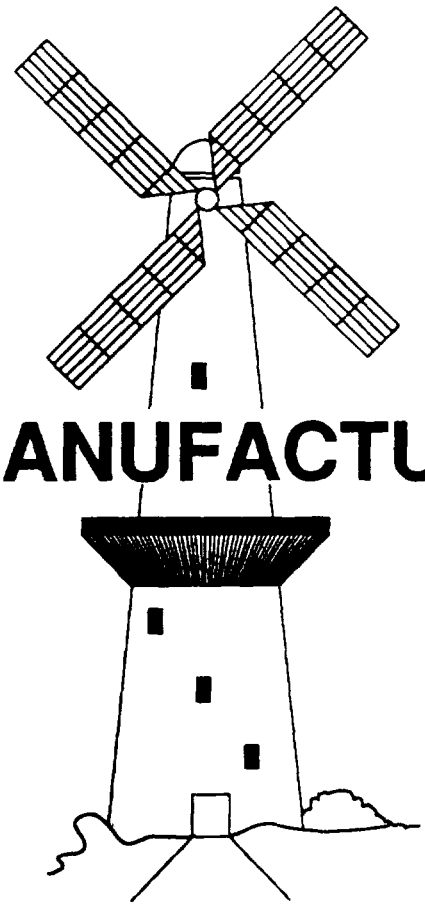
Final Remedial Investigation Report



HI-MILL MANUFACTURING CO.

1704 HIGHLAND ROAD
HIGHLAND, MICHIGAN

GERAGHTY & MILLER, INC.
Environmental Services

VOLUME 1 OF 4

FINAL
REMEDIAL INVESTIGATION
HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

March 1993

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FINAL
REMEDIAL INVESTIGATION
HI-MILL MANUFACTURING COMPANY
HIGHLAND, MICHIGAN

March 5, 1993

Geraghty & Miller, Inc. submits this Remedial Investigation Report on behalf of Hi-Mill Manufacturing Company for work performed at their Highland, Michigan, facility. This report was prepared in conformance with Geraghty & Miller's strict quality assurance and quality control procedures to ensure that the project meets the highest standards in terms of the methods used and the information presented. If you have any questions concerning this report, please contact one of the individuals listed below.

Respectfully submitted,

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CONTENTS

Page

PREFACE xiii

1.0 INTRODUCTION 1

1.1 PURPOSE OF REPORT 1
1.2 SITE BACKGROUND 2

1.2.1 Site Description 2
1.2.2 Site History 4
1.2.3 Previous Investigations 7

1.2.3.1 MDNR Investigations - 1972 to 1978 7
1.2.3.2 MDNR Study of the Target Pond/Wetland Area - 1976 7
1.2.3.3 MDNR Hydrogeological Investigation - 1981/1982 8
1.2.3.4 Lagoon Closure - 1983 9
1.2.3.5 MDNR Ecological Survey - 1984 9
1.2.3.6 The MDNR ecological survey report concluded that 10
1.2.3.7 Oakland County Health Department Well Survey - 1988 12
1.2.3.8 Techna Corporation Hydrogeological Study - 1988 13
1.2.3.9 Michigan Department of Public Health Public Well Sampling - 1989 15
1.2.3.10 Techna Corporation Remedial Investigation - 1990 15
1.2.3.11 Geraghty & Miller, Inc. Remedial Investigation - 1990 to 1992 18

1.2.4 Report Organization 20

2.0 STUDY AREA INVESTIGATION 22

2.1 SITE CHARACTERIZATION AND FIELD PROCEDURES 22

2.1.1 Surface Features 23
2.1.2 Investigations of Potential Sources 24

CONTENTS (Continued)

Page

2.1.3 Climatological Investigation 26
2.1.4 Surface-Water and Sedimentological Investigations 27

2.1.4.1 Techna Corporatic ıvestigation 27
2.1.4.2 Geraghty & Miller vestigation 30

2.1.5 Soils/Geological Investigations 30

2.1.5.1 Physical Characteristics 31

2.1.5.1.1 General 31
2.1.5.1.2 Techna Drilling Activities 31

2.1.5.1.2.1 Grid and Off-Grid Soil Sampling 33

2.1.5.1.3 Geraghty & Miller Drilling Activities 34

2.1.5.1.3.1 Hand-Auger Borings and Piezometer Installation 36

2.1.5.2 Chemical Characteristics 37

2.1.5.2.1 Techna Soil Sampling 37
2.1.5.2.2 Geraghty & Miller Soil Sampling 38

2.1.6 Ecological Assessment and Inventory 38
2.1.7 Ground-Water Investigations 39

2.1.7.1 Hydraulic Characteristics 40

2.1.7.1.1 General 40
2.1.7.1.2 Staff Gauge, Piezometer, and Well Installation 41

CONTENTS (Continued)

Page

2.1.7.1.2.1 Staff Gauges 41
2.1.7.1.2.2 Piezometers 42
2.1.7.1.2.3 Monitoring Wells 43

2.1.7.1.3 Ground-Water Monitoring 49
2.1.7.1.4 In-Situ Hydraulic Testing 51
2.1.7.1.5 Laboratory Hydraulic Testing 52

2.1.7.2 Chemical Characteristics 53

2.1.7.2.1 General 53
2.1.7.2.2 Hand-Auger Borings 54

2.1.7.2.2.1 Installation 54

2.1.7.2.3 Vertical Profiling 55

2.1.7.2.3.1 Methodology 56

2.1.7.2.4 Monitoring Well Installation 59

2.1.7.2.4.1 Techna Monitoring Well Installation 60
2.1.7.2.4.2 Geraghty & Miller Monitoring Well Installation 61

2.1.7.2.5 Ground-Water Sampling 62

2.1.7.2.5.1 Techna Ground-Water Sampling Methodology 63
2.1.7.2.5.2 Geraghty & Miller Ground-Water Sampling Methodology 65

2.2 TECHNICAL MEMORANDUM 67

CONTENTS (Continued)

Page

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA 70

3.1 SURFACE FEATURES 70
3.2 CLIMATE 73
3.3 SURFACE-WATER HYDROLOGY 73

3.3.1 Target Pond 74
3.3.2 Waterbury Lake and North Arm 74
3.3.3 Alderman Lake 74
3.3.4 Conceptual Model of Surface Water Hydrology 75

3.3.4.1 Hydraulic Connection Between the North Arm of Waterbury Lake and the Alderman Wetland Under M-59 76
3.3.4.2 Hydraulic Connection Between Target Pond and Waterbury Lake 80
3.3.4.3 Hydraulic Connection Between Target Pond and Wetland Under M-59 80
3.3.4.4 Hydraulic Connection Between Waterbury Lake and the North Arm of Waterbury Lake 80

3.4 GEOLOGY AND SOILS 81

3.4.1 Regional Geology 81
3.4.2 Site Geology and Soils 82

3.4.2.1 Subsurface Exploration Results 82
3.4.2.2 Physical Soil Testing Results 86

3.5 HYDROGEOLOGY 88

3.5.1 Regional Hydrogeology 88
3.5.2 Site Hydrogeology 89

3.5.2.1 Hydraulic Gradients and Ground-Water Flow 89

CONTENTS (Continued)

Page

3.5.2.1.1 General 89
3.5.2.1.2 Shallow Discontinuous Flow System 90
3.5.2.1.3 Intermediate Flow System 96
3.5.2.1.4 Deep Flow System 99
3.5.2.1.5 Vertical Hydraulic Gradients 101
3.5.2.1.6 Potential Leakance Through Gray Aquitard 102

3.5.2.2 Hydraulic Conductivity, Transmissivity, Storativity 104
3.5.2.3 Ground-Water Flow Velocities 106
3.5.2.4 Ground-Water Elevation Fluctuations 108
3.5.2.5 Conceptual Ground-Water Flow Model 109
3.5.2.6 Uses of Aquifers 119

3.6 PAST AND PRESENT LAND USE 119

3.7 ECOLOGY 123

3.7.1 Summary of Results 123

3.7.1.1 Surface-Water Chemistry 124
3.7.1.2 Ecological Inventory 125
3.7.1.3 Literature 125
3.7.1.4 Sediment Chemistry 126
3.7.1.5 Sediment Toxicity 126

4.0 NATURE AND EXTENT OF CONTAMINATION 128

4.1 SOURCES 128

4.1.1 Underground and Aboveground Storage Tanks 129
4.1.2 Containment and Transport of Process Materials 130
4.1.3 Manufacturing Activities 132
4.1.4 Potential Off-Site Sources of Contamination 132

CONTENTS (Continued)

Page

4.2 SOILS AND VADOSE ZONE 133

4.2.1 Inorganics 134

4.2.1.1 Introduction 134
4.2.1.2 Short List Metals 135

4.2.1.2.1 Surface Soil Samples (0.0 Feet to 1.0 Feet Below Ground Surface) 136
4.2.1.2.2 Shallow Soil Samples (1.0 to 3.0 Feet Below Ground Surface) 138
4.2.1.2.3 Intermediate Soils (3.0 to 8.0 Feet Below Ground Surface) 140
4.2.1.2.4 Deep Soils (8.0 to 16.0 Feet Below Ground Surface 141
4.2.1.2.5 Phase II Soil Sampling 142

4.2.1.3 TAL Inorganics 144

4.2.2 Organics 145

4.2.2.1 TCL Volatile 145
4.2.2.2 TCL Organics (BNA,PCB,PEST) 150

4.3 SURFACE WATER AND SEDIMENTS 151

4.3.1 Background Pond 152

4.3.1.1 Surface Water 152
4.3.1.2 Sediments 153

4.3.2 Target Pond 154

4.3.2.1 Surface Water 154
4.3.2.2 Sediments 155

CONTENTS (Continued)

Page

4.3.3 Waterbury Lake 156

4.3.3.1 Surface Water 156
4.3.3.2 Sediments 157

4.4 GROUND WATER 157

4.4.1 Inorganics 158

4.4.1.1 Short List Metals 159
4.4.1.2 Target Analyte List 159

4.4.2 Organics 160

4.4.2.1 Shallow "Discontinuous" Flow System 161

4.4.2.1.1 Monitoring Well Sampling 161
4.4.2.1.2 Hand-Auger Boring Water Sampling 163

4.4.2.2 Intermediate Flow System 166

4.4.2.2.1 Vertical Profiling 166
4.4.2.2.2 Monitoring Well Sampling 167

4.4.2.3 Deep Flow System 168

4.4.3 Base Neutral and Acid Extractable Compounds 168

4.5 AIR 169

5.0 CONTAMINANT FATE AND TRANSPORT 170

5.1 POTENTIAL MIGRATION PATHWAYS 170

CONTENTS (Continued)

Page

5.1.1 General 170
5.1.2 Soils 172

5.1.2.1 Inorganics 172
5.1.2.2 Organics 175

5.1.3 Surface Water 178
5.1.4 Ground Water 180
5.1.5 Air 185

5.2 CONTAMINANT PERSISTENCE 186

5.2.1 Inorganics 186
5.2.2 Organics 187

5.3 CONTAMINANT MIGRATION 188

5.3.1 Soils 188
5.3.2 Surface Water 190
5.3.3 Ground Water 191

5.3.3.1 Inorganics 192
5.3.3.2 Organics 194

5.3.4 Air 197

6.0 SUMMARY AND CONCLUSIONS 198

6.1 SUMMARY 198

6.1.1 Nature and Extent of Contamination 198
6.1.2 Fate and Transport 201

6.2 CONCLUSIONS 206

CONTENTS (Continued)

Page

6.2.1 Data Limitations and Recommendations for Future Work 206

6.2.1.1 Data Limitations 206
6.2.1.2 Recommendations for Future Work 208

6.2.2 Recommended Remedial Action Objectives 211

REFERENCES

LIST OF FIGURES

1.1 Site Location Map
1.2 Site Topography (11" x 17")
2.1 Base Map - Well Location Map
2.2 1978 Aerial Photograph
2.3 1988 Aerial Photograph
3.1 Phreatic Surface of Shallow Aquifer
3.2 Oakland County Soil Survey
3.3 Surficial Geology, Oakland County
3.4 Cross Section A-A
3.5 Cross Section B-B
3.6 Cross Section C-C
3.7 Cross Section D-D
3.8 Cross Section E-E
3.9 Cross Section Traces
3.10 Intermediate Pot Surface
3.11 Deep Pot Surface
3.12 Water Supply Well Location
3.13 Current and Previous Operations
4.1 Site Layout
4.2 Surface Soil Geology and Sample Localities
4.3 Shallow Soil Geology and Sample Localities
4.4 Intermediate Soil Geology
4.5 Deep Soil Geology

LIST OF FIGURES (Cont'd)

4.6 Inorganics (Soil) Above Background
4.7 Organics (Soil) Results and Sampling Localities
4.8 Hand Auger Boring Locations
4.9 Inorganics (Ground Water) Above Background
4.10 Oakland County Soil Survey
4.11 TCE Extent
4.12 DCE Extent
4.13 VC Extent
4.14 BTEX Results

LIST OF TABLES

2.1 Surface Water Sediment Sampling Analytical Summary
2.2 Surface Water Sampling Analytical Summary
2.3 Soil Analytical Analysis Summary
2.4 Headspace PID/FID Screening
2.5 Well Construction Summary
2.6 Ground-Water Monitoring Well Analytical Summary
3.1 Annual Climatological Data for the Years of 1987-1990, Pontiac, Michigan
3.2 Climatological Observations for Pontiac, Michigan, for 1991
3.3 Phase II Surface Water Elevations
3.4 Phase I Surface Water Elevations
3.5 Ground-Water Measurements
3.6 Horizontal Hydraulic Gradients
3.7 Vertical Gradients at Selected Monitoring Well Pairs
3.8 Aquifer Parameters
3.9 Vertical Permeability Summary
3.10 Ground Water Seepage Velocities
4.1 Summary of Background Concentrations and Statistical Analysis for Short List Metals in Soils
4.2 Summary of Soil Background Concentrations and Statistics for TAL Inorganics, Techna Analytical Results
4.3 Summary of Techna Grid Inorganics in Soil (mg/kg) Above Background Soil Survey Levels
4.4 Detectable Inorganics in Soil (mg/kg) Above Background Soil Survey Levels

4.5 Sample Results of TAL Inorganics, Techna Analytical Results
4.6 Techna Detectable Organics in Soil (mg/kg)
4.7 Detectable Organics in Soil (mg/kg)
4.8 Techna Detectable Base Neutral and Acid Extractable Compounds, Pesticides and PCBs in Soil (mg/kg)
4.9 Surface Water Analytical Results for, 3/1/90 - 3/2/90, Short List Metals, Chromium (+6), Ammonia Nitrogen, Nitrate and Nitrite Nitrogen
4.10 Surface Water Sediment Analytical Results for, 2/20/90 - 2/22/90, Short List Metals, Chromium (+6), Ammonia Nitrogen, Nitrate and Nitrite Nitrogen
4.11 Techna Detectable Inorganics in Ground Water (μg/L)
4.12 Ground-Water Samples Analyzed for Target Analyte (TAL), Techna Analytical Results
4.13 Detectable Inorganics in Ground Water (μg/L)
4.14 Detectable Inorganics in Ground Water (μg/L) Above MDNR Background Ground Water Survey Levels
4.15 Techna Detectable Organics in Ground Water (mg/L)
4.16 Detectable Organics in Ground Water (μg/L)
4.17 Field Gas Chromatograph Results for Chlorinated Solvents in Hand Auger Borings
4.18 Field Gas Chromatograph Results for BTEX in Hand Auger Borings
4.19 Field Gas Chromatograph Results Vertical Profiles
4.20 Ground-Water Analytical Results for Base Neutral and Acid Extractable Compounds

APPENDIX

A. Techna Boring Logs, Initial Hydrogeologic Investigation
B. Techna Boring Logs, Phase I Remedial Investigation
C. Techna Soil Sampling Boring Logs, Phase I Remedial Investigation
D. Geraghty & Miller Soil Sampling Boring Logs, Phase II Remedial Investigation
E. Geraghty & Miller Piezometer Boring Logs, Phase II Remedial Investigation
F. Geraghty & Miller Hand-Auger Boring Logs, Phase II Remedial Investigation
G. Geraghty & Miller Piezometer Installation Logs, Phase II Remedial Investigation
H. MDNR Boring and Well Installation Logs
I. Techna Monitoring Well Installation Logs, Phase I Remedial Investigation
J. Geraghty & Miller Well Installation Logs, Phase II Remedial Investigation
K. Geraghty & Miller Well Hydrographs, Phase II Remedial Investigation
L. Techna Slug Test Data, Phase I Remedial Investigation
M. MTC Report, Phase II Remedial Investigation
N. Fast Environmental GC Report, Phase II Remedial Investigation
O. Geraghty & Miller Ground-Water Sampling Logs, Phase II Remedial Investigation
P. Geraghty & Miller Hi-Mill Manufacturing Company Final Technical Memorandum
Q. National Oceanic Atmospheric Administration Climate Data
R. Geraghty & Miller Ecological Inventory/Assessment Report, Phase II Remedial Investigation
S. Geraghty & Miller Laboratory Validation Report, Phase II Remedial Investigation

PREFACE

Analyte	The chemicals for which a sample is analyzed
BGS	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BNA	Base, Neutral and Acid Extractables
CERCLA	Comprehensive Environmental Compensation and Liability Act
CLP	Contract Laboratory Program
CRDL	Contract Required Detection Limit
DCE	Dichloroethylene or Dichloroethene
FID	Flame Ionization Detector
GC	Gas Chromatograph
FS	Feasibility Study
HAB	Hand-Auger Boring
HPDE	High Density Polyethylene
I.D.	Inside Diameter
Kd	Adsorption Coefficient
ME	Methylene Chloride
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
MDPH	Michigan Department of Public Health
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanographic and Atmospheric Administration
NPL	National Priorities List
OCHD	Oakland County Health Department
O.D.	Outside Diameter
OVA	Organic Vapor Analyzer
PCB	Polychlorinated Biphenyls
PID	Photoionization Detector
PVC	Polyvinyl Chloride
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAPjP	Quality Assurance Project Plan
QC	Quality Control
RA	Risk Assessment
RI	Remedial Investigation
SLM	Short List Metals
SVOC	Semi-Volatile Organic Compounds

PREFACE (Continued)

TAL	Target Analyte List
TCA	Trichloroethane
TCE	Trichloroethylene or Trichloroethene
TCL	Target Compound List (analysis for organics: VOCs, BNAs, PCBs and Pesticides
TSP	Trisodium Phosphate
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
VOA	Volatile Organic Analyte
VOC	Volatile Organic Compound

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HIGHLAND, MICHIGAN

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

The purpose of this Draft Remedial Investigation Report is to present the findings and conclusions of the Phase I and II Remedial Investigation (RI) conducted at the Hi-Mill Manufacturing facility located at 1704 Highland Road in Highland, Michigan. The Hi-Mill Manufacturing facility is included on the National Priorities List (NPL) and, as such, is subject to investigation with the objective of defining the nature and extent of contamination and securing enough data to implement an appropriate Feasibility Study (FS) that will be used to assess potential remedial alternatives in a manner consistent with the National Contingency Plan.

Included in this report is a description of all detected compounds, potential sources for those compounds, and migration pathways along with an analysis of the impact these compounds may have on both the local ecology and upon human health and safety. In addition, all supporting evidence with respect to field procedures, forms of data analysis, and quality control/assurance techniques have been provided. The Remedial Investigation consists of a series of phased investigations of various aspects of the study area such as impact on local wetlands; subsurface geology, hydrogeology, and soils; and the presence of organic and inorganic chemical species in soils, ground water, and surface water.

Presented in the following section is a description of the site background/history along with a summary of all of the investigations conducted thus far at the Hi-Mill Manufacturing facility.

1.2 SITE BACKGROUND

1.2.1 Site Description

The Hi-Mill Manufacturing facility is located at 1704 Highland Road (M-59) in Highland Township, Oakland County, Michigan (Figure 1.1). The manufacturing facility itself is approximately 4.5 acres in area and is located within Section 23, T7N, R18W at an elevation of about 1010 feet above National Geodetic Vertical Datum (NGVD) (Figure 1.2).

The Hi-Mill Manufacturing property is dominated by the manufacturing facility and a paved parking area. The primary function of the Hi-Mill Manufacturing plant is the production of assorted tubular parts. The factory has been expanded several times since its original construction in 1946 and houses administrative offices and raw material storage and preparation areas in addition to actual production facilities. Paved parking areas occupy the northeast corner of the property and a portion of the southwest margin of the site. The remainder of the property is covered by vegetation.

The Hi-Mill Manufacturing site is bounded to the northwest by Michigan State Route 59 (M-59) and, generally, on all other sides by the Highland State Recreation Area, which is owned and operated by the Michigan Department of Natural Resources (MDNR). Property located to the northwest of the site across M-59 is also part of the Highland State Recreation Area. A manufacturing facility owned by Numatics, Inc. is located approximately 1000 feet northeast of the Hi-Mill Manufacturing property. Correspondence provided through the Livonia District office of the MDNR indicates that Numatics, Inc. is engaged in the cleaning and assembling of small parts used in air control valves (MDNR Fact Sheet, 1987). Numatics, Inc. reportedly discharges process wastewater to a drain and septic field located on Numatics property. A

private land owner, Mr. Dan Teeples of Waterbury Road, owns some of the land adjoining part of the Hi-Mill Manufacturing facility to the southeast.

Target Pond, a marshy area of approximately 8 to 10 acres is located approximately 200 feet east of the site building. Situated approximately 450 feet south of the facility is the North Arm of Waterbury Lake. The North Arm is drained by Waterbury Lake which is located at a distance of some 900 feet south of the Hi-Mill Manufacturing factory. A lightly wooded area is present immediately behind the site buildings to the southeast.

The area surrounding the Hi-Mill Manufacturing facility is rural and, thus, sparsely populated. The nearest dwellings are located approximately 2000 feet east-southeast of the site along Waterbury Road. The population of Highland Township is roughly 17,000 to 19,000 people. The township has little commercial development and few municipal services. Many of the area inhabitants obtain fresh drinking water from domestic water wells and dispose of sanitary sewage through septic systems generally located on their residential property. Hi-Mill Manufacturing disposes of sanitary sewage by way of a septic drain field located behind the site building.

The topography of the area surrounding Hi-Mill Manufacturing is reflective of the glaciation which was active over 16,000 years ago. The area landscape is dotted with numerous small lakes and wetland areas which were created during the last ice age as huge blocks of ice were left behind at discrete locations as the main ice sheets retreated northward. These blocks of ice melted in place forming the small basins which now act to retain precipitation and runoff forming the present-day surface-water features. The topography of the Hi-Mill Manufacturing property itself is relatively flat lying with maximum relief of approximately 6 feet across the site. The land surface across the back of the property generally slopes toward adjacent Target Pond (Figure 1.2).

Soils in the region encompassing the site are comprised of clays, silts, sands, and gravels deposited by glacial ice sheets. These sediments may be as thick as 300 feet in some areas. The soils and geology of the Hi-Mill Manufacturing facility and adjacent study area will be discussed in greater detail in a later section of this report.

