

Site: _____
Break: 3.6
Other: 2-15-83

Woburn Environmental Studies

PHASE I REPORT

Volume 1 Environmental Assessment

Prepared By: Stauffer Chemical Company

Hydrogeologic Assessment By: Roux Associates

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TABLE OF CONTENTS

VOLUME 1: Environmental Assessment

PAGE NUMBER

Introduction	I-1
Executive Summary	
SECTION I: Background/History	I-1
I.1 1853-1933 - Woburn Chemical Works, Merrimac Chemical Company and Monsanto.	I-3
A) History.	I-3
B) Chemical Lists	I-6
C) Chemical Processes	I-7
D) Waste Disposal	I-9
I.2 1934-1969 - New England Chemical Company, Consolidated Chemical Company, Stauffer Chemical Co. .	I-10
A) History.	I-10
B) Chemical Lists	I-11
C) Chemical Processes	I-12
D) Waste Disposal	I-15
I.3 1969-Present - Mark Phillips Trust (M-P Trust)	I-20
A) History.	I-20

SECTION II: Phase I Study: Scope & Purpose.	II-1
A) Background.	II-1
B) Purpose	II-2
C) Scope	II-2
1) Review of Investigation Information	II-3
2) Preparation of Site Safety & Health Plan.	II-4
3) Preparation of Site Survey & Topo. Map.	II-4
4) Surface Water	II-4
a) Surface Water Investigation	II-5
b) Sediments	II-5
c) Leachate.	II-6
5) Subsurface Investigation.	II-6
a) Resistivity	II-6
b) Groundwater Monitoring Wells.	II-6
c) Soil/Waste Deposits	II-7
d) Bore Hole	II-7
6) Microbiological Evaluation.	II-8
7) Analytical Testing.	II-8
8) Organization/Staffing/Facilities.	II-9
a) Consultants	II-9
b) Stauffer Staff.	II-10
c) Facilities.	II-11

SECTION III: Work Accomplished.	III-1
A) Background.	III-3
B) Comparison of Consent Order to Work Actually Done	III-3
1) Prior Site Investigations and Available Information	III-3
2) Review of Prior Investigative Data.	III-4
3) Preparation of Boundary Site Survey	III-4
4) Safety & Health Survey & Plan Preparation	III-5
5) Analytical Testing.	III-6
6) Computerized Data File.	III-8
7) Chain of Custody Records.	III-8
8) Quality Assurance	III-8
9) Performance of Soil Resistivity Survey.	III-9
10) Test Pits & Soil Borings.	III-9
11) Surface Water Analyses.	III-10
12) Stream Sediment Samples	III-11
13) Leachate Samples.	III-11
14) Groundwater Monitor Wells	III-12
15) Bore Hole Air Analyses.	III-12
16) Installation of Meteorological Tower.	III-13
C) Other Accomplishments Not Specified in Consent Order.	III-13
1) Industrial Hygiene Monitoring Requirements.	III-13
2) Microbiological Evaluation-Pathogens.	III-14

SECTION IV: Safety and Health Program

PAGE NUMBER

A) Background	IV-1
B) Safety and Health Plan	IV-2
1) Airborne Particulates.	IV-2
2) Biological Agents.	IV-4
3) General Area Gas and Vapors Sampling	IV-6
4) Personal Samples - Volatile Organics	IV-7
C) Comparison of Worker Protection During Project Health/Safety Plan	IV-9
1) Security and Access.	IV-9
2) Personal Protective Equipment.	IV-9
3) Exposure Monitoring.	IV-10
4) Medical Program.	IV-10
5) Dust Control & Equipment Offsite	IV-10
6) Health and Safety Facilities/Equipment	IV-11
7) Health and Safety Training	IV-11
8) Other Topics	IV-11
D) Findings/Conclusions	IV-12
<hr/>	
SECTION V: Analytical Testing.	VI-1
1) Evaluation of Performance of Laboratories	VI-1
2) Discussion of Methods and Procedures.	VI-9
a) Evaluation of Methods for Screening Metals in Soil.	VI-9
b) Evaluation of Methods for Screening Organics in Soil.	VI-11
c) Comparison of Methods Proposed to Methods Actually Used	VI-15
3) Findings and Conclusions.	VI-18

SECTION VI: Bore Hole Air	V-1
A) Background	V-1
B) Purpose.	V-1
C) Description of Work.	V-2
D) Sampling/Analysis.	V-2
1) Arsine	V-3
2) Total Reduced Sulfur (TRS)	V-3
3) Volatile Organics (VOC).	V-4
E) Findings/Conclusions	V-5
<hr/>	
SECTION VII: Hydrogeologic Evaluation of Waste Deposits and Subsurface Conditions	VII-1
Methods of Investigation.	VII-1
Conductivity Survey	VII-2
Soil Boring Program	VII-7
Test Pit Program.	VII-9
Observation Well Installation	VII-11
Rock Wells	VII-12
Sand and Gravel Wells.	VII-13
Ground Water Sampling	VII-15
Hydrogeology.	VII-16
Soil and Waste Investigation.	VII-25
Conductivity Survey Results.	VII-25
Soil and Waste Analytical Results.	VII-29
Ground-Water Levels and Flow.	VII-37
Ground-Water Quality.	VII-40
Findings and Conclusions.	VII-44

PAGE NUMBER

SECTION VIII: Surface Water Investigation.	VIII-1
A) Background	VIII-1
B) Description of Work/Purpose.	VIII-3
1) Surface Water.	VIII-3
2) Stream Sediments	VIII-6
3) Leachate	VIII-7
C) Findings/Conclusions	VIII-8
1) Surface Water.	VIII-8
2) Sediments.	VIII-15
3) Leachate	VIII-21

VOLUME 2: Appendices — Data/Procedures

PAGE NUMBER

Appendix I: History/Background Figures

Fig. A.1: Plan of Woburn Site.	Append. I-1
Fig. A.2: Plant Layout Merrimac/Monsanto Chemical Plant. . .	Append. I-2
Fig. A.3: 1938/63 Dead/Distressed Vegetation	Append. I-3
Fig. A.4: 1938 Dead/Distressed Vegetation.	Append. I-4
Fig. A.5: 1963 Dead/Distressed Vegetation.	Append. I-5

Appendix I(a): Chemical Lists

Table A.1: Woburn Chemical Works Chemical List 1853 - 1963	Append. I(a)
Table A.2: Merrimac Chemical Company Chemical List	
A.2.1- 1888.	Append. I(a)
A.2.2- 1894.	Append. I(a)
A.2.3- 1899.	Append. I(a)
A.2.4- 1904.	Append. I(a)
A.2.5- 1910.	Append. I(a)
A.2.6.1- 1918.	Append. I(a)
A.2.6.2- 1918 (New England Manufacturing).	Append. I(a)
A.2.7- Merrimac Chemical	Append. I(a)
Table A.3: Stauffer Chemical Company Chemical List	Append. I(a)
Table A.4: Typical Analysis of Stauffer Waste.	Append. I(a)

Appendix II: Analytical Data

Table B.1 - Soil Heavy Metal Analysis.	Append. II-1
B.1.1 - Summary of Analysis.	Append. II-1
B.1.2 - Physical Property Correlation.	Append. II-2
B.1.3 - Analysis	Append. II-3
B.1.4 - Old Data	Append. II-9
Table B.2 - Soil Organic Screening	Append. II-11
Table B.3 - Total Site Sampling & Analysis	
Table B.4 - Bore Hole Air Sampling	
Table B.5 - Analyte Code & Lower Limit of Detection for Various Media.	
Table B.6 - Bore Hole Arsine, TRS & VOC Analysis	
B.6.1 - Bore Hole Arsine and TRS Analysis.	
B.6.2 - Bore Hole & Ambient Air TOC/TRS Analysis	
Table B.7 - Monitor Well & Leachate Analysis	
B.7.1 - Monitor Well Analysis.	
B.7.2 - Leachate Analysis.	
Table B.8 - Surface Water Analysis	
B.8.1 - Heavy Metal, Suspended Solids, Dissolved Solids -- Cyanide & Organic Pollutants	
B.8.2 - Standard Water Analysis.	
B.8.3 - Previous Water Analysis.	
Table B.9 - Sediment Analysis.	
Table B.10 - Sediment/Drainage Area Evaluations	
Table B.11 - DEQE Sampling & Analysis/Leachates	

PAGE NUMBER

Appendix II(a): Sampling Location Figures

Figure B.1 - Phase I Soil Sampling Locations	Append. II(a)-1
Figure B.2 - Bore Hole Sampling Location	Append. II(a)-2
Figure B.3 - Surface Water and Sediment Sampling Locations	Append. II(a)-3
Figure B.4 - Monitor Well and Leachate Sampling Locations	Append. II(a)-4

Appendix II(b): Bibliography/History. Append. II(b)-1

Appendix III: Analytical Program. Append. III-1

Table C.I: Woburn Environmental Studies/ Phase I Screening Program	Append. III-1
---	---------------

Table C.II: Accuracy of Fusion-AA Procedure.	Append. III-3
--	---------------

Table C.III: Lower Limits of Detection for Metals Determination in Soil (ppm).	Append. III-8
---	---------------

Appendix III(a): Analytical Methods/Procedures. Append. III(a)-1

Attachment I(1): Chain of Custody	Append. III(a)-1
---	------------------

Attachment I(2): Quality Assurance Protocol	Append. III(a)-9
---	------------------

Attachment II: Batch Audit Report for Evaluation of Data from ERT.	Append. III(a)-14
---	-------------------

Attachment III: Comparison of Results of Metal Analysis - Stauffer Chemical Company/ERT for Selected Soil Samples.	Append. III(a)-17
---	-------------------

Attachment IV: ERT Analytical Method for the Determination of Selected Metals in Soil	Append. III(a)-32
---	-------------------

Appendix III(a): Analytical Methods/Procedures (continued)

Attachment V: Analytical Methods	Append. III(a)-36
V(1): SCC Methods for Screening Volatile Organic Compounds	Append. III(a)-37
V(2): EPA Method 5020 Head Space Method.	Append. III(a)-48
V(3): EPA Method 8010 Halogenated Volatile Organics.	Append. III(a)-51
V(4): EPA Method 8015 Non-Halogenated Volatile Organics.	Append. III(a)-61
V(5): EPA Method 8020 Aromatic Volatile Organics .	Append. III(a)-69

<u>Appendix V: Safety & Health Plan/Procedures</u>	Append. V-1
--	-------------

VOLUME 3: Subsurface: Data/Maps/Figures

<u>Appendix IV: Borings/Test Pits/Wells Logs</u>	Append. IV-1
1) Test Pit Logs	Append. IV-1
2) Test Boring Logs.	Append. IV-60
3) Observation Well Logs	Append. IV-61

Appendix IV(a): Tables/Maps/Figures

A) Tables.	1
Table 1 - Well Construction Data.	1
Table 2 - Comparison of Chromium, Lead and Arsenic in Borings and Test Pits.	2
Table 3 - Characterization of Natural or Artificial Deposits	3

Appendix IV(a): Tables/Maps/Figures (continued)

Note: The following is an index of Figures located in the plastic pocket retainers contained in this volume.

- Figure 1 - Site Location Map (refer to Sec. VII Text)
- Figure 2 - Areas of Investigation
- Figure 3 - Conductivity Measuring Point Locations
- Figure 4 - Locations of Test Borings and Pits
- Figure 5 - Well and Peizometer Location Map
(showing stream sampling locations) (refer to Sec. VII Text)
- Figure 6 - Geologic Cross Section A-A' (refer to Sec. VII Text)
- Figure 7 - Geologic Cross Section B-B' (refer to Sec. VII Text)
- Figure 8 - Geologic Cross Section C-C' (refer to Sec. VII Text)
- Figure 9 - Geologic Cross Section D-D' (refer to Sec. VII Text)
- Figure 10 - Initial Interpretation of Conductivity Results
- Figure 11 - Reinterpretation of Conductivity Results
- Figure 12 - Distribution of Lead
- Figure 13 - Distribution of Arsenic
- Figure 14 - Distribution of Chromium
- Figure 15 - Distribution of Barium
- Figure 16 - Distribution of Cadmium
- Figure 17 - Distribution of Copper
- Figure 18 - Distribution of Mercury
- Figure 19 - Distribution of Zinc
- Figure 20 - Distribution of Antimony

Appendix IV(a): Tables/Maps/Figures (continued)

- Figure 21 - Distribution of Nickel
- Figure 22 - Distribution of Selenium
- Figure 23 - Distribution of Silver
- Figure 24 - Distribution of Thallium
- Figure 25 - Contour Map of Arsenic and Lead Concentrations
- Figure 26 - Contour Map of Chromium Concentrations
- Figure 27 - Contour Map of Copper & Zinc Concentrations
- Figure 28 - Location of Hide Residue Areas
- Figure 29 - Contour Map of Counts per Gram
- Figure 30 - Water Table Map (January 12, 1983) (refer to Sec. VII Text)

WOBURN ENVIRONMENTAL STUDIES
PHASE I INVESTIGATION

Introduction

Legislative Prospective

In December 1980, Congress passed the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly called "Superfund". CERCLA was passed to assure the prompt and cost effective response to inactive hazardous waste disposal sites and releases or threatened release of hazardous substances. The Act required the United States Environmental Protection Agency (EPA) to take the following major actions:

- 1) Prepare an Inventory of Hazardous Waste Sites;
- 2) Prepare and Publish a National List of at least "400" Top Priority Known or Threatened Releases of Hazardous Substances;
- 3) Revise the National Contingency Plan published under the Authority of Section 311 of the Clean Water Act to include procedures and criteria for investigations and developing cost effective remedial action for hazardous waste releases listed on the National Priority List.

The Act also established a tax on oil and feedstock chemicals. The tax revenues would be used to establish a \$1.6 billion dollar Fund to be used by EPA for investigations, studies and remedial actions.

Regulatory Prospective

EPA assembled an inventory of hazardous waste sites that might require CERCLA attention. In December 1981, from this Inventory, EPA published an Interim List of "115" Top Priority Sites. The Woburn Industri-Plex 128 site was on the list. In 1982, EPA proposed the revisions to the National Contingency Plan. The revisions specified procedures for setting priorities, investigating, evaluating and selecting remedial actions to cost effectively and expeditiously achieve the objectives of CERCLA, i.e., clean up of hazardous substances releases.

EPA implemented a program to negotiate with potentially responsible parties to pay for and clean up hazardous waste sites. This negotiated settlement approach would reserve the Superfund monies for truly abandoned waste sites, would provide the scarce management and technical expertise needed to clean up the Top Priority Waste Sites as expeditiously as possible, and would avoid unnecessary legal costs.

EPA Action

On May 25, 1982 the Stauffer Chemical Company, a former site owner and responsible party voluntarily signed a Consent Order with EPA and the Massachusetts Department of Environmental Quality and Engineering. Incorporated into the Consent Order was an Investigative Plan prepared by Stauffer to undertake an investigation of the Woburn Industri-Plex 128 Site listed on the Interim "115" Top Priority List of Hazardous Waste Sites. The objective of the investigation was to collect the information needed to locate waste deposits, assess the environmental impacts of waste deposits, apportion responsibilities, and evaluate and recommend remedial actions.

The site investigation consists of two Phases. Phase I detailed specific data collection requirements. It was designed to screen the site to cost effectively locate waste deposits and gather information on groundwater, surface water and odors needed to assess impacts. The details of the Phase II investigation were not specified. The objectives of Phase II was to collect any additional site information in addition to the Phase I data needed to apportion costs and evaluate remedial alternatives.

The Phase I Report is comprised of three volumes. Volume 1: Environmental Assessment is the Report narrative that describes the work done and the findings and conclusions. Volume 2 is the appendices of data collected in Phase I and prepared into tables. Volume 3 is the appendices of maps, plot plans and figures showing sampling locations, waste deposit locations, surface water locations and structures. Each volume has an index to facilitate its use.

Phase I Report Composition

Volume 1: Environmental Assessment consists of the sections listed below:

I. Site Background/History:

This section traces the industrial use of the site to guide the Phase I sampling and analysis.

II. Scope/Purpose:

This section describes the area studied in the Phase I investigation, sets forth the sampling and analysis work and discusses the environmental objectives.

III. Work Accomplished:

This section compares the work done in the Phase I study to the requirements specified in the Investigative Plan.

IV. Health/Safety

This section describes the Safety and Health Plan prepared to assure protection of workers and the public during field work activities. It includes findings and conclusions from the evaluation of procedures used and monitoring conducted in Phase I.

V. Analytical Testing:

The method of collection and analytical test used are described for each type of sample collected. This section also discusses the evaluations of screening methods and provides the reason for selection of the methods chosen. The section also discusses the Quality Assurance procedures and evaluations included in the study.

VI. Bore Hole Air:

This section discusses the sampling and analysis of volatile and hazardous chemicals in air that might be generated deep inside the waste deposits. It also relates the findings to odor emissions and worker health.

VII. Subsurface Investigation:

This section describes the sampling and analysis done to locate waste deposits and assess the groundwater quality. The section also discusses the findings and conclusions that can be made based upon Phase I results.

VIII. Surface Water:

This section describes the sampling and analysis done to evaluate impacts of waste deposits on surface waters and the surface water sediments in the vicinity of the site. It also addresses the impact of direct discharges of liquid streams emanating from waste deposits on the surface water.

WOBURN ENVIRONMENTAL STUDIES
PHASE I INVESTIGATION

EXECUTIVE SUMMARY

Site Background/History

The Woburn Industri-Plex 128 site was used for manufacturing various products from 1853 to present. The records of insurance companies, newspaper and journal accounts, and aerial photographs were researched to determine the materials handled at this site and the waste disposal practices.

The following three periods are most appropriate to describe the activities on the 244 acres investigated in Phase I:

1853-1933 - Woburn Chemical Works, Merrimac Chemical Company, Monsanto Chemical Company

1934-1969 - New England Chemical Company, Consolidated Chemical Company, Stauffer Chemical Company

1969-present - Mark Phillip Trust and a few other parties.

1853-1933

During this period the Woburn site was used for manufacturing chemicals for local textile mills, leather and paper industries and arsenic insecticides, acetic acid and dry colors.

A major product produced at the site was sulfuric acid. The acid was then used to manufacture hydrochloric acid and tin chlorides. The sulfuric acid process used both sulfur and pyrite ore as feedstock. Pyrites contain a significant number of heavy metals.

Based on aerial photographs and maps, most wastes from these operations were disposed onsite by filling in swampy, low lying areas. Also, these maps and photographs show a settling lagoon area in the vicinity of the present arsenic pit.

The major substances used in these processes were lead, arsenic, sulfur, pyrite ore containing heavy metals, and dry colors probably contained lead, mercury, chromium, etc.

1934-1969

In 1934 the property was sold to the New England Chemical Company. New England Chemical constructed an animal glue manufacturing plant on the property which was subsequently purchased by Consolidated Chemical Company, and then by Stauffer Chemical Company.

The glue manufacturing process took raw animal hides and waste chrome tanned hides from the area industries and extracted the glue by cooking these materials and concentrating the extract by evaporation and drying. To speed the extraction process, sodium hydroxide, sulfuric acid and magnesium carbonate were used.

Hide residues from the extraction were buried in pits on the property. Wastewater from the washing and disinfection process steps were sent to a settling lagoon to remove suspended solids and separate the grease for sale. The water was then sent to the municipal sewer system.

The major substances used in these processes were chrome tanned hides, raw animal hides, lime, caustic, sulfuric acid and magnesium carbonate.

1969-Present

In 1969, Stauffer sold the major portion of the property to Mark Phillip Trust and a small fraction to others. Mark Phillip Trust began to develop the site for industrial uses. Excavation activities during this development period created noxious odors by exposing decaying hide material. In addition, these activities relocated and commingled many waste deposits into piles near swampy areas on the property.

In 1977, the neighbor complaints about odor and site development activities resulted in DEQE obtaining a restraining order to stop site development. Development activity continued until 1979 when EPA obtained a Court Order to stop further development activities. In 1981, the site was listed on the Superfund Interim List of "115" Top Priority Hazardous Waste Sites.

On May 25, 1982, EPA and DEQE signed a Consent Order with Stauffer Chemical Company requiring Stauffer to undertake a site investigation and recommend remedial action.

Scope/Purpose/Description of Work

The Consent Order agreed to by Stauffer Chemical Company, EPA, and DEQE specified a two phase site investigation for the purpose of assessing environmental conditions at the site, selecting remedial action and apportioning responsibility.

The site boundaries specified for investigation are shown on the map below.

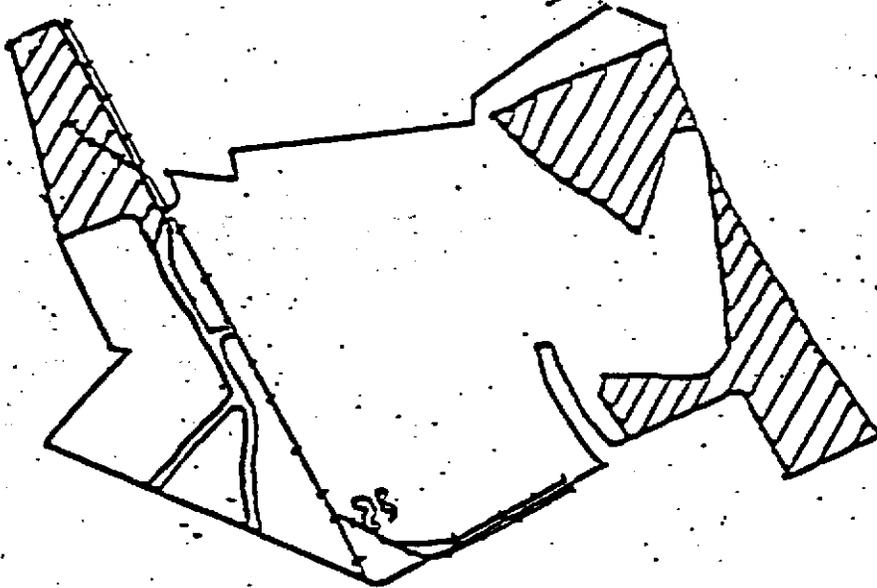


Fig. I 244 Acre Woburn Site
Clear Area Formerly Owned B
Stauffer Chemical Company.

This is a 244 acre piece of property in an industrial area of North Woburn called the Industri-Plex 128 property. The site has streams and ponds, operating facilities, abandoned facilities, waste deposits buried and in piles, roads, railroad tracks, and utility rights of way. About 150 acres are fenced.

Purpose

The purpose of the Phase I investigation is to expeditiously and cost effectively locate hazardous waste deposits and assess their impact on surface waters, groundwaters and air. The Phase II investigation would gather additional information needed to apportion responsibility and evaluate and recommend remedial actions.

Description of Phase I Work

The Investigative Plan specified that Stauffer assemble, collect, evaluate and report the following information and data:

- Review and Evaluate Prior Site Investigations and Available Site Information

Newspaper and journal accounts, aerial photographs and insurance maps, from 1853 were reviewed to identify possible hazardous substances manufactured at the site. Also, prior studies to which Stauffer had access were reviewed and evaluated in Phase I.

- Prepare a Boundary Site Survey

A site survey and topographic map were prepared. Also, a consolidated map showing locations of known or suspected waste disposal areas was prepared based upon site history and aerial photographs.

- Prepare a Safety and Health Plan

A Certified Industrial Hygienist visited and surveyed the site and reviewed the substantial amount of information available on the site. He prepared a Safety and Health Plan to assure the protection of workers and the public during field work activities. The plan includes the following: worker health and safety training, protective equipment requirements, worker exposure and area monitoring, and medical examinations.

- Analytical Testing

Samples of groundwater and surface water were analyzed for the EPA priority pollutants, plus up to 20 other organic chemicals. Methods were evaluated and developed for screening metals and organics in soil.

We established and staffed a laboratory near the site at 10A Henshaw Street to prepare soil, water and air samples for analysis at ERT Laboratories and installed a Perkin-Elmer Head Space Gas Chromatograph to conduct the organic chemical screening of soil samples.

EPA priority pollutant analyses were performed on all surface water, groundwater, leachate and stream sediment samples.

For each batch of 10 samples, 4 quality assurance samples were prepared and analyzed. The analysis of the quality assurance results required resampling and analysis of soil samples for mercury and volatile organics in bore hole air samples. The evaluation of the quality assurance results showed that the data was acceptable for the objectives of the Phase I study.

Samples of air deep inside bore holes were analyzed for total reduced sulfur compounds, arsine and volatile organic chemicals.

- Provide a Computerized Data File System

A computer program was developed to collect, store, retrieve, and correlate the 15000+ pieces of information collected in Phase I.

- Provide Sample Chain of Custody and Quality Assurance

A chain of custody procedure was established that successfully tracked over 2000 samples. A Quality Assurance testing program that required preparation of four Q.A. samples for every 10 site samples was implemented to assure data reliability.

- Perform a Soil Resistivity Survey

Roux Associates, a hydrogeologic consulting firm, conducted a resistivity survey on 200 foot grid spacing to help locate waste deposits versus the Consent Order's 400 foot grid spacing requirement and took continuous readings in areas between the grid.

- Test Pits and Soil Borings

To locate waste deposits and contaminated areas, 100 test pits and soil borings were originally planned. Field findings during the course of the study dictated additional work was needed in this area. Therefore, under the supervision of Roux Associates, 175 test pits and soil borings were dug and 461 soil samples were collected, of which 151 were selected for organic chemical screening and 199 for heavy metal analyses.

- Surface Water Samples

Stream flow measuring devices were installed at three (3) locations. Samples of surface water at 9 locations were collected and analyzed during low flow conditions, as required in the Investigative Plan. The 9 high flow surface water samples specified in the Investigative Plan could not be collected because of insufficient rain during Phase I. Samples of surface water during high stream flow conditions will be collected in April 1983 during the spring rainy season.

- Stream Sediment Samples

The 14 samples of soil sediments in streams and ponds were collected and analyzed per the Investigative Plan.

- Samples of Leachate

Only one of the three (3) proposed samples of water seeping from waste disposal areas was collected and analyzed. Again, the rainfall was not sufficient during Phase I to produce visible seepage and additional samples will be collected in April 1983 if any are found.

- Groundwater Monitoring Wells

We collected and analyzed water samples from the 15 groundwater monitoring wells installed in Phase I. This is two more than originally planned in the Investigative Plan. We also installed 8 piezometers in order to map the groundwater flow direction.

• Bore Hole Air Samples

Per the Investigative Plan, Stauffer installed 10 bore holes in the waste deposit areas and collected air samples from deep inside the bore holes for analysis of total reduced sulfur (TRS) compounds, (i.e., hydrogen sulfide, methyl mercaptan), arsine and volatile organic chemicals (VOC). A total of 98 samples were collected versus the 90 specified in the Order. Thirty samples were analyzed for TRS compounds, 30 for arsine and 38 for VOC's. However, only 6 VOC analyses were valid. Cross contamination and high concentration of reduced sulfur compounds invalidated the other VOC samples.

• Install a Meteorological Tower

Stauffer installed a wind speed sensor and recorder on a 30 foot tower in a location agreed to by EPA.

• Industrial Hygiene Monitoring and Microbiological Evaluation

These actions were not specified in the Investigative Plan. Stauffer collected a large number of industrial hygiene measurements for dust, lead, arsenic, chromium, H₂S, etc. to assure the protection of workers and public health during Phase I field work activities. Stauffer also retained a consultant Microbiologist (Dr. Stephen Edberg of Yale University) to evaluate the potential for pathogen exposures.

The following summarizes the findings and conclusions based upon the Phase I investigation results.

Findings/Conclusions

Safety and Health

The purpose of the safety and health plan was to assure that worker health and safety would be protected during Phase I. The safety and health plan was prepared by Stauffer's certified Industrial Hygienist and was followed during Phase I activities. Protective clothing and equipment was used during trenching and drilling. Monitoring was done. Procedures were followed and were effective in protecting worker health and safety.

Airborne Contaminants: Based upon industrial hygiene worker exposure monitoring of airborne contaminants onsite during the Phase I study, no exposures to arsenic, lead or chromium were found above OSHA safe limits. Total dust measurements averaged well below OSHA's permissible exposure level.

Biological Agents: Based on the site inspection, process review, sampling and analysis of waste deposits made by Dr. Stephen Edberg (Yale School of Medicine), no hazard exists from anthrax or other disease causing microbes.

Analytical Testing

The purpose of the analytical testing in Phase I was to use as much as possible rapid, cost effective screening techniques to analyze soil and assure the quality of the results is adequate for the objective of Phase I.

X-Ray Fluorescence (XRF): We evaluated X-ray fluorescence as an analytical screening method for determining metals in soil at Woburn. We found XRF to be unsuitable because of variation in the Woburn soil and the metals in it. Therefore, we used the more precise and traditional atomic absorption method to analyze the soil.

Organic Chemical Screening: We evaluated the following analytical screening techniques for soil: Loss on Drying, Loss on Ignition, Solvent Extraction/Residue on Evaporation to Dryness, Oil and Grease, Capillary G.C. Analysis of Solvent Extract and Head Space Gas Chromatography. "Head Space" Gas Chromatography was selected as the method suitable for rapidly screening soil for volatile organic chemicals. The other methods lacked sensitivity.

Bore Hole Air

The purpose of analyzing air in bore holes installed in the waste deposits was to identify possible odor causing compounds and hazardous air contaminants.

Total Reduced Sulfur: The sampling and analysis of air 6-20 feet deep inside two 6" diameter borings showed high levels of hydrogen sulfide (up to 47,000 parts per million (ppm)) and methyl mercaptan (up to 470 parts per million (ppm)) in the east waste pile. At no time during Phase I did we detect hydrogen sulfide above ground level in the worker breathing zone. We concluded that no health hazard existed during the Phase I investigation from H₂S exposure.

Hydrogen sulfide and methyl mercaptan gases are produced during degradation of natural substances such as hides, animal remains, etc. The odor produced by household septic systems is hydrogen sulfide (H₂S). Hydrogen sulfide and methyl mercaptan odors are recognizable at 5 ppb (parts per billion) and 2 ppb, respectively. Since no H₂S or other total reduced sulfur compounds were found in the other 8 bore holes samples, we concluded that one of the probable sources of the Woburn odor is the degradation of east waste pile material to H₂S.

Arsine: No arsine was detected in 23 of 27 air samples collected from the 10 bore holes 6-20 feet below surface. Arsine was detected in 4 bore hole air samples collected from the east and west waste piles at levels from 0.3-0.5 ppb, barely above the detection limit of 0.3 ppb. The OSHA safe limit is 50 ppb. Therefore, based on this data, no potential for health hazard from arsine exists at the Woburn site. In addition, at these very low concentrations, i.e. tenths of a part per billion, the analysis could have represented a microscopic particle of natural soil with naturally occurring arsenic levels, rather than arsine vapors.

Volatile Organics: We had sampling and analysis difficulties due to high sulfur compound interference and cross contamination and were able to collect and analyze only 6 valid bore hole air samples from 2 of the 10 bore hole locations.

The 2 bore holes where 6 valid samples were collected were selected in areas which we thought were the most likely sources of volatile organic chemicals based upon preliminary Phase I data. In these six valid samples, no priority pollutant volatile organic chemicals were detected and 95% of the volatile organics found were sulfur or compounds containing sulfur.

Based on this limited data, no large quantities of volatile organic chemical deposits have been identified to date.

Subsurface

The purpose of this investigation was to locate hazardous waste deposits and assess the impact of waste deposits on the groundwater.

Locate Waste Deposits: To locate the waste deposits, a total of 175 test pits (dug by backhoe) and soil borings (drilled by auger rig) were installed and 461 samples of waste and contaminated soil were collected. Based upon the observation of Roux Associates, 199 soil/waste samples were selected for heavy metals analysis and 151 were screened for organic chemicals.

In addition, Roux Associates performed a resistivity survey of the entire site to provide a screen for unnatural deposits. This survey supported and added confidence to our test pit and boring findings.

Of the 244 acres that required investigative test pits, soil borings and resistivity work, we found the following:

- . 32 acres east of Commerce Way contained no waste deposits
- . 120 acres is shallow bedrock and buildings
- . 92 acres have some contamination

Of the 92 acres with some contamination we found the following:

- . Lead and arsenic were the most widespread contaminants and 22 acres had lead and/or arsenic levels above 1000 ppm
- . Chromium was found on about 5 acres above 1000 ppm and such findings were generally detected in the area where hide residues were found and near the chromium lagoon
- . Barium, copper, and zinc were widespread throughout the site in levels greater than 100 ppm

- Mercury was found in a few samples above 100 ppm. Such findings were always associated with high levels of lead
- Hide residues were found on about 8 acres
- Analytical screening of soil for organic chemicals identified a few areas that might contain volatile organic chemicals. However, the screening technique did not identify or quantify chemicals and more data is needed to assess these findings.

A finding that might be helpful in the Phase II investigation is that waste materials and contaminated soil can be distinguished visually from natural soil.

Groundwater: Fifteen (15) groundwater monitoring wells and 8 piezometric wells were installed upgradient, lateral to and downgradient of the site of the groundwater flow direction. The purpose of these wells was to determine the groundwater flow direction and rate to assess the impact of waste deposits on the groundwater quality.

- The groundwater flows from north to south in both the bedrock and deeper portions of sands immediately above the bedrock.
- No potable supply wells are downgradient of the site in the area north of Mishawum Road (about 1/2 mile from the site).
- Organic priority pollutants were found in higher concentrations in wells upgradient of the site than in downgradient wells.
- Arsenic was found in one downgradient well at 420 ppb which is above the drinking water standard of 50 ppb.
- Arsenic was found at 200 ppb in a well lateral to the site groundwater flow.
- Lead was found in two wells, one lateral to the site groundwater flow at 74 ppb and one onsite at 120 ppb, which are above the drinking water standard of 50 ppb.
- Cadmium was found in one well onsite at 28 ppb which is above the drinking water standard of 10 ppb.
- Only three organic priority pollutants were detected in downgradient wells and none at levels greater than 100 ppb-the drinking water standard for trihalomethanes.
- One downgradient well showed 1.8 ppm of benzene acetic acid. This compound is not on EPA's priority pollutant list.

Surface Water

Stauffer collected and analyzed 9 low flow surface water samples, 14 soil sediment samples from bottom of ponds and streams and 1 leachate sample. We were unable to collect the 9 high flow surface water samples and 2 of three leachate samples because of insufficient rainfall during Phase I. The purpose of collecting these samples was to evaluate impacts of waste deposits on surface waters, either through seepage, erosion of wastes and sedimentation and/or direct discharges of water seepage emanating from waste deposits.

We found the following based upon the low flow sampling:

- No heavy metals were found above drinking water standards in samples of surface water on the site and downstream of the waste deposits.
- Lead was found at 100 ppb (drinking water standard is 50 ppb) upstream of the site.
- A common plasticizer used in many plastic products, Bis(2-ethylhexyl)phthalate was found in all surface water samples.
- Surface water samples collected in locations upstream and downstream of the site show no noticeable increase in organic chemical concentration.
- While sediment samples collected downstream of waste deposits showed elevated levels of arsenic (up to 808 ppm), Lead (up to 1374 ppm), Copper (up to 3366 ppm) and Zinc (up to 1386 ppm), the surface water analyses show that these metals are not dissolving in and migrating with surface water at low flow conditions.
- The waste deposits do not appear to be contributing chromium contamination to sediments.
- Only one elevated level of an organic priority pollutant in sediments (Benzene at 320 ppm) was found. The sample was collected near the west waste pile.
- Generally, there were few organic chemicals found in sediments and their concentrations were in the low parts per million concentrations. In any event, the low flow surface water analyses showed that organics are not dissolving in and migrating with the water.
- During dry weather conditions, direct liquid discharges (leachate) from waste deposits are not a significant source of contamination to surface waters because only one small leachate stream was observed.

We have made substantial progress toward evaluating the impacts of the waste deposits at the Superfund listed site called "Woburn-Industri-Plex 128". However, we need more information to apportion responsibility and evaluate and select remedial action(s). A proposal is being prepared for the Phase II investigation that will be designed to collect the additional information needed.

I. BACKGROUND/HISTORY OF SITE

The 244 acre Woburn site, commonly referred to as the Mark Phillips Trust or Industriplex 128, was designated a hazardous site by the EPA, based on water and soil analysis by the Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Quality and Engineering (DEQE) EPA/DEQE. The site boundary and former Stauffer property is shown on Figure A.1. From 1934 to 1969, Stauffer Chemical Company (or companies Stauffer acquired) had owned and operated a hide glue manufacturing plant on portions of 184 acres of the 244 acre site. Stauffer started negotiations with EPA/DEQE in late 1981 about participating in a study and remedial action at the 244 acre site. A Consent Order between Stauffer and EPA/DEQE was signed on May 25, 1982. Stauffer would undertake a two phase investigative study and recommend appropriate remedial action for the 244 acre site shown on Fig. A.1.

When Stauffer shutdown their plant, it sold the bulk of its property to the Mark Phillips Trust. The Trust began extensive excavation, leveling and moving of soil on the property during the 1970's. This caused very objectionable odors due to exposing hide residue waste that was buried on the site. Hide waste and excavated soil was used to fill wetlands on the site, principally on both sides of a pond at the northern border. Complaints due to noxious odors and filling of wetlands was a cause of the EPA/DEQE investigation. Subsequent investigation discovered hazardous waste deposits which lead to the hazardous waste site designation.

A review of available information was undertaken to identify type, source and extent of hazardous wastes which could be present. This was based on a history of the site by Metcalf & Eddy and an internal search of all Stauffer records. EPA/DEQE files were also reviewed for information on site activities. Especially helpful were Sanborn Fire Insurance Maps dated 1888, 1904, 1910, 1918 and 1926. Aerial photographs for 1938, 1963, 1979 and 1980 were examined for dead or distressed vegetation indicating possible waste deposits.

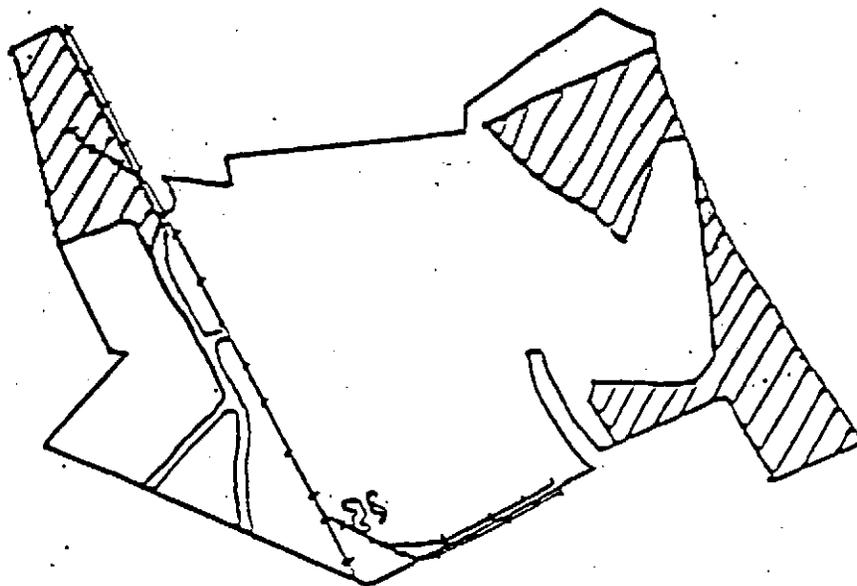


Fig. 1 244 Acre Woburn Site
Clear Area Formerly Owned By
Stauffer Chemical Company

The history of the site will be broken down into the following three periods:

- 1) 1853 - 1933 - Woburn Chemical Works, Merrimac Chemical Company, Monsanto Chemical Company
- 2) 1934 - 1969 - New England Chemical Company, Consolidated Chemical Company, Stauffer Chemical Company
- 3) 1969 - present - Mark Phillips Trust and a few other parties

I.1 1853 - 1933 - Woburn Chemical Works, Merrimac Chemical Company
Monsanto Chemical Company

A. History

On February 17, 1853, Robert Eaton purchased three tracts of land totalling approximately 100 acres in the North Woburn area. An additional five acres were purchased by Eaton on February 26. Of the 105 acres purchased by Eaton, a substantial portion is included in the 244 acre site (Fig. A.1) as defined by the Consent Order.

Eaton founded the Woburn Chemical Works and erected a plant to manufacture chemicals for the local textile, leather and paper industries. According to a local newspaper (Woburn Journal, August 27, 1853), the plant was in operation the summer of 1853. The firm went bankrupt in 1857 but was reorganized with new capital in 1858.

The Merrimac Manufacturing Company owned and operated a string of textile mills in New England. In 1858, they started to manufacture their own sulfuric acid and other treatment chemicals. In addition to supplying their own chemical requirements, Merrimac sold chemicals to other textile mills, tanners and papermakers.

In 1863, Merrimac operations producing sulfuric acid and treatment chemicals merged with the Woburn Chemical Works into the Merrimac Chemical Company (American Chemical Industry: A History, Vol. I, p. 186).

