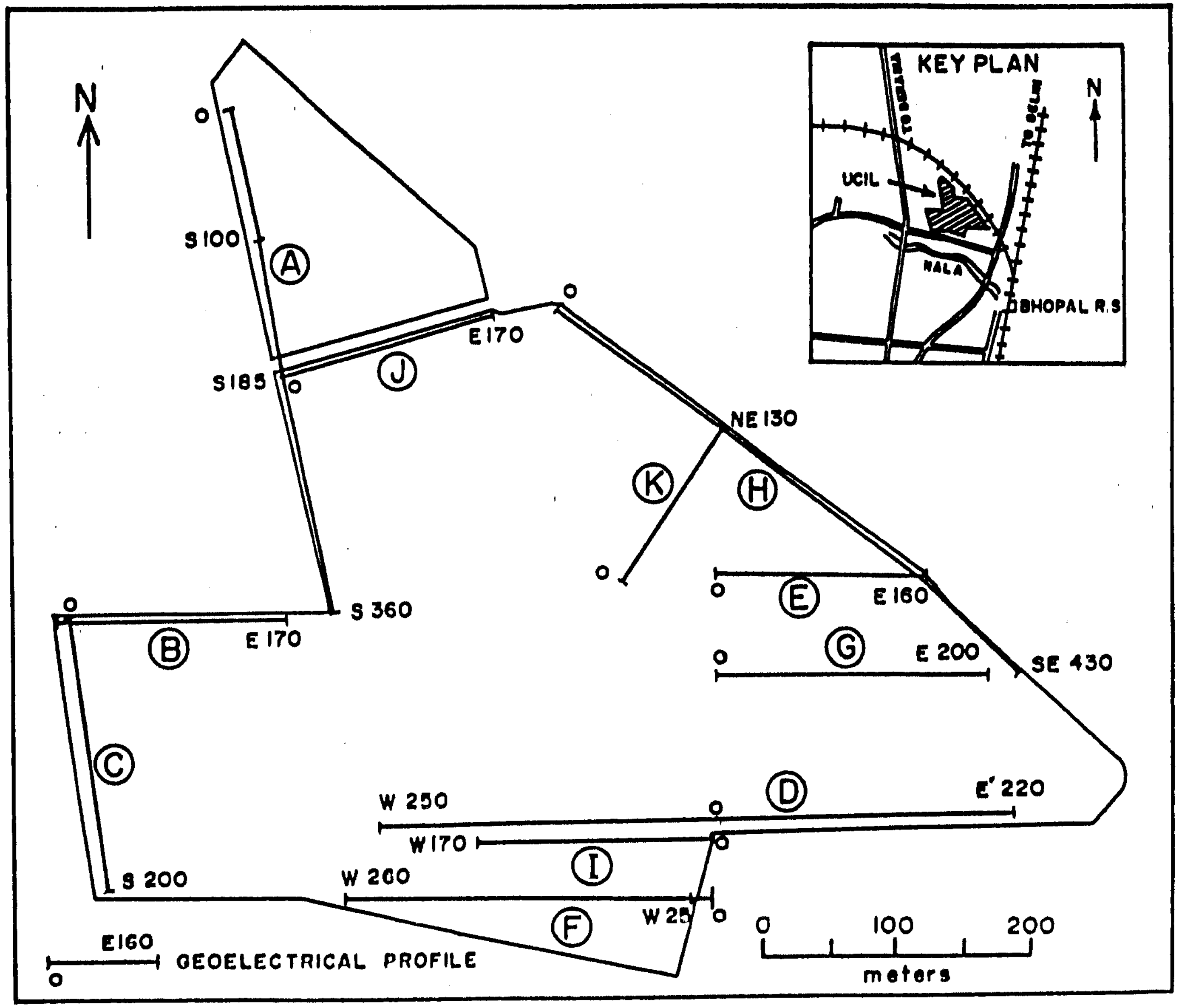


FIG 5.6 LOCATION MAP OF GEOELECTRIC TRAVERSES

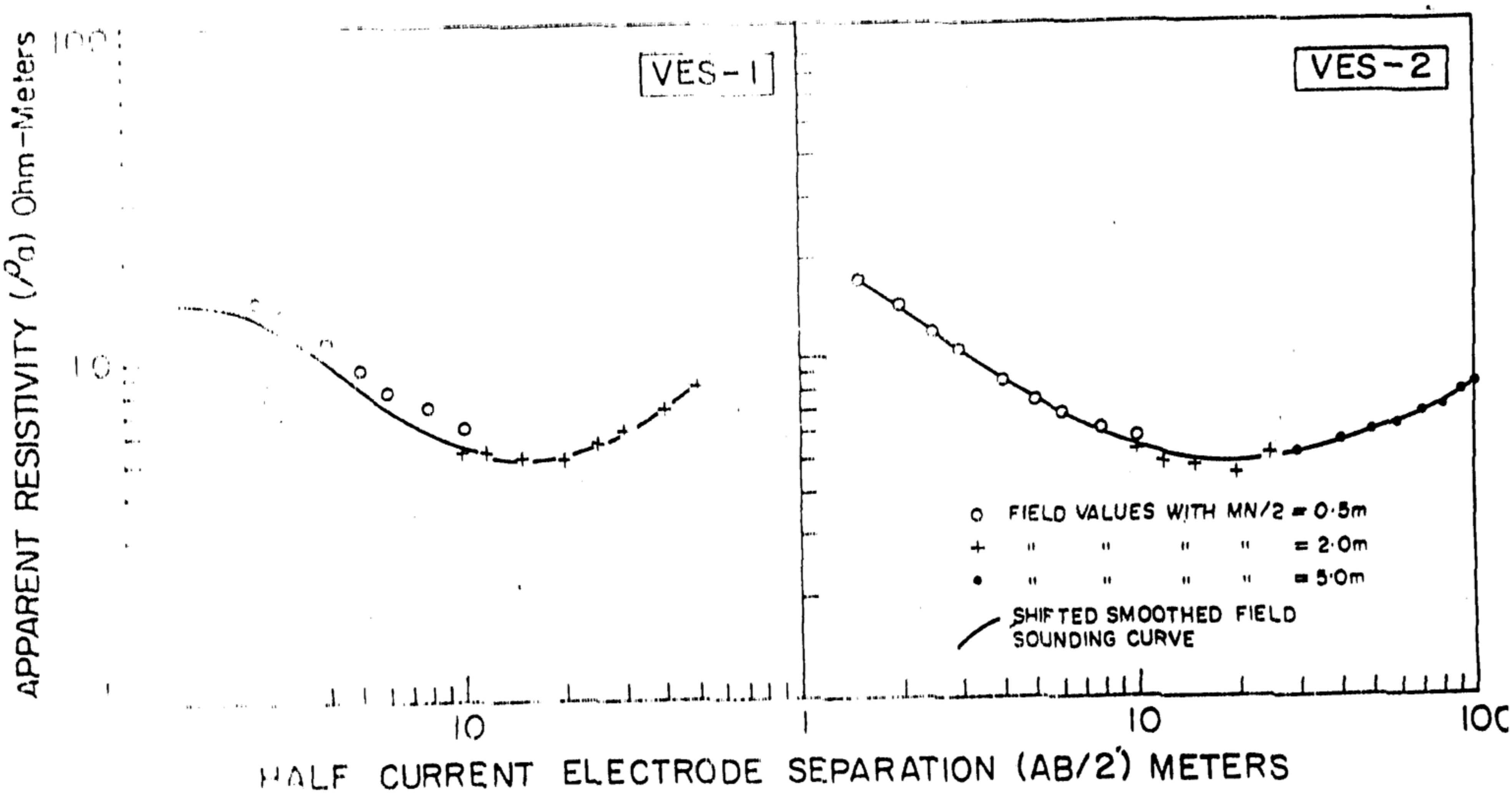


FIG 5 ELECTRICAL SOUNDING CURVES

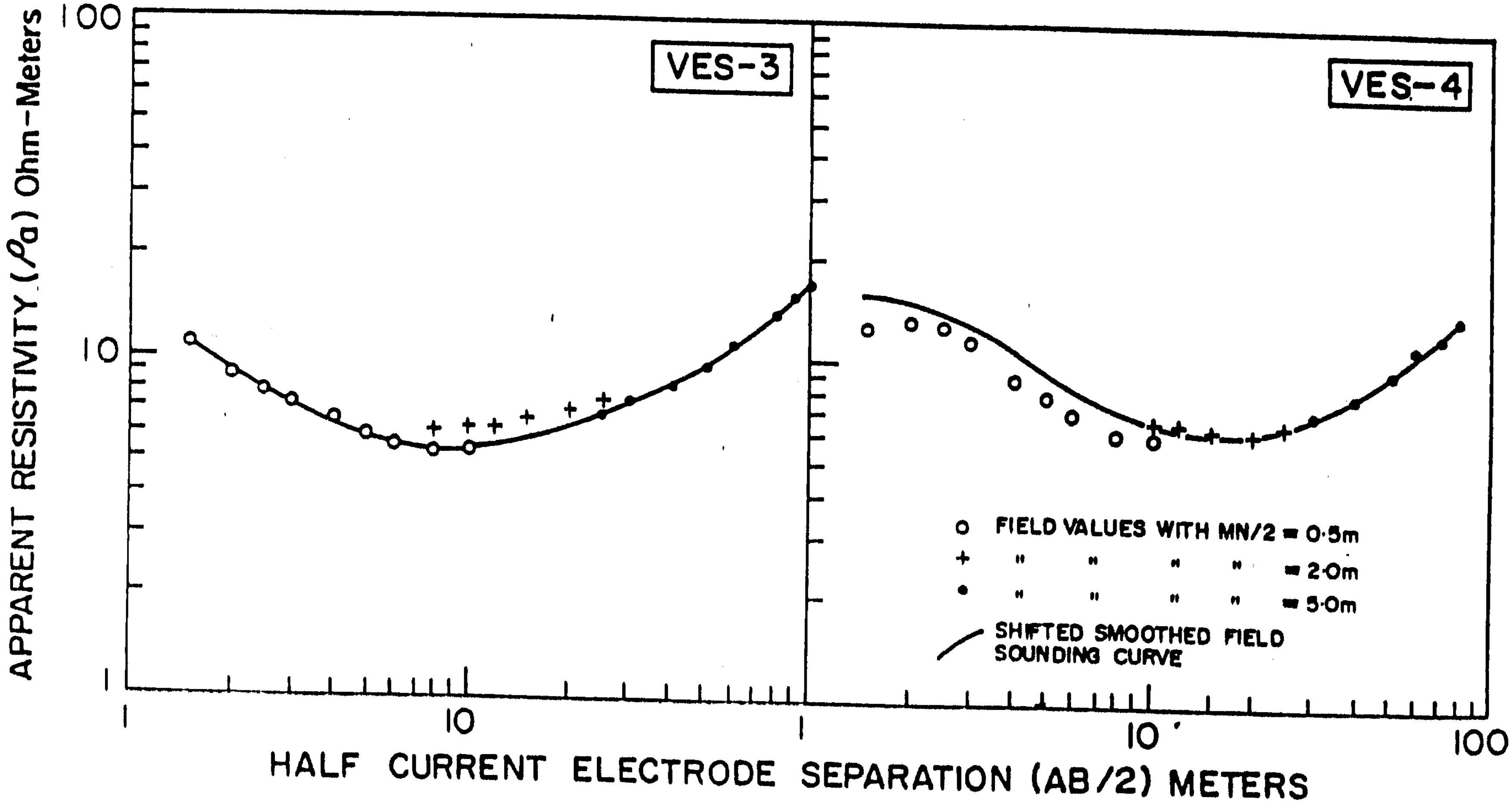


FIG 5.8 ELECTRICAL SOUNDING CURVES

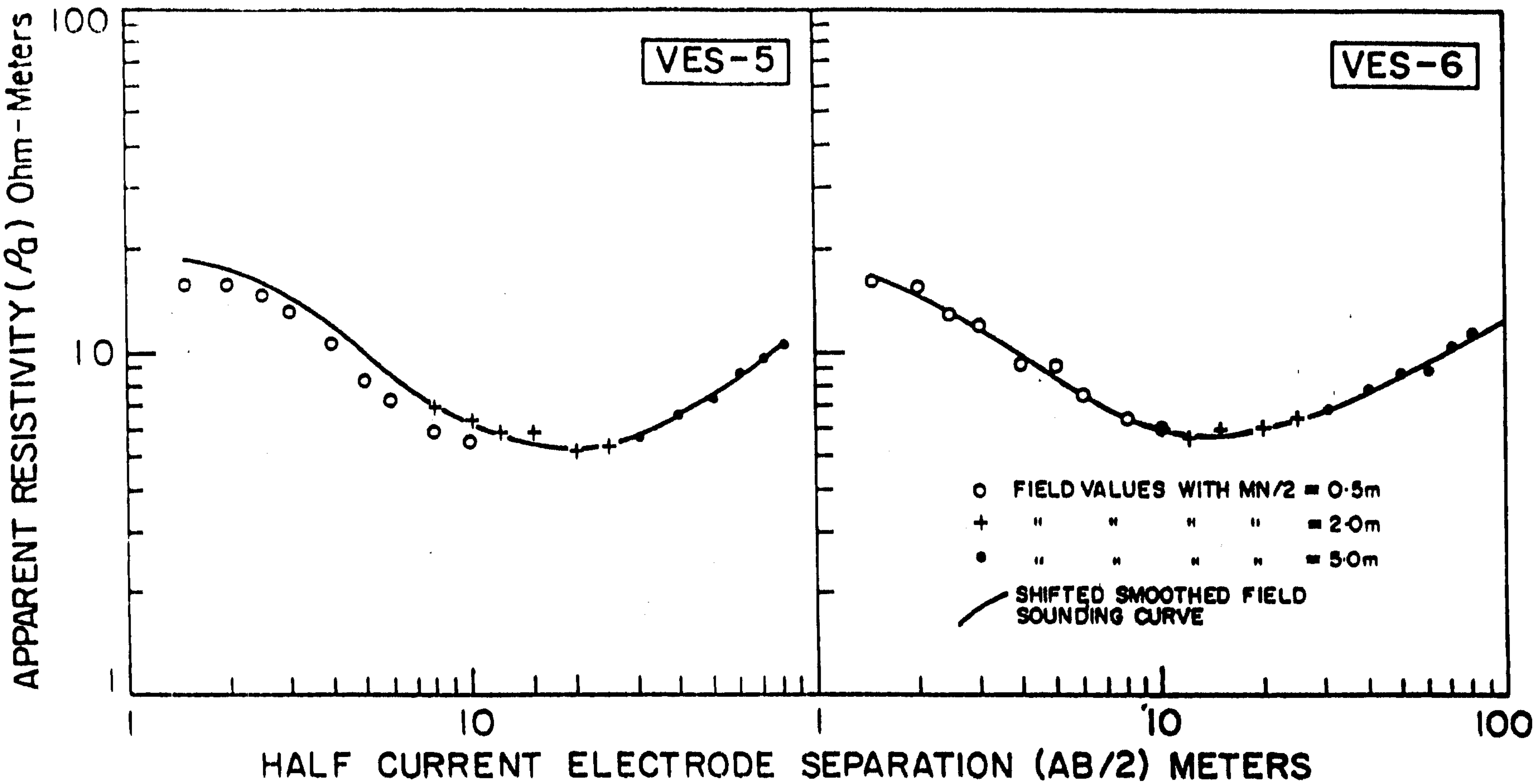


FIG 5.8 · ELECTRICAL SOUNDING CURVES

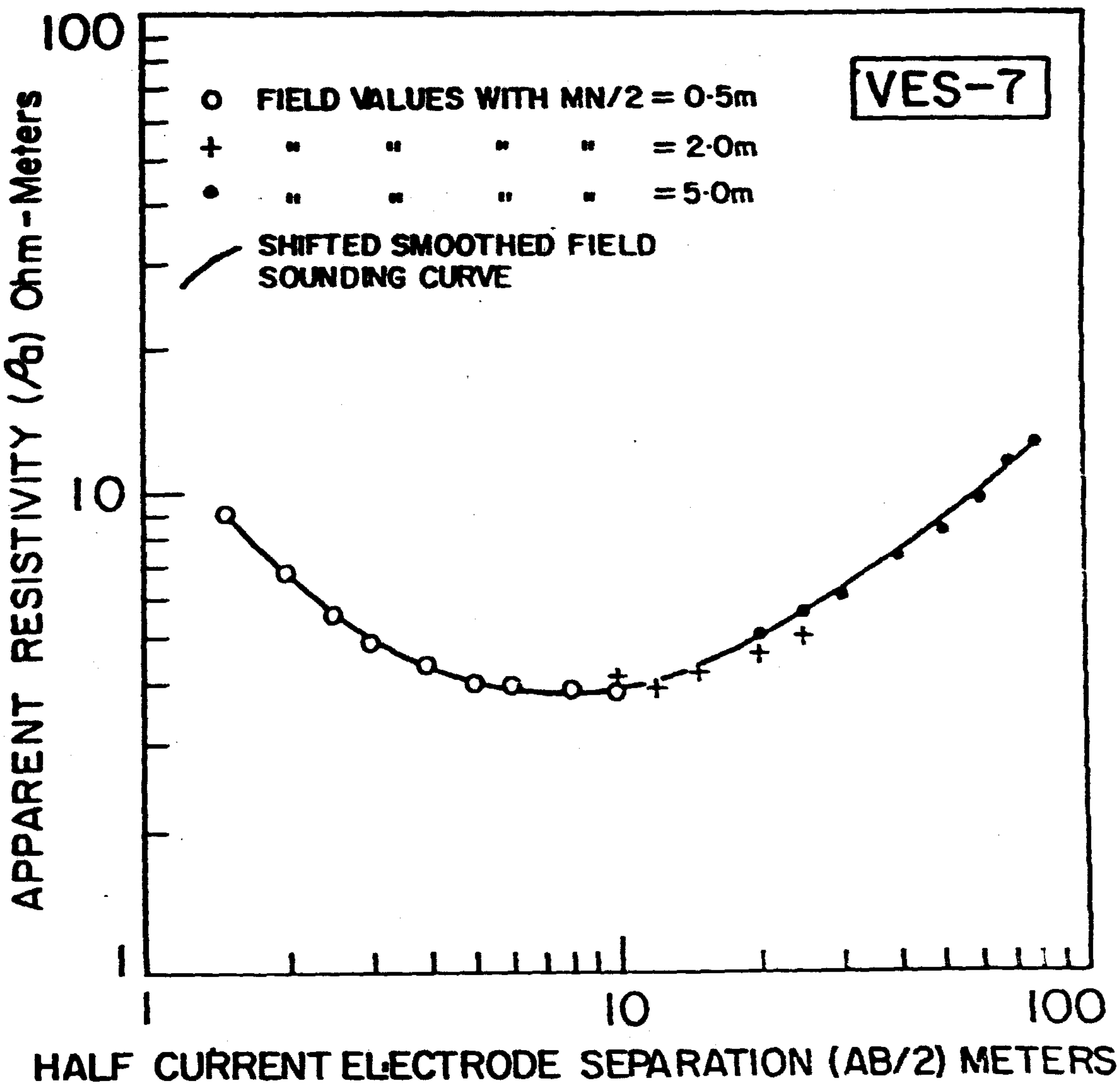


FIG 5.10 ELECTRICAL SOUNDING CURVES

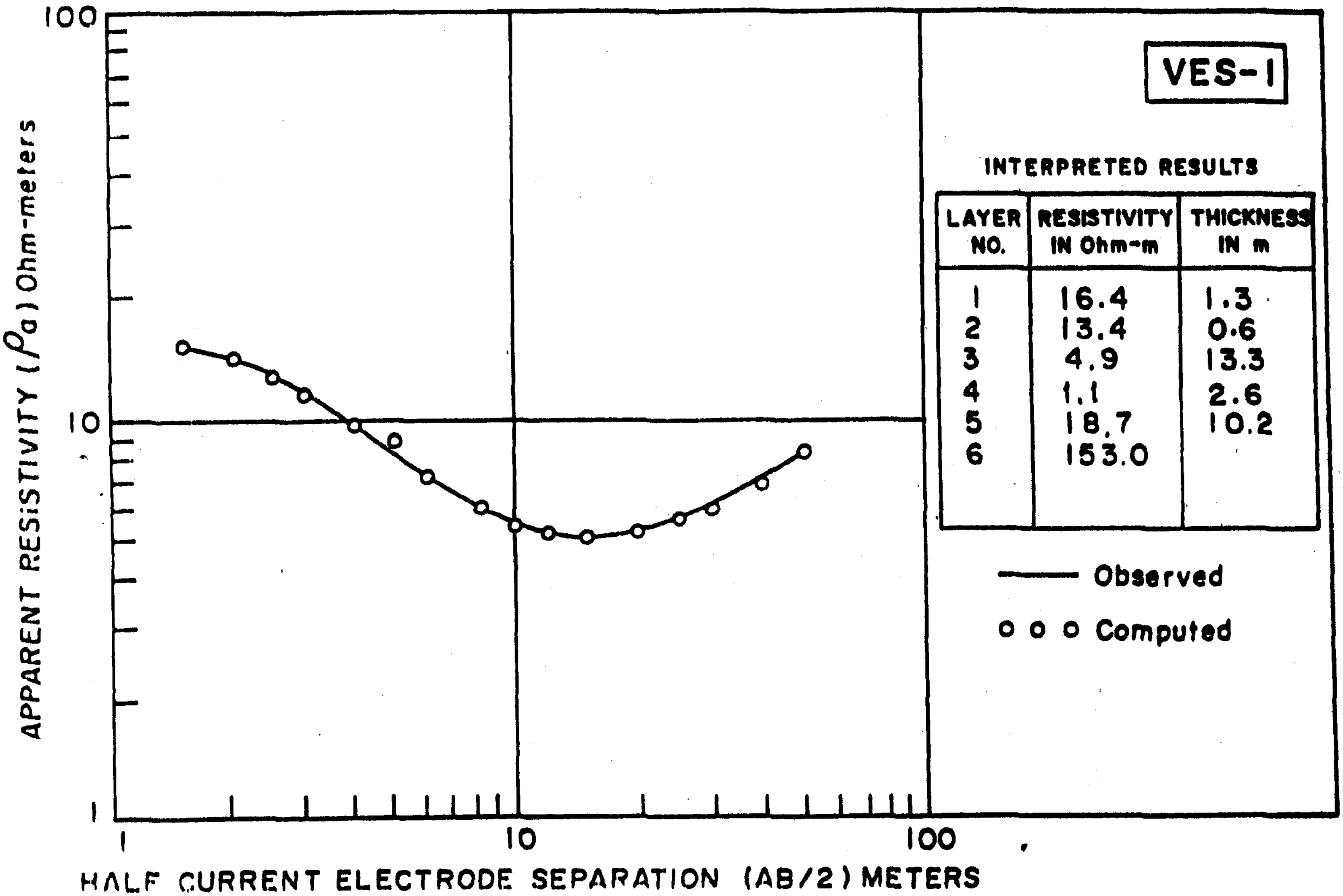
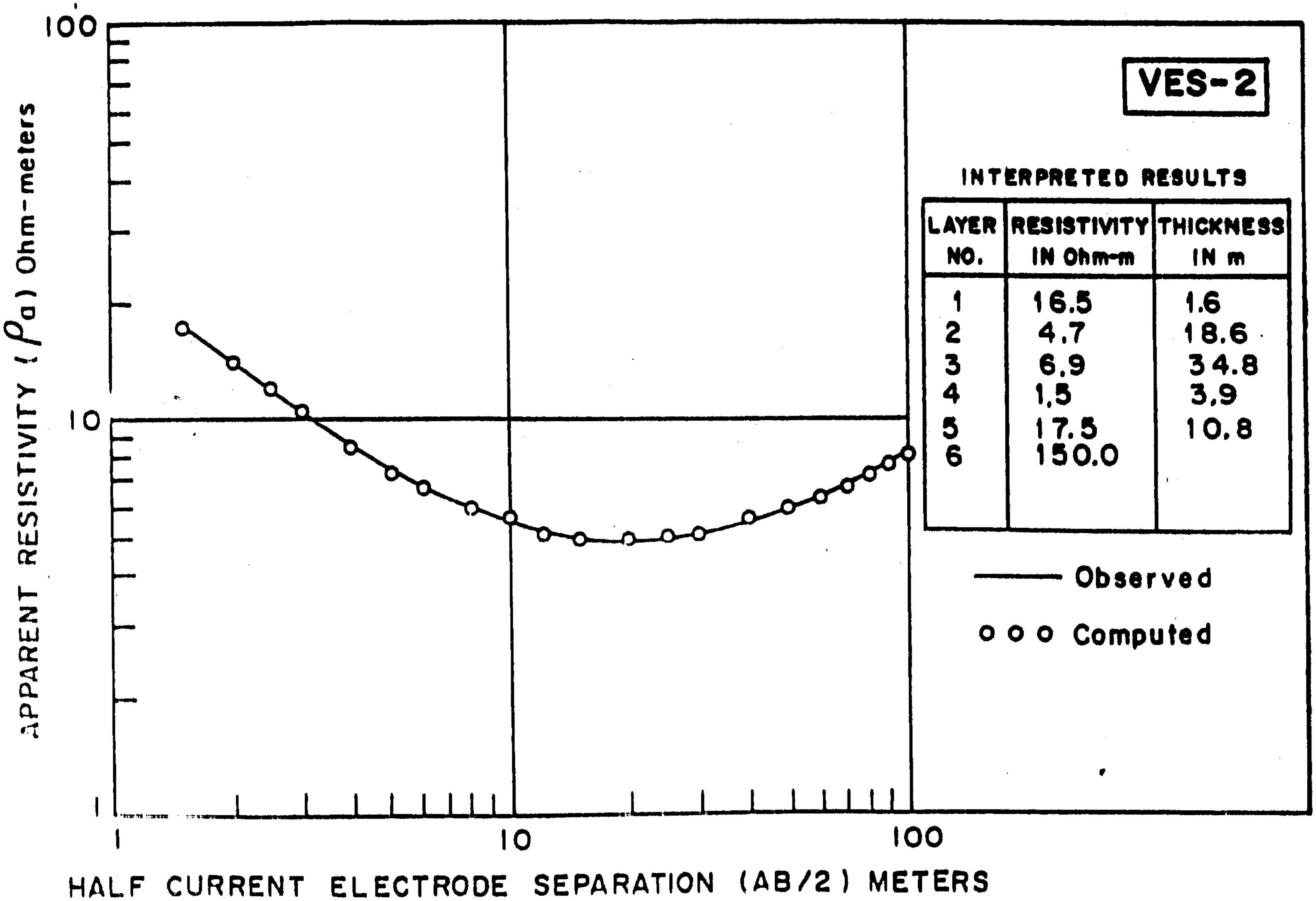
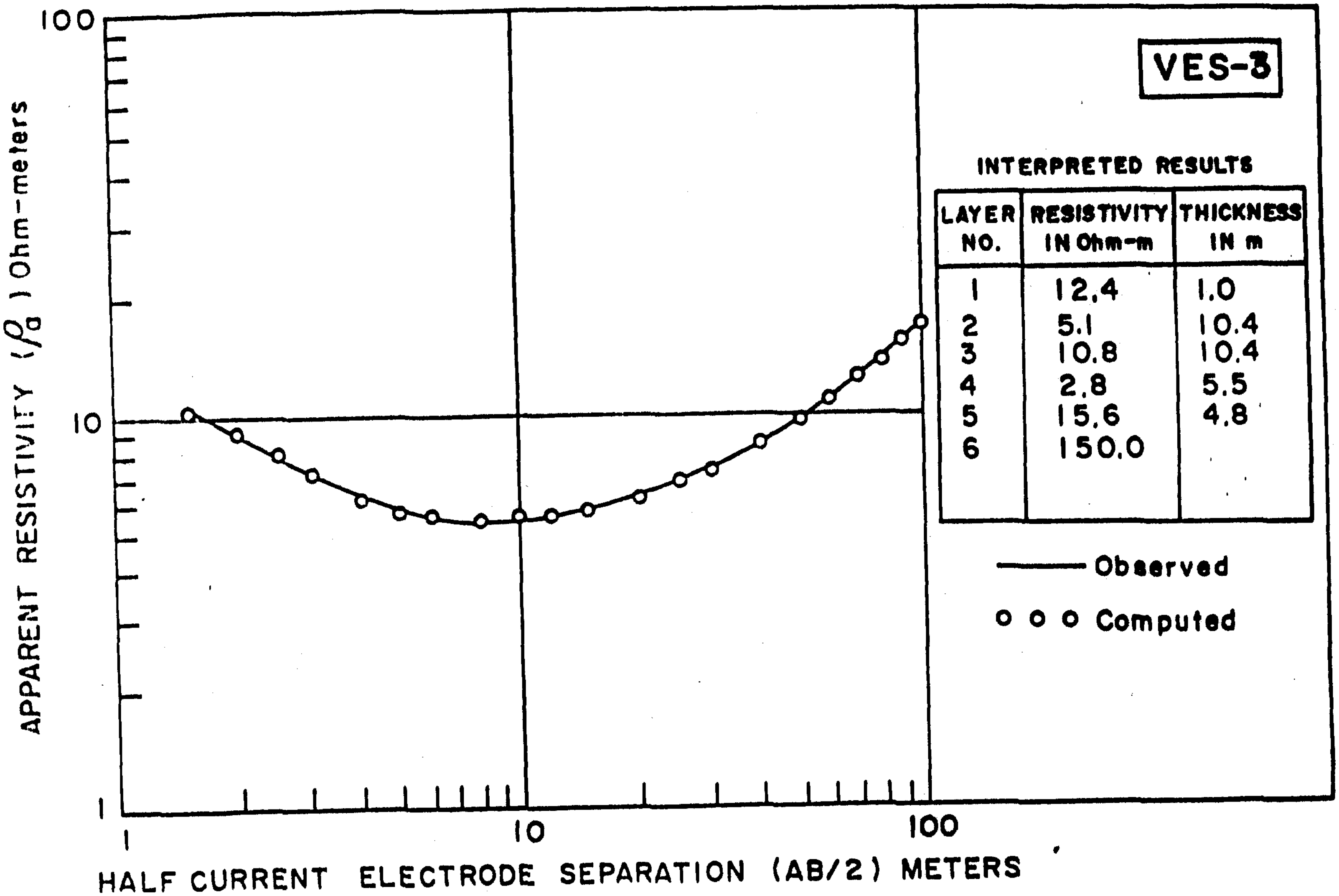


FIG 5.11 INTERPRETED SOUNDING CURVES



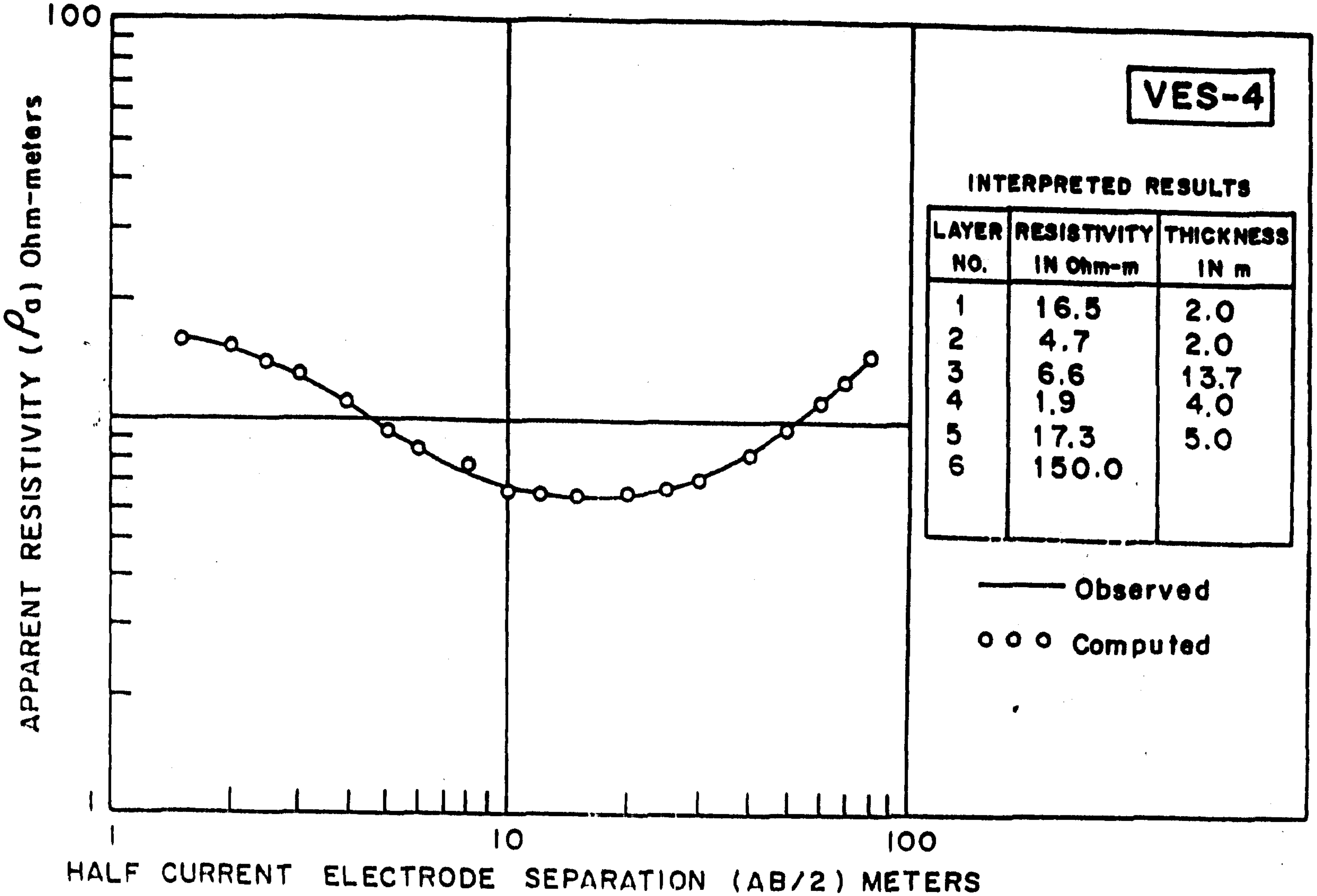
LAYER NO.	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	16.5	1.6
2	4.7	18.6
3	6.9	34.8