1.2.2 Site History

Hi-Mill Manufacturing has engaged in the fabrication of copper-, aluminum-, and brass-tubing parts and fittings since it was first established in 1946. Processing operations have included or currently include nitric and sulfuric acid cleaning and brightening, chromic acid washing, and degreasing using chlorinated solvents. Soldering activities do not make use of tin-lead solder but employ silver solder or aluminum-bar brazing instead. However, an MDNR-activity report dated April 20, 1972, indicates that Hi-Mill Manufacturing personnel informed the MDNR that lead had been used in the Hi-Mill Manufacturing process for a single project lasting about one month.

Wastewater from plant operations was historically discharged to two lagoons located behind the building to the southeast; the former locations are shown in Figure 1.2. Process wastewater consisting chiefly of water and diluted acid-brightening solutions and were discharged to the largest of the two site lagoons (the bottom of which was keyed in the top of the brown clay and approximately 90 feet x 90 feet) prior to 1960 (exact date unknown) until sometime in 1981. The base of this lagoon was reportedly excavated approximately 6 feet into an underlying clay unit. A second, smaller lagoon was constructed in the fall of 1976 south of the existing wastewater lagoon (Figure 1.2). This second lagoon was constructed to accept overflow from the larger, original lagoon. Although the lagoons were designed to serve as evaporation basins only, wastewater from these two lagoons was unintentionally discharged into Target Pond due to overflow from the impoundment area, particularly during periods of high rainfall. Between

1981 and 1983, Hi-Mill Manufacturing attempted to dissipate the volume of wastewater effluent more effectively by discharging water contained within the lagoons through spray nozzles located both atop the roof of the production facility and along portions of an 8-foot high fence which surrounds the rear of the property.

In September of 1983, Hi-Mill Manufacturing submitted a request to the MDNR to remove the sludge from the larger of the two lagoons along with adjacent soils and to backfill the area with clean fill. Following approval by the MDNR, the sludge and related soils were removed between November and December 1983 by the General Oil Company of Livonia, Michigan. In addition to the removal of the sludge, soils located along the sides of the lagoon were excavated along with approximately one foot of clay from the bottom to ensure that all contaminated material had been removed. All of the excavated soils and sludge were transported to an appropriate disposal facility. All operations during excavation were monitored by representatives of the MDNR, and the excavated lagoon area was inspected by the MDNR prior to final closure. The smaller lagoon completed in 1976 was not evident during reclamation of the large lagoon and, as such, was not excavated. While the fate of the smaller impoundment is not currently known, it is possible that portions of the lagoon were regraded across the property by either natural and/or proactive means.

Degreasing of fabricated tubular parts has been a part of Hi-Mill Manufacturing's production process since prior to 1970 (exact date unknown). A trichloroethylene-based solvent was received and stored in an aboveground tank located approximately 50 feet east of the present production building. Solvent was transferred to the degreasing equipment located in the northeast section of the production facility. Between 1978 and 1980 (exact date unknown), activities related to the construction of an addition on the northeast side of the building resulted in the damage of the solvent delivery line between a former aboveground storage tank and degreaser (as shown in Figure 1.2). As a result of the damage, a maximum of 250 gallons of

solvent leaked from the damaged underground product line. The product loss was discovered the following work day, and the damaged underground product line was replaced with an aboveground product line. The location of various existing and former storage tanks and degreasing units is discussed in greater detail in Section 4.0 (see Figure 4.1 also for more location details).

The Hi-Mill Manufacturing facility previously obtained supplies of fresh water from two production wells formerly located near the northeast and southwest corners of the building, respectively (Figure 1.2). The well located northeast of the building was installed shortly after the commencement of activities at the facility in 1946 (exact date unknown) and was approximately 89 feet deep. The other well, located southwest of the facility, was installed to a depth of 50 feet below ground surface (bgs) in January 1969. The water formerly supplied by these two wells was used for drinking, sanitary, and processing purposes. Between March and November 1988, the Oakland County Health Department and the Michigan State Department of Health sampled and analyzed both of the former production wells a total of seven times. Although the chemistry of the water samples collected from both wells differed somewhat over this period, varying concentrations of benzene and trichloroethylene (TCE) were found in the northeast production well, while TCE and 1,2 dichloroethylene (DCE) were detected several times in the well located southwest of the factory. As a result of these findings, the Michigan Department of Health (MDH) notified Hi-Mill Manufacturing that the quality of the water provided by the two wells was not suitable for continued use by its employees. Consequently, both wells were decommissioned by Jim Layman of Layman Drilling in December 1989. A new production well was installed away from the site building to serve as a replacement supply of potable water for the facility. The new well (the location of which is shown in Figure 1.2), installed in January 1989 by Layman Drilling, is 6 inches in diameter and was screened at an interval of from 99 feet to 107 feet below ground surface.

1.2.3 Previous Investigations

Contained within this section is a synopsis of the investigations conducted thus far at the Hi-Mill Manufacturing facility. A total of nine investigations related to the identification of contamination and/or the assessment/control of chemical species within the ground water and soil at Hi-Mill Manufacturing, has been delineated. Presented below, in chronological order, are descriptions of each of these nine distinct investigations.

1.2.3.1 MDNR Investigations - 1972 to 1978

The MDNR conducted an ongoing investigation into various aspects of operations at the Hi-Mill Manufacturing facility during this period. In April 1972, representatives of the MDNR investigated a complaint by a Hi-Mill Manufacturing employee that the plant water wells might be contaminated. Samples of the ground water from the two site production wells and the adjacent Target Pond were collected by the MDNR and submitted for analysis. The MDNR reported that "slightly elevated" concentrations of copper were measured in one well, and elevated levels of copper and nitrates were detected in the waters of Target Pond. Additional surface-water samples were collected from Target Pond by MDNR officials in October 1975, and again in May, November, and December of 1976. In both instances, analyses of these samples indicated that the concentrations of copper, aluminum, zinc, chromium, and nitrates were all elevated (Techna Corp., 1990).

1.2.3.2 MDNR Study of the Target Pond/Wetland Area - 1976

In April 1976, personnel from the MDNR Water Quality Division initiated a study of the Target Pond/wetland area adjacent to Hi-Mill Manufacturing. MDNR investigated both the water and soils from Target Pond, as well as the ground-water quality from one of the Hi-Mill

Manufacturing water supply wells. Background sediment samples were collected from Pontiac Lake, located approximately 7.5 miles northeast of the Hi-Mill Manufacturing site.

Analyses of the ground-water samples collected from the site production well failed to indicate elevated levels of metals as had been suggested during past investigations. The concentrations of nitrate, nitrite, ammonia, chromium, copper, zinc, and aluminum in water samples collected from the lagoon and marsh waters were reported as elevated, however, by the MDNR (Techna Corp., 1990). Elevated concentrations of total chromium, copper, and aluminum were also reported in sediment samples collected from both the lagoon and marsh sediments.

1.2.3.3 MDNR Hydrogeological Investigation - 1981/1982

A hydrogeological investigation of the Hi-Mill Manufacturing facility was conducted by representatives of the MDNR Water Quality Division in August 1982. The investigation consisted of the installation of six, 1.25-inch PVC monitoring wells into the upper clay layer located approximately 4 to 7 feet below grade at the Hi-Mill Manufacturing site. The piezometers were placed along the eastern and southern margins of the property, adjacent to the Highland State Recreation Area. The MDNR utilized these wells for the collection of ground-water-quality samples and the measurement of ground-water elevations.

The MDNR concluded that the flow of water in the upper perched unit was generally toward the Target Pond/wetland area. Ground-water samples collected from wells located near the site lagoon were found to contain elevated levels of copper, total chromium, zinc, and aluminum (Techna Corp., 1990).

1.2.3.4 Lagoon Closure - 1983

Hi-Mill Manufacturing submitted correspondence in September 1983 to the MDNR that requested approval to initiate the excavation and backfilling of the evaporation lagoons located behind the Hi-Mill Manufacturing facility. Following approval by the MDNR, excavation and backfilling operations were completed between November and December 1983 by the General Oil Company of Livonia, Michigan. Sludge was removed from the larger of the two site lagoons along with soil from the sides and bottom of the impoundment. Approximately one foot of clay was excavated from the bottom of the lagoon to ensure that all contaminated materials had been removed. All excavation activities were monitored by representatives of the MDNR, who inspected the lagoon area prior to the commencement of backfilling operations. A reported quantity of 142 cubic yards of soil; 34,400 gallons of sludge; and 63,300 gallons of water were removed from the lagoon and transported to an appropriate disposal facility (Techna Corp., 1990). The smaller of the two lagoons was not evident during these operations and, as such, was not excavated. While the status of the small overflow lagoon is not specifically known, it is speculated that the lagoon may have been regraded flush with the existing topography by either natural and/or proactive means.

1.2.3.5 MDNR Ecological Survey - 1984

An ecological survey was conducted in April 1984 by representatives of the MDNR Surface Water Quality Division. The ecological survey consisted of a limited investigation of the biological, surface-water, and sediment characteristics of the Target Pond/wetland area and nearby Waterbury Lake. An inspection of the plant roof and parking areas was also conducted to assess potential runoff patterns. The surface-water and bottom-sediment samples collected were analyzed for aluminum, arsenic, iron, mercury, zinc, cadmium, total chromium, copper,

nickel, and lead. Benthic and phytoplankton organisms were also collected and visually identified on-site and by laboratory microscopy.

The chemical analyses of surface-water samples collected from Target Pond indicated that the concentrations of zinc, chromium, and copper were higher than those measured in the background samples collected from Waterbury Lake. The levels of chromium and zinc did not exceed freshwater aquatic life criteria, but the concentration of copper exceeded the chronic criteria for warm-water fish (Techna Corp., 1990).

Analyses of sediment samples collected from Target Pond were reported to contain concentrations of aluminum, zinc, total chromium, and copper in excess of those detected in the background sediment samples obtained from Waterbury Lake. No significant difference in concentration was found between the Target Pond and Waterbury Lake samples analyzed for arsenic, mercury, cadmium, nickel, and lead (Techna Corp., 1990).

The MDNR reported finding few benthic or other bottom-dwelling organisms during their biological survey of Target Pond. Data were insufficient to determine if the absence of these organisms was due to water-level fluctuations within the wetland or impact by the Hi-Mill Manufacturing facility. The MDNR reported finding zooplankton at both of their sampling stations. *Daphnia* (a copper-sensitive organism) were found in quantity as were a variety of filamentous green algae, flagellates, other algae, and macrophytes (Techna Corp., 1990).

1.2.3.6 The MDNR ecological survey report concluded that:

1. Waterbury Lake was not interacting via a surface water connection with the Target Pond/wetland area and was not impacted by activities at the Hi-Mill Manufacturing facility;

2. Surface-water samples from Target Pond generally contained higher concentrations of heavy metals than did background samples collected from Waterbury Lake;

3. Concentrations of copper in Target Pond waters exceeded the chronic criteria for warm water species of fresh-water aquatic life;

4. Concentrations of heavy metals contained within the sediments of Target Pond exceeded the background concentrations measured in sediments collected from Waterbury Lake; and

5. Algae and zooplankton were found to be abundant in the waters of Target Pond; however, bottom-dwelling organisms were limited to pollutant-tolerant forms. Insufficient data exist as to whether the lack of diversity among benthic organisms was due to natural fluctuations in water and nutrient supply or impact from Hi-Mill Manufacturing.

In its February 1985, Report, the MDNR recommended:

1) that the sources of heavy metals entering Target Pond from Hi-Mill should be "minimized."

2) that the existing lagoons should be filled.

3) that a determination should be made as to whether ground water should be purged.

1.2.3.7 Oakland County Health Department Well Survey - 1988

The Oakland County Health Department (OCHD) and the Michigan State Department of Health (MSDH) collected a total of seven water samples from the two site production wells between March 1988 and November 1988. Samples were analyzed for general parameters, metals, and volatile organic compounds (VOC). The OCHD and MSDH reportedly did not detect concentrations of metals in excess of drinking water standards; however, trihalomethanes and benzene were both detected in a composite sample of the two wells collected in March 1988.

While no VOCs were detected in the composite sample collected in June 1988, TCE was measured at levels near the detection limit of 1 microgram/liter (μg/l) in the well located at the southwest corner of the building during the July 1988 sampling event. Benzene was detected during the same sampling event in the well formerly located at the northeast margin of the Hi-Mill Manufacturing property.

Analysis of a composite sample collected in September 1988, did not indicate the presence of VOCs; however, another set of samples collected from each well in the following month of October was found to contain TCE in both wells and cis-1,2-dichloroethylene in the southwest well.

Subsequent water samples collected during the months of October and November indicated the presence of TCE in both the northeast and southwest supply wells and that DCE (a degradation product of TCE) was also present in the southwest site well.

The MSDH notified Hi-Mill Manufacturing on November 7, 1988, that the results of the ground-water sampling and analysis of both wells indicated that water from these wells was not suitable for human consumption. Hi-Mill Manufacturing was instructed by MSDH to warn

employees of the quality of the water, to provide a supply of bottled water for drinking purposes, to abandon both of the existing wells, and to install a new production well further away from the facility to serve as a replacement source of potable water.

1.2.3.8 Techna Corporation Hydrogeological Study - 1988

A limited hydrogeological assessment of the Hi-Mill Manufacturing site was conducted by Techna Corporation (Techna) in November 1988 in response to the disclosure of the presence of chlorinated solvents in the Hi-Mill Manufacturing supply wells. The stated objectives of the Techna hydrogeological assessment were as follows:

1. To determine the subsurface stratigraphy to a depth of 100 feet;

2. To collect and analyze ground-water samples in order to delineate the distribution of chlorinated solvents below the water table;

3. To determine the ground-water flow direction in the deep aquifer system(s);

4. To evaluate the hydraulic interconnection between hydrostratigraphic units at depth; and

5. To assess the potential for contaminants in the surficial saturated zones near the supply wells.

Three boreholes were completed by Techna to a depth of approximately 100 feet below ground surface. These boreholes were located at the northeast corner of the property, at the west corner of the property, and south of the production building in the vicinity of the former lagoon. Soils were logged during drilling, and temporary, 2-inch diameter PVC monitoring wells were installed at each location.

Techna reported that the general subsurface stratigraphy consisted of 1.5 feet to 3 feet of fill underlain by a thickness of from 26 feet to 45 feet of stiff, moist, silty, blue clay. Techna indicated that this clay layer was contiguous at the northeast and south boring localities. However, an approximately 5-foot layer of fine, silty sand was found at the west boring location which was contained within the clay stratum at a depth of from 12 feet to 17 feet below ground surface. In addition, a sandy silt layer about 3-feet thick was also found between the depths of 24 feet to 27 feet below ground surface in the west boring (Techna Corp., 1990).

The upper clay unit found in each of the three boreholes was generally underlain by a sequence(s) of wet sand. The sand sequence was reportedly interbedded with stiff, blue clay at all three locations. Wet sand and gravel were logged in both the northeast and south borings below a depth of approximately 90 feet below ground surface (Techna Corp., 1990).

Two temporary ground-water monitoring wells were set in the northeast boring location and were screened at depths of 55 feet and 105 feet below ground surface, respectively. One well was set at the west location at a depth of 56 feet below ground surface, and two wells were installed south of the production building at respective depths of 50 feet and 93 feet below ground surface (Techna Corp., 1990). All wells were fitted with 5-foot screens. The depths described above represent the locations of the bottom of each well screen. Monitoring wells were reportedly developed and allowed to return to static conditions following completion.

Techna reported the following conclusions:

1. The direction of ground-water flow was generally to the southeast;

2. The analyses of ground-water samples collected from the temporary monitoring wells did not indicate the presence of any VOCs; and

3. The samples of the surficial soils were collected near each of the supply wells and analyzed for the presence of VOCs. No chlorinated solvents were detected in either soil sample (Techna Corp., 1990).

1.2.3.9 Michigan Department of Public Health Public Well Sampling - 1989

The Michigan Department of Public Health (MDPH) sampled seven residential wells located along the west side of Waterbury Road in early November 1989. These wells were the closest known to the Hi-Mill Manufacturing site. Ground-water samples collected from the wells were analyzed for metals and some VOCs. No VOCs were detected, and concentrations of metals were well within established limits (Techna Corp., 1990). The MDPH concluded that these seven wells showed no evidence of contamination.

1.2.3.10 Techna Corporation Remedial Investigation - 1990

Techna prepared and submitted a Remedial Investigation/Feasibility Study Work Plan, Site Safety Plan, and Quality Assurance Project Plan (QAPjP) to the U.S. EPA as Revision 2 on October 26, 1989. This plan was subsequently amended following review by the U.S. EPA and approved in January 1990.

The initial Remedial Investigation was conducted by Techna and its subcontractors and was funded by Hi-Mill Manufacturing Company in accordance with the Administrative Order of Consent, U.S. EPA Docket Number V-W-88-C-127. Oversight of the Remedial Investigation field activities was provided by the U.S. EPA and its designated contractors.

The Techna Remedial Investigation generally consisted of the extensive sampling and analysis of site soils as well as the installation of twenty-nine monitoring wells and six staff

gauges (surface water). Of the twenty-nine monitoring wells, twenty-one were classified as "shallow", five were classified as "intermediate", and three as "deep". Staff gauges were installed in Target Pond and Waterbury Lake to monitor fluctuations in surface-water elevation. Logs of the stratigraphy encountered during drilling operations were recorded by Techna and utilized to interpret the site soils and geology. Monitoring wells were utilized to determine site ground- water quality and flow characteristics. Piezometers were used to supplement hydraulic data gathered from the monitoring wells, and staff gauges were necessary to develop an understanding of the interaction between adjacent surface waterbodies and the ground-water flow system.

Techna established sampling grids around the facility in order to determine suitable locations for the collection of soil samples. Soil samples were analyzed for short list metals (SLM) including aluminum, chromium, copper, nickel, silver, and zinc. Techna developed isoconcentration maps to reflect the distribution of metals in both site soils and within the Target Pond/wetland area. Soils were also collected for analysis of the potential presence of VOCs in the vicinity of the former facility supply wells. Ground-water samples were collected from the shallow, intermediate, and deep monitoring wells for analyses of VOCs, metals, and standard water-quality parameters (e.g., pH).

A Baseline Risk Assessment was performed by Techna for the site and provided in the Remedial Investigation report submitted to the U.S. EPA and MDNR.

As a result of its investigation, Techna developed several conclusions for the Remedial Investigation which may be summarized as follows:

1. Techna classified the subsurface soils and glacial drift into three flow systems: shallow, intermediate, and deep aquifers; separated by clay of varying thickness;

2. Techna concluded that the shallow aquifer was essentially representative of perched water and generally flowed away from the Hi-Mill Manufacturing plant toward Target Pond and Waterbury Lake;

3. The flow direction of the intermediate aquifer (as defined by Techna) was evaluated to be in a westerly direction away from the Target Pond/wetland area, while the ground-water flow direction within the deep aquifer was believed to be toward the southeast;

4. Techna detected metal concentrations in site soils and within the Target Pond/wetland area in excess of background levels at several locations;

5. VOCs such as TCE, DCE, methylene chloride (ME), acetone, and toluene were detected in soils at several locations in the vicinity of the former water supply wells (which also happen to be near either existing or former aboveground storage tanks);

6. Techna postulated that overflows from the former lagoon area may have resulted in the transport of metals into the Target Pond/wetland area, and infiltration through the lagoons may have carried metals into the shallow ground-water flow system;

7. The shallow ground-water system is suspected to have transported dissolved metals and VOCs (Techna Corp., 1990); and

8. Techna concluded that "due to the obvious dearth of both the diversity and the numbers of individuals per species represented, the risks associated with the

heavy metal contaminants are probably minimal" (Techna Corp., 1990). No conclusions were presented with regard to the existence of VOCs around the site building.

A draft version of the Techna Remedial Investigation report was submitted to the U.S. EPA in June 1990 for review. Agency officials rejected the Techna document due to reported concerns over the scope of the investigation and its conclusions (and/or lack thereof).

1.2.3.11 Geraghty & Miller, Inc. Remedial Investigation - 1990 to 1992

Geraghty & Miller, Inc. (Geraghty & Miller) was retained to perform a review of the Techna Remedial Investigation report and data and to submit its findings to the U.S. EPA and MDNR officials in the form of a Technical Memorandum. The primary objectives of the Technical Memorandum were:

1. To assess the conclusions and technical adequacy of the Techna investigation and to identify potential data gaps; and

2. To recommend any additional data collection which may be necessary to complete the Remedial Investigation and Risk Assessment.

Following finalization of the Technical Memorandum, a Phase II Hydrogeologic Investigation Work Plan, Sampling Plan, and QAPjP package was prepared to address the additional work items needed to complete the Remedial Investigation. This document, representing the fourth revision, was submitted to the U.S. EPA on September 24, 1991, and following final amendments by agency officials, was approved by the U.S. EPA in October 1991. Some modifications to the original scope of work were made during the course of the

investigation as conditions warranted. Approval was sought by U.S. EPA and MDNR officials whenever possible.

The Geraghty & Miller Phase II investigation consisted of the following primary elements:

1. The installation of fifteen shallow piezometers in the upper perched aquifer;

2. The advance of four vertical profiles through the sand zone referred to by Techna as the "intermediate aquifer";

3. The installation of one additional monitoring well at a location and depth determined by vertical-profile sampling and analysis;

4. The drilling and sampling of 4-foot to 15-foot deep soil borings; two near each of the tank areas at the northeast and southwest corners of the building. Soil samples were analyzed for VOC content;

5. The completion of sixteen hand-auger borings (HABs) around the Hi-Mill Manufacturing plant. Another thirty-three hand-auger borings were also completed in the M-59 median. Ground-water samples were extracted from all hand-auger borings and analyzed with a portable gas chromatograph (GC) for VOC content;

6. The additional collection of ground-water elevations, ground-water chemistry data, and soil chemistry data for further delineation of the distribution of chemical species in and around the site;

7. A proposed Risk Assessment (RA) (concurrent with U.S. EPA) to reassess potential risks to the environment and human health and safety, which was later deleted by the U.S. EPA;

8. An Ecological Assessment and Inventory of the Target Pond/wetland area to determine the potential impact of metals on local ecosystems; and

9. A complete revision of the Remedial Investigation report performed by Techna including all new data collected during the Phase II investigation, and a corresponding reassessment of all conclusions for the Remedial Investigation, Risk Assessment, and Ecological Assessment.

The field procedures, findings, and conclusions of the Phase II investigation will be discussed in detail in the latter portions of this document. Presented in the following section, however, is a brief summary of this report's organization with respect to the presentation of the data obtained from the above-described investigations.

1.2.4 Report Organization

The RI report has been subdivided into seven primary sections in accordance with the recommendations set forth by the U.S. EPA guidance document: "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA". Six of these sections have been provided within this document as prepared by Geraghty & Miller, Inc., while the seventh (Baseline Risk Assessment) was prepared by the U.S. EPA. Modifications have been made to the structure of each section, as needed, to facilitate the presentation of the data gathered from the investigations conducted at the Hi-Mill Manufacturing site. Presented below is a brief description of each of the major sections of the RI report:

1. **Introduction** - Presents basic information on the history of the site including general location and setting, current and prior land use, and previous investigations;

2. **Study Area Investigation** - Describes in detail, the scope and field procedures used for the various investigations conducted at the site;

3. **Physical Characteristics of the Study Area** - Presents the results of the field investigations including analyses of the site geology, hydrogeology, surface water, soils, and ecology;

4. **Nature and Extent of Contamination** - Defines potential and/or positively identified source areas and the distribution of various chemical species in the soil, ground water, and surface water;

5. **Contaminant Fate and Transport** - Identifies all potential migration pathways existing within the soil, surface water, and ground water. The known limits of compound migration are discussed as is the persistence of the chemical species detected during the investigation;

6. **Summary and Conclusions** - Provides a summary of all relevant findings of the investigations conducted at the Hi-Mill Manufacturing facility, in conjunction with conclusions as to the need and type of recommended remedial objectives. An evaluation of the data limitations and the possible need for future work are also presented.