During the period of 1858 - 1890, the main product of the Merrimac Chemical Company was sulfuric acid and related chemicals. At this time, sulfuric acid was the key to chemical production, being the intermediate for many chemicals required by the textile, paper and leather industries. A brief summary of the chemicals produced using sulfuric acid is given in the process section of this report.

In 1899, Merrimac purchased the William H. Swift Company (Eastern Boston), a producer of arsenic insecticides, acetic acid and dry colors. The Sanborn Fire Insurance Map of 1904 shows that these chemicals were being produced at the 244 acre Woburn site.

Between then and 1915, Merrimac became the leading U.S. producer of arsenic insecticides and in 1917 merged with its main competitor, the Cochrane Chemical Company, a producer of sulfuric acid and related chemicals (Haynes, "Chemical Pioneers", pp. 69-73).

Merrimac expanded rapidly from 1890 to 1918, often leading the industry in the introduction of new products. In 1890, Merrimac introduced aluminum chloride use on a large scale in the textile mills of Lawrence and Lowell. The first American plant to manufacture hydrate by the Bayer Process (using bauxite) was built at the 244 acre Woburn site and its operations increased significantly during this period.

Merrimac organized the New England Manufacturing Company in 1915. This company was established adjacent to the Merrimac plant in North Woburn and Merrimac supplied it with acid by a pipeline. New England Manufacturing produced organic chemicals, including phenol, benzene, picric acid and toluene. During World War I, industry practice was to produce phenol from benzene by sulfonation and alkyl fusing (benzene was reacted with H_2SO_4 and SO_3 , washed and then reacted with $NaOH$ at $320-350^\circ C$). The overall yield was only 60-75%. In the commercial process, picric acid is to sulfonate phenol to the 2,4, disulfonic acid with sulfuric acid and then nitrate with nitric acid to the 2,4,6 trinitro phenol. The process is simple and the yield of 70% is obtainable (Footnote 1). Light oils recovered from coal tar distillation were shipped to the North Woburn site for refining. Numerous hydrocarbons could be recovered from the crude coal tar, but principal constituents are benzene, toluene, xylene, and naphthalene (Footnote 1). Typical coal tar purification (thought characteristic of this period) involves treatment with concentrated sulfuric acid to polymerize olefins, washing with 10% aqueous sodium hydroxide and then distillation. Contrary to available literature, trinitrotoluene (TNT) was not produced by New England

Manufacturing in significant quantities at Woburn during World War I. A TNT plant was built at this site but it blew up prior to full operation. New England Manufacturing thereafter sold the pure toluenes (Haynes, Vol. II, p. 131n).

For an extended period, paint grinding or manufacturing was done on the 244 acre Woburn site. EPA files mention paint grinding occurring in 1899 and the 1918 and 1926 Sanborn Fire Insurance Maps show paint manufacturing taking place in Building 29 at Woburn. It is not known what pigments were ground. However, paint pigments could have contained heavy metals such as found onsite. The literature (Footnotes 2 & 3) lists the following heavy metal compounds in various paint formulations: mercury, cadmium, chromium, copper, selenium, nickel, zinc, lead, barium, antimony and arsenic. As added support, that paint manufacturing occurred at the 244 acre site, it is recorded that Merrimac in 1924 acquired the Anderson Chemical Company of Wallington, N.J., a producer of solvents, nitro-cellulose and laquer solutions. Since Merrimac transferred the Anderson Chemical Company operations to Everett, MA, it is possible that some paint operations were performed on the 244 acre Woburn site.

On November 15, 1929, the Monsanto Chemical Works of St. Louis purchased and merged with the Merrimac Chemical Company. Merrimac was allowed to retain its identity as the Merrimac Division of Monsanto. By 1931 all Merrimac operations were consolidated at the Everett, MA site. From 1931 to 1934, no operations were conducted on the site. In 1934, 184 acres of the 244 acre site were sold to New England Chemical Industries (Haynes, VI, pp. 214-18).

B. Chemical Lists

Lists of chemicals known to be present at the 244 acre Woburn site were prepared from available literature (Tables A.1 and Tables A.2.1 through A.2.7). These chemicals were used as raw materials, intermediates or manufactured as products. The lists are by no means complete. Merrimac was known to have manufactured over 50 acids, technical and intermediate chemicals.

The most accurate sources of information currently available are the Sanborn Fire Insurance Maps (Fig. A.2) developed to record safety precautions and hazards. These maps show all buildings as they existed and identified their main function. Information was also obtained from reports and books available at the Woburn Public Library and local college libraries.

The chemical lists were prepared chronologically. The name of the new chemical (as it appears on the map) at that time, the common name, and formula are listed (Table A.1 and Tables A.2.1 through A.2.7). The industrial use of each chemical is also included.

A newspaper article published in 1898 confirms the Sanborn Insurance accounts of the Merrimac Chemical operations as follows:

Three buildings are dedicated to the manufacture of sulfuric acid (40-50 tons/day). Approximately half is sold with the balance used to make muriatic acid, nitric acid, alum, sulphate of alumina (15 tons/day) and Glauber salts (16 tons/day).(1)

C. Chemical Processes

The initial products of the Woburn Chemical Works and Merrimac Chemical Company were sulfuric acid and related chemicals. The plant established by Eaton was of the lead chamber type. The typical H_2SO_4 process was to ignite sulfur and niter (potassium/sodium nitrate) and condense the fumes (sulfur trioxide) in water within the chamber to form sulfuric acid. The acid was reacted with common salt to yield muriatic acid and salt cake. The muriatic or hydrochloric acid was used to make tin chlorides. Sulfuric acid heated with potassium/sodium nitrate formed nitric acid. Salt cake (Na_2SO_4) was reacted to yield hydrated forms, Glauber Salts ($Na_2SO_4 \cdot 10H_2O$) and sulphate of sodas ($Na_2SO_4 \cdot 10H_2O$).

After the Civil War, pyrite ore (as a sulfur source) was substituted for sulfur in sulfuric acid manufacture by the lead chamber method. The transition at the Woburn site was slower. The Sanborn map of 1888 indicates that sulfur was burned in the manufacture of sulfuric acid. After 1904, pyrite was the major source of sulfur. Sanborn maps of 1918 and 1926 indicate that both pyrites and sulfur were used during World War I.

After the pyrite ore was burned to produce H_2SO_4 , the pyrite slag was apparently treated to recover copper. A copper leaching plant is shown on 1918 and 1926 Sanborn maps. Pyrite ore contains substantial amount of metal sulfides, principally arsenic, copper,

lead and zinc, with lesser quantities of antimony, cadmium, nickel, silver, selenium, thallium, etc. (Footnotes 4 & 5). From 1891-1910, Spanish ore accounted for 68% of the U.S. consumption of pyrite (Footnotes 4 & 5). A typical analysis of imported Spanish ore is as follows (Footnote 5):

Copper	(1.75%-2.00%)
Lead	(0.94%)
Bismuth	(0.14%)
Arsenic	(0.45%)
Sulfur	(47.47%)
Phosphorus	(0.007%)
Iron	(40.41%)
Alumina	(1.69%)
Zinc	(1.31%)
Manganese	(0.041%)
Nickel & Cobalt	(0.122%)
Lime	(0.324%)
Magnesia	(0.115%)
Siliceous Residue	(3.59)
Silver	(0.0047%)
Gold	(0.407%)

A 1893 analysis of 7 U.S. pyrite ore sources had low arsenic (trace - 0.02%), 0.6-5.2% copper, 0.8-5.5% zinc and 0.01-0.1% cadmium. No other heavy metals were analyzed (Footnote 4).

Glover and Gay-Lussac acid towers were introduced to the lead chamber acid plants at the turn of the century to accommodate the demand for higher strength acids.

Alum was initially manufactured from alunite. The mineral was ground, calcined, moistened and aged. The potash alum was leached out and crystallized. In 1896, Merrimac built a plant to produce iron-free alum. Aluminum hydrate was manufactured from bauxite using the Bayer process. The hydrate was then reacted with sulfuric acid to form the sulfate.

D. Waste Disposal

The 1888 Sanborn Fire Insurance Maps shows two streams and ponds or swamps running through the site. However, by 1926 large areas of ponds or swamps have been filled in. This is supported by the October 1981 JANPET Study, reporting up to 10 feet of artificial fill over most of the 26 acres (now owned by JANPET) on the 244 acre site. The 1926 map shows an approximate 100' x 300' sludge pond, i.e., present arsenic pit location (see Appendix I, Fig. A.2).

A 1938 aerial photograph (Fig. A.4) was examined for identification of dead/distressed vegetation indicating possible waste disposal areas. The 1938 photo was compared with a 1963 aerial photo (Fig. A.5) to locate areas that still had dead/distressed vegetation. Numerous 1963 locations still had dead/distressed vegetation as in 1938, (Fig. A.3) which appeared unrelated to traffic or plant use. These locations could be considered probable sources of waste deposits. Other 1963 locations had dead/distressed vegetation in the same areas as in 1938, but could have resulted from 1963 traffic or use. Those locations could also be considered probable waste deposits. (See Appendix I, Figures A.3 and A.4.)

I.2. 1934-1969 NEW ENGLAND CHEMICAL COMPANY, CONSOLIDATED CHEMICAL COMPANY, STAUFFER CHEMICAL COMPANY

A. History

New England Chemical Company purchased approximately 370 acres, formerly owned by Merrimac in North Woburn on January 1, 1934⁽²⁾ of which 184 acres is included in the 244 acre site as defined

by the Consent Order (5/25/82). The remaining 186 acres are located to the south of the site. New England Chemical began construction of an animal hide glue manufacturing plant on the site in 1934, and started up the plant in March, 1953 (3). New England Company was purchased by Consolidated Chemical Company in 1936. Consolidated was purchased by Stauffer Chemical Company in the late 1950's. Stauffer then sold various portions of the original 370 acres, beginning in the 1960's and continuing into 1970's. However, the bulk of the property including 147 acres of the 244 acre site as defined in the Consent Order was sold to the Mark Phillips Trust on December 31, 1968. The remaining approximate 35 acres owned by Stauffer of the 244 acre site (Fig. A.1) was sold to others (property owners shown on Fig. A.1-Appendix I). Stauffer continued plant operation until mid 1969, when it completed equipment removal and vacated the site.

B. Chemical Lists

On October 1966 monthly inventory lists 31 chemicals used at the Woburn Plant. (Appendix I(a), Table A.3.) This is believed to broadly represent the chemicals used at the site from 1934-1969.

C. Chemical Process

Glue is made by extracting collagen from animal tissue or bones with hot water. Stauffer only made glue from animal hides but Consolidated might have also made bone glue. Stauffer's raw materials were principally the following:

1. Raw, salted or limed hides or hide pieces from cattle, hogs, sheep, goats, rabbits, deer, etc.
2. Fleshings (fatty skin tissue) removed from raw hides before tanning.
3. Chrome tanned leather wastes consisting of chrome trims, shavings and chrome splits.

The 1968 consumption of (raw materials) Items 1, 2 and 3 above, was approximately 115 million pounds of which chrome tanned leather accounted for approximately 25%. The 1966 and 1967 consumption of chromed tanned leather waste and the other raw materials was approximately the same.

Glue was made in four basic steps:

- Prepare raw materials (glue stock) for cooking;
- Cook glue stock 3 times and collect cooking water;
- Concentrate 3-5% glue in cooking water to 30-40% glue in triple effect evaporator;
- Dry the 30-40% glue on a continuous belt dryer to approximately 90% glue, grind and bag.

The four basic processes were essentially the same for all types of glue stock with the exception of the first step, preparing the glue stock for cooking. The first process step varied for each type of raw material. Fleshings were washed, pH adjusted and then cooked. Hide trims were washed, mixed with lime and then sent to the vats to soak in a lime solution for 50-60 days, which caused the protein content to swell and be more easily extracted. They were then

brought back, washed to remove most of the lime, pH adjusted to 6-7 and cooked. The chrome tanned trims or shavings were treated in various ways to remove the chromium before cooking. Methods used to prepare chrome tanned leather for cooking in the late 1960's are as follows:

1. The chromium stock was washed, mixed with lime and then sent to vats to soak in a lime solution for 50-60 days. The material was then transferred back to wash mills where the lime was washed out. The concentrated sulfuric acid was added to detan the chromium which was next washed from the glue stock. The pH was adjusted and the chrome stock was cooked.
2. A shortened detanning process used sodium hydroxide. The chrome trims were treated with sodium hydroxide, then allowed to set for various periods, 24 hours up to several days. It was then washed to remove sodium hydroxide. It was next treated with sulfuric acid and pH adjusted, similar to the longer chrome detanning process.
3. Sometimes the chrome shavings were treated in an accelerated process consisting of washing, milling with magnesite, (magnesium carbonate), pH adjusted and then sent to cooking.

The hide waste found buried on the Woburn site was the left over material (commonly called tankage) after the raw material was cooked three times. Based upon reviews of production records, this was estimated in a January 6, 1967 report to consist of 50-60,000 pounds of tankage/day at around 25% solids and the remainder water. The quantity varied according to the raw materials and the fact that some materials cooked down much more than others. It

was estimated that about 30% would be from fleshings, 25% from hide trims and about 45% would be from chrome stock.

The tankage from fleshings was treated with concentrated sulfuric acid, steam sparged (inject live steam) and allowed to settle to remove the grease for sale. The degreased fleshing, hide trim and chrome tankage was then put into trucks and hauled to burial pits on site. Some pits were up to 18 to 20 feet deep and dug large enough to receive one to three weeks of waste from the plant. All trash from the plant was placed in here.

Another large source of materials for disposal in these pits was wood shavings from the cooking operation. When cooking the glue stock, a 6 inch layer of wood shavings was placed underneath planks at the bottom to act as a filter. Every time the kettles were cleaned, the wood shavings were thrown away along with the cooked glue stock (raw materials). Chloride of lime was thrown on the hide waste daily in the pits to minimize odor emissions (4).

D. Waste Disposal

All wastewater was given primary treatment and then discharged to the Metropolitan District Commission sewer. The primary treatment system consisted of the following:

1. A small settling basin estimated at 75' to 100' on each side;
2. A series of grease collection basins; and
3. Large settling lagoons.

The small settling basin was cleaned about every other week with a clam shell crane. Sludge, consisting of primarily lime, hair and larger pieces of hide, was placed into two small pits on the east and west side of the basin to dewater. There was a five inch pipe on the bottom of each pit to drain the water back to the settling basin.

The grease from the top of the grease collection basins was cleaned weekly by skimming with a crane bucket and dumped in adjacent concrete basins to concentrate. It was then hauled in a dump truck back to the plant for recovery and sale as non-edible grease. The wastewater from the grease collection basins discharged to one of two large sludge lagoons used for settling. About 1938, one large sludge lagoon about 300' x 400' was constructed. However, it was too large to easily clean and the sludge could never dewater. Therefore, after approximately 10 years of operation, the lagoon was spilt, divided lengthwise into two (2) sections and fingers were built out from each side so that a crane could easily clean the lagoons. Supposedly, when the lagoons were first split, one section was used for a year. It was then taken out of service and the other section was put into service by diverting the water through valves. The out-of-service section of the lagoon was allowed to dewater for several months and then the sludge cleaned out and hauled to the disposal pits or spread on the ground east of the main plant buildings, creating a white flat area. When pits for disposal were dug in the area east of the main building, this sludge was placed in those pits. To the best of Stauffer personnel's knowledge, no sludge was piled for dewatering west or south of the present Mayflower Trucking Company.

During the last several years that Stauffer operated the plant, the east lagoon was out of service and had trees and vegetation growing in it. The west lagoon was being used but was not cleaned frequently enough to be effective. Sludge had built up and water was short circuiting through it. The material in the west lagoon was also very odorous. Benthic deposits would produce gas bubbles and odors.

All solid waste was buried on site in pits a few of which are estimated to be up to 18 to 20 feet deep. These pits were covered with soil when filled. The pits were constructed by excavation or where terrain permitted, by piling dirt up to make a diked pit. The principal solids were as follows:

- . Trash - broken pallets, empty bags, broken planks from wash mills and cooking kettle bottoms, paper, etc.
- . Dewatered solids from the pits on the east and west side of the small concrete settling basin. This material was cleaned from the dewatering pits about every two weeks and hauled to the disposal pits. It was primarily lime, hair and larger pieces of hide.
- . Dewatered solids from wastewater settling lagoons. About once a year an alternate lagoon was taken out of service and drained. After dewatering, the sludge was hauled from the lagoons to the burial pits. (However, as noted above for the last few years of Stauffer operations only one lagoon was in service.)

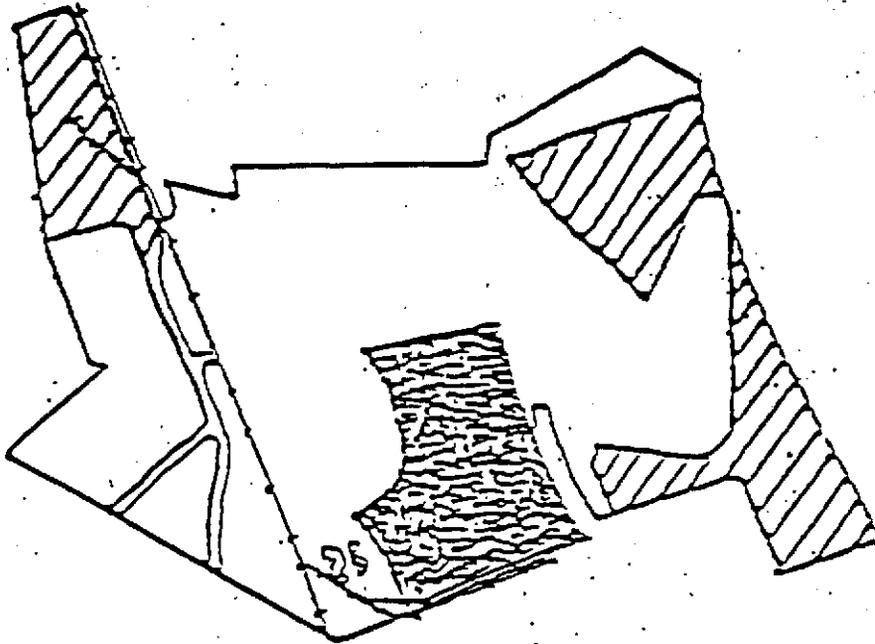
• Tankage and wood shavings left after cooking hides for glue.

After the hides had been cooked three times there was a residue at the bottom of each cooking kettle. The depth of this depending on raw material varied from six inches up to 1 to 1-1/2 feet. It was removed with a clam shell crane and placed into a large tankage vat. The planks at the bottom of the cooking kettle were then taken up and the four to six inch layer of wood shavings taken out and also placed in the tankage vat. The tankage was then loaded into dump trucks and hauled to the burial pits for disposal. Customarily, chloride of lime was thrown on top of the sludge to minimize odors.

The crescent shaped pile of material northeast of the lagoons, in the 1938 photos, was not glue manufacturing waste. The material, was on the site when New England Chemical bought the site, and was reportedly bauxite. It was sold and hauled away in railroad cars in the late 1930's. It was also thought some material north of the plant, near present pile of red iron deposits, was also sold at this time.

The area where Stauffer buried waste on the site (see sketch below) was bound roughly as follows:

- On the north by an east-west road running just north of the old warehouse.
- On the east by the Aberjona River (approximate location of present Commerce Way).
- On the west by the eastern edge of the JANPET property and at the southern end by the old lagoons.
- On the south by the edge of the site as defined by the Consent Order.



Dark Area - Approximate Location Of
Stauffer Waste Burial

Crossed Hatched - Property Not Owned By Stauffer

I.3 1969 - Present Mark Phillips Trust (M-P Trust)

A. History

The M-P Trust purchased approximately 300 acres of the 370 acres owned in Woburn by Stauffer, including 147 acres of the 244 acre site on December 31, 1968. The balance of Stauffer's 370 acre property was sold to others, including about 35 acres of the 244 acre site under investigation. M-P Trust also purchased an additional 39 acres of the 244 acre site from other parties about this time. The M-P Trust combined the 188 acres of the 244 acre site under investigation that they owned with several hundred acres to the south of the site.

M-P Trust began development of the larger site (Industriplex-128) for commercial use in the 1970's. This involved filling, excavating, etc. to facilitate sale of various parcels of property. When old hide burial areas were uncovered, this created noxious odors and neighbor complaints.

There were continued complaints about odors and site development. Concerned local citizens attempted through local, state and federal officials to force the M-P Trust to control odors, dust, etc. or stop development completely. DEQE and the Town of Redding obtained a restraining order in 1977. However, activity continued until EPA obtained a Court Order stopping development in 1979.

The M-P Trust had a consulting engineer, Melvin W. First, make a study of potential site hazards. On 27 November 1972, he reported that buried chromium and arsenic waste was present. However, he advised this was not a hazard if dust due to earth moving was kept low. He said that unpleasant odors were caused by opening old burial pits on site. A principal constituent of the odor was hydrogen sulfide. He reported that the odor could best be controlled by minimizing waste exposure at the old burial pits and the relocated waste sites.

These relocated waste deposits, so called east and west waste piles, covered several acres adjacent to or in the north pond. Other site development operations uncovered and mixed waste deposits from past manufacturing operations.

The excavated waste was deposited in a pile (east waste pile) under Boston Edison's Right-of-Way (R/W) #14 high voltage support, which decreased the normal distance of 80 feet from conductor to ground level to approximately 15 feet.⁽⁶⁾

While owned by M-P Trust, the site was allegedly used by third parties for dumping various sludges and liquids. According to local newspaper articles, various wastes were observed being dumped at the site.

II. PHASE I STUDY: Scope and Purpose

A. - Background

On May 25, 1982 a Consent Order between Stauffer Chemical Company, the U.S. Environmental Protection Agency (EPA), and the Massachusetts Department of Environmental Quality and Engineering (DEQE) was signed after months of negotiations. The Consent Order required Stauffer Chemical Company to undertake a site investigation of the Woburn Industri-Plex 128 site listed on EPA's interim list of the "115" top priority sites established under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, commonly called "Superfund". Stauffer would pay for and manage the investigation under the close scrutiny of both the EPA and the DEQE. Once the investigative study was completed, and prior to implementation of remedial action, a plan will be prepared for apportioning financial responsibilities.

The Consent Order called for a two phase investigation of the Woburn site. Phase I tasks were specifically delineated in the Consent Order while only the objectives for Phase II were described. The overall purpose of the Woburn site investigation is to develop information needed to evaluate environmental impacts of waste deposits and develop a cost effective remedial action.

B. Purpose of Phase I Study:

The purpose of the Phase I study was to expeditiously locate hazardous waste deposits and assess their impact on surface waters, groundwaters and air.

C. Scope

The area of investigation was approximately defined in the Consent Order. A better definition of the site boundaries was needed to help locate waste deposits. Therefore a more precise boundary survey of the 244 acre site under investigation was prepared and is shown on Appendix I, Figure A.1. The site is located at the north end of the Industri-Plex 128 property. The site is bounded roughly as follows:

- east by Rt. 93
- north by the Sheehy property and Moss & Gilberston, et al property
- west by the western boundaries of the Boston Edison Right of Way, New England Pigments and Resin and the Phyllis O'Neill property
- south on a line running parallel to the railroad spur.

The properties as owned on November 1, 1981, included in the site investigation are as follows:

- Mark Phillip Trust Parcel consisting of the following properties: Janpet, Woodcraft Supply, Anthony Femmini, Ganglani, Ronald F. Liss, Mary E. Fitzgerald, John J. Mulkerin, Boyd Corp., Woburn Industrial Association
- Other Properties West of the R.R. Tracks:
 - Paul K. O'Neill - De Rosa Realty
 - John Corta - Boston Edison Right of Way
 - Stafford - New England Resin and Pigment
 - Pepco Company

The Phase I study was detailed in Appendix B of the Consent Order.

The scope of the work can be summarized as follows:

- 1) Review, Assemble and Prepare a Report on Available Site Investigation Information; A substantial amount of information was available on the site, including previous subsurface investigations, accounts of industrial activities in local journals, libraries, aerial photographs, etc. This review was needed to avoid duplication of work, aid in locating waste deposits, selecting appropriate chemical analyses by identifying likely composition of waste, and assuring an expeditious and cost effective study.

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After Pg II-3

Before Pg II-4

- 2) Preparation of a Site Safety and Health Plan: The health and safety plan included specifications for protective equipment, worker exposure monitoring, worker training and medical examinations. The plan was needed to assure the protection of worker and public health and safety during the Woburn field investigation. As an added benefit, some information developed by industrial hygiene (I.H.) monitoring would be useful in assessing impacts on air.
- 3) Prepare an Accurate Site Survey and Topographic Map: The topographic map of the 244 acre site would show 2 foot contours of ground surface elevations, known contamination areas identified from site history and observations and suspected contamination from areas on aerial photographs indicating distressed or dead vegetation. The topographic map was needed to aid in the assessment of groundwater flow and the selection of surface water sediment samples.
- 4) Surface Water:

The surface water on the site consists of the following:

- The Aberjona River and its three tributaries;
- The Railroad Drainage Ditch fed by two to three smaller ditches; and

- Phillip's pond next to Rt. 93 and two to three others east of Commerce Way.

To assess the impact of waste deposits on these surface waters, the following analyses were needed:

a. Surface Water:

Surface water investigation included collecting samples at high and low flow conditions as the water entered the site, on the site and as it left the site, installing flow measuring devices and measuring flow, and analyzing the water samples for heavy metals and organic chemicals.

b. Sediments:

Investigation of sediments in surface water included collecting 14 samples of soil at the bottom of surface waters and analyzing the samples for heavy metals and organic chemicals. The purpose was to assess the effects of erosion, runoff and leaching on surface waters and the sedimentation/precipitation of contaminated soil or eroded wastes in the surface waters.

c. Leachate:

Water that was observed emanating from waste deposits during the investigation was sampled and analyzed for heavy metals and organic chemicals to assess effects of point source discharges of possible concentrated pollutant streams to the surface waters.

5) Subsurface Investigation

The subsurface investigation was conducted to determine the location of waste deposits and to assess their impact on the groundwaters. The investigation included the following:

a. Resistivity Survey:

A resistivity survey was conducted to help locate and define buried wastes. Resistivity is a geo-physical technique which can be used to identify waste deposits by measuring differences in the electrical conductance of unnatural and natural deposits.

b. Groundwater Monitoring Wells:

Groundwater monitoring wells were installed to define the quality, flow direction and flow rate of groundwater entering the site, on the site, and leaving the site. Fifteen (15) monitoring wells were drilled and water samples collected and analyzed for heavy metals and organic chemicals.

Piezometric wells were installed and water level measurement were made to determine groundwater flow direction and prepare a water level map.

c. Soil/Waste Deposits:

To locate waste deposits, soil borings/holes were made by auger rig drilling or by backhoe. Soil samples were collected with a split spoon in bore holes or by a hand held auger rig. The locations for the auger rig drilling and/or backhoe digging were based upon aerial photographs, a geologist's expert observations, the resistivity survey and site history. The portions of the soil samples that were analyzed were selected based upon a geologist's observation of unnatural deposits. Some samples were collected of naturally looking deposits to verify geologist's observations. The samples were analyzed for heavy metals and analytically screened for volatile organic chemicals.

d. Bore Holes:

Bore holes were drilled at 10 locations and the air inside these holes was analyzed for volatile organic chemicals (VOC), total reduced sulfur compounds, and arsine. The purpose of these analyses was to identify odor producing compounds and hazardous volatile organic chemicals.

6) Microbiological Evaluation:

Samples of waste material selected by an expert microbiologist were collected and analyzed for anthrax and other possible pathogenic microbes to address the extremely remote possibility of health hazard due to pathogens.

7) Analytical Testing:

- a) Soil: Evaluations were made of several cost effective and rapid analytical screening methods for identifying heavy metals and organic chemicals in soil. Intense evaluation was made of X-ray fluorescence (XRF) for metals, and a method was developed for screening soil for volatile organics. These methods were needed to effectively and rapidly investigate 244 acres for possible waste deposits.
- b) Water: EPA methods for collection and analysis of water samples were used, where suitable.
- c) Bore Hole Air: Industrial Hygiene sampling and analysis procedures were used to collect and analyze samples of air down inside bore holes.

- d) Quality Assurance: For each batch of 10 samples collected and analyzed. Four (4) quality assurance samples were prepared and analyzed to assure reliable results.
- e) Chain of Custody: Documentation procedures were established along with appropriate forms to permit accurate tracing of each sample from collection to final analysis.
- f) Computer Program: A computer program was developed to cost effectively manage and evaluate the huge volume of data generated and help assure procedures were followed.

8) Organization/Staffing/Facilities:

The Phase I study was completed over a five month period.

The project organization is shown in Appendix IV.

a) Consultants:

Consultants were employed to provide the following special services:

Hydrogeology/geology, soil sampling,

groundwater monitoring -

Roux Associates

Evaluation of microbiological possible

from buried wastes -

Stephen Edberg, M. D.
Yale University

Analytical analyses of metals in
 soil water samples, bore hole air
 samples, leachate samples,
 stream sediment samples -

Environmental
 Research and
 Technology (ERT)
 Laboratories
 Concord, MA

Title Search of Property -

Rackemann,
 Sawyer and
 Brewster

Measurement of flow rate in surface
 water at high flow conditions

- Metcalf and Eddy

b) Stauffer Staff:

About 12 Stauffer Chemical Company specialists performed
 the following tasks:

- Extensive preliminary and on-going Industrial
 Hygiene and Safety monitoring;
- Surveying all locations sampled or investigated;
- Computer system to catalog and retrieve all sample
 data, analytical results, locations, etc.;
- Preparation of analytical methods and quality
 assurance procedure in compliance with EPA
 standards and regulations at the Stauffer operated
 Woburn laboratory facility;
- Sample preparation, field quality assurance;
- Organic chemical screening of soil samples; and
- Stream flow measurements at low flow conditions.

c) Facilities:

Stauffer rented facilities for offices adjacent to the site to provide administrative support. The existing onsite EPA trailer was used for equipment storage and office space for onsite field workers. At 10A Henshaw Street; Woburn, Ma., a laboratory was outfitted with hoods, benches, analytical equipment, laboratory supplies, etc. and was staffed to prepare samples for possible subsequent analysis, securely store retained samples for future analysis, and perform soil organic screening analysis.

Environmental Control facilities included the following:

- . Construction of a cement pad with a collection sump near the Woburn site to contain any washwater from mandatory onsite equipment cleaning and boot washing prior to leaving the site. The washwater was discharged to a settling tank and then to the municipal sewer, as approved by the local authorities.
- . Existing EPA shower trailer was used for field workers' showers. The shower water was discharged to the municipal sewer, as approved by the local authorities.

III. OBJECTIVES/ASSIGNMENTS VS. ACCOMPLISHMENTS:

A. Background

The Consent Order (Appendix B) stated the following objectives for the Phase I Study:

- . Locate hazardous waste deposits on Woburn site;
- . Assess the impacts of the waste deposits on surface waters, groundwater, and air;
- . Expedite the investigation by using onsite analytical screening techniques.

The Phase I investigation met or exceeded these objectives.

The waste deposits were roughly located on 92 acres (of the 244 acre site) located west of Commerce Way. The waste deposits were initially characterized chemically and visually. Extensive sampling and analysis soil and waste deposits, groundwater, surface waters, and surface water sediments was completed and evaluated. Based upon these analyses, the Phase I report provided initial assessments of the impacts on surface waters, groundwaters and air.

The analytical testing methods were selected to provide the most rapid results that would be scientifically supportable and provide the data needed to locate waste deposits and assess the impacts on the environment. For example, a method for screening soils for volatile organic compounds (VOC's) was developed, correlated and used.

Over 15,000 pieces of analytical information were obtained which covered all the specified environmental media and over 95% of the 244 acre site. This extensive investigation was accomplished in less than 6 months.

A few specific assignments which were not completed in Phase I but will be addressed in Phase II are as follows:

- . Collection/analysis of (9) high flow surface water samples could not be done because weather conditions did not produce high flow in streams at the time of the field investigation;
- . Collection/analysis of three (3) leachate samples was not possible because of insufficient rainfall. Only one sample was collected;

- Six (6) air samples, three from each of the (2) _____ holes were successfully obtained and analyzed _____ volatile organic chemicals. While more than 30 _____ samples collected from the 10 bore holes as re _____ Consent Order, sampling and analysis methodology _____ problems invalidated most sample results; _____

- Soil sampling in the west waste pile and in the _____ lagoon area was limited due to inability to get _____ equipment into areas. _____

B) Detailed Comparison of Consent Order Assignments _____

Work Actually Done: _____

- 1) The following discusses each task specified in the _____ Order and Investigative Plan and then compares the _____ accomplished during the Phase I investigation: _____

• Prior Site Investigations and Available Information _____

The Investigative Plan required as a first step, a _____ and evaluation of available information. Prior in _____ gations, site history, investigation of newspaper _____ insurance records, and local libraries were resea _____ the earliest date that the site was used for indus _____ manufacturing. A list of chemicals manufactured or _____ onsite was prepared. _____

2) Review Prior Investigative Data

Data available from all accessible sources on soil, surface water, groundwater, leachate, sediment and air was obtained and reviewed. There are approximately (60) prior sample results which are considered reliable and are included in Appendix II, Analytical Data.

3) Prepare a Boundary Site Survey

The Investigative Plan submitted by Stauffer required upgrading, the Camp, Dresser and McKee (CDM) Survey and Topographic map map prepared for EPA in February 1982. In addition, it required a revised map that was to show all known areas of contamination from site history, and observation of dead or distressed vegetation shown on existing aerial photographs of the site.

The CDM map was reviewed and upgraded. A survey was made to provide field bench marks for sampling locations and water level measurements. A consolidated map was prepared showing location of known waste deposits from site history and suspected waste deposits from aerial photographs of 1938, 1963, 1970 and 1979.

4) Safety & Health Survey and Plan

The Investigative Plan (IP) required a survey of the site by a health and safety specialist, as well as preparation of a safety and health plan to assure protection of worker and public health and safety during the field work.

A review of available data was made to determine what potential hazards could be present. A certified Industrial Hygienist headed a team that made a complete 3 day survey of the site to identify potential hazards. The team evaluated potential hazards using portable equipment which included:

- .. Photoionization instrument
- .. Combustible gas meter
- .. Portable aerosol monitor
- .. Detection tube air measurements of arsine, and aromatic hydrocarbons

In addition, personal samplers were used to collect total dust samples and selected particulate samples collected were analyzed for arsenic, lead and chromium.

A certified Industrial Hygienist prepared a safety and health plan, based on his own 3 day inspection and measurements, prior findings and records, and in accordance with stringent Federal recommendations and standards. It

provided for site security and access, controls to prevent off-site contamination, personnel hygiene requirements, appropriate medical pre-placement physicals, worker training and emergency planning. In addition, personal protective equipment, respirator and Industrial Hygiene monitoring requirements were established based on the types of work activities and their locations.

5) Analytical Testing

The I.P. specified analytical techniques for water, stream sediments and bore hole air and required evaluation for screening techniques for metals and organics in soil.

It was believed that X-Ray fluorescence would be a cost effective method to rapidly analyze soil for heavy metals. Two X-Ray fluorescence equipment manufacturers were contacted, and the most promising was visited in Texas to discuss soil analysis and inspect equipment. Several contract laboratories were also visited to inspect X-Ray fluorescence facilities.

Stauffer prepared and analyzed "typical" Woburn soil with atomic absorption (AA), for use as test samples for two equipment manufacturers and contract laboratories. However, X-Ray fluorescence proved unsuitable because of Woburn soil variations. Therefore, it was not possible to develop a rapid screening method for heavy metals, and use of the slower but more accurate atomic absorption method was necessary.

Various analytical methods were investigated to provide a soil organic screening method. These included loss on drying, loss on ignition, extraction and head space gas chromatography analysis. The only method that proved suitable was head space analysis. Head space analysis required extensive method development, i.e., samples had to be ground at liquid nitrogen temperature, special calibration, etc. Stauffer provided and installed a Perkins- Elmer Model F-45 head space analyzer with automated feed and computer printout, and the required support equipment such as a grinder and freezers were installed at 10A Henshaw Street Laboratory. All other analytical methods followed requirements of the standard EPA procedure for priority pollutant analyses.

6) Provide Computerized Data File for Storage and Retrieval

The I.P. specified the development of a computer system to help assure procedures were followed, and provide for rapid, cost effective management and evaluation of the large volume (greater than 15,000 pieces) of information.

The computer system was developed specifically for the Woburn project. It organized, stored, retrieved and correlated the large volume of data from Phase I. More than 1350+ separate analysis on field samples and Q.A. samples were completed which generated over 15,000 results. It was possible to account for all of the 1350+ separate analyses and their results. The very few sample analyses missing were traced to specific causes, e.g., broken sample vial in contract laboratory, high sulfur compound interference, etc.

7) Provide Sample Chain of Custody Records

It was necessary to track over 2000 samples. There were less than (5) samples which could not be tracked through each preparation and transfer step. These were soil samples 73631809 and 73631828 and bore hole air arsine samples from bore hole AS-1, AS-3 and AS-4. Apparently the two soil sample vials were empty when the analyst opened them. The three (3) air samples were apparently not analyzed or the analyst did not record the results.

8) Quality Assurance

The Investigative Plan required an extensive Quality Assurance Program to assess the data reliability. Four (4) Q.A. samples were prepared and analyzed for every batch of 10 or less samples collected.

9) Perform Soil Resistivity Survey

The I.P. required that Stauffer determine if resistivity could be used to locate buried wastes and determine the extent of groundwater contaminated. If suitable, Stauffer would make a resistivity survey of the site on 400 foot grid spacing with closer grid spacing in areas of concern.

The resistivity survey was performed with the following equipment: A Geonics, Limited Model EM-31 to measure 0-20 foot depths and a Model EM-34 for depths up to 90 foot. The survey used a 200 foot grid spacing. In addition, to assure total area coverage, continuous resistivity readings were made in areas between grid points.

10) Test Pits and Soil Borings

The I.P. specified that 100 test pits and borings should be dug and soil samples selected for analysis.

A total of one hundred and seventy five (175) test pits and borings were dug. Four hundred and sixty-one (461) soil samples were collected from these test pits and borings. Based upon the consultant geologist's

observations of natural and unnatural deposits, 199 of the 461 samples were selected for heavy metal analyses and 151 were selected for organic chemical screening. A substantial number of these samples were analyzed for both heavy metal and organics. Duplicate samples of all 461 samples collected were retained for possible further heavy metal analysis. Additionally, approximately 140 soil quality assurance (Q.A.) samples were also prepared and analyzed.

11) Surface Water

The I.P. specified that (9) low flow water and (9) high flow water samples be collected and analyzed for standard water parameters and priority pollutants. In addition, installation of three flow measuring devices in selected streams was required.

The (9) low flow surface water samples were collected and prepared along with (4) additional Q.A. samples and analyzed for standard water parameters, priority pollutants, and up to 20 other organics. Weirs were installed at appropriate locations in the stream to measure flow rates. As mentioned previously, high flow surface water samples were not collected due to lack of rain. The high flow samples will be collected in March-April 1983 and the results included in the Phase II Study.

12) Stream Sediments

The I.P. specified that (14) sediment samples would be collected and analyzed for priority pollutants. All the required (14) sediment samples, along with (8) Q.A. samples were collected and analyzed for priority pollutants and up to 20 other organic chemicals.

13) Leachate

The I.P. specified that (3) leachate samples be collected and analyzed for priority pollutants. However, due to insufficient rain, only one leachate sample could be collected. Additional leachate samples will be collected in March-April 1983 and included in the Phase II Study. One (1) leachate and (1) background natural spring sample along with (4) Q.A. samples were collected, prepared and analyzed for priority pollutants and up to 20 other organics.

14) Groundwater Monitor Wells

The I.P. specified that (13) groundwater monitor wells be drilled, sampled and analyzed for priority pollutants. Conversion of soil boring holes that encountered groundwater to piezometers was required to provide water level measurement. In addition, selected soil samples from the aquifer were to be tested for permeability, grain size distribution and ion exchange capacity.

Fifteen (15) wells were drilled and water samples collected. Samples were analyzed for priority pollutants and up to 20 other organics. In addition, (8) soil bore holes where groundwater was encountered were converted to piezometers to measure water levels. Water levels were measured and a water table map prepared. Because of homogeneity of the aquifer sands and absence of clay particles/beds, the consultant hydrogeologist determined that testing the aquifer soils for permeability, grain size distribution and ion exchange capability was not needed. The homogeneity of the aquifer sands allowed data in published literature to be used to determine permeabilities.