4	1.5	3.9
5	17.5	10.8
6	150.0	

FIG 5.~~12~~2 INTERPRETED SOUNDING CURVES



LAYER NO.	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	12.4	1.0
2	5.1	10.4
3	10.8	10.4
4	2.8	5.5
5	15.6	4.8
6	150.0	

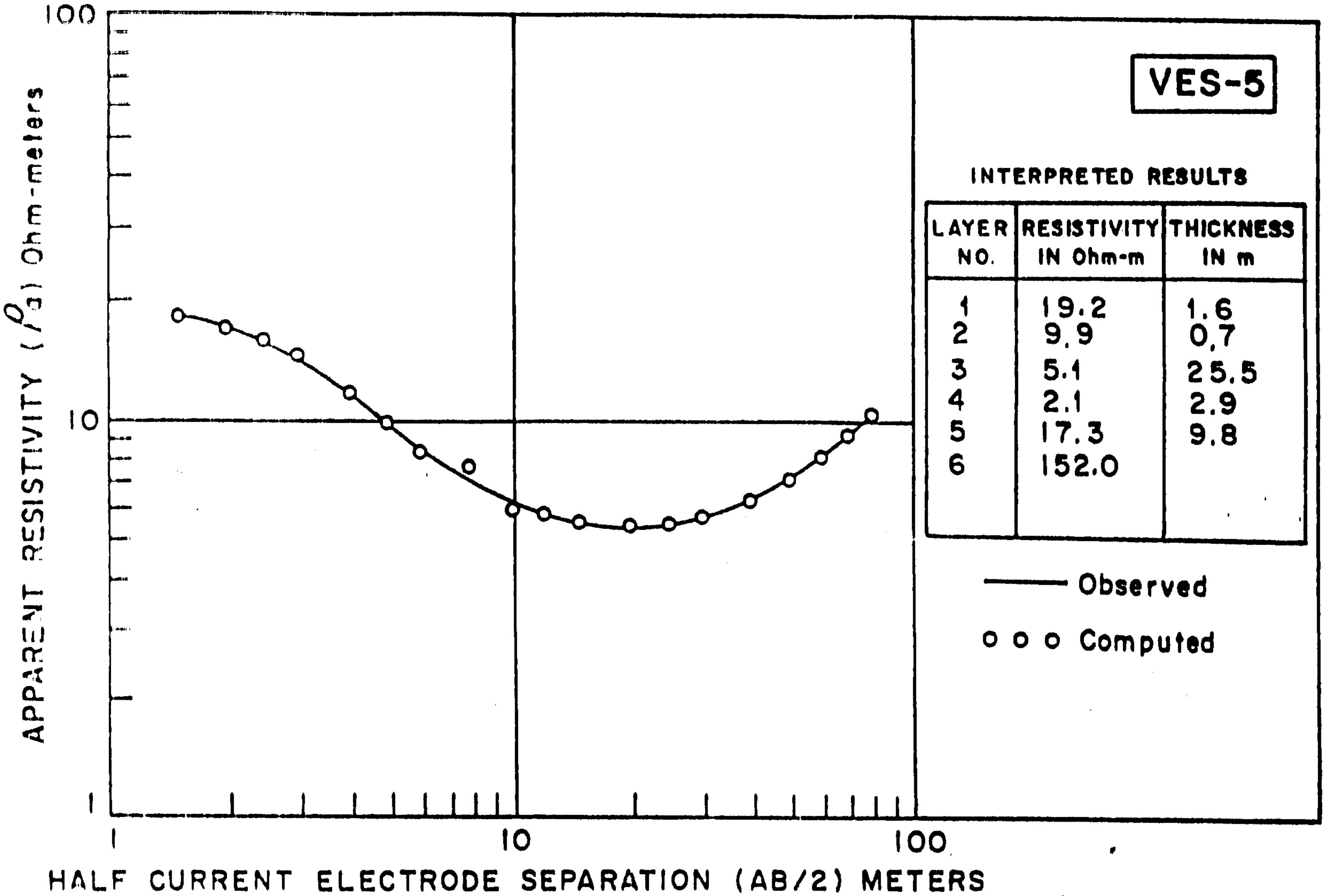
FIG 5.12 INTERPRETED SOUNDING CURVES



INTERPRETED RESULTS

LAYER NO.	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	16.5	2.0
2	4.7	2.0
3	6.6	13.7
4	1.9	4.0
5	17.3	5.0
6	150.0	

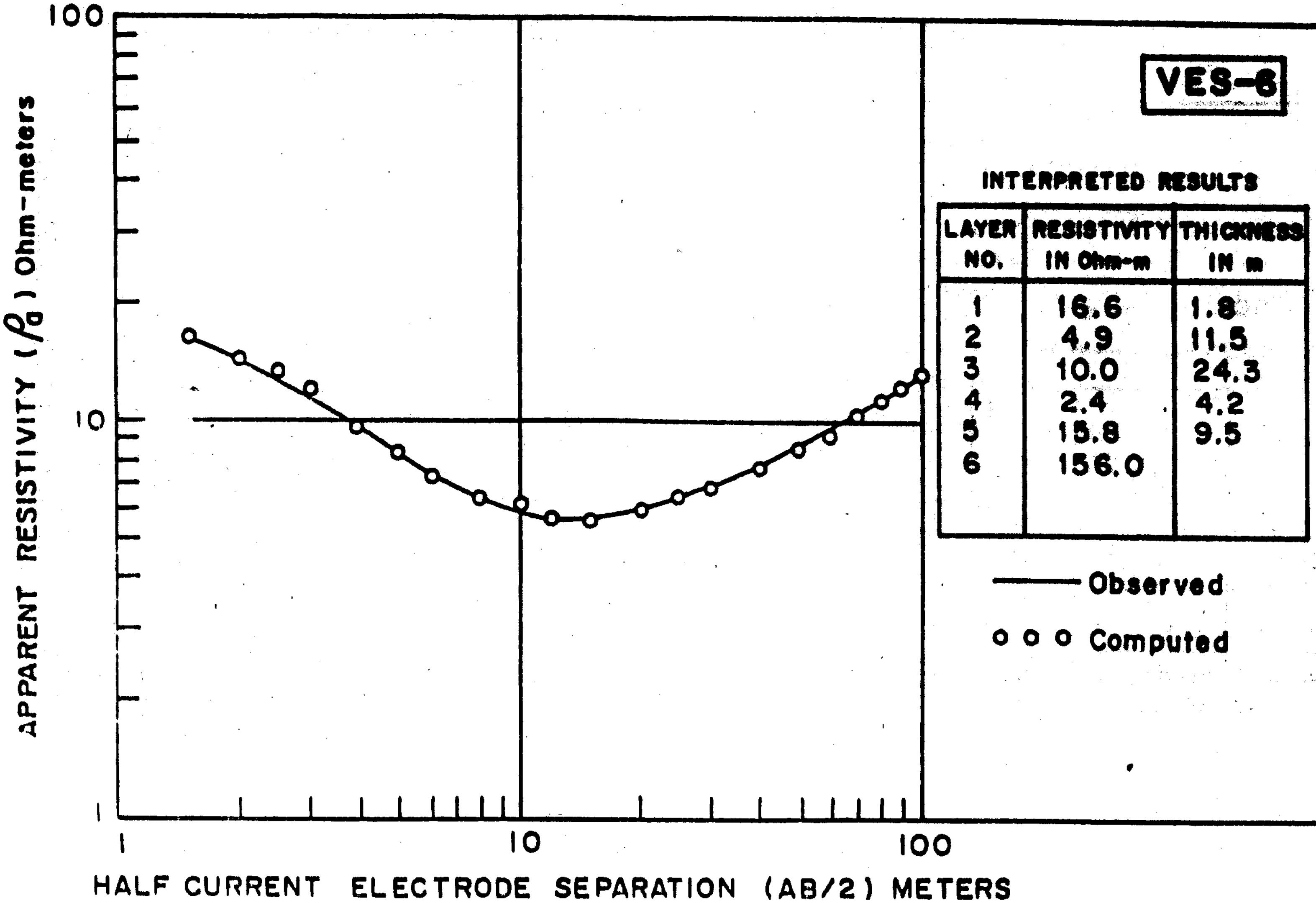
FIG 5.14 INTERPRETED SOUNDING CURVES



INTERPRETED RESULTS

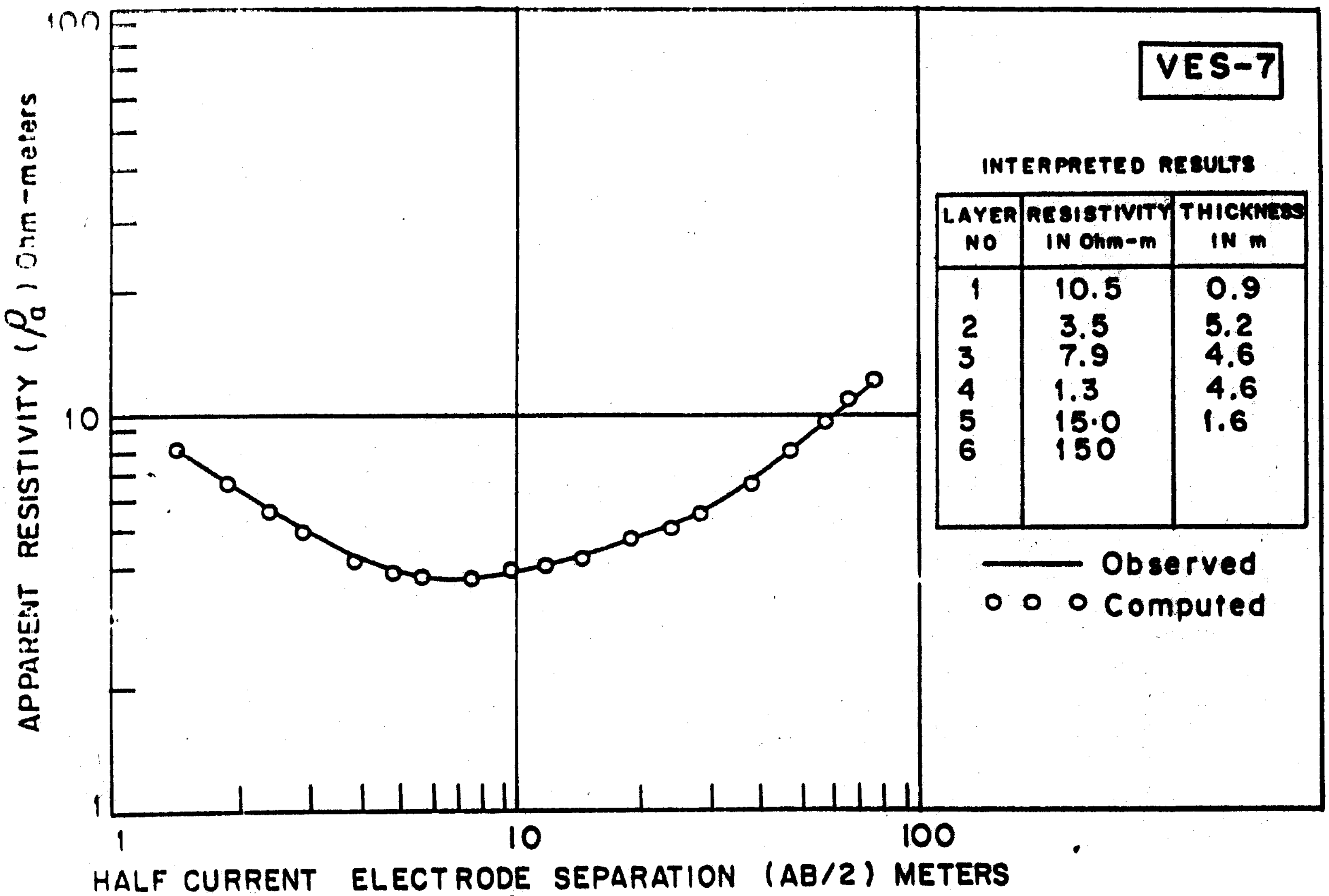
LAYER NO.	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	19.2	1.6
2	9.9	0.7
3	5.1	25.5
4	2.1	2.9
5	17.3	9.8
6	152.0	