7. **Baseline Risk Assessment** - Prepared independently by the U.S. EPA and not presented within this document.

2.0 STUDY AREA INVESTIGATION

Presented in the following sections is a description of the nature and scope of the field investigations conducted as part of the Remedial Investigation. A brief discussion of the Technical Memorandum issued for the Hi-Mill Manufacturing site is also provided.

2.1 SITE CHARACTERIZATION AND FIELD PROCEDURES

Two separate field investigations were conducted at the Hi-Mill Manufacturing facility as part of the Remedial Investigation. The first (Phase I) was performed by Techna between November 6, 1989, and May 11, 1990, during which time technical oversight was provided by the U.S. EPA and its contractors, Donohue, and Donohue's subcontractors, Soil Testing Services, Inc. The MDNR also provided some technical advice during this phase of the investigation.

The second major field investigation (Phase II) was conducted by Geraghty & Miller between September 1991 and February 1992. The U.S. EPA, MDNR, and Donahue provided technical oversight during this portion of the investigation.

Summarized in the following sections are discussions of the scope of work performed for each of the major components of the Remedial Investigation.

2.1.1 Surface Features

An aerial survey of the Hi-Mill Manufacturing site and surrounding area was performed by Abrams Aerial Survey Corporation in May 1989. The purpose of the survey was to establish the topography of the study area as well as the location of nearby surface waterbodies and man-made physical structures.

A detailed site survey of all well and soil-sampling locations installed during the Techna investigation was performed by Ayres, Lewis, Norris & May, Inc. (Ayres). The Ayres survey also included site utilities and pertinent physical structures such as fence lines, power poles, and the facility septic field.

Additional site surveys were conducted by Ayres in January and March 1992 to incorporate the additional piezometers, wells, soil borings, and hand-auger borings installed by Geraghty & Miller during the Phase II portion of the site investigation. Pertinent topographic, surface and physical features have been incorporated into one base map and provided as Figure 1.2. A base map depicting ground-water, surface-water, and soil-observation-point data has also been provided (Figure 2.1).

Various aerial photographs dating from 1949 to 1988 have been examined to determine the historical use of the land adjacent to the Hi-Mill Manufacturing facility. These photographs have also proved useful in documenting the changes in processing operations at the Hi-Mill Manufacturing plant since its initial construction. Presented in Figures 2.2 and 2.3 are aerial photographs of the site area from 1978 and 1988, respectively. The 1978 aerial photograph indicates the presence of several structures which formerly existed around the Hi-Mill Manufacturing site which are no longer present. The two wastewater lagoons mentioned previously can be seen on the 1978 photo as can a gas station and two residences on the north

side of M-59. These latter structures were removed when M-59 was widened to four lanes during the early 1980s. A portion of a small private airport formerly located west of Hi-Mill Manufacturing can also be observed in the 1978 photograph. The aerial photograph taken in 1988 shows the Hi-Mill Manufacturing site and surrounding area much as it appears today.

As-built construction drawings of the M-59 median and east- and west-bound traffic lanes were obtained from the Michigan Department of Transportation (MDOT). These drawings were useful in assessing water-level and chemistry data obtained from borings and piezometers completed in the M-59 median and how previous site activities may have influenced the distribution of compounds beneath the roadway.

2.1.2 Investigations of Potential Sources

Portions of the Phase I and II field investigations that pertained to the investigation of potential sources focused on aspects of site-manufacturing processes which could contribute various chemical species to the soil, surface-water, or ground-water flow systems. Constituents of interest are generally divided into organic compounds and metals.

Potential sources of organic compounds include an underground heating oil storage tank; USTs associated with a former service station located in the current M-59 median area; an active TCE tank located at the southwest edge of the building; a TCE tank formerly located at the northeast end of the building; and the production facility itself which houses two degreasing units within which TCE was used for cleaning newly machined parts, and affiliated piping and filling operations. A below ground product delivery line located between a former TCE storage tank on the northeast corner of the building and a degreasing unit formerly located at the east end of the factory, was damaged in the late 1970s and was known to have leaked. This incident may also represent a possible source of VOCs (Figures 1.2 and 4.1). Potential sources of metals

discovered across the site and within Target Pond include the evaporation lagoons formerly located behind the facility and the production area itself which was the source of metal-containing process water which had been previously discharged to the evaporation lagoons.

In order to evaluate the potential sources described above, the field investigation was subdivided to delineate the impact of each individual source on site soils, ground water, and surface-water flow systems.

The potential sources of organic compounds in the shallow site soils and ground water included the existing TCE tank at the southwestern end of the building, the former TCE tank area northeast of the plant, and the production facility itself. A series of forty-nine shallow hand-auger borings were installed during Phase II around the tank areas and production facility, in the median of M-59, and along the north and south edges of the M-59 highway. The hand-auger borings were generally used for the collection of ground-water samples which were analyzed for the presence of VOCs by a portable GC. Some of the water samples collected were sent to an analytical laboratory for analysis of VOCs to confirm the data obtained from the portable GC. In addition, Techna collected a total of fifty-four soil samples during Phase I around both TCE tank locations and submitted these samples to a laboratory for analysis of VOC concentration.

In order to address the possibility of migration of either organic and/or inorganic compounds into deeper flow systems, a total of four vertical profiles was advanced below the uppermost clay unit. During this profiling, ground-water samples were collected from discrete intervals and analyzed by a portable GC for the presence of VOCs. Monitoring wells were to be installed if either VOCs were detected or if unusual values of specific conductance or pH were measured. One such monitoring well was installed near the TCE tank formerly located near the northeast corner of the production facility.

Metals detected in the surrounding shallow site soils, surface water, and ground-water flow systems were believed introduced by overflow from the site evaporation lagoons that accepted process water from the Hi-Mill Manufacturing production facility. The distribution of metals around the Hi-Mill Manufacturing site was evaluated by means of an extensive soil-sampling program conducted by Techna behind the Hi-Mill Manufacturing factory. Techna also collected sediment and water samples from Target Pond during their investigation. Sampling of the adjacent Target Pond/wetland area in conjunction with an assessment/inventory of the Target Pond ecosystem was also conducted by Geraghty & Miller.

Monitoring wells were installed to various depths by both Geraghty & Miller and Techna, in order to facilitate the delineation of organic and inorganic compound migration within the ground-water flow systems beneath the Hi-Mill Manufacturing site.

Details of the field investigations and the potential impacts of all source areas will be discussed in subsequent sections of this report.

2.1.3 Climatological Investigation

Area climatological data was obtained from the National Oceanic and Atmospheric Administration (NOAA) for the period extending from January 1987 through December 1991. All climatological data was recorded by an observer at the Pontiac State Hospital in Pontiac, Michigan, and represents the nearest NOAA climatological monitoring station relative to the Hi-Mill Manufacturing site. These data include maximum, minimum, and mean monthly temperature data; total monthly snowfall and maximum depth (in winter); and total monthly precipitation and the largest precipitation event for each month. Data are for the years 1987 through 1990. Daily precipitation and temperature data were also obtained for the entire year of 1991.

Climatological data are useful in interpretations of ground-water fluctuations and in assessing the potential impact of varying seasonal flow system discharge/recharge on the migration of various chemical species. A detailed discussion of the findings of the climatological investigation is presented in a subsequent section describing the physical characteristics of the Hi-Mill Manufacturing study area.

2.1.4 Surface-Water and Sedimentological Investigations

Investigations of the surface water and sediment of the adjacent lakes and wetlands were necessary in order to determine the impact of previous site activities on the area surrounding the facility. Of particular concern were the metals contained within the process water formerly discharged to the site evaporation lagoons. Data obtained from investigations into the surface water and sediments of Target Pond and Waterbury Lake were useful in assessing what affect, if any, the introduction of metals into the environment had on the local ecology. The results of the Ecological Assessment and Inventory will be discussed in a later section.

Surface-water and sedimentological investigations of the Target Pond/wetland area were conducted by Techna in 1990 and again by Geraghty & Miller in 1991. Presented below are descriptions of both investigations.

2.1.4.1 Techna Investigation

Techna samples were collected at the locations indicated in Figure 2.1. Of the stations where samples were collected, ten were located in Target Pond/wetland area, two within Waterbury Lake, and one was positioned north of M-59. Sediment and water samples were collected from all thirteen of the aforementioned locations. Background samples were also collected from the wetland area located approximately 1000 feet southwest of Waterbury Lake.

Samples collected by Techna were analyzed for aluminum, copper, chromium, nickel, silver, and zinc. Surface-water and sediment samples obtained at three of the stations in Target Pond/wetland area were analyzed for Target Analyte List (TAL) inorganic parameters.

The specific number and types of analyses performed on the Techna surface-water samples included twelve samples for SLM, including one field blank and one field duplicate; five samples for TAL inorganics, including one field duplicate and one field blank; seventeen samples for hexavalent chromium, with two field blanks and two duplicates; nine samples for ammonia and nitrate/nitrite, which included one field blank and one field duplicate. The resulting analyses of the Techna sediment samples produced twenty-two samples for SLM, including three field duplicates; five samples for TAL inorganics, with one field blank and one duplicate; and twenty-five samples for hexavalent chromium, with three field duplicates. Summaries of the analyses performed for the Techna investigation are provided for the sediment and surface-water samples collected in Tables 2.1 and 2.2 respectively.

According to the original Remedial Investigation report submitted by Techna (1990), all sampling and testing procedures conformed to either approved Remedial Investigation protocols or were modified and subsequently approved by U.S. EPA. Surface-water and sediment samples were collected from separate holes cut through the approximately 3 to 8 inches of ice that covered the lakes and wetlands sampled. Loose ice was reportedly removed from around each hole prior to the collection of samples (Techna Corp., 1990). Sediment samples were collected using split-spoon samplers pushed or driven into the upper 1 to 1.5 feet of bottom sediment. The sediment samples were then placed into a plastic collection bowl and homogenized with stainless steel sample scoops and subsequently transferred to 8-ounce plastic containers within which they were shipped to the laboratory for analysis. Split-spoon samplers were decontaminated between each successive collection by means of a Liquinox and tap water wash, followed by a tap-water rinse, a 10 percent nitric acid rinse, a distilled-water rinse, and then air

dried (Techna Corp., 1990). The cutting edge of each split-spoon sampler was then wrapped in plastic and overwrapped in aluminum foil before being transported to the next sampling location. Sample scoops and plastic bowls were also decontaminated and wrapped in a similar manner.

Surface-water samples were collected at a depth of approximately 6 inches below the water surface. Clean collection bottles were rinsed with surface water before actual sample extraction. Dedicated collection bottles were used to transport the surface-water sample to a central location in a site trailer for filtering prior to shipping to the laboratory for metals analysis (Techna Corp., 1990). Filtering of the samples was performed by decanting the water directly into a Geotech barrel filtration unit and forcing the sample under pressure through a 0.45-micron disposable filter and into an appropriate laboratory sample bottle (Techna Corp., 1990). The 0.45-micron filter was disposed of, and the barrel filtration unit decontaminated between each sample. The Geotech unit was decontaminated with a Liquinox and tap-water wash, a tap-water rinse, a 10 percent nitric acid rinse, followed by a distilled-water rinse, and allowed to air dry (Techna Corp., 1990). A new 0.45-micron filter was subsequently inserted following each decontamination procedure.

Quality Assurance/Quality Control (QA/QC) sampling consisted of field duplicates, field blanks, and trip blanks. Trip blanks were prepared by ENCOTEC Laboratories using organic-free deionized water. One trip blank was supplied with each sample shuttle (cooler). Approximately one duplicate sample was collected for every ten surface-water or sediment samples collected (Techna Corp., 1990). Duplicates were analyzed for the same parameters as "original" samples. Field blanks were prepared for VOC, organic, and metals analyses. Field blanks for metals analyses were prepared by pouring distilled water into a dedicated, laboratory-prepared sample-collection bottle which was rinsed prior to sampling with a 10 percent nitric acid solution and distilled water then pumped through a decontaminated Geotech barrel filter and

0.45-micron filter into another laboratory-prepared sample bottle. Field blanks for VOCs and organics were prepared by pouring deionized water into a sample-collection bottle and then transferring the water into a laboratory-prepared sample bottle (Techna Corp., 1990).

All sample bottles were reported to have been labeled properly and placed on ice while on-site (Techna Corp., 1990). At the end of each day of sampling, sample coolers were transported by Techna personnel to ENCOTEC Laboratories in Ann Arbor, Michigan, for analysis. Samples collected for analysis of inorganic compounds were subsequently shipped by ENCOTEC to Wilson Laboratories in Salina, Kansas (Techna Corp., 1990). Techna (1990) reports that all chain-of-custody procedures were strictly followed.

2.1.4.2 Geraghty & Miller Investigation

An Ecological Assessment and Inventory was conducted on Target Pond and Waterbury Lake by Geraghty & Miller during the Phase II investigation. The investigation examined the flora and fauna of both waterbodies as well as the sediment chemistry. Please refer to the Ecological Assessment and Inventory Report in Appendix R for details.

2.1.5 Soils/Geological Investigations

Soil samples were collected to identify the vertical and horizontal extent of organic and inorganic constituents within the subsurface, determine the location of potential ground-water contamination sources and to characterize the geology at the Hi-Mill Manufacturing site. Initial soil sampling activities were conducted by Techna in 1988 and were broadened during the Techna Remedial Investigation of 1990. Geraghty & Miller was retained in 1990 to perform an additional investigation to improve the understanding of the geology of the Hi-Mill Manufacturing site and to better define the distribution of organic and inorganic constituents

within the shallow soils both on the Hi-Mill Manufacturing site and north of M-59. Presented in the following sections are discussions of the various stages of work performed to define the physical and chemical characteristics of the Hi-Mill Manufacturing site.

2.1.5.1 Physical Characteristics

2.1.5.1.1 General

Physical parameters used in determining the physical characteristics of the soils and sediments present at the Hi-Mill Manufacturing site include the following:

1. Grain Size;
2. Atterberg Limits;
3. Moisture Content;
4. Vertical Hydraulic Conductivity; and
5. Geologic logging (USCS Classification).

2.1.5.1.2 Techna Drilling Activities

During Techna's initial Hydrogeologic Investigation three soil borings were drilled to a depth of approximately 100 feet below ground surface. Though the exact locations are not available, these soil borings were approximately located at the northeast corner of the Hi-Mill Manufacturing property, at the west corner of the Hi-Mill Manufacturing property, and south of the Hi-Mill Manufacturing production building in the vicinity of the former lagoons. Soils were logged during drilling operations, and temporary, 2-inch diameter PVC monitoring wells were installed in the boreholes. Two additional soil borings were completed at 5.5 feet below ground surface. According to boring logs developed by Techna, the soil borings were drilled

using a combination of hollow-stem auger and mud-rotary drilling methodologies. However, detailed information concerning drilling methodologies is not available. Boring logs developed by Techna during the initial investigation are provided in Appendix A.

The original Remedial Investigation report submitted in 1990 and boring logs generated by McDowell and Associates provide relevant information concerning drilling methodologies used during the Phase I Remedial Investigation. A total of thirty-two soil borings was completed for the purpose of monitoring well installation during the Phase I field investigation at the Hi-Mill Manufacturing site. In addition, during the Phase II Remedial Investigation, Geraghty & Miller completed four vertical profiles and five soil borings. A vertical profile (IW-6) and one soil boring (IW-7) were installed north of M-59 and west of the Hi-Mill Manufacturing facility. Two soil borings (SB-3 and SB-4) and one vertical profile (VP-1) were drilled at the northeast end of the Hi-Mill Manufacturing facility to investigate the area surrounding the location of the former aboveground TCE storage tank. Two additional soil borings (SB-1 and SB-2) and a vertical profile (VP-3) were completed at the southwest end of the Hi-Mill Manufacturing facility to investigate the area surrounding the location of the active aboveground TCE storage tank. Geologic data from the Phase I and Phase II Remedial Investigations were obtained by examination of soil samples collected from the borings described above.

Techna (1990) reported that all soil boring procedures conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modification. Drilling during the Phase I Remedial Investigation was supervised by Techna and conducted by MacDowell and Associates using 4.25-inch inside diameter (I.D.) hollow-stem augers. In the borings completed beneath the brown clay zone, the shallow saturated zone was isolated from the intermediate sand by installing surface casing into the clay which was constructed of 10-inch PVC and ranged in length from 11 to 20 feet. A hole large enough for the casing was drilled using 12-inch I.D. hollow-stem augers, and the casing was installed to the desired depth. After

the proper depth was attained, the surface casing was grouted in place, the inside flushed with water, and the boring then further advanced using 4.25-inch I.D. hollow-stem augers. Soil samples were collected during drilling at 5-foot intervals and when changes in drilling pressure suggested changes in soil lithology. Soil samples were collected using either an 18-inch or 24-inch long split-spoon sampler driven below the auger bit in accordance with ASTM Method D-1586. Blow counts were recorded for every 6 inches that the split-spoon sampler was driven. Shelby tubes and brass-lined split-spoon samplers were used to collect soil samples for grain size analysis, Atterberg limits, moisture content, and the analysis of vertical hydraulic conductivity. At nested monitoring well locations, logging of the soil in the deeper borings commenced when the bottom of an adjacent, shallower boring was reached. Either a Techna representative or a McDowell and Associates representative logged the geology of the soils. Boring logs developed during the Phase I investigation are provided in Appendix B.

2.1.5.1.2.1 *Grid and Off-Grid Soil Sampling*

Techna (1990) reported that shallow soil sampling was conducted using a system of grid and off-grid sampling points. Three sampling grids were constructed on the Hi-Mill Manufacturing property. A 60 foot by 60 foot sampling grid was constructed southeast of the Hi-Mill Manufacturing facility, and 20 foot by 40 foot grids were constructed near each former water supply well on the northeast and southwest sides of the production building, respectively. Additional off-grid sampling points were located in potential areas of surface runoff, former lagoon locations, and the existing raised septic leach field. Soil samples were collected using either a stainless steel hand auger or split-spoon sampler. The split spoons were 2-inch in diameter and either 18 inches or 24 inches long. The split-spoon sampler was attached to an AW rod and driven by a portable drop hammer or by advancing 4.25-inch I.D. hollow-stem augers and collecting samples with a 2-inch diameter, 18-inch or 24-inch long split-spoon sampler. Hollow-stem auger drilling and sampling procedures are described above.

The soil samples were logged by a representative of Techna noting such features as color, grain size, sorting, roundness structure, composition, and obvious presence of chemical impacts such as discoloration and odor. Representative splits of soil samples were collected and retained as visual records. Boring logs generated by Techna during the grid and off-grid soil sampling are provided in Appendix C.

Decontamination procedures for drilling activities conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modification (Techna Corp., 1990). Drilling equipment such as augers, rods, bits, drilling rig and tooling were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated area in the Hi-Mill Manufacturing parking area located northeast of the building.

Modified Level D protection was used by Techna personnel and its subcontractors during all drilling, well installation, and development procedures (Techna Corp., 1990). Techna (1990) reported that all site personnel complied with the approved Health and Safety Plan. A photoionization detector (PID) was used to monitor the quality of the air within the work area for the presence of volatile organic vapors. A combustible gas indicator was also used to safeguard against the presence of flammable gases such as methane. No hazardous air conditions were detected that required the use of personnel respiratory protection equipment during the Phase I investigation.

2.1.5.1.3 Geraghty & Miller Drilling Activities

The soil borings and vertical-profile borings were installed by Mateco Drilling using 4.25-inch I.D. hollow stem augers. The soil borings extended 15 feet below grade, while the vertical profiles generally extended until the bottom of the intermediate sand horizon was encountered. Within cohesive soils, samples were collected continuously using a CME continuous, 5-foot, stainless steel, split-spoon sampler. Granular sediments and soil samples

were collected using a 2-inch diameter, 24-inch long, stainless steel, split-spoon sampler. Upon retrieval of the split-spoon sampler, cores were split lengthwise using a decontaminated stainless steel knife. One core half was logged by a Geraghty & Miller geologist noting such features as color, grain size, sorting, roundness structure, composition, and obvious presence of impacts such as discoloration and odor and retained in a labeled cardboard core box for later review. Sample/core boring logs for Geraghty & Miller borings are provided in Appendix D. The other half was retained for field screening for VOCs using either a portable PID or flame ionization detector (FID). The samples possessing the highest PID or FID readings and the bottom samples from soil borings SB-1, SB-2, SB-3, SB-4, IW-6, and IW-7 were submitted for analysis to ENSECO/RMAL. Upon completion of each boring or vertical profile, the borehole was filled from the bottom up with a bentonite slurry using a tremie pipe. If the boring was located in a paved area, the borehole was finished with a concrete pad that rests flush with the surrounding ground surface. All cuttings were containerized and staged to a location in the northeast section of the Hi-Mill Manufacturing parking area.

To isolate the surficial saturated sediments from the intermediate sand horizon, 10-inch I.D., Schedule 80 PVC casings were emplaced from the ground surface and seated within the first significant gray clay layer. The surface casings were installed by advancing 4.25-inch I.D. hollow-stem augers until the stiff gray clay was encountered. Using the 4.25-inch borehole as a pilot hole, 10.25-inch I.D. hollow-stem augers were advanced to the completion depth of the 4.25-inch augers. Using a liquid laboratory-grade detergent as a thread lubricant, 10-foot sections of 10-inch diameter, Schedule 80 PVC were threaded together and installed inside the 10.25-inch I.D. hollow-stem augers. The surface casings were grouted in place using a cement-bentonite grout pumped through a tremie pipe inside the surface casing while simultaneously withdrawing the augers. When the borehole was completely filled with grout and all of the augers removed, the surface casing was pushed down 1 foot to 2 feet into the undisturbed clay. A portion of the grout inside the casing was removed; the remaining grout was diluted using tap water from the Hi-Mill Manufacturing facility and pumped out of the casing leaving diluted residual grout inside the casing and undiluted grout outside the casing.

Decontamination procedures for the drilling and soil sampling activities followed decontamination protocols established by Techna's 1989 Remedial Investigation/Feasibility Study Work Plan. All drilling equipment such as augers, rods, bits, drilling rig and tooling were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated area in the Hi-Mill Manufacturing parking area located northeast of the building. Fluids generated during decontamination operations were captured and stored in a 1000-gallon agricultural storage tank. Soil-sampling equipment (split spoons, CME sampler, stainless steel knife, stainless steel spoons and spatula) were decontaminated between samples with a trisodium phosphate (TSP) and tap-water wash, tap-water rinse, 10 percent nitric acid rinse, laboratory-grade methanol rinse followed by distilled-water rinse and steam cleaned between borings.