15) Bore Hole Air

The I.P. specified that ten (10) bore holes be installed and air samples collected and analyzed from inside the bore holes as follows: 30 arsine, 30 total reduced sulfur (TRS) and 30 volatile organic chemical compounds (VOC) samples. Ten (10) bore holes were installed and (30) arsine, (30) TRS, (38) VOC plus an estimated 30 Q.A. samples were prepared and analyzed. The results of 32 of the 38 VOC air samples were invalidated because of sample cross contamination. However, we modified the sample collection method to avoid cross contamination. We went back to the field after field work had ceased and resampled two existing bore holes. A total of (6) air samples were collected; (3) from each bore hole by the modified method and analyzed for VOC's.

16) Install a Meteorological Tower to Measure and Record Wind Speed and Direction

The I.P. specified that a Meteorological Tower be installed to measure wind direction and velocity.

A Weather Measure Model W-203-RP13L wind speed sensor with 0.6 mph threshold vanes, a WTS 102-HF/540 wind translator and EPR 200A Dial channel polyrecorder was purchased. It was mounted on a 30 foot tower and placed to avoid wind turbulence and interference. The recorder and indicator were permanently mounted in the EPA trailer at Commerce Way.

C. Other Accomplishments Not Specified in Consent Order:

1) Industrial Hygiene

No specific Industrial Hygiene monitoring requirements were required in the Consent Order. However, Stauffer collected and analyzed (16) filter samples for particulates which resulted in (9) arsenic, (9) lead, (16) chromium (total) and (12) total dust results. Additionally, 142 total dust measurements were made with a direct reading aerosol monitor during field work. Screening measurements were made for vapor and gases using detector tubes, a photoionization meter and combustible gas meter.

2) Microbiological Evaluation

The I.P. did not specify any analysis of the potential for the wastes deposited at the Woburn site to contain microbial pathogens. However, because of community concern in this regard, Stauffer hired a consultant on pathogenic microbes. He visited the site and reviewed the site safety and health plan and the available process information. Four (4) samples of waste were collected and analyzed for anthrax and other microbes, per the instructions of the consultant.

IV. SAFETY AND HEALTH PROGRAM

A. Background:

The senior Stauffer certified Industrial Hygienist assigned to the project had visited the site prior to beginning field work. He reviewed records pertaining to site history, reviewed findings from other waste site studies, reviewed past results from site environmental studies/sampling. The information available was substantial (Appendix V) and sufficient to prepare a draft Safety and Health Plan. The Phase I field investigation began with a site safety and health survey to gather data needed to finalize a site Safety and Health Plan (SHP). This investigation was accomplished by the safety and health specialist who was assigned to monitor site field work throughout Phase I on a daily basis. This safety and health specialist in consultation with Stauffer Corporate Industrial Hygiene Safety personnel, surveyed the site and collected samples for airborne particulates (total dust, lead, arsenic and chromium), gas and vapors (photoionization detector), aromatic hydrocarbons, carbon disulfide, hydrogen sulfide, arsine and combustible gas.

B. Safety and Health Plan:

Based on the initial survey and the detailed review of the available information, the safety and health plan was finalized (Appendix V). It provided for site security and access, controls to prevent offsite contamination, personnel hygiene requirements, appropriate medical pre-placement physicals, worker training and emergency planning. Personal protective equipment, respirator, and industrial hygiene monitoring requirements were established based on the types of work activities and their locations. Based upon the accumulated knowledge of site conditions, worker exposures were expected to be below the permissible exposure limits (PEL's) established by the Federal Occupational Safety and Health Administration (OSHA). In any event, activities that might create exposure were carefully controlled and supervised by a health/safety specialist.

- 1) Airborne Particulates: The SHP provided for the determination of worker exposures to lead, arsenic, chromium and total dust. Past ambient air sampling results around the inactive site and previous soil analyses indicated no significant potential for exposure unless operations in contaminated areas became very dusty.

Appendix III, Table B.1 summarizes 36 results for Lead (Pb), Arsenic (As), and Chromium (Cr) from personal breathing zone filter samples collected during various field tasks. All results except two were below detectable levels. One Arsenic result was $0.11 \mu\text{g}/\text{m}^3$ (at the detection limit) which is about 100 times less than the OSHA permissible Time Weighted Average of $10 \mu\text{g}/\text{m}^3$. Lead was not detected in any sample with the highest limit of detection being $17 \mu\text{g}/\text{m}^3$ compared to the OSHA-PEL of $50 \mu\text{g}/\text{m}^3$. One Chromium (total) sample was at $4 \mu\text{g}/\text{m}^3$ and in all others, Chromium was not detected with detection limits $\leq 6.3 \mu\text{g}/\text{m}^3$. Thus, Chromium exposures were much less than the most conservative of the OSHA permissible exposure limits for Chromium compounds ($100 \mu\text{g}/\text{m}^3$).

Appendix II, Table B.2 summarizes the 142 total dust measurements accomplished during all aspects of the Phase I field investigation with a GCA Corporation, RAM-1 aerosol monitor. These measurements were made throughout Phase I in order to verify that operations were being properly controlled to keep dust generation to a minimum. The average for all total dust measurements for all tasks was low and less than $1 \text{ mg}/\text{m}^3$. (On

8/3/82 a high 80 mg/m³, total dust level was initially seen in the immediate area of a worker starting to drill in the northeast area of the site with sandy soil considered to be clean. The site safety and health specialist immediately required application of water to reduce dust generation and follow-up total dust measurement verified adequate control (0.34 mg/m³.) These total dust results represent peak total dust levels in the breathing zone of workers onsite, since measurements were taken during tasks most likely to generate dust. Actual full shift time weighted average exposures of workers and dust levels away from the immediate vicinity of these activities would be significantly lower. Thus, monitoring data for lead, arsenic, chromium and total dust demonstrate that, as expected, worker exposures were well below levels recommended for the protection of health during a working lifetime.

- 2) Biological Agents: A review of hide tanning and glue manufacture process was made to address questions concerning the potential for exposure to pathogenic organisms during work on the waste piles. All indications were that the potential for a health hazard was remote.

Dr. Stephen C. Edberg, Director, Clinical Microbiology Laboratory, Yale-New Haven Hospital and Associate Professor of Laboratory Medicine, Yale University School of Medicine was retained as a microbiological consultant to visit the site with Stauffer's Director of Occupational Medicine, to review the tanning and glue manufacture processes, review the Safety and Health Plan and recommend any investigations/controls considered necessary for health protection.

As recommended by the consultant, bacteriological soil samples were collected from both new (relocated) and old waste piles at 6 inch and 6 foot depths. These samples were sent to Madison Bacteriological Laboratories, Inc. for anthrax analyses and the Clinical Microbiological Laboratory, Yale-New Haven Hospital for isolation of both pathogenic and common soil microbes. All anthrax results were negative and none of the microbes, fungi, yeasts and molds were considered by the consultant to represent a hazard for workers on site at levels observed (Appendix V).

- 3) General Area Survey for Gas and Vapors: During the initial site safety and health survey, screening measurements were made with a photoionization meter (HNU Systems, Inc.) to determine the potential for gas/vapor exposures. All readings were non-detectable

(≤ 6 ppm) based on an 11.7 ev. lamp and calibration against isobutylene. Draeger detector tube measurements were made at ground level where maximum gas/vapor concentrations were likely (see Appendix V for limitation of Draeger tube). Results for aromatic hydrocarbons, carbon disulfide, hydrogen sulfide were all non-detectable (Table B.3) and below health limits. Combustible gas could not be detected using a survey instrument calibrated against methane, except briefly, when gas noted to be bubbling through surface water near the waste piles was confined in a drainage tile. The peak instrument reading was well above the lower explosive limit (20% of LEL).

The review of background information and the initial site visit indicated that gas and vapor concentrations in the breathing zone of workers should be minimal when compared to occupational health limits. The potential for nuisance odors associated with low levels of volatile sulfur compounds and the evolution of methane gas from the waste piles was recognized.

- 4) Personal Samples, Volatile Organic Compounds: Three breathing zone (BZ) air samples for organics were taken during Phase I work in the vicinity of the bore holes to provide additional exposure information. These results and the organic vapor samples collected from within ten bore holes have been invalidated because of cross contamination as indicated by excessively high blank results. However, no

detectable levels of vapor and gases were measured in the breathing zone of workers using the photoionization instrument. Only when the photoionization detector was held next to the surface of freshly extracted bore hole soil samples or in the top of a bore hole was a response noted (2 to 9 ppm referenced to the isobutylene standard provided by the instrument manufacturer). One reading made directly in the top of bore hole B-10 was 56 ppm. As indicated by BZ measurements, it is important to emphasize that these surface readings do not represent worker exposures or general ambient air levels. Both BZ measurements and ambient air measurements were non-detectable.

On 1/24/83, two air samples were collected inside bore holes AS-1 and AS-6 and analyzed for volatile organic compounds. These results are presented in Table B.6.2. An ambient air sample was also collected 30 ft. downwind from AS-1 and analyzed for volatile organic compounds. These results are presented in Table B.4. Detector tube measurements for H₂S made during the collection of the above samples are included in Table B.3, and additional information on the range and limitations of detector tubes used are presented in Appendix V. The hydrogen sulfide measurements document that worker breathing zone levels were non-detectable (<0.5 ppm) and well below health limits even when

directly above an open bore hole which contained > 2000 ppm H₂S. Table B.4 shows that ambient air concentrations of all substances detected in the bore hole AS-1 were non-detectable and below established occupational health limits. This is consistent with the H₂S data reported above. For the mercaptans and sulfides, odor would be detected at levels 1000 times less than occupational health limits.

The above data document that airborne concentrations of vapors/gases during Phase I investigation activities were well below applicable occupational health limits and that Phase I activities posed no potential hazards to worker or public health.

C. Comparison of Worker Protection During Project to Health/Safety Plan

Site work followed the guidelines set by the Health and Safety Plan (Appendix V). A safety and health specialist was assigned and with the site project engineer, implemented the plan. A comparison of key safety and health requirements of the plan and site actions follows:

- 1) Security and Access: A log of visitors was maintained daily. The site was secured when not in use and a security firm was hired to maintain surveillance over the main site entrance, trailers and equipment during off-hours.

- 2) Personal Protective Equipment: Protective equipment was provided and utilized as required. Clean work clothing was provided to workers daily. The wearing of respirators was required during initial boring, trenching, and drilling on the waste piles and initially in the arsenic caution area. Although disposable odor/particulate respirators had been authorized in the plan, a better model air purifying respirator with organic vapor/acid gas cartridges and high efficiency filters was used. The safety and health specialist required the wearing of respirators in the immediate vicinity of bore holes on the waste piles to alleviate nuisance odors.

There was use of respirators during operations such as excavation in contaminated areas or when significant contamination was found. This use of respirators was in accordance with the written Plan.

- 3) Exposure Monitoring: Exposure monitoring was accomplished as indicated by the Plan and described earlier. Fence line ambient air samples for dust were not collected since the low ambient air levels found in the immediate work area indicated adequate control of dust emissions. Combustible gas measurements were not required because trenching work on the waste piles was kept to a minimum and such trenches were not entered.

- 4) Medical Program: Arrangements were made with a local physician for medical support. Personnel expected to work 30 or more days within the fenced area received a preplacement medical examination. Employees required to wear respirators were medically certified.
- 5) Dust Control & Release of Contractor Equipment Offsite:
As described earlier, once when indicated by total dust measurements, water was added to a well drilling operation to control dust emissions. The effectiveness of the procedure was documented by follow-up monitoring. All equipment leaving the site was washed down and steam cleaned on a cement pad with the water collected and discharged to a settling pond and then to the municipal sewer.
- 6) Health and Safety Facilities/Equipment: Health and Safety equipment as outlined in the Safety and Health Plan (Appendix V) was maintained onsite and was adequate. Health facilities established onsite included showers, boot wash and laundry areas. A first aid kit was maintained and the site safety and health specialist was first aid certified by the American Red Cross.
- 7) Health and Safety Training: All workers entering the site were trained on site rules, hazardous materials onsite, the location of suspected hazardous materials, respirator requirements and health effects at expected exposure levels (Appendix V). Workers involved in

extensive excavation work showered prior to leaving the site. All workers changed clothing prior to leaving the site.

- 8) Other Topics: One minor injury occurred - a worker received a cut on the wrist during drilling. He did not immediately report the injury as required by the Plan. Corrective action was taken and workers were again briefed on the requirement to report promptly all injuries, however minor.

D. Findings/Conclusions:

- 1) No potential for significant exposure was associated with Phase I activities. Industrial hygiene exposure monitoring results were generally non-detectable and always well below occupational health limits established to protect workers, who may be exposed daily, for a working lifetime.
- 2) Phase I site survey data support that no special protective equipment (e.g., respirators, special clothing) is required for health protection on onsite personnel who are not directly involved with specific investigative activities such as trenching, boring, etc.
- 3) In order to preclude the possibility of shoe contamination or the tracking of contamination offsite, all personnel are required to wear, while onsite, impervious foot

protection, either disposable shoe covers which may be discarded prior to leaving the site or boots which are cleaned prior to leaving the site.

- 4) Biological analysis of appropriate site samples and subsequent data evaluation by an expert consultant documented that site materials do not present a microbiological hazard.
- 5) The strategy employed in the Phase I - Safety and Health Plan provided sound and comprehensive health protection to all site personnel, particularly those involved directly with investigative tasks such as trenching, well drilling, sampling, etc., and a similar approach should be employed for all future activity.

V. ANALYTICAL TESTING

1. Evaluation of Performance of Laboratories

Prior to the beginning of the field sampling program at the Woburn site, Stauffer evaluated several commercial laboratories as potential contractors to perform the analytical work. The selection procedure involved a site visit to review laboratory operating practices and submission of quality assurance samples to determine laboratory proficiency. Extra consideration was given to laboratories in close proximity to the Woburn site in order to allow for closer interaction of Stauffer and contractor personnel. Based on results of the site visit and performance on quality assurance samples, Environmental Research and Technology (ERT) was found to be acceptable to perform Phase I analyses.

Screening analyses to characterize the extent of contamination on the Woburn site were performed in the field, at the Stauffer site laboratory and at ERT. A listing of the analyses performed on each sample type is included in Table C.1, Appendix III. With the exception of pH, specific conductance, dissolved oxygen and temperature which were measured in the field, and soil organics screening which was performed at the site lab, all analyses were performed at ERT.

The quality assurance (QA) program instituted for the Phase I study is outlined in Stauffer's "Woburn Sampling and Analysis Manual", Chapters 5 and 6, Attachment I, Appendix III. Data collected from analyses performed by Stauffer personnel in the field or the site laboratory was judged according to the standards of the quality assurance program requirements. The laboratory supervisor frequently reviewed test results and evaluated data quality accordingly.

A separate QA program was instituted by Stauffer to monitor the quality of the data from ERT, since the major portion of the analyses was performed by them. This program was in addition to ERT's internal QA program.

Quality assurance procedures started during field sampling operations. Samples were collected by or under the observation of a sampling chemist. Pertinent data was recorded in a field notebook and each sample was given a field identification number. Samples were returned to the site laboratory, logged in, given a laboratory identification number and possession was transferred from the sampling chemist for processing. Following preparation, the samples were transferred to the sample custodian for shipment to ERT for analysis. Each transfer of the sample was documented on a Chain of Custody sheet, initiated by the sampling chemist.

A computer log of all samples collected from the site was maintained. The sampling chemist prepared a Sample Data Entry Form for each sample collected. Those samples selected for analysis were included on an Analysis Batch Transmittal Data Entry Form. Data from these forms were then entered in a computer to produce the log of sample information which included identification, description and analyses to be performed. As analyses were completed by ERT, a cross-check of outstanding analyses was performed by comparing results to the master computer log.

Evaluation of ERT's performance in analyzing samples was monitored by adding quality assurance samples to each batch of samples submitted. Stauffer's Sample Custodian prepared four blind QA samples for each batch of 10 samples submitted for analysis. These included:

- Sample Blank - a sample of similar matrix to others in the batch with low, known levels of analytes.
- Sample Duplicate - a sample chosen from the batch of 10 samples to be analyzed in duplicate.
- Blank Spike - the sample blank overspiked with a known amount of a specific analyte(s).
- Sample Spike - a sample from the batch overspiked with a known amount of a specific analyte(s).

Since all potential contaminants on the site were not known, only selected analytes in each analysis category were chosen as QA spikes. Up to four separate analytes were added to each of the four QA samples in each batch. Known site contaminants, i.e., arsenic, lead and chromium were added more frequently as QA spikes than other compounds.

The validity of the data from sample analyses performed at ERT were judged according to the laboratory's performance on the QA samples in each batch. An evaluation system was developed, whereby a batch of samples in a particular analysis category was given a score based on the recovery of the individual analytes in the QA samples.

Since the purpose of Phase I was to screen areas of potential contamination, the criteria to judge the quality of analytical data was not based on strict accuracy and precision limits for each analyte. Instead, the performance of ERT to perform an analysis type, i.e., metals analysis, organic priority pollutants, etc., for all Investigative Plan analytes was judged by their performance on four selected analytes added in the four QA samples in each batch. For the purpose of Phase I, it was assumed that the performance of all Investigative Plan analytes was represented by the four QA samples in each batch of samples.

Results of ERT's analysis of the blind QA samples in each batch were evaluated automatically with the aid of Stauffer's computer program to determine the percent recovery of the added analytes. An empirical score for the entire batch of ten samples was then calculated from the recovery of the four QA samples according to the guidelines outlined in the following table (see next page).

As an example, for a particular batch, up to 16 analytes could be present in the four QA samples. Scores for each analyte in the batch were obtained from the guidelines in the table. The average analyte QA score was then calculated and converted to a percentage based on a maximum possible score of 3.0. This represents the QA score for the entire batch of samples and all analytes. Since the scoring system tends to average the performance of the laboratory for an entire batch on a few selected samples, its primary value is to point out gross errors in the laboratory. It does not provide specific QA information on selected analytes.

The scoring data for an analysis is summarized in a Batch Audit Report, which is included in Attachment II, Appendix III(a). The Batch Audit Report summarizes all essential information concerning sample and quality assurance analyses. For each batch of 10 samples and 4 QA samples, the following information is included in the report:

TABLE

Woburn Environmental Studies Project

Proficiency Scoring System for Quality Assurance Data

	<u>Score</u>	<u>% Recovery*</u>
1. If the analytical result is within one order of magnitude of the lower limit of detection for the analyte	3	> 50 to 150
	2	10 to 50; > 150 to 200
	1	< 10; > 200
	0	0
2. If the analytical result is greater than one order of magnitude of the lower limit of detection	3	> 75 to 125
	2	> 50 to 75; > 125 to 150
	1	5 to 50; > 150 to 200
	0	< 5; > 200

*% Recovery of the analyte is based on total amount present in the sample

$$\%R = \frac{\text{Result Amount}}{\text{Original Amount} + \text{Spike Amount}} \times 100$$

Ship Date - Date samples were sent to the contract laboratory for analysis.

Result Date - Date results received from laboratory.

Category ID - Analysis to be performed, i.e., M2 is metals analysis, Group 2.

Reference No. - The unique identification number given to each sample in the site.

Sample Type - Regular sample or QA sample.

Analyte ID - Specific analyte determined.

Quantitation Results - For field samples, amount of analyte in sample, analyte spike amount, laboratory result amount, recovery of the added analyte, and proficiency score as calculated from the guidelines.

In addition to the QA scoring system, individual data were reviewed to resolve discrepancies in results.

Three problems in the Phase I analysis program were discovered as a result of the QA program that required additional analytical work. These concerned the results of mercury in soil analyses, lead in surface waters and volatile organic compounds in bore hole air samples.

ERT's initial results for mercury analyses in soils indicated levels up to ~ 5% in some samples. Mercury was not an expected contaminant at the site and QA results for mercury analyses were poor. Based on these results, selected retain soil samples were reanalyzed for all Consent Decree metals at Stauffer's Eastern Research Center (ERC) using EPA-approved procedures. Mercury results reported by ERT were found to be two orders of magnitude higher than results obtained by ERT. A review of ERT's data indicated that a computational error had been made in the mercury analyses. Results of other metal analyses were found to be in good agreement, Attachment III, Appendix III(a).

A review of ERT's results for lead in surface water samples indicated that six sites had identical concentrations of 100 ppb. ERT was contacted to confirm these results. A review of their records indicated that five of the samples were below the lower limit of detection for lead and only one had 100 ppb.

Results of analyses of volatile organic compounds (VOC's) in bore hole air samples were judged to be invalid, due to a severe contamination problem. Triplicate air samples had been collected on Tenax adsorbant tubes from each bore hole. Field blanks and samples were returned in a common container to ERT for analysis. Results of analyses indicated that gross contamination of the field blank samples had occurred. Since ERT retains of the Tenax

were not contaminated, it was concluded that either the samples and blanks had been exposed to an unknown source of contamination or that cross-contamination of samples and blanks had occurred during sample shipment to ERT. Based on these findings, it was recommended that these analyses be invalidated.

Following completion of the Phase I program, Stauffer personnel reviewed ERT's laboratory records for completeness. During the audit, nothing was found that would significantly alter the results of Phase I analyses. Records were found to be in order so that tracking of samples from receipt to final report could be made.

2. Discussion of Methods and Procedures

During the planning stages for the investigation of the Woburn site, several analytical methods were considered for screening to identify contaminated and clean areas. The collection of the methods that were proposed both by EPA and Stauffer for the investigation have been previously submitted to the USEPA and the Massachusetts DEQE for review ("Woburn Environmental Studies Sampling and Analysis Manual").

Stauffer's evaluation of the proposed screening methods prior to the start of the field sampling indicated some problems in accuracy and precision for selected methods. As a result, alternate procedures were proposed by Stauffer that would provide more reliable data for the Phase I site investigation.

a) Evaluation of Methods for Screening Metals in Soil

Metals analyses were of prime concern in the Phase I investigation. X-ray fluorescence (XRF) was originally proposed in Stauffer's "Woburn Environmental Studies Sampling and Analysis Manual" (Manual), in order to provide a rapid screening technique to locate suspected waste deposits. XRF is often used to analyze samples to determine metals content. However, as a screening technique, its accuracy can be affected by the matrix and the sample particle size distribution.

Prior to the initiation of the Phase I study, the XRF technique was evaluated on two commercially available portable XRF instruments. In addition, results of these analyses were compared to those obtained at Stauffer's Eastern Research Center on a research-grade XRF instrument and also by atomic absorption spectrophotometry (AA). As part of the evaluation, a precision and accuracy study was conducted to validate the AA reference method by analyzing NBS reference materials.

Representative samples were obtained from the Woburn site and analyzed to determine arsenic, lead and chromium by the following procedures:

- 1) AAS reference method
- 2) Research-grade XRF instrument
- 3) Portable wave length dispersive XRF instrument
- 4) Portable energy dispersive XRF instrument

From the study, it was found that results with acceptable accuracy and precision were obtained only by the AA and research-grade XRF instruments. Both portable XRF units produced inaccurate results due to variations in the sample matrices. The portable XRF instruments also were found to have insufficient sensitivity to determine lower levels of metals. Results of the comparison study are summarized in Table C.II, Appendix III.

As a result of the study, it was recommended that the proposed XRF screening procedure be replaced with the more accurate AA method for metals analysis. Sample preparation and AA analysis techniques are described in ERT Analytical Method for the Determination of Selected Metals in Soil, Attachment IV, Appendix III(a).

This change in the analytical procedure provided improved sensitivity and accuracy for the metals analyses in the Phase I screening program. The method detection limits for the AA are attached in Table C.III, Appendix III. Accuracy of the ERT AA procedures was verified by comparison of results from the analysis of a selected set of retains by Stauffer. Stauffer used official EPA AA methods for all analyses. A comparison of the results is given in Attachment III, Appendix III(a).

b. Evaluation of Methods for Screening Organics in Soil

Another major area of investigation at the Woburn site was the location of areas of potential organic contamination in soils. Organic screening, as originally proposed in the Manual, included five separate tests:

- 1) Loss on Drying at 105°C
- 2) Loss on Ignition at 550°C
- 3) Oil and Grease
- 4) Solvent Extraction/Residue on Evaporation to Dryness
- 5) Capillary GC Analysis of Solvent Extract from 4 (above)

These tests were designed to be semi-quantitative in terms of defining the amounts of organics present in the samples. No means of compound identification was proposed for Phase I investigation.

Before initiating Phase I studies, these methods were evaluated at Stauffer's Eastern Research Center as potential semi-quantitative screening procedures.

Several problems were discovered in the evaluation:

- . The difference between loss on drying at 105°C and loss on ignition at 550°C was initially intended to be a representation of the organic content of soil samples. This method was found to be insensitive to changes in the ppm range. Volatile organics lost below 105°C would not be measured by the technique.

- The EPA oil and grease procedure and solvent extraction/residue on evaporation procedures were both found to be insensitive to ppm levels of organics in soil.
- The solvent extraction-capillary GC method was not considered further for Phase I as a screening tool, due to the excessive length of time required for sample preparation and analysis, and the possibility for loss of volatile organics during the extraction procedure.

Since the original methods lacked suitable sensitivity, an alternative technique was sought for screening areas of organic contamination. A head space gas chromatographic technique was developed by Stauffer as a replacement for the procedures originally proposed.

The method was designed to allow rapid screening of up to ten samples per day in duplicate with ppm sensitivity and minimal sample preparation. The Stauffer method was adapted from EPA procedures published in "Test Methods for Evaluating Solid Wastes", SW-846, Methods 5020, 8010, 8015 and 8020. The EPA and Stauffer methods are included in Attachment V, Appendix III.

In principle, known weights of soil samples were placed in sealed vials, equilibrated at 110°C in a Perkin-Elmer F-45 Automated Head Space Analyzer. The head space gas above the sample was analyzed by gas chromatography with a flame ionization detector to measure the organics volatilized from the soil.

The relative amount of organics in the soil samples was measured by totalling the area of all peaks that eluted in the chromatogram. A semi-quantitative determination of the organics was calculated by dividing the total area counts in the chromatogram by the sample weight, i.e., area counts/gram.

In order to add more meaning to the empirical area counts/gram values for the soil samples, representative compounds from the EPA methods were run using the Stauffer procedure to determine response factors. The compounds included benzene, dichloromethane, methyl ethyl ketone, 1,2-dichloroethane, toluene, methyl isobutyl ketone, chlorobenzene and dichlorobenzene. These compounds were also chosen to represent a range of boiling points up to 180°C. From these experiments it was demonstrated that ppm levels of organics could be detected. Also, a range of compound types that could be potential organic contaminants in Woburn soils were shown to be detectable by this procedure. No means of compound identification was possible using this procedure, which was consistent with the Phase I screening goal.

c. Comparison of Methods Proposed to Methods Actually Used

A review of changes made in the procedures proposed in each section of the "Woburn Environmental Studies Sampling and Analysis Manual" follows:

- i) Section 1.00 Introduction
No changes from original plan were needed.
- ii) Section 2.00 Safety
No changes from original plan were needed.
- iii) Section 3.0 Sampling Principles
The procedures used were the same as described in the Manual.
- iv) Section 4.00 Documentation of Samplings - Recordkeeping
The procedures used were the same as described in the Manual.
- v) Section 5.00 Quality Assurance Protocol
The procedures used were the same as described in the Manual.
- vi) Section 7.00 Data Correlation and Evaluation
The computer software package described in the Manual was developed as described. Some modifications to the original programs were required for data evaluation. The procedures employed are described in greater detail in Section V, Part 1 of this report.
- vii) Section 8.00 Surface Water
Sampling and analysis procedures used for surface water samples were the same as originally proposed in the Manual, with the exception of metal analyses. Atomic absorption spectrophotometry (AA) was used for all metals determination

since the proposed method, inductively coupled plasma - atomic emission spectrometry (ICAP), was not available at ERT.

Specific AA methods for each metal are included in ERT's "Analytical Method for Determination of Selected Metals in Soils", included in Attachment IV, Appendix III(a).

viii) Section 9.00 Monitoring Well

Sampling and analysis procedures used for monitoring well samples were the same as originally proposed in the Manual, with the exception of metal analyses.

Atomic absorption spectrophotometry was used for all metals determinations as described in Section 8.00, Surface Water.

ix) Section 10.00 Surface Stream Sediments

Sampling and analysis procedures used for Surface Stream Sediments were the same as originally proposed in the Manual, with the exception of metals analyses. Atomic absorption spectrophotometry was used for all metals determinations. Samples were prepared and analyzed as described in the ERT Analytical Method for the Determination of Selected Metals in Soil, Attachment IV, Appendix III(a).

x) Section 11.00 Test Pit/Soil Borings

Several changes were made in the procedures for the analysis of test pit/soil boring samples from those proposed in the Manual. Organics were determined using the Stauffer head space technique, Attachment V, Appendix III(a). All metals were

50

100

After Page V-16

Before Page V-17

determined using atomic absorption spectrophotometry as described in the ERT Analytical Method for the Determination of Selected Metals in Soil, Attachment IV, Appendix III(a).

xi) Section 12.00 Leachate

Sampling and analysis procedures used for Leachate were the same as originally proposed in the Manual, with the exception of metals analyses. Atomic absorption spectrophotometry was used for all determinations. Samples were analyzed at ERT using the methods referenced in Attachment IV, Appendix III(a).

xii) Section 13.00 Standard Water Quality Parameters

The procedures used for sampling and analysis were the same as proposed in the Manual.

xiii) Section 14.00 Ambient Air

Procedures were described in the Manual for monitoring volatile organic compounds (VOC's), arsine, total reduced sulfur compounds (TRS) and total dust. All procedures were used as described, except for VOC's, due to problems encountered in the analysis.

VOC's were determined in bore hole air samples by collection on a polymeric adsorbent, Tenax-GC, followed by thermal desorption into a GC/MS. Results of analyses were judged to be invalid, due to gross contamination problems indicated by the quality assurance sample blanks. This problem was discussed previously in Section V, Part 1, Evaluation of Performance of Laboratories.

A limited resampling of bore hole air contaminants was conducted using a modified analytical procedure. Composite air samples were collected from bore holes AS-1, AS-6 and downwind from AS-1 in triplicate in aluminized-mylar air bags. Gas samples were analyzed directly, without preconcentration on Tenax, by GC/MS.

Aluminized-mylar air bags were chosen as the alternative analytical technique for several reasons. The technique is specified by the EPA in the National Emission Standards for Hazardous Air Pollutants, 40 C.F.R. Part 61, Method 106, "Determination of Vinyl Chloride from Stationary Sources". The technique has suitable sensitivity, i.e., 1 ppm for volatile organic compounds. Multiple analyses of each sample were possible, since only a small portion of the integrated air bag sample is actually used in each GC/MS analysis. References to the suitability of the air bag method are also outlined in "Controlled Test Atmospheres Principles and Techniques", G.O. Nelson, Ann Arbor Science, 1971, pp. 76-81.

Field blank air bag samples were found to contain methylene chloride, toluene, acetone, ethyl acetate and benzene at approximately the same levels as found in the actual field samples. In no case did any contaminant exceed 10 ppm. As is normal analytical practice, results of field sample analyses are corrected for blank contributions of analytes. The levels of contaminants found in the field blanks represent normally expected levels of background contamination.

3. Findings and Conclusions

The main goal of the Woburn Phase I study was to locate areas of contamination on the site. To meet this goal, analytical methods were sought that would produce semi-quantitative data rapidly, so that the areas requiring further study in Phase II could be defined. During the process of the investigation, modifications to the original proposals were required in order to meet the goals. Important findings included:

- a) Use of a portable X-ray fluorescence instrument to locate areas of metal contamination in Woburn soil samples was not feasible. Inadequate sensitivity and resolution, as well as matrix problems, resulted in inaccurate results.
- b) Atomic absorption spectrophotometry was found to be an accurate technique to determine metals in soils. The procedures used in the study allowed determination of 14 metals on a single sample. Sensitivity of the AA procedure was demonstrated to be in the ppm range for all metals.
- c) Accurate or sensitive measurement of organics in soil using drying or extraction techniques followed by a measurement in sample weight loss was not possible. Substitution of a modified EPA head space procedure allowed analysis of up to ten samples per day in duplicate.

- d) Head space method development experiments proved that the Stauffer procedure was sensitive to ppm levels of organics in soil.
- e) Quantitation of the amounts of organics in soil by the head space procedure was not accurate since the method does not identify the compounds detected. Relative responses for eight test compounds chosen by EPA head space methods indicated a variation of approximately a factor of 10, depending on the compound type. Semi-quantitative results for the eight compounds chosen by EPA were obtained by determining an average response using the Stauffer methodology.
- f) Collecting air samples in aluminized Tedlar bags minimized the potential for cross-contamination. Organics in air at the sub 1 ppm level were thereby accurately measured by direct analysis by GC/MS.
- g) Evaluation of analytical results from Stauffer's contract laboratory, ERT, was possible using a computer scoring system. Assignment of a Quality Assurance score for each batch of ten site samples was made based on the performance on four pre-selected analytes in the four Q.A. samples prepared for each batch of ten.

- h) Measurement of data quality for each potential analyte in every sample was not attempted in Phase I, due to the scope of the investigation. Representative QA was provided to obtain general performance trends and locate problems.

VI. BORE HOLE AIR

A. Background

The Investigative Plan specified that 10 bore holes were to be installed. Five bore hole locations were specifically identified as follows: two in each major waste pile and, one in the minor waste pile. The five remaining locations were left for selection during Phase I field work. (Appendix II(a), Figure B.2). The Investigative Plan required that three arsine, three total reduced sulfur (TRS) and three volatile organic chemicals (VOC) air samples from each bore hole (or a total of 90 air samples) be collected. The proposed collection procedures and analytical methods were described in the "Red Book" - Woburn Environmental Sampling and Analysis Manual.

B. Purpose

The purpose of collecting air samples from inside the 10 bore holes was to identify possible odorous compounds and determine if arsine or volatile organic chemicals were present. Sampling procedures (sampling as far down in the holes as possible and/or after capping) that intended to maximize the concentrations of chemicals in the bore hole air samples were employed. The results, therefore, do not in any way represent worker or public exposure levels.

C. Description of the Work

Once the locations of the bore holes were approved by EPA/DEQE, bore holes were installed under the close supervision of the hydrogeologic consultant. All bore holes were drilled 6" in diameter by an auger rig, except for 2 (AS-7 & AS-8). Because of terrain and stability problems the auger rig could not gain access to the west waste pile. Therefore the two bore holes in the west waste pile were drilled with a hand auger.

The 8 bore holes drilled with the auger rig ranged from 14 to 39 feet in depth. The depth of the holes varied because: a) the water table was reached, b) undisturbed soil was reached, or c) the auger rig hit refusal (bedrock). Two of the selected bore holes were installed as part of the soil sampling program (B-31 & B-32) and served dual functions. The holes installed on the west waste pile using the hand auger were 2-4 inches in diameter and about 6 feet deep.

D. Sampling/Analysis

Except for six (6) arsine samples, all bore hole air samples were collected after the holes were covered and allowed to equilibrate for one week in an attempt to assure the maximum concentration of any volatiles or odor producing substances. The six (6) arsine samples taken from AS-7 and AS-8, the shallow (6 feet deep) bore holes on the west waste pile, were collected one day after capping. We believe that the potential for dilution and/or escape of bore hole air from a shallow well (6') is greater, even with the hole covered than holes 20-30' below surface. We therefore collected the samples immediately.

1. Arsine: Air sampling was accomplished by adsorption of arsine gas onto charcoal. The charcoal is in a glass tube containing first a high purity glass wool section. The charcoal tube was lowered into the hole via standard tubing. Air at a known flow rate and for a measured time period was sucked through the charcoal tube and then PVC tubing by a battery operated pump connected at the end of the sampling train. After sampling, the charcoal tubes were sealed and sent to the analytical laboratory (ERT). The arsine was extracted and analyzed via atomic adsorption spectroscopy. This procedure was repeated three times at each bore hole location with each sample drawn from the same depth. No results were obtained for three of the thirty samples because of laboratory problems. However, since triplicate samples were collected, others were available and no significant data loss resulted.
2. Total Reduced Sulfur (TRS): Samples of air from within the bore holes were drawn directly through a purged teflon tube and into a special tedlar sampling bag which was contained in a sealed container connected to a battery operated pump. The sample was collected by evacuating air around the tedlar bag. Thus, the tedlar bag was filled with bore hole air that did not first flow through a sampling pump. The bags were taken promptly to ERT Laboratories where the air was analyzed via a gas chromatographic separation and flame photometric detection (see "Red Book") immediately upon receipt.

As was done with the arsine samples, three (3) air samples from each bore hole were collected and analyzed for Total Reduced Sulfur compounds. In an attempt to maximize TRS concentrations each bore hole sample was collected from the deepest depth possible. This technique should minimize the diffusion of ambient air into the hole and the dilution of the sample.

A total of 30 air samples were collected and analyzed for hydrogen sulfide, methyl mercaptan, dimethyl sulfide and dimethyl disulfide.

3. Volatile Organics (VOC): Air sampling was accomplished by the adsorption of VOC's on Tenax. Samples of air were drawn up from each bore hole directly through the Tenax collection tube at a known flow rate and for a measured sampling time via a battery powered pump connected at the end of the sampling train. The collection tube was then sealed to minimize any losses and sent to ERT for analyses. ERT thermally desorbed the volatile organics from the Tenax filled tube and analyzed the VOC's via gas chromatography and mass spectroscopy.

However, the Tenax sample collection was not suitable because of high reduced sulfur compounds interference and gross contamination problems among site samples and quality assurance field blanks. This invalidated any qualitative and quantitative results.

We re-evaluated our sampling and analysis techniques and selected the collection of VOC samples in bags similar to the TRS sample collection techniques. Since time was of the essence in completing Phase I, we selected two bore holes from the most representative areas and resampled these using the modified sample collection method. The bore holes sampled were AS-1 and AS-6. Since AS-6 had partially collapsed and AS-1 filled with groundwater, the samples could not be collected at the depth of previous samples.

The samples were analyzed for the volatile organic chemicals listed as priority pollutants and the 20 additional organic chemicals that produced the highest readings in the analytical instrument.

Appendix II(b), Table C.4, lists the date of sample collection, bore hole location, bore hole depth, and depth of sample point for each bore hole.

E. Findings/Conclusions

The following discussion pertains to the analytical results shown on Appendix II(b), Tables C.6.1 and C.6.2 for bore hole air samples:

1. Arsine:

As shown on Appendix II(b) Table C.6.1, of 27 samples for which analytical results were available, the findings and conclusions are as follows:

Findings:

- i) Four (4) samples showed results just at or above the detection level of 0.3 parts per billion (ppb).
- ii) The arsine was found near the chromium lagoon at levels of 0.3 ppb in bore hole AS-6 and at 0.3 and 0.4 ppb in bore hole AS-5.
- iii) In bore hole AS-8 located in the west waste pile, 0.5 ppb arsine was detected.
- iv) Arsine results in 23 of the 27 samples analyzed were non-detectable.

Conclusions:

- i) These extremely low levels of arsine were found 6-20 feet below the surface. The Federal Occupational Safety and Health Standard for protection of workers for eight hours of exposure to arsine is 50 ppb. These findings do not indicate that the waste deposits are producing hazards from arsine vapors.

- ii) At the extremely minute arsine levels (.3 ppb) the analysis cannot distinguish between arsine or a microscopic particle of natural soil containing naturally occurring levels of arsenic.

2. Total Reduced Sulfur (TRS):

Thirty bore hole air samples were analyzed for the following Total Reduced Sulfur Compounds: Hydrogen Sulfide (H_2S), Methyl Mercaptan (CH_3SH), Dimethyl Sulfide ($(CH_3)_2S$), and Dimethyl Disulfide (CH_3SSCH_3). The results are shown on Table C.6.1 - Appendix II(b).

Findings:

- i) No total Reduced Sulfur compounds were detected at the detection limit of 1 ppm down inside 8 bore holes.
- ii) High levels of H_2S were found down inside 2 bore holes (AS-1 and B-31) both located in the east waste pile. These levels were as high as 47,000 parts per million (ppm). The lowest level found in these bore holes was 9,400 ppm.
- iii) No Dimethyl Disulfide was detected in any bore hole air samples at or above the 1 ppm detection limit. This includes the two bore holes in the east waste pile where other TRS compounds were detected.

- iv) Methyl mercaptan was found at levels of 20-470 ppm in two east waste pile bore hole air samples.
- v) Dimethyl Sulfide was found at levels ranging from 2 to 20 ppm in the east waste pile bore hole air samples.

Conclusions:

- i) Since H_2S has an odor recognition threshold of 5 ppb and methyl mercaptan has odor at 2 parts per billion (ppb), the levels found in the east waste pile bore holes indicate that this waste pile is one probable source of odor.
- ii) The OSHA Standard for protection of workers from H_2S is 20 ppm (ceiling). Industrial Hygiene monitoring (see Section IV) results for H_2S above the ground surface and in the breathing zone were all non-detectable (less than 0.5 ppm for the 1/24/83 samples) and document that the high H_2S levels (up to 47,000 ppm) found in the bore holes during Phase I field work did not present a hazard to worker or public health.
- iii) Methyl mercaptan was found at levels 100 times less than H_2S in bore holes and methyl mercaptan's OSHA safe exposure level is 10 ppm (ceiling), half the H_2S OSHA PEL. Therefore, based on the H_2S I.H. and bore hole monitoring results in Phase I, we would expect to find above ground levels of methyl mercaptan about 100th of the H_2S level.