FIG 5.151 INTERPRETED SOUNDING CURVES



LAYER NO.	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	16.6	1.8
2	4.9	11.5
3	10.0	24.3
4	2.4	4.2
5	15.8	9.5
6	156.0	

FIG 5.16 \ \ INTERPRETED SOUNDING CURVES



INTERPRETED RESULTS

LAYER NO	RESISTIVITY IN Ohm-m	THICKNESS IN m
1	10.5	0.9
2	3.5	5.2
3	7.9	4.6
4	1.3	4.6
5	15·0	1.6
6	150	

FIG 5.17 INTERPRETED SOUNDING CURVES

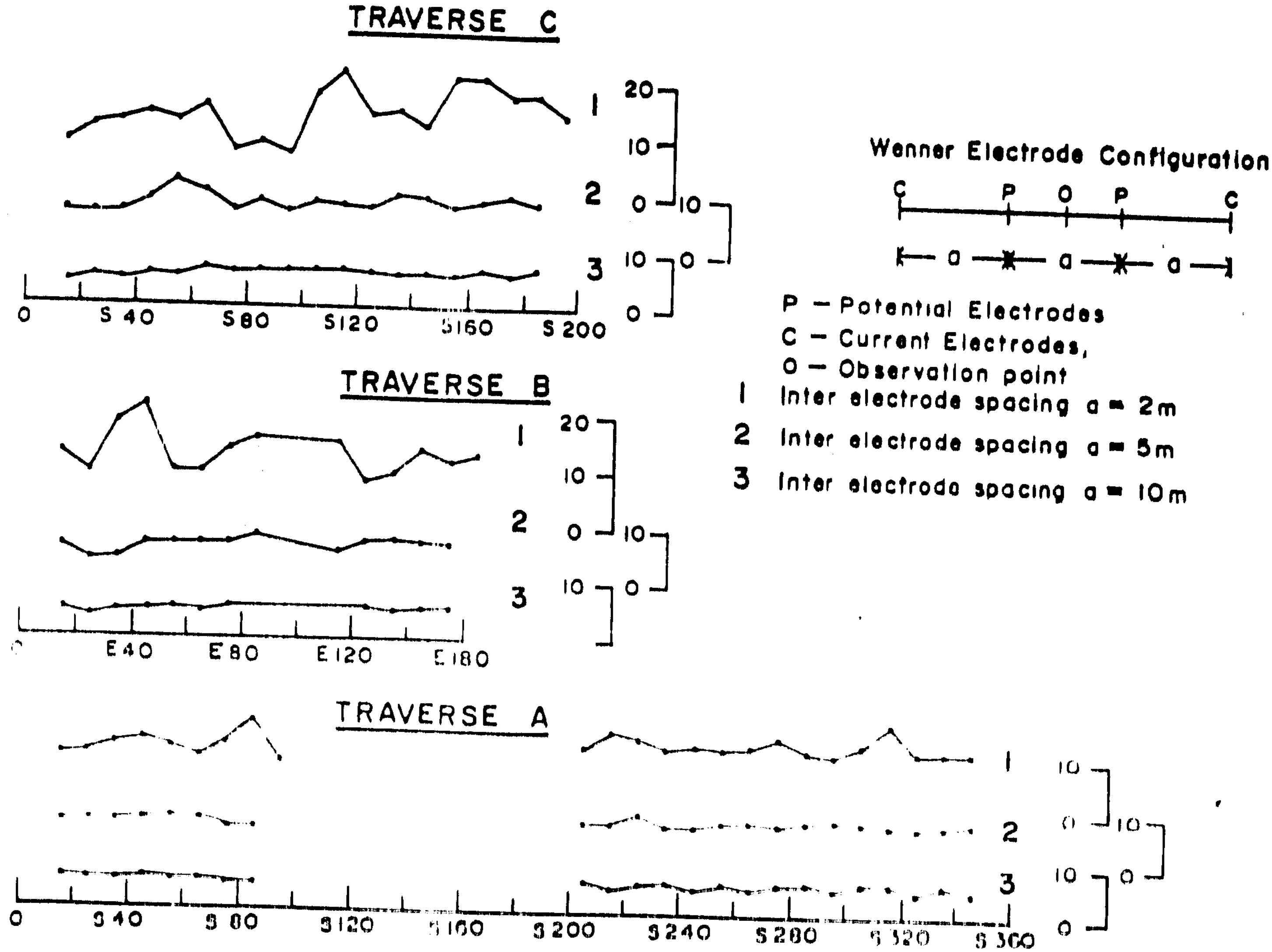


FIG 5.18 RESISTIVITY PROFILES ALONG TRAVERSES A, B AND C

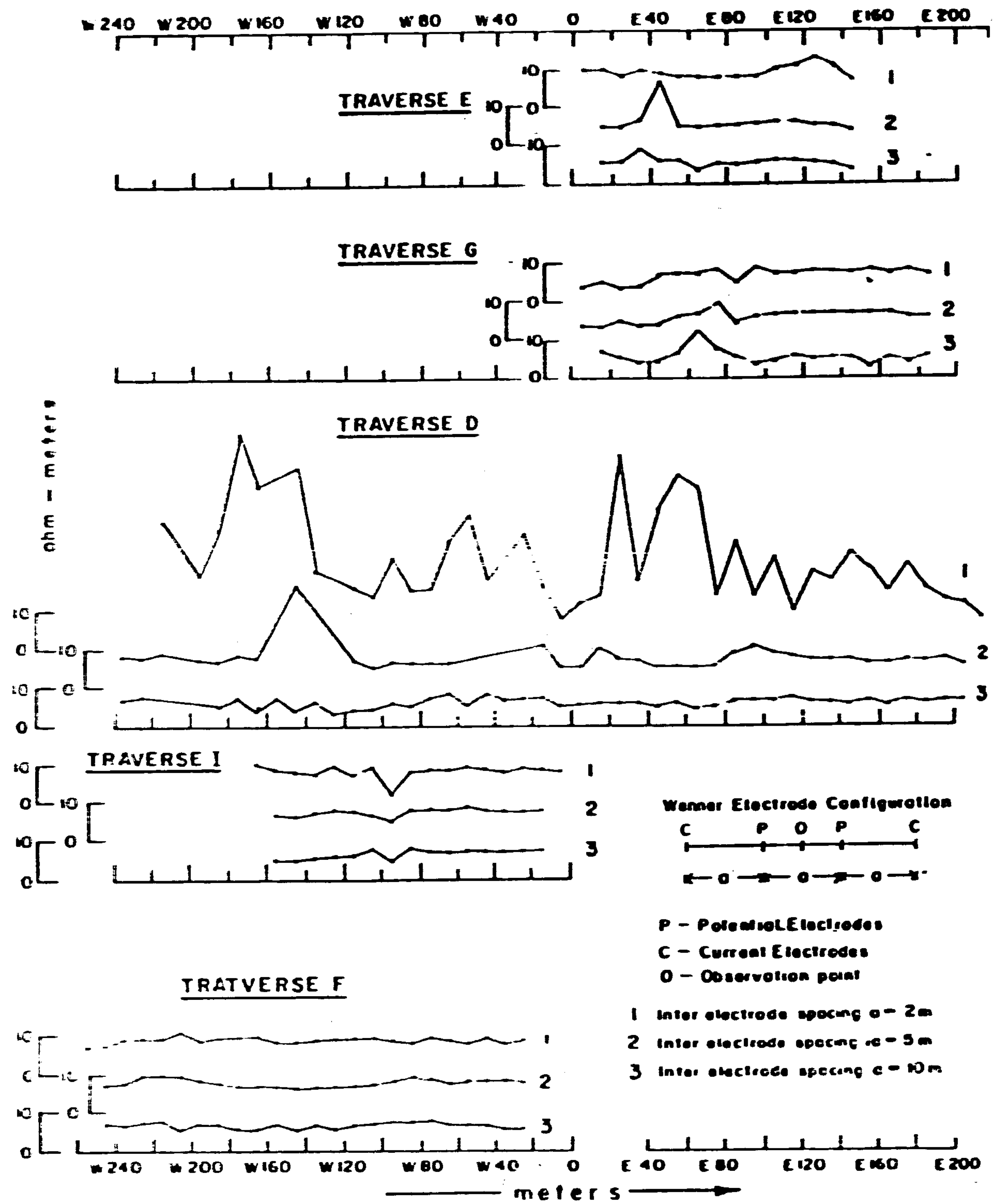


FIG 5.19 RESISTIVITY PROFILES ALONG TRAVERSES D,E,F,G,& I

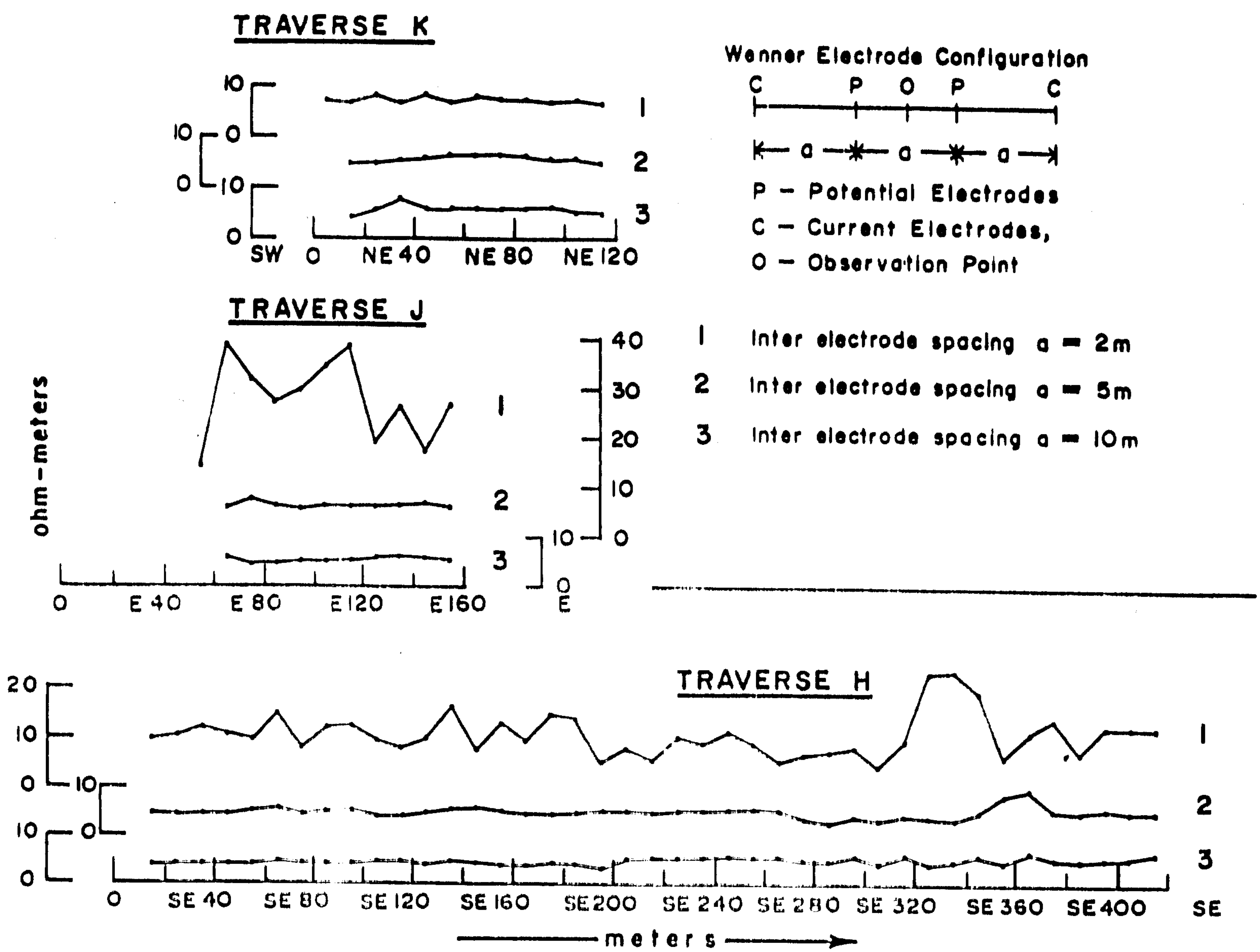


FIG 5.20 RESISTIVITY PROFILES ALONG TRAVERSES H, J, & K

TABLE 5.1

Summary of Soil Samples at UCIL, Bhopal

Area	No.of Sampling Location	Sample Depth (cm)	No.of Samples	No.of Sample for analysis			Remarks
				Volatile	Semi Volatile	Inorganics & Heavy Metals	
Dis.Area I	17	30,60*	34	6	6	6	
Dis.Area II	36	30,60*	71	71	71	71	
Target Area	34	15,30	40	19	19	19	9 for PCB
Along the Drain	6	90,120	12	NA	NA	12	
Rest Area	101	30	101	29	29	29	—
Control	3	30,60	6	3	3	3	—

* .... Additional sampling at 90 cm and 120 cm was carried out at a few stations where contamination at deeper depth was anticipated

TABLE 5.2

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area

Semi volatiles (mg/kg)

Sample ID No.	Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
DAI 0130	32.28	52.20	BDL	27.86	ND
DAI 0160	156.78	34.72	BDL	23.38	ND
DAI 0230	153.86	6.39	BDL	22.84	ND
DAI 0260	2.62	BDL	BDL	BDL	ND
DAI 0330	94.02	18.00	BDL	130.18	ND
DAI 0360	41.40	16.86	BDL	0.25	ND
DAI 0430	BDL	15.75	BDL	8.32	ND

Note:

DAI 0130 .... Composite of samples from Points 1 to 3 & 5 to 7 at 30 cm
DAI 0160 .... Composite of samples from Points 1 to 3 & 5 to 7 at 60 cm
DAI 0230 .... Composite of samples from Points 8 to 14 at 30 cm
DAI 0260 .... Composite of samples from Points 8 to 14 at 60 cm
DAI 0330 .... Composite of samples from Points 15 to 17 at 30 cm
DAI 0360 .... Composite of samples from Points 15 to 17 at 60 cm
DAI 0430 .... Waste material collected at Point 4

ND .... Not detected

BDL .... Below Detection Limit

Detection Limits (mg/kg) :

Sevin .... 1.0 Temik 5.0
Alpha napthol .... 10.0 Lindane 0.1
Napthalene 10.0

TABLE 5.3

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area

Semi volatiles
(mg/kg)

S. No.	Depth (cm)	Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
DAI 01						
F1	30	35.62	53.42	BDL	25.46	ND
F1	60	160.28	28.46	BDL	14.36	ND
F2	30	40.49	50.26	BDL	24.38	ND
F2	60	220.46	74.36	BDL	38.46	ND
F3	30	42.28	48.68	BDL	26.52	ND
F3	60	356.32	66.74	ND	24.26	ND
F5	30	30.46	57.64	BDL	27.38	ND
F5	60	80.28	28.00	ND	16.46	ND
F6	30	31.56	58.28	BDL	26.68	ND
F6	60	62.38	16.00	ND	12.36	ND
F7	30	26.01	47.32	BDL	28.46	ND
F7	60	32.16	12.32	ND	18.64	ND
DAI 02						
F8	30	156.68	8.78	ND	36.24	ND
F8	60	2.60	BDL	ND	6.28	ND
F9	30	210.64	10.43	ND	28.46	ND
F9	60	6.32	BDL	ND	ND	ND
F10	30	282.48	6.36	ND	22.32	ND
F10	60	7.2	BDL	ND	ND	ND

Contd ....

S. No.	Depth (cm)	Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
F11	30	78.64	BDL	ND	26.42	ND
F11	60	ND	BDL	ND	ND	ND
F12	30	60.76	BDL	ND	31.72	ND
F12	60	ND	BDL	ND	ND	ND
F13	30	76.42	BDL	ND	16.32	ND
F13	60	ND	BDL	ND	ND	ND
F14	30	47.38	BDL	ND	7.8	ND
F14	60	ND	BDL	ND	ND	ND
DAI 03						
F15	30	102.6	26.6	BDL	170.6	ND
F15	60	51.4	28.4	BDL	0.5	ND
F16	30	88.4	20.8	BDL	201.4	ND
F16	60	36.8	16.7	BDL	ND	ND
F17	30	96.4	12.8	BDL	16.2	ND
F17	60	48.6	6.6	BDL	ND	ND

BDL ..... Below Detection Limit

ND ..... Not Detected

Detection Limits (mg/kg) :

Sevin 1
Alpha napthol 10
Napthalene 10

Temik 5
Lindane 0.1

TABLE 5.4

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area

Semi volatiles
(mg/kg)

S. No.	Depth (cm)	Sevin	Temik	Alpha - Naphthol	Lindane
F2A	30	38.6	46.8	ND	25.2
F2A	60	224.3	75.6	ND	41.6
F2A	90	66.8	28.4	ND	11.3
F2A	120	7.8	11.4	ND	ND
F3A	30	38.6	44.4	BDL	24.3
F3A	60	296.4	56.8	ND	18.6
F3A	90	96.3	20.4	ND	ND
F3A	120	11.3	6.4	ND	ND

Note

Above samples were taken at F2 and F3 upto 120 cms in DAI

BDL ..... Below Detection Limit

ND ..... Not Detected

Detection Limits (mg/kg) :

Sevin 1
Alpha napthol 10
Napthalene 10
Temik 5
Lindane 0.1

Naphthalene was not analyzed as it was not detected in earli[er]
samples

TABLE 5.5

Characteristics of Soil Samples at ETTL, Bhopal - Disposal Area I

Volatiles
(mg/kg)

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
DAI 0130	ND	BDL	ND	ND	ND	ND	ND	ND
DAI 0160	ND	BDL	ND	ND	ND	ND	ND	ND
DAI 0230	ND	BDL	ND	BDL	ND	ND	ND	ND
DAI 0260	ND	BDL	ND	BDL	ND	ND	ND	ND
DAI 0330	ND	BDL	ND	ND	ND	ND	ND	ND
DAI 0360	ND	BDL	ND	ND	ND	ND	ND	ND

Note:

DAI 0130 .... Composite of samples from Points 1 to 3 & 5 to 7 at 30 cm
DAI 0160 .... Composite of samples from Points 1 to 3 & 5 60 cm
DAI 0230 .... Composite of samples from Points 8 to 14 at 30 cm
DAI 0260 .... Composite of samples from Points 8 to 14 at 60 cm
DAI 0330 .... Composite of samples from Points 15 to 17 at 30 cm
DAI 0360 .... Composite of samples from Points 15 to 17 at 60 cm
DAI 0430 .... Waste material collected at Point 4
ND .... Not detected
BDL .... Below Detection Limit

Detection Limits (mg/kg)

Chloroform	 50	Formaldehyde	....
Methylene Chloride	 20	1-2- Dichlorobenzene	 400
Toluene	 40	Monomethylamine	....
Carbon tetra Chloride	 100		

TABLE 5.6

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area

Heavy Metals
(mg/kg)

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
DAI 0130	110	690	10	90	BDL	160	662
DAI 0160	100	870	0.1	170	BDL	220	623
DAI 0230	50	140	14	100	BDL	200	978
DAI 0260	30	60	10	400	BDL	110	527
DAI 0330	90	190	40	90	BDL	230	403
DAI 0360	100	600	15	60	BDL	180	388

Note:

DAI 0130 .... Composite of samples from Points 1 to 3 & 5 to 7 at 30 cm
DAI 0160 .... Composite of samples from Points 1 to 3 & 5 to 7 at 60 cm
DAI 0230 .... Composite of samples from Points 8 to 14 at 30 cm
DAI 0260 .... Composite of samples from Points 8 to 14 at 60 cm
DAI 0330 .... Composite of samples from Points 15 to 17 at 30 cm
DAI 0360 .... Composite of samples from Points 15 to 17 at 60 cm
BDL .... Below detection limit

TABLE 5.7

Characteristics of Soil Samples at EITL, Bhopal - Disposal Area I

Inorganics

Sample ID No.	pH	EC	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	CEC
		mS/cm	meq/L								meq/100g
DAI 0130	7.0	6.01	0.00	3.60	9.72	26.00	42.80	4.80	2.80	0.82	33.20
DAI 0160	7.6	4.85	0.00	4.40	3.08	28.60	31.60	4.80	2.80	0.24	38.75
DAI 0230	7.0	4.06	0.00	3.40	3.12	28.60	24.00	5.20	3.20	0.56	42.00
DAI 0260	7.0	6.26	0.00	5.20	17.60	28.60	36.80	5.60	7.80	0.44	48.00
DAI 0330	7.0	6.62	0.00	2.60	22.80	22.40	40.80	7.60	2.60	0.52	47.00
DAI 0360	6.8	6.81	0.00	4.40	7.20	32.30	35.20	1.20	2.60	0.18	48.75

Note:

DAI 0130 .... Composite of samples from Points 1 to 3 & 5 to 7 at 30 cm
DAI 0160 .... Composite of samples from Points 1 to 3 & 5 to 7 at 60 cm
DAI 0230 .... Composite of samples from Points 8 to 14 at 30 cm
DAI 0260 .... Composite of samples from Points 8 to 14 at 60 cm
DAI 0330 .... Composite of samples from Points 15 to 17 at 30 cm
DAI 0360 .... Composite of samples from Points 15 to 17 at 60 cm

TABLE 5.8

Physical Characteristics Of Soils At EIIL, Bhopal - Disposal Area I

Sample No.	Soil Depth	Apparent Density	WHC	Pore Space	Particle Size Distribution				Text. Class	Hydraulic Conductivity
					Coarse Sand	Fine Sand	Silt	Clay		
	cm	(g/cc)	(%)	(%)	(%)	(%)	(%)	(%)		(cm/hr)
F1	0 - 30	1.34	42.8	45.19	21.4	11.6	22.4	42.8	Clay	0.65
	30 - 60	1.40	41.26	42.2	9.8	25.0	21.2	42.2	Clay	0.56
F3	0 - 30	1.38	39.47	42.22	18.6	12.2	23.8	43.6	Clay	0.64
	30 - 60	1.42	41.21	44.62	11.0	18.6	24.6	44.0	Clay	0.58
F6	0 - 30	1.42	40.62	45.21	20.6	11.8	22.5	43.3	Clay	0.56
	30 - 60	1.38	41.26	42.4	10.8	20.6	23.5	43.1	Clay	0.62
F8	0 - 30	1.36	41.21	44.78	22.1	12.1	21.2	43.6	Clay	0.61
	30 - 60	1.40	40.65	43.67	11.2	20.8	23.8	43.2	Clay	0.64
F11	0 - 30	1.38	41.45	44.32	22.4	12.4	21.6	42.4	Clay	0.65
	30 - 60	1.41	40.88	44.45	22.5	12.8	20.5	42.5	Clay	0.66
F13	0 - 30	1.38	41.23	44.25	22.3	12.5	21.2	42.5	Clay	0.59
	30 - 40	1.37	40.92	44.36	22.5	12.7	20.8	42.5	Clay	0.64
F16	0 - 30	1.42	41.43	43.98	22.4	12.6	21.3	42.6	Clay	0.67
	30 - 60	1.38	41.36	44.02	22.6	12.4	21.4	42.5	Clay	0.56

TABLE 5.9

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area II

Semivolatiles
(mg/kg)

Sample ID No.	Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
DAII 0130	7218.30	92.34	711.00	1.37	ND
DAII 0160	3600.00	36.90	1194.60	ND	ND
DAII 0230	232.53	30.3	45.54	1.18	ND
DAII 0260	38.53	BDL	BDL	ND	ND
DAII 0330	9.45	5.81	ND	0.22	ND
DAII 0360	ND	ND	BDL	0.94	--
DAII 0430	96.45	5.81	19.83	2.80	ND
DAII 0460	23.5	7.659	51.75	1.12	--
DAII 0530	48.78	ND	ND	1.19	--
DAII 0560	ND	ND	ND	ND	--
DAII 0630	BDL	BDL	ND	BDL	--
DAII 0730*	BDL	ND	ND	BDL	--
DAII 0830*	BDL	ND	ND	BDL	--
DAII 0930*	ND	ND	ND	BDL	--
DAII 1030*	ND	ND	ND	ND	--
DAII 1130*	BDL	ND	ND	ND	--
DAII 1230*	BDL	ND	ND	ND	--
DAII 1330*	BDL	ND	ND	ND	ND
DAII 1430*	ND	ND	BDL	ND	--

Contd ...