Modified Level D protection was used by Geraghty & Miller personnel and its subcontractors during all drilling and soil sampling procedures. All site personnel complied with the approved Health and Safety Plan. A PID or FID meter was used to monitor the quality of the air within the work area for the presence of organic vapors. A combustible gas indicator was also used to safeguard against the presence of flammable gases such as methane. When elevated levels of volatile organics were detected within the augers or breathing zone, air quality was monitored using vinyl chloride-specific and benzene-specific tubes. If vinyl chloride was detected in the breathing zone, all site personnel exited the exclusion zone and allowed for the ventilation of the work area. Elevated levels of methane, volatile organics, and vinyl chloride were detected during the installation of the surface casing at VP-1 which required the use of personnel respiratory protection and temporary work stoppages. None of the other drilling locations required personnel respiratory equipment during the Phase II investigation.

2.1.5.1.3.1 *Hand-Auger Borings and Piezometer Installation*

The hand-auger borings and piezometers were installed for the purpose of determining the horizontal extent of TCE in shallow ground water and to monitor the fluctuations of the

shallow water table, respectively. However, valuable information was gathered concerning the shallow stratigraphy on the Hi-Mill Manufacturing site during this process. Generally, the hand-auger borings and piezometer boreholes were installed by advancing a 3.25-inch diameter, stainless steel hand auger to the top of the brown silty-clay. Upon retrieval of the sample from the borehole, the soil was logged by a Geraghty & Miller geologist noting such features as color, grain size, sorting, roundness structure, composition, and obvious presence of impacts such as discoloration and odor. A detailed discussion of the methods used in the piezometer installation and hand-auger borings is discussed in Section 2.1.7.1.2 and 2.1.7.2.2, respectively. Sample/core logs for the piezometer boreholes and the hand-auger borings are provided in Appendix E and Appendix F, respectively.

2.1.5.2 Chemical Characteristics

2.1.5.2.1 Techna Soil Sampling

Soil sampling methodology and decontamination procedures for the soil sampling conducted at the grid and off-grid locations during Phase I are described above in Section 2.1.5.1. Upon removal from the split-spoon sampler, the samples for TCL non-volatile organics and TAL inorganic analyses were placed in a stainless steel bowl and plastic bowls, respectively, and homogenized with a stainless scoop before being placed in the sample containers. Samples for the TCL volatile organics were placed directly into sample containers. A total of one hundred-seventy-six (176) SLM samples, twenty-six TAL inorganics, fifty-four TCL volatile, and fifteen samples for TCL other organics was submitted to ENCOTEC of Ann Arbor, Michigan. Duplicate samples consisted of fifteen SLM, two TAL samples, five TCL volatiles, and two TCL other organics. A summary of the analyses performed are provided on Table 2.3.

2.1.5.2.2 Geraghty & Miller Soil Sampling

During the drilling of Soil Borings SB-1, SB-2, SB-3, SB-4, IW-7 and Vertical Profile IW-6, samples were collected for the purpose of submitting two soil samples from each boring to ENSECO/RMAL for analysis of the SLM and TCL organics. Drilling, decontamination, and health and safety methodologies are detailed above in Section 2.1.5.1. Upon retrieval and opening of the split-spoon or CME continuous sampler from the borehole, the core or split-spoon sample was immediately screened for the relative presence of VOCs using an FID or PID and split lengthwise using a decontaminated stainless steel knife. One half of the core or sample was retained for logging and the other half was split lengthwise for headspace VOC screening and laboratory submission. One quarter was immediately placed in labeled, precleaned, laboratory-supplied sample containers and placed in a cooler and maintained at 4°C. The other quarter was placed in labeled plastic bag, sealed, and allowed to warm in the interior of a vehicle for approximately 30 to 60 minutes. After the sample warmed to allow for the generation of vapors in the headspace of the plastic bag, the probe from either a PID or FID was inserted into the sealed bag to screen for the relative presence of VOCs. Empty plastic bags and plastic bags with several drops of water were also warmed and screened using the same method to determine background VOC levels within the sealed plastic bag. The sample possessing the highest PID and FID result and the sample from the bottom of the boring were shipped to ENSECO/RMAL of Arvada, Colorado, via Federal Express for analysis of TCL organics and SLM. The headspace PID and FID results are provided on Table 2.4.

2.1.6 Ecological Assessment and Inventory

This section briefly outlines the field procedures employed as part of the Ecological Assessment and Inventory Investigation conducted for Target Pond by Geraghty & Miller in 1991 as part of the Phase II Remedial Investigation.

The Ecological Assessment and Inventory Investigation involved the collection of ecological data as well as sedimentological chemistry data for both Target Pond and Waterbury Lake. Waterbury Lake was used as the intended background waterbody for comparison to the ecology of Target Pond, for the purpose of assessing whether or not the flora and fauna of Target Pond may have been impacted by previous site activities.

The Ecological Inventory consisted of a terrestrial survey (soil classification, biotic communities, tree study, and vegetation observations); an aquatic survey of phytoplankton, zooplankton, and benthic macroinvertebrates; and an assessment of threatened and endangered species. A literature survey, sediment bioassay, surface-water quality and sediment-impact assessment were also included in the investigation. For details relating to the performance of field work and the complete scope of the investigation, please refer to the Phase II Ecological Assessment and Inventory Report presented in Appendix R.

2.1.7 Ground-Water Investigations

A thorough investigation of the hydrogeology of the Hi-Mill Manufacturing facility was necessary in order to determine the distribution of inorganic and organic constituents within the ground-water flow regime. Detailed information of the hydraulics of the system was also required to delineate potential migration pathways.

The hydrogeology of the Hi-Mill Manufacturing site was initially evaluated by Techna in a preliminary study conducted in 1988. This preliminary assessment was performed because of the discovery of chlorinated solvents in the Hi-Mill Manufacturing water supply wells. The hydrogeologic investigation of the site was broadened during the Techna Remedial Investigation of 1990.

Geraghty & Miller was retained in 1990 to perform additional work at the Hi-Mill Manufacturing site in order to further define the distribution of organic compounds and metals

within the ground- water flow system and to further delineate the hydraulic relationship between the hydrostratigraphic units identified by Techna.

Presented in the following sections is a discussion of the various stages of work performed to define the physical and chemical characteristics of the Hi-Mill Manufacturing site's hydrogeologic system.

2.1.7.1 Hydraulic Characteristics

2.1.7.1.1 General

Physical parameters of interest used in defining the hydraulic characteristics of the Hi-Mill Manufacturing site's ground-water flow regime include the following:

1. Hydraulic Conductivity;
2. Horizontal Hydraulic Gradients;
3. Vertical Hydraulic Gradients;
4. Ground-Water Flow Directions;
5. Ground-Water Seepage Velocities;
6. Recharge Areas;
7. Discharge Areas;
8. Porosity;
9. Seasonal Ground-Water Fluctuations; and
10. Surface-Water/Ground-Water Interactions.

In addition, accurate geologic logging of all boreholes was essential in order to correctly delineate all hydrostratigraphic units underlying the study area which could be potentially impacted by past or present site activities. Assessment of the hydraulic parameters of the site flow regime was essential in the determination of potential migration pathways of various

chemical species as well as in the quantification of migration rates and compound fate and transport.

The hydrogeologic investigations conducted at the Hi-Mill Manufacturing site were designed to gather data of sufficient type and quantity to define the hydraulic parameters listed above. Presented in the following sections is a description of the methodologies employed during these field investigations. The results of the hydrogeological investigation are discussed in Section 3.5.

2.1.7.1.2 Staff Gauge, Piezometer, and Well Installation

2.1.7.1.2.1 *Staff Gauges*

Staff gauges were originally installed by Techna during the Phase I investigation at various locations in Target Pond and Waterbury Lake. A total of six gauges was installed as follows: two in Target Pond, two north of M-59, and two in Waterbury Lake. These staff gauges were later replaced by Geraghty & Miller during the Phase II investigation because the old gauges were becoming difficult to read. The replacement gauges were placed in the same locations as the original staff gauges, with the exception of the two installed in Waterbury Lake that were fixed in slightly different locations. The current and previous locations of all staff gauges (designated "SG") are shown in Figure 2.1.

In general, staff gauges were mounted to metal posts using U-bolts and PVC spacers. The posts were driven approximately 1.5 to 2.0 feet into the underlying lake bottom sediments. Each gauge is submerged below the water surface to a depth of from 2 to 3 feet. Gauge gradations are in feet. The tops of each gauge were surveyed to within .01 foot of mean sea level for the purpose of data reduction. Staff gauges were installed to monitor the fluctuations

in surface-water elevations around the Hi-Mill Manufacturing site. Data on the variation of surface-water elevations have been used in conjunction with ground-water elevation data to assess the hydraulic relationship between local surface-water and ground-water flow systems.

2.1.7.1.2.2 *Piezometers*

A total of fifteen piezometers ranging in depth from 3.7 feet to 11.2 feet has been installed on and adjacent to the Hi-Mill Manufacturing property. The piezometers were installed by Geraghty & Miller between October 1991 and January 1992. All piezometers were completed within the shallow saturated zone to monitor the fluctuations within the local perched flow system. Borings that failed to locate the shallow saturated zone, were backfilled with native material. The locations of all installed and abandoned piezometers are shown in Figure 2.1.

Piezometer boreholes were installed using a 3.25-inch diameter, stainless steel hand auger. Borings were generally advanced until the shallow saturated zone was encountered or until the upper brown clay layer was reached. When the upper perched zone was found to be present at a particular location, the hand-auger holes were advanced just into the top of the brown clay or about 3 feet below the surface of the shallow water table. A piezometer was then constructed in the hole. If the boring was found to be initially dry, the hole was generally allowed to sit open and undisturbed for a period of approximately 24 hours. If the boring was still dry after that period, it was backfilled with native material. The stratigraphy of the soils encountered during the completion of the borings was logged and recorded on an appropriate form. Sample/core logs for each piezometer borehole are provided in Appendix E.

Piezometers were generally constructed of 5-foot sections of 1-inch I.D. flush-threaded, Schedule 40 PVC. Screened sections were generally 1-foot long, 0.010-inch machine slotted

with a polyethylene drive tip fixed to the bottom. All threads were wrapped with Teflon™ tape to ensure a water-tight seal between sections. Screened intervals were packed with clean, fine silica sand to a thickness of approximately 1 foot above the top of the screen. A 1 foot- to 2 foot seal consisting of bentonite grout or 0.25-inch bentonite pellets was placed above the sand pack. The remaining annular space was backfilled with native material to grade. Slip caps were placed over the top end of each piezometer, which generally protrude 1 to 3 feet above grade. The tops of Piezometers P-11B, P-12, and P-13B, placed within the M-59 median, were completed flush with the ground surface. An annular space of approximately 1.5 feet was widened with a shovel; a flush-mounted, water-tight manhole with an aluminum skirt was installed to protect the piezometer. (The manhole assembly was set by placing hydrated 0.25-inch bentonite pellets to within 0.5 foot of grade, and installing a concrete surface seal.) The flush installation of this piezometer was required by the Michigan Department of Transportation (MDOT). Installation logs for all site piezometers are provided in Appendix G and are summarized on Table 2.5

In the event that compounds were later discovered within the shallow saturated zone, the hand auger used to advance each piezometer boring was decontaminated using a wash of biodegradable soap and deionized water, followed by a rinse of deionized water. Only clean, factory-wrapped materials were used in the construction of all shallow piezometers.

2.1.7.1.2.3 *Monitoring Wells*

A total of twenty-nine monitoring wells was installed by Techna during the Phase I Remedial Investigation field investigation of the Hi-Mill Manufacturing site. In addition, the MDNR installed six wells on Highland State Recreation Area property during its study conducted in 1981, and Geraghty & Miller installed one monitoring well on the northeast end of the Hi-Mill Manufacturing production facility during the Phase II investigation conducted in

1991. Although these wells were principally installed to permit the collection of ground-water samples from various portions of the site flow system, they are of considerable importance in the assessment of aquifer hydraulic properties. Several of the monitoring wells have been used for in-situ tests of hydraulic conductivity. Ground-water elevations are collected from all site wells on a regular basis and used for determinations of horizontal and vertical hydraulic gradients, flow directions, and seasonal fluctuations in the potentiometric surface(s). Wells have been completed within the shallow perched zone as well as deeper portions of the site flow system located beneath the uppermost brown clay horizon.

During May 1981, MDNR installed six monitoring wells (piezometers) along the edge of the Hi-Mill Manufacturing property within the Highland State Recreation Area. In general, the wells were constructed of 1.25-inch I.D., Schedule 80 PVC casing and a threaded 3-foot length of 7-slot well screen within a 3-inch diameter hand-augered borehole. The wells were sand packed to at least 1 foot above the top of the well screen. A seal consisting of powdered bentonite and bentonite pellets extended from the top of the sand pack to the surface. Monitoring Wells EW-3, EW-4, and EW-5 were sand packed to within approximately 2 inches of the surface, possibly resulting in surface water entering the well bore. There is no evidence that the wells were grouted in place. Boring and well construction logs for the MDNR monitoring wells are provided in Appendix H.

Information on the monitoring wells installed under the supervision of Techna has been obtained from well logs and the original Remedial Investigation report submitted in 1990 following the Phase I investigation.

Techna (1990) reported that all soil boring and monitoring well installation procedures used conformed to either approved Remedial Investigation protocols or subsequently approved U.S. EPA field modifications. Drilling for the Techna supervised monitoring well installations

was performed by McDowell and Associates using 4.25-inch I.D. hollow-stem augers. Soil samples were collected during drilling at 5-foot intervals or at major changes in soil type using either an 18-inch or 24-inch long split-spoon sampler driven below the auger bit in accordance with ASTM Method D-1586. Blow counts were recorded for every 6 inches that the split-spoon sampler was driven. Shelby tubes and brass-lined split-spoon samplers were used to collect soil samples for laboratory analyses of physical properties. At locations where more than one well was constructed in a cluster with each well completed at a different depth, logging of soil in deeper holes commenced only when the bottom of an adjacent shallower boring had been reached thus eliminating redundant logging of the same interval. Soil sampling/boring logs for the Techna wells are provided in Appendix B.

Each of the twenty-nine monitoring wells installed by Techna are constructed of 2-inch I.D., flush-threaded PVC riser of either 3-foot or 5-foot lengths. Screens were 2-inch I.D., 0.010-inch machine-slotted, stainless steel or PVC fitted with a bottom plug made of like material. The top ends of all wells were covered with vented slip-on PVC caps. All wells extended at least 1 foot above grade and were covered by locking steel protective casings with keyed-alike locks. Well installation logs for the monitoring wells installed under Techna supervision are provided in Appendix I and are summarized in Table 2.5.

Monitoring wells were installed by lowering the well screen and casing through the center of each hollow-stem auger until the bottom of the hole was reached. A silica sand pack was placed to a height of 2 feet above the top of the screen while simultaneously extracting the augers, allowing the sand pack material to settle in place within the annular space between the well screen and borehole wall. A seal consisting of bentonite pellets was placed in a similar manner to a height of 2 feet above the top of the sand pack. The remaining annular space was grouted with a cement/bentonite slurry to within about 3 feet of ground surface. The protective steel casing was then set at this depth and grouted in place with cement. Exceptions to this

design included some of the shallowest monitoring wells which, because of their limited depth, could not accommodate a full 2-foot thickness of sand above the top of the screened interval nor a 2-foot thick bentonite seal. In some cases, modifications were made to the bottoms of protective casings to permit installation to shallower depths. A "V"-notch, marking the preferred measurement point for the collection of water levels, was cut into the top of each PVC riser for each monitoring well. The top-of-casing elevation in feet above mean sea level was surveyed for each well as was the ground-surface elevation and the corresponding x,y grid coordinate.

Decontamination procedures for well installation conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modification (Techna Corp., 1990). All well casings, screens, caps, bottom plugs, and split-spoon samplers were washed with a solution of Liquinox (biodegradable detergent) and tap water, followed by a steam-cleaner rinse. Drilling equipment such as augers, rods and bits were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated decontamination area in the Hi-Mill Manufacturing parking area located northeast of the building.

After completion, wells were allowed to sit for a period of at least 24 hours before being developed. Shallow wells were developed by evacuating water with either a stainless steel or PVC bailer. Ground-water elevations were collected from each well before and after development for comparison. Bailers were decontaminated between wells by steam cleaning, followed by a 10 percent nitric acid rinse and distilled water rinse. Stainless steel bailers were additionally rinsed with methanol and a final rinse of distilled water. New, clean, Teflon™-coated wire or nylon string was used for each well developed and replaced following decontamination. In general, wells were first surged with the bailer for a period of 3 to 5 minutes before water was removed. Except for those wells that were bailed dry, approximately

five well volumes were removed from each of the shallow monitoring wells. Wells that were bailed dry, were allowed to recover before being bailed dry once again.

Intermediate and deep wells were developed using filtered, compressed air forced into the well at the depth of the screen through 1-inch, threaded PVC pipe. All PVC pipes were steam cleaned before being lowered into a new well. In general, five well volumes were removed from each intermediate and deep well with the exception of DW-2 which, because of its low yield, was developed gradually using a stainless steel bailer and a Geoguard bladder pump system.

Modified Level D protection was used by Techna personnel and its subcontractors during all drilling, well installation, and development procedures. Techna (1990) reported that all site personnel complied with the approved Health and Safety Plan. A PID was used to monitor quality of the air within the work area for the presence of organic vapors. A combustible gas indicator was also used to safeguard against the presence of flammable gases such as methane. No hazardous air conditions were detected which required the use of personnel respiratory protection equipment during the Phase I investigation.

One additional monitoring well (VP-1) was installed by Geraghty & Miller during the Phase II investigation in 1991. Well VP-1 was installed in response to the detection of compounds at this location during vertical profiling. This well has also been used to monitor fluctuations in ground-water elevation within the intermediate sand horizon. Suspected ground-water impacts identified at VP-1 during vertical profiling required that a monitoring well be installed at that location. Screen placement was determined after review of the portable GC results, pH, conductivity and temperature measurements by Geraghty & Miller, the U.S. EPA, and the MDNR.

The monitoring well constructed at VP-1 was constructed of 10-foot sections of 2-inch I.D., flush-threaded, Schedule 40 PVC riser with a threaded 5-foot long, 2-inch I.D., 0.010-inch machine-slotted stainless steel screen with a threaded stainless steel bottom plug. The top end of the well was covered with a vented slip-on PVC cap. The well extends at least 1 foot above grade and was covered by locking steel protective casing. The monitoring well installation log for VP-1 is provided in Appendix J and is summarized on Table 2.5.

The monitoring wells were installed by lowering the well screen and casing through the center of each hollow-stem auger until the bottom of the hole was reached. A silica sand pack was placed to a height of 2 feet above the top of the screen while simultaneously extracting the augers, allowing the sand pack material to settle in place within the annular space between the well screen and the borehole wall. A seal consisting of bentonite pellets was placed in a similar manner to a height of 2 feet above the top of the sand pack. The remaining annular space was grouted with a cement/bentonite slurry to within about 3 feet of ground surface. The protective steel casing was then set at this depth and grouted in place using concrete. A "V" notch, marking the preferred measurement point for the collection of water levels, was cut into the top of the PVC riser. The top-of-casing elevation in feet above mean sea level was surveyed for each well as was the ground-surface elevation and the corresponding x,y grid coordinate.

Decontamination procedures for well installation conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modification (Techna Corp., 1990). All well casings, screens, caps, bottom plugs, and split-spoon samplers were washed with a solution of Liquinox (biodegradable detergent) and tap water, followed by a steam- cleaner rinse. Drilling equipment such as augers, rods and bits were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated decontamination area in the Hi-Mill Manufacturing parking area located northeast of the building.

After completion, the well was allowed to sit for a period of at least 24 hours before being developed. Monitoring Well VP-1 was developed by evacuating water with a single-use disposable bailer followed by a submersible pump. New, clean, nylon string was attached to the used for each well developed and replaced following decontamination. In general, VP-1 was first surged with the bailer for a period of 20 to 30 minutes before the submersible pump was lowered into the monitoring well. Water was removed from the well until the water possessed a relatively sediment-free appearance, and pH, conductivity, and temperature had stabilized.

The locations of all monitoring wells installed during the Phase I and II investigations are shown in Figure 2.1. A monitoring well and piezometer construction summary has been provided as Table 2.5.

2.1.7.1.3 Ground-Water Monitoring

Ground-water levels are now routinely collected once each month from all site piezometers, monitoring wells, and staff gauges. Ground-water elevations in the monitoring wells installed during the Phase I investigation were recorded sporadically by Techna during 1990. Presented in Table 3.5 are the ground-water elevations recorded in all site wells, piezometers, and staff gauges for the most recent six-month period.

Ground-water levels are recorded by means of an electronic water-level meter. Water levels are measured by lowering the probe of a clean meter into the well or piezometer. When contact with the water surface is made, a small light on the meter is illuminated and an audible tone can be heard. The probe is raised and lowered slightly to sequentially break and re-establish contact in order to confirm the location of the water surface. Once the correct depth of the water-level probe has been determined, the point of intersection between the probe cable and the top-of-well measure point is marked with a thumb nail and the cable gradation

corresponding with this mark is recorded to the nearest 0.01 foot along with the time and date that the depth to water was measured. This establishes the depth to water within a particular well or piezometer. Staff gauges are read by observing and then recording the gradation which is intersected by the surface of the water in a pond, lake, or stream.

Water-level data are reduced to ground-water elevation in feet above mean sea level by subtracting the depth to water in a well or piezometer from the surveyed elevation of the measurement point designated at the top of the PVC riser. Similarly, surface-water elevations are determined by calculating the difference between the gradation corresponding to the water surface position and the surveyed top-of-gauge elevation.

Because many of the ground-water observation points at the Hi-Mill Manufacturing site are monitoring wells which are used for determinations of ground-water quality, it is necessary to ensure that the water-level probe is decontaminated between each measurement. This is generally accomplished by washing the probe and the bottom 1 to 2 feet of cable with a solution of biodegradable soap and deionized water, followed by a double rinse of deionized water. This procedure is followed prior to the commencement of water-level measurements and between each well or piezometer measured.

Whenever possible, water levels are recorded for all site piezometers, wells, and staff gauges within a single day in order to provide a "snapshot" of the subsurface flow system. Hydrographs of ground-water elevation versus time have been prepared for all site wells and piezometers for the period extending from December 1991 until June 1992. Hydrographs of surface gauge readings have also been prepared for the same period. Well and surface-water hydrographs are a useful means of tracking long-term seasonal fluctuations in water level and may be compared to climatological data for the same period. The interpretation of these hydrographs will be discussed in greater detail in Section 3.0. All hydrographs prepared are provided in Appendix K.

Ground-water elevations have been used to develop potentiometric surface maps of the shallow, intermediate, and deep site flow systems and are presented as Figures 3.1, 3.10, and 3.11, respectively, for the month of March 1992. These maps are useful for determinations of ground-water flow directions, horizontal gradients, and the calculation of ground-water seepage velocities. The section lines shown on each of the potentiometric surface maps, drawn at 90 degree angles to the equipotential lines, have been used to determine the horizontal hydraulic gradients at each location shown. These horizontal hydraulic gradients, in conjunction with hydraulic conductivity data and estimates of primary porosity, permit the calculation of ground-water seepage velocities for various portions of the three flow regimes. The interpretation of the potentiometric surfaces for each of the three flow systems is discussed in greater detail in Section 3.5.2.