Since H₂S was not detected at a .5 ppm detection limit above ground, the methyl mercaptan would be well below the OSHA PEL. An I.H. sample collected in January 1983 showed no detectable methyl mercaptan which supports this conclusion.

3. Volatile Organic Chemicals:

The results of the analysis of the 30 bore hole air samples collected in August and September using the Tenax tubes were invalidated due to high levels of contamination of field blank quality assurance samples which show no or low level of contamination. The contamination is believed to be due to improper seals on the sample tubes. In addition, high sulfur content in some bore holes caused interference in the analysis. The samples will therefore not be discussed, since the findings were not qualitatively or quantitatively reliable, i.e. the results could have produced false positive identifications. We promptly modified our methods and were able to collect samples from 2 bore holes in January. The results of the two bore hole air samples collected in January using the aluminized mylar bag collection techniques will be discussed and are shown on Table C.6.2. in Appendix II(b). Sample V: Analytical Testing describes the sample collection method in greater detail. The results are in the parts per million. The lower limit of detection is 0.1 ppm for non-sulfur compounds and 0.5 ppm for sulfur containing compounds.

AS-1 and AS-6 represent bore hole air samples collected from deep below the surface. I.H. is an Industrial Hygiene air sample collected 30 feet down wind from the open bore hole AS-1.

Findings:

- i) No volatile organics were found in bore hole AS-6 located adjacent to the chromium lagoon.
- ii) No volatile organics were detectable at 0.1 ppm detection limit in the industrial hygiene samples collected by same bore hole air sampling technique. These samples were collected at a point located 30' downwind of the bore hole sampled in the east waste pile (AS-1).
- iii) No priority pollutant volatile organics were detected in any bore holes samples collected on 1/24/83.
- iv) The bore hole air sample collected in the east waste pile (AS-1) showed a total of 64-103 ppm of volatile organic chemical compounds.
- v) Ninety five percent (95%) of the total volatile organic pollutant concentration in AS-1 was attributable to reduced sulfur compounds or sulfur containing compounds.

- vi) Butanone and methyl furan were the only non-sulfur containing compounds found in AS-1 at less than 1 ppm and 1.3 ppm, respectively.
- vii) Field Blank Quality Assurance samples showed contamination with benzene, methylene chloride, toluene, acetone and ethyl acetate in about the same ppm concentrations as levels of these compounds found in bore hole air samples (see Table C.6.2).
- viii) Using bags to collect bore hole air samples for VOC analysis is a rapid and effective tool for identifying possible volatile emissions because interference problems are reduced, multiple analysis can be performed on a single sample, detection limits are sub 1 ppm for most VOC's which is sufficient for bore hole air, and cross contamination is minimized.

Conclusions:

- i) In the limited sampling to date, the volatile organic chemicals found were reduced sulfur compounds that might produce odors at minute concentrations.
- ii) The limited results from the bore hole air samples have identified no significant volatile organic chemical deposits on the site but more data is needed to verify these preliminary and meager results.

PHASE I
EVALUATION OF WASTE DEPOSITS
AND SUBSURFACE CONDITIONS

Industri-Plex Site
Woburn, Massachusetts

March 1983

ROUX ASSOCIATES
50 North New York Avenue
Huntington, New York
11743

TABLE OF CONTENTS

	page
INTRODUCTION.	1
METHODS OF INVESTIGATION.	2
Conductivity Survey.	2
Soil Boring Program.	7
Test Pit Program	9
Observation Well Installation.	11
Rock Wells	12
Sand and Gravel Wells.	13
Ground Water Sampling.	15
HYDROGEOLOGY.	16
SOIL AND WASTE INVESTIGATION.	25
Conductivity Survey Results.	25
Soil and Waste Analytical Results.	29
GROUND-WATER LEVELS AND FLOW.	37
GROUND-WATER QUALITY.	40
FINDINGS AND CONCLUSIONS.	44

TABLES

	following page
TABLE 1 - Well Construction Data.	11
TABLE 2 - Comparison of Chromium, Lead and Arsenic in Borings and Test Pits	33
TABLE 3 - Characterization of Natural or Artificial Deposits.	36

FIGURES

	following page
Figure 1 - Site Location Map	1
Figure 2 - Areas of Investigation	Appendix IV
Figure 3 - Conductivity Measuring Point Locations	Appendix IV
Figure 4 - Locations of Test Borings and Pits	Appendix IV
Figure 5 - Well and Piezometer Location Map (showing stream sampling locations)	9
Figure 6 - Geologic Cross Section A-A'	16
Figure 7 - Geologic Cross Section B-B'	16
Figure 8 - Geologic Cross Section C-C'	16
Figure 9 - Geologic Cross Section D-D'	16
Figure 10 - Initial Interpretation of Conductivity Results	Appendix IV
Figure 11 - Reinterpretation of Conductivity Results	Appendix IV
Figure 12 - Distribution of Lead	Appendix IV
Figure 13 - Distribution of Arsenic	Appendix IV
Figure 14 - Distribution of Chromium	Appendix IV
Figure 15 - Distribution of Barium	Appendix IV
Figure 16 - Distribution of Cadmium	Appendix IV
Figure 17 - Distribution of Copper	Appendix IV
Figure 18 - Distribution of Mercury	Appendix IV
Figure 19 - Distribution of Zinc	Appendix IV
Figure 20 - Distribution of Antimony	Appendix IV
Figure 21 - Distribution of Nickel	Appendix IV
Figure 22 - Distribution of Selenium	Appendix IV
Figure 23 - Distribution of Silver	Appendix IV

FIGURES

	following page
Figure 24 - Distribution of Thallium	Appendix IV
Figure 25 - Contour Map of Arsenic and Lead Concentrations	Appendix IV
Figure 26 - Contour Map of Chromium Concentrations	Appendix IV
Figure 27 - Contour Map of Copper & Zinc Concentrations	Appendix IV
Figure 28 - Location of Hide Residue Areas	Appendix IV
Figure 29 - Contour Map of Counts per Gram	Appendix IV
Figure 30 - Water Table Map (January 12, 1983)	37

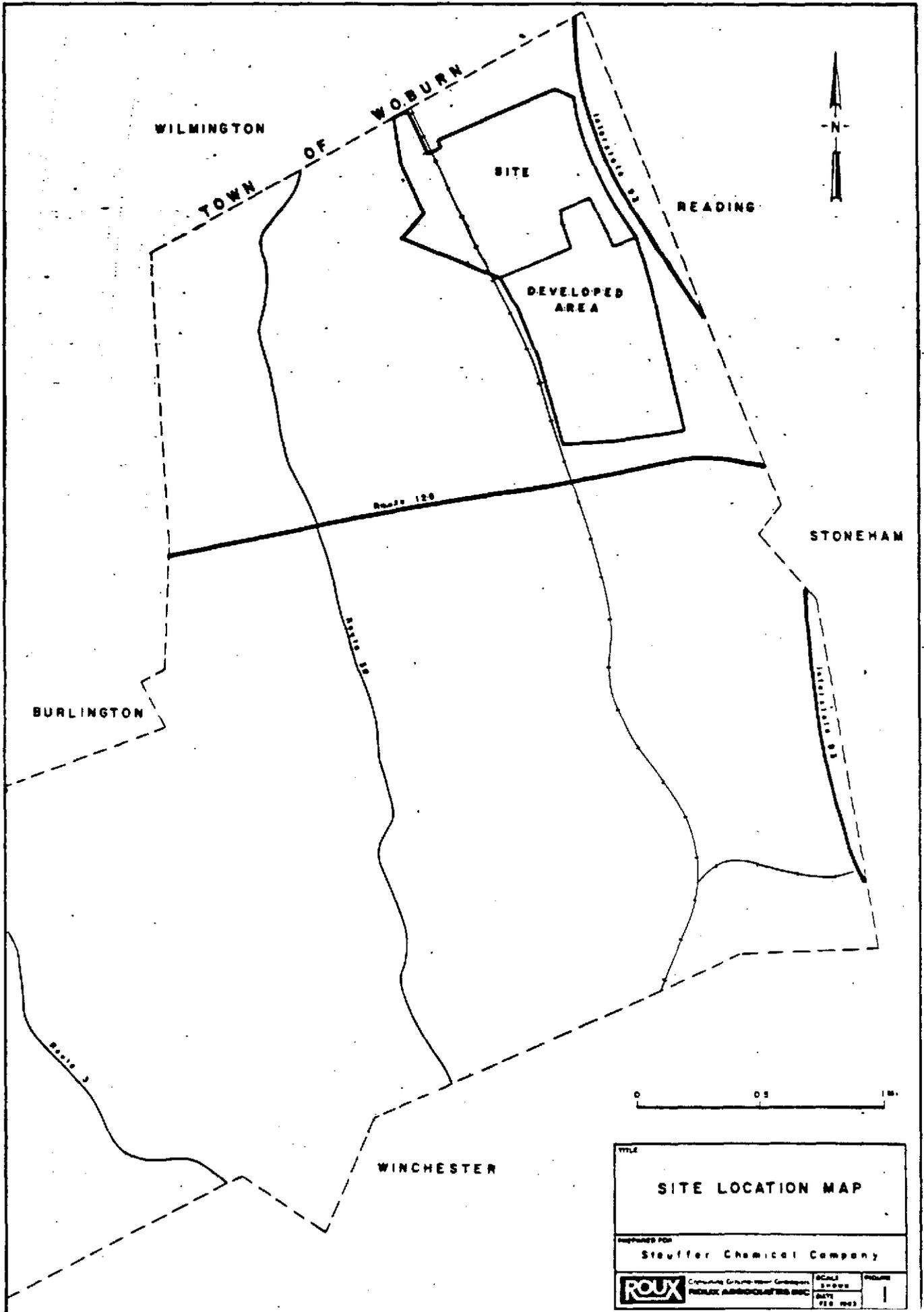
INTRODUCTION

The Phase I subsurface investigation at the Woburn Site included a preliminary definition of the nature and extent of waste deposits and contaminated soil and a preliminary evaluation of ground-water conditions. The work was carried out by, or under the supervision of geologists from Roux Associates with chemists, engineers and a safety officer from Stauffer Chemical Company.

The waste deposit and soil investigation was carried out with electrical conductivity surveying equipment, a backhoe and an auger drilling and core sampling rig. Many soil and waste samples were collected, described and chemically analyzed as part of this portion of the investigation.

The ground-water conditions at and around the Site were evaluated by installing fifteen observation wells, measuring water levels and collecting and analyzing water samples.

The location of the Site is shown on Figure 1. The portions of the Site that were included in the subsurface investigation are shown on Figure 2. Shaded areas on Figure 2 are either developed or very shallow bedrock and were investigated where possible as part of Phase I.



TITLE	
SITE LOCATION MAP	
PREPARED FOR	
Stuffer Chemical Company	
ROUX	<small>Corporate Geomatics Group</small> <small>PROJECT ASSOCIATES INC.</small> <small>DATE: FEB 1993</small>
SCALE	FIGURE
1:5000	1

The various methods of the Phase I subsurface investigation at the Woburn Site are described below. The results of these investigations, and the findings and conclusions drawn from the results are given in subsequent sections.

METHODS OF INVESTIGATION

Conductivity Survey

A preliminary screening of the Site was undertaken using a geophysical method known as induction conductivity. Induction conductivity makes use of a device called a "non-earth-contacting terrain conductivity meter", which utilizes the principle that the electrical properties of various natural earth materials and artificial fill (or waste) can be significantly different.

It was expected that the individual types of waste material at the Woburn Site would each have their own recognizable and distinct conductivity range, and that this would permit the delineation of these materials. At the very least, the waste materials were expected to have a substantially different conductivity from natural soils and rock at the Site. Thus, the conductivity survey was intended to provide the initial screening of the Site and help guide the boring and test pit programs to follow.

A second purpose of the conductivity survey was to give a very thorough coverage of the Site to insure that all buried waste deposits were located. This blanket coverage is not practical with pits and borings alone.

The conductivity equipment used in Woburn was manufactured by Geonics, Ltd. of Mississauga, Ontario. Two types of terrain conductivity meters were used: the one-man EM-31 and the two-man EM-34-3 (hereafter referred to as the EM-34). Both the EM-31 and the EM-34 work in a similar fashion. A time-varying electromagnetic field is produced by a battery-powered transmitter which in turn acts to generate electrical eddy currents in any subsurface conductors present. These eddy currents then serve as the source of a secondary electromagnetic field, generally 90 degrees out of phase with the transmitter-generator (primary) field. Since the secondary field is out of phase with the primary field, it can be detected at the receiver. At the low frequencies used by the EM-31 and EM-34, the strength of the secondary field is directly proportional to terrain conductivity, which allows the equipment to display direct readings of apparent conductivity.

The EM-31 was used for this project because its continuous-reading capabilities allowed for a rapid identification and delineation of high-conductance areas. The EM-34 was used to verify results from the EM-31 and determine conductivities at greater depths than

the EM-31 is capable of. The depth from which conductivity data can be gathered is related to the geometry of the receiver and transmitter coils. Since the EM-31 has a fixed intercoil spacing, the conductivity data it collects corresponds to conditions within six to seven meters (20 to 23 feet) of the surface. The EM-34 however, due to the flexible cable attaching the transmitter and receiver coils, allows for changes to be made in its intercoil geometry. The EM-34 can be used with a 10 meter, 20 meter, or 40 meter (30, 60 or 120 feet) intercoil spacing. When both coils are held coplanar and vertical (called the horizontal dipole mode), an effective depth of penetration of 7.5 meters (22 feet) for the ten meter intercoil spacing is obtained. Depth of penetrations of fifteen meters (45 feet) are obtained in the 20 meter intercoil spacing, and up to 30 meters (90 feet) penetration are obtained when the coils are 40 meters apart. The coil geometry can also be changed so that both coils are lying horizontal (known as the vertical dipole mode) which effectively doubles the depth of penetration possible for each intercoil spacing.

The EM-31 and EM-34, like any electromagnetic equipment, are subject to interference. Sources of interference can be numerous in developed areas, and may not be easily avoided. Interference may be caused by buildings, buried pipelines, metal fences, railroad tracks, power lines and other large metal objects. Their adverse effect on data quality can only be avoided by keeping

the equipment an appropriate distance away from the source of interference. The appropriate distance must be determined by the operator through past experience, or through on-site interference testing in an area of known terrain conductivity.

A second limitation that must be considered before interpretation of results can be made is imposed by the local geology. For example, since clay is a relatively good electrical conductor, it can mask the evidence of artificial (contamination-related) fill at a particular location. The degree of understanding of the local geology is, therefore, related to the degree of confidence of interpretation of conductivity data.

The conductivity survey at the Woburn Site was conducted on a 200-foot grid spacing. A tighter grid spacing was used in some areas. The orientation of the grid lines was chosen to coincide with the survey grid used on the two-foot contour-interval Woburn Site base map. The conductivity measuring points were then plotted on this map as the survey was being conducted. Altogether, over 640 conductivity measurements were made at approximately 460 locations. The conductivity measuring point locations are shown on Figure 3.

One of the stations was arbitrarily chosen as a starting point and located in the field with the aid of the map, a compass, and a tape measure. From this point, the other stations were located

through the use of a compass, optical tape measure, and the two-foot contour-interval map.

The grid network was designed to cover the entire Site, as well as portions beyond the Site, where possible, to allow for a conductivity contrast to be observed. Certain areas could not be included in the grid due to the presence of extensive sources of interference.

The conductivity at each grid site was first measured by the EM-31. These results indicated the need for a closer data spacing in several portions of the Site. A series of continuous-reading traverses were then conducted through these areas. This was done to better define the more complex zones, and to identify any deposits that may have been missed previously.

The EM-34 was used primarily in the western portion of the Site, as well as in land adjacent to the Woburn Landfill (west of the Site) and the area south of the Site near the chromium lagoons. Due to the high water table and relatively shallow bedrock throughout much of the Site, the ten-meter intercoil spacing was used for both horizontal and vertical dipole readings with the EM-34. The horizontal dipole data (with a 7.5 meter [22 ft.] depth of penetration) was used to verify data collected with the EM-31. The vertical dipole data (with a 15-meter [45 ft.] depth of penetration) was used to evaluate the possibility of deeper sources of contam-

ination, as well as to aid in the delineation of buried construction materials.

Soil Boring Program

Fifty-seven soil borings were drilled on the Woburn Site between July 27 and August 19, 1982 by Parratt-Wolff, Inc. of East Syracuse, New York, under the supervision of geologists from Roux Associates. In addition, eight borings were completed for the air sampling program (AS1-AS8). Boring logs are included in Appendix IV. The locations of the borings are shown on Figure 4.

The sites for the borings were located by the geologists based on information obtained from the conductivity survey, historical aerial photographs and an inspection of the surface. Borings were drilled primarily in areas where digging test pits with a backhoe was not practical, such as in developed areas where the surface could not be significantly disturbed and in areas where it was desirable to sample deeper than eight feet below the surface (the depth limitation of the backhoe).

A truck-mounted hollow stem auger rig was used to take continuous cores until refusal was met or until natural deposits were encountered. Where several borings were placed close together, one boring was advanced to refusal and the others were terminated approximately ten feet into natural deposits.

Split-spoon core samplers were used to collect continuous samples. The split-spoon samplers were driven two feet at a time into undisturbed sediments by a standard 140-lb. weight. The geologist opened the spoon on a plastic sheet, logged the core in detail, and then removed the sample from the split-spoon using vinyl gloves and plastic spoons. The sample was placed in a pre-cleaned, wide-mouth quart jar under the supervision of a chemist. Cross-contamination was minimized by using 10 different split-spoon samplers and thoroughly steam-cleaning each between samples.

After the 0-2 foot interval sample was collected, the hole was advanced to two feet with power driven six-inch diameter hollow stem auger flytes. The 2-4 foot interval was then sampled by split-spoon. Cross-contamination within a hole is minimized as samples are collected ahead of the auger flytes. The auger flytes were steam-cleaned before moving from one area of the site to another to further avoid cross-contamination. In addition, to prevent dilution of any contaminants that might be present, water was not used in the hole during drilling. After sampling was completed, the open hole was back-filled with the cuttings obtained from the boring. The site was marked with a metal stake and flagging. The location of each boring was surveyed and plotted on a site map.

At certain boring sites, it was determined that a piezometer might be useful to measure water levels in the shallow sand and gravel deposits. The piezometers consist of a 4.5-foot length of two-inch

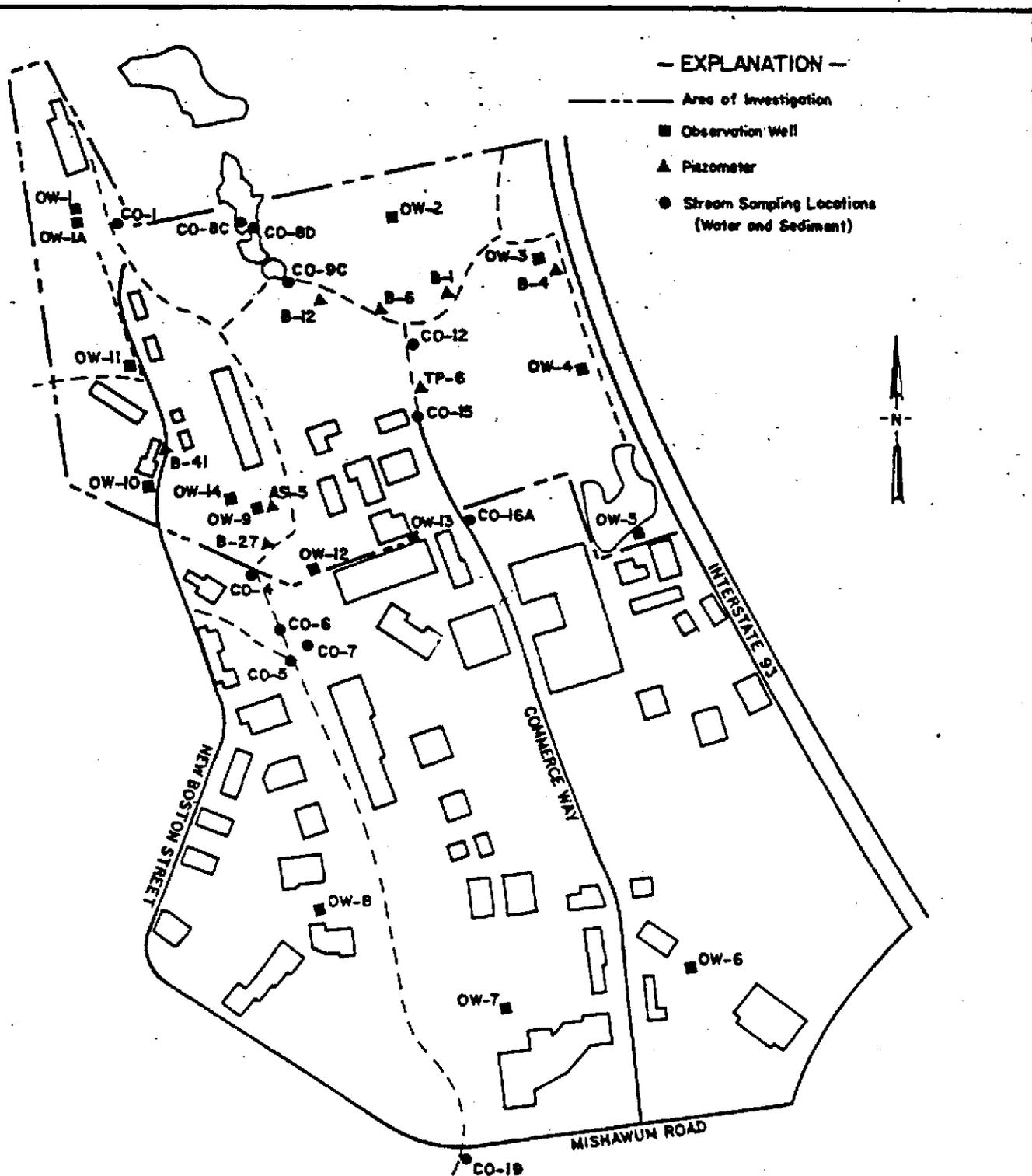
diameter PVC slotted pipe with blank PVC riser pipe extending above land surface. The formation was allowed to collapse around the screen zone and the remaining annular space was back-filled with material initially removed from the hole.

A total of eight piezometers were installed. The elevation of a designated measuring point at the top of the PVC casing was determined with respect to mean sea level. Water levels were measured with an electric probe and steel tape to ± 0.01 feet. The locations of the piezometers are shown on Figure 5.

Air sampling holes, (AS1 through AS6) were drilled in the same manner as the borings. Continuous cores were collected and logged by the geologist but no sediment samples were retained. After completion, each hole was left open and covered at land surface with a plastic sheet. A stake was driven into the ground near each boring to mark its location. Air sampling holes (AS-7 and AS-8) were drilled by using a hand auger since the drilling rig could not get to these locations. In addition, borings B-31 and B-32 were used as air monitoring points. All air monitoring points are shown on Figure 2.

Test Pit Program

A backhoe was used at the Woburn Site to dig 123 test pits. All pits were dug between August 26 and September 9, 1982 by Warren



TITLE		
OBSERVATION WELL LOCATION MAP (With Stream Sampling Points And Piezometers)		
PREPARED FOR		
Stauffer Chemical Company		
ROUX	Consulting Ground-Water Geologists	SCALE 1" = 823'
	ROUX ASSOCIATES INC.	DATE Feb. 1983
		FIGURE 5

Cummings of Woburn, Massachusetts, under the supervision of geologists from Roux Associates. As with the soil borings, test pit locations were selected by examination of historical aerial photographs, the conductivity data, surface deposits, and the soil borings. The locations of the test pits are shown on Figure 4.

Each test pit was dug to the limit of the backhoe (about 8 feet below land surface), to refusal (bedrock) or when collapse occurred due to intersection with the water table. Test pits allowed the geologist to view the shallow stratigraphy and could be dug at a faster rate than the soil borings. However, this method was limited to a maximum depth of about 8 feet below land surface and to areas where the surface could be disturbed.

Each individual test pit was excavated in steps allowing the geologist to accurately describe the deposits and obtain representative samples by hand. When the pits were more than five feet deep, samples were collected without the need for the geologist to enter the trench by using a steel trowel attached to the end of a long rod. The area of the wall of the trench where the sample was to be taken was scraped to remove any sediments that had been in contact with the backhoe. The depth to each sampling location was measured. Each sample collected by the geologist was immediately delivered to the chemist at the site for labeling and preservation.

After the sampling from each test pit was completed, it was back-filled with the material that had been removed from it. All sampling implements were either disposed of or cleaned thoroughly in distilled water. The backhoe itself was steam-cleaned between sampling areas and at the end of each working day.

The location of each test pit was plotted on a map and a stake was left at the location in the field. The location of each individual pit was surveyed and located on the site base map.

Observation Well Installation

All observation wells were installed between August 10 and September 22, 1982 by Domestic Wells, Inc. of Bolton, Massachusetts. Well drilling and installation were supervised by a geologist from Roux Associates. A truck-mounted combination air/mud rotary rig was used at all sites. Two types of wells were installed; sand/gravel wells and rock wells. The rock wells are simply an open hole cased off from the overburden, whereas the sand/gravel wells are constructed with a PVC screen (slotted pipe) and casing. The PVC casing is protected at the surface by an outer steel casing with a locking cover. The locations of the observation wells are shown on Figures 4 and 5. Well construction data are given in Table 1.

In areas where the saturated thickness of the sand and gravel deposits was greater than ten feet, a sand/gravel well was installed.

Table 1 - Well Construction Data

<u>Well Number</u>	<u>Well Type</u>	<u>Screen Zone 1)</u>	<u>Elevation of Measuring Point 2)</u>	<u>Elevation of Water Table 2)</u>		
				<u>9/22/82</u>	<u>10/27/82</u>	<u>1/12/83</u>
OW-1	Rock	24-108	80.32	72.71	72.68	72.64
OW-1A	Sand	5-25	79.72	72.59	72.55	72.78
OW-2	Rock	16-100	128.02	106.67	116.18	116.83
OW-3	Rock	25-83	74.76	66.06	66.56	66.99
OW-4	Rock	25-44	71.54	62.73	63.85	64.80
OW-5	Sand	9-49	68.08	58.84	58.88	59.10
OW-6	Sand	6-16	62.67	53.52	53.73	54.02
OW-7	Sand	6-36	57.88	50.67	50.84	51.18
OW-8	Rock	9-100	68.85	51.87	51.86	51.93
OW-9	Rock	28-123	68.88	57.87	58.27	58.38
OW-10	Sand	2.5-32.5	64.63	58.70	58.92	59.03
OW-11	Sand	2-42	71.22	66.76	66.72	67.07
OW-12	Sand	12-52	63.74	55.71	55.75	56.24
OW-13	Sand	8.5-33.5	64.99	58.90	59.01	59.20
OW-14	Sand	5-50	65.54	57.30	57.38	57.69
<u>Piezometer</u>						
B-1	Sand	5-9.5	74.80	63.64	64.20	64.50
B-4	Sand	9-13.5	74.15	67.13	67.35	67.71
B-6	Sand	7.5-12	77.02	68.94	69.44	70.12
B-12	Sand	7-11.5	75.00	69.81	70.00	70.43
B-27	Sand	20.5-25	64.73	56.01	56.37	56.70
B-41	Sand	7.5-12	66.77	59.66	60.14	60.18
AS-5	Sand	9-13.5	68.23	57.01	58.05	58.45
TP-6	Sand	1.5-6	67.79	62.27	62.69	62.90

- 1) Feet below land surface, length of open hole in rock wells
 2) Feet with respect to mean sea level

Where rock was close to or at the surface, a bedrock well was drilled. In two places, both rock and sand/gravel wells were determined to be necessary. A cluster well system, OW-1 (rock) and OW-1A (sand/gravel) was installed at site 1. North of the chrome lagoons, OW-9 (rock) and OW-14 (sand/gravel) are located in the same area about 200 feet apart. The rock and sand/gravel wells were installed in two different manners described in the following sections.

Rock Wells

Six rock wells were installed at the Woburn Site. For these wells, a thirteen-inch roller bit was used to drill through the unconsolidated materials and five feet into solid bedrock. Six-inch diameter steel casing was set in the hole allowing for a one-foot stick-up above land surface. The steel casing was used to seal off any ground water in the unconsolidated deposits and to prevent collapse. This assures that representative ground-water samples from the bedrock can be obtained. The annular space around the casing was pressure-grouted with a cement/bentonite slurry to land surface. The inside of the steel casing was then flushed out with clean water to remove any drilling fluids and sediment.

After the steel casing had set in the hole, a six-inch diameter pneumatic hammer was used to drill to the desired depth in the rock. Drilling continued until water-bearing fractures were encountered

or to at least eighty feet into rock if no such fractures were found. A geologist logged the rock fragments coming from the hole as the drilling progressed. Well logs are given in Appendix IV.

No casing was set in the hole since the rock is dense enough to allow the hole to stay open indefinitely. After the well was finished, a metal plate with a hasp was welded to the top of the steel casing allowing the well to be locked. All six rock wells were purged immediately after installation by a submersible pump. Each well was pumped until ten times the volume of water standing in the open hole was removed (OW-3 and OW-4) or until it went dry (OW-1, OW-2, OW-8 and OW-9).

A designated measuring point on top of each well casing was leveled in with respect to mean sea level. Water levels in all wells were measured on three occasions to ± 0.01 feet by an electric probe and measuring tape.

Sand/Gravel Wells

Nine (9) sand/gravel wells were installed for this investigation. These wells are screened in the saturated, unconsolidated deposits and to five feet into solid bedrock. All borings in sand/gravel were drilled by the mud rotary method using Revert and/or bentonite and water from the municipal supply system as drilling fluid additives.

In constructing these wells, an eight-inch roller bit was used to drill through the unconsolidated section and five feet into solid bedrock. After the hole was drilled, the geologist selected the appropriate length of four-inch diameter PVC slotted pipe (screen) to be used. The entire saturated thickness of the sand and gravel aquifer was screened. Threaded, four-inch, blank PVC casing was used in the unsaturated sections, allowing for a one-foot stickup above land surface.

The screen zone was packed with clean silica sand of a suitable grade for the slot sizes (.010-inch openings). A seal of bentonite pellets was placed immediately above the sand pack and the remaining annular space was pressure-grouted to about three feet below land surface with a cement-bentonite mixture. A cement seal was poured in the remaining few feet to land surface and a protective steel standpipe with a lock was used to protect each well.

The sand/gravel wells were developed in two steps. The first step consisted of surging and pumping the well with air. This process removes fluids introduced during drilling and much of the fine sediment from the formation around the screen, thus allowing a free flow of water from the aquifer into the well. The second step of the development process consisted of pumping with a submersible pump to remove at least ten times the volume of water

contained in the casing and sand pack. This step insures that all aerated water and/or water introduced during drilling has been removed.

Ground-Water Sampling

Ground-water samples were collected from the OW series of wells on September 27 and September 29, 1982. Immediately prior to sampling, each well was purged by pumping it dry or by removing from five to ten casing volumes of water. The submersible pump used for purging was thoroughly rinsed and steam-cleaned between wells.

Samples were collected by Roux Associates personnel with a stainless steel bailer. Prior to sampling each well, the bailer was thoroughly washed with tap water and rinsed three times in distilled water. In addition, the first three bailer volumes removed from the well were discarded. All sampling gloves, bailer cord, etc. were changed between wells.

HYDROGEOLOGY

Geologic deposits in the study area can be divided into groups or units based on sediment character, origin and permeability differences. From oldest (deepest) to youngest (shallowest), they are:

- Unit D - Mafic bedrock
- Unit C - Poorly sorted to unsorted mixture of clay, silt, sand and gravel
- Unit B - Fine to medium sands with finer and coarser layers and peat
- Unit A - Miscellaneous artificial fill deposits

From north to south, four geologic cross sections have been compiled, each crossing the Site in an east-west direction (Figures 6-9). The locations of these sections are shown on Figure 4. The oldest deposit in the study area, the bedrock (Unit D) will be discussed first, followed in succession by the younger, unconsolidated deposits of Units C, B and A.

Unit D

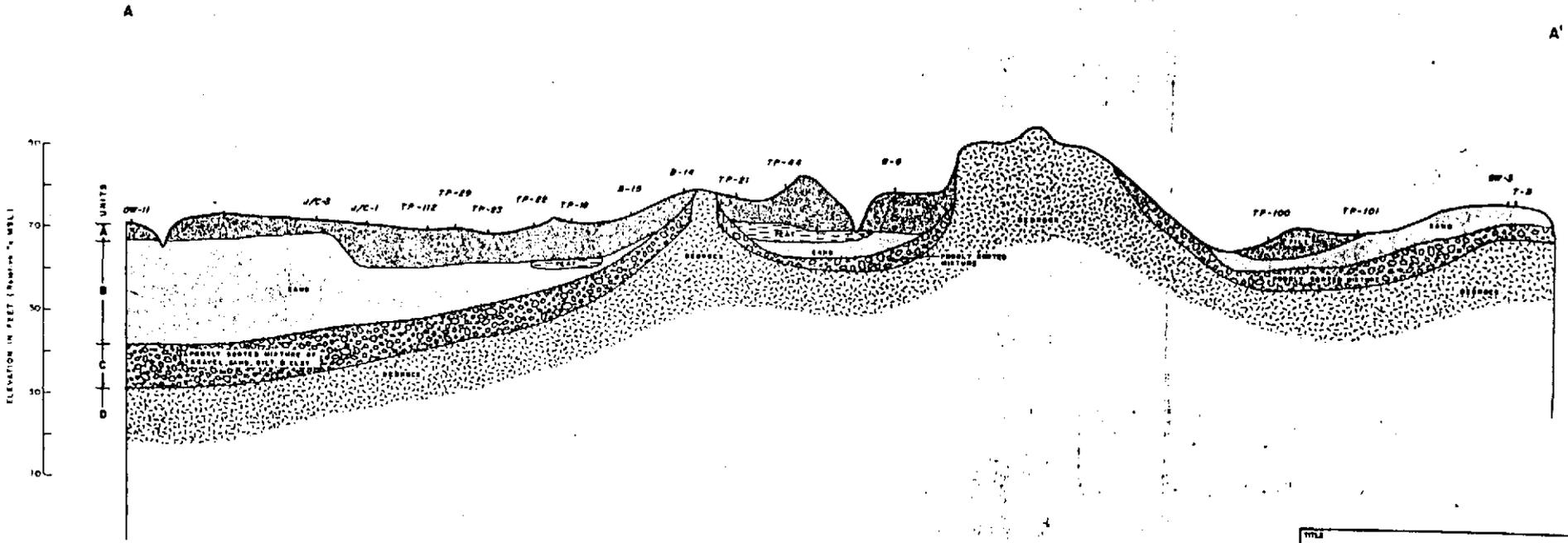
Woburn is located on the Eastern Avalonian Platform of the Northern Appalachian Mountain System. The area has been subject to several

39

139

After Page VII-16

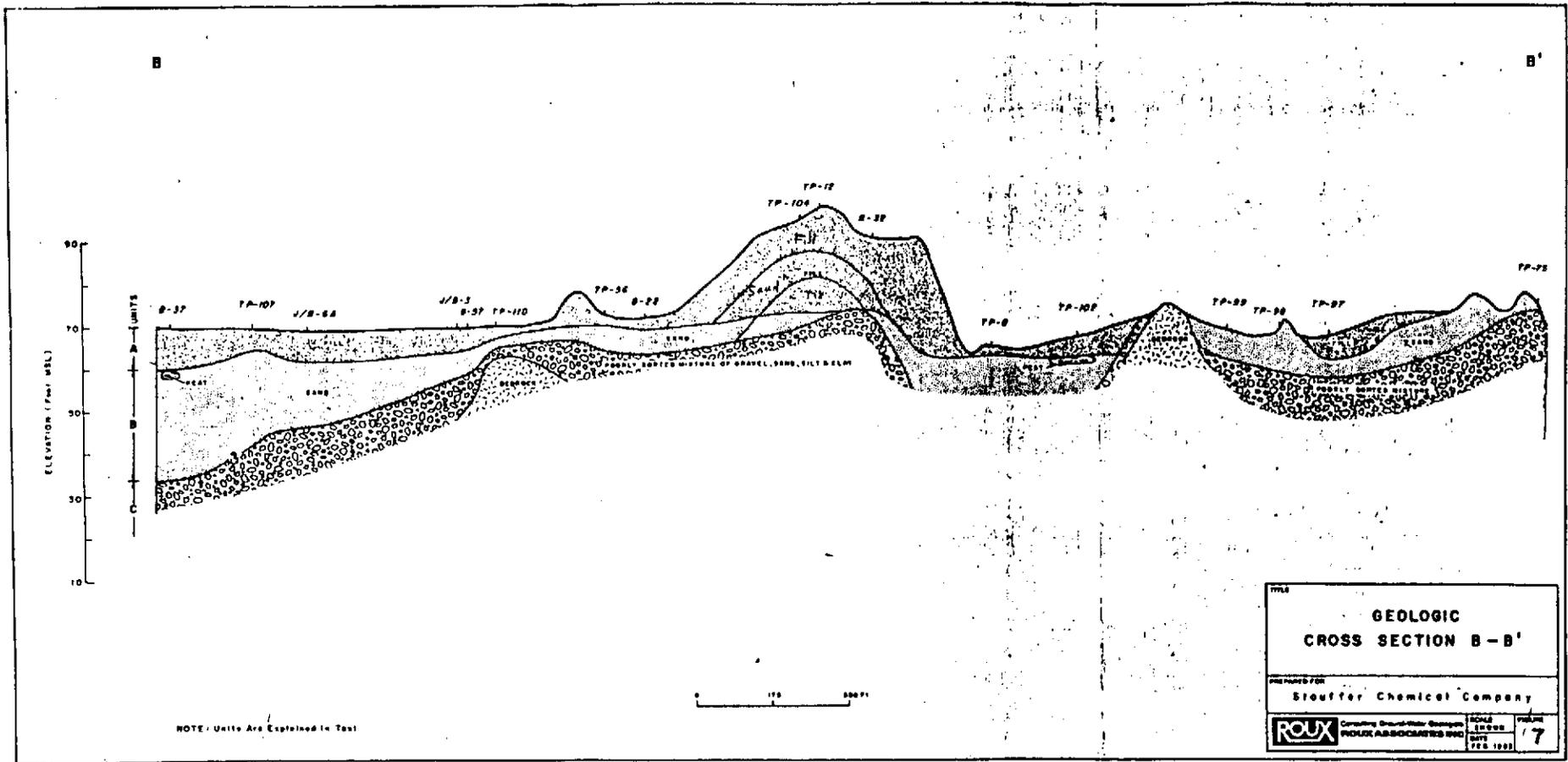
Before Large Maps

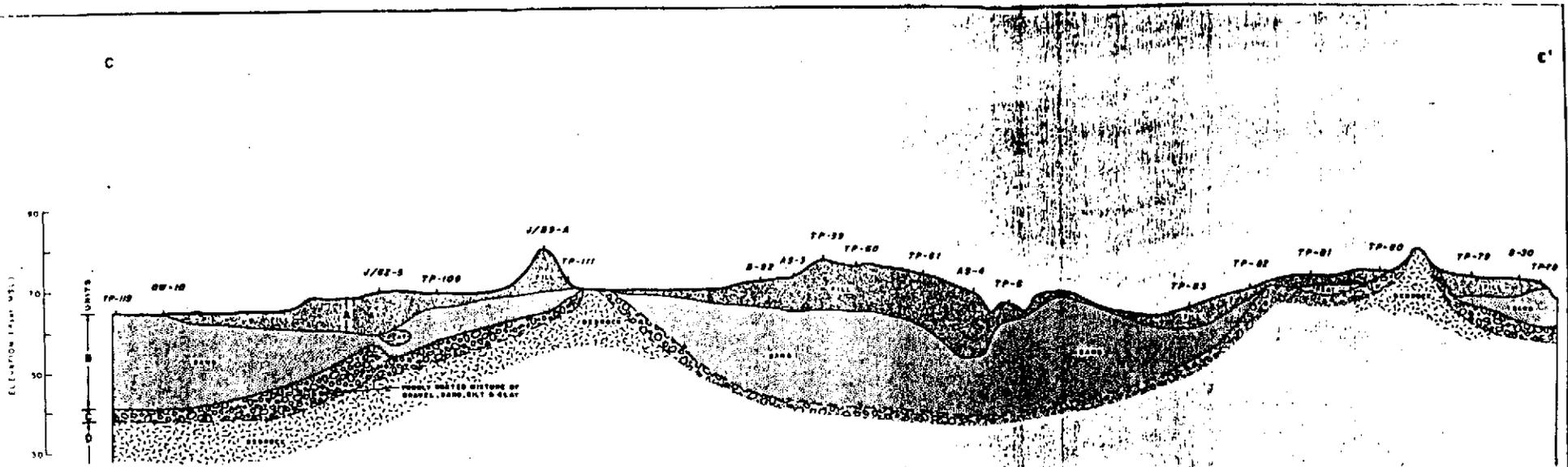


NOTE: Units Are Explained in Text



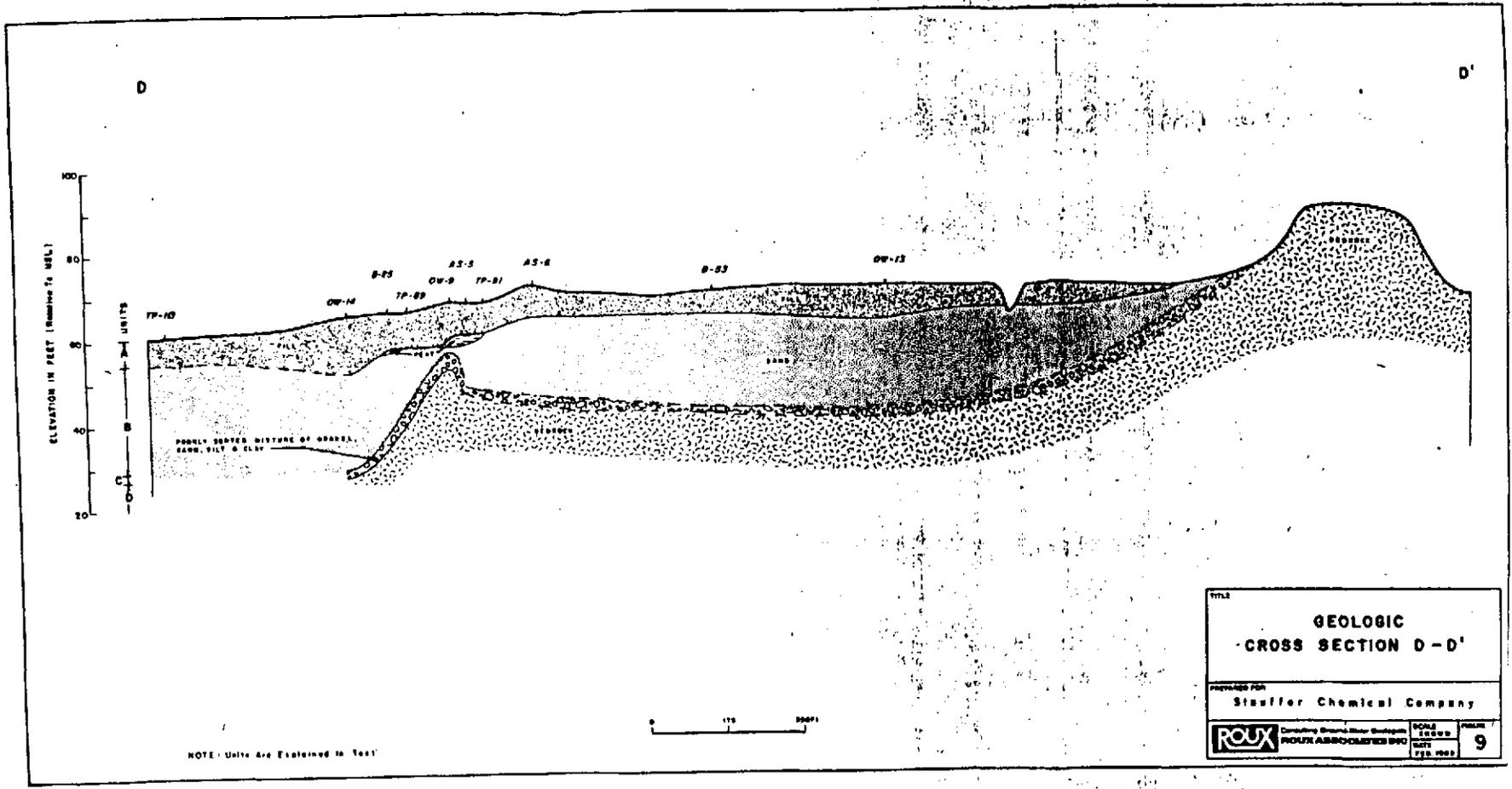
GEOLOGIC CROSS SECTION A-A'	
PREPARED FOR Stauffer Chemical Company	
ROUX Consulting Geologist-Professional ROUX ASSOCIATES INC.	SCALE AS SHOWN DATE FEB 1968
FIGURE 6	





NOTE: Units Are Explained in Text.