Sample ID No.	Sevin	Temik	Alpha-Naphthol	Lindane	Naphthalen
DAII 1530	ND	ND	71.70	0.52	ND
DAII 1560	ND	ND	ND	0.10	ND
DAII 1630	234.54	ND	ND	ND	ND
DAII 1660	ND	ND	ND	ND	--
DAII 1730	ND	ND	ND	1.40	--
DAII 1760	ND	ND	ND	ND	--
DAII 1830	296.28	9.4	54.00	0.88	--
DAII 1860	397.11	ND	45.78	BDL	ND
DAII 1930	ND	ND	ND	1.50	--
DAII 1960	ND	ND	ND	ND	--
DAII 2030	ND	ND	BDL	0.34	--
DAII 2060	1.92	ND	ND	ND	--
DAII 2130*	ND	ND	BDL	BDL	--
DAII 2230*	BDL	ND	ND	ND	ND
DAII 2315A	9.25	7.38	BDL	ND	ND
DAII 2430*	3.01	ND	BDL	ND	ND
DAII 2530*	12.1	ND	BDL	ND	--
DAII 2630	8.04	BDL	BDL	ND	--
DAII 2660	6.87	BDL	BDL	ND	--
DAII 2730*	86.1	BDL	BDL	ND	ND
DAII 2760	10.65	BDL	BDL	ND	ND

'A' : Sample at DAII 23 could be collected only upto 15 cm waste material storage was located at 15 cm depth

Contd .

Sample ID No.	Sevin	Temik	Alpha - Naphthol	Lindane	Naphthalene
DAII 2830*	BDL	ND	BDL	ND	ND
DAII 2930	6.54	ND	BDL	BDL	ND
DAII 2960	2.56	ND	BDL	ND	--
DAII 3030*	ND	ND	ND	ND	--
DAII 3130	156.4	6.28	76.28	ND	ND
DAII 3160	58.7	BDL	15.32	ND	ND
DAII 3230	65.82	BDL	11.46	ND	ND
DAII 3260	14.78	BDL	BDL	ND	--
DAII 3330*	ND	ND	BDL	ND	--
DAII 3430	126.64	6.28	42.40	BDL	ND
DAII 3460	52.32	0.48	21.68	ND	ND
DAII 3530	68.68	BDL	60.68	BDL	ND
DAII 3560	18.86	BDL	52.76	BDL	ND
DAII 3630	96.82	28.28	36.38	BDL	ND
DAII 3660	26.58	9.44	18.16	BDL	ND

NOTE :

Initially samples were analysed for 30 cm and 60 cm. Since the values were found to be less, samples collected at 30 cm and 60 cm were composited and analysed. The results for such composited samples are presented with astrix. However whenever the composited samples gave higher values, samples were analysed separately for 30 and 60 cms.

Detection Limits (mg/kg) :

Sevin	....	1	Temik	....	5
Alpha napthol	....	10	Lindane	....	0.1
Napthalene	....	10			

TABEL 5.10

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area II

Semivolatiles (mg/kg)

Sample ID No.			Sevin	Temik	Alpha - Naphthol	Lindane
DAII	01	30	6814	78	624	1.5
	01	60	2740	26	274	BDL
	01	90	120	BDL	16	BDL
	01	120	36	BDL	BDL	BDL
DAII	18	30	265	8	52	0.9
	18	60	424.6	BDL	62	BDL
	18	90	BDL	BDL	BDL	BDL
	18	120	BDL	BDL	BDL	BDL

Note

BDL .... Below Detection Limit

ND .... Not Detected

Naphthalene was recorded as BDL in composite samples and hence i was not analyzed subsequently

TABLE 5.11

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area II

Volatiles
(mg/kg)

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
DAII 0130	ND	BDL	ND	ND	ND	ND	ND	ND
DAII 0160	ND	ND	ND	ND	ND	ND	ND	ND
DAII 0230	ND	ND	ND	ND	--	--	ND	--
DAII 0260	ND	ND	ND	ND	--	--	ND	--
DAII 0330	ND	ND	ND	ND	--	--	ND	--
DAII 0360	ND	ND	ND	ND	ND	ND	ND	ND
DAII 0430	ND	ND	ND	ND	ND	ND	ND	ND
DAII 0460	ND	ND	ND	ND	--	--	ND	--
DAII 0530	ND	ND	ND	ND	ND	ND	ND	ND
DAII 0560	ND	ND	ND	ND	--	--	ND	--
DAII 0630	ND	ND	ND	ND	--	--	ND	--
DAII 0660	ND	ND	ND	ND	--	--	ND	--
DAII 0730	ND	ND	ND	ND	--	--	ND	--
DAII 0760	ND	ND	ND	ND	--	--	ND	--
DAII 0830	ND	ND	ND	ND	--	--	ND	--
DAII 0860	ND	ND	ND	ND	ND	ND	ND	ND
DAII 0930	ND	BDL	ND	ND	--	--	ND	--
DAII 0960	ND	BDL	ND	ND	--	--	ND	--

contd...

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TM
DAII 1030	ND	ND	ND	ND	ND	ND	ND	ND
DAII 1060	ND	BDL	ND	ND	--	--	ND	--
DAII 1130	ND	ND	ND	ND	--	--	ND	--
DAII 1160	ND	BDL	ND	BDL	--	--	ND	--
DAII 1230	ND	ND	ND	ND	--	--	ND	--
DAII 1260	ND	BDL	ND	ND	--	--	ND	--
DAII 1330	ND	ND	ND	ND	--	--	ND	--
DAII 1360	ND	ND	ND	ND	--	--	ND	--
DAII 1430	ND	ND	ND	ND	ND	ND	ND	ND
DAII 1460	ND	BDL	ND	BDL	ND	ND	ND	ND
DAII 1530	ND	ND	ND	ND	--	--	ND	--
DAII 1560	ND	ND	ND	ND	--	--	ND	--
DAII 1630	ND	ND	ND	ND	--	--	ND	--
DAII 1660	ND	ND	ND	ND	--	--	ND	--
DAII 1730	ND	ND	ND	ND	--	--	ND	--
DAII 1760	ND	ND	ND	ND	--	--	ND	--
DAII 1830	ND	BDL	ND	ND	ND	ND	ND	ND
DAII 1860	ND	ND	ND	ND	ND	ND	ND	ND
DAII 1930	ND	ND	ND	ND	--	--	ND	--
DAII 1960	ND	ND	ND	ND	--	--	ND	--
DAII 2030	ND	ND	ND	ND	--	--	ND	--
DAII 2060	ND	ND	ND	ND	--	--	ND	--

Contd

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
DAII 2130	ND	ND	ND	ND	--	--	ND	--
DAII 2160	ND	BDL	ND	ND	ND	ND	ND	ND
DAII 2230	ND	ND	ND	ND	--	--	ND	--
DAII 2260	ND	BDL	ND	BDL	--	--	ND	--
DAII 2315	ND	ND	ND	ND	--	--	ND	--
DAII 2430	ND	ND	ND	ND	--	--	ND	--
DAII 2460	ND	BDL	ND	ND	--	--	ND	--
DAII 2530	ND	ND	ND	ND	--	--	ND	--
DAII 2560	BDL	BDL	ND	BDL	--	--	ND	--
DAII 2630	ND	ND	ND	ND	ND	ND	ND	ND
DAII 2660	ND	BDL	ND	ND	ND	ND	ND	ND
DAII 2730	ND	ND	ND	ND	--	--	ND	--
DAII 2760	ND	BDL	ND	BDL	--	--	ND	--
DAII 2830	ND	ND	ND	ND	--	--	ND	--
DAII 2860	ND	BDL	ND	BDL	--	--	ND	--
DAII 2930	ND	ND	ND	ND	--	--	ND	--
DAII 2960	BDL	BDL	ND	BDL	--	--	ND	--
DAII 3030	ND	ND	ND	ND	--	--	ND	--
DAII 3060	ND	BDL	ND	ND	--	--	ND	--
DAII 3130	ND	ND	ND	ND	--	--	ND	--
DAII 3160	ND	BDL	ND	ND	--	--	ND	--

Contd ...

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
DAII 3230	ND	ND	ND	ND	--	--	ND	--
DAII 3260	ND	BDL	ND	ND	--	--	ND	--
DAII 3330	BDL	BDL	ND	ND	ND	ND	ND	ND
DAII 3360	ND	ND	ND	ND	ND	ND	ND	ND
DAII 3430	ND	ND	ND	ND	--	--	ND	--
DAII 3460	BDL	BDL	ND	BDL	--	--	ND	--
DAII 3530	ND	ND	ND	ND	--	--	ND	--
DAII 3560	ND	BDL	ND	ND	--	--	ND	--
DAII 3630	ND	ND	ND	ND	--	--	ND	--
DAII 3660	ND	BDL	ND	BDL	--	--	ND	--

Detection Limits (mg/kg)

Chloroform	 50	Formaldehyde	....
Methylene Chloride	 20	1-2- Dichlorobenzene	 400
Toluene	 40	Monomethylamine	....
Carbontetra Chloride	 100		

TABLE 5.12

Characteristics of Soil Samples at EIIL - Disposal Area II

Heavy Metals
(mg/kg)

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
DAII 0130	70	100	17	100	BDL	300	182
DAII 0530	20	30	5	30	BDL	80	113
DAII 0560	20	30	4	20	BDL	60	132
DAII 0730	65	62	2	97	BDL	48	146
DAII 0760	38	47	6	80	BDL	2	127
DAII 1130	78	78	34	102	BDL	62	144
DAII 1160	24	38	4	64	BDL	3	118
DAII 1530	48	25	13	106	BDL	68	124
DAII 1560	40	21	15	89	BDL	49	118
DAII 1830	160	10	14	80	BDL	300	170
DAII 1860	30	70	8	40	BDL	110	81
DAII 2315	58	52	26	85	BDL	156	64
DAII 2430	56	46	17	83	BDL	48	104
DAII 2460	38	48	13	78	BDL	70	112
DAII 2530	39	23	15	11	BDL	46	114
DAII 2560	37	32	16	87	BDL	51	94

contd...

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
DAII 2630	42	38	120	86	BDL	62	116
DAII 2660	28	32	80	42	BDL	46	90
DAII 2830	38	28	100	68	BDL	54	124
DAII 2860	28	19	60	34	BDL	38	72
DAII 3030	40	50	17	40	BDL	160	150
DAII 3060	40	80	17	60	BDL	150	198
DAII 3130	40	70	20	60	BDL	150	217
DAII 3160	40	70	10	60	BDL	160	168
DAII 3430	50	140	20	70	BDL	210	184
DAII 3460	40	80	13	60	BDL	150	106
DAII 3630	50	60	15	60	BDL	140	231
DAII 3660	40	60	17	60	BDL	150	158

TABLE 5.13

Characteristics of Soil Samples at EIIL, Bhopal - Disposal Area II

Inorganics

Sample ID No.	pH	EC	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	CEC
		mS/cm	meq/L								meq/100g
DAII 0130	7.3	1.59	0.80	2.80	0.52	7.30	10.00	0.40	0.62	0.10	45.00
DAII 0160	7.0	1.20	0.90	2.65	0.85	4.65	9.85	0.45	0.66	0.10	45.50
DAII 0430	7.0	0.80	1.20	2.00	1.00	2.08	0.40	2.00	1.92	0.03	47.00
DAII 0460	7.0	0.97	1.20	2.90	1.36	3.33	2.00	0.40	3.50	0.05	47.00
DAII 0730	7.2	1.67	0.00	50.41	2.20	4.70	11.00	5.00	1.90	0.61	47.25
DAII 0760	7.9	0.43	1.60	9.20	0.88	0.52	1.60	0.00	0.33	0.05	46.50
DAII 1130	7.6	1.58	1.46	3.40	1.45	3.36	2.08	0.42	3.68	0.05	46.68
DAII 1160	7.7	0.48	1.28	2.86	0.98	2.24	0.48	0.34	2.88	0.04	45.86
DAII 1530	7.7	0.42	3.20	7.60	0.40	0.62	0.80	0.40	0.55	0.05	45.50
DAII 1560	8.0	0.36	0.80	8.80	0.24	0.52	1.20	2.80	0.80	0.11	46.25
DAII 1830	7.1	0.97	0.00	3.60	2.60	4.79	2.00	0.00	0.37	0.09	43.25
DAII 1860	7.4	0.66	0.00	3.60	2.60	3.90	0.00	0.00	0.56	0.07	46.00
DAII 2315	7.4	1.25	0.00	36.0	1.20	1.56	5.60	4.00	2.20	0.34	46.25
DAII 2430	7.4	1.57	0.00	40.80	3.60	7.30	4.00	0.00	1.20	0.26	45.00
DAII 2460	7.9	0.29	0.00	42.80	0.40	3.64	2.00	0.00	0.46	0.03	47.75
DAII 2530	7.8	0.39	0.00	9.60	0.48	2.08	0.00	3.20	0.64	0.04	46.75
DAII 2560	7.7	0.43	4.00	6.80	0.40	2.60	2.00	0.80	0.52	0.05	46.50

contd...

Sample ID No.	pH	EC	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	CEC
		mS/cm	meq/L								meq/1
DAII 2630	7.5	0.54	1.18	4.80	3.86	0.32	1.32	1.82	0.36	0.15	46.50
DAII 2660	7.4	0.52	1.20	4.76	3.26	0.28	1.24	1.70	0.35	0.14	46.20
DAII 2830	7.6	0.62	1.45	4.86	3.56	0.32	1.46	1.98	0.42	0.20	46.62
DAII 2860	7.5	0.56	1.56	4.64	3.48	0.18	1.18	1.14	0.30	0.16	46.20
DAII 3030	7.4	0.54	1.20	4.60	3.40	0.21	1.20	1.60	0.33	0.11	45.50
DAII 3060	7.4	0.5	0.80	4.20	3.08	0.52	0.80	2.00	0.95	0.11	47.50
DAII 3130	7.2	0.51	0.00	5.60	4.20	0.52	2.40	0.00	0.55	0.07	47.50
DAII 3160	7.4	0.35	0.00	4.20	3.08	0.31	0.80	0.00	0.59	0.06	48.50
DAII 3430	7.3	0.91	0.00	6.60	5.00	2.81	6.00	0.00	0.62	0.15	47.50
DAII 3460	7.3	0.90	1.20	5.0	3.72	3.33	4.80	1.60	0.65	0.17	47.50
DAII 3630	7.4	0.45	0.00	6.60	5.00	0.52	1.60	2.00	0.36	0.07	47.50
DAII 3660	6.9	0.60	0.00	6.00	4.52	2.40	2.80	10.00	0.67	0.13	45.50

TABLE 5.14

Physical Characteristics Of Soils At EIIL Premises - Disposal Area II

Sample No.	Soil Depth	Apparent Density	WHC	Pore Space	Particle Size Distribution				Textural Class	Hydraulic Conductivity
					Course Sand	Fine Sand	Silt	Clay		
	cm	(g/cc)	(%)	(%)	(%)	(%)	(%)	(%)		(cm/hr)
DAII 01	0 - 30	1.38	42.6	47.8	14.5	15.8	24.8	43.1	Clay	0.72
	30 - 60	1.41	40.65	43.5	12.8	20.4	26.2	38.9	Clay	0.68
DAII 12	0 - 30	1.41	41.08	48.99	14.8	14.6	22.8	46.6	Clay	0.44
	30 - 60	1.34	43.26	45.37	8.4	23.2	24.2	42.8	Clay	0.57
DAII 13	0 - 30	1.30	40.15	48.99	20.4	15.2	20.6	42.2	Clay	0.91
	30 - 60	1.31	41.1	47.26	6.8	21.6	26.4	45.6	Clay	0.47
DAII 14	0 - 30	1.45	32.71	48.28	19.2	14.8	22.0	42.2	Clay	0.73
	30 - 60	1.41	39.48	46.48	13.6	20.2	22.2	42.4	Clay	0.67
DAII 15	0 - 30	1.31	40.21	48.23	11.6	20.6	21.8	44.2	Clay	0.44
	30 - 60	1.41	42.32	46.47	9.8	22.6	22.6	44.4	Clay	0.50
DAII 16	0 - 30	1.36	36.64	44.75	15.4	18.4	22.2	42.2	Clay	0.50
	30 - 60	1.41	40.21	42.28	11.4	22.6	21.6	42.6	Clay	0.54
DAII 40	0 - 30	1.31	46.92	31.88	19.8	14.2	21.8	42.4	Clay	0.52
	30 - 60	1.34	46.84	42.28	10.4	23.6	21.6	42.6	Clay	0.54
DAII 42	0 - 30	1.34	42.8	42.28	21.6	12.2	21.6	42.8	Clay	0.56
	30 - 60	1.42	40.6	42.6	13.0	20.6	21.8	42.8	Clay	0.54
DAII 47	0 - 30	1.42	39.66	47.52	19.2	15.4	21.2	42.4	Clay	0.66
	30 - 60	1.38	42.4	48.34	10.2	22.8	22.4	42.8	Clay	0.58

Detection Limits (mg/kg) :

Sevin	.... 1.0	Temik	.... 5.0
Alpha napthol	.... 10.0	Lindane	.... 0.1
Napthalene	.... 10.0		

TABLE 5.15

Compositing Of Soil Samples In Rest Of The Area, EIIL, BHOPAL For Analyis

Sample No. for Analysis	Sample Location No.
Inside the Facility Premises	
RA-1	G 1 To G 5
RA-2	G 6 To G 10
RA-3	G 11 To G 14
RA-4	G 15 To G 18
RA-5	G 19 To G 23
RA-6	G 24 To G 30
RA-7	G 32 To G 35
RA-8	G 36 To G 39
RA-9	G 44 To G 47
RA-10	G 48 To G 50
RA-11	G 54 To G 58
RA-12	G 59 To G 62
RA-13	G 40, G 51 & G 63
RA-14	G 31, G 43, & G 53
RA-15	G 41, G 52 & G 64
RA-16	G 42
RA-17	G 65 To G 68
RA-18	G 69 To G 72
RA-19	G 73 To G 76
RA-20	G 77 To G 79
RA-21	G 80 To G 82
RA-22	G 83 To G 86
RA-23	G 87 To G 90
RA-24	G 91 To G 93
RA-25	G 94 To G 97
Outside the Facility Premises	
RA-26	G 98
RA-27	G 99
RA-28	G 100
RA-29	G 101

Note : Samples collected within facility premises have been composited while samples collected outside the facility premises have not been composited

TABLE 5.16

Characteristics of Soil Samples at EIIL, Bhopal
- Rest of the area
Semi Volatiles (mg/kg)

Samples	Sevin	Temik	Alpha Naphthol	Lindane	Napthalene
RA-1	BDL	ND	ND	ND	ND
RA-2	BDL	ND	ND	ND	ND
RA-3	BDL	ND	ND	ND	ND
RA-4	ND	ND	ND	ND	ND
RA-5	BDL	BDL	BDL	ND	ND
RA-6	ND	BDL	ND	ND	ND
RA-7	ND	ND	ND	ND	ND
RA-8	ND	ND	BDL	ND	ND
RA-9	BDL	ND	ND	ND	ND
RA-10	BDL	ND	ND	ND	ND
RA-11	BDL	ND	ND	ND	ND
RA-12	BDL	5.49	ND	ND	ND
RA-13	ND	ND	ND	ND	ND
RA-14	ND	ND	ND	ND	ND
RA-15	ND	ND	ND	ND	ND
RA-16	ND	BDL	ND	ND	ND
RA-17	BDL	16.24	BDL	ND	ND
RA-18	8.65	7.73	BDL	ND	ND
RA-19	BDL	5.22	BDL	ND	ND
RA-20	2.416	BDL	BDL	ND	ND
RA-21	5.236	BDL	BDL	ND	ND
RA-22	ND	ND	ND	ND	ND
RA-23	BDL	51.64	BDL	ND	ND
RA-24	BDL	5.86	BDL	ND	ND
RA-25	BDL	ND	ND	ND	ND
RA-26	BDL	BDL	ND	ND	ND
RA-27	ND	BDL	ND	ND	ND
RA-28	BDL	20.03	ND	ND	ND
RA-29	BDL	6.381	ND	ND	ND