2.1.7.1.4 In-Situ Hydraulic Testing

In-situ testing of horizontal hydraulic conductivity was conducted in several site wells by Techna during the Phase I investigation. Slug testing was utilized as the method of determining the in-situ hydraulic conductivity at each location. Slug tests were conducted in fourteen wells with duplicate tests performed in Wells SW-9A, IW-1, IW-4, IW-5, and DW-3 (Techna Corp., 1990). Presented in Table 3.8 is a summary of the results of the slug testing performed at the Hi-Mill Manufacturing site, along with a list of the wells tested. Raw flow system testing data and graphs are provided in Appendix L.

Information on the slug testing and analysis was obtained from the original Remedial Investigation report submitted by Techna following the completion of the Phase I investigation. Techna (1990) reported that all slug testing procedures conformed with approved Remedial Investigation protocols. Prior to the commencement of testing, three initial static water-level measurements were recorded in each well. Slug testing was initiated by submerging a solid

polypropylene cylinder into each well, thereby, resulting in the displacement of from 0.5 to 0.75 gallons depending upon the size of the slug used. Changes in water-level elevation following displacement were measured using a Hermit Environmental SE1000B Datalogger and a down-hole pressure transducer with an accuracy of 0.01 foot. The transducer was placed at a sufficient depth to preclude any incidental contact between it and the slug. Following initial displacement, the water level in each well was allowed to recover to pre-test conditions, or in the case of very slow recovering wells, to within 90 percent of the initial static water levels. Techna has reported that Wells SW-8, SW-11, SW-15, and DW-3 all exhibited "slow recharge" (Techna Corp., 1990).

Slug test data was then analyzed by the Bouwer and Rice Method (1976). A discussion of the analysis, interpretation, and results of the slug testing data is provided in Section 3.5.2.

2.1.7.1.5 Laboratory Hydraulic Testing

A total of fifteen soil samples was collected for laboratory-determined estimates of vertical hydraulic conductivity, including one duplicate sample (Techna Corp., 1990). Techna (1990) reported that all soil-boring and sampling procedures were performed in accordance with approved Remedial Investigation protocols or subsequently approved field modification (U.S. EPA RPM). In general, soil samples were collected for every 5 feet drilled or whenever a different soil type was encountered. Select soil samples were shipped by Techna to a geotechnical laboratory for analysis. Presented in Table 3.9 is a summary of the soil samples collected for analysis of vertical hydraulic conductivity and the results of those analyses. Split-spoon samplers and Shelby tubes were used to collect undisturbed soil samples from below the bottom of the auger bit. The sample numbers shown in Table 3.9 reflect the well boring from which each was collected, and a corresponding depth interval for each sample has been listed along with a general description of the soil type. The results and interpretation of these permeability analyses will be discussed in greater detail in Section 3.2.5.

One soil sample was collected by Geraghty & Miller for geotechnical analysis of vertical hydraulic conductivity during the Phase II investigation. The sample was collected from the boring designated IW-7 (Figure 2.1) which was originally intended as a location for an intermediate depth monitoring well. The well was never placed due to the absence of a saturated sand seam in the upper brown clay unit into which the well was to be screened. However, a soil sample was collected using a Shelby tube sampler at a depth interval of from 32 to 34 feet below ground surface and shipped to Materials Testing Consultants, Inc. (MTC) of Grand Rapids, Michigan, for analysis. The results of the falling head permeameter test on the sample are presented in Appendix M in the original MTC report. Other physical parameters were also measured by MTC, the results of which are discussed in Section 3.4.2. The interpretation of the resulting hydraulic conductivity will be discussed in Section 3.5.2.

2.1.7.2 Chemical Characteristics

2.1.7.2.1 General

During the Techna (1990) Remedial Investigation, a total of twenty-nine monitoring wells was installed: twenty-one shallow monitoring wells, five intermediate monitoring wells, and three deep monitoring wells. To determine the chemical characteristics of the Hi-Mill Manufacturing ground water and the extent and degree of the occurrence of metals and VOCs, ground-water samples at the site were collected and analyzed for TAL inorganics, TCL volatiles, TCL other organics, ammonia, nitrate/nitrite, pH, temperature, and conductivity. Due to the identification of data gaps in the results of Techna's Phase I investigation, Geraghty & Miller conducted a Phase II Remedial Investigation which included the drilling and water sampling of thirty-three hand-auger borings, four vertical profiles, monitoring well installation and ground-water sampling for the occurrence of the SLM and TCL volatiles.

2.1.7.2.2 Hand-Auger Borings

To define the extent of VOCs in the shallow perched ground water, a series of hand-auger borings were completed. Initially, ten hand-auger borings were installed immediately surrounding the Hi-Mill Manufacturing facility. As a result of the detection of VOCs within water samples collected from the hand-auger borings, an additional six hand-auger borings were drilled on the south and southeast side of the facility. The eastern portion of the facility property was found to have non-detectable levels of compounds of concern. Due to VOCs detected in HAB-8, thirty-three borings were drilled in the median and on the northwest side of M-59. Figure 4.8 depicts the location of the hand-auger borings completed around the Hi-Mill Manufacturing facility.

2.1.7.2.2.1 *Installation*

During the installation of the hand-auger borings, ground-water samples were collected from the shallow saturated zone beneath the site. Stainless steel hand augers equipped with a 3.25-inch I.D. bucket auger were utilized to drill 3- to 5-foot deep boreholes. The depth of the borehole was dependent upon the depth to the top of the perched water table. The borings extended to at least 2 feet below the water table unless the borings penetrated the brown clay layer. The boring holes that did not collapse and remained open were sampled directly. Due to dry conditions above the brown clay, hand-auger borings drilled within the median of M-59 were advanced into the brown clay until a fine sand/silt layer was encountered. The borings in the median of M-59 collapsed due to the presence of a fine sand/silt layer either interbedded within the brown clay or above the brown clay. To keep the collapsing borehole open, a dedicated, hand-slotted, 2-inch, Schedule 40 PVC casing was installed within the boring.

A disposable polyethylene bottom-filling bailer was used to collect the ground-water sample. Ground-water samples were decanted from the bailer into a labeled 40-milliliter vial and immediately submitted for VOC field screening using the portable GC.

The hand auger and temporary well casing were decontaminated with a trisodium phosphate (TSP) and tap-water wash, tap-water rinse, 10 percent nitric acid rinse, laboratory-grade methanol rinse followed by a distilled-water rinse. Level D protection was used by Geraghty & Miller personnel during hand-auger boring installation. All site personnel complied with the approved Health and Safety Plan.

Refer to Figure 4.8 for the location of the hand-auger borings and Appendix F for sample/core logs for each boring.

2.1.7.2.3 Vertical Profiling

Vertical profiling was conducted at four locations to chemically characterize the ground water within the intermediate flow system and to ascertain if VOCs have impacted the intermediate flow system. Vertical Profile VP-1 was completed near the former water supply well and former TCE storage tank. Vertical Profile VP-3 was completed near the former water supply well and present TCE storage tank. Vertical Profile VP-2 was completed in an area adjacent to the former lagoon area and present leaching field. Vertical Profile IW-6 was completed in an area hydraulically downgradient from the potential sources of contamination at the Hi-Mill Manufacturing site. The locations of the four vertical profiles are depicted in Figure 2.1.

2.1.7.2.3.1 *Methodology*

The vertical-profile techniques used at the Hi-Mill Manufacturing were a drive-screen sampling system (Hydropunch) and auger pull-back. The drive-screen system was used at VP-1 and VP-3. However, due to the uncertainties related to the performance of the Hydropunch and the occurrence of large amounts of sand flowing into the hollow-stem augers, the Hydropunch system was discontinued and replaced with the auger pull-back method.

To isolate the surficial saturated sediments from the intermediate sand horizon and to reduce the risk of introducing surface contamination, 10-inch I.D., Schedule 80 PVC casings were emplaced from the ground surface to the first significant clay layer. The surface casings were installed by advancing 4.25-inch I.D. hollow-stem augers until the first significant clay was encountered. To assure that the surface casing was set within a low permeability clay horizon, soil samples were collected continuously using a CME continuous, 5-foot, stainless steel split-spoon sampler. Once an adequate thickness (3 to 5 feet) of an apparent low permeability clay horizon was encountered, 10.25-inch I.D. hollow-stem augers were advanced to the completion depth of the 4.25-inch augers. Using a liquid laboratory-grade detergent as a thread lubricant, 10-foot sections of Schedule 80 PVC were threaded together and installed inside the 10.25-inch I.D. hollow-stem augers. The surface casings were grouted in place using a cement-bentonite grout pumped through a tremie pipe inside the surface casing while simultaneously withdrawing the augers. When the borehole was completely filled with grout and all of the augers removed, the surface casing was pushed down 1 foot to 2 feet into the clay layer. This method ensured an adequate seal between the surface casing and the clay layer and resulted in the surface casing being set within a minimum of 5 feet of clay. A portion of the grout was removed; the remaining grout inside the casing was diluted several times using tap water from the Hi-Mill Manufacturing facility and pumped out of the casing leaving diluted residual grout inside the casing and undiluted grout outside the casing. The surface casings at VP-1, VP-2, VP-3, and

IW-6 were set at 30 feet below ground surface, 20 feet below ground surface, 20 feet below ground surface, and 35 feet below ground surface, respectively.

After allowing adequate time for the curing of the grout, 4.25-inch hollow-stem augers were advanced through the soft cement plug at the base of the surface casing. Once the cement was breached, continuous split-spoon samples were collected until the intermediate flow system was encountered.

A drive-screen sampling system (Hydropunch II) was used to collect water samples for the purpose of vertical profiling the intermediate flow system until difficulties related to flowing sands necessitated a change to a different method. The Hydropunch II consists of a 2-inch diameter, and 55.5-inch long stainless steel barrel with an attached drive shoe and a 5.25-inch long, 120-mesh stainless steel screen. After the top of the intermediate flow system was encountered, a precleaned hydropunch was attached to the drill rods and driven approximately 2 feet into the uppermost undisturbed horizon at the base of the augers. The hydropunch was then retracted approximately 12 inches exposing the stainless steel screen allowing ground water to flow into the hydropunch sample chamber. After approximately 30 to 45 minutes, the hydropunch sampling assembly was withdrawn from the borehole. The water contained in the hydropunch sample chamber was decanted into two 40-milliliter (ml) VOA vials and a 250-ml glass jar. The augers were then advanced to the approximate depth of the base of the hydropunch sampling interval; and a confirmatory 1-foot split-spoon sample was collected. The augers were then advanced to the base of the split-spoon sampling interval, and the hydropunch sampling procedure was repeated. This process of collecting a confirmatory geologic sample followed by driving the hydropunch and collecting a ground-water sample was repeated until the base of the intermediate flow system was encountered.

Hydropunch sampling attempts near the top of the intermediate flow system were not successful possibly as a result of an insufficient hydraulic head above the hydropunch assembly. At VP-3, samples collected using the hydropunch contained high pH and conductivity possibly as a result of either uncured cement/bentonite grout being dragged down on the augers or possibly due to high pH and conductivity water leaking into the drill rods and filling the hydropunch through the upper check valve.

The auger-advancement and pull-back method consisted of either continuous or every 5 feet soil sampling and auger advancement until the base of the intermediate flow system was encountered. A well assembly, consisting of a 2-foot long, 2-inch diameter stainless screen attached to a sufficient number of 10-foot sections of 2-inch galvanized steel riser, was installed in the borehole at the depth of the base of the intermediate flow system. The augers were then pulled back to the top of the screened interval and the natural materials were allowed to collapse upon the screen. The temporary well was purged using either a Grundfos Rediflo-2 or a Keck sampling pump until approximately three to five well volumes were removed or until the pH and conductivity of the purge water stabilized or approximately. Once a sufficient amount of water was removed from the temporary well, the pumping rate was reduced to the minimum amount, and the samples were collected in labeled 40-milliliter VOAs. Upon completion of the sampling of each zone, the pump was removed and the augers and temporary well assembly were pulled up approximately 5 feet. The sampling procedure was then repeated until the top of the intermediate flow system was encountered. In zones where the hydraulic conductivity was not sufficient to use a pump, the well was purged by using either an inertial pumping system consisting of relatively inert high-density polyethylene tubing with an attached foot valve (check valve) or a single-use disposable polyethylene bailer.

Water samples collected during the vertical profiling were submitted to FAST Environmental (GARTECH) for analysis of trichloroethene, 1,2-dichloroethene and vinyl

chloride using a portable GC. Due to the presence of a high TCE background within the Hi-Mill Manufacturing facility, the portable GC was set up in a hotel room in Hartland, Michigan. A water sample was also collected for analysis of pH, conductivity, and temperature. The pH and conductivity was measured using the field equipment set up within the Hi-Mill Manufacturing facility. GC, temperature, conductivity, and pH results are summarized in Table 4.19 and the actual GC lab reports are contained within Appendix N.

Decontamination procedures for the vertical profiling procedures followed decontamination protocols established by Techna's 1989 Remedial Investigation/Feasibility Study Work Plan. All drilling equipment such as augers, rods, bits, drilling rig, tooling, and temporary well screen and casing were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated area in the Hi-Mill Manufacturing parking area located northeast of the building. Fluids generated during decontamination operations were captured and stored in a 1000-gallon agricultural storage tank. Soil sampling equipment (split-spoons, stainless steel knife, stainless steel spoons and spatula) and the disassembled hydropunch were decontaminated between each sample using a trisodium phosphate (TSP) and tap-water wash, tap-water rinse, 10 percent nitric acid rinse, laboratory-grade methanol rinse followed by distilled-water rinse and steam cleaned between vertical profiles.

2.1.7.2.4 Monitoring Well Installation

During the Phase I and Phase II investigations a total of thirty ground-water monitoring wells had been installed in order to the determine chemical characteristics of the ground water at the Hi-Mill Manufacturing site. During the Phase I Remedial Investigation, Techna installed twenty-nine monitoring wells, twenty-one were installed within the shallow (0 to 30 feet) saturated materials, five monitoring wells were installed in the intermediate (30 to 60 feet)

saturated sands, and three were installed within the deep (60 to 90 feet) sands. Geraghty & Miller installed one monitoring well within the intermediate sands at VP-1 after VOCs were detected during vertical profiling.

2.1.7.2.4.1 *Techna Monitoring Well Installation*

Each of the twenty-nine monitoring wells installed by Techna were constructed of 2-inch I.D., flush-threaded PVC riser of either 3-foot or 5-foot lengths. Screens were 2-inch I.D., 0.010-inch machine-slotted stainless steel or PVC fitted with a bottom plug made of like material. The top ends of all wells were covered with vented slip-on PVC caps. All wells extended at least 1 foot above grade and were covered by locking steel protective casings with keyed-alike locks. Well installation logs for the monitoring wells installed under Techna supervision are provided in Appendix I.

Monitoring wells were installed by lowering the well screen and casing through the center of each hollow-stem auger until the bottom of the hole was reached. A silica sand pack was placed to a height of 2 feet above the top of the screen while simultaneously extracting the augers, allowing the sand pack material to settle in place within the annular space between the well screen and borehole wall. A seal consisting of bentonite pellets was placed in a similar manner to a height of 2 feet above the top of the sand pack. The remaining annular space was grouted with a cement/bentonite slurry to within about 3 feet of ground surface. The protective steel casing was then set at this depth and grouted in place with cement. Exceptions to this design included some of the shallowest monitoring wells which, because of their limited depth, could not accommodate a full 2-foot thickness of sand above the top of the screened interval nor a 2-foot thick bentonite seal. In some cases, modifications were made to the bottoms of protective casings to permit installation to shallower depths. A "V"-notch, marking the preferred measurement point for the collection of water levels, was cut into the top of each PVC

riser for each monitoring well. The top-of-casing elevation in feet above mean sea level was surveyed for each well as was the ground-surface elevation and the corresponding x,y grid coordinate.

2.1.7.2.4.2 *Geraghty & Miller Monitoring Well Installation*

Potential ground-water impacts identified at VP-1 during vertical profiling required that a monitoring well be installed at that location. Screen placement was determined after review of the portable GC results, pH, conductivity, and temperature measurements by Geraghty & Miller, the U.S. EPA, and the MDNR.

The monitoring well was constructed at VP-1 is constructed of 10-foot sections of 2-inch I.D., flush-threaded, Schedule 40 PVC riser with a threaded 5-foot long, 2-inch I.D., 0.010-inch machine slotted stainless steel screen with a threaded stainless steel bottom plug. The top ends of all wells were covered with vented slip-on PVC caps. The well extends at least 1 foot above grade and was covered by a locking steel protective casing with a keyed-alike lock.. The monitoring well installation log for the VP-1 is provided in Appendix J.

The monitoring well was installed by lowering the well screen and casing through the center of the hollow-stem auger until the bottom of the hole was reached. A silica sand pack was placed to a height of 2 feet above the top of the screen while simultaneously extracting the augers, allowing the sand pack material to settle in place within the annular space between the well screen and the borehole wall. A seal consisting of bentonite pellets was placed in a similar manner to a height of 2 feet above the top of the sand pack. The remaining annular space was grouted with a cement/bentonite slurry to within about 3 feet of ground surface. The protective steel casing was then set at this depth and grouted in place using concrete. A "V" notch, marking the surveyed measurement point for the collection of water levels, was cut into the top of the PVC riser. The top-of-casing elevation in feet above mean sea level was surveyed for each well as was the ground-surface elevation and the corresponding x,y grid coordinate.

Decontamination procedures for well installation conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modification (Techna, 1990). All well casing sections, screens, caps, bottom plugs, and split-spoon samplers were washed with a solution of Liquinox (biodegradable detergent) and tap water, followed by a steam-cleaner rinse. Drilling equipment such as augers, rods and bits were steam cleaned prior to the onset of drilling and between each boring location. All steam cleaning was conducted in a designated decontamination area in the Hi-Mill Manufacturing parking area located northeast of the building.

After completion, the well was allowed to sit for a period of at least 24 hours before being developed. Monitoring Well VP-1 was developed by evacuating water with a single-use disposable bailer followed by a submersible pump. In general, VP-1 was first surged with the bailer for a period of 20 to 30 minutes before a submersible pump was lowered into the monitoring well. Water was removed from the well until the water possessed a relatively sediment-free appearance and pH, conductivity, and temperature had stabilized.

2.1.7.2.5 Ground-Water Sampling

During the Phase I Remedial Investigation, ground-water samples were collected and analyzed for the following constituents: thirty-one samples for SLM, including three field duplicates and three field blanks; eight samples for TAL inorganics, including one field duplicate and one field blank; twenty-nine samples for TCL volatiles, including three field duplicates, three field blanks and three matrix spikes; five samples for TCL other organics including one field duplicate and one field blank; twenty-nine samples for ammonia and nitrate/nitrite including three field duplicates and three field blanks and thirty-two samples for pH, conductivity and temperature. Table 2.6 summarizes the type and number of samples collected during the Phase I Remedial Investigation. After the evaluation of the results obtained from the Phase I Remedial

Investigation, Geraghty & Miller collected a new set of ground-water samples and analyzed for the following constituents: thirty-two samples for dissolved SLM (not including two field duplicates, one field blank and one matrix spike); seven samples for total SLM and thirty-two samples for TCL VOCs (not including three field duplicates, one field blank, four trip blanks, and two matrix spike and matrix spike duplicates). Table 2.6 summarizes the type and number of samples collected during the Phase II Remedial Investigation.

2.1.7.2.5.1 *Techna Ground-Water Sampling Methodology*

Techna (1990) reported that all water-sampling and testing procedures conformed to either approved Remedial Investigation protocols or subsequently approved (U.S. EPA RPM) field modifications. Prior to the water sampling, static ground-water levels were recorded and subtracted from previously obtained total depth measurements to calculate the volume of standing water in each monitoring well. Three to five well volumes were removed from all of the intermediate and deep monitoring wells and Shallow Wells SW-5, SW-17, SW-20, and EW-4 prior to the collection of water samples. Due to poor recharge, all of the other shallow wells (SW and EW) were bailed dry and then were allowed to recharge prior to sampling. The deep and intermediate wells were purged and sampled using a gas-driven, airlift Geoguard bladder pump system. The Teflon™ bladder and stainless steel pump ensured that air did not come into contact with the ground-water sample during pumping action. Two 3-3-foot and one 18-inch stainless steel bottom-filling bailers with Teflon™ check valves were dedicated to the Hi-Mill Manufacturing site and used to purge and sample the shallow wells.

Samples collected for the analysis of organic parameters were poured directly from the bailer or collected directly from the bladder pump discharge hose. Metals samples were collected in a dedicated sample collection bottle and were immediately filtered through 0.45-micron disposable filter using a Geotech barrel filter. The temperature of each ground-water

sample was measured immediately upon sample collection. The pH and specific conductivity of most ground-water samples were measured immediately upon sample collection; however, measurements on samples collected from wells SW-9A, SW-22, EW-1, EW-2, EW-6, IW-2, IW-5, DW-1, and DW-3 were performed at Brighton Analytical. Instrument probes used to measure field parameters were calibrated daily in accordance with the QAPjP and used according to manufacturer's directions.

All sampling equipment was decontaminated prior to use by a laboratory-grade detergent and tap-water wash, tap-water rinse, 10 percent nitric acid rinse and distilled-water rinse. The dedicated laboratory-prepared sample collection bottle was rinsed prior to sample collection with 10 percent nitric acid and distilled water.

QA/QC samples consisted of field duplicates, field blanks, and trip blanks. Trip blanks were prepared by ENCOTEC using organic-free deionized water for each cooler shipment. Duplicate ground-water samples were collected in a second set of bottles at a rate of one per ten samples collected for each parameter. Field blanks for metal analyses were prepared by pouring distilled water into a decontaminated bailer then into a laboratory-prepared sample collection bottle and filtered using the Geoguard filtering system described above. Field blanks for organic analysis were prepared by pouring organic-free deionized water into a decontaminated bailer then into the laboratory-prepared sample bottle. Field blanks for volatile analysis were prepared by pouring distilled water into a decontaminated bailer then into the laboratory- prepared sample bottle.

All samples were properly labeled and placed on ice while on site. At the end of each sampling day, samples were transported in coolers by Techna personnel to ENCOTEC in Ann Arbor, Michigan. Samples for inorganic analyses were subsequently shipped to Wilson Laboratories in Salina, Kansas, by ENCOTEC for analyses. Proper chain-of-custody procedures were strictly followed.

2.1.7.2.5.2 *Geraghty & Miller Ground-Water Sampling Methodology*

Prior to the water sampling, static ground-water levels were recorded and subtracted from previously obtained total depth measurements to calculate the volume of standing water in each monitoring well. Except for SW-4 and SW-7, three to five well volumes were removed from all of the intermediate, deep and shallow monitoring wells prior to the collection of water samples. Due to poor recharge at SW-4 and SW-7, the wells were bailed dry several times prior to sampling. The intermediate and deep monitoring wells were purged using dedicated high density polyethylene (HDPE) tubing attached to a KECK sampling pump. The KECK sampling pump was set at maximum flow rate (≈1.3 gpm) to evacuate the well. Samples were collected when a sufficient amount of water had been purged from the well and the KECK pumping rate was set to a minimum. Shallow wells were purged using a sufficient length of dedicated, relatively inert HDPE tubing with an attached foot valve (check valve) and gasoline-powered centrifugal pump. Once a sufficient amount of water had been evacuated from the well, the tubing was disconnected from the centrifugal pump and the section of tubing in contact with the pump was cut off. The samples were decanted directly from the HDPE tubing by gently raising and lowering the tubing until water flowed from the tubing.