TITLE	
GEOLOGIC CROSS SECTION C-C'	
PREPARED FOR Stauffer Chemical Company	
ROUX	Consulting Ground-Water Geologists ROUX ASSOCIATES INC.
SCALE 1:2,000	DATE Feb. 1952
FIGURE 8	



4 (8½ x 14)

143

After Figure 9

Before Page VII-17

mountain building or deformational events that occurred more than 200 million years ago. What is observed today in the bedrock are remnants of these tectonic events. The area of investigation is located between the North Boundary and Blood Bluff fault zones which divide the greater Boston area into a series of northeast trending blocks. These blocks are in turn dissected by north-south trending faults, one of which has controlled the location of the Aberjona River Valley. The deformation associated with faulting caused a suture and a weakening of the bedrock, paving the way for preferential weathering along this plane of weakness.

The bedrock at the Site is the Salem Gabbro-Diorite (Barosh, et al 1977) which has been radiometrically dated as late Middle Ordovician (approximately 450 million years old). At the northern portions of the site, bedrock is exposed as knobs and ridges throughout (Figures 6 and 7). Towards the south where the Aberjona River Valley is more pronounced, bedrock occurs as knobs rising rapidly from the valley to the east and west (Figure 9).

Where fresh, the dominant rock type is a gray gabbro that consists of mafic minerals (pyroxene and/or hornblende) and plagioclase feldspar, with minor biotite and pyrite cubes. This rock is massive in appearance and has a fine to medium grained texture.

In outcrop, the bedrock weathers chalky with a green or gray tinge. The rock is dissected by numerous fractures, many of

which are filled with white or pink quartz. Layers of green rock are common and show phyllitic partings. This compositional banding as well as a pronounced foliation, give the rock a gneissic texture.

The green bands or layers are much softer and are highly fractured. They consist of epidote, chlorite, muscovite and plagioclase. The contact between the massive gray rock and the green layers is very irregular and often fractured.

The permeability of bedrock is dependent upon the occurrence of joints and faults and the extent of weathering. The extent of weathering of the bedrock in this area is minimal because the rock is very dense and tends to resist weathering and because geologically recent glaciation has abraded the surface and removed the loose rock that may have been present. Permeability, therefore, is dependent upon fractures that have been developed in response to volume changes, or to externally applied forces such as those that produce faulting. In general, these joint and fault openings decrease markedly with depth.

Overall, the bedrock appears to be massive at topographic highs (OW-2) and fractured/jointed in lower areas (OW-9). The gray massive phase of the bedrock, where dominant, is unfractured. Thin (less than one foot) quartz veins appear to fill any fractures.

At OW-1 and OW-8, the gray rock alternated with zones of softer, green rock. However, no major water bearing fractures were encountered at those locations. At OW-1, a very soft zone (non-water bearing) was encountered between 96 and 106 feet below land surface. This is believed to be a gouge or finely abraded material that occurs along the wall of a fault. Wells OW-1, OW-2 and OW-8 went dry during pumping and recovered at less than 0.1 gpm (gallons per minute).

At OW-9 the rock was very fractured at the top and became massive with depth. Though fractures were abundant, they were filled with quartz and yielded less than one gpm to the well.

At OW-3, the massive gray rock was present the length of the hole. However, at approximately 83 feet below land surface, a thin fracture partially filled with rosy quartz, yielded three gpm.

The rock quarrying operation has facilitated the development of fractures in the area where OW-4 is located. Fractures filled with quartz have been reopened by the blasting operations. OW-4 yielded greater than 15 gpm during development.

In summary, the bedrock of Unit D, even though fractured at many locations, generally has a very low permeability. Many fractures

are filled with quartz and the open, water-bearing fractures, such as found at OW-3 and OW-4, may be localized and not connected to other fractures in the area. Thus, the bedrock cannot be considered a significant aquifer for industrial and/or municipal water supply in this area.

Unit C

Unit C was formed during the last glacial period (12,000 years ago) when glaciers in the Aberjona River Valley stopped advancing. Initially, the glacial ice mass had widened the existing bedrock valley by plucking blocks of rock and abrading the valley walls. As the glacier advanced over the land surface, it picked up sediment. However, when the rate of advance equaled the rate of retreat, the sediment it had picked up was deposited in conveyor belt-like fashion. Thus, Unit C consists of unsorted sediments showing a high variability in grain sizes.

Unit C can be designated a till which mantles the irregular surface of the bedrock. Till is exposed at the surface where bedrock is close to the surface (Figure 9). The till was found to be twelve feet thick as a maximum. It is thin at the sides of the valley (OW-13 and OW-14), and is absent near the center of the valley (OW-12) where it was probably scoured away by currents.

The till can be divided into three distinct types in the study area. Immediately overlying the bedrock is a gray-colored non-

sorted mixture of particles ranging in size from clay to boulders. Examination of the coarser particles indicates that this till was derived locally as rock fragments of the bedrock are found exclusively. Above this layer is an assemblage of mafic bedrock and quartz cobbles and boulders in a greenish-gray clayey matrix. The rock fragments are exclusively of Unit D and are partially weathered. This layer is generally thin (less than 4 feet in thickness) and may represent a weathered part of the till below it. Overlying these deposits in a few isolated areas is a brown, medium to coarse sand with boulders and cobbles of lithologies exotic to the immediate area (such as granite, schist and gneiss).

Regardless of type, Unit C has a very low permeability due to the variable sizes, poor sorting and tight packing of the individual grains. In the core samples, the till is observed to be moist or dry, even though overlying sands (Unit B) are saturated. In a number of test pits, a small amount (0.1 gpm) of water was observed perched above clayey parts of the till, demonstrating that the till layer inhibits the downward movement of water to the bedrock.

Unit B

Overlying Unit C are younger deposits of glacio-fluvial origin called outwash. These were formed by meltwaters from the

retreating glacier which sorted sediments previously carried and deposited by the ice. Therefore, these deposits contain sediments having more uniform grain sizes and are more permeable than till deposits.

The contact between the till and outwash is easy to see because of color and sedimentological differences. Moreover, the outwash deposits below the water table are saturated, while the underlying till appears dry and is much denser.

Unit B is either very thin or absent where bedrock is close to the surface, but reaches a maximum observed thickness of 42 feet near the center of valley (OW-12). This unit consists of a series of graded sand beds that vary in thickness from four to twelve feet. From the top to the base, each graded bed consists of:

- Medium to coarse sand with granules and pebbles
50% quartz, 30% rock fragments (schist, gneiss, granite, mafic rock, etc.) and 20% feldspar, muscovite and dark minerals.
- Fine to medium sand; well-sorted; quartzose;
10 to 20% feldspar, muscovite, dark minerals and rock fragments.
- Silty fine sand; quartzose; 10 to 15% muscovite;
finely laminated; disseminated organic material.

Based on the uniform sizes, degree of sorting and loose packing of the individual grains, Unit B has a high permeability. The sand/gravel observation wells are screened in this unit and have high yields. The piezometers are screened in thinner deposits of Unit B which occur toward the fringe of the Aberjona River Valley. Where the sands and gravels of Unit B are thick, they can serve as a water supply aquifer.

At OW-6, twelve feet of sandy deposits were found to overlie 36 feet of a gray clayey silt resting on bedrock. During the time meltwaters were active in the valley transporting and depositing sands of Unit B, a body of standing water existed in the area of OW-6. Finer clay and silt-sized particles settled out of suspension. Coarser sand particles and gravel are found in places embedded in the clayey silt. Due to the fine grain sizes and cohesiveness, this deposit is of very low permeability.

Overlying the outwash deposits in part of the Site are peat deposits. Peat consists of partially decomposed organic matter such as mosses, trees and other flora that flourish in marshes and wetlands. Peat deposits have been covered by man-made fills on the Site. Marshy areas still exist within the Site suggesting that these conditions have persisted at various locations for the past 10,000 years.

The peat deposits have been considered part of Unit B, even though

they are younger. In places, peat can be seen interlayered with sand as the contact between the two deposits is gradational. Peat was encountered in many borings and test pits. At OW-5, 11.5 feet of brown peat was present beneath a thin veneer of fill and above the sands of Unit B. Peat deposits generally have a high porosity, but a low permeability because water is tied up by molecular attraction.

Unit A

Unit A consists of a heterogeneous assemblage of artificial fills and is present throughout the site and industrial complex to the south. The waste deposits on the Site, which are part of this unit, are discussed in later sections of this report.

On the portion of the Site east of Commerce Way, Unit A is a coarse regolith that mantles the natural deposits of Units B, C and D. This regolith consists of gravel and coarse sand and is essentially reworked and redistributed till. Piles of this material, which was used for road beds in the area, are found throughout this part of the Site.

Within the industrial complex south of the Site, the thickness of fill deposits averages from approximately two to four feet and are sandy. Even though it is poorly sorted in places, its loose consistency readily allows percolation of water to Unit B and to the water table.

SOIL AND WASTE INVESTIGATION

An important part of the Phase I investigation was the characterization of waste types on the Site and determination of the volumes and distributions of the various wastes identified. To accomplish this, the following tasks were undertaken: an earth conductivity survey, test pit and test boring programs, and a soil sample analysis program. These tasks are described in detail in the methods of investigation section of this report. The waste types and distributions at the Site, based on the interpretation of the results of these tasks, are described below.

Conductivity Survey Results

The purposes of the conductivity survey were to help locate optimum sites for pits and borings, and to help insure that the entire site had been surveyed and no waste deposits were missed. A description of the conductivity equipment and its operation is included in the methods of investigation section.

To provide the control necessary to make the initial interpretation of the conductivity data, measurements were made in areas where subsurface conditions could be determined from the surface. These control measurements were made on the large hide residue piles, bedrock outcrops, the Arsenic Pit, piles of construction debris, wetlands and in the area east of Commerce Way where no waste materials were visible. There were, however, no boring or test

pit logs or analytical results from soil samples for the initial conductivity interpretation.

The conductivity survey was based on a 200-foot grid system (Figure 3). A reading from at least one and frequently both instruments was made at all of the accessible grid points. In addition, continuous readings were made with the EM-31 along traverse lines through critical areas. Some EM-31 readings between grid points are shown on Figure 11. In many cases, however, the operator simply noted the changes in readings as he walked without recording them. In this way, it was determined that no waste deposits were missed by the survey.

For the purposes of defining areas containing waste materials and contaminated soil, the EM-31 and EM-34 (H) (Horizontal dipole mode) data proved to be the most useful. EM-34 (V) (vertical dipole mode) data reflects deeper conditions and was not used to locate waste deposits.

Based on the control points established, the experience of the operator at other sites, and a comparison of conductivity results between the two instruments, the initial conductivity interpretation was made. This interpretation divided the site into six classifications based on conductivity: 1) bedrock and clean, nonconductive soil, 2) contaminated ground water, 3)

solid waste, 4) hide residue, 5) construction debris containing metal objects, and 6) areas where there was interference and conductivity would not work. The results of this interpretation are shown on Figure 10.

This preliminary interpretation was used to help guide the Phase I boring and test pit digging program. Borings and test pits were located in all of the different areas defined by the conductivity survey. Also, an attempt was made to evaluate the accuracy of the conductivity area limits by locating pits and borings on both sides of various boundaries.

After completion of the Phase I soil sampling and analysis program, the conductivity data were reinterpreted. The reinterpretation indicated that it is not possible to distinguish as many categories of site conditions and waste types as are shown on Figure 10. It was found that the EM-31 and EM-34 (H) data could be combined and divided into three ranges that represented site conditions quite accurately. These categories are, in mmho/m:

- less than 10 - uncontaminated (background)
- between 10 and 50 - contaminated soil or ground water,
or thin waste deposit
- greater than 50 - waste deposit

The areas defined by these three conductivity ranges are illustrated

on Figure 11. The effectiveness of the conductivity equipment in identifying waste deposits is evident when the figures showing soil and waste sample analytical results (next section) are compared to Figure 11.

Figure 11 shows that a large portion (32 acres) of the site (east of Commerce Way) contains natural sediments and rock with no waste materials. The one exception is a small area directly north of the site trailer which was initially thought to be buried waste, but has subsequently been determined to be shallow contaminated ground water from the hide residue burial area to the west. This hide residue burial area is quite clearly defined by the conductivity, as are the two hide residue and waste material stockpiles in the northern portion of the Site.

The portion of the Site that has been developed and is not a part of the investigation could not be surveyed with the conductivity equipment because of interference. In addition, portions of the Site that contain metallic construction debris, steel fences, railroad tracks, etc. could not be surveyed with the conductivity equipment. These areas are shown on Figure 2.

The conductivity survey has provided a useful tool in guiding the boring and test pit program and has substantiated the location of waste materials as defined by analyses of soil samples. The conductivity survey has also helped to demonstrate areas containing wastes have not been overlooked.

Soil and Waste Analytical Results

Both the selection of appropriate remedial measures and the apportionment of their costs as provided for in the consent order, require that the extent and types of wastes and contaminated soil at the Site be defined. To accomplish this, samples of the waste materials and soil were collected and analyzed.

For the Phase I soil and waste sampling survey, 462 samples from 53 boreholes and 115 test pits were collected. Of these 204 were analyzed for selected metals. The metals analyzed for were antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, thallium, silver, selenium, and zinc. (Arsenic is grouped with the metals because of its similar environmental properties, but is technically a semi-conductor and not a metal). In addition, the following analyses of sediments were obtained, 21 from Janpet, 7 from EPA/DEQE, 7 from earlier Stauffer work and 15 from Boston Edison. The results of all of the analyses are given in Appendix II of this report.

In the test borings, continuous cores were taken through the fill and into natural deposits. All split-spoon samples collected were retained. The geologists selected the samples that would be analyzed based on color, odor and texture, since these physical characteristics separated the fill deposits from underlying, natural geologic deposits. The geologists selected at least one soil sample for analysis from each of the variations in color and texture, so that every fill

sample having a different color and texture would be analyzed. In addition, samples collected in natural deposits beneath the fill deposits were retained and some were selected for analysis.

The geologists had greater visibility of subsurface fill deposits in the test pits. Samples were selected to represent all different deposits encountered in a test pit. In addition, samples of natural materials were collected below the fills or where they were exposed at the surface.

The results of the soil and waste analyses for heavy metals show that while all of the metals analyzed for except beryllium, are present at 100 ppm in at least one location, six (arsenic, barium, chromium, copper, lead and zinc) are by far the predominant species. Mercury, found at a relatively few locations, may be of concern.

The distributions of the various metals identified in the soil and wastes over the area of investigation are shown on Figures 12 through 24 and give an unbiased, general view of the distribution of each metal to the extent that the Phase I data has defined it.

Arsenic and lead, because of their concentrations and widespread distribution on the Site, have been further defined on Figure 25. This figure illustrates the distribution of arsenic and/or lead

in two ranges, 100-1000 ppm and greater than 1000 ppm. The shaded areas representing these ranges were constructed by tightly contouring the points of known concentration and thus represent approximate minimum areas where these metals are present at the reported concentrations.

The total area of the Site is approximately 250 acres. Half of this area consists of shallow bedrock and buildings. Of the remaining 125 acres, 32 acres east of Commerce Way do not contain waste materials and require no further soil sampling. Combining the arsenic and lead data and eliminating overlapping areas, there are 22 acres containing arsenic and/or lead at concentrations greater than 1000 ppm and an additional 13 acres greater than 100 ppm (Figure 25).

Figure 26 shows the distribution of chromium at the Site in the same manner that Figure 25 showed lead and arsenic. Five acres contain chromium concentrations greater than 1000 ppm and another 5 acres greater than 100 ppm.

The distribution of the other widely distributed species of metals found at the Site, (barium, copper and zinc), can be seen on Figures 15, 17 and 19. A contour map of zinc and copper concentrations is shown on Figure 27. This figure shows that all of the area that contains these metals also contain arsenic, lead and chromium. Mercury, on the other hand, is not widely distributed,

but is found in several areas not containing the more common metals (Figure 18).

The thicknesses of waste materials and soil containing arsenic, lead and chromium is less certain than the areal extent, although they generally range from 1 to 8 feet below grade. Table 2 shows a comparison of concentrations of chromium, lead and arsenic at various depths in all pits and borings where samples were collected and analyzed at more than one depth. This table shows that while concentrations decrease with depth in many cases, there are also a significant number where the reverse is true. This second case reflects the areas where clean fill was placed over waste materials. In all of the borings and many of the test pits, however, natural sediments were identified under the waste materials. Soil samples were collected and analyzed from these natural sediments at several locations and were found to contain background concentrations of metals.

In addition to the metals, hide residues, because of odor problems, are a waste product of concern at the Woburn Site. Hide residues are readily identified in the field because of their color and odor and chemical analyses are not necessary for defining extent. The Phase I investigation has defined areas containing hide residues which are eight acres in extent. These are shown on Figure 28. The

Table 2 - Comparison of chromium, lead and arsenic in borings and test pits where two or more samples taken at different depths were analyzed

<u>Location</u>	<u>SOIL ANALYSIS (in ppm)</u>			<u>Depth (ft.)</u>
	<u>Chromium</u>	<u>Lead</u>	<u>Arsenic</u>	
B-9	637	86	118	1
B-9	16	-	12	3
B-12	7	8803	1026	1
B-12	7	11	-	9
B-13	409	525	194	.25
B-13	161	503	281	5
B-14	112	1837	235	1
B-14	16	212	289	3
B-15	20	2143	296	5
B-15	19	2062	237	6.4
B-21	11	13	1215	5.5
B-21	31	13	210	9.5
B-22	4956	196	88	7
B-22	216	8	5	8.9
B-22	42	12	5	14.65
B-23	1753	445	237	1
B-23	36	207	95	3
B-23	-	131	12	5
B-24	6	866	11	1
B-24	16	3800	15	7
B-27	4090	555	64	5
B-27	51	45	71	21
B-31	830	126	9	3.5
B-31	1170	149	8	9.85
B-32	688	156	6	5
B-32	1619	385	6	7
B-33	12	70	11	3
B-33	17	26	7	5.75
B-34	23	108	-	1
B-34	22	15	3	6.35
B-35	42	2857	1122	1
B-35	36	1152	133	2.35

Location	SOIL ANALYSIS (in ppm)			Depth (ft.)
	Chromium	Lead	Arsenic	
B-36	10	4660	1262	1
B-36	-	5849	1321	3
B-36	5	343	1944	5
B-36	14	123	858	7
B-37	30	540	1500	3
B-37	48	1944	204	9
B-40	10	1010	19	1
B-40	7	5	-	3
B-40	7	6	-	5
B-41	25	465	101	1
B-41	28	570	250	3
B-42	131	1616	93	1
B-42	-	5243	814	3
B-43	63	94	20	1
B-43	13	7476	1845	3
B-43	7	52	190	5
B-44	18	51	14	1
B-44	11	10	6	7
B-49	6	4950	881	.3
B-49	27	606	21	.5
B-50	15	190	19	1
B-50	21	10	-	2.65
B-52	6	5	9	5
B-52	7	5	10	11
B-54	110	140	9	1
B-54	33	5	3	11
B-55	12	8200	680	1
B-55	22	871	782	5
B-55	19	27	73	11
T-2	51	4694	2755	1.5
T-2	22	7071	8081	5.5
T-4	-	26699	1748	.5
T-4	29	417	204	4.5
T-9	28	165	23	3.5
T-9	22	25	7	4.5

Location	SOIL ANALYSIS (in ppm)			Depth (ft.)
	Chromium	Lead	Arsenic	
T-10	44444	227	10	Unknown
T-10	15481	396	8	10
T-12	248	30	7	2
T-12	15	30	10	4.5
T-16	12121	253	-	1
T-16	94	-	50	Unknown
T-17	15	1881	743	3 (2-4)
T-17	-	10400	1100	3.5 (3-4)
T-17	104	1832	238	Unknown
T-29	49	2353	93	3
T-29	29	98	5882	4
T-31	110	320	175	2.5
T-31	12	5100	2050	4
T-45	16000	2600	8	5.2
T-45	5	5979	928	9
T-63	37	888	1633	1
T-63	-	22222	5556	2.55
T-73	7	-	3	.7
T-73	-	-	3	1
T-85	75	1576	675	2
T-85	-	158	594	5.5
T-89	198	1980	941	2.7
T-89	82	7475	1414	7.2
T-95	303	1313	727	.85
T-95	13	149	12	1.75
T-95	949	424	101	4.1
T-107	-	1500	290	1.8
T-107	-	567	639	2.8
T-110	28	810	500	1
T-110	18	110	5	Unknown (0.7-1.8)
T-112	347	412	48	2.4
T-112	2300	480	75	3.5
T-113	4343	8788	14141	1.5
T-113	7	160	17000	4.5
T-114	7	55	12	1
T-114	21	4200	2400	1.5

thicknesses of these deposits range from a few feet to about 8 feet below land surface and, in the waste piles, up to 40 feet above grade.

The southern hide residue area shown on Figure 28 is where the hide residues were originally buried during the glue plant's operation. This area contains primarily hide residues and associated chromium. The northern waste pile area is a stockpile of wastes that was deposited by the Site developers during construction. This waste pile is composed of a comingled variety of materials, including hide residues, arsenic, and lead. There are also two areas that are suspected of containing hide residues that were not investigated during Phase I and are shown on Figure 27. Both of these sites contain stockpiled wastes and may contain a variety of substances in addition to hide residues.

An attempt was made in the Phase I survey to correlate various physical characteristics of samples with their chemical composition. Details of dominant and subordinant sediment, texture, color and odor were recorded for each sample and coded into the computer printout. The results are shown in Appendix II.

The coding system failed to establish a visual method of distinguishing between the various metals at the Site. However, some

generalizations based on color and texture can be made. Initially, a fill deposit with a red color was thought to be indicative of high lead concentrations. This has held true, though arsenic, barium, copper and zinc were almost as abundant in red-colored fill deposits. In addition, trace metals at the Site including antimony, cadmium, nickel, silver and thallium are found at greater than 100 ppm levels in red-colored deposits.

The gray or white colored deposits associated with what has been referred to as the Arsenic Pit, not only reflected high arsenic concentrations, but in most cases contained even higher concentrations of lead, zinc, copper and barium. A black color, when associated with hide residues, was thought to reflect higher chromium concentrations. However, as previously mentioned, the reworked hide residue pile at the northern end of the Site contains other metals as well (arsenic, barium, lead, copper and zinc).

Defining specific wastes based on the dominant and subordinate textures of the sediment grains, was also not a total success. When a fill containing artificial components, such as demolition debris, was analyzed, arsenic, lead, copper, barium and zinc were usually abundant. However, these metals, as well as chromium, were found in abundance in deposits ranging in texture from coarse to clay.

A fill deposit of certain colors (red, gray, white and orange) and comprised of artificial components, such as construction debris, contained high concentrations of barium, copper, lead and zinc, as opposed to chromium. Chromium deposits generally occur independently of the other metals, though the other dominant metals, arsenic, lead, copper, zinc, have been admixed where chromium deposits were disturbed and redeposited.

It is concluded that the only way to accurately characterize a waste material at the Woburn Site is through chemical analyses of the fill deposits. However, it was determined by the geologists in the field who examined the samples, that waste materials could be distinguished from natural sediments by visual inspection. This proves to be useful since the chemical analyses indicate that most of the waste material contains at least one of the metals of concern. Table 3 shows, for the samples collected, the geologist's characterization as natural or artificial texture, odor and color in comparison to the total concentrations of lead, arsenic and chromium where analyzed.

The samples characterized as having natural physical characteristics invariably contain approximate background concentrations of metals. Ninety percent of samples that have been classified as artificial fill or waste materials contain greater than 100 ppm of at least one metal and usually greater than 100 ppm of several metals. Thus,

Table 3 - Characterization of Natural or Artificial Deposits Compared to the Total Concentrations of lead, arsenic and chromium (where analyzed)

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
B-1	1	2	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	39
	5	1	1	1	-
B-2	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	17
B-3	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	18
	4	1	1	1	-
B-4	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	13
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-5	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
B-6	1	2	2	1	5602
	2	2	2	1	-
	3	1	1	1	-
	4	1	1	1	-
B-7	1	2	1	1	-
	2	2	2	1	332
	3	1	1	1	-
	4	1	1	1	-
B-8	1	2	2	2	14
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
B-9	1	1	1	2	841
	2	1	1	1	28
	3	1	1	1	-
	4	1	1	1	-

1- Natural 2- Artificial or Unnatural
 - No Analysis Performed

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
B-10	1	2	2	2	-
	2	2	2	2	-
	3	2	2	2	2331
	4	2	2	2	-
B-11	1	2	2	2	1269
B-12	1	2	2	2	9836
	2	2	2	1	-
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	18
	6	1	1	1	-
	7	1	1	1	-
B-13	1	2	1	1	1146
	2	2	2	1	-
	3	1	1	1	945
	4	1	1	1	-
B-14	1	2	2	1	2184
	2	2	2	1	517
	3	2	2	1	-
	4	1	1	1	-
	5	1	1	1	-
B-15	1	2	1	1	-
	2	2	2	1	-
	3	2	2	1	2459
	4	2	2	1	2318
B-19	1	2	1	2	1046
B-20	1	2	2	1	1407
	2	1	1	1	-
	3	1	1	1	-
B-21	1	2	1	1	-
	2	2	2	2	-
	3	1	2	2	1239
	4	1	1	2	-
	5	1	2	2	254
B-22	1	2	2	1	-
	2	2	2	2	-
	3	2	2	2	-
	4	2	2	2	5240
	5	1	2	2	229
	6	1	2	2	-
	7	1	1	2	-
	8	1	1	2	59

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-23	1	2	2	2	2435
	2	2	2	2	338
	3	2	2	2	142
	4	1	2	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-24	1	2	2	1	883
	2	2	1	1	-
	3	2	1	1	-
	4a	2	2	2	-
	4b	2	2	2	3831
	5	1	1	1	-
6	1	1	1	-	
B-25	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	2013
	5	1	1	2	-
	6	1	1	1	-
B-26	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	-
	5	2	2	2	-
	6	2	2	2	2504
	7	1	2	2	-
	8	1	2	2	-
B-27	1	2	2	1	-
	2	2	2	1	-
	3	2	2	2	4709
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	1	-
	7	1	1	1	-
	8	1	1	1	-
	9	1	1	1	-
	10	1	1	1	-
	11	1	1	1	167
B-28	1	2	1	1	-
	2	2	1	1	-
	3	2	1	1	-
	4	2	2	1	-
	5	2	1	1	-
	6a	1	1	1	-
	6b	2	2	2	5114
	7	1	1	1	-
8	1	1	2	-	

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-29	1	2	1	1	-
	2	2	2	1	5952
	3	2	2	1	-
	5	2	1	2	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	2	-
	B-30	1	2	2	1
2		2	1	1	-
3		1	1	1	-
4		1	1	1	-
B-31	1	2	2	1	-
	2	2	2	2	965
	3	2	2	2	-
	4	2	2	2	-
	5	2	2	2	1327
	6	2	2	2	-
	7	2	2	2	-
	8	2	2	2	-
	9	2	2	2	-
	10	2	2	2	-
	11	2	2	2	-
	12	2	2	2	-
	13	2	2	2	-
	14	2	2	2	-
	15	2	2	2	-
	16	2	2	2	-
	17	2	2	2	-
	18	1	2	2	-
B-32	1	2	1	1	-
	2	2	2	1	-
	3	2	2	2	850
	4	2	2	1	2010
	5	2	2	2	-
	6	2	2	2	-
	7	2	2	2	-
	8	2	2	2	-
	9	1	2	2	-
	10	1	2	2	-
	11	1	1	1	-
	12	1	1	2	-
	13	1	1	2	-
B-33	1	2	2	1	-
	2	2	2	2	93
	3	2	2	2	50
	4	1	1	2	-
	5	1	1	1	-
	6	1	1	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-34	1	2	1	1	131
	2	2	2	1	-
	3	2	2	1	40
	4	2	1	2	-
	5	1	1	2	-
	6	1	1	1	-
	7	1	1	2	-
B-35	1	2	2	1	4021
	2	2	2	2	1321
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-36	1	2	2	1	5932
	2	2	2	1	7170
	3	2	2	1	2292
	4	2	2	1	995
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-37	1	2	2	1	-
	2	2	2	2	2070
	3	2	1	1	-
	4	2	1	1	-
	5	2	2	2	2196
	6	1	1	1	-
	7	1	1	1	-
B-38	1	2	2	2	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
B-39	1	1	1	1	95
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-40	1	2	1	1	1039
	2	1	1	1	12
	3	1	1	2	13
	4	1	1	2	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	1	-
	9	1	1	1	-
B-41	1	2	2	1	591
	2	2	2	2	848
	3	2	2	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-42	1	2	2	1	1840
	2	2	2	1	6057
	3	1	1	2	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	1	-
B-43	1	2	2	1	177
	2	2	2	1	9334
	3	1	2	2	249
	4	1	1	1	-
	5	1	1	1	-
B-44	1	2	1	2	83
	2	2	1	1	-
	3	1	1	1	-
	4	1	1	2	27
B-45	1	2	1	1	-
	2	2	2	2	-
	4	1	1	1	200
B-46	1	2	2	2	8172
	2	2	2	2	-
	3	2	2	2	-
	4	1	1	1	-
B-47	1	2	1	1	1237
	2	2	1	1	-
	4	1	1	2	52

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-48	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	-
	5	2	2	2	44
	7	2	2	2	-
	B-49	1	2	2	1
2		2	2	1	654
B-50	1	2	2	2	224
	2	1	1	1	31
	3	1	1	1	-
B-52	1	2	2	2	-
	2	2	2	2	-
	3	1	2	2	20
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	2	22
	7	1	2	2	-
	8	1	2	2	19
	9	1	2	2	-
B-53	1	2	2	2	1750
	2	2	1	2	-
	3	1	1	1	-
	4	1	2	2	-
	5	1	2	2	22
	6	1	2	2	-
	7	1	2	2	-
	8	1	2	2	-
B-54	1	2	2	2	259
	2	2	1	2	-
	3	2	2	2	-
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	2	41
	7	1	2	2	-
B-55	1	2	2	1	8892
	2	2	2	1	-
	3	2	2	2	1675
	4	2	2	1	-
	5	2	2	2	-
	6	1	1	2	119
	7	1	2	1	-
	8	1	1	1	-
	9	1	1	1	-
	10	1	1	2	-
B-51	1	2	1	1	-
	2	2	1	1	187

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-56	1	2	2	1	-
	2	2	2	1	45408
	3	2	2	1	-
	4	2	2	1	1479
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-57	1	2	2	2	541
	2	2	2	2	-
	3	2	2	2	163
	4	2	2	2	-
	5	2	2	2	-
	6	1	1	2	-
<u>Test Pit</u>					
TP-1	1	1	1	1	-
	2	1	1	1	32
	3	1	1	1	-
TP-2	1	2	2	1	7500
	2	1	2	1	15174
TP-3	1	2	2	1	8594
	2	2	2	1	-
TP-4	1	2	2	1	621
	2	2	2	2	28447
TP-5	1	2	2	1	6009
	2	1	1	1	-
TP-7	1	1	2	2	52
TP-8	1	1	2	2	12
TP-9	1	2	2	2	216
	2	2	2	2	54
TP-10	1	2	2	2	15885
	2	2	2	2	44681
TP-11	1	2	2	2	202
TP-12	1	1	1	2	55
	2	2	2	2	285
TP13-	1	1	2	1	18
TP-14	1	2	2	2	145594
	2	2	2	1	34
TP-15	1	2	2	2	312
TP-16	1	1	2	1	144
	2	1	2	1	12374

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total lead, Arsenic & Chromium Concn. (ppr)</u>
TP-17	1	2	2	1	15013
	2	2	2	1	11500
	3	2	2	2	2174
TP-18	1	2	2	1	3825
	2	2	2	1	-
TP-19	1	2	2	1	11755
TP-20	1	2	2	1	-
	2	2	2	1	643
TP-22	1	2	2	1	100
	2	2	2	1	-
	3	1	1	1	-
TP-23	1	2	2	1	11300
TP-24	1	2	2	1	128
TP-25	1	2	2	1	24681
TP-26	1	2	2	1	2507
TP-27	1	2	2	1	2224
TP-28	1	2	2	1	521
TP-29	1	2	2	2	2495
	2	2	2	2	6009
TP-30	1	2	2	1	105446
TP-31	1	2	2	1	605
	2	2	2	1	7162
TP-32	1	2	2	1	569
TP-33	1	2	2	1	3175
TP-34	1	1	1	1	-
TP-35	1	2	2	2	1225
TP-36	1	1	2	2	122
TP-37	1	2	1	1	-
TP-38	1	2	2	1	15453
TP-39	1	2	2	1	-
	2	2	2	1	-
TP-40	1	2	2	1	16305
TP-41	1	2	2	1	-
TP-42	1	1	2	2	338

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
TP-43	1	2	2	1	5398
TP-44	1	2	2	1	-
TP-45	1 2	2 2	2 2	2 1	18608 6912
TP-46	1	2	2	2	423
TP-47	1	2	2	2	3415
TP-48	1	2	2	2	1053
TP-49	1	2	2	1	-
TP-50	1	2	2	1	12515
TP-51	1 2	2 2	2 2	2 1	- -
TP-52	1	2	2	1	-
TP-53	1	2	2	1	-
TP-54	1	2	1	1	-
TP-55	1	1	1	1	-
TP-56	1 2	2 1	2 1	1 1	- -
TP-57	1	2	2	2	17550
TP-58	1	2	2	2	-
TP-59	1	2	2	2	1772
TP-60	1	2	2	2	5049
TP-61	1	2	2	2	-
TP-62	1	2	2	2	-
TP-63	1 2	2 2	2 2	1 1	2558 27778
TP-64	1	2	2	1	34490
TP-65	1	2	2	1	25247
TP-66	1	2	2	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
TP-67	1	2	2	1	-
TP-68	1	2	2	1	-
TP-69	1	1	1	1	-
TP-70	1	2	2	1	6597
TP71	1	2	2	1	-
	2	1	1	1	-
TP-72	1	1	1	1	-
TP-73	1	1	2	1	10
TP-74	1	2	1	1	-
TP-75	1	1	2	1	68
TP-76	1	1	1	1	-
TP-77	1	1	1	1	-
TP-78	1	2	1	1	-
TP-79	1	1	2	1	17
TP-80	1	1	1	1	-
TP-81	1	2	2	1	38
TP-82	1	2	1	1	-
TP-83	1	2	2	1	62
TP-84	1	2	2	1	567
TP-85	1	2	2	1	2326
	2	2	2	2	752
TP-86	1	2	2	1	3800
TP-87	1	2	2	1	14313
TP-88	1	2	2	1	11889
TP-89	1	2	2	2	3119
	2	2	2	2	8971
TP-90	1	2	2	2	-
TP-91	1	2	2	1	2502

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
TP-92	1	1	1	1	-
TP-93	1	1	2	1	0
TP-94	1	2	2	1	3139
TP-95	1	2	2	1	2343
	2	2	2	1	174
	3	2	2	1	1474
TP-96	1	1	2	1	6
TP-97	1	1	1	1	-
TP-98	1	1	2	1	7
TP-99	1	2	1	1	-
TP-100	1	2	2	1	19
TP-101	1	1	2	1	0
TP-102	1	2	2	1	-
	2	2	2	1	18
TP-103	1	2	2	1	29
TP-104	1	2	2	2	1563
TP-105	1	2	2	2	229
TP-106	1	1	1	1	28
TP-107	1	2	2	1	1790
	2	1	2	2	1206
TP-108	1	2	2	1	670
TP-109	1	2	1	1	-
TP-110	1	2	2	1	1338
	2	2	2	1	133
TP-111	1	1	2	1	10
TP-112	1	2	2	1	807
	2	2	2	1	2855
TP-113	1	2	2	1	17167
	2	2	2	1	27272
TP-114	1	2	2	1	74
	2	2	2	1	6788
TP-115	1	1	1	1	-

while the type of waste cannot be determined visually, the physical inspection can distinguish between contaminated and natural deposits.

In addition to analysis for metals, most soil samples were screened for organic compounds. Figure 29 shows the areas where sediment samples collected registered organic content of greater than one hundred and greater than one thousand counts per gram. An area encompassing New Boston Street and the adjacent industrialized sector shows the highest levels of counts per gram.

GROUND-WATER LEVELS AND FLOW

Ground-water levels in all wells and piezometers were measured on September 22, 1982, October 27, 1982 and January 12, 1983 (Table 1). The data were used to plot water table elevation contours so that the flow direction could be determined. The resulting representative water table, which is based on data collected from the OW-series wells on January 12, 1983, is shown on Figure 30. This water table map is similar to earlier maps based on data collected in September and October.