Temik at the individual samples at RA 23

Station No	Temik mg/kg
87	102.40
88	78.36
89	28.46
90	10.56

Detection Limits (mg/kg) :

Sevin 1.0
Alpha napthol 10.0
Napthalene 10.0
Temik 5.0
Lindane 0.1

TABLE 5.17

Characteristics of Soil Samples at ETIL, Bhopal
Rest of the area - Volatile Organics (mg/kg)

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
RA-1	ND	ND	ND	ND	ND	ND	ND	ND
RA-2	ND	ND	ND	ND	ND	ND	ND	ND
RA-3	ND	ND	ND	ND	ND	ND	ND	ND
RA-4	ND	ND	ND	ND	ND	ND	ND	ND
RA-5	ND	ND	ND	ND	ND	ND	ND	ND
RA-6	ND	ND	ND	ND	ND	ND	ND	ND
RA-7	ND	ND	ND	ND	ND	ND	ND	ND
RA-8	ND	ND	ND	ND	ND	ND	ND	ND
RA-9	ND	ND	ND	ND	ND	ND	ND	ND
RA-10	ND	ND	ND	ND	ND	ND	ND	ND
RA-11	ND	ND	ND	ND	ND	ND	ND	ND
RA-12	ND	ND	ND	ND	ND	ND	ND	ND
RA-13	ND	ND	ND	ND	ND	ND	ND	ND
RA-14	ND	ND	ND	ND	ND	ND	ND	ND
RA-15	ND	ND	ND	ND	ND	ND	ND	ND
RA-16	ND	ND	ND	ND	ND	ND	ND	ND
RA-17	ND	ND	ND	ND	ND	ND	ND	ND
RA-18	ND	ND	ND	ND	ND	ND	ND	ND
RA-19	ND	ND	ND	ND	ND	ND	ND	ND
RA-20	ND	ND	ND	ND	ND	ND	ND	ND
RA-21	ND	ND	ND	ND	ND	ND	ND	ND
RA-22	ND	ND	ND	ND	ND	ND	ND	ND
RA-23	ND	ND	ND	ND	ND	ND	ND	ND
RA-24	ND	ND	ND	ND	ND	ND	ND	ND
RA-25	ND	ND	ND	ND	ND	ND	ND	ND
RA-26	ND	ND	ND	ND	ND	ND	ND	ND
RA-27	ND	ND	ND	ND	ND	ND	ND	ND
RA-28	ND	ND	ND	ND	ND	ND	ND	ND
RA-29	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 5.18

Characteristics of Soil Samples at EIIL, Bhopal - Rest of Area Inorganics

Sample ID No.	pH	EC	CO_3	HCO_3	Cl^-	SO_4	Ca^+	Mg^+	Na^+	K^+	CEC
		mS/cm	meq/L								meq/100g
RA 01	6.5	0.44	0.0	2.8	0.0	0.63	1.55	0.25	0.59	0.24	45.2
RA 02	6.7	0.50	0.0	2.4	0.2	0.72	1.55	0.65	0.72	0.10	44.6
RA 03	7.0	0.40	0.0	2.4	0.8	0.58	1.45	0.15	0.62	0.09	46.24
RA 04	7.0	2.14	0.0	16.2	1.0	0.46	3.55	0.25	53.00	3.80	45.86
RA 05	7.0	6.90	0.0	57.0	14.0	1.04	5.75	1.75	55.00	4.20	42.56
RA 06	7.0	0.69	0.0	2.8	1.6	0.86	2.25	0.55	0.75	0.11	44.65
RA 07	7.0	7.00	0.0	60.0	0.0	0.79	2.95	0.25	31.00	4.30	45.23
RA 08	7.1	0.45	0.0	2.0	0.4	0.82	2.55	0.15	0.98	0.09	43.56
RA 09	6.5	0.49	0.0	2.4	0.8	1.06	1.55	0.25	0.64	0.10	44.65
RA 10	7.2	0.33	0.0	2.0	0.2	0.64	1.35	0.55	0.55	0.04	42.46
RA 11	6.8	0.35	0.0	2.0	0.4	0.32	1.35	0.65	0.30	0.06	46.78
RA 12	6.3	0.70	0.8	4.0	0.2	0.58	3.45	0.35	0.86	0.09	42.36
RA 13	7.0	0.40	0.0	2.8	1.0	0.63	1.25	0.35	0.93	0.07	45.68
RA 14	7.1	0.42	0.0	2.4	1.2	1.08	2.15	1.05	0.41	0.07	45.74
RA 15	7.1	0.44	0.0	4.0	13.8	0.96	2.60	0.15	0.42	0.08	45.24
RA 16	6.9	0.51	0.0	2.8	1.2	0.78	1.75	0.05	0.67	0.08	42.34
RA 17	7.1	0.41	0.0	2.6	1.3	0.82	1.68	0.04	0.72	0.07	43.25
RA 18	7.2	0.48	0.0	3.1	1.4	0.68	1.54	0.06	0.68	0.06	42.54
RA 19	6.9	0.50	0.0	2.6	1.1	0.65	1.67	0.15	0.58	0.09	43.67
RA 20	7.2	0.61	0.0	3.8	0.8	0.56	1.25	0.35	0.47	0.09	44.56
RA 21	7.4	0.61	0.0	4.0	1.6	1.06	2.14	0.45	0.47	0.09	43.56
RA 22	7.3	0.62	0.0	3.1	1.4	0.68	1.85	0.55	0.77	0.10	42.56
RA 23	6.9	0.52	0.0	4.1	1.1	0.62	1.25	0.35	0.47	0.09	43.64
RA 24	7.2	0.61	0.0	3.8	1.6	1.04	1.75	0.45	0.67	0.08	42.78
RA 25	7.0	0.59	0.0	2.9	1.2	0.82	1.65	0.05	0.41	0.07	43.68
RA 26	7.1	0.64	0.0	3.4	1.6	0.67	1.67	0.05	0.67	0.07	44.42
RA 27	7.0	0.54	0.0	3.1	1.4	0.68	2.14	1.05	0.98	0.10	43.56
RA 28	6.9	0.45	0.0	2.8	1.2	0.76	1.54	0.35	0.72	0.08	46.42
RA 29	7.4	0.45	0.0	2.4	1.0	0.98	1.75	0.25	0.86	0.07	44.56

TABLE 5.19
Characteristics of Soil Samples at EIIL, Bhopal - Rest of Are[a]
Heavy Metals
(mg/kg)

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
RA 01	1	BDL	BDL	4	BDL	3	BDL
RA 02	37	18	6	5	0.1	57	323
RA 03	45	6	5	4	BDL	46	318
RA 04	51	12	7	5	BDL	62	347
RA 05	49	25	7	43	0.1	58	336
RA 06	62	32	11	47	0.3	58	268
RA 07	37	21	7	35	0.3	65	246
RA 08	68	50	8	53	BDL	63	296
RA 09	74	13	10	46	BDL	75	146
RA 10	44	1	28	39	BDL	41	186
RA 11	34	8	67	36	BDL	58	216
RA 12	33	6	74	41	0.2	44	124
RA 13	54	9	79	39	BDL	478	143
RA 14	40	17	79	50	0.1	65	114
RA 15	35	19	64	46	BDL	59	118
RA 16	43	29	54	48	BDL	59	58
RA 17	77	32	65	43	0.4	65	51
RA 18	42	29	79	44	0.1	47	41
RA 19	68	31	26	45	0.1	62	76
RA 20	76	29	12	42	BDL	209	58
RA 21	41	27	57	46	BDL	59	51
RA 22	48	62	73	38	BDL	60	52
RA 23	85	128	BDL	90	BDL	59	46
RA 24	37	59	95	37	BDL	42	43
RA 25	80	14	9	79	0.3	86	67
RA 26	44	39	5	48	BDL	62	50
RA 27	28	73	3	29	BDL	39	38
RA 28	46	59	4	52	0.4	62	112
RA 29	54	85	9	50	0.3	55	86

TABLE 5.20

Physical Characteristics Of Soil At EITI, Bhopal - Rest Of Area

Sample No.	Soil Depth cm	Apparent Density (g/cc)	WHC (%)	Pore Space (%)	Particle Size Distribution: Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Textural Class	Hydraulic Conductivity (cm/hr)
RA2	0 - 30	1.33	40.8	52.3	20.2	15.4	20.4	42.6	Clay	1.03
RA5	0 - 30	1.18	45.9	49.2	19.0	15.8	20.6	42.8	Clay	0.95
RA7	0 - 30	1.18	40.3	46.0	16.6	18.2	21.0	42.2	Clay	1.03
RA9	0 - 30	1.41	41.5	48.9	17.2	16.8	22.0	42.0	Clay	1.00
RA12	0 - 30	1.45	43.6	36.2	16.6	15.6	22.6	44.2	Clay	1.00
RA13	0 - 30	1.38	41.1	42.8	17.2	15.0	21.8	44.0	Clay	0.97
RA16	0 - 30	1.34	41.9	51.1	16.2	16.0	22.6	43.8	Clay	0.93
RA18	0 - 30	1.30	43.5	39.5	17.2	16.4	23.8	41.0	Clay	0.94
RA22	0 - 30	1.30	47.6	49.7	14.6	13.8	26.8	43.2	Clay	0.89
RA28	0 - 30	1.33	41.4	47.3	15.2	15.0	26.8	41.2	Clay	0.96
RA32	0 - 30	1.34	42.3	52.0	16.2	14.6	25.4	42.0	Clay	0.68
RA36	0 - 30	1.31	41.3	49.2	15.8	15.2	24.8	42.4	Clay	0.96
RA40	0 - 30	1.31	40.9	46.0	16.8	14.2	23.6	43.6	Clay	0.87
RA42	0 - 30	1.23	46.2	51.4	16.6	15.2	23.8	42.6	Clay	0.96
RA46	0 - 30	1.32	41.3	45.3	15.8	14.6	25.8	42.2	Clay	0.95
RA50	0 - 30	1.29	41.2	49.9	15.6	14.8	25.4	42.2	Clay	0.95
RA54	0 - 30	1.34	40.1	51.9	15.2	15.0	25.6	42.4	Clay	0.87
RA60	0 - 30	1.32	41.2	46.0	18.2	16.2	22.2	41.6	Clay	0.98
RA65	0 - 30	1.37	41.1	52.0	16.2	14.6	23.8	43.6	Clay	0.97
RA70	0 - 30	1.38	40.1	53.3	14.8	18.2	23.4	41.8	Clay	0.94
RA75	0 - 30	1.39	40.9	52.0	15.8	15.2	25.8	41.4	Clay	0.96
RA82	0 - 30	1.36	43.3	51.4	16.2	14.8	24.4	42.8	Clay	0.97
RA90	0 - 30	1.37	40.5	46.0	15.8	14.2	25.4	42.8	Clay	0.96
RA95	0 - 30	1.43	45.0	48.9	18.2	15.2	22.8	42.0	Clay	0.86
RA98	0 - 30	1.37	43.1	45.3	18.2	15.2	22.8	42.0	Clay	0.86
RA101	0 - 30	1.29	44.1	52.0	17.2	15.6	23.6	41.8	Clay	0.99

TABLE 5.21
Characteristics of Soil Samples at EIIL, Bhopal - Target Area
Semi Volatiles (mg/kg)

Sample ID.No.	Sevin	Temik	1-Naphthol	Lindane	Naphthalene
T-9	BDL	ND	ND	ND	ND
T-10	BDL	ND	ND	ND	ND
T-18	BDL	ND	BDL	ND	ND
T-18A	BDL	ND	ND	ND	ND
T-27A	BDL	ND	ND	ND	ND
T-29	3.39	ND	BDL	ND	ND
T-29A	BDL	ND	BDL	ND	ND
T-32	ND	ND	ND	ND	ND
T-32A	BDL	ND	ND	ND	ND
T-41	1226.7	ND	12.6	ND	ND
T-41A	68.6	ND	BDL	ND	ND
T-42	168.9	ND	14.8	ND	ND
T-42A	42.6	BDL	13.6	ND	ND
T-60	11	360	BDL	ND	ND
T-61	BDL	480	BDL	ND	ND
T-62	160	BDL	BDL	ND	ND
T-62A	280	ND	BDL	ND	ND
T-63	56	ND	BDL	ND	ND
T-64, 65 66	46	162	11	ND	ND

Detection Limits (mg/kg) :

Sevin	1	Temik	5
Alpha napthol	10	Lindane	0.1
Napthalene	10		

TABLE 5.22

Characteristics of Soil Samples at ETTL, Bhopal - Target Area
Volatile Organics
(mg/kg)

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TMA
T-9	ND	ND	ND	ND	ND	ND	ND	ND
T-10	ND	ND	ND	ND	ND	ND	ND	ND
T-18	ND	ND	ND	ND	ND	ND	ND	ND
T-18A	ND	ND	ND	ND	ND	ND	ND	ND
T-27A	ND	ND	ND	ND	ND	ND	ND	ND
T-29	ND	ND	ND	ND	ND	ND	ND	ND
T-29A	ND	ND	ND	ND	ND	ND	ND	ND
T-32	ND	ND	ND	ND	ND	ND	ND	ND
T-32A	ND	ND	ND	ND	ND	ND	ND	ND
T-41	ND	ND	ND	ND	ND	ND	ND	ND
T-41A	ND	ND	ND	ND	ND	ND	ND	ND
T-42	ND	ND	ND	ND	ND	ND	ND	ND
T-42A	ND	ND	ND	ND	ND	ND	ND	ND
T-60	ND	ND	ND	ND	ND	ND	ND	ND
T-61	ND	ND	ND	ND	ND	ND	ND	ND
T-62	ND	ND	ND	ND	ND	ND	ND	ND
T-62A	ND	ND	ND	ND	ND	ND	ND	ND
T-63	ND	ND	ND	ND	ND	ND	ND	ND
T-64, 65 66	ND	ND	ND	ND	ND	ND	ND	ND

Detection Limits (mg/kg)

Chloroform 50
Methylene Chloride 20
Toluene 40
Carbon tetra Chloride 100
Formaldehyde ....
1-2- Dichlorobenzene 400
Monomethylamine ....

TABLE 5.23

Characteristics of Soil Samples at EIIL - Target Area

Heavy Metals
(mg/kg)

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Plant/Sheds							
T 09	83	56	15	65	BDL	53	124
T 10	76	61	20	72	BDL	70	86
T 18	90	40	36	80	BDL	80	92
T 20	44	53	10	77	BDL	51	45
T 27	54	102	21	63	BDL	28	24
T 27A	31	33	9	63	BDL	44	51
T29	40	50	16	80	BDL	50	65
T 32	38	52	16	81	BDL	54	80
T 32A	59	79	11	71	BDL	63	36
T 41	99	32	38	14	BDL	49	216
T 43	57	52	17	80	BDL	65	54
T 64&65	60	85	12	22	BDL	30	19
Storage Tanks							
T 11	54	67	23	65	BDL	45	65
T 13	46	79	11	76	BDL	56	63
T 14	10	54	19	94	BDL	63	90
T 16	35	43	16	62	BDL	74	30
T 17	52	41	11	63	BDL	174	20
T 36,37 37A & 48	60	70	30	50	BDL	164	46
T 39	54	56	45	67	BDL	78	28
T 55	56	54	23	22	BDL	46	36

TABLE 5.24

Characteristics of Soil Samples at EIIL, Bhopal - Target Area

Inorganics

Sample ID No.	pH	EC	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K
		mS/cm	meq/L							
Plant/Sheds										
T 09	7.1	0.84	0.8	7.8	1.36	3.02	4.0	0.8	1.55	0.19
T 10	6.8	0.79	0.0	6.1	1.28	2.84	3.4	0.9	1.62	0.20
T 18	7.2	0.82	0.0	7.9	1.16	2.68	4.2	0.7	1.48	0.18
T 20	6.9	0.85	0.0	12.0	0.24	2.39	6.0	0.8	0.68	0.17
T 27	6.0	0.24	0.0	2.6	0.0	1.04	1.6	0.0	0.40	0.11
T 27A	7.0	0.65	0.8	5.4	0.24	3.64	4.0	0.8	0.82	0.15
T 29	6.9	0.71	0.0	6.2	1.32	2.80	3.9	0.7	0.78	0.21
T 32	7.3	0.27	0.8	4.4	0.04	0.26	2.0	0.0	0.31	0.04
T 32A	7.0	1.28	0.0	21.0	0.0	5.20	11.2	2.8	0.98	0.25
T 43	7.1	0.54	0.0	12.0	1.44	1.53	7.2	0.0	1.32	0.14
Storage Tanks										
T 11	7.1	0.52	0.0	4.8	0.32	0.82	2.6	1.4	2.80	0.16
T 13	6.9	0.38	0.0	4.6	0.28	0.68	2.1	1.4	2.6	0.16
T 14	8.0	0.50	1.6	3.4	0.18	0.47	0.0	0.8	3.48	0.07
T 16	9.5	1.33	0.0	130.0	0.11	0.47	0.0	0.0	21.0	0.02
T 17	4.9	0.48	1.2	4.8	0.68	1.53	2.8	0.0	1.73	0.13
T 36,37 37A & 48	6.8	0.49	0.0	4.8	0.32	0.82	2.6	1.4	2.80	0.16
T 39	7.2	0.51	0.6	5.2	0.41	0.68	1.9	1.2	3.50	0.1
T 55	6.8	0.34	0.5	4.6	0.36	0.59	1.7	1.1	2,76	0.14

TABLE 5.25

Characteristics of Soil Samples at EIIL, Bhopal - Target Area

Poly chlorinated Biphenyls (PCBs)

Sample	PCB
T-6	ND
T-8A & 8B	ND
T-12	ND
T-15	ND
T-24	ND
T-25	ND
T-26	ND
T-34	ND
T-52&53	ND
T-55	ND

TABLE 5.26

Characteristics of Soil Samples at EIIL, Bhopal -

Along Wastewater Drain
(mg/kg)

Sample	Depth (Cm)	Cl	Cu	Cr	Pb	Ni	Cd	Zn	Mn
D1	90	1487	24	26	6	30	BDL`	50	256
	120	1986	25	20	4	16	BDL	46	264
D2	90	2486	17	23	6	18	BDL	52	160
	120	2686	17	21	5	19	BDL	46	176
D3	90	2461	20	21	8	22	BDL	56	160
	120	2578	22	22	8	19	BDL	62	162
D4	90	2461	20	26	5	24	BDL	76	186
	120	2461	21	20	5	26	BDL	43	168
D5	90	2268	13	14	6	19	BDL	84	210
	120	2461	16	17	5	21	BDL	62	178
D6	90	987	15	20	5	27	BDL	71	176
	120	1736	18	17	7	19	BDL	71	186

Note : Semi volatiles (Sevin, Temik, Alpha Naphthol, Lindane & Naphthalene were recorded as 'Not Detected'

TABLE 5.27

Characteristics of Soil Samples at EIIL, Bhopal - Control Semi Volatiles (mg/kg)

Samples	Temik	Sevin	1-Naphthol	Lindane
C1	ND	ND	ND	ND
C2	ND	ND	ND	ND
C3	ND	ND	ND	ND

TABLE 5.28

Characteristics of Soil Samples at EIIL, Bhopal - Control Volatile Organics (mg/kg)

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride	TDA
C1	ND	ND	ND	ND	ND	ND	ND	ND
C2	ND	ND	ND	ND	ND	ND	ND	ND
C3	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 5.29

Characteristics of Soil Samples at EIIL, Bhopal - Control Inorganics

Sample ID No.	pH	EC	CO_3	HCO_3	Cl^-	SO_4	Ca^+	Mg^+	Na^+	K^+
		mS/cm	meq/L							
C1	7.2	0.464	0.0	2.4	0.4	0.92	1.35	0.65	0.68	0.070
C2	7.2	0.643	0.0	2.4	0.4	0.82	1.45	0.65	1.38	0.080
C3	7.3	1.440	0.0	2.4	12.0	0.76	4.25	3.45	26.5	0.036

TABLE 5.30
Characteristics of Soil Samples at EIIL, Bhopal - Control
Heavy Metals
(mg/kg)

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
C1	25	42	79	51	BDL	58	329
C2	26	43	96	52	BDL	58	149
C3	32	38	117	52	BDL	53	518

TABLE 5.31

Physical Characteristics Of Soil At EIIL, Bhopal - CONTROL

Sample No.	Soil Depth	Apparent Density	WHC	Pore Space	Particle Size Distribution				Textural Class	Hydraulic Conductivity
					Coarse Sand	Fine Sand	Silt	Clay		
	cm	(g/cc)	(%)	(%)	(%)	(%)	(%)	(%)		(cm/hr)
C1	0 - 30	1.34	43.45	46.35	18.2	17.8	20.8	42.2	Clay	0.98
	30 - 60	1.32	44.34	45.98	17.5	18.4	20.5	42.6	Clay	0.97
C2	0 - 30	1.33	42.86	47.82	17.9	17.2	20.7	43.0	Clay	0.86
	30 - 60	1.34	42.89	46.98	16.8	16.5	21.4	44.3	Clay	0.78
C3	0 - 30	1.34	42.68	46.98	17.6	18.2	21.5	41.7	Clay	0.89
	30 - 60	1.36	42.34	46.45	16.4	19.2	21.6	41.8	Clay	0.98

TABLE 5.32

Geoelectric Sounding Data at EIIL, Bhopal

Sounding No.	p & h	Layers I	II	III	IV	V	VI
VES - 1	p	16.4	13.4	4.9	1.1	18.7	153.0
	h	1.3	0.6	13.3	2.6	10.2	
VES - 2	p	16.5	4.7	6.9	1.5	17.5	150.0
	h	1.6	18.6	34.8	3.9	10.8	
VES - 3	p	12.4	5.1	10.8	2.8	15.6	155.0
	h	1.0	10.4	10.4	5.5	4.8	
VES - 4	p	16.5	4.7	6.6	1.0	17.3	150.0
	h	2.0	2.0	13.7	4.0	5.0	
VES - 5	p	19.2	9.9	5.1	2.1	17.3	152.0
	h	1.6	0.7	25.5	2.9	9.8	
VES - 6	p	16.6	4.9	10.0	2.4	15.8	156.0
	h	1.8	11.5	24.5	2.9	9.8	
VES - 7	p	10.5	3.5	7.9	1.3	15.0	150.0
	h	0.9	5.2	4.6	4.6	1.6	

Note :
p ... Resistivity in ohm-m
h ... Thickness in meters

TABLE 5.33

Geoelectric Investigation at EIIL, Bhopal - Litholog & VES Interpretation

From Lithologs		VES Interpretation	
Depth (m)	Formation	Depth (m)	Resistivity (Ohm-m)
		0.0 - 0.7	10.5
0.0 - 6.1	Black Cotton Soil	0.7 - 6.1	3.5
6.1 - 10.7	Hard Sandy Soil	6.1 - 10.7	7.9
10.7 - 15.3	Yellow Sandy Soil	10.7 - 15.3	1.3
15.3 - 16.9	Soft Sandstone	15.3 - 16.9	15.0
> 16.9	Hard Sandstone	> 16.9	150.0

TABLE 5.34

Geoelectric Investigation at EIIL, Bhopal - Profilling Details

Traverse No.	Length of Profile (m)	Orientation
A	360	N 10° W
B	170	N 80° W
C	200	N 7° E
D	470	N 80° W
E	160	N 76° W
F	250	N 75° W
G	200	N 82° W
H	430	N 42° W
I	170	N 81° W
J	120	E - W
K	130	N 45° E

6.0 Groundwater Quality

6.1 Results and Discussion

The data are presented in Tables 6.1 to 6.4. It can be seen from Tables 6.1 and 6.2 showing semi volatiles and volatiles that these compounds were not detected in any wells. This indicated that the wells have not been impacted due to past disposal activities of EIIL till the studies were completed. This could probably due to longer travel time required for a pollutant to travel from the source to the wells. The ground water flow direction is towards northeast and Well Nos. 1, 2 & 3 are in the ground flow direction. These three wells and Well Nos. 4 to 7 are within 500 m from the Disposal Area II, the major disposal site at EIIL. This could partly attributed to the presence of clayey soils with a very low permeability (about x 10^{-6} cm/sec). The other parameters presented in Tables 6.3 and 6.4 on heavy metals and other cations and anions also did not show any traces of contamination. Even the monitoring well (Well A) located near Disposal Area II also did not show any sign of contamination. The ground water appears to be suitable for drinking purpose.