TCL volatile samples were placed in labeled 40-ml VOC vials and capped with Teflon™-lined lids. Zero head space was ensured by gently tapping the capped vial several times. Total metals samples were placed directly in the sample bottle. Dissolved metals samples were placed in a dedicated polyethylene container that had been rinsed in distilled water followed by a triple rinse using the water sample. After the repeated rinsings of the sample container, the sample was collected and filtered through a single-use 0.45μ QED High Capacity Quick Filter into a laboratory-provided, prelabeled and prepreserved, sample container using a sufficient amount of silicon tubing and a peristaltic pump. Field parameters (pH and conductivity) were measured

immediately using a Myron L pH/Conductivity meter. The pH/conductivity was calibrated at the start of each day using pH 7 and pH 10 buffer solutions and a standard conductivity solution.

All reused sampling equipment (KECK pump, wire and water-level meter) was decontaminated using a wash in laboratory-grade detergent and distilled water and a rinse in distilled water. All HDPE tubing, foot valves, silicon tubing, 0.45μ filters were dedicated to each well and were placed in barrels after the completion of sampling for proper disposal.

QA/QC samples consisted of field duplicates, field blanks, and trip blanks. Trip blanks were prepared by ENSECO using organic-free deionized water for each cooler shipment. Duplicate ground-water samples were collected in a second set of bottles at a rate of one per ten samples collected for each parameter. Field blanks for metals analyses were prepared by pouring distilled water into a unused single-use bailer then into a dedicated sample collection bottle and filtered into laboratory-prepared, prelabeled and prepreserved sample bottle using the system described above. A field blank for volatile analysis was prepared by pouring distilled water into an unused single-use bailer then into the laboratory-prepared sample bottle. An additional volatile blank was prepared by using a short length of HDPE tubing with an attached foot valve and pumping distilled water directly from an unused distilled water container into the sample bottles. Field blanks were also collected by pumping distilled water from a decontaminated bucket through the KECK pump into a sufficient length of HDPE tubing. The field blank was collected into the VOC vials and a dedicated polyethylene container. The water in the polyethylene container was then filtered using the system described above.

All samples were properly labeled and placed on ice while on-site. At the end of each sampling day, samples were shipped by Federal Express to ENSECO in Arvada, Colorado, in coolers maintained at 4°C. Proper chain-of-custody procedures were strictly followed. Pertinent ground-water sampling information is summarized on the Ground-Water Sampling Logs provided in Appendix O.

2.2 TECHNICAL MEMORANDUM

A Final Technical Memorandum for the Hi-Mill Manufacturing site was issued by Geraghty & Miller during June 1991 to the U.S. EPA and the MDNR. The complete version of this memorandum is presented in Appendix P. Geraghty & Miller was given three objectives for this document which were:

1. To comment on the interpretation of the data in the Phase I Remedial Investigation Report;

2. To evaluate the quality of the data in the Phase I Remedial Investigation Report; and

3. To recommend any additional data necessary to complete the Remedial Investigation and Risk Assessment.

The memorandum consists of an executive summary, a review of the geologic/hydrogeologic data, an analytical data validation, a proposed sampling program, a proposed scope for an ecological assessment and inventory, initial revisions to the baseline risk assessment, an assessment of additional work required to complete the Remedial Investigation and Risk Assessment, and a schedule for completion of additional work.

A review of the geologic and hydrogeologic data resulted in the identification of the following areas of concern and consequently these recommendations:

1. Further definition of the hydraulic gradient of the shallow flow zone west of the Hi-Mill Manufacturing facility. Two additional shallow wells were recommended in this area;

2. Two additional intermediate zone monitoring wells were recommended to be installed northwest of Hi-Mill Manufacturing in order to better define the geology and hydrogeology downgradient of the site;

3. Target Pond could be acting as a source of recharge to the intermediate zone;

4. The construction log of Deep Zone Well DW-1 indicates formational collapse up through the intermediate flow zone which could have resulted in erroneous hydraulic potential measurements, and thus, could cause problems in the interpretation of the deep zone flow direction and hydraulic gradient;

5. Uncertainty in the hydraulic relationship between Target Pond, Waterbury Lake and the shallow perched zone. Geraghty & Miller recommended the installation of staff gauges in the two surface waterbodies, and two additional shallow piezometers to be placed between Target Pond and Waterbury Lake;

6. A soil gas survey was initially recommended to determine VOC "hot spots" in the shallow site soils. While this survey was never performed, hand-auger borings were installed and the ground water sampled and analyzed with a portable GC for the presence of VOCs;

7. The ground-water metals database developed by Techna was inconclusive; it was recommended that SLM be collected from more of the site monitoring wells;

8. Based upon a near-CLP (contract laboratory program) validation of the Phase I analytical data, it was concluded that only 1 percent of the data were unusable, while the remainder were of either quantitative (75 percent) or qualitative (25 percent) value;

9. A second round of ground-water sampling was recommended for all site monitoring wells; and

10. An ecological assessment and inventory was recommended for the site, the results of which were proposed for use in a site risk assessment. Existing ecological data from Phase I was deemed inadequate for use in a CERCLA quality risk assessment.

Information and recommendations in the Geraghty & Miller Technical Memorandum were used in the development of the Phase II Remedial Investigation Work Plan. A similar technical memorandum and data completeness review was completed by Techna during Phase I and submitted to the U.S. EPA and the MDNR. For details regarding the findings of the Geraghty & Miller Technical Memorandum, refer to the complete document provided as Appendix P.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The following sections contain a detailed description of the physical characteristics of the Hi-Mill Manufacturing study area based upon the results of the various field investigations conducted. The discussion focuses on the geology, hydrology, and hydrogeology of the site and establishes the basis for a conceptual hydrogeologic model of the subsurface flow regime. The conclusions developed from investigations of the study area hydrology and hydrogeology will be used in subsequent portions of this R.I. report to delineate the migration of various chemical species and identify potential sources.

3.1 SURFACE FEATURES

Surface and physical features at the Hi-Mill Manufacturing site are depicted on Figure 1.2. Natural features within the site area consist of features typical of regions within a glacial interlobate morainic system. Surface features are controlled by glacial and/or post-glacial processes. The Hi-Mill Manufacturing site generally occupies a gently (less than 2 percent) sloping area ranging in elevation from approximately 999 feet at Waterbury Lake to 1011 feet south of the Hi-Mill Manufacturing facility. Several irregularly shaped upland areas range in elevation from 1034 feet northeast of the site to 1028.7 northwest of Hi-Mill Manufacturing. Numerous shallow closed depressions exist within the area and during periods of high rainfall and/or snowmelt may contain water.

Several surface waterbodies are present within the study area including Target Pond, Waterbury Lake, and Alderman Lake. Target Pond, located 100 to 200 feet east of the Hi-Mill Manufacturing facility, is a shallow surface waterbody and marshy area occupying a shallow

depression in the ground surface. A culvert exists on the north edge of Target Pond and may extend beneath M-59. However, no culvert or pipe was identified on the north side of M-59 and it is uncertain whether this culvert connects Target Pond to the wetland north of M-59 or to the M-59 drainage system. Waterbury Lake and the North Arm of Waterbury Lake are located approximately 250 to 900 feet south and southwest of the Hi-Mill Manufacturing property respectively. A berm or levee constructed between 1949 and 1956 (exact date unknown) separates the North Arm and Waterbury Lake preventing direct connection between the two waterbodies. Alderman Lake, located approximately 1000 feet northwest of the Hi-Mill Manufacturing site, receives drainage from the storm sewer located within the east and west bound lanes of M-59 and the M-59 median via a shallow creek flow into Alderman Lake. Specific local drainage and surface-water flow is discussed in Section 3.2.

The Hi-Mill Manufacturing facility consists of an approximately 50,000-square foot structure used for manufacturing, raw material storage and preparation, finished product storage and administration. Shipping and receiving facilities are located on the southwest and northeast sections of the building, respectively. No active underground storage tanks (USTs) are present on the site. However, a former fuel oil UST has been abandoned in place below the present office area on the north side of the building. Presently, one 1000-gallon aboveground storage tank located on the southwest end of the building supplies TCE to the two degreasers located within the Hi-Mill Manufacturing facility. An additional aboveground storage tank was located on the northwest end of building until it was removed during expansion of the facility and replaced with the present tank. The remainder of the Hi-Mill Manufacturing property consists of an approximately 60,000-square-foot paved parking area and an unpaved vegetated area. An 8-foot high chain-link fence topped with barbed wire surrounds the approximately two acres of unimproved Hi-Mill Manufacturing property located south and east of the manufacturing facility. A raised septic field, located southwest of the main manufacturing facility, is used to discharge wastewater from the Hi-Mill Manufacturing facility. Prior to 1983, two wastewater

lagoons were located behind the production facility. The larger of the lagoons and associated sludges were excavated and replaced with clean fill in 1983. While the fate of the smaller lagoon is not known, it is possible that portions of the smaller lagoon were regraded across the property by either natural and/or proactive means.

The Hi-Mill Manufacturing site is bounded on the northwest by Michigan State Route 59 (M-59) and, generally, on all other sides by the Highland State Recreation Area, which is owned and operated by the Michigan Department of Natural Resources (MDNR). Property located northwest of the facility is also part of the Highland State Recreation Area. A manufacturing facility owned by Numatics, Inc. is approximately 800 feet northeast of the Hi-Mill Manufacturing property. Numatics occupies an approximately 12,000-square-foot manufacturing building on site of about two acres in area. Numatics, Inc. reportedly discharges process wastewater to a drain and septic field located on the Numatics property. Several residences exist approximately 2,000 feet southeast of the site along Waterbury Road with two properties adjoining the east shore of the Target Pond/wetland area.

Prior to the expansion of M-59 from a two-lane highway to a four-lane limited-access divided highway and the establishment of the Highland State Recreation area, a private residence, airfield and former gas station existed adjacent to Hi-Mill Manufacturing. The former gas station, purchased by Hi-Mill Manufacturing in 1946, was located approximately 150 feet northwest of the production facility. Hi-Mill Manufacturing used the structure for tool storage until the State of Michigan exchanged the presently paved parking area at the south end of the plant for the former gas station property in 1981. The private residence, located north of the site, and the airfield, located south of the site, were both incorporated into the Highland State Recreation Area.

3.2 CLIMATE

The Hi-Mill Manufacturing facility site is located within a temperate climate zone with average monthly temperatures ranging (over the period 1987 through 1990) from approximately 25.9°F in February up to 74.3°F in July (Table 3.1). Overall, the area received an average of approximately 33 inches of precipitation annually over the same period, with the highest volume of precipitation occurring most commonly in June or July and the driest months occurring at the beginning of the year in January or February (Table 3.1).

Table 3.2 presents a summary for daily precipitation data measured at Pontiac, Michigan (the nearest location to Hi-Mill Manufacturing), for the year 1991. The cumulative precipitation for 1991 was just over 32 inches, with the largest rainfall event occurring on May 26 (2.0 inches). The wettest months in 1991 were May and October with 4.98 inches and 6.08 inches of rainfall, respectively. Conversely, the driest months of 1991 were February and September with 0.79 inches and 0.87 inches of rainfall, respectively. The raw climatological data obtained from National Oceanic and Atmospheric Administration (NOAA) for the years 1987 through 1991 is provided in Appendix Q. Correlations between the climatological data and ground-water fluctuations at the Hi-Mill Manufacturing site will be discussed in Section 3.5.2.4.

3.3 SURFACE-WATER HYDROLOGY

The Hi-Mill Manufacturing property is situated among several surface-water features (Figure 1.1). Target Pond is adjacent to the east. Waterbury Lake is located to the south, with the North Arm of Waterbury Lake extending to the west of the facility. Alderman Lake is northwest of Hi-Mill on the north side of M-59, and an extensive wetland area is located across M-59 from Hi-Mill. These waterbodies are surficially unconnected and lie within respective closed basins which do not possess surface-water drainage outlets.

3.3.1 Target Pond

Target Pond is rimmed by adjoining wetland areas as denoted in Figure 2.1. Examination of historical aerial photographs indicates that the size of these wetland areas change depending upon the surface water level of Target Pond, which generally has a surface water area of 8 to 10 acres, and a maximum water depth less than 10 feet. During particularly dry years, Target Pond has been relatively devoid of standing water and has been present as only a small wetland area. The U.S.G.S. topographic map (1968, photo revised 1983) of the study area (Figure 1.1), in fact, depicts Target Pond as a wetland area.

3.3.2 Waterbury Lake and North Arm

The surface area of Waterbury Lake typically ranges from 35 to 40 acres. Similar to Target Pond, it is rimmed by wetland areas, but differs from Target Pond in that its maximum depth of water is much greater than 10 feet.

The North Arm of Waterbury Lake, with a surface water area of a couple of acres, is generally isolated surficially from the main portion of Waterbury Lake (Figure 2.1). Surface-water-level data suggests, however, that the two bodies are hydraulically interconnected through the levee located between them.

3.3.3 Alderman Lake

Alderman Lake is approximately the same size as Waterbury Lake and is approximately one-half mile northwest of Hi-Mill (Figure 1.1). The Alderman wetland is a variably-sized and shaped area tributary to Alderman Lake.

An arm of the Alderman wetland extends southeast of Alderman Lake to the north side of M-59 across from the North Arm of Waterbury Lake. It has been stated previously that the North Arm of Waterbury lake drains northward beneath M-59 into this wetland area situated north of M-59 by way of a culvert located under the roadway (Figure 2.1). Despite three separate field inspections, the existence of such a culvert between the two waterbodies has not yet been verified. The wetland area north of M-59 is fed by drainage from a storm sewer and diversion ditch located in the roadway median. No surface-water interconnection between the North Arm and the small wetland area has been confirmed, and no surface-water exit point for the water in the North Arm has been located south of M-59.

A second arm of the Alderman wetland is located north of M-59 across from the north edge of Target Pond. Previous investigations have suggested that these waterbodies are connected during high water periods via a culvert beneath M-59 (See Figure 2.1 for location of culvert). Despite the depiction of an 18-inch diameter conduit connecting Target Pond and the wetland north of M-59 on the MDOT M-59 construction plans, no outflow pipe has been observed on the north side of M-59. Therefore, it is likely that the conduit extending north from Target Pond connects into the M-59 drainage system located in the median of M-59.

3.3.4 Conceptual Model of Surface Water Hydrology

Surface water elevations have been recorded at eight staff gauges situated in various locations in Target Pond, Waterbury Lake, the North Arm, and the Alderman wetland areas north of M-59 (Figure 3.1). Four of the six staff gauges originally installed by Techna were subsequently replaced by Geraghty & Miller and re-surveyed for accuracy. Two additional Surface-Water Gauges, SG-7 and SG-8 (Figure 3.1), were added near the levee between the North Arm and Waterbury Lake. All surface-water elevations have been normalized to feet

above mean sea level. A summary of the recorded data is presented in Table 3.3. Changes in gauge elevation following replacement are reflected in the data appearing in Table 3.3.

The recorded surface water elevation data indicate that the surface waterbodies previously discussed are generally ground-water discharge areas. Any hydraulic connection between surface waterbodies appears to be only through shallow ground-water systems. During deficiencies in precipitation, the hydraulic connection between surface waterbodies through the ground-water system may be disrupted. During periods of heavy precipitation, the surface waterbodies may recharge the ground-water systems, but they do not appear to be directly connected to each other at any time by surface water. Several specific interpretations based on collected data are presented in the following sections.

3.3.4.1 Hydraulic Connection Between the North Arm of Waterbury Lake and the Alderman Wetland Under M-59

Examinations of the surface-water data collected previously by Techna (1990) between April and June 1990 (Table 3.4) indicate that the surface-water elevation in the Alderman wetland north of M-59 at Gauge SG-5 (Figure 3.1) was between 3.64 feet and 4.1 feet higher in elevation than surface-water elevations recorded at SG-4 in the North Arm of Waterbury Lake. This information tends to support the conclusion that there is no surficial flow from the North Arm toward Alderman wetland, north of M-59, as flow toward the north would require the movement of water against prevailing hydraulic gradients.

The comparison of surface-water elevations collected during 1992 by Geraghty & Miller indicates a different situation than that observed by Techna during 1990. Geraghty & Miller measured a difference of surface-water elevations between the North Arm and the Alderman wetland north of M-59 ranging from 0.78 foot to 1.28 feet with surface water elevations higher

in the North Arm. These measurements are significantly different in both magnitude and direction than the 3- to 4-foot difference measured by Techna in 1990. There are several potential explanations for these differences.

Observations made by Geraghty & Miller field personnel indicated that the Techna gauges were damaged in some cases and in different/locations and orientations than expected in others. Some of these gauges had clearly been tampered with and were subsequently replaced by Geraghty & Miller during Phase II. One possible explanation for the difference between the Phase I and II results may be that the Techna staff gauges were either improperly surveyed, measured, or damaged subsequent to the survey, or misread due to tampering. The surface-water data collected during 1992 suggest water could potentially flow between the North Arm and the Alderman wetland, with water moving from the North Arm toward the wetland. While the apparent lack of conduit between the two waterbodies suggests that there is no direct surface connection between the North Arm and the wetland, there may be a degree of interconnection related to ground-water flow beneath the M-59 roadway and within the shallow flow system.

It is also possible that the discrepancies between the observations made by Techna in 1990 and Geraghty & Miller in 1992, could be due to seasonal fluctuations in surface water levels in the North Arm and Alderman wetland and/or in the shallow phreatic surface. However, inspections of the Techna (1990) Phase I RI Report indicate that interpolated elevations of the shallow ground-water flow system are quite similar, both in terms of flow directions and elevations, to those observed by Geraghty & Miller in 1992. These facts then tend to suggest that a seasonal fluctuation in shallow ground-water elevations (and thus, flow directions) may not explain the variation in surface water elevations in the two waterbodies between 1990 and 1992, if hydraulic communication between surface and ground-water systems is sufficient to permit concordant responses in the elevations of surface water and ground water.

One other possible explanation for the difference in hydraulic potential between the North Arm and Alderman wetland from 1990 to 1992 might be that one or both of the waterbodies are not in full hydraulic communication with the shallow ground-water flow system. This condition could be created by the presence of layers of semi-pervious sediments lining the bottoms of either the North arm and/or Alderman wetland. Thus, if a series of precipitation events caused an increase in the surface water elevation of a waterbody lined with semi-pervious materials, a delay in a commensurable response in the shallow water table elevation could be observed. The hydraulic potential trends observed by Techna were fairly consistent over a 3-month period and ground-water data collected by both Techna and Geraghty & Miller indicate that local surface waterbodies are likely discharge areas for baseflow from the shallow ground-water flow system. It is anticipated that "perching" of surface water would most likely occur at the Alderman wetland due to the characteristics most commonly associated with surface water features of this type. That is, the rich organic bottom sediments and vegetation often found in wetlands, can act to occlude or limit hydraulic communication with shallow ground-water flow systems. This does not necessarily imply that there is no hydraulic communication between Alderman wetland and the shallow ground-water flow system; rather this is to merely suggest that the presence of semi-pervious sediments at the bottom of the wetland may retard equilibration of surface water and ground-water elevations, especially following periods of significant precipitation. This theory may provide an explanation for the observations made by Techna during their investigation of the site.

Further examination of the Techna ground water and surface water data suggests that, during May 1990, the surface water elevation in the southern tip of Alderman wetland was nearly 6 feet higher than the shallow ground-water table in this area. This comparison was made between readings recorded at staff gauge SG-5 (level measured as 1003.95 ft msl on 5-11-90) and the shallow phreatic surface map (closest ground-water contour, 998 ft msl) presented as Figure 3.3 in the Phase I RI Report (Techna, 1990). Examinations of area topography (see

Figure 1.1) indicate that the ground surface elevation near SG-5 is approximately 1000 ft msl. Therefore, the depth of the water in this part of the wetland was about 4 feet, and a depth of approximately 2 feet separated the base of the wetland from the top of the shallow ground-water table. It is likely, however, that the material underlying the bottom of the wetland was at least partially saturated and may have acted to retard infiltration and, thus, communication with the shallow aquifer.

The most important characteristic not yet discussed with regard to variations in surface water elevation in the Alderman wetland is that this waterbody is fed by discharge from storm sewers situated within the median of M-59. Runoff from the roadway and median areas is intercepted by drains which, in turn, are connected by buried pipes to a discharge point located in the culvert directly across M-59 (north) of the North Arm. Stormwater discharged at this point is fed directly into Alderman wetland at the same location as Staff Gauge SG-5 (Figure 3.1). Geraghty & Miller field personnel have witnessed relatively significant flow emanating from this discharge pipe following major precipitation and snowmelt events. In many of these instances, standing water ranging in depth from about 1 to 2 feet has been observed in the M-59 median which, in turn, was seen to flow directly into drainage grates in the median which supply water to the discharge culvert. Thus, much of the standing water observed and measured at Staff Gauge SG-5 likely emanates from the storm sewer discharge pipe and not discharges from the shallow ground-water flow system.

The best conceptual model, based upon the available data, would indicate that although shallow ground water does flow in the direction of Alderman wetland and although the wetland is probably a zone of ground-water discharge, the Techna results likely do not reflect a change in shallow ground-water flow directions during this period of 1990; rather, they are probably more indicative of increased flows into the wetland from stormwater and snow melt runoff. Increased fluxes of water into the portion of the wetland near SG-5 may not infiltrate very

rapidly toward the shallow water table; rather, it is likely that surface water will tend to flow down the channel toward the main portion of the wetland following the path of least resistance. Some infiltration through the channel bottom is likely however.

3.3.4.2 Hydraulic Connection Between Target Pond and Waterbury Lake

Surface-water elevations between Target Pond and Waterbury Lake are approximately 6 feet, with Target Pond being the higher of the two waterbodies. However, a direct surface-water interconnection between Target Pond and Waterbury Lake has not been observed. The discussion of the possible hydraulic communication of Target Pond and Waterbury Lake will be discussed in detail in Section 3.5.2.1.2 of this report.

3.3.4.3 Hydraulic Connection Between Target Pond and the Alderman Wetland Under M-59

A comparison of the surface-water data between Staff Gauge SG-1 in Target Pond and Staff Gauge SG-6 in the Alderman wetland north of M-59 indicates that surface water within the wetland is approximately 0.10 inches higher during the period between March 1992 and May 1992, and is approximately 0.10 inches lower during the month of June 1992. If there is a hydraulic connection between Target Pond and the Alderman wetland, the ground-water gradient is very flat and may reverse itself frequently.

3.3.4.4 Hydraulic Connection Between Waterbury Lake and the North Arm of Waterbury Lake

The differences between surface-water elevations of the North Arm of Waterbury Lake and Waterbury Lake have varied between 0.01 foot in June 1992, and 0.12 foot in May 1992. The surface-water data suggests that hydraulic connection exists between the North Arm and

Waterbury Lake, with a gradient sloping to the south beneath or through the levee connecting the two waterbodies.