Ground water flows downgradient and approximately perpendicular to the water table elevation contours. Figure 30 shows that ground water enters the Site from the north. Ground water west of the Aberjona River Valley will flow towards the southeast, whereas ground water east of the valley will flow towards the southwest.

The highest water levels (72.6 and 72.7) were measured at OW-1 and OW-1A located at the northern edge of the Site. The lowest level (51.2) was measured at OW-7, the most southerly well. These values indicate an overall gradient of 0.005 ft/ft. However, the slope of the water table is steepest under the Site (0.008 ft/ft) and flattens out below the industrial complex (0.002 ft/ft).

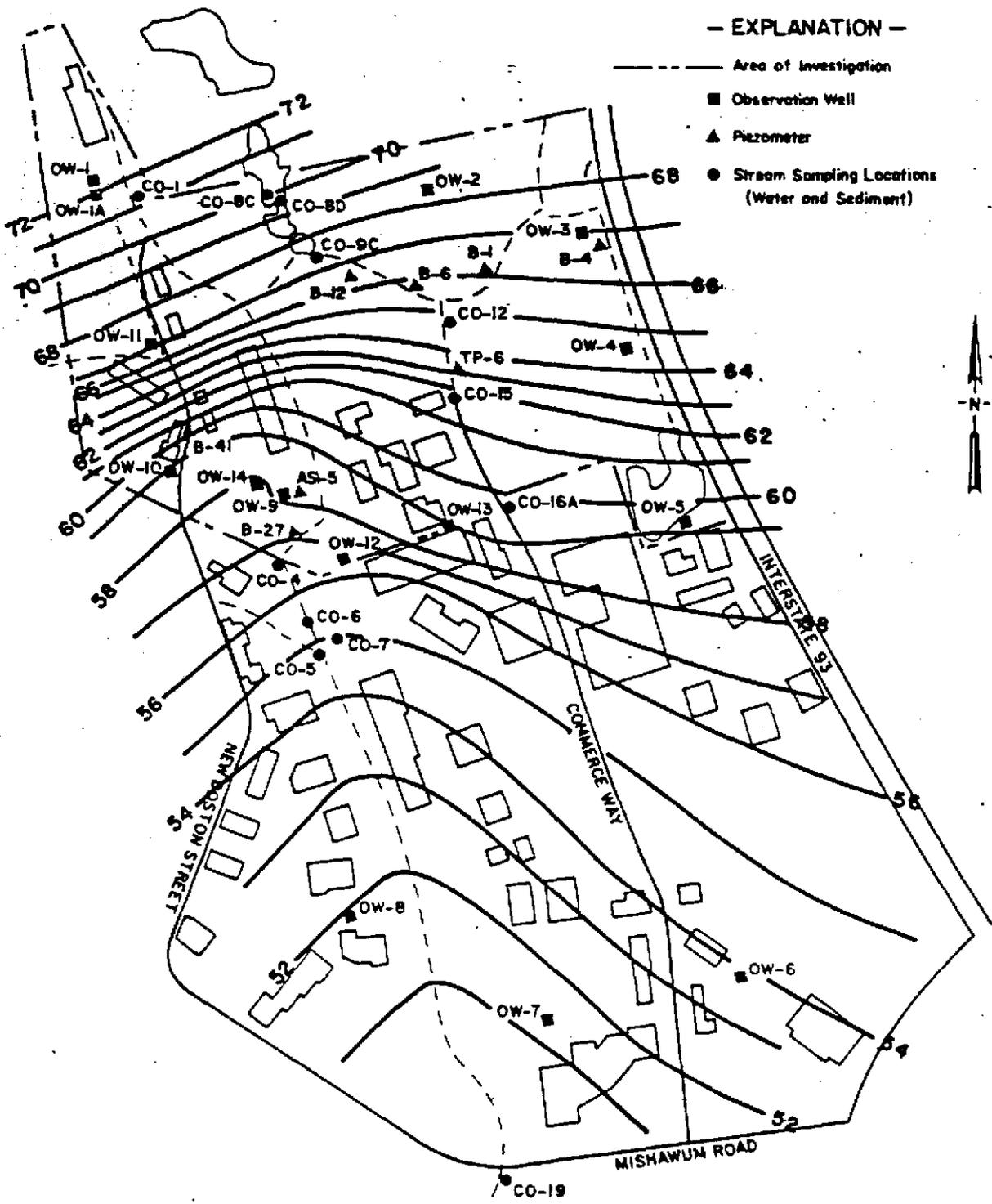
Based on the direction of ground-water flow, OW-9, OW-12, OW-13 and OW-14 are located immediately downgradient of the Site. Ground-water samples collected from these wells will reflect the quality of ground water leaving the Site. OW-1, OW-1A, OW-10 and OW-11 are upgradient wells tapping ground water that is entering the Site from the northwest and west. OW-2, OW-3 and OW-4 are upgradient to the north and east. The remaining wells, OW-5, OW-6, OW-7 and OW-8, are located lateral to the Site with respect to ground-water flow.

Examination of the water table map (Figure 30) indicates that ground water entering the Site from the northeast (east of Commerce Way) will flow under the eastern portion of the Site and into the Aberjona River Valley or thickest part of the aquifer north of Mishawum Road.

Ground water entering the Site from the north will turn towards the southwest and into the Aberjona River Valley just to the south

— EXPLANATION —

- Area of Investigation
- Observation Well
- ▲ Piezometer
- Stream Sampling Locations (Water and Sediment)



— 58 — Water Table Contour, In Feet Relative To MSL

TITLE		
WATER TABLE MAP JANUARY 12, 1983		
PREPARED FOR		
Stouffer Chemical Company		
ROUX	Consulting Ground-Water Geologists	SCALE 1" = 825'
	ROUX ASSOCIATES INC.	DATE Feb. 1983
		FIGURE 30

of the Site. Ground water entering the site from the northwest will flow under the western half of the Site and into the valley north of Mishawum Road. The ground-water flow rate throughout the area of investigation is estimated to be approximately one foot per day.

Water levels from both the rock and sand/gravel wells were used to compile the water table map because they correlate well with each other. Water levels obtained from the piezometers are generally higher than nearby upgradient observation wells. Since most of the piezometers are screened in the sands of Unit B where the unit forms a thin veneer over till and bedrock, they are essentially measuring local recharge. Water levels from the piezometers indicate a portion of this shallow ground water discharges into small tributaries of the Aberjona and other surface water bodies on the Site.

Water levels measured in OW-2 are anomalously higher than levels in nearby OW-1 and OW-3. The water level measured on January 12, 1983 is 44.19 feet higher than OW-1. This is probably due to the well intercepting an isolated and confined water-bearing fracture near the bottom of the hole. In this case, water entering the well will be under artesian pressure and will not reflect the regional water table.

Water levels have increased in all wells from late September to mid-January, with the exception of OW-1 which showed a decrease of 0.07 feet. The water levels in the sand/gravel wells rose between 0.19 and 0.53 feet while the rock wells were more variable, ranging from -0.07 feet (OW-1) to +2.07 feet (OW-4). Water levels in the piezometers showed a greater increase than the sand and gravel wells (between 0.52 and 0.44 feet). These levels reflect recharge to the ground-water aquifer from precipitation during this period.

GROUND-WATER QUALITY

All ground-water samples were analyzed for the EPA listed priority pollutants and 22 highest organic peaks on GC/MS scan. Concentrations of metals in ground water will be discussed first, followed by the organic compounds detected. Ground-water quality results are given in Appendix 4.

Of the fifteen monitoring wells, six contained metals exceeding drinking water standards. They may be summarized as follows:

- * Arsenic was found at 200 and 420 ppb in ground-water samples collected at OW-5 and OW-9 respectively. The drinking water standard (USEPA, July 1976) is set at

50 ppb. Arsenic was not detected in any other well samples.

- * Lead was found at 120 and 74 ppb at OW-7 and OW-14 respectively. The drinking water standard for lead is 50 ppb.
- * Cadmium was detected at 28 and 11 ppb at OW-10 and OW-12 respectively. The drinking water standard for cadmium is 10 ppb.
- * Chromium was detected at 54 ppb in ground water from OW-12. The drinking water standard for hexavalent chromium is 50 ppb. The type of chromium found in Well OW-12 is not known.

As previously discussed, OW-9, OW-12, OW-13 and OW-14 are the wells located immediately downgradient of the Site. Arsenic at levels greater than four times the drinking water standard was found at OW-9. Lead was detected above the drinking water standard at OW-14. Ground water from OW-12 contained cadmium and chromium just above drinking water standards. OW-13 did not contain any arsenic, lead, chromium or cadmium.

A review of data collected from monitoring wells on Janpet property,

(Goldberg, Zoino and Associates, Inc. Report L-2) also indicates the presence of arsenic and lead in the ground water. Ground water from four wells screened in sand and gravel deposits contain arsenic greater than drinking water standards. Two of these wells contain lead in concentrations above potable standards. These data correlate with data obtained from OW-9 and OW-14 which are immediately downgradient of Janpet property. Chromium was not found above drinking water standards in ground water under Janpet property.

Based on the analytical results from the downgradient wells, it appears that waste deposits on the Site are contributing arsenic and lead to the ground water. The one chromium concentration found is just above the drinking water standard right at the edge of the Site.

One upgradient well, OW-10, contains cadmium at 28 ppb. The remaining upgradient wells contain no detectable lead, arsenic or chromium, nor do metals exceed drinking water standards in any of these wells. Of the wells lateral to the Site, ground-water samples from OW-5 and OW-7 contained arsenic and lead respectively. Wells OW-6 and OW-8 did not contain detectable concentrations of these metals.

The monitoring wells were also analyzed for EPA's list of priority pollutants and other organic compounds. All of the wells downgradient

of the Site, with the exception of OW-14, contained at least one organic compound at levels greater than 100 ppb. Ground water from OW-9 showed two priority pollutants less than 17 ppb and carbon disulphide at 108 ppb. Ground water from OW-12 contained five organic compounds greater than 100 ppb, but only one organic priority pollutant at 15 ppb. OW-13 showed no priority pollutants and sulphur at 233 ppb. From this information, it appears that areas on the Site are contributing organic compounds other than the priority pollutants to the ground water. It should be noted that no volatile organic compounds were detected from ground-water samples collected on Janpet property.

Ground water from well OW-11, upgradient of the Site, contained four organic compounds and two priority pollutants, each at a concentration less than 66 ppb. Two organic compounds (carbon disulphide and trichloropropane) were detected each at 90 ppb in the sample collected from OW-6. OW-6 is located in the southeastern portion of the developed area and is lateral to the Site with respect to ground-water flow.

Downgradient monitoring wells had lower organic priority pollutant concentrations than upgradient wells. Ground-water samples from upgradient and lateral wells (OW-2, OW-3, OW-5 and OW-11) contained 52, 110, 69 and 86 ppb organic priority pollutants respectively.

Downgradient wells (OW-9 and OW-12) contained 27 and 15 ppb organic priority pollutants. There was an increase in non-priority pollutants in OW-12 which is downgradient of a waste pile and the Chrome Lagoons.

In summary, the Phase I ground-water data show several metals and organic compounds in both up and downgradient wells and in wells lateral to the Site. No significant plume of contaminants emanating from the Site was identified.

FINDINGS AND CONCLUSIONS

1. The Woburn Site is underlain by bedrock of low permeability. Unconsolidated deposits overlying bedrock are low permeability glacial till, permeable outwash sands, peat and miscellaneous fill deposits (including chemical wastes and hide residues.
2. Substantial progress has been made towards areal definition of the waste deposits. These deposits were found to range from one to eight feet deep. In several areas, wastes have been piled on the ground up to forty feet above grade.
3. Waste deposits at the Site include animal hide residue, construction debris, and chemical waste containing the following metals: arsenic, barium, chromium, copper, lead and zinc with lesser amounts of mercury and cadmium.
4. The stockpile of hide residues and other wastes in the northern portion of the Site contains all of the metals identified in other places.
5. Soil samples collected from pits and borings were analyzed for fourteen metals. The results can be summarized as follows:
 - (a) Lead is the most widespread metal found at the Site and arsenic is the second most widespread. Lead and arsenic

are frequently found together in wastes at the Site. There are approximately twenty-two acres of the Site where greater than 1,000 ppm of lead and/or arsenic are found and an additional thirteen acres containing 100 ppm of lead and/or arsenic.

- (b) Chromium is found on approximately five acres of the Site at levels greater than 1,000 ppm and on an additional five acres at greater than 100 ppm. Chromium is generally found in the same areas as the hide residues and in the Chrome Lagoon area.
- (c) Barium, copper and zinc are found across the Site at concentrations of 100 ppm in the same areas as arsenic and lead are found.
- (d) Mercury is generally found to be associated with high levels of lead.
- (e) No other metals were found in significant amounts (greater than 100 ppm) occurring independently of lead, arsenic, chromium, barium, zinc, copper and mercury.

6. Hide residues are found on approximately eight acres of the Site. In some of this area, hide residues are mixed with other wastes.

7. A preliminary screening for organics in the soil samples identified several areas around the Site, particularly in the western portion (Figure 29), that contain greater than 1000 counts per gram. Specific organic compounds present were not identified by this screening technique.
8. The area to the east of Commerce Way and an extension of Commerce Way does not contain waste materials.
9. Waste materials and contaminated soil can be distinguished from natural sediments in the field by their physical characteristics (texture, color, odor).
10. Waste types often can be recognized by observation of physical characteristics, however, positive determination of waste type must be made by chemical analysis.
11. The conductivity survey of the Site was useful in locating the best areas for subsurface exploration with pits and borings. The conductivity results were also helpful in insuring that waste deposits did not remain undetected in the subsurface.
12. Interpretation of the conductivity data shows a very good correlation with chemical analytical results. Conductivity

results did not prove to be helpful in mapping the bedrock surface with depth and only partially successful in defining areas of contaminated ground water.

13. Ground water in the bedrock and deeper portions of the outwash sands flows from north to south into the more permeable sands of the buried Aberjona Valley south of the Site.
14. A portion of the shallow ground water at the Site discharges into the Aberjona River, its tributaries and surface water bodies, whereas some flows into the deeper portion of the buried valley.
15. The ground-water flow rate in the more permeable sediment (Unit B) of the Aberjona Valley is estimated at approximately one foot per day.
16. There are no potable supply wells in the Aberjona Valley downgradient of the Site within the area of investigation north of Mishawum Road.
17. Ground-water samples collected from upgradient wells (north of the Site) had higher organic priority pollutant concentrations than downgradient wells. The samples from upgradient well OW-10 also contained cadmium (28 ppb) at a concentration greater than the drinking water standard (10 ppb).

18. In ground-water samples collected from the four wells downgradient of the Site:

(a) OW-9 contained arsenic at 420 ppb (drinking water standard 50 ppb), two organic priority pollutants less than 17 ppb and another organic compound, (carbon disulphide) at 108 ppb.

(b) OW-12 contained cadmium (11 ppb) and chromium (54 ppb) just above drinking water standards (10 and 50 ppb, respectively). One organic priority pollutant was found at 15 ppb and six other compounds were present, ranging from 22 to 1850 ppb.

(c) OW-13 contained three organic compounds, but no priority pollutants.

(d) OW-14 contained no organic compounds, but lead (74 ppb) was found exceeding the drinking water standard of 50 ppb.

19. Arsenic was found at 200 ppb in a sample from well OW-5 which is lateral to the Site with respect to regional ground-water flow, but may be influenced by shallow ground-water flow or surface-water flow.

20. Lead was found at 120 ppb in a sample from well OW-7 which is lateral to the Site.

Respectfully Submitted

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March 14, 1983

50
193

After Page VII-49
Before Page VII-50

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VIII. SURFACE WATER INVESTIGATION

A. Background

The 244 acres defined by the Investigative Plan as the Woburn hazardous waste site contain a number of surface waters that might be affected by waste deposits on the site.

The surface water streams that needed study are roughly defined as follows and are shown on Figure B.3, Appendix II(a).

- . The Aberjona River and three of its tributaries;
- . The Railroad Drainage Mitch fed by two to three smaller ditches; and
- . Phillips' pond next to Rt. 93 and two to three others east of Commerce Way.

These surface waters, stormwaters, runoff ditches and natural streams lead to the Aberjona River.

Since some of the waste deposits on the Woburn site are uncovered and exposed to the elements, contamination of surface waters by rainwater runoff, erosion, and direct discharges of contaminated water leaching from piles or waste deposits is possible. Therefore, the Investigative Plan specified a substantial part of the investigation to determine the effects of onsite hazardous waste deposits upon the surface waters entering, onsite and leaving the site.

To achieve this objective, the Investigative Plan specified that the following be done:

- 1) collect at separate locations nine (9) surface water samples at two stream flow conditions — high and low flow. To measure the flow, weirs would be installed in the appropriate stream locations. The samples would be analyzed for fourteen (14) heavy metals, Ammonia (NH_3), Total Suspended Solids (TSS), Cyanide (CN) and Total Dissolved Solids (TDS), pH, specific conductivity, Dissolved Oxygen (DO), and organic chemical priority pollutants;
- 2) Collect samples of at least three (3) liquid discharges (leachate) emanating from waste deposits. The samples would be analyzed for 14 heavy metals and organic priority pollutants;
- 3) Collect nine (9) stream sediment samples and (5) pond sediment samples at low flow conditions. The fourteen (14) sediment samples would be analyzed for heavy metals and organic priority pollutants.

Purpose: The purpose of the surface water investigation was to collect and analyze samples of surface waters, stream sediments and direct discharges to surfaces to evaluate the impacts of onsite waste desposits, if any, on the surface waters.

B. Description of Work/Purpose:

The sampling and analysis to evaluate the surface waters is divided into three distinct categories as follows:

1) Surface Water

The nine (9) low flow surface water samples were collected at locations shown on Figure B.3, Appendix II(a), and are designated by SW1-19. The sample numbers were selected from a pre-numbered list of possible sampling locations as shown in the Investigative Plan. Therefore, the samples are not numbered consecutively.

The nine (9) high flow surface water samples were not collected during the first phase of the investigation because the weather conditions did not produce sufficiently high flow stream conditions to enable collection of meaningful data. These will be addressed in Phase II.

Since streams on and near the Woburn property are small and narrow, the method of sample collection was to place a bottle in the stream. The bottles were then sealed, sent to the 10A Henshaw Street laboratory for preparation of quality assurance samples and then to ERT Laboratories for analysis of the priority pollutants, plus the up to 20 other organic pollutants

that might be found. In addition, the following parameters were analyzed: Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, Cyanide (CN), Specific Conductivity, Dissolved Oxygen (DO) and Ammonia (NH_3).

In addition, surface water flow measuring devices were installed at three (3) locations as shown on Figure B.3, Appendix II(a). An H-Flume was installed at location SW15, and the two other locations SW4 and SW15, "V" notch weirs were installed. The design details of these devices are as described in the Investigative Plan.

The manufacturer's curve ratios were used to calibrate these devices. The surface water flow measurements were recorded at the time of the sampling.

Also, as specified in the Consent Order, we reviewed prior studies and found previous surface water samples collected and analyzed by EPA, DEQE, and the Metropolitan District Commission (MDC) from 1979 to 1981 suitable for discussion. We placed these results in Table B.8.3 and Table B.8.4 and correlated them with Phase I Study findings. The analyses included heavy metals and some organic chemicals. However, some of the surface water results from prior studies might be on the high side for dissolved heavy metals, since in one instance it was found that water samples were not filtered prior to analysis. This would cause naturally occurring metals in soil particles suspended in water to be analyzed as dissolved metals.

Purpose: The purpose of sampling and analyzing the surface waters was to determine if hazardous substances as defined by the Consent Order were being added to the surface water as it passed through the site. The low flow samples were taken to determine the effect of groundwater seepage to the streams and/or release of contaminants from sediment to the surface waters, at probable maximum concentrations. The high flow samples were specified to determine the effects of erosion, runoff and possible high water table leaching.

2) Stream Sediments:

Fourteen (14) stream/pond sediment samples were collected at low flow conditions to avoid turbulence and thereby gain a representative sample of the soil on the bottom of the surface waters at the Woburn site. The samples were taken at the locations shown on Figure B.3, Appendix II(a). Nine (9) locations were at the bottom of streams and five (5) were at the bottom of ponds. The locations were chosen because they are downstream of (9) surface drainage areas that might contribute heavy metals or organics by leaching or runoff.

Again, the numbers do not appear consecutively, because the sample locations were selected from a list of possible sampling locations identified in Appendix B of the Consent Order. The selection was based on the proximity to exposed waste deposits.

The sediment samples were collected by driving a one to one and one half (1-1 1/2") inch diameter pipe three to six inches into the pond or stream bottom. The top of the pipe was sealed to create a partial vacuum. The pipe was removed and the soil held in the bottom of the pipe was discharged to a glass sampling jar. The samples were taken to the 10A Henshaw Street Laboratory and prepared, along with quality assurance samples for priority pollutant analyses and up to 20 other organic chemicals at ERT's Laboratory.

Purpose: The purpose of sampling and analyzing the sediments at the bottom of the ponds and streams was to develop information needed to evaluate the effects of exposed waste deposits, erosion of contaminated soil and the possible concentration of surface water contaminants in bottom sediments by precipitation and adsorption.

3) Leachate:

The Investigative Plan required collection of three samples of liquid emanating from known or potential waste deposits. Since rainfall was not abundant during the Phase I Study, only one liquid stream was identified in a known waste deposit area. Another liquid stream was identified in an area near Rt. 93, which is remote from any known waste deposits and was classified as a groundwater spring.

Samples of these two liquid streams were collected and sent to the 10A Henshaw Street Laboratory for preparation, along

with quality assurance samples for analysis of the priority pollutants, plus up to 20 other organic chemicals at ERT'S Laboratory.

The sample locations are shown on Figure B-3 (Appendix II(a)) and are designated as L-1 and L-2. L-2 was not considered a leachate, but as a surface expression of shallow groundwater. L-1 was considered a satisfactory sample of leachate.

Purpose: The purpose of collecting and analyzing samples of liquid emanating from known waste deposits was to develop data needed to evaluate the impact of direct discharges to surface waters of water with elevated levels of contaminants and to determine the leachability of the waste deposits on site.

C. Findings/Conclusions:

The results of the analysis of the surface waters, stream/pond sediments and leachate samples are shown on Tables B.7, B.8, and B.9 in Appendix II. The Tables list the priority pollutants by coded numbers (AE, BE or VO). The heavy metals and organic chemicals that are not priority pollutants and other parameters are listed by name. The names for organic priority pollutant codes are listed on Table C.5 (Appendix II). Where a blank is shown for an analysis, nothing was detected

at the detection limits. Only the organic chemicals (including priority pollutants) that were detected above the analytical detection limits are shown. If an organic priority pollutant or other organic chemical is not listed, it was not detected. The detection limit for each chemical is shown on Table B.5, Appendix II.

The findings and conclusions based upon the results shown on Tables B.7, B.8 and B.9 will be discussed separately for each type of sample, e.g. surface water, sediments and leachate.

1) Surface Water:

Table B.8.1 lists the results for each of the nine (9) low flow sample locations for the following parameters: 14 metals ($\mu\text{g/l-ppb}$), ammonia (mg/l-ppm), cyanide (mg/l-ppm), organic pollutants (mg/l-ppb), total suspended solids (mg/l-ppm) and total dissolved solids (mg/l-ppm).

Table B.8.2 lists the results of (9) low flow surface water samples for the following parameters: pH, temperature ($^{\circ}\text{C}$), Total Dissolved Oxygen (mg/l-ppm) and specific conductivity ($\mu\text{mho/cm}$). In addition, the three flow rate measurements in gallons per day (gpd) are shown at location SW1, SW4 and SW15.

The units of concentration for each parameter are shown in parentheses.

The sampling locations considered upstream of the Woburn site are SW1 and SW8. The sampling locations considered onsite are SW4, SW7, SW12, and SW15. The site downstream sampling locations are SW5, SW16, and SW19. SW1 is in the railroad drainage ditch upstream of SW4 and SW5. SW8 is upstream of the tributary system to the Aberjona River and samples SW12, SW15 and SW16. SW7 is a separate onsite tributary. SW19 is the downstream location of the entire Industri-Plex drainage system.

Tables B.8.3 and B.8.4 lists the results of surface water sampling and analysis done by EPA, DEQE, MDC and others, prior to Phase I investigation for the following heavy metals in units of parts per billion: Beryllium (Be), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), Silver (Ag), Thallium (Tl), Zinc (Zn), Barium (Ba), Antimony (Sb), Arsenic (As), Mercury (Hg) and Selenium (Se) and priority pollutant organics.

a. Findings:

The following findings are based upon Phase I investigation work only:

- 1) Only three heavy metals, Beryllium, Nickel and Zinc, were detected at onsite or downstream sampling locations, Beryllium findings are questionable since it is just above the detection limit of 5 ppb;

- ii) All heavy metal concentrations were below drinking water standards at onsite and downstream locations;
- iii) Lead was found at 100 ppb at the upstream location (SW8). This is above the drinking water standard of 50 ppb;
- iv) Bis(2-ethylhexyl)phthalate also called di-octyl phthalate (DOP, BE13) was found in every surface water sample and ranged from 160 to 354 parts per billion (ppb). DOP is a common pollutant that is usually associated with fabricated plastics. It is not unique to the Industri-Plex site.
- v) The total concentration of organic priority pollutants at the sampling location upstream in the Railroad Ditch (SW1 = 475 ppb) is higher than the downstream sample (SW5 = 368 ppb);
- vi) The total concentration of organic priority pollutants at sampling location SW8 is 145 ppb which is lower than the corresponding downstream location (SW16) total concentration of 269 ppb. However, SW8 has a total organic priority pollutant concentration higher than SW19, the location downstream of the entire site, which had a total organic priority pollutant concentration of 130 ppb;

- vii) The total of the organic chemical concentrations upstream in SW1 is 1198 ppb which is higher than the corresponding downstream location (SW5) total organic chemicals concentration of 412 ppb;
- viii) The total of the concentrations of organic chemicals at upstream location SW8 is 202 ppb which is lower than the corresponding location downstream location (SW16) concentration of 568 ppb, but higher than SW19, the location downstream of the entire site, which showed total organic chemical concentrations of 130 ppb;
- ix) Only one organic chemical; Bis(2-ethylhexyl)phthalate could be detected in the Aberjona River downstream of the entire Industri-Plex complex at SW19 at a concentration of 130 ppb;
- x) Only the following six (6) priority pollutants were detected at onsite or downstream sampling locations: Bis(2-ethylhexyl)phthalate; 1,1,1-trichloroethane; di-N-octyl butyl phthalate; di-N-butyl phthalate; Trichloroethylene and phenol.
- xi) Standard water parameters such as pH, conductivity, suspended solids, temperature and dissolved solids showed no unusual readings/levels for any sample;

- xii) An increase in ammonia concentration was detected downstream of the north pond (e.g. SW-7 and SW-12);
- xiii) No Chromium or Arsenic was detected in any surface water samples, and
- xiv) No Cyanide was detected in any surface water samples collected.

The following findings are based upon the sample results in Tables B.8.3 and B.8.4 obtained prior to the investigation: (As a reminder, these results must be viewed as possibly high because the samples may not have been filtered, and analysis could represent some suspended soil/sediment particles.)

- xv) Chromium was detected at a few locations in range of 5-40 ppb, but all findings were below 50 ppb (the drinking water standard);
- xvi) Zinc was detected in most of the samples in range of 30 to 850 ppb, but below the drinking water standard of 5 ppm;
- xvii) Only one out of 22 samples where As was detected was above the drinking water standard of 50 ppb. The sample was located onsite and 200 ppb As was detected;
- xviii) One sample downstream of the site showed lead at 160 ppb which is above the drinking water standard of 50 ppb;

- xix) Mercury was found at a concentration of 3 ppb minutely above the drinking water standard of 2 ppb onsite in the railroad ditch in the Hall's brook area;
- xx) Organic chemical concentrations were higher in upstream sampling locations than downstream.

b. Conclusions:

Based on the results of the Phase I low flow surface water analysis and the surface water analyses done by others prior to Phase I from 1979 - 1981, we believe sufficient data is available to make the following conclusions:

- 1) There is no significant contribution of heavy metals to surface water by the onsite waste deposits
- ii) There is no significant contribution of organic chemicals by onsite waste deposits

2) Sediments:

Contamination of stream and pond sediments can result from erosion of contaminated soil or waste deposits by stormwater and subsequent settling in surface water, or it can occur from contaminated liquid leaching directly to the surface waters and precipitating. For instance, soluble heavy metals such as Arsenic and Lead are reported in literature to precipitate in surface waters.

The results of the 14 sediment samples taken at the locations shown on Figure B.3, Appendix II(a) and are listed on Table 9.

The results are presented in parts per million (ppm) units of concentration and are reported for the following heavy metals: Beryllium (Be), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni), Silver (Ag), Thallium (Tl), Zinc (Zn), Barium (Ba), Antimony (Sb), Arsenic (As), Mercury (Hg) and Selenium (Se) and organic pollutants.

The Lower Limit of Detection (LLD) for each metal is shown on the Table directly below each metal.

A blank space indicates that the metal was not detected at its LLD and only the organic chemicals detected at or above their respective detection limits are listed.

If an organic chemical was not listed, it was not found.

Organic priority pollutants are listed by code number AE, BE or VO and can be referenced to names on Table B.5, Appendix II.

Sediment sample locations were selected based upon the potential for leaching and runoff from waste deposit drainage areas shown on Map V(a). Sample number SD1 (the ditch west of the Railroad tracks) and sample number SD8 (the dam overflow next to DEQE's Woburn office) are upstream of the drainage waste deposits on the Woburn site. Table B.10 (Appendix II) associates the drainage areas with the sediment samples collected in each area.

a. Findings:

The following findings are based upon data shown on Table 9--
Sediment Analyses in Appendix II.

- i) Sediment sample SD8 is located upstream of onsite waste deposits and no levels of heavy metals above 100 ppm were found.
- ii) Sediment samples collected at locations upstream of any onsite waste deposits showed Chromium at higher levels (470 ppm) than samples collected at downstream locations.
- iii) Highest level of Chromium found in onsite sediment was 160 ppm in the Drainage Area C-East Waste Pile.
- iv) Drainage Area B-Chromium Lagoon Area showed less than 100 ppm Chromium but had 548 - 808 ppm Arsenic (As) 396 - 636 ppm Lead (Pb), 223 - 284 ppm Copper, and 212 - 606 ppm Zinc.
- v) Drainage Area B-Chromium Lagoon had the highest level of Mercury (Hg) found in any sediment samples - 96 ppm.
- vi) Drainage Area E-Arsenic Pit sediment samples showed the highest level of Lead (Pb) - 1374 ppm. It also had Copper at 879 ppm and Zinc at 566 ppm.
- vii) Drainage Area D-West Waste Pile had the highest level of Copper (Cu) and Zinc (Zn), 3366 ppm and 1386 ppm, respectively. Lead at 656 ppm was also found in this area.

- viii) Drainage Area G-Phillips' Pond and the Aberjona River, downstream of the site had no levels of heavy metals above 75 ppm in the sediments.
- ix) Drainage Area I-Offsite south of the Railroad ditch had no outstanding levels of heavy metals.
- x) Drainage Area J-Offsite in Aberjona River near Mishawum Road had the only sediment sample other than the drainage area near the Chromium Lagoon that showed Mercury above 50 ppm, (i.e., Hg at 77 ppm). No other metals were found above 55 ppm.
- xi) Drainage Area D-West Waste Pile had the only elevated level of an organic priority pollutant - Benzene at 320 ppm.
- xii) Sediment sample SD1 which is upstream of the site west of the railroad track.
- . contains all of the priority pollutants found in sediment samples collected downstream of the western sector of the site.
 - . has a total of organic chemical concentrations of 234 ppm which is higher than any sample downstream of it.

- xiii) Sediment samples collected from the Aberjona River onsite and offsite (i.e. Drainage areas F, G and J) had a total organic chemical concentration of no greater than 78 ppm.
- xiv) Only two organic chemicals other than Benzene were above 100 ppm - Sample SD9c-Drainage Area E/Arsenic Pit had 140 ppm Methyl Ethyl Ketone and Sample SD5c-Drainage Area A/Halls Brook had 230 ppm Oxybis Ethanol.

b. Conclusions:

Based on findings listed above and the previous surface water results, conclusions are as follows:

- i) The West Waste Pile drainage area indicates possible contribution from the waste deposits of Copper, Zinc, Lead and Benzene to the surface water sediments.
- ii) Waste Deposit areas near the Chromium Lagoon indicate possible Lead, Zinc, Arsenic and Mercury, but no unusual amounts of Chromium.
- iii) Chromium does not appear to be significantly affecting the surface water sediments.
- iv) Since no elevated levels of heavy metals or organic chemicals were found in the surface water samples, the contamination found in the sediments is not dissolving in and moving with the surface water at low flow condition.

3) Leachate

The Investigative Plan specified that leachate would be collected at the three waste piles. Leachate would also be collected where there was seepage from concentrated heavy metal sources, such as the arsenic pit. However, there was insufficient rain during the study to cause many observable liquid streams seeping from waste deposits.

There was only one leachate sample, L-1 on the north side of the east waste pile. A sample of groundwater East of Commerce Way was collected entering the site next to Interstate I-93.

In October 1981, the Massachusetts Department of Environmental Quality and Engineering collected leachate samples prior to this investigation. We received these analytical results late and did not have time to evaluate.

The results of these Phase I analyses of leachate are shown on Table B.7 and the following discusses the findings and conclusions of these results.

a. Findings:

With one explainable exception, the groundwater seepage sample next to I-93 showed no concentrations of heavy metals above drinking water standards. The exception was that Lead was found at 62 ppb slightly above the drinking water standard of 50 ppb. However, this is not unexpected due to leaded gasoline emissions from motor vehicle traffic on the adjacent I-93.

- 1) The groundwater samples showed three priority pollutant organics, bis(2-ethylhexyl)phthalate (BE-13), methylene chloride (VOC 22), and trichloro fluoromethane (VO 30) for a total concentration of 97 ppb. This seems partially if not wholly attributable to background water contamination in the site area since the upstream site surface water samples, SW-1 and SW-8 had priority pollutant concentrations about 2-5 times higher. The major organic constituent bis(2-ethylhexyl)phthalate was 54 ppb.
- ii) Phase I study sample of Leachate L-1 contained the following
 - a) 860 ppb of the priority pollutant phenol, b) 1425 ppb total concentration of other organics, i.e., methyl phenol, benzoic acid and benzene propanoic acid; c) antimony at 200 ppb and; d) arsenic at 300 ppb.

b. Conclusions:

- 1) Leaching during dry weather conditions does not appear to be a problem since few liquid streams were observed and surface water analyses did not show significant levels of contaminants.

20

213

After Page VII-49

End Volume I

PHASE I
EVALUATION OF WASTE DEPOSITS
AND SUBSURFACE CONDITIONS

Industri-Plex Site
Woburn, Massachusetts

March 1983

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TABLE OF CONTENTS

	page
INTRODUCTION.	1
METHODS OF INVESTIGATION.	2
Conductivity Survey.	2
Soil Boring Program.	7
Test Pit Program	9
Observation Well Installation.	11
Rock Wells	12
Sand and Gravel Wells.	13
Ground Water Sampling.	15
HYDROGEOLOGY.	16
SOIL AND WASTE INVESTIGATION.	25
Conductivity Survey Results.	25
Soil and Waste Analytical Results.	29
GROUND-WATER LEVELS AND FLOW.	37
GROUND-WATER QUALITY.	40
FINDINGS AND CONCLUSIONS.	44

TABLES

	following page
TABLE 1 - Well Construction Data.	11
TABLE 2 - Comparison of Chromium, Lead and Arsenic in Borings and Test Pits	33
TABLE 3 - Characterization of Natural or Artificial Deposits.	36

FIGURES

	following page
Figure 1 - Site Location Map	1
Figure 2 - Areas of Investigation	Appendix IV
Figure 3 - Conductivity Measuring Point Locations	Appendix IV
Figure 4 - Locations of Test Borings and Pits	Appendix IV
Figure 5 - Well and Piezometer Location Map (showing stream sampling locations)	9
Figure 6 - Geologic Cross Section A-A'	16
Figure 7 - Geologic Cross Section B-B'	16
Figure 8 - Geologic Cross Section C-C'	16
Figure 9 - Geologic Cross Section D-D'	16
Figure 10 - Initial Interpretation of Conductivity Results	Appendix IV
Figure 11 - Reinterpretation of Conductivity Results	Appendix IV
Figure 12 - Distribution of Lead	Appendix IV
Figure 13 - Distribution of Arsenic	Appendix IV
Figure 14 - Distribution of Chromium	Appendix IV
Figure 15 - Distribution of Barium	Appendix IV
Figure 16 - Distribution of Cadmium	Appendix IV
Figure 17 - Distribution of Copper	Appendix IV
Figure 18 - Distribution of Mercury	Appendix IV
Figure 19 - Distribution of Zinc	Appendix IV
Figure 20 - Distribution of Antimony	Appendix IV
Figure 21 - Distribution of Nickel	Appendix IV
Figure 22 - Distribution of Selenium	Appendix IV
Figure 23 - Distribution of Silver	Appendix IV

FIGURES

following page

Figure 24 - Distribution of Thallium	Appendix IV
Figure 25 - Contour Map of Arsenic and Lead Concentrations	Appendix IV
Figure 26 - Contour Map of Chromium Concentrations	Appendix IV
Figure 27 - Contour Map of Copper & Zinc Concentrations	Appendix IV
Figure 28 - Location of Hide Residue Areas	Appendix IV
Figure 29 - Contour Map of Counts per Gram	Appendix IV
Figure 30 - Water Table Map (January 12, 1983)	37

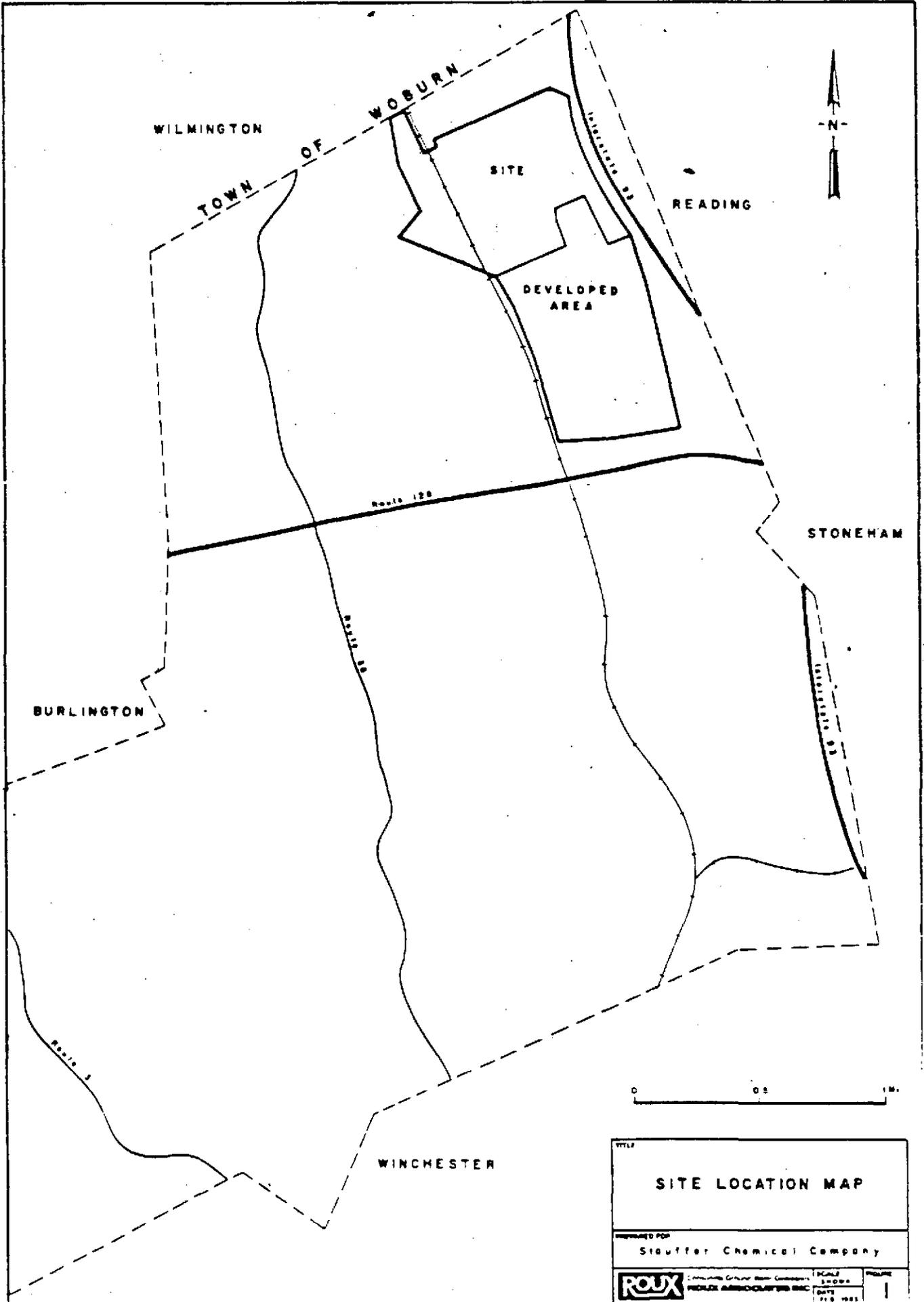
INTRODUCTION

The Phase I subsurface investigation at the Woburn Site included a preliminary definition of the nature and extent of waste deposits and contaminated soil and a preliminary evaluation of ground-water conditions. The work was carried out by, or under the supervision of geologists from Roux Associates with chemists, engineers and a safety officer from Stauffer Chemical Company.