NEERI has assessed the ground water quality near EIIL in 1990 and 1992. The data generated during the earlier studies and the present studies are comparable.

TABLE 6.1

Semi Volatiles in Ground Water

Sl.No.	Sevin	Temik	Alpha Naphthol	Lindane	Naphthalene
Production Wells - Outside EIIL					
1	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND
7	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND
9	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND
12	ND	ND	ND	ND	ND
13	ND	ND	ND	ND	ND
14	ND	ND	ND	ND	ND
Production Wells - EIIL Premises					
15	ND	ND	ND	ND	ND
16	ND	ND	ND	ND	ND
Monitoring Wells - EIIL Premises					
A	ND	ND	ND	ND	ND

All values expressed in ug/L

Detection Limits (ug/L)

Sevin	 200	Alpha naphthol	... 300
Temik	 50	Lindane	... 0.004

TABLE 6.2

Organics in Ground Water

Sample ID No.	Chloroform	Methylene Chloride	1-2- Di chlorobenzene	Toluene	Formaldehyde	Mono methylamine	Carbontetra Chloride
Production Well - Outside EIIL							
1	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND	ND	ND
7	ND	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND	ND	ND
9	ND	ND	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	ND	ND
12	ND	ND	ND	ND	ND	ND	ND
13	ND	ND	ND	ND	ND	ND	ND
14	ND	ND	ND	ND	ND	ND	ND
Production Wells - EIIL Premises							
15	ND	ND	ND	ND	ND	ND	ND
16	ND	ND	ND	ND	ND	ND	ND
Monitoring Wells - EIIL Premises							
A	ND	ND	ND	ND	ND	ND	ND

Detection Limits (mg/L)

Chloroform	.... 0.05	Formaldehyde	 1000
Methylene Chloride	.... 0.25	1-2- Dichlorobenzene	.... 0.15
Toluene	.... 0.20	Monomethylamine	 1000
Carbontetra Chloride	.... 0.12	TMA	 1000

TABLE 6.3

Physico-chemical Characteristics of Ground Water

Sl. No.	pH	EC micro siemens	Hardness as $CaCO_3$		Na	K	Cl	SO_4	C
			Total	Ca					
Production Wells - Outside EIIL Premises									
1.	7.4	1194	604	336	124	2.1	270	45	23
2.	7.1	860	314	232	162	1.4	104	19	17
3.	7.1	812	402	256	85	2.1	122	27	17
4.	7.0	1192	635	488	95	6.2	244	130	31
5.	7.0	1279	714	468	84	1.4	300	113	24
6.	6.9	1260	526	516	104	12.4	266	126	<10
7.	7.0	1400	678	496	107	1.8	372	66	39
8.	6.8	1052	644	408	73	5.6	188	85	30
9.	6.7	1585	1008	536	119	1.6	528	47	27
10.	7.1	838	348	156	182	1.6	54	24	40
11.	7.0	1390	640	372	189	1.9	376	16	42
12.	6.7	1150	648	268	187	1.4	250	19	12
13.	6.7	946	532	288	87	5.2	204	36	27
14.	7.0	1186	776	3765	90.5	1.5	270	34	18
Production Well - EIIL Premises									
15.	7.2	860	402	186	189	1.8	124	34	27
16.	7.0	878	526	256	204	2.1	154	45	40
Monitoring Wells - EIIL Premises									
A	7.1	848	358	162	187	1.5	54	24	24

All values are expressed in mg/l except EC (us/cm)

TABLE 6.4
Heavy Metals in Ground Water
(mg/L)

S.No.	Fe	Zn	Pb	Mn	Cr	Cd	Ni	Cu
Production wells - Outside EIIL								
1	9.17	0.01	BDL	0.08	BDL	BDL	BDL	BDL
2	0.28	0.01	0.03	0.02	0.01	BDL	BDL	BDL
3	0.11	0.20	0.01	0.01	BDL	BDL	BDL	0.04
4	0.28	0.01	0.03	BDL	BDL	BDL	0.04	BDL
5	4.03	1.29	0.01	0.14	BDL	BDL	BDL	0.10
6	0.76	0.06	0.09	0.04	BDL	BDL	BDL	0.02
7	3.00	0.12	0.06	0.06	BDL	BDL	0.03	0.04
8	0.14	0.02	0.06	0.03	BDL	BDL	BDL	BDL
9	0.30	1.20	BDL	0.04	BDL	BDL	BDL	BDL
10	0.23	0.03	0.06	0.05	0.03	BDL	BDL	BDL
11	0.16	0.44	0.06	0.07	0.02	BDL	BDL	0.02
12	0.48	0.11	BDL	0.05	BDL	BDL	BDL	BDL
13	1.76	1.74	0.05	0.02	0.04	BDL	BDL	0.05
14	0.53	1.87	0.05	0.07	BDL	BDL	0.01	BDL
Production Wells - EIIL Premises								
15	0.45	0.65	0.07	0.04	0.01	0.02	BDL	BDL
16	0.48	0.13	BDL	0.06	0.03	BDL	BDL	BDL
Monitoring Wells - EIIL Premises								
A	0.33	0.83	0.06	0.07	0.02	BDL	BDL	0.04

All values are expressed in mg/L

7.0 QUALITY CONTROL PROGRAMME

7.1 Introduction

In this study at EIIL, Bhopal, samples collected include dump materials, soil and ground water. These samples were subjected to specific analytical procedures depending on the type of analyte. The final decision of declaring the area as contaminated or uncontaminated and subsequent action on remediation depends on the data generated during the study. It is essential to establish quality assurance of the analyses by adopting a well defined Quality Control (QC) programme. The quality of analytical data generated by the laboratory was monitored by QC samples. The QC samples were used to evaluate measurement system control and the effect of matrix on the data generated (1).

In this study, QC programme was broadly divided into two major topics viz.,

* Field samples
* Analytical samples

7.2.1 Field QC Samples

Field Duplicate Samples

During field sampling, additional samples were collected at selected intervals to represent Field Duplicate Samples. In this, independent soil samples were collected as close as possible to the same point in space and time and which are intended to be identical. In case of dump materials, samples were divided into two portions including one for QC programme.

Trip Blank

A sample of analyte-free media was taken from the laboratory to the sampling site and returned to the laboratory unopened. This was adopted to document any contamination during transportation to Nagpur from Bhopal. This was used for volatile organics as the contamination can occur mainly due to volatile organic compounds.

Equipment Blank

All sampling equipments were washed, rinsed, and dried after sampling each site and before using in the next site. This was adopted to prevent any cross contamination transported to the next site from the previous site through the samplers and equipment. All equipments were rinsed with water. The water was collected after completion of decontamination and prior to sampling. This was carried out at random.

Back Ground Samples

Three soil samples were collected from three sites about 500 m away from EIIL to represent background level. This data also represents baseline data for the area under investigation.

7.2.2 Laboratory QC Samples

Reagent Blank (Method Blank)

An analyte-free media (Reagent Water) to which all reagents were added in the same volume. This method was carried out through the entire sample preparation and analysis procedure and is used to document contamination resulting from the analytical process. This was adopted for each batch of samples processed.

Analytical Duplicate Sample

Two aliquots of sample were taken from the same sample container after sample homogenization and intended to be identical. Duplicates were analyzed independently and were used to assess the precision of the analytical process. Duplicates were used to assess precision when there is a high likelihood that the sample contains the analyte of interest.

Matrix Spike

An aliquot of sample (natural matrix) spiked with known concentration of target analyte(s) is known as matrix spike. A matrix spike is used to document the affect of the matrix on the accuracy of the method, when compared to an aliquot of the unspiked sample. Matrix spike samples were analyzed independently and were used to assess the effect of the matrix on the precision of the analytical process.

Table 7.1 summarizes the number of samples collected /analyzed for various QC samples.

7.3 Relative Percent Difference

The data generated from the duplicate sample analyses were subjected to interpretation using Relative Percent Difference (RPD) as guiding criteria. RPD is a measure of analytical precision of the laboratory procedures (2). RPD is the relative percent difference between the actual (original) concentration and the duplicate sample (QC sample). It is calculated by the following equation (3):

$$RPD = 2 \times \frac{(A - B)}{(A + B)} \times 100$$

where A and B are the original and duplicate (QC) sample concentration respectively. The RPD values for field duplicate and analytical duplicate samples were computed and presented in Tables.

7.4 Results and Discussion

The data are presented in Tables 7.2 to 7.29 and data are summarized in Tables 7.30 to 7.33.

The RPD values for duplicate field samples for semi volatiles was less than 40% in most of the samples. However, in a few samples the duplicate samples showed greater variation (7.30). This was more significant at lower concentrations (< 50 mg/kg). The RPD for analytical duplicate samples for semi volatiles was less than 32%

except for DM4 (38.3%) and for lindane (40%). In general, a percent error of less than 20% is acceptable for duplicate analysis (4). However, the RPD values of 50% or less for the analysis of PCBs in soil was established as a guideline by Contract Laboratory Programme (2). The higher RPD values observed for a few samples could be due to soil matrix, which is clayey soil in this case. A high variation in duplicate samples could not be ruled out in highly contaminated sites (5). An average RPD of 92 for semi volatiles in clayey soil was reported by Marcia A Kuchl (2) and RPD precision control limits for semi volatiles in clayey soils is given as $\leq$ 194 percent.

None of the equipment blank samples showed any traces of suspected semi volatiles respectively. This indicated that the decontamination procedure adopted in the field was effective.

The trip blanks did not show the presence of suspected volatile organics and it indicated that there was no cross contamination during handling of samples.

The accuracy of the analytical methods is validated by carrying out the percent recovery of the target analytes from spike data. Accuracy is calculated as follows (3) :

$$\text{Percent Recovery} = \frac{(\text{Observed Value} - \text{Back ground value})}{(\text{Known Value})} \times 100$$

Observed values = Analytical values after spiking
Back ground value = Analytical result of the matrix

before spiking
Known value = Concentration of the spike

The percent recovery observed for sevin in dump materials and soil samples ranged from 74 to 140 percent, and for temik from 58.4 to 154.0 percent. The percent recovery for alpha naphthol varied from 50.26 to 62.8 percent in dump materials and from 42 to 94.8 percent in soil samples. The average percent recovery for lindane in dump materials and soil was 82.5 to 87 percent and from 68.8 to 120 percent respectively. The acceptance criteria are generally set at 80 to 120 percent (4) . An average percentage recovery of ranging from 57.3 to 93 percent was also reported for chlorinated organic compounds (2). The variation of 17 to 32 % for recovery from 20 ug/L was observed for lindane (2). Table 7.30 summarizes the results for reagent water samples spiked with the analytes of interest in this study. The percentage recovery of the semi volatiles were above 72 percent.

The QC data for heavy metals are presented in Tables 7.18 to 7.29 . The RPD for field duplicate in dump materials between 7.1 and 66.67 percent. The RPD values for manganese ranged from 7.1 to 64.13% and lead from 20 to 78.26%. The variation in other heavy metals is rather low. In soil samples, the heavy metal RPD ranged between 7.39 and 76.90 percent. The RPD values 0 to 64 percent for the heavy metals (Cd, Cr, Cu, Fe, Pb, Ni, Zn) for silty clay to clay matrix was reported (2). The matrix spike values showed a percent recovery ranging from 50.2 to 154.0 percent.

References

1. Methods of Environmental Data Analysis. Edited by C.N. Hewitt., Elsevier Applied Science, London.
2. Proceedings of US EPA Symposium on Waste testing and Quality Assurance Vol II, 1988

3. Handbook of Environmental Analysis., Edited by Roy, & Keith Smith., Published by Gessium Publishing Corporation, 1994

4. Proceedings of Challenges Facing Environmental Laboratories: Methods, Quality, Media and Liability., Speciality Conference, Water Environment Federation, 1993

5. Ground Water Contamination and Analysis at HAzardous Waste Sites. Ed. S. Lesage and R.E. Jackson., Marcel Dekkar Inc., New York, 1992

TABLE 7.1

Details on QC Samples

QC Samples	No. of Samples		
	Dump Material	Soil	Water
Field Samples			
Duplicate	20 %	20 % for DA & 10 % in RA	10 %
Equipment Blank	1/trip	1/trip	1/trip
Trip Blank	NA	NA	1/trip
Field Blank	NA	1/trip	1/trip
Back ground	NA	Three	NA
Analytical Samples			
Reagent Blank	NA	NA	Each batch
Analytical Duplicate	Random	Random	10%
Matrix Spike	Random	Random	10%

NA ... Not Applicable

TABLE 7.2

Quality Control Data - Dump Materials
Field Samples - Semi Volatiles

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES			
SEVIN			
DM 5	56	65	14.9
DM 12	BDL	15	—
DM 18	2868	3206	11.2
DM 26	216	320	38.8
DM 33	328	260	23.2
DA 2	68	72	5.8
DA 7	1238	1085	13.2
DA 13	2672	2825	5.6
DA 18	276	322	15.4
DA 22	376	395	4.9
TEMIK			
DM 5	BDL	BDL	—
DM 12	396	320	21.2
DM 18	4246	4535	6.6
DM 26	14	25	56.4
DM 33	116	82	34.3
DA 2	32	48	40.0
DA 7	26	30	14.3
DA 13	62	75	18.9
DA 18	BDL	BDL	—
DA 22	BDL	BDL	—
ALPHA NAPHTHOL			
DM 5	12	BDL	—
DM 12	BDL	BDL	—
DM 18	256	312	19.7
DM 26	11	32	97.7
DM 33	17	19	11.1
DA 2	41	35	15.8
DA 7	306	258	17.0
DA 13	671	750	11.1
DA 18	67	58	14.4
DA 22	82	95	14.7

Contd ....

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
LINDANE			
DM 5	BDL	BDL	--
DM 12	BDL	BDL	--
DM 18	26	21	27.3
DM 26	59	25	80.9
DM 33	14	10	33.3
DA 2	BDL	BDL	--
DA 7	14	18	25.0
DA 13	22	18	20.0
DA 18	BDL	BDL	--
DA 22	BDL	5.2	--
NAPHTHALENE			
DM 5	ND	ND	--
DM 18	ND	ND	--
DM 33	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
EQUIPMENT BLANK			
Trip I, II & III			
Sevin	BDL	NA	NA
Temik	BDL	NA	NA
Alpha Naphthol	BDL	NA	NA
Lindane	BDL	NA	NA
Naphthalene	BDL	NA	NA

Detection Limits (mg/kg) :

Sevin 1.0
Alpha Naphthol 10.0
Naphthalene 10.0
Temik 5.0
Lindane 0.1

RPD ..... 2 x[(A-B)/(A+B)] x 100
ND ..... Not Detected
BDL ..... Below Detection Limit]
NA .... Not Applicable

Since the concentration of naphthalene is recorded as ND, analysis for QC was done at lesser samples i.e.,10%

TABLE 7.3

Quality Control Data - Soil Samples - Disposal Area I

Field Samples - Semivolatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES				
Sevin				
F6	30	31.56	24.83	23.90
	60	62.38	55.50	11.70
F12	30	60.76	71.20	15.80
	60	ND	ND	--
F15	30	102.60	108.20	5.30
	60	51.40	60.20	15.80
Temik				
F6	30	58.28	45.30	25.00
	60	16.00	12.10	27.8
F12	30	BDL	BDL	--
	60	BDL	BDL	--
F15	30	26.60	30.20	12.70
	60	28.40	36.20	24.10
Alpha Naphthol				
F6	30	BDL	BDL	--
	60	ND	BDL	--
F12	30	ND	ND	--
	60	ND	ND	--
F15	30	BDL	BDL	--
	60	BDL	11.5	--

Contd ...

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Lindane				
F6	30	26.68	20.40	26.70
	60	12.36	9.20	29.30
F12	30	31.72	36.82	14.90
	60	ND	BDL	--
F15	30	170.6	182.40	6.70
	60	0.50	BDL	--
Naphthalene				
F6	30	ND	ND	--
	60	ND	ND	--
F12	30	ND	ND	--
	60	ND	ND	--
F15	30	ND	ND	--
	60	ND	ND	--
EQUIPMENT BLANKS				
Sevin		BDL		
Temik		BDL		
Alpha Naphthol		BDL		
Lindane		BDL		
Napthalene		BDL		

Detection Limits (mg/kg)

Sevin 1
Alpha Naphthol 10
Naphthalene 10
Temik 5
Lindane 0.1

TABLE 7.4

Quality Control Data - Soil Samples in Disposal Area II

Field Duplicate Samples - Semi Volatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES				
Sevin				
DAII 05	30	48.8	56.6	14.8
	60	ND	12.5	—
DAII 15	30	ND	5.5	—
	60	ND	ND	—
DAII 20	30	ND	ND	—
	60	1.92	2.18	12.7
DAII 27	30	86.10	96.72	11.6
	60	10.65	8.40	23.6
DAII 34	30	126.64	135.20	6.5
	60	52.32	64.35	20.5
Temik				
DAII 05	30	ND	ND	—
	60	ND	ND	—
DAII 15	30	ND	ND	—
	60	ND	ND	—
DAII 20	30	ND	ND	—
	60	ND	ND	—
DAII 27	30	BDL	5.1	—
	60	BDL	BDL	—
DAII 34	30	46.28	61.45	28.2
	60	10.48	14.55	32.6

Contd ...

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Alpha Naphthol				
DAII 05	30	ND	ND	--
	60	ND	BDL	--
DAII 15	30	71.70	52.45.	30.9
	60	ND	11.0	--
DAII 20	30	BDL	BDL	--
	60	ND	BDL	--
DAII 27	30	BDL	BDL	--
	60	BDL	BDL	--
DAII 34	30	42.40	54.34	24.8
	60	21.68	37.54	51.1
Lindane				
DAII 05	30	1.19	0.8	40.2
	60	ND	ND	--
DAII 15	30	0.52	0.94	57.5
	60	0.07	0.10	35.3
DAII 20	30	0.34	0.50	38.1
	60	ND	ND	--
DAII 27	30	ND	ND	--
	60	ND	ND	--
DAII 34	30	BDL	0.1	--
	60	ND	ND	-
Naphthalene				
DAII 05	30	ND	ND	--
DAII 15	30	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	30	ND	BDL	--
DAII 34	30	ND	ND	--

TABLE 7.5

Quality Control Data - Rest of Area Soil Samples

Field Samples - Semi volatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Differen
FIELD DUPLICATE SAMPLES				
Sevin				
G20	30	BDL	BDL	—
G40	30	ND	ND	—
G60	30	BDL	BDL	—
G80	30	3.20	5.80	—
G100	30	BDL	BDL	—
Temik				
G20	30	BDL	BDL	—
G40	30	ND	ND	—
G60	30	5.40	BDL	—
G80	30	BDL	BDL	—
G100	30	20.00	16.00	—
Alpha napthol				
G20	30	BDL	BDL	—
G40	30	ND	ND	—
G60	30	ND	ND	—
G80	30	BDL	BDL	—
G100	30	ND	ND	—

Contd...

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Lindane				
G20	30	ND	ND	--
G40	30	ND	ND	--
G60	30	ND	ND	--
G80	30	ND	ND	--
G100	30	ND	ND	--
Napthalene				
G20	30	ND	ND	--
G40	30	ND	ND	--
G60	30	ND	ND	--
G80	30	ND	ND	--
G100	30	ND	ND	--

NOTE : Samples were analysed on independent field samples and not on composite samples

Detection Limits (mg/kg) :

Sevin 1.0
Alpha napthol 10.0
Napthalene 10.0
Temik 5.0
Lindane 0.1

TABLE 7.6

Quality Control Data - Dump Materials
Analytical Samples - Semi Volatiles

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percentage Difference
DUPLICATE SAMPLES			
Sevin			
DH 21	48728.3	53204.0	8.8
DH 23	598.0	655.0	9.1
DH 4	162.0	170.0	4.8
DH 20	3291.0	2895.0	12.8
DA 9	416.0	355.0	15.8
DA 21	254.0	200.0	23.8
Temik			
DH 21	ND	ND	—
DH 23	56.0	50.0	11.3
DH 4	BDL	5.5	—
DH 20	BDL	BDL	—
DA 9	BDL	6.5	—
DA 21	182.0	145.0	22.6
Alpha Naphthol			
DH 21	9914.0	9756.8	16.1
DH 23	1342.0	1485.0	10.2
DH 4	28.0	19.0	38.3
DH 20	854.0	822.0	3.8
DA 9	96.0	85.0	12.2
DA 21	67.0	50.0	29.1
Lindane			
DH 21	76.0	68.4	10.5
DH 23	67.0	71.6	6.6
DH 4	22.0	24.3	9.9
DH 20	21.0	19.5	7.4
DA 9	BDL	BDL	—
DA 21	BDL	BDL	—

Contd ....