3.4 GEOLOGY AND SOILS

A background search was conducted to obtain materials related to the regional geology of the Hi-Mill Manufacturing facility. The materials referenced include the Soil Survey of Oakland County, Michigan (1980); the Surficial Geology of Oakland County, Michigan (1980); the Bedrock Geology Map of Oakland County (1980); and the boring logs generated by Techna during the Phase I Remedial Investigation activities and Geraghty & Miller's Phase II Remedial Investigation at the Hi-Mill Manufacturing site.

3.4.1 Regional Geology

The Oakland County soil survey report revealed that the study area consisted of two soil types. The soil located south and east of M-59 was classified in the Oshtemo-Spinks-Houghton association, and the soil located north and west of M-59 was classified in the Urban land-Spinks-Oshtemo associations (Figure 3.2). Both are categorized as well drained, sandy soils on outwash plains, beach ridges, and moraines. The Oshtemo-Spinks-Houghton soil can also include poorly drained, mucky soils formed in bogs.

According to the surficial geology map of Oakland County (Figure 3.3), the entire site is located on an outwash plain. Typical materials represented in this fluvioglacial environment consist of relatively well-stratified deposits of well-sorted sands, silts, and clays. Deposition of these materials occurred in a proglacial environment, beyond the terminal edge of the ice. The sands are typically deposited by moving stream channels; the finer sediments are deposited in calmer, lacustrine environments. The combined thickness of the unconsolidated glacial deposits in the area range between 300 and 320 feet.

Underlying the unconsolidated glacial material is the early Mississippian Coldwater Shale. The Coldwater consists of a gray micaceous shale and interbedded sands resembling a deltaic sequence ranging in thickness from 500 feet in southwestern Michigan to approximately 1250 feet in southeastern Michigan.

3.4.2 Site Geology and Soils

3.4.2.1 Subsurface Exploration Results

Interpretive cross sections (Figures 3.4, 3.5, 3.6, 3.7, and 3.8) of the stratigraphy underlying the site were developed by Geraghty & Miller from boring logs compiled by Techna during the Phase I Remedial Investigation and Geraghty & Miller during the Phase II Remedial Investigation. Please note that of the five cross-sections, one section (E-E') possesses a different horizontal and vertical scale from the others. This has been done to illustrate details beneath M-59 which are relevant to later discussions on TCE impacts in this area. Techna directed the installation of the twenty-nine monitoring wells presently located at the site (Figure 2.1). Four vertical profiles, one monitoring well, five soil borings and forty-nine hand-auger borings and twenty-one borings for piezometer installation were drilled during the Phase II Remedial Investigation. The logs from each of the monitoring wells, soil borings and vertical profiles, and hand-auger borings are contained within Appendices B, D, E, and F, respectively. Cross-section traces are depicted on Figure 3.9.

In general, shallow, intermediate and deep borings that have had wells installed in them are designated "SW," "IW," and "DW," respectively. An exception to this was boring IW-7 which was originally intended to contain a well but in which no well was ever completed. Soil borings from which samples have been collected but no well has been installed have been designated as "SB" with the exception of those completed in and around the M-59 median which

were labeled "SBM." Vertical profiles completed by Geraghty & Miller were labeled "VP," in which only one well was installed (VP-1). At the beginning of the Phase II investigation, Geraghty & Miller completed a series of hand-auger borings around the Hi-Mill plant to locate VOC impacts, and these have been designated "HAB." A vertical profile was completed and named IW-6 because an intermediate well was to be installed at this location. No well was installed at IW-6 since no impacts were detected with the portable GC and hence, the designation has not been changed. Piezometers installed during Phase II were labeled "P." No replicate boring or well names have been used between the Techna and Geraghty & Miller investigations. When the same identifier prefix has been used between Phase I and II (e.g., IW) the next logical number in sequence has been used as a suffix (e.g., IW-5, then IW-6). For a given boring where a well has been installed, the boring and well log both have the same designation (e.g., boring log VP-1 and well log VP-1). To cross-reference logs with boring/well locations on maps and cross-sections, it is only necessary to select the boring/well log of interest and check the appropriate Appendix for a log labeled in the same way.

The stratigraphic profiles shown in the Cross Sections A-A', B-B', C-C', D-D', and E-E' include the following seven distinct geologic units: shallow soils and granular material, brown periglacial and/or post-glacial lacustrine deposits, blue periglacial and/or post-glacial lacustrine deposits, interglacial lacustrine deposits, glacial outwash deposits, and post-glacial fluvioglacial outwash.

A thin veneer of sandy topsoil occurs as the uppermost unit that overlies a thin horizon of fine sands, silts, and other various soil compositions. Properties of this profile are outlined in the Oakland County Soil Survey. This 1-foot to 5-foot thick horizon is perched on a stiff, brown and gray variegated clay (brown clay). On the Hi-Mill Manufacturing property, the thin sandy soil is generally absent and has been replaced by a clayey fill material above what appears to be an organic-rich topsoil or possibly peat.

The brown clay appears to be quite uniform in thickness across the study area and generally occurs between 1000 and 1010 feet above mean sea level and, except for the rear of the facility, is generally continuous across the site. The brown clay pinches out toward the south and west possibly due to erosion resulting from alluvial processes. The proportion of silt within the brown clay increases toward the west until the brown "clay" is actually a clayey silt. Furthermore, interbedded within the brown clay are numerous thin sand and silt seams which appear to be the water-bearing material within this horizon. The occurrence of the sand and silt seams appears to decrease with depth within the brown clay.

On the southwest edge of the study area, the brown clay is absent and has been replaced by alternating deposits of sand, silt, and clay. The brown clay appears to have been eroded by fluvial or glaciofluvial activities and replaced by the stratified sands and silts. Furthermore, the underlying gray clay described below also appears to be eroded by the same process. The geology beneath the west edge of the Hi-Mill Manufacturing site consists of complex interfingering of the lacustrine brown clay and fluvial silty fine sands/fine sandy silts. This alternating depositional sequence is indicative of the boundary between a calm lacustrine environment and a higher energy fluvial environment where the stratified sand and silt were deposited. Farther to the south and west, the brown clay pinches out and is replaced by a tan fine sandy silt/silty fine sand which occurs from 1005 to 985 feet above mean sea level and pinches out beneath the Hi-Mill Manufacturing facility. Figure 3.8 (Cross Section E-E') shows a brown clayey silt, occurring between 1009 and 1005 feet above mean sea level at Vertical Profile IW-6 and Monitoring well SW-2 which may be conformable (Figure 3.5, Cross Section B-B') to the brown variegated clay observed elsewhere at the site.

Except for the west edge of the study area, the brown clay grades with depth into a stiff blue/gray clay (gray clay) that occurs between approximately 955 to 1000 feet above mean sea level. Generally, the gray clay contains numerous sand and silt varves which indicate a

lacustrine depositional environment. As shown in the cross sections, the gray clay thins toward the west and the south and pinches out southeast of the Target Pond/wetland area. If the contact line between the gray clay and the underlying outwash sands were projected past our data points, the clay unit would likely pinch out south of Waterbury Lake and east of Monitoring Well SW-19. Similar to the brown clay, several interbedded sand/silt seams or lenses exist within the upper portions of the gray clay, especially on the western edge of the study area near SW-11 and SW-1. A significant thickness (≈2 feet) of interbedded fine sand and silt was encountered in Soil Borings SB-1, SB-2, and Vertical Profile VP-3 at a depth of about 9 feet bgs. As shown on Figure 3.4 (Cross Section A-A'), the interbedded gray fine sand and silt may correlate with a gray sand and silt encountered west of Hi-Mill Manufacturing at IW-7. The occurrence of the sand/silt seams decreases with depth until a stiff gray clay with thin (<0.1") silt and sand varves is encountered at approximately 985 feet above mean sea level.

Underlying the gray clay are the saturated outwash sands of the "intermediate" flow system occurring from 897 to 972 feet above mean sea level in the southwest and 948 to 972 feet above mean sea level beneath the site. Except toward the north and southwest, the intermediate sand is approximately 28- to 30-feet thick across the site. The intermediate sand thins toward the north and thickens toward the south and west when an underlying clay pinches out and joins the "intermediate" with the "deep" sand. The intermediate sand generally consists of medium-to-coarse sand and fine gravel in the upper portions of the unit and grades into a fine silty sand toward the south and west and a medium sand beneath the Hi-Mill Manufacturing property.

A second blue/gray clay (gray clay) forms the base of the intermediate flow system, and is composed of interglacial lacustrine gray clay similar to that of the upper gray clay. The lower gray clay pinches out toward the south and west and thickens toward the east forming the confining cap of the flow system.

A second horizon of outwash sands is encountered beneath the gray clay at Monitoring Wells DW-1 and DW-2. The gray clayey sand encountered within the gray clay at DW-3 does not appear to correlate with the intermediate or deep sands and is most likely a sand unit interbedded within the lower gray clay. The deep sand is similar in appearance to the intermediate sand and was deposited prior to the deposition of the quiet/deep-water gray clay wedge. The deep sand unit joins with the intermediate sand to the southeast after the gray clay pinches out.

Below the "deep" sand, the lack of soil-sampling information prohibits additional correlation. However, based on Monitoring Wells DW-1, DW-2, DW-3, and information collected during Techna's 1988 Hydrogeologic Investigation, a coarse sand, gravel, and boulder unit was encountered at approximately 90 feet below ground surface. Toward the west, the first unit underlying the sand is a clayey silt encountered at Vertical Profiles IW-6 and VP-3 and Monitoring Well DW-1.

3.4.2.2 Physical Soil Testing Results

During the Phase I investigation, Techna (1990) collected sixteen soil samples which were analyzed for various physical properties including grain size, Atterberg Limits, and vertical hydraulic conductivity. Techna (1990) reported that samples were collected from both "confining layers and saturated zones." The Techna analyses indicated that moisture contents ranged from 12% to 31%; liquid limits, plastic limits, and plasticities ranged from 25.5 to 42.9, 16.0 to 25.5, and 9.5 to 22.1, respectively; and vertical hydraulic conductivities ranged from 1.4×10^{-2} cm/sec to 7.46×10^{-8} cm/sec. For a more detailed description of the Techna results, please refer to the Phase I Draft Remedial Investigation Report (Techna, 1990).

Geraghty & Miller collected a total of seven soil samples during the Phase II investigation for analysis of physical properties including grain size, soil classification, wet and dry densities, moisture content, and vertical hydraulic conductivity. Testing was performed in accordance with ASTM D422 with preparation of the samples performed in accordance with ASTM D421. Of these seven samples, one was collected at an interval between 32 and 34 feet ~~below~~ ground surface from boring IW-7, and the others were collected from sediments lying at the bottoms of Target Pond and Waterbury Lake.

The laboratory (Materials Testing Consultants [MTC] of Grand Rapids, Michigan) described the sample collected from IW-7 as a "SILT, some clay, little fine sand" or "ML" (USCS classification system). The interval from which the sample was collected is near the interface of the units described as gray/blue silty clay and gray sand and silt as determined from the boring log of IW-7. Thus, the field and laboratory results for this interval are generally in agreement with one another. Other results from the physical testing of IW-7 (32 to 34 feet below ground surface) included: a moisture content of 20.6%; and a vertical hydraulic conductivity of 1.8×10^{-7} cm/sec.

Grain size analysis and USCS classification for all of the remaining samples collected from Target Pond and Waterbury Lake, indicated that the bottom sediments lining both of these waterbodies consist of "peat and organic silt" or "OH" (USCS classification system). No falling head permeameter tests of vertical hydraulic conductivity were conducted on these samples. Additionally, no moisture contents were determined for these samples.

Details on the potential hydraulic characteristics of the soil samples tested by Techna and Geraghty & Miller are discussed in Section 3.5.2.2.

3.5 HYDROGEOLOGY

3.5.1 Regional Hydrogeology

The shallow flow regimes of interest in the region encompassing the Hi-Mill Manufacturing site, generally consist of unconsolidated glacial drift composed of sand, silt, gravel, and clay. Most of the glacial drift within the vicinity of the Hi-Mill Manufacturing facility has been classified as either glacial outwash deposits or glacial moraine sediments (Hydrogeologic Atlas of Michigan, 1981). This glacial drift generally forms unconfined aquifers near the surface and consists of an interbedded system of aquifers, aquicludes, and aquitards at depth. However, shallow unconfined aquifers are often isolated and limited in extent across the region as permeable horizons are generally discontinuous, resulting in perched flow systems (Hydrogeologic Atlas of Michigan, 1981).

Aquifers in this region are principally comprised of sand or gravel deposits, or some combination thereof. Intervening layers of clay and sometimes silt often serve as aquitards or aquicludes. Confined/artesian flow systems in this area are commonly manifested by more permeable lenses of sand and gravel bounded vertically by clay horizons. In general, the region (particularly the glacial lake plain areas) is characterized by the presence of numerous small and imperfect artesian systems which possess widely varying degrees of hydraulic interconnection both vertically and laterally (Groundwater Resources Oakland County, 1954). Thus, due to the high level of spacial variability in permeability, porosity, and hydraulic interconnectivity, static water levels observed at stratigraphically similar depths situated in close proximity to one another may vary substantially. This reflects the lack of continuity of hydrostratigraphic units regionally. The shallow phreatic surface of localized perched aquifer systems is found to be generally consistent with surface water elevations in nearby lakes (Groundwater Resources Oakland County, 1954).

Recharge areas are controlled by the distribution of shallow coarse clastic material, and the interconnection of these zones to deeper permeable horizons. Discharge areas are often manifested by the abundant local lakes which may act as ground-water sinks or by effluent rivers and streams (Groundwater Resources Oakland County, 1954). Isolated surface waterbodies are commonly characterized by organic-rich layers of bottom sediment which can significantly reduce the degree of hydraulic interconnection with local ground-water flow systems.

3.5.2 Site Hydrogeology

3.5.2.1 Hydraulic Gradients and Ground-Water Flow

3.5.2.1.1 General

Since December 1991 static water levels within the monitoring wells, piezometers and staff gauges have been measured at the beginning of each month. Static levels were used to develop potentiometric surface maps of the ground-water flow systems underlying the site. Three flow regimes were previously identified during the Phase I investigation of the Hi-Mill Manufacturing site hydrogeology. The hydrostratigraphic units delineated previously include a shallow discontinuous flow system consisting of the uppermost layers of sand, fill, and clayey silt which are interbedded with brown clay; an intermediate flow system occurring between the upper and lower gray clay layers; and a deep flow system underlying the lower gray clay. The upper shallow system is separated from the intermediate system by the upper gray clay horizon. Additional geologic data collected during the Phase II Remedial Investigation suggests that the intermediate and deep flow systems actually represent a single flow system owing to hydraulic interconnection between the two sand units. The upper portions of the lower gray clay consist of interbedded lenses of stiff clay and fine-to-medium sands that, owing to the discontinuous nature of some of the *gray* clay lenses, result in hydraulic communication between the sand

lenses and the intermediate flow system. This condition is particularly evident on the southwest side of the site where the lower gray clay was either comparatively thin or completely absent (Figure 3.4).

3.5.2.1.2 Shallow Discontinuous Flow System

The potentiometric surface map for the shallow ground-water flow system was constructed by using monitoring wells that were completely screened within or above the first clay unit (brown clay) encountered at the site. The brown clay was frequently found to contain interbedded layers of silt, sand, and clayey silt which are believed to represent the primary saturated zones comprising the shallow flow system. The data set included Shallow Monitoring Wells SW-2, SW-3, SW-4, SW-5, SW-9A, SW-10, SW-15, SW-20; existing Piezometers EW-1, EW-2, EW-3, EW-4, EW-5; new Piezometers P-1RD', P-3, P-3RD, P-6, P-6RD, P-7, P-8, P-9, P-10, P-11B, P-12, P-14, P-15, P-17; and Staff Gauges SG-1, SG-2, SG-5, SG-6, SG-7 and SG-8. Shallow Monitoring Wells SW-1, SW-6, SW-7, SW-8, SW-11, and SW-14 were not used for the interpolation of the shallow phreatic surface because the wells were screened either partially or totally with the underlying gray clay. Monitoring Wells SW-17, SW-18, SW-19 were not included within the data set utilized to describe the shallow flow regime because these wells were screened within the intermediate sand rather than the shallow zone which is interbedded with silt, sand and brown clay. Comparisons between those wells completed in the shallow zone (interbedded with silt, sand and brown clay) and gray clay indicated a clear separation in hydraulic heads between the two units. Heads measured within the zone of interbedded silt, sand and brown clay could be readily contoured into a surface which was consistent with the local topography and drainage, whereas potentiometric pressures obtained from the gray clay were consistently lower than those in the shallow zone with the exception of SW-9A (shallow zone) whose heads were lower than well SW-9 screened in the upper gray clay. The contoured surface of the shallow zone has been interpolated based on the assumption that the upper gray clay is not part of the shallow flow system. Ground-water elevations observed in the gray clay are believed to be more representative of pore pressures within the relatively

impermeable stiff clays and are not consistent with the characteristics of a discrete flow system. In some cases, wells completed within the gray clay are believed to exhibit potentiometric pressure, which represent the average between heads within the shallow system and pressures within the clay, owing to the installation of the well filter pack into the lower portions of the perched flow regime. The potentiometric surface map for the shallow ground-water flow system is presented as Figure 3.1. Static water levels and ground-water elevations are summarized on Table 3.5.

Shallow ground-water elevations ranged from 1009.79 feet mean sea level at SW-12 to 996.75 feet mean sea level at SW-2 (Figure 3.1). The potentiometric surface map indicates that ground water flows radially away from a ground-water high located near the Hi-Mill Manufacturing facility toward Target Pond, Waterbury Lake, North Arm of Waterbury Lake, and M-59. The ground-water high and general radial flow pattern of the shallow flow system is the result of local topography and recharge at the rear of the Hi-Mill Manufacturing facility. The relatively flat topography of the area behind the site building (≈1009 feet mean sea level) serves as the principal zone of recharge locally to the upper flow system, owing to the abundance of paved areas surrounding the facility. Water discharged from the facility's down spouts and septic field, in addition to direct precipitation and runoff from adjacent paved areas, serves to increase recharge to the shallow aquifer and produces the local potentiometric high at the rear of the Hi-Mill Manufacturing facility.

Horizontal hydraulic gradients within the shallow zone were calculated using section lines depicted on Figure 3.1 and by dividing the change in hydraulic head (dh) across the selected line by the length of the section line (dl). Section lines were selected to reflect the variability in gradients within the shallow zone and to achieve sufficient areal coverage. Table 3.6 presents the calculated horizontal gradients for the six section lines depicted in Figure 3.1. Horizontal gradients within the shallow zone range from 0.0025 ft/ft at Section Line F-F' to 0.129 ft/ft

along Section Line D-D'. The steeper horizontal hydraulic gradients observed at section lines A-A' and D-D' are consistent with the steepening topography present on the edge of Waterbury Lake and the North Arm. The relatively flat horizontal hydraulic gradient observed at Section Line F-F' is consistent with the relatively flat topography at the rear of the Hi-Mill Manufacturing facility where recharge to the shallow system is believed to occur.

Several of the piezometers previously proposed in the Phase II Work Plan which were to be installed in the shallow system were found to be dry upon completion of the hand-auger borings. Proposed piezometer locations P-1, P-2, P-4, P-5, and P-16 (Figure 3.1) were all found to be dry locations following completion of each respective boring. Holes were allowed to sit open for several hours, and in some cases overnight, to determine if the borings would eventually fill with water. If the boring was found to be dry, the hole was backfilled with native material in all cases. Proposed piezometers were installed to provide further delineation of the shallow phreatic surface and to aid in determining if a horizontal hydraulic interconnection is present between the shallow system and Target Pond and Waterbury Lake. The presence of "dry" locations within the shallow flow system are indications that this regime is discontinuous with respect to continuity in ground-water flow. Dry locations may be explained by the relative absence of small silt and sand lenses capable of bearing water and periods of low precipitation which result in relatively minor recharge to the system.

An inspection of the shallow phreatic surface map (Figure 3.1) indicates that surface water elevations within the local surface waterbodies are consistent with horizontal flow from the shallow system into Target Pond and Waterbury Lake. Horizontal gradients are particularly steep near Waterbury Lake and the North Arm of Waterbury Lake. Flow to the adjacent surface waterbodies from the shallow system is anticipated to occur through small, relatively discontinuous lenses of silt and sand interbedded within the brown clay. Other sources of recharge to the surface waterbodies include direct precipitation and runoff along small drainages located at the rear of the Hi-Mill Manufacturing facility. Comparisons of available surface water elevations in Target Pond and shallow ground-water elevations indicate that Target Pond is a

zone of discharge from the shallow system. Vertical hydraulic communication between Target Pond and the intermediate flow regime is expected to be minimal as the vertical hydraulic conductivities of the underlying gray clay is relatively low. While it is possible that a series of heavy precipitation events could raise the elevation of the surface water in Target Pond to a level which is higher than that of the adjacent shallow system (thus allowing recharge from the Pond to the shallow system), none of the existing data show that such an event has occurred. Thick organic-rich sediments present at the bottom of the wetland area are also anticipated to restrict hydraulic communication vertically. Target Pond, in particular, likely represents a surface expression of the shallow system. Water within this body is believed to merely "sit" atop the gray clay as recharge to the surface system occurs through minor amounts of ground-water baseflow from silt and sand layers in the brown clay, direct precipitation, and surface runoff.

Based upon the available hydraulic and geologic data, the shallow flow system may be defined as being comprised of the brown clay and interbedded lenses of silt and sand. During the advancement of hand-auger borings through the shallow system, it was evident to field personnel that the interbedded lenses of sand and silt (or combinations thereof) were, generally, at least partially saturated, and that in some instances, the brown clay was moist and in other cases dry. The occurrence and thickness of water-bearing silt and sand lenses were found to be irregular with depth and from location to location. Additionally, intervening layers of brown clay were seldom devoid of notable quantities of silt and sometimes sand. Because of the irregularity of the occurrence of water-bearing seams within the soil located above the upper gray clay, and due to the extremely variable composition of the brown clay itself, it is not practical to map individual flow seams within the soils lying atop the upper gray clay. Therefore, these interbedded surficial soils have been grouped together and described within this report as brown/gray variegated silty clay, due to scale-dependent consistencies in geologic and hydraulic characteristics.

Since water-bearing lenses of silt and sand interbedded within the brown clay are irregular with respect to lateral extent, occurrence, and thickness, it would be extremely impractical to attempt to monitor either the hydraulic potential and/or water quality of individual water-bearing sediments. For example, many of the silt and sand seams are only a few inches thick, and within a vertical depth range of only a foot or two there are typically many changes in soil type from brown clay to silt, to sandy silt, to silty sand, etc. To individually monitor each potential flow pathway would constitute a virtually impossible (and likely unproductive) task. Additionally, examinations of water elevation data collected from the interbedded brown clay unit, coupled with available water quality and geologic data, would suggest that sufficient lateral and vertical interconnection of water-bearing sediments does exist to define the interbedded brown clay unit as a whole, as a more or less contiguous flow system. Although the shallow system is comprised of unconsolidated sediments, one possible analogous model which could be used to characterize flow within the brown clay might be a fractured bedrock. That is, flow primarily takes place within available conduits (in this case, silt and sand seams) which may be vertically or horizontally interconnected to a greater or lesser degree depending upon depositional history and location. The "matrix" of the system, in this case, would compare to portions of the shallow system chiefly comprised of brown clay which possesses little silt and sand. This "matrix" is anticipated to possess comparatively low horizontal and vertical hydraulic conductivity and, as such, is not responsible for transporting much of the flow occurring within the shallow system as a whole. When a dry boring is advanced into the shallow system (such as occurred several times during the Phase II investigation), it is likely that no water was encountered due to the general absence of relatively transmissive water-bearing lenses of silt and sand and/or the presence of lenses of silt and sand which are highly limited in lateral and vertical extent which, as a result, have very low storage capacities. Therefore, dry borings were likely advanced into the "matrix" of the shallow flow system. In addition, the shallow phreatic surface map presented in Figure 3.1 is a generalization of flow within the numerous sand and silt

conduits interbedded within the brown clay (as are all water table maps in reality) and, as such, cannot address known and unknown "dry" spots in the shallow flow system.