The waste deposit and soil investigation was carried out with electrical conductivity surveying equipment, a backhoe and an auger drilling and core sampling rig. Many soil and waste samples were collected, described and chemically analyzed as part of this portion of the investigation.

The ground-water conditions at and around the Site were evaluated by installing fifteen observation wells, measuring water levels and collecting and analyzing water samples.

The location of the Site is shown on Figure 1. The portions of the Site that were included in the subsurface investigation are shown on Figure 2. Shaded areas on Figure 2 are either developed or very shallow bedrock and were investigated where possible as part of Phase I.



TITLE			
SITE LOCATION MAP			
PREPARED FOR			
Stouffer Chemical Company			
ROUX	ENGINEER	DATE	PROJECT
	PROJECT ASSOCIATES INC.	11/8 1981	

The various methods of the Phase I subsurface investigation at the Woburn Site are described below. The results of these investigations, and the findings and conclusions drawn from the results are given in subsequent sections.

METHODS OF INVESTIGATION

Conductivity Survey

A preliminary screening of the Site was undertaken using a geophysical method known as induction conductivity. Induction conductivity makes use of a device called a "non-earth-contacting terrain conductivity meter", which utilizes the principle that the electrical properties of various natural earth materials and artificial fill (or waste) can be significantly different.

It was expected that the individual types of waste material at the Woburn Site would each have their own recognizable and distinct conductivity range, and that this would permit the delineation of these materials. At the very least, the waste materials were expected to have a substantially different conductivity from natural soils and rock at the Site. Thus, the conductivity survey was intended to provide the initial screening of the Site and help guide the boring and test pit programs to follow.

A second purpose of the conductivity survey was to give a very thorough coverage of the Site to insure that all buried waste deposits were located. This blanket coverage is not practical with pits and borings alone.

The conductivity equipment used in Woburn was manufactured by Geonics, Ltd. of Mississauga, Ontario. Two types of terrain conductivity meters were used: the one-man EM-31 and the two-man EM-34-3 (hereafter referred to as the EM-34). Both the EM-31 and the EM-34 work in a similar fashion. A time-varying electromagnetic field is produced by a battery-powered transmitter which in turn acts to generate electrical eddy currents in any subsurface conductors present. These eddy currents then serve as the source of a secondary electromagnetic field, generally 90 degrees out of phase with the transmitter-generator (primary) field. Since the secondary field is out of phase with the primary field, it can be detected at the receiver. At the low frequencies used by the EM-31 and EM-34, the strength of the secondary field is directly proportional to terrain conductivity, which allows the equipment to display direct readings of apparent conductivity.

The EM-31 was used for this project because its continuous-reading capabilities allowed for a rapid identification and delineation of high-conductance areas. The EM-34 was used to verify results from the EM-31 and determine conductivities at greater depths than

the EM-31 is capable of. The depth from which conductivity data can be gathered is related to the geometry of the receiver and transmitter coils. Since the EM-31 has a fixed intercoil spacing, the conductivity data it collects corresponds to conditions within six to seven meters (20 to 23 feet) of the surface. The EM-34 however, due to the flexible cable attaching the transmitter and receiver coils, allows for changes to be made in its intercoil geometry. The EM-34 can be used with a 10 meter, 20 meter, or 40 meter (30, 60 or 120 feet) intercoil spacing. When both coils are held coplanar and vertical (called the horizontal dipole mode), an effective depth of penetration of 7.5 meters (22 feet) for the ten meter intercoil spacing is obtained. Depth of penetrations of fifteen meters (45 feet) are obtained in the 20 meter intercoil spacing, and up to 30 meters (90 feet) penetration are obtained when the coils are 40 meters apart. The coil geometry can also be changed so that both coils are lying horizontal (known as the vertical dipole mode) which effectively doubles the depth of penetration possible for each intercoil spacing.

The EM-31 and EM-34, like any electromagnetic equipment, are subject to interference. Sources of interference can be numerous in developed areas, and may not be easily avoided. Interference may be caused by buildings, buried pipelines, metal fences, railroad tracks, power lines and other large metal objects. Their adverse effect on data quality can only be avoided by keeping

the equipment an appropriate distance away from the source of interference. The appropriate distance must be determined by the operator through past experience, or through on-site interference testing in an area of known terrain conductivity.

A second limitation that must be considered before interpretation of results can be made is imposed by the local geology. For example, since clay is a relatively good electrical conductor, it can mask the evidence of artificial (contamination-related) fill at a particular location. The degree of understanding of the local geology is, therefore, related to the degree of confidence of interpretation of conductivity data.

The conductivity survey at the Woburn Site was conducted on a 200-foot grid spacing. A tighter grid spacing was used in some areas. The orientation of the grid lines was chosen to coincide with the survey grid used on the two-foot contour-interval Woburn Site base map. The conductivity measuring points were then plotted on this map as the survey was being conducted. Altogether, over 640 conductivity measurements were made at approximately 460 locations. The conductivity measuring point locations are shown on Figure 3.

One of the stations was arbitrarily chosen as a starting point and located in the field with the aid of the map, a compass, and a tape measure. From this point, the other stations were located

through the use of a compass, optical tape measure, and the two-foot contour-interval map.

The grid network was designed to cover the entire Site, as well as portions beyond the Site, where possible, to allow for a conductivity contrast to be observed. Certain areas could not be included in the grid due to the presence of extensive sources of interference.

The conductivity at each grid site was first measured by the EM-31. These results indicated the need for a closer data spacing in several portions of the Site. A series of continuous-reading traverses were then conducted through these areas. This was done to better define the more complex zones, and to identify any deposits that may have been missed previously.

The EM-34 was used primarily in the western portion of the Site, as well as in land adjacent to the Woburn Landfill (west of the Site) and the area south of the Site near the chromium lagoons. Due to the high water table and relatively shallow bedrock throughout much of the Site, the ten-meter intercoil spacing was used for both horizontal and vertical dipole readings with the EM-34. The horizontal dipole data (with a 7.5 meter [22 ft.] depth of penetration) was used to verify data collected with the EM-31. The vertical dipole data (with a 15-meter [45 ft.] depth of penetration) was used to evaluate the possibility of deeper sources of contam-

ination, as well as to aid in the delineation of buried construction materials.

Soil Boring Program

Fifty-seven soil borings were drilled on the Woburn Site between July 27 and August 19, 1982 by Parratt-Wolff, Inc. of East Syracuse, New York, under the supervision of geologists from Roux Associates. In addition, eight borings were completed for the air sampling program (AS1-AS8). Boring logs are included in Appendix IV. The locations of the borings are shown on Figure 4.

The sites for the borings were located by the geologists based on information obtained from the conductivity survey, historical aerial photographs and an inspection of the surface. Borings were drilled primarily in areas where digging test pits with a backhoe was not practical, such as in developed areas where the surface could not be significantly disturbed and in areas where it was desirable to sample deeper than eight feet below the surface (the depth limitation of the backhoe).

A truck-mounted hollow stem auger rig was used to take continuous cores until refusal was met or until natural deposits were encountered. Where several borings were placed close together, one boring was advanced to refusal and the others were terminated approximately ten feet into natural deposits.

Split-spoon core samplers were used to collect continuous samples. The split-spoon samplers were driven two feet at a time into undisturbed sediments by a standard 140-lb. weight. The geologist opened the spoon on a plastic sheet, logged the core in detail, and then removed the sample from the split-spoon using vinyl gloves and plastic spoons. The sample was placed in a pre-cleaned, wide-mouth quart jar under the supervision of a chemist. Cross-contamination was minimized by using 10 different split-spoon samplers and thoroughly steam-cleaning each between samples.

After the 0-2 foot interval sample was collected, the hole was advanced to two feet with power driven six-inch diameter hollow stem auger flytes. The 2-4 foot interval was then sampled by split-spoon. Cross-contamination within a hole is minimized as samples are collected ahead of the auger flytes. The auger flytes were steam-cleaned before moving from one area of the site to another to further avoid cross-contamination. In addition, to prevent dilution of any contaminants that might be present, water was not used in the hole during drilling. After sampling was completed, the open hole was back-filled with the cuttings obtained from the boring. The site was marked with a metal stake and flagging. The location of each boring was surveyed and plotted on a site map.

At certain boring sites, it was determined that a piezometer might be useful to measure water levels in the shallow sand and gravel deposits. The piezometers consist of a 4.5-foot length of two-inch

diameter PVC slotted pipe with blank PVC riser pipe extending above land surface. The formation was allowed to collapse around the screen zone and the remaining annular space was back-filled with material initially removed from the hole.

A total of eight piezometers were installed. The elevation of a designated measuring point at the top of the PVC casing was determined with respect to mean sea level. Water levels were measured with an electric probe and steel tape to ± 0.01 feet. The locations of the piezometers are shown on Figure 5.

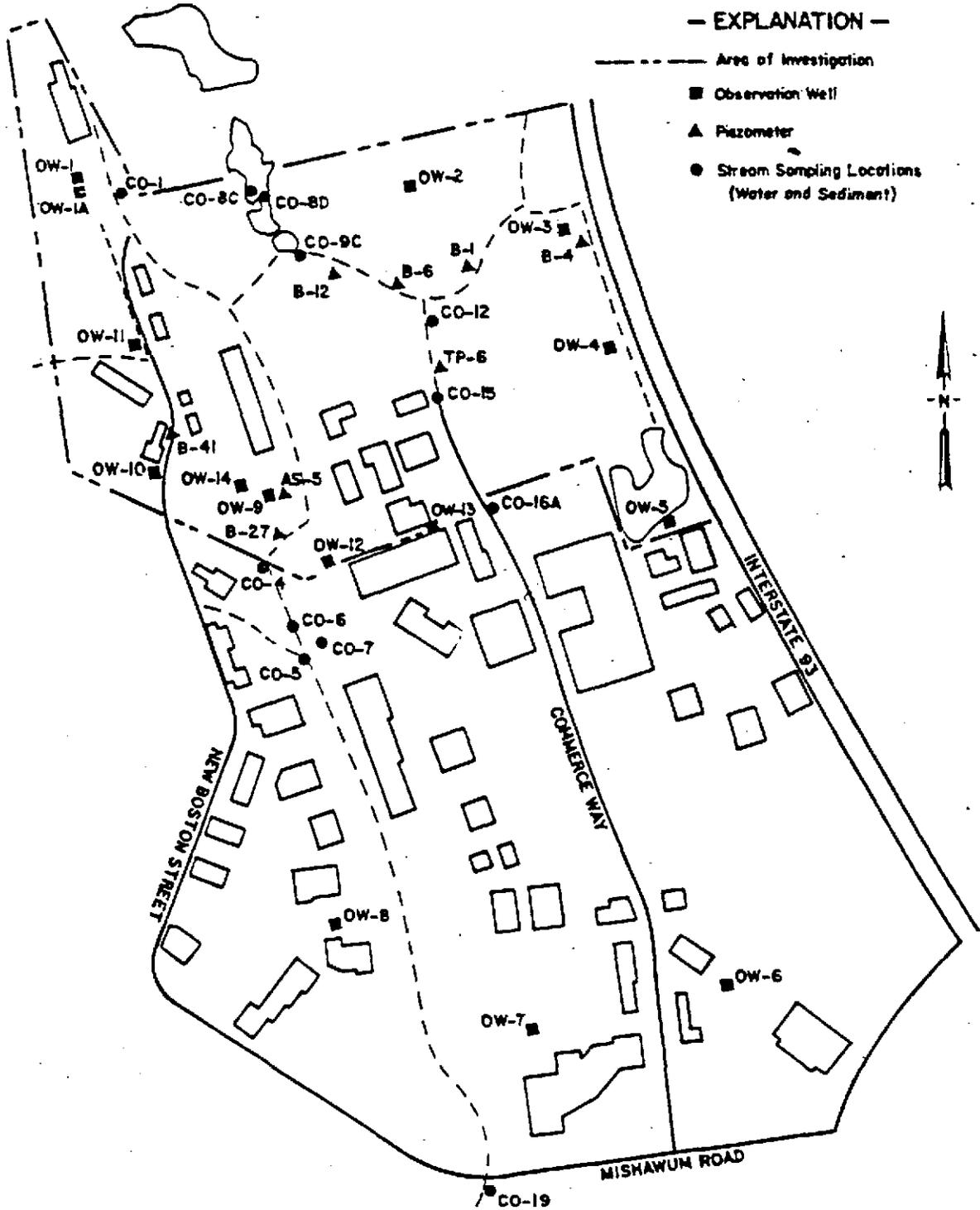
Air sampling holes, (AS1 through AS6) were drilled in the same manner as the borings. Continuous cores were collected and logged by the geologist but no sediment samples were retained. After completion, each hole was left open and covered at land surface with a plastic sheet. A stake was driven into the ground near each boring to mark its location. Air sampling holes (AS-7 and AS-8) were drilled by using a hand auger since the drilling rig could not get to these locations. In addition, borings B-31 and B-32 were used as air monitoring points. All air monitoring points are shown on Figure 2.

Test Pit Program

A backhoe was used at the Woburn Site to dig 123 test pits. All pits were dug between August 26 and September 9, 1982 by Warren

— EXPLANATION —

- Area of Investigation
- Observation Well
- ▲ Piezometer
- Stream Sampling Locations (Water and Sediment)



0 500 1000 FT.

TITLE		
OBSERVATION WELL LOCATION MAP (With Stream Sampling Points And Piezometers)		
PREPARED FOR		
Stauffer Chemical Company		
ROUX	Consulting Ground-Water Geologists	SCALE 1" = 825'
	ROUX ASSOCIATES INC.	DATE Feb. 1983
		PAGE 5

Cummings of Woburn, Massachusetts, under the supervision of geologists from Roux Associates. As with the soil borings, test pit locations were selected by examination of historical aerial photographs, the conductivity data, surface deposits, and the soil borings. The locations of the test pits are shown on Figure 4.

Each test pit was dug to the limit of the backhoe (about 8 feet below land surface), to refusal (bedrock) or when collapse occurred due to intersection with the water table. Test pits allowed the geologist to view the shallow stratigraphy and could be dug at a faster rate than the soil borings. However, this method was limited to a maximum depth of about 8 feet below land surface and to areas where the surface could be disturbed.

Each individual test pit was excavated in steps allowing the geologist to accurately describe the deposits and obtain representative samples by hand. When the pits were more than five feet deep, samples were collected without the need for the geologist to enter the trench by using a steel trowel attached to the end of a long rod. The area of the wall of the trench where the sample was to be taken was scraped to remove any sediments that had been in contact with the backhoe. The depth to each sampling location was measured. Each sample collected by the geologist was immediately delivered to the chemist at the site for labeling and preservation.

After the sampling from each test pit was completed, it was back-filled with the material that had been removed from it. All sampling implements were either disposed of or cleaned thoroughly in distilled water. The backhoe itself was steam-cleaned between sampling areas and at the end of each working day.

The location of each test pit was plotted on a map and a stake was left at the location in the field. The location of each individual pit was surveyed and located on the site base map.

Observation Well Installation

All observation wells were installed between August 10 and September 22, 1982 by Domestic Wells, Inc. of Bolton, Massachusetts. Well drilling and installation were supervised by a geologist from Roux Associates. A truck-mounted combination air/mud rotary rig was used at all sites. Two types of wells were installed; sand/gravel wells and rock wells. The rock wells are simply an open hole cased off from the overburden, whereas the sand/gravel wells are constructed with a PVC screen (slotted pipe) and casing. The PVC casing is protected at the surface by an outer steel casing with a locking cover. The locations of the observation wells are shown on Figures 4 and 5. Well construction data are given in Table 1.

In areas where the saturated thickness of the sand and gravel deposits was greater than ten feet, a sand/gravel well was installed.

Table 1 - Well Construction Data

Well Number	Well Type	Screen Zone 1)	Elevation of Measuring Point 2)	Elevation of Water Table 2)		
				9/22/82	10/27/82	1/12/83
OW-1	Rock	24-108	80.32	72.71	72.68	72.64
OW-1A	Sand	5-25	79.72	72.59	72.55	72.78
OW-2	Rock	16-100	128.02	106.67	116.18	116.83
OW-3	Rock	25-83	74.76	66.06	66.56	66.99
OW-4	Rock	25-44	71.54	62.73	63.85	64.80
OW-5	Sand	9-49	68.08	58.84	58.88	59.10
OW-6	Sand	6-16	62.67	53.52	53.73	54.02
OW-7	Sand	6-36	57.88	50.67	50.84	51.18
OW-8	Rock	9-100	68.85	51.87	51.86	51.93
OW-9	Rock	28-123	68.88	57.87	58.27	58.38
OW-10	Sand	2.5-32.5	64.63	58.70	58.92	59.03
OW-11	Sand	2-42	71.22	66.76	66.72	67.07
OW-12	Sand	12-52	63.74	55.71	55.75	56.24
OW-13	Sand	8.5-33.5	64.99	58.90	59.01	59.20
OW-14	Sand	5-50	65.54	57.30	57.38	57.69
<u>Piezometer</u>						
B-1	Sand	5-9.5	74.80	63.64	64.20	64.50
B-4	Sand	9-13.5	74.15	67.13	67.35	67.71
B-6	Sand	7.5-12	77.02	68.94	69.44	70.12
B-12	Sand	7-11.5	75.00	69.81	70.00	70.43
B-27	Sand	20.5-25	64.73	56.01	56.37	56.70
B-41	Sand	7.5-12	66.77	59.66	60.14	60.18
AS-5	Sand	9-13.5	68.23	57.01	58.05	58.45
TP-6	Sand	1.5-6	67.79	62.27	62.69	62.90

- 1) Feet below land surface, length of open hole in rock wells
 2) Feet with respect to mean sea level

Where rock was close to or at the surface, a bedrock well was drilled. In two places, both rock and sand/gravel wells were determined to be necessary. A cluster well system, OW-1 (rock) and OW-1A (sand/gravel) was installed at site 1. North of the chrome lagoons, OW-9 (rock) and OW-14 (sand/gravel) are located in the same area about 200 feet apart. The rock and sand/gravel wells were installed in two different manners described in the following sections.

Rock Wells

Six rock wells were installed at the Woburn Site. For these wells, a thirteen-inch roller bit was used to drill through the unconsolidated materials and five feet into solid bedrock. Six-inch diameter steel casing was set in the hole allowing for a one-foot stick-up above land surface. The steel casing was used to seal off any ground water in the unconsolidated deposits and to prevent collapse. This assures that representative ground-water samples from the bedrock can be obtained. The annular space around the casing was pressure-grouted with a cement/bentonite slurry to land surface. The inside of the steel casing was then flushed out with clean water to remove any drilling fluids and sediment.

After the steel casing had set in the hole, a six-inch diameter pneumatic hammer was used to drill to the desired depth in the rock. Drilling continued until water-bearing fractures were encountered

or to at least eighty feet into rock if no such fractures were found. A geologist logged the rock fragments coming from the hole as the drilling progressed. Well logs are given in Appendix IV.

No casing was set in the hole since the rock is dense enough to allow the hole to stay open indefinitely. After the well was finished, a metal plate with a hasp was welded to the top of the steel casing allowing the well to be locked. All six rock wells were purged immediately after installation by a submersible pump. Each well was pumped until ten times the volume of water standing in the open hole was removed (OW-3 and OW-4) or until it went dry (OW-1, OW-2, OW-8 and OW-9).

A designated measuring point on top of each well casing was leveled in with respect to mean sea level. Water levels in all wells were measured on three occasions to ± 0.01 feet by an electric probe and measuring tape.

Sand/Gravel Wells

Nine (9) sand/gravel wells were installed for this investigation. These wells are screened in the saturated, unconsolidated deposits and to five feet into solid bedrock. All borings in sand/gravel were drilled by the mud rotary method using Revert and/or bentonite and water from the municipal supply system as drilling fluid additives.

In constructing these wells, an eight-inch roller bit was used to drill through the unconsolidated section and five feet into solid bedrock. After the hole was drilled, the geologist selected the appropriate length of four-inch diameter PVC slotted pipe (screen) to be used. The entire saturated thickness of the sand and gravel aquifer was screened. Threaded, four-inch, blank PVC casing was used in the unsaturated sections, allowing for a one-foot stickup above land surface.

The screen zone was packed with clean silica sand of a suitable grade for the slot sizes (.010-inch openings). A seal of bentonite pellets was placed immediately above the sand pack and the remaining annular space was pressure-grouted to about three feet below land surface with a cement-bentonite mixture. A cement seal was poured in the remaining few feet to land surface and a protective steel standpipe with a lock was used to protect each well.

The sand/gravel wells were developed in two steps. The first step consisted of surging and pumping the well with air. This process removes fluids introduced during drilling and much of the fine sediment from the formation around the screen, thus allowing a free flow of water from the aquifer into the well. The second step of the development process consisted of pumping with a submersible pump to remove at least ten times the volume of water

contained in the casing and sand pack. This step insures that all aerated water and/or water introduced during drilling has been removed.

Ground-Water Sampling

Ground-water samples were collected from the OW series of wells on September 27 and September 29, 1982. Immediately prior to sampling, each well was purged by pumping it dry or by removing from five to ten casing volumes of water. The submersible pump used for purging was thoroughly rinsed and steam-cleaned between wells.

Samples were collected by Roux Associates personnel with a stainless steel bailer. Prior to sampling each well, the bailer was thoroughly washed with tap water and rinsed three times in distilled water. In addition, the first three bailer volumes removed from the well were discarded. All sampling gloves, bailer cord, etc. were changed between wells.

HYDROGEOLOGY

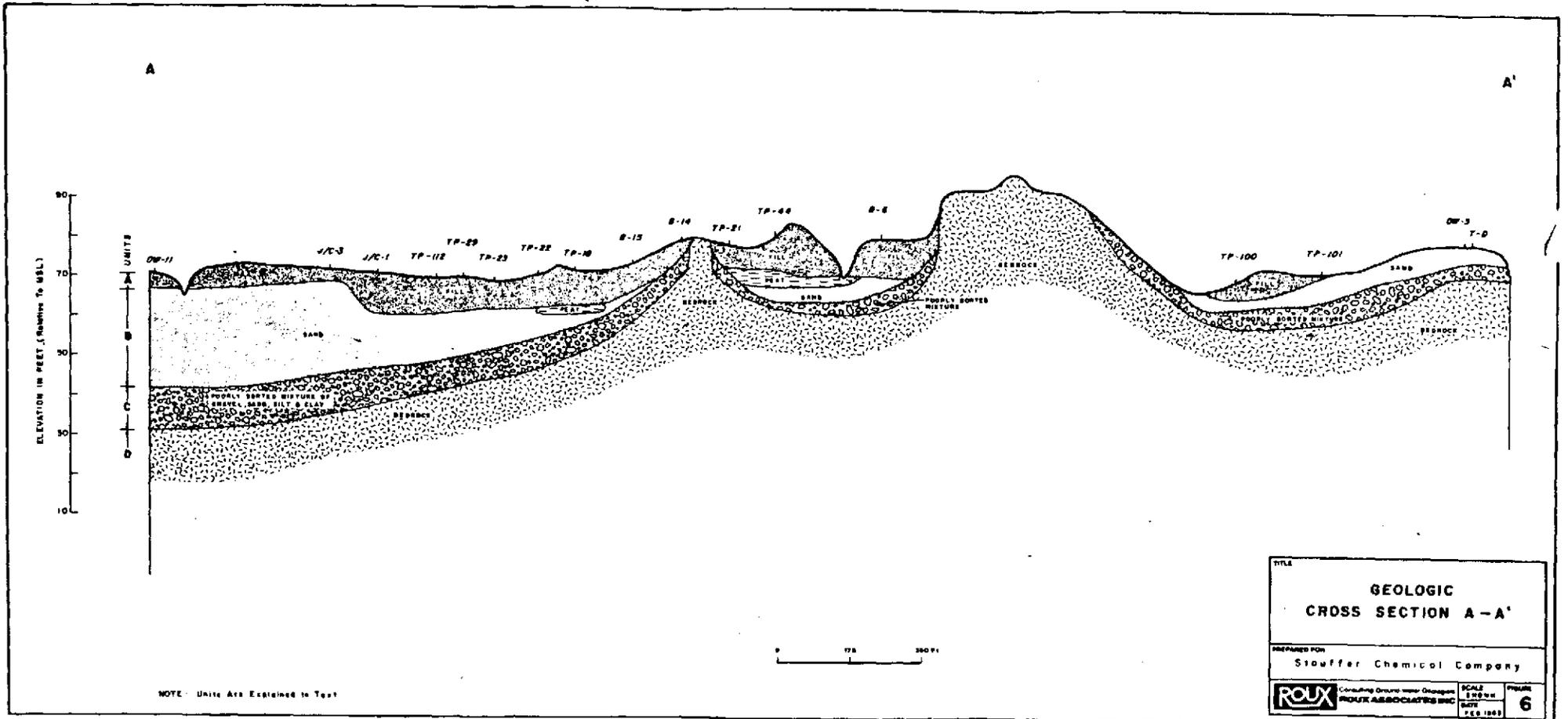
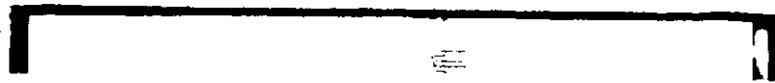
Geologic deposits in the study area can be divided into groups or units based on sediment character, origin and permeability differences. From oldest (deepest) to youngest (shallowest), they are:

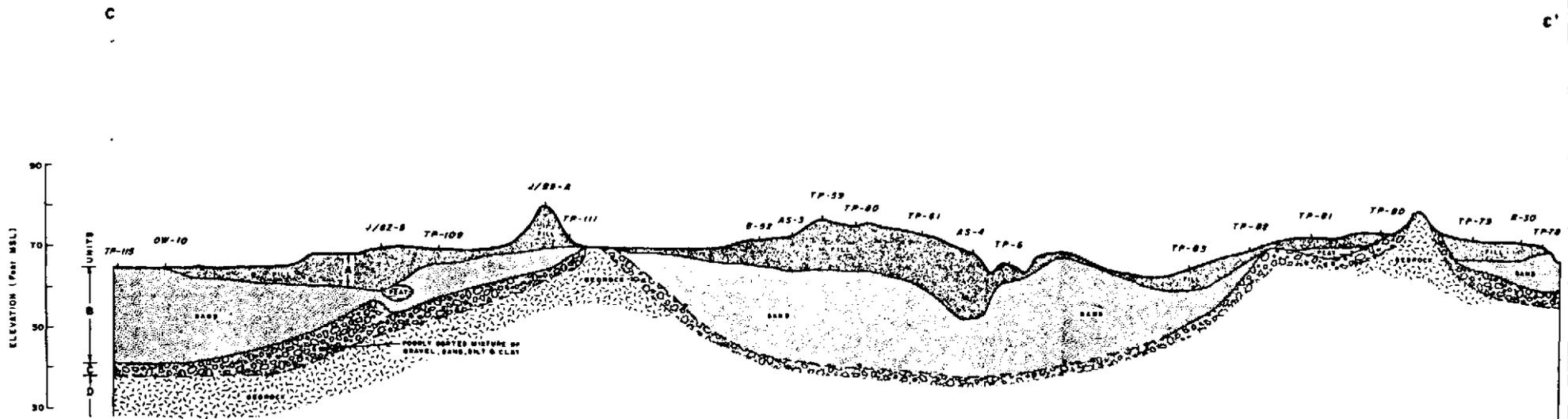
- Unit D - Mafic bedrock
- Unit C - Poorly sorted to unsorted mixture of clay, silt, sand and gravel
- Unit B - Fine to medium sands with finer and coarser layers and peat
- Unit A - Miscellaneous artificial fill deposits

From north to south, four geologic cross sections have been compiled, each crossing the Site in an east-west direction (Figures 6-9). The locations of these sections are shown on Figure 4. The oldest deposit in the study area, the bedrock (Unit D) will be discussed first, followed in succession by the younger, unconsolidated deposits of Units C, B, and A.

Unit D

Woburn is located on the Eastern Avalonian Platform of the Northern Appalachian Mountain System. The area has been subject to several.





NOTE: Units Are Explained in Text

TITLE	
GEOLOGIC CROSS SECTION C - C'	
PREPARED FOR Stouffer Chemical Company	
 CONSULTING ENGINEERS-GEOTECHNICAL ROUX ASSOCIATES INC.	SCALE AS SHOWN DATE FEB. 1993
FIGURE 8	

mountain building or deformational events that occurred more than 200 million years ago. What is observed today in the bedrock are remnants of these tectonic events. The area of investigation is located between the North Boundary and Blood Bluff fault zones which divide the greater Boston area into a series of northeast trending blocks. These blocks are in turn dissected by north-south trending faults, one of which has controlled the location of the Aberjona River Valley. The deformation associated with faulting caused a suture and a weakening of the bedrock, paving the way for preferential weathering along this plane of weakness.

The bedrock at the Site is the Salem Gabbro-Diorite (Barosh, et al 1977) which has been radiometrically dated as late Middle Ordovician (approximately 450 million years old). At the northern portions of the site, bedrock is exposed as knobs and ridges throughout (Figures 6 and 7). Towards the south where the Aberjona River Valley is more pronounced, bedrock occurs as knobs rising rapidly from the valley to the east and west (Figure 9).

Where fresh, the dominant rock type is a gray gabbro that consists of mafic minerals (pyroxene and/or hornblende) and plagioclase feldspar, with minor biotite and pyrite cubes. This rock is massive in appearance and has a fine to medium grained texture.

In outcrop, the bedrock weathers chalky with a green or gray tinge. The rock is dissected by numerous fractures, many of

which are filled with white or pink quartz. Layers of green rock are common and show phyllitic partings. This compositional banding as well as a pronounced foliation, give the rock a gneissic texture.

The green bands or layers are much softer and are highly fractured. They consist of epidote, chlorite, muscovite and plagioclase. The contact between the massive gray rock and the green layers is very irregular and often fractured.

The permeability of bedrock is dependent upon the occurrence of joints and faults and the extent of weathering. The extent of weathering of the bedrock in this area is minimal because the rock is very dense and tends to resist weathering and because geologically recent glaciation has abraded the surface and removed the loose rock that may have been present. Permeability, therefore, is dependent upon fractures that have been developed in response to volume changes, or to externally applied forces such as those that produce faulting. In general, these joint and fault openings decrease markedly with depth.

Overall, the bedrock appears to be massive at topographic highs (OW-2) and fractured/jointed in lower areas (OW-9). The gray massive phase of the bedrock, where dominant, is unfractured. Thin (less than one foot) quartz veins appear to fill any fractures.

At OW-1 and OW-8, the gray rock alternated with zones of softer, green rock. However, no major water bearing fractures were encountered at those locations. At OW-1, a very soft zone (non-water bearing) was encountered between 96 and 106 feet below land surface. This is believed to be a gouge or finely abraded material that occurs along the wall of a fault. Wells OW-1, OW-2 and OW-8 went dry during pumping and recovered at less than 0.1 gpm (gallons per minute).

At OW-9 the rock was very fractured at the top and became massive with depth. Though fractures were abundant, they were filled with quartz and yielded less than one gpm to the well.

At OW-3, the massive gray rock was present the length of the hole. However, at approximately 83 feet below land surface, a thin fracture partially filled with rosy quartz, yielded three gpm.

The rock quarrying operation has facilitated the development of fractures in the area where OW-4 is located. Fractures filled with quartz have been reopened by the blasting operations. OW-4 yielded greater than 15 gpm during development.

In summary, the bedrock of Unit D, even though fractured at many locations, generally has a very low permeability. Many fractures

are filled with quartz and the open, water-bearing fractures, such as found at OW-3 and OW-4, may be localized and not connected to other fractures in the area. Thus, the bedrock cannot be considered a significant aquifer for industrial and/or municipal water supply in this area.

Unit C

Unit C was formed during the last glacial period (12,000 years ago) when glaciers in the Aberjona River Valley stopped advancing. Initially, the glacial ice mass had widened the existing bedrock valley by plucking blocks of rock and abrading the valley walls. As the glacier advanced over the land surface, it picked up sediment. However, when the rate of advance equaled the rate of retreat, the sediment it had picked up was deposited in conveyor belt-like fashion. Thus, Unit C consists of unsorted sediments showing a high variability in grain sizes.

Unit C can be designated a till which mantles the irregular surface of the bedrock. Till is exposed at the surface where bedrock is close to the surface (Figure 9). The till was found to be twelve feet thick as a maximum. It is thin at the sides of the valley (OW-13 and OW-14), and is absent near the center of the valley (OW-12) where it was probably scoured away by currents.

The till can be divided into three distinct types in the study area. Immediately overlying the bedrock is a gray-colored non-

sorted mixture of particles ranging in size from clay to boulders. Examination of the coarser particles indicates that this till was derived locally as rock fragments of the bedrock are found exclusively. Above this layer is an assemblage of mafic bedrock and quartz cobbles and boulders in a greenish-gray clayey matrix. The rock fragments are exclusively of Unit D and are partially weathered. This layer is generally thin (less than 4 feet in thickness) and may represent a weathered part of the till below it. Overlying these deposits in a few isolated areas is a brown, medium to coarse sand with boulders and cobbles of lithologies exotic to the immediate area (such as granite, schist and gneiss).

Regardless of type, Unit C has a very low permeability due to the variable sizes, poor sorting and tight packing of the individual grains. In the core samples, the till is observed to be moist or dry, even though overlying sands (Unit B) are saturated. In a number of test pits, a small amount (0.1 gpm) of water was observed perched above clayey parts of the till, demonstrating that the till layer inhibits the downward movement of water to the bedrock.

Unit B

Overlying Unit C are younger deposits of glacio-fluvial origin called outwash. These were formed by meltwaters from the

retreating glacier which sorted sediments previously carried and deposited by the ice. Therefore, these deposits contain sediments having more uniform grain sizes and are more permeable than till deposits.

The contact between the till and outwash is easy to see because of color and sedimentological differences. Moreover, the outwash deposits below the water table are saturated, while the underlying till appears dry and is much denser.

Unit B is either very thin or absent where bedrock is close to the surface, but reaches a maximum observed thickness of 42 feet near the center of valley (OW-12). This unit consists of a series of graded sand beds that vary in thickness from four to twelve feet. From the top to the base, each graded bed consists of:

- Medium to coarse sand with granules and pebbles
50% quartz, 30% rock fragments (schist, gneiss, granite, mafic rock, etc.) and 20% feldspar, muscovite and dark minerals.
- Fine to medium sand; well-sorted; quartzose;
10 to 20% feldspar, muscovite, dark minerals and rock fragments.
- Silty fine sand; quartzose; 10 to 15% muscovite;
finely laminated; disseminated organic material.

Based on the uniform sizes, degree of sorting and loose packing of the individual grains, Unit B has a high permeability. The sand/gravel observation wells are screened in this unit and have high yields. The piezometers are screened in thinner deposits of Unit B which occur toward the fringe of the Aberjona River Valley. Where the sands and gravels of Unit B are thick, they can serve as a water supply aquifer.

At OW-6, twelve feet of sandy deposits were found to overlie 36 feet of a gray clayey silt resting on bedrock. During the time meltwaters were active in the valley transporting and depositing sands of Unit B, a body of standing water existed in the area of OW-6. Finer clay and silt-sized particles settled out of suspension. Coarser sand particles and gravel are found in places embedded in the clayey silt. Due to the fine grain sizes and cohesiveness, this deposit is of very low permeability.

Overlying the outwash deposits in part of the Site are peat deposits. Peat consists of partially decomposed organic matter such as mosses, trees and other flora that flourish in marshes and wetlands. Peat deposits have been covered by man-made fills on the Site. Marshy areas still exist within the Site suggesting that these conditions have persisted at various locations for the past 10,000 years.

The peat deposits have been considered part of Unit B, even though

they are younger. In places, peat can be seen interlayered with sand as the contact between the two deposits is gradational. Peat was encountered in many borings and test pits. At OW-5, 11.5 feet of brown peat was present beneath a thin veneer of fill and above the sands of Unit B. Peat deposits generally have a high porosity, but a low permeability because water is tied up by molecular attraction.

Unit A

Unit A consists of a heterogeneous assemblage of artificial fills and is present throughout the site and industrial complex to the south. The waste deposits on the Site, which are part of this unit, are discussed in later sections of this report.

On the portion of the Site east of Commerce Way, Unit A is a coarse regolith that mantles the natural deposits of Units B, C and D. This regolith consists of gravel and coarse sand and is essentially reworked and redistributed till. Piles of this material, which was used for road beds in the area, are found throughout this part of the Site.

Within the industrial complex south of the Site, the thickness of fill deposits averages from approximately two to four feet and are sandy. Even though it is poorly sorted in places, its loose consistency readily allows percolation of water to Unit B and to the water table.

SOIL AND WASTE INVESTIGATION

An important part of the Phase I investigation was the characterization of waste types on the Site and determination of the volumes and distributions of the various wastes identified. To accomplish this, the following tasks were undertaken: an earth conductivity survey, test pit and test boring programs, and a soil sample analysis program. These tasks are described in detail in the methods of investigation section of this report. The waste types and distributions at the Site, based on the interpretation of the results of these tasks, are described below.

Conductivity Survey Results

The purposes of the conductivity survey were to help locate optimum sites for pits and borings, and to help insure that the entire site had been surveyed and no waste deposits were missed. A description of the conductivity equipment and its operation is included in the methods of investigation section.

To provide the control necessary to make the initial interpretation of the conductivity data, measurements were made in areas where subsurface conditions could be determined from the surface. These control measurements were made on the large hide residue piles, bedrock outcrops, the Arsenic Pit, piles of construction debris, wetlands and in the area east of Commerce Way where no waste materials were visible. There were, however, no boring or test

pit logs or analytical results from soil samples for the initial conductivity interpretation.

The conductivity survey was based on a 200-foot grid system (Figure 3). A reading from at least one and frequently both instruments was made at all of the accessible grid points. In addition, continuous readings were made with the EM-31 along traverse lines through critical areas. Some EM-31 readings between grid points are shown on Figure 11. In many cases, however, the operator simply noted the changes in readings as he walked without recording them. In this way, it was determined that no waste deposits were missed by the survey.

For the purposes of defining areas containing waste materials and contaminated soil, the EM-31 and EM-34 (H) (Horizontal dipole mode) data proved to be the most useful. EM-34 (V) (vertical dipole mode) data reflects deeper conditions and was not used to locate waste deposits.

Based on the control points established, the experience of the operator at other sites, and a comparison of conductivity results between the two instruments, the initial conductivity results between the two instruments, the initial conductivity interpretation was made. This interpretation divided the site into six classifications based on conductivity: 1) bedrock and clean, nonconductive soil, 2) contaminated ground water, 3)

solid waste, 4) hide residue, 5) construction debris containing metal objects, and 6) areas where there was interference and conductivity would not work. The results of this interpretation are shown on Figure 10.

This preliminary interpretation was used to help guide the Phase I boring and test pit digging program. Borings and test pits were located in all of the different areas defined by the conductivity survey. Also, an attempt was made to evaluate the accuracy of the conductivity area limits by locating pits and borings on both sides of various boundaries.

After completion of the Phase I soil sampling and analysis program, the conductivity data were reinterpreted. The reinterpretation indicated that it is not possible to distinguish as many categories of site conditions and waste types as are shown on Figure 10. It was found that the EM-31 and EM-34 (H) data could be combined and divided into three ranges that represented site conditions quite accurately. These categories are, in mmho/m:

- less than 10 - uncontaminated (background)
- between 10 and 50 - contaminated soil or ground water,
or thin waste deposit
- greater than 50 - waste deposit

The areas defined by these three conductivity ranges are illustrated

on Figure 11. The effectiveness of the conductivity equipment in identifying waste deposits is evident when the figures showing soil and waste sample analytical results (next section) are compared to Figure 11.

Figure 11 shows that a large portion (32 acres) of the site (east of Commerce Way) contains natural sediments and rock with no waste materials. The one exception is a small area directly north of the site trailer which was initially thought to be buried waste, but has subsequently been determined to be shallow contaminated ground water from the hide residue burial area to the west. This hide residue burial area is quite clearly defined by the conductivity, as are the two hide residue and waste material stockpiles in the northern portion of the Site.