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percentage Difference
Naphthalene			
DM 21	BDL	BDL	--
DM 23	BDL	ND	--
DM 4	ND	ND	--
DM 20	BDL	BDL	--
DA 9	ND	ND	--
DA 21	BDL	BDL	--

TABLE 7.7

Quality Control Data - Soil Samples - Disposal Area I

Analytical Samples - Semivolatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percentage Difference
DUPLICATE SAMPLES				
Sevin				
F3	30	42.3	55.2	26.50
	60	356.0	295.0	18.70
F14	30	47.4	39.2	18.90
	60	ND	6.5	—
Temik				
F3	30	48.7	62.3	24.50
	60	66.7	48.5	31.60
F14	30	BDL	BDL	—
	60	BDL	BDL	—
Alpha Naphthol				
F3	30	BDL	BDL	—
	60	ND	ND	—
F14	30	ND	ND	—
	60	ND	ND	—
Lindane				
F3	30	26.5	30.2	13.00
	60	24.3	20.5	16.90
F14	30	7.8	5.2	40.00
	60	ND	ND	--
Naphthalene				
F3	30	ND	ND	—
	60	ND	ND	--

TABLE 7.8

Quality Control Data - Soil Samples in Disposal Area II

Analytical Sample - Semi Volatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percentage Difference
DUPLICATE SAMPLES				
Sevin				
DAII 18	30	296.3	325.0	9.2
	60	397.1	302.5	27.0
DAII 31	30	156.5	130.2	18.3
	60	58.7	48.7	18.6
Temik				
DAII 18	30	9.4	6.8	32.1
	60	ND	ND	--
DAII 31	30	6.3	4.5	32.1
	60	BDL	BDL	--
Alpha naphthol				
DAII 18	30	54.0	68.0	23.0
	60	45.8	40.0	13.5
DAII 31	30	76.3	55.0	28.1
	60	15.3	11.3	30.1
Lindane				
DAII 18	30	0.9	0.6	40.0
	60	BDL	BDL	--
DAII 31	30	ND	ND	--
	60	ND	ND	--
Naphthalene				
DAII 18	30	ND	ND	--
	60	ND	ND	--
DAII 31	30	ND	ND	--
	60	ND	ND	--

TABLE 7.9

Quality Control Data - Rest of Area Soil Samples

Analytical Samples - Semi volatiles

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relativ Percent Differe
DUPLICATE SAMPLES				
Sevin				
G 20	30	2.4	3.3	31.[illegible]
G 28	30	BDL	BDL	—
Temik				
G 20	30	BDL	BDL	—
G 28	30	20.0	25.0	22.[illegible]
Alpha naphthol				
G 20	30	BDL	BDL	—
G 28	30	ND	ND	—
Lindane				
G 20	30	ND	ND	—
G 28	30	ND	ND	—
Naphthalene				
G 20	30	ND	ND	—
G 28	30	ND	ND	—

TABLE 7.10
Quality Control Data - Dump Materials
Analytical Samples - Matrix Spiking

Sample	Spike Concentration (ug/g)	Percent Recovery (%)
SEVIN		
DM 8	21.50	125.00
DM 5	50.00	78.50
DM 17	152.5	84.20
DM 30	1013.00	75.90
TEMIK		
DM 8	150.00	76.50
DM 5	5.23	69.14
DM 17	50.00	71.20
DM 30	40.00	62.10
ALPHA NAPHTHOL		
DM 8	20.00	52.00
DM 5	10.00	62.80
DM 17	100.00	50.20
DM 30	50.00	55.20
LINDANE		
DM 8	0.25	82.50
DM 30	0.10	87.00
NAPHTHALENE		
DM 8	50.00	81.00
DM 30	20.00	72.00

TABLE 7.11

Quality Control Data - Soil Samples - Disposal Area I

Analytical Samples - Matrix Spiking

Sample	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
SEVIN			
F7	30	25.0	74.0
F10	60	10.00	110.0
F17	30	100.00	120.0
F14	60	2.00	80.6
TEMIK			
F7	30	45.00	154.0
F10	60	5.00	58.4
F17	30	15.00	59.6
F14	60	10.00	68.5
ALPHA NAPHTHOL			
F7	30	20.00	42.0
F10	60	10.00	48.5
F17	30	10.00	54.5
F14	15.00	62.5	53.5
LINDANE			
F7	30	0.5	72.0
F17	60	1.00	85.0
NAPHTHALENE			
F7	30	12.00	92.4
F17	30	15.00	93.5

TABLE 7.12

Quality Control Data - Soil Samples in Disposal Area II

Analytical Sample - Matrix Spiking - Semi Volatiles

Sample ID No.	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
SEVIN			
DAII 04	60	25.0	83.5
DAII 10	30	5.0	130.0
DAII 16	30	250.0	80.0
DAII 25	30	15.0	120.0
TEMIK			
DAII 04	60	10.0	133.0
DAII 10	30	5.0	80.0
DAII 16	30	5.6	125.0
DAII 25	30	25.0	60.0
ALPHA NAPHTHOL			
DAII 04	60	20.0	50.0
DAII 10	30	10.0	52.0
DAII 16	30	50.0	48.0
DAII 25	30	100.0	62.0
LINDANE			
DAII 04	60	1.2	73.3
DAII 10	30	0.5	120.0
DAII 16	30	1.0	88.0
DAII 25	30	2.0	68.6
NAPTHALENE			
DAII 04	60	12.0	88.4
DAII 10	30	15.0	91.4
DAII 16	30	10.0	79.9
DAII 25	30	13.0	90.6

TABLE 7.13

Quality Control Data - Rest of Area Soil Samples

Analytical Samples - Matrix Spiking - Semi volatiles

Sample	Spike Concentration (ug/g)	Percentage Recovery (%)
SEVIN		
G-1	1.5	88.4
G-20	1.0	76.4
TEMIK		
G-1	5.0	92.4
G-23	2.0	124.0
ALPHA NAPHTHOL		
G-1	10.0	92.7
G-20	12.0	94.8
LINDANE		
G-1	0.5	88.4
G-20	0.6	92.7
NAPHTHALENE		
G-1	0.5	73.4
G-20	0.8	88.9

TABLE 7.14

Quality Control Data - Dump Materials
Field Samples - Organics

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
FIELD DUPLICATE SAMPLES			
Chloroform			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
Methylene Chloride			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
1-2- Dichlorobenzene			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
Toluene			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
Formaldehyde			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
Mono methylamine			
DM 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--

Contd ...

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Carbontetra Chloride			
DH 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--
THN			
DH 5	ND	ND	--
DA 7	ND	ND	--
DA 18	ND	ND	--

Detection Limits (mg/kg)

Chloroform 50
Methylene Chloride 20
Toluene 40
Carbon tetra Chloride 100
Formaldehyde ....
1-2- Dichlorobenzene 4
Monomethylamine ....
BDL ...... Below Detection Limit
ND ...... Not Detected

As the organics were at low levels, QC analysis for organics was carried out at selected samples at increased frequency

TABLE 7.15

Quality Control Data - Soil Samples - Disposal Area I

Field Samples - Organics

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
FIELD DUPLICATE SAMPLES				
Chloroform				
F6	30	ND	ND	--
F12	30	ND	ND	--
F15	30	ND	ND	--
Methylene Chloride				
F6	30	ND	ND	--
F12	30	BDL	ND	--
F15	30	BDL	BDL	--
1-2-Dichlorobenzene				
F6	30	ND	ND	--
F12	30	ND	BDL	--
F15	30	ND	ND	--
Toluene				
F6	30	ND	ND	--
F12	30	BDL	BDL	--
F15	30	ND	ND	--

Contd ...

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Carbontetra Chloride				
F6	30	ND	ND	—
F12	30	ND	ND	—
F15	30	ND	ND	—

Analysis has been carrie dout on individual samples and not composite samples

Detection Limits (mg/kg)

Chloroform	 50	Formaldehyde	....
Methylene Chloride	 20	1-2- Dichlorobenzene	 4
Toluene	 40	Monomethylamine	....
Carbon tetra Chloride	 100		

TABLE 7.16

Quality Control Data - Soil Samples in Disposal Area II

Field Duplicate Samples - Organics

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES				
Chloroform				
DAII 05	30	ND	ND	--
DAII 15	60	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	60	ND	ND	--
Methylene Chloride				
DAII 05	30	ND	ND	--
DAII 15	60	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	60	BDL	ND	--
1-2 Dichlorobenzene				
DAII 05	30	ND	ND	--
DAII 15	60	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	60	ND	ND	--
Toulene				
DAII 05	30	ND	ND	--
DAII 15	60	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	60	ND	ND	--

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
Carbon tetra chloride				
DAII 05	30	ND	ND	--
DAII 15	60	ND	ND	--
DAII 20	30	ND	ND	--
DAII 27	60	ND	ND	--

QC studies were not carried out for Formaldehyde, Monomethylene and THA as they are categorsied as unimportant

Detection Limits (mg/kg)

Chloroform	 50	Formaldehyde	....
Methylene Chloride	 20	1-2- Dichlorobenzene	 400
Toluene	 40	Monomethylamine	....
Carbon tetra Chloride	 100		

TABLE 7.17

Quality Control Data - Rest of Area Soil Samples

Field Samples - Volatiles Organics

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
FIELD DUPLICATE SAMPLES				
CHLOROFORM				
G-1	30	ND	ND	--
G-20	30	ND	BDL	--
METHYLENE CHLORIDE				
G-1	30	ND	ND	--
G-20	30	ND	ND	--
1-2-DI CHLOROBENZENE				
G-1	30	ND	ND	--
G-20	30	ND	ND	--
TOLUENE				
G-1	30	ND	ND	--
G-20	30	ND	BDL	--
CARBON TETRA CHLORIDE				
G-1	30	ND	ND	--
G-20	30	ND	BDL	--

Most of the samples were in BDL/ND levels, QC studies were carried out for two samples selected at random.

QC studies were not carried out for Formaldehyde, Monomethylene and TMA as they are categorsied as unimportant

TABLE 7.18

Quality Control Data - Dump Materials
Field Samples - Heavy Metals

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES			
Manganese			
Disposal Area I	986	872	12.23
Disposal Area II	1040	1265	19.52
Disposal Area III	678	886	26.59
Tarry Residues	214	416	64.13
Temik Neutralisation Pits	978	1050	7.10
Temik ponds	1648	2178	27.71
Zinc			
Disposal Area I	178	154	14.46
Disposal Area II	186	246	27.78
Disposal Area III	178	218	20.20
Tarry Residues	8	16	66.67
Temik Neutralisation Pits	9	12	28.57
Temik ponds	10	8	22.22
Copper			
Disposal Area I	16	26	47.62
Disposal Area II	20	14	35.29
Disposal Area III	16	28	54.54
Tarry Residues	14	21	40.00

Contd ....

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	RPD
Temik Neutralisation Pits	8	13	47.62
Temik ponds	12	8	40.00
Nickel			
Disposal Area I	7	11	55.55
Disposal Area II	9	6	40.00
Disposal Area III	8	13	47.62
Tarry Residues	18	11	48.28
Temik Neutralisation Pits	5	9	57.14
Temik ponds	6	4	40.00
Lead			
Disposal Area I	9	11	20.00
Disposal Area II	9	14	43.48
Disposal Area III	7	16	78.26
Tarry Residues	7	13	60.00
Temik Neutralisation Pits	6	8	28.57
Temik ponds	8	5	46.15
Chromium			
Disposal Area I	61	87	35.14
Disposal Area II	51	39	26.67
Disposal Area III	36	47	26.51
Tarry Residues	78	61	24.46

Contd ...

Sample No	Original Sample (mg/kg)	QC Sample (mg/kg)	RPD
Temik Neutralisation Pits	138	110	22.58
Temik ponds	98	71	31.95
Cadmium			
Disposal Area I	0.1	0.1	—
Disposal Area II	0.2	0.15	28.57
Disposal Area III	0.1	0.22	75.00
Tarry Residues	0.2	0.14	35.23
Temik Neutralisation Pits	BDL	0.2	—
Temik ponds	BDL	ND	—

TABLE 7.19

Quality Control Data - Soil Samples - Disposal Area I

Field Samples - Heavy Metals

Sample No	Sample Depth (cm)	Original Sample (mg/kg)	QC Sample (mg/kg)	Relative Percent Difference
DUPLICATE FIELD SAMPLES				
Manganese				
DAI 01	30	662	746	11.93
DAI 03	60	388	276	33.73
Zinc				
DAI 01	30	160	182	12.87
DAI 03	60	180	236	26.92
Copper				
DAI 01	30	110	186	51.35
DAI 03	60	100	146	37.39
Nickel				
DAI 01	30	90	124	31.78
DAI 03	60	60	84	33.33
Lead				
DAI 01	30	10	18	57.14
DAI 03	60	15	11	30.77
Chromium				
DAI 01	30	690	743	7.39
DAI 03	60	600	486	20.99
Cadmium				
DAI 01	30	BDL	ND	--
DAI 03	60	BDL	BDL	--

TABLE 7.20

Quality Control Data - Soil Samples in Disposal Area II

Field Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample DAII 0560 (mg/kg)	20	30	5	30	BDL	80	113
QC Sample (mg/kg)	28	41	9	16	BDL	94	98
RPD	33.3	30.9	57.1	60.9	--	16.1	14.2
Original Sample DAII 0560 (mg/kg)	20	30	4	20	BDL	60	132
QC Sample (mg/kg)	32	24	7	15	BDL	49	149
RPD	46.2	22.2	54.5	28.6	--	20.2	12.1
Original Sample DAII 1530 (mg/kg)	48	25	13	106	BDL	68	124
QC Sample (mg/kg)	32	31	19	88	BDL	78	98
RPD	40.0	21.4	37.5	18.6	--	13.7	23.4

Contd ....

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample DAII 1560 (mg/kg)	40	21	15	89	BDL	49	118
QC Sample (mg/kg)	56	32	11	79	BDL	59	134
RPD	33.3	41.5	30.8	11.9	--	18.5	12.7

RPD ..... Relative Percent Difference

TABLE 7.21

Quality Control Data - Rest of Area Soil Samples

Field Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample G 71 (mg/kg)	48	36	18	38	0.1	60	54
QC Sample (mg/kg)	40	51	34	46	BDL	78	66
RPD	18.2	34.5	61.5	19.0	—	25.9	20.0
Original Sample G 28 (mg/kg)	46	59	4	52	0.4	62	112
QC Sample (mg/kg)	62	39	9	76	0.8	83	178
RPD	29.6	40.8	76.9	37.5	66.7	26.2	45.5

RPD .... Relative Percent Difference

TABLE 7.22

Quality Control Data - Dump Material

Analytical Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample DM 32 (mg/kg)	30	185	7	35	0.1	4	327
QC Sample (mg/kg)	51	102	5	40	0.15	7	198
RPD	51.9	57.8	33.3	13.3	40.0	54.5	49.1

RPD .... Relative Percent Difference

TABLE 7.23

Quality Control Data - Disposal Area I

Analytical Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample DA I 09 30 (mg/kg)	62	176	8	96	0.1	148	898
QC Sample (mg/kg)	46	152	4	102	BDL	118	678
RPD	29.6	14.6	66.7	6.1	—	22.6	27.9
Original Sample DAI 0960 (mg/kg)	56	68	6	256	BDL	96	392
QC Sample (mg/kg)	71	81	7	198	BDL	122	476
RPD	23.6	17.4	15.5	25.6	—	23.9	4.9

RPD .... Relative Percent Difference

TABLE 7.24

Quality Control Data - Disposal Area II

Analytical Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample DAII 30 30 (mg/kg)	40	50	17	40	BDL	160	150
QC Sample (mg/kg)	56	32	32	61	BDL	90	162
RPD	33.3	43.9	61.2	41.5	---	56.0	7.7
Original Sample DAII 20 60 (mg/kg)	42	62	9	32	BDL	76	118
QC Sample (mg/kg)	32	48	15	56	BDL	68	120
RPD	27.0	25.4	50.0	54.5	---	16.7	1.7

RPD .... Relative Percent Difference

TABLE 7.25

Quality Control Data - Rest of Area Soil Samples

Analytical Duplicate Samples - Heavy Metals

Sample ID No.	Cu	Cr	Pb	Ni	Cd	Zn	Mn
Original Sample G 10 (mg/kg)	44	1	13	39	BDL	41	92
QC Sample (mg/kg)	76	3	8	21	BDL	48	110
RPD	53.3	100.0	47.6	60.0	—	15.7	17.8
Original Sample G 23 (mg/kg)	85	128	BDL	60	BDL	59	46
QC Sample (mg/kg)	96	116	BDL	51	BDL	48	51
RPD	12.1	9.8	—	19.8	—	20.6	10.3

RPD .... Relative Percent Difference

TABLE 7.26
Quality Control Data - Dump Materials

Analytical Sample- Matrix Spiking - Heavy Metal

Sample ID No.	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
Copper			
DM 1	—	20.00	76.0
DM 18	—	25.00	81.0
Chromium			
DM 1	—	30.00	82.0
DM 18	—	20.00	73.0
Lead			
DM 1	—	5.00	120.0
DM 18	—	3.00	98.0
Nickel			
DM 1	—	20.00	118.0
DM 18	—	15.00	110.0
Cadmium			
DM 1	—	0.20	78.0
DM 18	—	0.1	80.0
Zinc			
DM 1	—	60.00	92.0
DM 18	—	50.00	101.0
Managanese			
DM 1	—	130.00	115.0
DM 16	—	120.0	98.0

TABLE 7.27

Quality Control Data - Soil Samples in Disposal Area I

Analytical Samples - Matrix Spiking - Heavy Metal

Sample ID No.	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
F 3	60		
Copper		150.00	80.0
Chromium		10.0	85.0
Lead		10.0	88.0
Nickel		100.0	92.0
Cadmium		1.0	88.0
Zinc		200.0	75.0
Managanese		500.0	90.0

TABLE 7.28

Quality Control Data - Soil Samples in Disposal Area II

Analytical Sample - Matrix Spiking - Heavy Metal

Sample ID No.	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
Copper			
DAII 04	60	20.00	80.0
DAII 07	30	65.00	107.0
Chromium			
DAII 04	60	30.00	70.0
DAII 07	30	60.00	95.0
Lead			
DAII 04	60	5.00	140.0
DAII 07	30	2.00	113.0
Nickel			
DAII 04	60	20.00	125.0
DAII 07	30	100.00	113.0
Cadmium			
DAII 04	60	0.20	75.0
DAII 07	30	0.1	80.0
Zinc			
DAII 04	60	60.00	117.0
DAII 07	30	150.00	83.0
Managanese			
DAII 04	60	130.00	118.0
DAII 07	30	150.0	112.0

TABLE 7.29

Quality Control Data - Soil Samples in Rest of Area

Analytical Sample - Matrix Spiking - Heavy Metal

Sample ID No.	Sample Depth (cm)	Spike Concentration (ug/g)	Percent Recovery (%)
G - 5	30		
Copper		50.00	73.5
Chromium		25.0	72.0
Lead		10.0	90.0
Nickel		50.0	114.0
Cadmium		1.0	85.0
Zinc		60.0	120.0
Managanese		350.0	108.0
G 23	30		
Copper		100.00	78.5
Chromium		150.0	82.0
Lead		5.0	95.0
Nickel		100.0	92.0
Cadmium		5.0	84.0
Zinc		60.0	91.6
Managanese		50.0	94.0

TABLE 7.30

Summary of QC Data - Semi Volatiles

QC Sample	No. of samples	Relative Percentage Difference (RPD)				
		Sevin	Temik	Alpha Naphthol	Lindane	Naphthale
FIELD DUPLICATE						
Dump Material	10	4.9 - 38.8	6.6 - 56.4	11.1 - 97.7	20.0 - 80.0	—
Soil Samples - DA I	6	5.3 - 23.9	12.7- 27.8	—	6.7 29.3	—
- DA II	10	6.5 - 23.6	28.2 - 32.6	24.8 - 51.1	38.1 - 57.5	—
- Rest of Area	5	—	—	—	—	—
ANALYTICAL DUPLICATE SAMPLES						
Dump Material	6	4.8 - 23.8	11.3 - 22.6	3.8 - 38.3	6.6 - 10.5	—
Soil Samples - DA I	4	18.7 - 26.5	24.5 - 31.6	—	13.0 - 40.0	—
- DA II	8	9.2 - 27.0	32.1	13.5 - 30.1	40.0	—
- Rest of Area	2	31.5	22.2	—	—	—

TABLE 7.31

Summary of QC Data - Heavy Metals

Parameter	No. of samples	Relative Percentage Difference (RPD)	
		Dump Material	Soil
FIELD DUPLICATE			
Managanese		7.10 - 64.13	11.93 - 33.73
Zinc		14.46 - 66.67	12.87 - 26.92
Copper		35.29 - 54.54	18.20 - 51.35
Nickel		40.00 - 57.14	18.60 - 60.90
Lead		20.0 - 78.26	30.77 - 76.90
Chromium		22.58 - 35.14	7.39 - 41.50
Cadmium		28.57 - 75.00	28.57 - 75.00

TABLE 7.32

Summary of QC Data - Analytical Samples - Matrix Spike

Analyte	Percent Recovery		
	Dump Material	Soil	Water
Sevin	75.9 - 125.0	74.0 - 130.0	92.0
Temik	62.1 - 76.5	58.4 - 154.0	87.0
Alpha Naphthol	50.2 - 62.8	42.0 - 94.8	72.0
Lindane	82.5 - 87.0	68.6 - 120.0	90.0
Naphthalene	72.0 - 81.0	73.4 - 93.5	93.0
Copper	76.0 - 81.0	73.5 - 107.0	NA
Chromium	73.0 - 82.0 -	70.0 - 95.0	NA
Lead	98.0 - 120.0	88.0 - 140.0	NA
Nickel	110.0 - 118.0	92.0 - 125.0	NA
Cadmium	78.0 - 80.0	75.0 - 88.0	NA
Zinc	92.0 - 101.0	75.0 - 120.0	NA
Manganese	98.0 - 115.0	90.0 - 118.0	NA

NA .... Not Applicable

TABLE 7.33

QC Sample Data - Ground Water (Production Well)

Analytical Sample - Matrix Spike

Analyte	Spike Con. (ug/L)	Percent Recovery (%)
Sevin	500	92.0
Temik	500	87.0
Alpha Naphtol	500	72.0
Lindane	1	90.0
Naphthalene	10.0	93.0
Chloroform	10.0	70.0
Carbontetra Chloride	10.0	62.0
Methylene Chloride	10.0	80.0
Toluene	10.0	60.0
1,2-Dichloro-benzene	10.0	75.0

8.0 CLEANUP CRITERIA FOR CONATAMINATED SOIL AND GROUNDWATER

8.1 Preamble

The contaminated soil and groundwater due to past disposal activities have to be remediated as a method of restoration of environmental quality. In order to delineate the environmental media as contaminated or to set limit to which the remedial steps to be taken, it is necessary to develop criteria. Cleanup criteria for contaminated soil and groundwater have taken many different forms which include the following (1) :

* Cleanup to "background" levels
* Cleanup to levels established by the limits of detection
* Cleanup to "non-detect" levels
* Cleanup to Technology based
* Cleanup to levels established by precedent
* Cleanup to existing standards or guidelines
* Cleanup to levels protective of potentially exposed individuals as established by a health risk assessment and
* Combination of above

8.1 Cleanup to Background level

The cleanup of contaminated environmental media to the condition that existed before the contamination occurred is a reasonable and often pursued goal. However the characterization of background soil quality is just complex while the background level of groundwater vary with time. As it is difficult to establish the correct background level, this method is not considered.