The portion of the Site that has been developed and is not a part of the investigation could not be surveyed with the conductivity equipment because of interference. In addition, portions of the Site that contain metallic construction debris, steel fences, railroad tracks, etc. could not be surveyed with the conductivity equipment. These areas are shown on Figure 2.

The conductivity survey has provided a useful tool in guiding the boring and test pit program and has substantiated the location of waste materials as defined by analyses of soil samples. The conductivity survey has also helped to demonstrate areas containing wastes have not been overlooked.

Soil and Waste Analytical Results

Both the selection of appropriate remedial measures and the apportionment of their costs as provided for in the consent order, require that the extent and types of wastes and contaminated soil at the Site be defined. To accomplish this, samples of the waste materials and soil were collected and analyzed.

For the Phase I soil and waste sampling survey, 462 samples from 53 boreholes and 115 test pits were collected. Of these 204 were analyzed for selected metals. The metals analyzed for were antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, thallium, silver, selenium, and zinc. (Arsenic is grouped with the metals because of its similar environmental properties, but is technically a semi-conductor and not a metal). In addition, the following analyses of sediments were obtained, 21 from Janpet, 7 from EPA/DEQE, 7 from earlier Stauffer work and 15 from Boston Edison. The results of all of the analyses are given in Appendix II of this report.

In the test borings, continuous cores were taken through the fill and into natural deposits. All split-spoon samples collected were retained. The geologists selected the samples that would be analyzed based on color, odor and texture, since these physical characteristics separated the fill deposits from underlying, natural geologic deposits. The geologists selected at least one soil sample for analysis from each of the variations in color and texture, so that every fi

sample having a different color and texture would be analyzed. In addition, samples collected in natural deposits beneath the fill deposits were retained and some were selected for analysis.

The geologists had greater visibility of subsurface fill deposits in the test pits. Samples were selected to represent all different deposits encountered in a test pit. In addition, samples of natural materials were collected below the fills or where they were exposed at the surface.

The results of the soil and waste analyses for heavy metals show that while all of the metals analyzed for except beryllium, are present at 100 ppm in at least one location, six (arsenic, barium, chromium, copper, lead and zinc) are by far the predominant species. Mercury, found at a relatively few locations, may be of concern.

The distributions of the various metals identified in the soil and wastes over the area of investigation are shown on Figures 12 through 24 and give an unbiased, general view of the distribution of each metal to the extent that the Phase I data has defined it.

Arsenic and lead, because of their concentrations and widespread distribution on the Site, have been further defined on Figure 25. This figure illustrates the distribution of arsenic and/or lead

in two ranges, 100-1000 ppm and greater than 1000 ppm. The shaded areas representing these ranges were constructed by tightly contouring the points of known concentration and thus represent approximate minimum areas where these metals are present at the reported concentrations.

The total area of the Site is approximately 250 acres. Half of this area consists of shallow bedrock and buildings. Of the remaining 125 acres, 32 acres east of Commerce Way do not contain waste materials and require no further soil sampling. Combining the arsenic and lead data and eliminating overlapping areas, there are 22 acres containing arsenic and/or lead at concentrations greater than 1000 ppm and an additional 13 acres greater than 100 ppm (Figure 25).

Figure 26 shows the distribution of chromium at the Site in the same manner that Figure 25 showed lead and arsenic. Five acres contain chromium concentrations greater than 1000 ppm and another 5 acres greater than 100 ppm.

The distribution of the other widely distributed species of metals found at the Site, (barium, copper and zinc), can be seen on Figures 15, 17 and 19. A contour map of zinc and copper concentrations is shown on Figure 27. This figure shows that all of the area that contains these metals also contain arsenic, lead and chromium. Mercury, on the other hand, is not widely distributed,

but is found in several areas not containing the more common metals (Figure 18).

The thicknesses of waste materials and soil containing arsenic, lead and chromium is less certain than the areal extent, although they generally range from 1 to 8 feet below grade. Table 2 shows a comparison of concentrations of chromium, lead and arsenic at various depths in all pits and borings where samples were collected and analyzed at more than one depth. This table shows that while concentrations decrease with depth in many cases, there are also a significant number where the reverse is true. This second case reflects the areas where clean fill was placed over waste materials. In all of the borings and many of the test pits, however, natural sediments were identified under the waste materials. Soil samples were collected and analyzed from these natural sediments at several locations and were found to contain background concentrations of metals.

In addition to the metals, hide residues, because of odor problems, are a waste product of concern at the Woburn Site. Hide residues are readily identified in the field because of their color and odor and chemical analyses are not necessary for defining extent. The Phase I investigation has defined areas containing hide residues which are eight acres in extent. These are shown on Figure 28. The

Table 2 - Comparison of chromium, lead and arsenic in borings and test pits where two or more samples taken at different depths were analyzed

<u>Location</u>	<u>SOIL ANALYSIS (in ppm)</u>			<u>Depth (ft.)</u>
	<u>Chromium</u>	<u>Lead</u>	<u>Arsenic</u>	
B-9	637	86	118	1
B-9	16	-	12	3
B-12	7	8803	1026	1
B-12	7	11	-	9
B-13	409	525	194	.25
B-13	161	503	281	5
B-14	112	1837	235	1
B-14	16	212	289	3
B-15	20	2143	296	5
B-15	19	2062	237	6.4
B-21	11	13	1215	5.5
B-21	31	13	210	9.5
B-22	4956	196	88	7
B-22	216	8	5	8.9
B-22	42	12	5	14.65
B-23	1753	445	237	1
B-23	36	207	95	3
B-23	-	131	12	5
B-24	6	866	11	1
B-24	16	3800	15	7
B-27	4090	555	64	5
B-27	51	45	71	21
B-31	830	126	9	3.5
B-31	1170	149	8	9.85
B-32	688	156	6	5
B-32	1619	385	6	7
B-33	12	70	11	3
B-33	17	26	7	5.75
B-34	23	108	-	1
B-34	22	15	3	6.35
B-35	42	2857	1122	1
B-35	36	1152	133	2.35

<u>Location</u>	<u>SOIL ANALYSIS (in ppm)</u>			<u>Depth (ft.)</u>
	<u>Chromium</u>	<u>Lead</u>	<u>Arsenic</u>	
B-36	10	4660	1262	1
B-36	-	5849	1321	3
B-36	5	343	1944	5
B-36	14	123	858	7
B-37	30	540	1500	3
B-37	48	1944	204	9
B-40	10	1010	19	1
B-40	7	5	-	3
B-40	7	6	-	5
B-41	25	465	101	1
B-41	28	570	250	3
B-42	131	1616	93	1
B-42	-	5243	814	3
B-43	63	94	20	1
B-43	13	7476	1845	3
B-43	7	52	190	5
B-44	18	51	14	1
B-44	11	10	6	7
B-49	6	4950	881	.3
B-49	27	606	21	.5
B-50	15	190	19	1
B-50	21	10	-	2.65
B-52	6	5	9	5
B-52	7	5	10	11
B-54	110	140	9	1
B-54	33	5	3	11
B-55	12	8200	680	1
B-55	22	871	782	5
B-55	19	27	73	11
T-2	51	4694	2755	1.5
T-2	22	7071	8081	5.5
T-4	-	26699	1748	.5
T-4	29	417	204	4.5
T-9	28	165	23	3.5
T-9	22	25	7	4.5

<u>Location</u>	<u>SOIL ANALYSIS (in ppm)</u>			<u>Depth (ft.)</u>
	<u>Chromium</u>	<u>Lead</u>	<u>Arsenic</u>	
T-10	44444	227	10	Unknown
T-10	15481	396	8	10
T-12	248	30	7	2
T-12	15	30	10	4.5
T-16	12121	253	-	1
T-16	94	-	50	Unknown
T-17	15	1881	743	3 (2-4)
T-17	-	10400	1100	3.5 (3-4)
T-17	104	1832	238	Unknown
T-29	49	2353	93	3
T-29	29	98	5882	4
T-31	110	320	175	2.5
T-31	12	5100	2050	4
T-45	16000	2600	8	5.2
T-45	5	5979	928	9
T-63	37	888	1633	1
T-63	-	22222	5556	2.55
T-73	7	-	3	.7
T-73	-	-	3	1
T-85	75	1576	675	2
T-85	-	158	594	5.5
T-89	198	1980	941	2.7
T-89	82	7475	1414	7.2
T-95	303	1313	727	.85
T-95	13	149	12	1.75
T-95	949	424	101	4.1
T-107	-	1500	290	1.8
T-107	-	567	639	2.8
T-110	28	810	500	1
T-110	18	110	5	Unknown (0.7-1.1)
T-112	347	412	48	2.4
T-112	2300	480	75	3.5
T-113	4343	8788	14141	1.5
T-113	7	160	17000	4.5
T-114	7	55	12	1
T-114	21	4200	2400	1.5

thicknesses of these deposits range from a few feet to about 8 feet below land surface and, in the waste piles, up to 40 feet above grade.

The southern hide residue area shown on Figure 28 is where the hide residues were originally buried during the glue plant's operation. This area contains primarily hide residues and associated chromium. The northern waste pile area is a stockpile of wastes that was deposited by the Site developers during construction. This waste pile is composed of a comingled variety of materials, including hide residues, arsenic, and lead. There are also two areas that are suspected of containing hide residues that were not investigated during Phase I and are shown on Figure 27. Both of these sites contain stockpiled wastes and may contain a variety of substances in addition to hide residues.

An attempt was made in the Phase I survey to correlate various physical characteristics of samples with their chemical composition. Details of dominant and subordinant sediment, texture, color and odor were recorded for each sample and coded into the computer printout. The results are shown in Appendix II.

The coding system failed to establish a visual method of distinguishing between the various metals at the Site. However, some

generalizations based on color and texture can be made. Initially, a fill deposit with a red color was thought to be indicative of high lead concentrations. This has held true, though arsenic, barium, copper and zinc were almost as abundant in red-colored fill deposits. In addition, trace metals at the Site including antimony, cadmium, nickel, silver and thallium are found at greater than 100 ppm levels in red-colored deposits.

The gray or white colored deposits associated with what has been referred to as the Arsenic Pit, not only reflected high arsenic concentrations, but in most cases contained even higher concentrations of lead, zinc, copper and barium. A black color, when associated with hide residues, was thought to reflect higher chromium concentrations. However, as previously mentioned, the reworked hide residue pile at the northern end of the Site contains other metals as well (arsenic, barium, lead, copper and zinc).

Defining specific wastes based on the dominant and subordinate textures of the sediment grains, was also not a total success. When a fill containing artificial components, such as demolition debris, was analyzed, arsenic, lead, copper, barium and zinc were usually abundant. However, these metals, as well as chromium, were found in abundance in deposits ranging in texture from coarse to clay.

A fill deposit of certain colors (red, gray, white and orange) and comprised of artificial components, such as construction debris, contained high concentrations of barium, copper, lead and zinc, as opposed to chromium. Chromium deposits generally occur independently of the other metals, though the other dominant metals, arsenic, lead, copper, zinc, have been admixed where chromium deposits were disturbed and redeposited.

It is concluded that the only way to accurately characterize a waste material at the Woburn Site is through chemical analyses of the fill deposits. However, it was determined by the geologists in the field who examined the samples, that waste materials could be distinguished from natural sediments by visual inspection. This proves to be useful since the chemical analyses indicate that most of the waste material contains at least one of the metals of concern. Table 3 shows, for the samples collected, the geologist's characterization as natural or artificial texture, odor and color in comparison to the total concentrations of lead, arsenic and chromium where analyzed.

The samples characterized as having natural physical characteristics invariably contain approximate background concentrations of metals. Ninety percent of samples that have been classified as artificial fill or waste materials contain greater than 100 ppm of at least one metal and usually greater than 100 ppm of several metals. Thus,

Table 3 - Characterization of Natural or Artificial Deposits Compared to the Total Concentrations of lead, arsenic and chromium (where analyzed)

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concn. (ppm)</u>
B-1	1	2	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	39
	5	1	1	1	-
B-2	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	17
B-3	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	18
	4	1	1	1	-
B-4	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	13
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-5	1	1	1	1	-
	2	1	1	1	-
	3	1	1	1	-
B-6	1	2	2	1	5602
	2	2	2	1	-
	3	1	1	1	-
	4	1	1	1	-
B-7	1	2	1	1	-
	2	2	2	1	332
	3	1	1	1	-
	4	1	1	1	-
B-8	1	2	2	2	14
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
B-9	1	1	1	2	841
	2	1	1	1	28
	3	1	1	1	-
	4	1	1	1	-

1- Natural 2- Artificial or Unnatural
 - No Analysis Performed

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-10	1	2	2	2	-
	2	2	2	2	-
	3	2	2	2	2331
	4	2	2	2	-
B-11	1	2	2	2	1269
B-12	1	2	2	2	9836
	2	2	2	1	-
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	18
	6	1	1	1	-
	7	1	1	1	-
B-13	1	2	1	1	1146
	2	2	2	1	-
	3	1	1	1	945
	4	1	1	1	-
B-14	1	2	2	1	2184
	2	2	2	1	517
	3	2	2	1	-
	4	1	1	1	-
	5	1	1	1	-
B-15	1	2	1	1	-
	2	2	2	1	-
	3	2	2	1	2459
	4	2	2	1	2318
B-19	1	2	1	2	1046
B-20	1	2	2	1	1407
	2	1	1	1	-
	3	1	1	1	-
B-21	1	2	1	1	-
	2	2	2	2	-
	3	1	2	2	1239
	4	1	1	2	-
	5	1	2	2	254
B-22	1	2	2	1	-
	2	2	2	2	-
	3	2	2	2	-
	4	2	2	2	5240
	5	1	2	2	229
	6	1	2	2	-
	7	1	1	2	-
	8	1	1	2	59

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-23	1	2	2	2	2435
	2	2	2	2	338
	3	2	2	2	142
	4	1	2	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-24	1	2	2	1	883
	2	2	1	1	-
	3	2	1	1	-
	4a	2	2	2	-
	4b	2	2	2	3831
	6	1	1	1	-
B-25	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	2013
	5	1	1	2	-
	6	1	1	1	-
B-26	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	-
	5	2	2	2	-
	6	2	2	2	2504
	7	1	2	2	-
	8	1	2	2	-
B-27	1	2	2	1	-
	2	2	2	1	-
	3	2	2	2	4709
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	1	-
	7	1	1	1	-
	8	1	1	1	-
	9	1	1	1	-
	10	1	1	1	-
	11	1	1	1	167
B-28	1	2	1	1	-
	2	2	1	1	-
	3	2	1	1	-
	4	2	2	1	-
	5	2	1	1	-
	6a	1	1	1	-
	6b	2	2	2	5114
	8	1	1	2	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-29	1	2	1	1	-
	2	2	2	1	5952
	3	2	2	1	-
	5	2	1	2	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	2	-
	B-30	1	2	2	1
2		2	1	1	-
3		1	1	1	-
4		1	1	1	-
B-31	1	2	2	1	-
	2	2	2	2	965
	3	2	2	2	-
	4	2	2	2	-
	5	2	2	2	1327
	6	2	2	2	-
	7	2	2	2	-
	8	2	2	2	-
	9	2	2	2	-
	10	2	2	2	-
	11	2	2	2	-
	12	2	2	2	-
	13	2	2	2	-
	14	2	2	2	-
	15	2	2	2	-
	16	2	2	2	-
	17	2	2	2	-
	18	1	2	2	-
B-32	1	2	1	1	-
	2	2	2	1	-
	3	2	2	2	850
	4	2	2	1	2010
	5	2	2	2	-
	6	2	2	2	-
	7	2	2	2	-
	8	2	2	2	-
	9	1	2	2	-
	10	1	2	2	-
	11	1	1	1	-
	12	1	1	2	-
	13	1	1	2	-
B-33	1	2	2	1	-
	2	2	2	2	93
	3	2	2	2	50
	4	1	1	2	-
	5	1	1	1	-
	6	1	1	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-34	1	2	1	1	131
	2	2	2	1	-
	3	2	2	1	40
	4	2	1	2	-
	5	1	1	2	-
	6	1	1	1	-
	7	1	1	2	-
B-35	1	2	2	1	4021
	2	2	2	2	1321
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-36	1	2	2	1	5932
	2	2	2	1	7170
	3	2	2	1	2292
	4	2	2	1	995
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-37	1	2	2	1	-
	2	2	2	2	2070
	3	2	1	1	-
	4	2	1	1	-
	5	2	2	2	2196
	6	1	1	1	-
	7	1	1	1	-
B-38	1	2	2	2	-
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
B-39	1	1	1	1	95
	2	1	1	1	-
	3	1	1	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (pp</u>
B-40	1	2	1	1	1039
	2	1	1	1	12
	3	1	1	2	13
	4	1	1	2	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	1	-
	9	1	1	1	-
B-41	1	2	2	1	591
	2	2	2	2	848
	3	2	2	1	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-42	1	2	2	1	1840
	2	2	2	1	6057
	3	1	1	2	-
	4	1	1	1	-
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
	8	1	1	1	-
B-43	1	2	2	1	177
	2	2	2	1	9334
	3	1	2	2	249
	4	1	1	1	-
	5	1	1	1	-
B-44	1	2	1	2	83
	2	2	1	1	-
	3	1	1	1	-
	4	1	1	2	27
B-45	1	2	1	1	-
	2	2	2	2	-
	4	1	1	1	200
B-46	1	2	2	2	8172
	2	2	2	2	-
	3	2	2	2	-
	4	1	1	1	-
B-47	1	2	1	1	1237
	2	2	1	1	-
	4	1	1	2	52

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (pp</u>
B-48	1	2	2	1	-
	2	2	2	1	-
	3	2	2	1	-
	4	2	2	2	-
	5	2	2	2	44
	6	2	2	2	-
	7	2	2	2	-
B-49	1	2	2	1	5837
	2	2	2	1	654
B-50	1	2	2	2	224
	2	1	1	1	31
	3	1	1	1	-
B-52	1	2	2	2	-
	2	2	2	2	-
	3	1	2	2	20
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	2	22
	7	1	2	2	-
	8	1	2	2	19
	9	1	2	2	-
B-53	1	2	2	2	1750
	2	2	1	2	-
	3	1	1	1	-
	4	1	2	2	-
	5	1	2	2	22
	6	1	2	2	-
	7	1	2	2	-
	8	1	2	2	-
B-54	1	2	2	2	259
	2	2	1	2	-
	3	2	2	2	-
	4	1	2	2	-
	5	1	2	2	-
	6	1	2	2	41
	7	1	2	2	-
B-55	1	2	2	1	8892
	2	2	2	1	-
	3	2	2	2	1675
	4	2	2	1	-
	5	2	2	2	-
	6	1	1	2	119
	7	1	2	1	-
	8	1	1	1	-
	9	1	1	1	-
	10	1	1	2	-
B-51	1	2	1	1	-
	2	2	1	1	187

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
B-56	1	2	2	1	-
	2	2	2	1	45408
	3	2	2	1	-
	4	2	2	1	1479
	5	1	1	1	-
	6	1	1	1	-
	7	1	1	1	-
B-57	1	2	2	2	541
	2	2	2	2	-
	3	2	2	2	163
	4	2	2	2	-
	5	2	2	2	-
	6	1	1	2	-
<u>Test Pit</u>					
TP-1	1	1	1	1	-
	2	1	1	1	32
	3	1	1	1	-
TP-2	1	2	2	1	7500
	2	1	2	1	15174
TP-3	1	2	2	1	8594
	2	2	2	1	-
TP-4	1	2	2	1	621
	2	2	2	2	28447
TP-5	1	2	2	1	6009
	2	1	1	1	-
TP-7	1	1	2	2	52
TP-8	1	1	2	2	12
TP-9	1	2	2	2	216
	2	2	2	2	54
TP-10	1	2	2	2	15885
	2	2	2	2	44681
TP-11	1	2	2	2	202
TP-12	1	1	1	2	55
	2	2	2	2	285
TP13-	1	1	2	1	18
TP-14	1	2	2	2	145594
	2	2	2	1	34
TP-15	1	2	2	2	312
TP-15	1	1	2	1	144
	2	1	2	1	12374

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total lead, Arsenic & Chromium Concen. (pp</u>
TP-17	1	2	2	1	15013
	2	2	2	1	11500
	3	2	2	2	2174
TP-18	1	2	2	1	3825
	2	2	2	1	-
TP-19	1	2	2	1	11755
TP-20	1	2	2	1	-
	2	2	2	1	643
TP-22	1	2	2	1	100
	2	2	2	1	-
	3	1	1	1	-
TP-23	1	2	2	1	11300
TP-24	1	2	2	1	128
TP-25	1	2	2	1	24681
TP-26	1	2	2	1	2507
TP-27	1	2	2	1	2224
TP-28	1	2	2	1	521
TP-29	1	2	2	2	2495
	2	2	2	2	6009
TP-30	1	2	2	1	105446
TP-31	1	2	2	1	605
	2	2	2	1	7162
TP-32	1	2	2	1	569
TP-33	1	2	2	1	3175
TP-34	1	1	1	1	-
TP-35	1	2	2	2	1225
TP-36	1	1	2	2	122
TP-37	1	2	1	1	-
TP-38	1	2	2	1	15453
TP-39	1	2	2	1	-
	2	2	2	1	-
TP-40	1	2	2	1	16305
TP-41	1	2	2	1	-
TP-42	1	1	2	2	338

<u>Spring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
TP-43	1	2	2	1	5398
TP-44	1	2	2	1	-
TP-45	1 2	2 2	2 2	2 1	18608 6912
TP-46	1	2	2	2	423
TP-47	1	2	2	2	3415
TP-48	1	2	2	2	1053
TP-49	1	2	2	1	-
TP-50	1	2	2	1	12515
TP-51	1 2	2 2	2 2	2 1	- -
TP-52	1	2	2	1	-
TP-53	1	2	2	1	-
TP-54	1	2	1	1	-
TP-55	1	1	1	1	-
TP-56	1 2	2 1	2 1	1 1	- -
TP-57	1	2	2	2	17550
TP-58	1	2	2	2	-
TP-59	1	2	2	2	1772
TP-60	1	2	2	2	5049
TP-61	1	2	2	2	-
TP-62	1	2	2	2	-
TP-63	1 2	2 2	2 2	1 1	2558 27778
TP-64	1	2	2	1	34490
TP-65	1	2	2	1	25247
TP-66	1	2	2	1	-

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
TP-67	1	2	2	1	-
TP-68	1	2	2	1	-
TP-69	1	1	1	1	-
TP-70	1	2	2	1	6597
TP71	1	2	2	1	-
	2	1	1	1	-
TP-72	1	1	1	1	-
TP-73	1	1	2	1	10
TP-74	1	2	1	1	-
TP-75	1	1	2	1	68
TP-76	1	1	1	1	-
TP-77	1	1	1	1	-
TP-78	1	2	1	1	-
TP-79	1	1	2	1	17
TP-80	1	1	1	1	-
TP-81	1	2	2	1	38
TP-82	1	2	1	1	-
TP-83	1	2	2	1	62
TP-84	1	2	2	1	567
	2	2	2	2	2326 752
TP-86	1	2	2	1	3800
TP-87	1	2	2	1	14313
TP-88	1	2	2	1	11889
TP-89	1	2	2	2	3119
	2	2	2	2	8971
TP-90	1	2	2	2	-
TP-91	1	2	2	1	2502

<u>Boring</u>	<u>Sample</u>	<u>Texture</u>	<u>Color.</u>	<u>Odor</u>	<u>Total Lead, Arsenic & Chromium Concen. (ppm)</u>
TP-92	1	1	1	1	-
TP-93	1	1	2	1	0
TP-94	1	2	2	1	3139
TP-95	1	2	2	1	2343
	2	2	2	1	174
	3	2	2	1	1474
TP-96	1	1	2	1	6
TP-97	1	1	1	1	-
TP-98	1	1	2	1	7
TP-99	1	2	1	1	-
TP-100	1	2	2	1	19
TP-101	1	1	2	1	0
TP-102	1	2	2	1	-
	2	2	2	1	18
TP-103	1	2	2	1	29
TP-104	1	2	2	2	1563
TP-105	1	2	2	2	229
TP-106	1	1	1	1	28
TP-107	1	2	2	1	1790
	2	1	2	2	1206
TP-108	1	2	2	1	670
TP-109	1	2	1	1	-
TP-110	1	2	2	1	1338
	2	2	2	1	133
TP-111	1	1	2	1	10
TP-112	1	2	2	1	807
	2	2	2	1	2855
TP-113	1	2	2	1	17167
	2	2	2	1	27272
TP-114	1	2	2	1	74
	2	2	2	1	6788
TP-115	1	1	1	1	-

while the type of waste cannot be determined visually, the physical inspection can distinguish between contaminated and natural deposits.

In addition to analysis for metals, most soil samples were screened for organic compounds. Figure 29 shows the areas where sediment samples collected registered organic content of greater than one hundred and greater than one thousand counts per gram. An area encompassing New Boston Street and the adjacent industrialized sector shows the highest levels of counts per gram.

GROUND-WATER LEVELS AND FLOW

Ground-water levels in all wells and piezometers were measured on September 22, 1982, October 27, 1982 and January 12, 1983 (Table 1). The data were used to plot water table elevation contours so that the flow direction could be determined. The resulting representative water table, which is based on data collected from the OW-series wells on January 12, 1983, is shown on Figure 30. This water table map is similar to earlier maps based on data collected in September and October.

Ground water flows downgradient and approximately perpendicular to the water table elevation contours. Figure 30 shows that ground water enters the Site from the north. Ground water west of the Aberjona River Valley will flow towards the southeast, whereas ground water east of the valley will flow towards the southwest.

The highest water levels (72.6 and 72.7) were measured at OW-1 and OW-1A located at the northern edge of the Site. The lowest level (51.2) was measured at OW-7, the most southerly well. These values indicate an overall gradient of 0.005 ft/ft. However, the slope of the water table is steepest under the Site (0.008 ft/ft) and flattens out below the industrial complex (0.002 ft/ft).

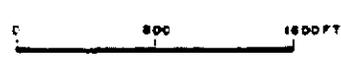
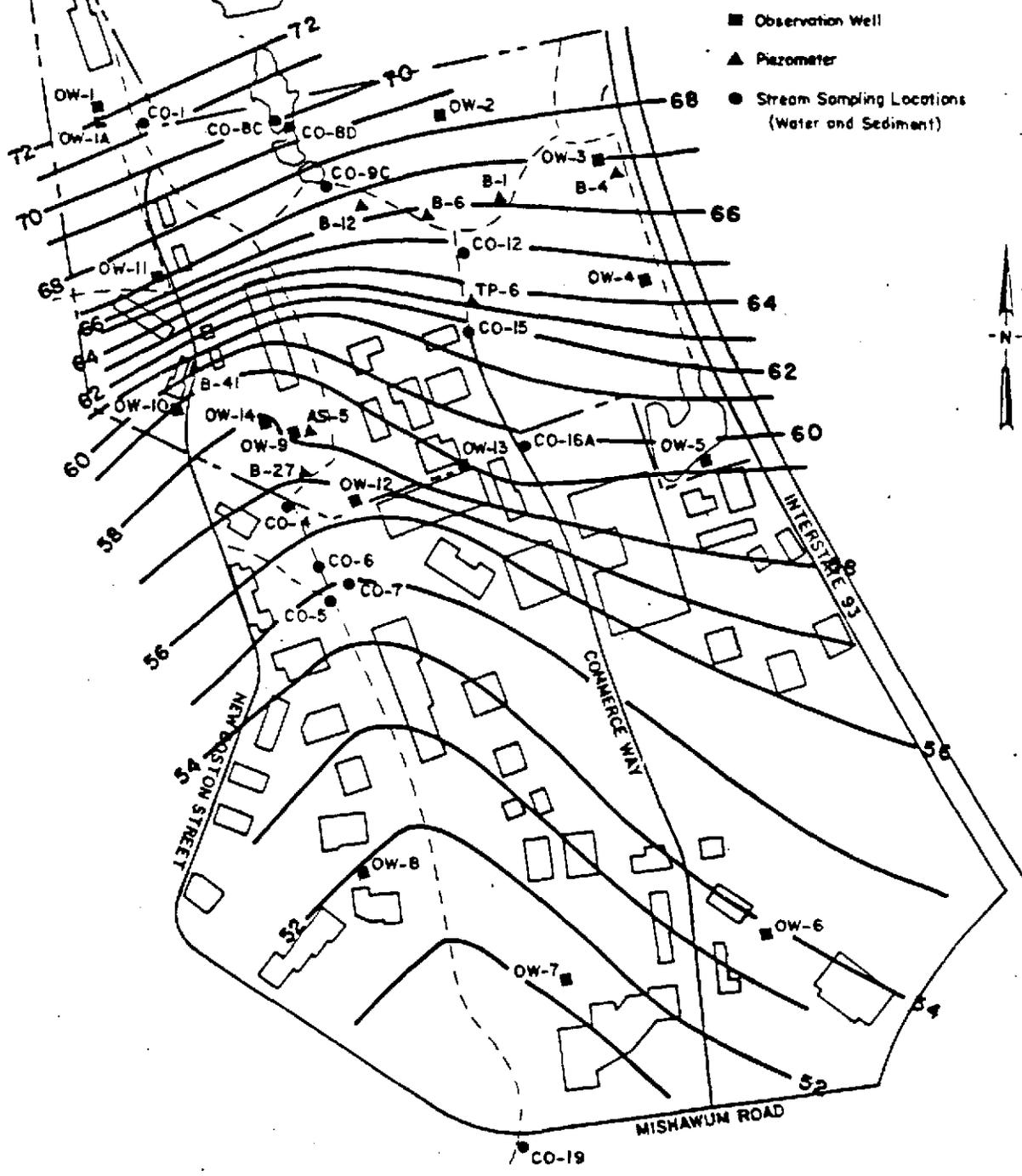
Based on the direction of ground-water flow, OW-9, OW-12, OW-13 and OW-14 are located immediately downgradient of the Site. Ground-water samples collected from these wells will reflect the quality of ground water leaving the Site. OW-1, OW-1A, OW-10 and OW-11 are upgradient wells tapping ground water that is entering the Site from the northwest and west. OW-2, OW-3 and OW-4 are upgradient to the north and east. The remaining wells, OW-5, OW-6, OW-7 and OW-8, are located lateral to the Site with respect to ground-water flow.

Examination of the water table map (Figure 30) indicates that ground water entering the Site from the northeast (east of Commerce Way) will flow under the eastern portion of the Site and into the Aberjona River Valley or thickest part of the aquifer north of Mishawum Road.

Ground water entering the Site from the north will turn towards the southwest and into the Aberjona River Valley just to the south

— EXPLANATION —

- Area of Investigation
- Observation Well
- ▲ Piezometer
- Stream Sampling Locations (Water and Sediment)



— 58 — Water Table Contour,
In Feet Relative To MSL

TITLE		
WATER TABLE MAP JANUARY 12, 1983		
PREPARED FOR		
Stauffer Chemical Company		
ROUX	Consulting Ground-Water Geologists	SCALE 1" = 82.3'
	ROUX ASSOCIATES INC.	FIGURE 30
	DATE Feb. 1983	

of the Site. Ground water entering the site from the northwest will flow under the western half of the Site and into the valley north of Mishawum Road. The ground-water flow rate throughout the area of investigation is estimated to be approximately one foot per day.

Water levels from both the rock and sand/gravel wells were used to compile the water table map because they correlate well with each other. Water levels obtained from the piezometers are generally higher than nearby upgradient observation wells. Since most of the piezometers are screened in the sands of Unit B where the unit forms a thin veneer over till and bedrock, they are essentially measuring local recharge. Water levels from the piezometers indicate a portion of this shallow ground water discharges into small tributaries of the Aberjona and other surface water bodies on the Site.

Water levels measured in OW-2 are anomalously higher than levels in nearby OW-1 and OW-3. The water level measured on January 12, 1983 is 44.19 feet higher than OW-1. This is probably due to the well intercepting an isolated and confined water-bearing fracture near the bottom of the hole. In this case, water entering the well will be under artesian pressure and will not reflect the regional water table.

Water levels have increased in all wells from late September to mid-January, with the exception of OW-1 which showed a decrease of 0.07 feet. The water levels in the sand/gravel wells rose between 0.19 and 0.53 feet while the rock wells were more variable, ranging from -0.07 feet (OW-1) to +2.07 feet (OW-4). Water levels in the piezometers showed a greater increase than the sand and gravel wells (between 0.52 and 0.44 feet). These levels reflect recharge to the ground-water aquifer from precipitation during this period.

GROUND-WATER QUALITY

All ground-water samples were analyzed for the EPA listed priority pollutants and 22 highest organic peaks on GC/MS scan. Concentrations of metals in ground water will be discussed first, followed by the organic compounds detected. Ground-water quality results are given in Appendix 4.

Of the fifteen monitoring wells, six contained metals exceeding drinking water standards. They may be summarized as follows:

- * Arsenic was found at 200 and 420 ppb in ground-water samples collected at OW-5 and OW-9 respectively. The drinking water standard (USEPA, July 1976) is set at

50 ppb. Arsenic was not detected in any other well samples.

- * Lead was found at 120 and 74 ppb at OW-7 and OW-14 respectively. The drinking water standard for lead is 50 ppb.
- * Cadmium was detected at 28 and 11 ppb at OW-10 and OW-12 respectively. The drinking water standard for cadmium is 10 ppb.
- * Chromium was detected at 54 ppb in ground water from OW-12. The drinking water standard for hexavalent chromium is 50 ppb. The type of chromium found in Well OW-12 is not known.

As previously discussed, OW-9, OW-12, OW-13 and OW-14 are the wells located immediately downgradient of the Site. Arsenic at levels greater than four times the drinking water standard was found at OW-9. Lead was detected above the drinking water standard at OW-14. Ground water from OW-12 contained cadmium and chromium just above drinking water standards. OW-13 did not contain any arsenic, lead, chromium or cadmium.

A review of data collected from monitoring wells on Janpet property,

(Goldberg, Zoino and Associates, Inc. Report L-2) also indicates the presence of arsenic and lead in the ground water. Ground water from four wells screened in sand and gravel deposits contain arsenic greater than drinking water standards. Two of these wells contain lead in concentrations above potable standards. These data correlate with data obtained from OW-9 and OW-14 which are immediately downgradient of Janpet property. Chromium was not found above drinking water standards in ground water under Janpet property.

Based on the analytical results from the downgradient wells, it appears that waste deposits on the Site are contributing arsenic and lead to the ground water. The one chromium concentration found is just above the drinking water standard right at the edge of the Site.

One upgradient well, OW-10, contains cadmium at 28 ppb. The remaining upgradient wells contain no detectable lead, arsenic or chromium, nor do metals exceed drinking water standards in any of these wells. Of the wells lateral to the Site, ground-water samples from OW-5 and OW-7 contained arsenic and lead respectively. Wells OW-6 and OW-8 did not contain detectable concentrations of these metals.

The monitoring wells were also analyzed for EPA's list of priority pollutants and other organic compounds. All of the wells downgradient

of the Site, with the exception of OW-14, contained at least one organic compound at levels greater than 100 ppb. Ground water from OW-9 showed two priority pollutants less than 17 ppb and carbon disulphide at 108 ppb. Ground water from OW-12 contained five organic compounds greater than 100 ppb, but only one organic priority pollutant at 15 ppb. OW-13 showed no priority pollutants and sulphur at 233 ppb. From this information, it appears that areas on the Site are contributing organic compounds other than the priority pollutants to the ground water. It should be noted that no volatile organic compounds were detected from ground-water samples collected on Janpet property.

Ground water from well OW-11, upgradient of the Site, contained four organic compounds and two priority pollutants, each at a concentration less than 66 ppb. Two organic compounds (carbon disulphide and trichloropropane) were detected each at 90 ppb in the sample collected from OW-6. OW-6 is located in the southeastern portion of the developed area and is lateral to the Site with respect to ground-water flow.

Downgradient monitoring wells had lower organic priority pollutant concentrations than upgradient wells. Ground-water samples from upgradient and lateral wells (OW-2, OW-3, OW-5 and OW-11) contained 52, 110, 69 and 86 ppb organic priority pollutants respectively.

Downgradient wells (OW-9 and OW-12) contained 27 and 15 ppb organic priority pollutants. There was an increase in non-priority pollutants in OW-12 which is downgradient of a waste pile and the Chrome Lagoons.

In summary, the Phase I ground-water data show several metals and organic compounds in both up and downgradient wells and in wells lateral to the Site. No significant plume of contaminants emanating from the Site was identified.

FINDINGS AND CONCLUSIONS

1. The Woburn Site is underlain by bedrock of low permeability. Unconsolidated deposits overlying bedrock are low permeability glacial till, permeable outwash sands, peat and miscellaneous fill deposits (including chemical wastes and hide residues.)
2. Substantial progress has been made towards areal definition of the waste deposits. These deposits were found to range from one to eight feet deep. In several areas, wastes have been piled on the ground up to forty feet above grade.
3. Waste deposits at the Site include animal hide residue, construction debris, and chemical waste containing the following metals: arsenic, barium, chromium, copper, lead and zinc with lesser amounts of mercury and cadmium.
4. The stockpile of hide residues and other wastes in the northern portion of the Site contains all of the metals identified in other places.
5. Soil samples collected from pits and borings were analyzed for fourteen metals. The results can be summarized as follows:
 - (a) Lead is the most widespread metal found at the Site and arsenic is the second most widespread. Lead and arsenic

are frequently found together in wastes at the Site. There are approximately twenty-two acres of the Site where greater than 1,000 ppm of lead and/or arsenic are found and an additional thirteen acres containing 100 ppm of lead and/or arsenic.

- (b) Chromium is found on approximately five acres of the Site at levels greater than 1,000 ppm and on an additional five acres at greater than 100 ppm. Chromium is generally found in the same areas as the hide residues and in the Chrome Lagoon area.
- (c) Barium, copper and zinc are found across the Site at concentrations of 100 ppm in the same areas as arsenic and lead are found.
- (d) Mercury is generally found to be associated with high levels of lead.
- (e) No other metals were found in significant amounts (greater than 100 ppm) occurring independently of lead, arsenic, chromium, barium, zinc, copper and mercury.

- 6. Hide residues are found on approximately eight acres of the Site. In some of this area, hide residues are mixed with other wastes.

7. A preliminary screening for organics in the soil samples identified several areas around the Site, particularly in the western portion (Figure 29), that contain greater than 1000 counts per gram. Specific organic compounds present were not identified by this screening technique.
8. The area to the east of Commerce Way and an extension of Commerce Way does not contain waste materials.
9. Waste materials and contaminated soil can be distinguished from natural sediments in the field by their physical characteristics (texture, color, odor).
10. Waste types often can be recognized by observation of physical characteristics, however, positive determination of waste type must be made by chemical analysis.
11. The conductivity survey of the Site was useful in locating the best areas for subsurface exploration with pits and borings. The conductivity results were also helpful in insuring that waste deposits did not remain undetected in the subsurface.
12. Interpretation of the conductivity data shows a very good correlation with chemical analytical results. Conductivity

results did not prove to be helpful in mapping the bedrock surface with depth and only partially successful in defining areas of contaminated ground water.

13. Ground water in the bedrock and deeper portions of the outwash sands flows from north to south into the more permeable sands of the buried Aberjona Valley south of the Site.
14. A portion of the shallow ground water at the Site discharges into the Aberjona River, its tributaries and surface water bodies, whereas some flows into the deeper portion of the buried valley.
15. The ground-water flow rate in the more permeable sediment (Unit B) of the Aberjona Valley is estimated at approximately one foot per day.
16. There are no potable supply wells in the Aberjona Valley downgradient of the Site within the area of investigation north of Mishawum Road.
17. Ground-water samples collected from upgradient wells (north of the Site) had higher organic priority pollutant concentrations than downgradient wells. The samples from upgradient well OW-10 also contained cadmium (28 ppb) at a concentration greater than the drinking water standard (10 ppb).

18. In ground-water samples collected from the four wells downgradient of the Site:
- (a) OW-9 contained arsenic at 420 ppb (drinking water standard 50 ppb), two organic priority pollutants less than 17 ppb and another organic compound, (carbon disulphide) at 108 ppb.
 - (b) OW-12 contained cadmium (11 ppb) and chromium (54 ppb) just above drinking water standards (10 and 50 ppb, respectively). One organic priority pollutant was found at 15 ppb and six other compounds were present, ranging from 22 to 1850 ppb.
 - (c) OW-13 contained three organic compounds, but no priority pollutants.
 - (d) OW-14 contained no organic compounds, but lead (74 ppb) was found exceeding the drinking water standard of 50 ppb.
19. Arsenic was found at 200 ppb in a sample from well OW-5 which is lateral to the Site with respect to regional ground-water flow, but may be influenced by shallow ground-water flow or surface-water flow.

20. Lead was found at 120 ppb in a sample from well OW-7 which is lateral to the Site.

Respectfully Submitted

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March 14, 1983

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