8.3 Cleanup to Limits of Detection

All the analytical methods have limitations and detection limits have to be established for reproducibility of data. In this study also, detection limits for all semivolatiles and volatile organics have been developed and reported (Tables). Detection limits are function of the particular analytical equipment used and analysis protocol, and there may be considerable variability in the capabilities of different laboratories. Further, health-derived cleanup criteria may be below the detection limit and in such cases the criteria have to be limited to detection limit. This method is also not considered for this study.

8.4 Cleanup to Non-Detect Levels

In this method the contaminated media have to remediated below the detection limits or in other words, 'complete decontamination' has to be achieved. As the contaminants present in EIIL plant premises mainly include semivolatile such as sevin, and aldicarb and volatile organics which are not highly toxic, there was no need to decontaminate fully. In addition the hazardous wastes were disposed within the plant premises. Hence this method is also not considered.

8.5 Cleanup to Technology based

It is a usual practice to adopt standards based on the technology available for remedial measure. In this method, the maximum efficiency of each technology is evaluated and based on technical feasibility and economics, standards are developed. Since treatability studies are yet to be carried out, this approach is not considered.

8.6 Cleanup to Levels Established by Precedent

Had there been any steps adopted for remediation of similar cases elsewhere, the methods adopted must be analyzed and may be extended to the present case. As there was no similar incidence in this country and in the absence of any published reports, this method is not included.

8.6 Cleanup Established by Existing Standards and Guidelines

In India, there is no standards or guidelines available for decontamination of contaminated environmental media.

8.7 Cleanup to Health-based Criteria

Most of the contaminants present in and around hazardous waste disposal sites may be carcinogenic. They pose risk to human health and also on the environment. Conservative assumptions and expert opinions frequently must be relied on when specifying the desired cleanup level because factual evidence is often lacking. The result generally is a concentration level that, if exposure occurs, will result in a level of risk of adverse consequences that will be acceptable. This approach has been considered in this report as this method appears to be more scientific than any other methods.

8.8 Risk - Based Criteria

The most critical components of a risk assessment are the exposure assessment and the toxicity evaluation. Critical factors influencing exposure include : exposure pathways, potentially exposed populations, frequency and duration of potential exposure, transport and fate of the chemical in the site's environment, and site characteristics, such as paving or fences and distances to potential receptor populations.

Considering the importance of exposure pathways for human receptors at this site and its application in the risk analysis, this was evaluated during the preliminary reconnaissance survey. In this case at EIIL, Bhopal, it is felt that the potential for contaminants in soil to reach groundwater as the main pathway. For soils, it is important to consider the potential for contaminants in soil to reach groundwater. Some contaminants such as lead and cadmium are relatively immobile and may not pose a significant threat to groundwater quality. Other contaminants such as sevin, temik, benzene, etc., are relatively soluble in water and much more mobile and likely to move from soil to the groundwater. The cleanup level for each medium should include all possible pathways that contribute to exposure or risk. Foe example, the cleanup levels for soil at this site should be developed using all possible exposure routes for soil that ar appropriate e.g. ingestion, dermal contact, inhalation of soil as dust particles etc. There are three primary routes by which toxic agents can enter the body :

* Ingestion of contaminated water and food
* Inhalation of vapours and dust
* Dermal contact with water or soil

For an exposure pathway to be considered important or complete at a site, there must be a receptor that is exposed to contamination via this pathway. A receptor is any organism that may be exposed to the contamination. In this study, direct exposure of general public to contaminated soil is not feasible as the disposal areas are within the plant premises and entry of public is not allowed. However a few labors who are working may get exposed. Thus the receptors in this case is assumed as humans. These labors are exposed to contaminated soil while working only in the disposal areas during removal excess vegetation. These labors are likely to be exposed when remedial measures are to be implemented. However, these labors are exposed to contaminated groundwater. The public residing nearby areas may likely to get exposed to contaminated groundwater but not exposed to contaminated soil. Thus there are two scenarios anticipated viz., exposure of contaminated soil to a few selected labors and for limited periods, and general public due to possible contamination of groundwater.

The possible exposure pathways for human receptors are summarized in Table 8.1.

8.9 Determination of Action Levels

The carcinogenicity or cancer-causing potential of a chemical is evaluated qualitatively by the weight-of-evidence classification. The weight-of-evidence scheme used by USEPA is as follows :

A Human carcinogen

B Known probable human carcinogen

B1 Limited human evidence but sufficient animal evidence

B2 Inadequate or no human evidence but sufficient animal evidence

C Possible human carcinogen

D Not classifiable as to human carcinogenicity

E Evidence of non-carcinogenicity in humans

The carcinogenicity of a chemical is evaluated quantitively by a slope factor which is a measure of the relative cancer potency of a chemical. The slope factor represents the dose-response relationship of the carcinogen. The slope factor is defined as a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. In simpler terms the slope factor is the excess cancer risk per unit of dose and is expressed as risk/mg/kg/day. The higher the value of slope factor, the more potent the carcinogen is considered to be.

However, for chemicals other than that can produce cancer, there is a low dose level, at which there is no observed adverse effect (NOAEL),i.e., there is an assumed threshold. For these chemicals that cause systematic toxicity, it is believed that some organic homeostatic, compensatory, or adoptive mechanism exists that must overcome before toxicity is manifested. For example, it would take a lot of diseases liver cells before liver function would be damaged. The reference dose (RfD), developed by USEPA, is the toxicity value used to estimate non-carcinogenic effects. It is derived by consistent application of generally order-of magnitude uncertainty factors (UF) and modifying factors (MF).

$$RfD = NOAEL / (UF \times MF)$$

Toxicity values presented in the Integrated Risk Information System (IRIS) Database are used in risk assessments.

RfD can be used to determine the action level for noncarcinogens as follows :

$$C_m = (RfD \times W) / (I \times A)$$

where

C_m = action level (mg/kg for soil & mg/L for water)
RfD = Reference Dose (mg/kg/day)
W = Body weight (kg)
I = Intake (g/day for soil & L/day for water)
A = Absorption factor, dimensionless (assumed as 1)

Slope factor (mg/kg/day) can be used to determine the action level for carcinogens as follows :

$$C_m = (R \times W \times LT) / (CSF \times I \times A \times ED)$$

where

R	=	assumed risk level, e.g., 10^{-6} for Class A and Class B, 10^{-5} for Class C carcinogens
LT	=	assumed life time, years
CSF	=	carcinogenic slope factor $(mg/kg/day)^{-1}$, and
ED	=	exposure duration, years

The toxicity data for predetermined parameters for this study are presented in Table 8.2.

In deriving action levels for hazardous constituents following assumptions were made :

	Soil	Water
Intake	0.1 g/d (for carcinogens) 0.2 g/d (for noncarcinogens)	2 L/d
Weight (kg)	70	70
Lifetime (years)	70	70
Risk level	1 in 100000	1 in 100000

Based on the above, the proposed limits for soil as per US EPA is presented in Table . The Drinking Water Quality criteria based on the maximum concentration levels (MCLs) formulated under the Safe Drinking Water is presented in Table.

8.10 Proposed Criteria

After reviewing various alternatives, it is suggested to adopt risk based criteria. The criteria for soil (residential/industrial areas) and ground water adopted by Region III of US EPA is being considered. The data for the parameters considered for this study is presented in Table 8.3. There is no standard prescribed for alpha naphthol and lindane. The criteria level for lindane is taken from the paper published in The Hzardous Waste Consultant, August 1994. There is no criteria level for alpha napthol in any literature surveyed.

8.11 Contaminated Areas at EIIL

The risk based criteria for soil is given for both residential and industrial areas (Table 8.3). The area in and around EIIL has been declared as industrial area. In view of this soil criteria for industrial area has to be considered. However, due to habitation around EIIL premises, and as the end-use of the facility premises after remediation is not finalized, it is suggested to comnpare the exisiting soil quality with the soil quality criteria for residenetial area also. Table 8.4 summarises the soil quality data exceeded the criteria level (residential area) and the area where the soil criteria exceeded may be termed as contaminated area.

The maximum concentration of Carbaryl (sevin) in soils is 7218 mg/kg in Disposal Area II (DAII 0130) and the criteria limit is 7800 mg/kg for residential area. Thus the soil criteria for sevin is within the criteria level and hence soil quality may be considered as not affected with sevin.

However temik exceeded the criteria level (78 mg/kg for residential) at three sites viz., Disposal Area II (DAII

0130), Rest of Area (G 87 & G 88). However the concentration of temik is 5% of the soil criteria level (2000 mg/kg) for industrial area.

Most of the soil samples in Disposal Area I and 8 samples (25%) in Disposal Area II have exceeded the criteria level of 0.5 mg/kg for residential area. The lindane criteria level exceeded in most of the samples even at industrial criteria level. Thus the entire Disposal Area I can be considered as contaminated area. However in Disposal Area I, 8 samples exceeded the residential criteria level and only one site (DAII 04 30) exceeded the industrial criteria level.

As there was no criteria level available for alpha naphthol, the same is not considered. This is because of nonavailability of slope factor.

Naphthalene was not detected in any soil sample and hence the concentration of soil is observed to be far below the criteria levels.

The concentration of volatile organics in all soil samples were either 'below detection limit' or 'not detected'. Hence the soil within EIIL premises can be considered as uncontaminated with respect to volatile organics.

Among the various heavy metals analyzed, manganese exceeded the criteria level of 390 mg/kg (residential area) in three stations (DAI 01, 02 & 03 both at 30 and 60 cms depths) and two stations (DAI 01 & 02) for industrial area.

Further it is concluded that the soil upto 60 cm in Disposal Area I can be considered as contaminated. In Disposal Area I, the contamination is upto 30 cm except at DAII 04 where the contamiantion is upto 60 cm.

It can be concluded that the entire Disposal Area I (about 0.5 ha and a depth of 60 cm) and in Disposal Area II, about 0.32 ha (i.e. 8 location of each 400 m^2) and depth upto 30 cm can be declared as contaminated area. The total volume of contaminated soil is around 2040 m^3. The conclusion is based on the lindane criteria level. The contaminated areas requiring remediation is shown in Fig 8.1.

The ground water quality in all wells meets the criteria level and hence there is no need of remediation.

Reference :

1. Cleanup Criteria for Contaminated Soil and Groundwater. ASTM DS64 Edited by Anthony J. Buonocore, Air & Waste Management Association, Philadelphia, Jan. 1995

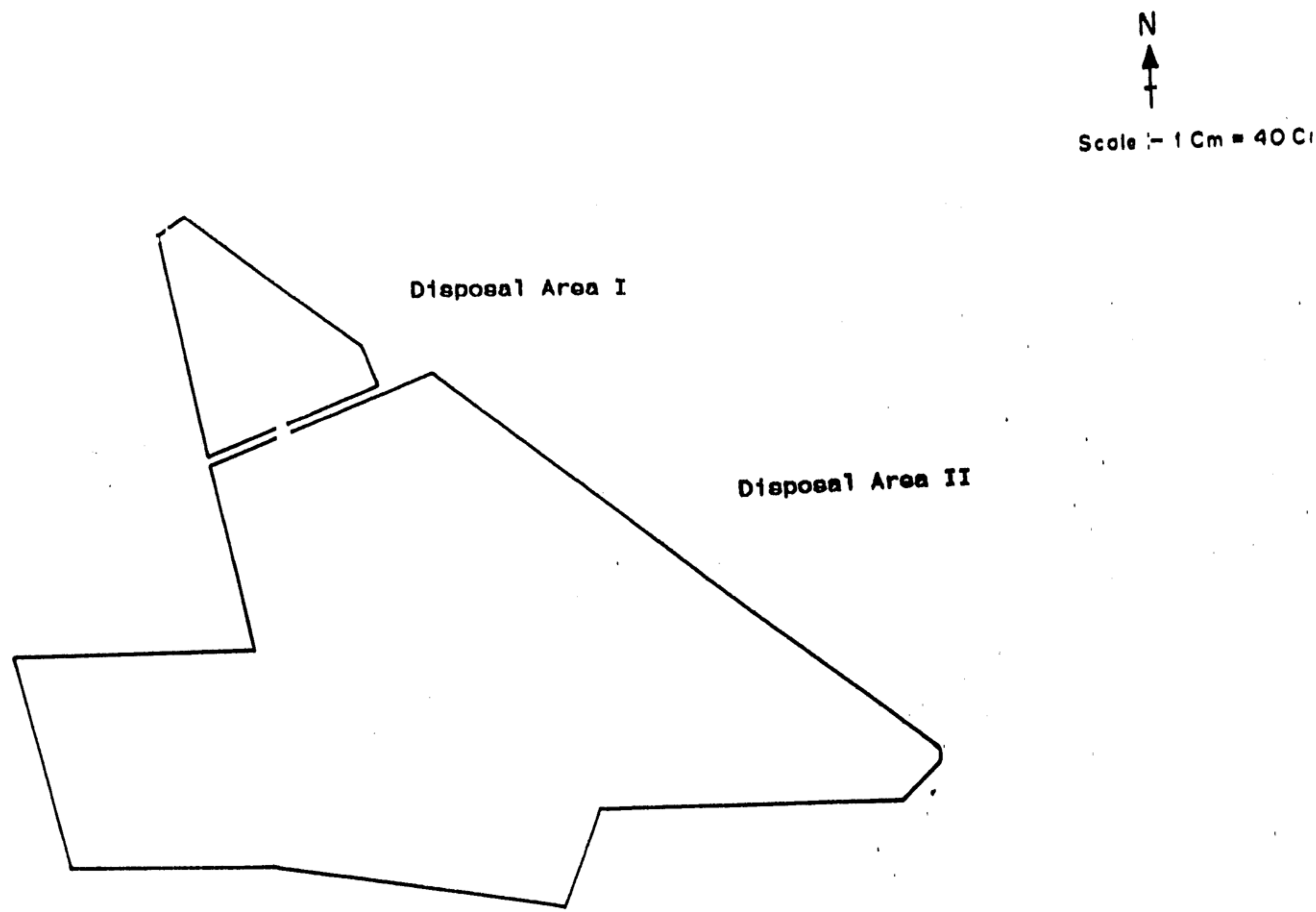


FIG 8.1 CONTAMINATED AREA AT EIIL, BHOPAL

TABLE 8.1

POTENTIAL EXPOSURE PATHWAYS FOR HUMAN RECEPTORS

Contaminated Medium	Exposure Scenario	Potential Pathway	Important for Calculation of Cleanup Criteria
Soil	Industrial	Ingestion	Yes
		Dermal contact	Yes
		Inhalation of dust/volatiles	Yes
		Potential source of Groundwater contamination	Yes
Groundwater	Residential	Ingestion	Yes
		Inhalation of volatiles	Yes
		Dermal contact of volatiles	Yes
		Transfer to food crops, or livestock	Yes

TABLE 8.2

TOXICITY DATA

Constituent	CAS No.	RfD (mg/kg/d)	Class
Noncarcinogenic Effects (Oral)			
Aldicarb	116-06-3	0.0013	D
Cadmium	7440-43-9	0.0005	B1
Carbon tetra-chloride	56-23-5	0.0007	B2
Chloroform	67-66-3	0.01	B2
Chromium(VI)	18540-29-9	0.005	A
Lindane	58-89-9	0.0003	B2/C
Nickel	7440-02-0	0.02	D
Toluene	108-88-3	0.3	D
Noncarcinogenic Effects (Inhalation)			
Toluene	108-88-3	2.0	D
Carcinogenic Effects (Oral)			
Carbontetra-chloride	56-23-5	0.13	B2
Chloroform	67-66-3	0.0061	B2
Lindane	58-89-9	1.3	B2/C
Carcinogenic Effects (Inhalation)			
Asbestos	1332-21-4	0.23	A
Cadmium	7440-43-9	6.1	B1
Carbontetra-chloride	56-23-5	0.13	B2
Chloroform	67-66-3	0.081	B2
Formaldehyde	50-00-0	0.045	B1
Lindane	58-89-9	—	—

TABLE 8.3

Suggested Risk Based Soil Quality Criteria

Contaminants of Concern	Soil Quality Criteria		Ground Water Quality Criteria (ug/L)
	Residential (mg/kg)	Industrial (mg/kg)	
SEMI VOLATILES			
Sevin	7800	200000	3700
Temik	78	2000	7
a-Napthol	NA	NA	NA
Lindane	0.49	2.2	0.2
Napthalene	3100	82000	1500
VOLATILE ORGANICS			
Carbon tetra chloride	5	44	5
Chloroform	110	940	100
Methylene Chloride	85	760	4.1
1,2-Dichlorobenzene	7000	180000	600
Toluene	16000	410000	1000
Formaldehyde	16000	200000	700
Monomethylene	NA	NA	—
Trimethylene	NA	NA	—
HEAVY METALS			
Copper	290	380	1.4
Chromium	390	10000	0.1
Lead	400	–	3.7
Nickel	1600	41000	0.1
Cadmium	39	1000	0.005
Zinc	23000	610000	11
Manganese	390	10000	0.18

NA ..... Not Available

Source : Risk - Based Concentration Table, July- December 1995, Region III, US EPA, Phildelphia, Pennsylvania, October 20, 1995

For Lindane : The Hazardous Waste Consultant : Aug 1995

TABLE 8.4

Abstract of Sampling Locations Where Soil Quality Criteria Exceeded

Location	Soil Con. mg/kg	Residential Soil Criteria mg/kg	Exceeds Criteria by a Factor	Industrial Soil Criteria mg/kg	Exceeds Criteria by a Factor
Sevin					
Maximum sevin is 7218.3 mg/kg (DAII 0130) and hence all samples are within the Criteria level					
Temik					
Disposal Area II					
DAII 0130	92.34	78	1.18	2000	--
Rest of Area					
G 87	102.4	78	1.3	2000	--
G 88	78.35		1		
Lindane					
Disposal Area I					
F1	25.46	0.49	52	2.2	11.57
F1	14.36		29		6.53
F2	24.38		50		11.08
F2	38.46		78		17.48
F2A	25.2		51		11.45
F2A	41.6		85		18.9
F2A	11.3		23		5.14
F3	26.52		54		12.05
F3	24.26		49		11.02
F3A	24.3		50		11.05
F3A	18.6		38		8.45
F5	27.38		56		12.45
F5	16.46		34		7.48
F6	26.68		54		12.12
F6	12.38		25		5.63
F7	28.46		58		12.94
F7	18.64		38		8.47

Contd .....

Location	Soil Con. mg/kg	Residential Soil Criteria mg/kg	Exceeds Criteria by a Factor	Industrial Soil Criteria mg/kg	Exceeds Criteria by a Factor
F8	36.24		74		16.47
F8	6.28		13		2.85
F9	28.46		58		12.94
F10	22.32		45		10.45
F11	26.42		54		12.00
F12	31.72		65		14.42
F13	16.32		33		7.42
F14	7.8		16		3.55
F15	170.6	0.49	364	2.2	77.54
F15	0.5		1		--
F16	201.4		411		91.55
F17	16.2		33		7.36
Disposal Area II					
DAII 01	1.37	0.49	3	2.2	--
DAII 02	1.18		2		--
DAII 04	2.8		6		1.27
DAII 04	1.12		2		--
DAII 05	1.19		2		--
DAII 15	0.52		1		--
DAII 17	1.40		3		--
DAII 18	0.88		2		--
DAII 19	1.50		3		--

Alpha Naphthol

No Criteria is developed

Naphthalene

	BDL/ND	3100.00	--	82000.0	--

Volatile Organics

All samples were either BDL or ND and hence far below the Criteria level

Location	Soil Con. mg/kg	Residential Soil Criteria mg/kg	Exceeds Criteria by a Factor	Industrial Soil Criteria mg/kg	Exceeds Criteria by a Factor
<u>Heavy Metals</u>					
Manganese					
DAI 01	662	390.0	2	510.0	1.30
DAI 01	623		2		1.22
DAI 02	978		2.5		1.92
DAI 02	527		1.4		1.03
DAI 03	403		1		—
DAI 03	388		1		—

Annexure I

INVENTORISATION OF DUMPS AT EIIL, BHOPAL

S.No.	Location	Type of Material	Above/ Below GL	Size

NEERI, NAGPUR	**Monitoring Well Sampling Data Sheet**	Well No.
		Project No.

			LOCATION
Date Sampled:		Sampled By:	
Depth to Water:		Total Depth:	
O_2	LEL	PID	
Measuring Point:			
Equipment:			

WELL VOLUME (* use appropriate values in table for each code letter)

V well [ ] x [(Depth Screen Bottom [ ] - Depth Water [ ])] = Liter of Water (well) [ ]

ANNULAR VOLUME (ASSUME 30% POROSITY)

V annulus [ ] x [(Depth Screen Bottom [ ] - Depth Bottom of Seal [ ])] = Litre of Water (annulus) [ ]

WATER TO BE REMOVED (Liters)

[((well) [ ] + (annulus) [ ])] x Removal Multiplier [ ] = Total Volume to be Removed [ ]

Actual Volume Removed [ ]

MEASUREMENTS

Well Purging

Time	Number of Litres Removed	pH	Conductivity	Temperature	Dissolved Oxygen
Post Sampling					

SAMPLING

Sample ID	Analysis	Volume (ml)	Filtered (Y/N)	Preservation	Container	Time

Notes (include data on floaters/sinkers with measuring device, well condition, etc.)

* Assumes 30% porosity

Signature ____________ Date ________ No. of Bottles ______

Annexure

NEERI, NAGPUR	Soil Sample Log	Project No Date

Sampling Method	Equipment Used
..eologist(s)	Decontamination Procedure

Comments

..ocation Diagram (Give distances to ensure reproducibility)

Sample Number	Auger Hole ID	Total Organics (ppm)	GEOLOGIC DESCRIPTION Unified Soil Class ID, color (Munsell System), g size, sorting, moisture, compaction, indicatior contaminants (unusual odor or sheen), and gen stratigraphic description