Thus, the definition of those sediments overlying the upper gray clay as either a more or less contiguous flow system, or as a complex series of flow conduits with varying degrees of interconnectivity, is a scale-dependent problem. From a practical and functional standpoint, the evidence would indicate that the shallow system can be described as a single flow system. However, it must be recognized that the presence of saturated zones capable of transmitting flow can vary considerably both vertically and laterally, although the most viable of these pathways (larger silt and sand seams) are likely interconnected to some degree. As a result, it is possible to have localized areas which, in essence, will not yield significant quantities of water, if monitored, and are essentially or literally "dry." It is also possible to have transmissive saturated zones underlain and/or separated by "dry" horizons. Additionally, lateral and vertical flow through any portion of the shallow zone will depend upon the presence or absence of available silt and sand conduits at that location. It is likely that the amount of available recharge to the system does influence both the amount of water transported as well as the number of pathways available for that transport. The latter condition may be influenced by the quantity of water (and thus, available driving head) in a transmissive zone, such that if sufficient pressure exists, some water may exit that conduit and enter another through a relatively tenuous connector by overcoming capillary forces.

While the brown clay unit, as a whole, cannot be considered to serve as an aquitard, portions of the horizon certainly do act to restrict the flow of ground water at some locations when viable conduits of silt and sand are absent. This is evidenced by field observations made during the advancement of hand-auger borings and drill holes, estimates of hydraulic conductivity (discussed in Section 3.5.2), and the presence of "dry" borings during the Phase II investigation. On a localized scale, the brown clay horizon could be considered similar to a

perched flow system in that the presence of saturated flow zones and "dry" zones varies both laterally and vertically with depth. However, the presence of numerous flow conduits, which are more or less hydraulically interconnected in many cases, tends to contradict the use of the description of the flow system as "perched." Therefore, perhaps the shallow flow zone may be better described as a "discontinuous" flow system, or as a "mixed" flow system with a combination of both "perched" and "phreatic" hydraulic conditions.

The upper gray clay horizon is believed to represent the hydraulic "bottom" of the shallow flow system (i.e., an aquitard). This is evidenced by the comparatively low vertical hydraulic conductivities observed during soil testing (See Section 3.5.2.2), examinations of soil type, and the clear separation in the hydraulic potentials of the shallow and intermediate systems (See Sections 3.5.2.1.3 and 3.5.2.5). Although there is little contrast between the vertical hydraulic conductivity estimates of the brown clay and upper gray clay horizons, no specific data are available on the permeability of the sand and silt seams interbedded within the brown clay which are believed to carry the preponderance of flow within the shallow zone. It is believed that vertical hydraulic conductivity estimates obtained for the brown clay are not necessarily wholly representative of the more transmissive sand and silt seams; rather, these estimates have likely been affected more by the general lack of permeability associated with the brown clay "matrix." With regard to apparent hydraulic conductivity contrasts between the shallow flow zone (i.e., interbedded brown clay and silt/sand seams) and the upper gray clay, these apparent contrasts are evidenced primarily by geologic observations made from soil samples collected from both horizons. That is, the upper gray clay appears more massive and possesses far less potentially transmissive sand and silt than does the brown clay horizon.

3.5.2.1.3 Intermediate Flow System

The potentiometric surface map for the intermediate zone was constructed using the data

set collected on March 17, 1992, for Monitoring Wells SW-17, SW-18, SW-19, IW-1, IW-2, IW-3, IW-4A, IW-5, and VP-1 (Figure 3.10). Intermediate ground-water elevations ranged from 1002.52 feet mean sea level at SW-19 to 995.91 mean sea level at IW-1. The approximate ground-water flow direction within the intermediate zone is toward the west. The potentiometric surface for the intermediate zone is presented in Figure 3.10. Static water levels and ground-water elevations are summarized on Table 3.5. Horizontal hydraulic gradients for the intermediate zone were calculated along the four section lines shown in Figure 3.10 and are summarized in Table 3.6. In general, hydraulic gradients ranged from 0.0026 ft/ft along Section Line C-C' to 0.00403 ft/ft along Section Line A-A'. Overall flow in the intermediate system is believed to be controlled by the gentle dip of the intermediate sand horizon which gradually thickens toward the west. The ultimate areas of discharge from and recharge to the intermediate system are not specifically known; however, inspection of Cross-Section A-A' (Figure 3.4) suggests the intermediate sands may approach land surface toward the east of the site, and this may be the likely zone of recharge to the intermediate system.

Comparisons were made between ground-water elevations collected in March 1992 and Cross-Section B-B' (Figure 3.5) to assess the hydraulic characteristics of the intermediate flow system and to determine if any hydraulic interaction was likely between the intermediate system and Target Pond. Intermediate Zone Wells SW-19, IW-3, VP-1, and IW-1 all exhibit potentiometric pressures which are clearly above the top of the intermediate sand unit even though the screened intervals of all four wells are completed within the intermediate zone (Figure 3.5). Pressures within the aforementioned wells indicate that the intermediate flow system is a confined flow system and that the overlying gray clay may be classified as an aquitard. A clear separation in heads is evident between wells completed in the upper shallow flow zone and those screened within the intermediate sand. Heads observed within wells actually completed in the gray clay (situated between the shallow and intermediate zones) are often at elevations between those observed for the shallow and intermediate flow systems. The

evidence that suggests that the shallow and intermediate systems are tenuously interconnected hydraulically includes:

1. A separation in ground-water elevations between shallow and intermediate zone wells;

2. The lithology of the intervening stiff, gray clay compared to the intermediate sands and shallow clayey silts and sands;

3. The vertical hydraulic conductivity of the gray clay is generally three to four orders of magnitude lower than that for the shallow silts, clays, and sands, and the intermediate sand horizon (see Section 3.5.2.2); and

4. The potentiometric pressures within wells completed in the intermediate zone are several feet above the top of the intermediate sand horizon and the top of the screened interval.

Therefore, based upon the evidence described above, the vertical hydraulic interconnection between the shallow perched system and the intermediate flow regime is not expected to be significant (see further discussion of gray clay layers in Section 3.5.2.1.6). Further, the comparatively low vertical hydraulic conductivity of the gray clay underlying Target Pond would suggest that little hydraulic interconnection would be expected between the wetland area and the intermediate flow system. Surface and ground-water elevation data collected during Phases I and II indicate Target Pond was a zone of discharge from the shallow system during the periods when observations were made.

3.5.2.1.4 Deep Flow System

Ground-water flow within the deep zone is generally toward the southwest as shown in Figure 3.11, which is consistent with the direction of flow identified previously by Techna during the Phase I Remedial Investigation. This differs somewhat from the flow direction differentiated previously during the preparation of the Final Technical Memorandum (flow to the southeast). This apparent discrepancy may be due to the limited number of data points in the deep flow system (only 3), questionable construction of well DW-1, and/or questionable location of the monitoring screen for well DW-3. The deep zone potentiometric surface is based on ground-water-level data collected from deep Monitoring Wells DW-1, DW-2, and DW-3 during the March 17, 1992 site visit. However, it is not certain whether DW-1 and DW-3 are actually screened within the "deep" zone. At Monitoring Well DW-1, the clay separating the deep and intermediate zones was penetrated during drilling and was not sealed during the construction of the monitoring well as illustrated in Cross-Section A-A' (Figure 3.4). Monitoring Well DW-3 may not be screened within the deep flow system but may actually be screened within a discrete lense of clayey sand interbedded within the clay underlying what has been previously regarded as the deep zone as shown in Cross-Section D-D' (Figure 3.7). A deep zone horizontal hydraulic gradient of 0.0047 was calculated along the Cross-Section A-A' shown in Figure 3.11.

Comparisons were made from the March 1992 water-level elevations collected from deep Wells DW-1, DW-2 and DW-3 to nearby intermediate zone Wells IW-2, IW-3, and IW-5 respectively. The ground-water elevations from these well pairs may be found in Table 3.5 but are presented below for clarity:

IW-2	DW-1	IW-3	DW-2	IW-5	DW-3
996.94	996.16	997.69	997.15	998.21	996.64

As the values above indicate, very little hydraulic head separation exists within intermediate/deep well pairs IW-2/DW-1 and IW-3/DW-2. While these data alone do not decisively demonstrate that the "intermediate" and "deep" systems are in fact one contiguous hydrostratigraphic unit, the water-level information taken in conjunction with lithologic data collected from site borings (particularly those west of the site) does suggest that some hydraulic communication may exist between the two systems. One exception to this observation is Well DW-3 which shows a clear separation in head of nearly 1.5 feet as compared to Intermediate Well IW-5. As mentioned previously, however, DW-3 is screened within a narrow lense of clayey sand which appears to be interbedded within the lower gray clay unit and, as such, may exhibit a ground-water elevation which is indicative of a more hydraulically isolated flow regime than those formerly identified as the "intermediate" and "deep" flow systems. When water-level elevations from Deep Wells DW-1 and DW-2 are added to the intermediate potentiometric surface map presented as Figure 3.10, the ground-water levels from these wells are in general agreement with the interpolated surface. It should be noted that, due to formation collapse up through the intermediate zone in the borehole within which DW-1 was installed, a seal may not actually exist in DW-1 which is adequate to preclude hydraulic communication between the intermediate and deep sands. Thus, results from this well should be regarded as suspect.

Thus, the data suggest that the intermediate and deep sand horizons may in fact be hydraulically interconnected, possibly in the area lying immediately west of the Hi-Mill Manufacturing facility (see Cross-Section A-A', Figure 3.4). As Cross-Section A-A' demonstrates, the upper gray clay layer which separates the intermediate and deep sand horizons appears to pinch-out somewhere between Hi-Mill Manufacturing and the M-59 median. This upper clay was not located during the drilling and profiling of VP-3 and IW-6. In addition, the head observed in Well DW-3 is likely reflective of pressures within a more discrete and hydraulically isolated layer of clayey sand and, as such, should not be used in conjunction with Wells DW-1 and DW-2 in the interpolation of flow within the deep sand horizon. The

potentiometric surface map of the deep sand presented as Figure 3.11 is provided for consistency but is not believed to accurately depict the distribution of hydraulic heads and flow directions within the deep sand unit. The actual distribution of ground-water elevations and flow directions within the deep sand horizon are anticipated to be consistent with those observed in the intermediate sand, owing to hydraulic communication between the two units. The source of hydraulic interconnection is believed to be caused by the contact or merging of the two sand units created by the "pinch-out" of the intervening lower gray clay layer. Some uncertainty does also exist with the seal in Well DW-1; hydraulic potential data collected from this well may reflect an averaging between heads in the intermediate and deep zones.

3.5.2.1.5 Vertical Hydraulic Gradients

Vertical hydraulic gradients were calculated from several well clusters located across the site; the results are presented in Table 3.7. Vertical gradients were calculated by dividing the difference in hydraulic head obtained from adjacent monitoring wells within a given cluster by the distance between the midpoints of the monitoring well screens. Vertical gradients were calculated between shallow and intermediate wells and intermediate and deep wells to determine potential vertical hydraulic interaction between each of the three water-bearing units. Calculated vertical gradients between the shallow zone and the intermediate sand were downward at all locations and ranged from 0.198 ft/ft at IW4A/SW4 to 0.313 ft/ft at IW5/SW14. The vertical gradient between the intermediate zone and the sand lens encountered at SW-2 was downward toward the intermediate sand horizon and estimated at 0.047 ft/ft. Vertical gradients between the intermediate and deep zones were similarly downward at all locations and ranged from 0.014 ft/ft at IW3/DW2 to 0.044 ft/ft at IW5/DW3. The only upward vertical gradient measured from the ırch water-level data was estimated at -0.022 ft/ft which was observed between wells con ed in the brown (shallow system) and the gray clay at the monitoring well cluster SW-9A/SW-9.

Despite the determination that head potentials do exist which could facilitate downward vertical flow between the shallow and intermediate flow systems, data on the vertical hydraulic conductivity of the intervening gray clay layers coupled with lithologic data collected from site borings suggest that actual flow between these units is not significant. Evidence does exist, however, which indicates that the formerly delineated intermediate and deep sand units are likely interconnected west of the Hi-Mill Manufacturing site and, as such, vertical hydraulic communication may occur. The upper gray clay unit separating the shallow and intermediate systems appears continuous across the bottom of the site as delineated from boring logs of exploratory holes completed on-site. Therefore, communication between the shallow and intermediate systems is anticipated to be restricted beneath the area of interest.

3.5.2.1.6 Potential Leakance Through Upper Gray Aquitard

Since the upper gray clay unit is believed to represent the hydraulic "bottom" of the shallow flow system, calculations of potential leakance through this zone were performed in order to assess the approximate rate at which impacts to the shallow ground water could potentially migrate downward into the intermediate system. The rate of vertical movement (e) through the upper gray clay was estimated using the equation:

$$e = k' \frac{(ho-h)}{b'}$$

where:
- k' = vertical hydraulic conductivity of the aquitard
- b' = vertical thickness of the aquitard
- ho = the hydraulic head in the aquifer above the aquitard
- h = the hydraulic head in the aquifer below the aquitard

The equation presented above is provided in Fetter (1980).

Leakance through the upper gray clay was estimated at two locations where vertical permeability data were available: IW-4A and IW-5. During the Phase I investigation, Techna (1990) collected one sample from the upper gray clay at IW-4A and IW-5 at depths of 40 feet below ground surface and 25 feet below ground surface respectively. The samples, designated IW-4AD and IW-5A, were tested for vertical hydraulic conductivity and other physical characteristics. To calculate the vertical leakance, those permeability estimates were used in conjunction with head data collected at shallow/intermediate well clusters SW-4/IW-4A and SW-14/IW-5 during March 1992; and the thickness of the upper gray clay at locations IW-4A and IW-5 as estimated from cross-sections C-C' and D'D', respectively (Figures 3.6 and 3.7). Presented below are the parameters used and the calculated leakance through the upper gray clay for locations IW-4A and IW-5:

Sample	k'(cm/sec)	b'(ft)	ho(ft msl)	h (ft msl)	e (ft/yr)
IW-4AD	1.4×10^{-6}	41	1006.34	998.03	0.29
IW-5	1.39×10^{-7}	22	1004.15	998.21	0.039

Therefore, based upon the leakance rates listed above, and the vertical thickness of the upper gray clay at each location, it would take approximately 139 years for water to move from the top of the aquitard to the bottom of the aquitard at location IW-4A, and approximately 564 years at location IW-5.

Therefore, based upon the results of the leakance calculations, geologic observations in the field, the difference in hydraulic heads between the shallow and intermediate flow systems, and the estimates of vertical hydraulic conductivity, it is reasonable to conclude that the upper gray clay does function as a confining aquitard between the shallow and intermediate flow zones. While leakage through the upper gray clay is possible, the rate at which this leakage could occur is comparatively slow. Additionally, no potential retardation of impacts moving through the

gray clay has been considered in these calculations, although retardation would undoubtedly occur. Thus, the leakance numbers presented previously may be regarded as conservative estimates. However, this observation is not intended to supplant the necessity of prompt remedial action within impacted portions of the shallow flow system.

3.5.2.2 Hydraulic Conductivity, Transmissivity, Storativity

Table 3.8 summarizes the horizontal hydraulic conductivities calculated from slug test data collected by Techna during the Phase I investigation. Hydraulic conductivities within the shallow flow zone ranged from 1.53 x 10^{-5} cm/sec at SW-8 to 2.25 x 10^{-3} cm/sec at SW-9A. Intermediate zone hydraulic conductivities ranged from 6.86 x 10^{-4} cm/sec at IW-1 to 1.09 x 10^{-2} at IW-2. Horizontal hydraulic conductivities within the deep zone ranged from 1.04 x 10^{-4} cm/sec at DW-3 to 2.20 x 10^{-3} at DW-2.

Horizontal hydraulic conductivities for the upper gray clay originally reported by Techna (1990) included tests from wells which, although screened in the upper gray clay, possessed sand packs which extended upward into the shallow flow zone. The only well for which a slug test was completed which appears to have been constructed entirely within the upper gray clay is well SW-11. Techna (1990) estimates the horizontal hydraulic conductivity of SW-11 at approximately 3.73 x 10^{-5} cm/sec (Table 3.8). It should be noted, however, that inspections of cross-section C-C' (Figure 3.6) indicate that the top of the sand pack of SW-11 is in close proximity to the contact between the upper gray clay and shallow flow zone. The integrity of the seal between the two units is unknown. Since examinations of lithologic logs from borings completed in the brown and upper gray clays suggest different hydraulic characteristics of the two units, slug tests performed in wells completed within both the brown and gray clay units may not necessarily provide reliable estimates of horizontal hydraulic conductivity in the upper gray clay. Rather, wells completed across both units may exhibit permeabilities more indicative of the transmissive silt and sand lenses in the shallow zone.

With regard to the potential transport of ground water impacts, the magnitude of hydraulic conductivity, storativity, and seepage velocity are of principal importance. Storativity was not measured at the site; however, values can be obtained from the literature, if necessary, for future investigations.

Soil samples were collected from several soil borings during the Phase I Remedial Investigation were submitted to McDowell and Associates for analysis of vertical permeability using a falling head permeameter test. The reported permeability results, depth, and lithology are summarized in Table 3.9. In general, the vertical permeability of the brown clay ranged from 7.46 x 10^{-8} cm/sec for sample SW-15C (depth of 11.5 feet below ground surface) to 1.05 x 10^{-7} cm/sec in sample SW-10C (depth of 5 feet below ground surface) with an overall average permeability estimated at 2 x 10^{-8} cm/sec. Vertical permeabilities of the upper gray clay were 1.4 x 10^{-6} cm/sec and 1.39 x 10^{-7} cm/sec at IW-4AD (40 feet below ground surface) and IW-5A (25 feet below ground surface), respectively, with an overall mean vertical permeability of 4.4 x 10^{-7} cm/sec. The intermediate sand possessed vertical permeabilities of 6.98 x 10^{-3} cm/sec and 1.14 x 10^{-2} cm/sec at IW-5C (35 feet below ground surface) and IW-1C (45 feet below ground surface), respectively and a mean permeability of 8.9 x 10^{-3}. The vertical permeability of the gray clay separating the intermediate and deep sands was found to range from 1.67 x 10^{-7} cm/sec for DW-3F (70 feet below ground surface) to 1.44 x 10^{-2} cm/sec for DW-3C (56 feet below ground surface) with an overall average vertical permeability of 5 x 10^{-3} cm/sec. Vertical permeabilities of the deep sand ranged from 2.41 x 10^{-5} cm/sec at DW-1P (80 feet below ground surface) to 8.24 x 10^{-3} cm/sec for sample DW-2K (86 feet below ground surface) with an overall estimated average of 3 x 10^{-3} cm/sec.

Based on the results of the laboratory-permeability analysis, the brown clay portions of the shallow zone and the upper gray clay separating the shallow and intermediate flow systems appear to possess relatively low intergranular vertical permeabilities of 2 x 10^{-8} cm/sec and 4.4

x 10^{-7} cm/sec (means), respectively. The lower gray clay possesses a vertical permeability significantly higher than what was measured in the upper gray and brown clays. Vertical hydraulic communication between the shallow zone and intermediate sands is anticipated to be tenuous, while interaction between the intermediate and deep zones is expected to occur.

Vertical hydraulic conductivities have been used to characterize the relative potential of various aquitards to transmit ground water from one flow system to another. Similarly, leakances for the upper gray clay horizon were determined using vertical permeabilities determined from laboratory tests performed on samples collected from this unit (see Section 3.5.2.1.6). While it is true that laboratory estimates of hydraulic conductivity can produce somewhat erroneous results if not performed carefully, it is also true that in-situ hydraulic conductivities as determined using slug tests are often subject to misleading results due to the effects of the sand pack, near borehole phenomena such as wellbore storage and skin effects, and the limited "stress" often exerted on the formation (i.e., low driving head). In addition, the slug tests conducted at the site were intended to measure horizontal and not vertical hydraulic conductivity. Vertical hydraulic conductivity is often considerably different than horizontal hydraulic conductivity (often lower) and, as such, care must be exercised when attempting to extrapolate horizontal permeability in determinations of strictly vertical flow (in this case leakance). Thus, the best data available for the determination of potential leakage characteristics of the site confining layers are the vertical hydraulic conductivities determined from laboratory tests of site soils.

3.5.2.3 Ground-Water Flow Velocities

Ground-water seepage velocities were calculated using the previously determined horizontal hydraulic gradients presented in Table 3.7 and the geometric means of the hydraulic conductivity estimates (Table 3.8) for the shallow, intermediate, and deep flow zones. A range

of ground-water seepage velocities was calculated by varying the effective porosity from 3 percent to 28 percent for the shallow zone, 10 percent to 35 percent for the intermediate zone and deep zone. The effective porosity ranges were determined from tables provided in Fetter (1980, pg. 68). Specific yields were used since specific yield is essentially equivalent to effective porosity. The minimum value for fine sand and the maximum value for coarse sand were used to define the range for the intermediate and dry zones, while the minimum value for silt and maximum value for fine sand were used for the shallow zone. Effective porosities were selected based upon the material types and grain sizes observed for each stratigraphic unit. Seepage velocities were calculated for each horizontal hydraulic gradient line depicted in Figures 3.1, 3.10, and 3.11 using the equation:

$$Vs = (K/ne)(dh/dl)$$

where:
- Vs = seepage velocity;
- K = horizontal hydraulic conductivity;
- ne = effective porosity; and,
- dh/dl = horizontal hydraulic gradient.

Since ground-water flow is actually 3-dimensional, the calculated values of seepage velocity (and horizontal hydraulic gradient) are actually idealized velocities in a 2-dimensional horizontal plane. Estimates of seepage velocity do, however, provide a reliable approximation of the rate of transport of a conservative solute (i.e., retardation = 1; e.g., chlorine) downgradient from a potential source area.

A summary of ground-water seepage velocities for each section line is presented in Table 3.10. In the shallow zone, assuming an effective porosity of 3 percent, seepage velocities varied from 0.043 ft/day to 2.193 ft/day and from 0.005 ft/day to 0.235 ft/day using an effective

porosity of 28 percent. Intermediate zone seepage velocities ranged from 0.186 ft/day to 0.288 ft/day using a 10 percent effective porosity and from 0.053 ft/day to 0.082 ft/day using a 35 percent effective porosity. Within the deep zone, the seepage velocity was 0.031 ft/day for a 10 percent effective porosity and 0.009 ft/day using an effective porosity of 35 percent.

Seepage velocities were somewhat higher in the shallow zone as compared to the intermediate zone although hydraulic conductivities within the intermediate sands were generally higher. This phenomenon is due in part to higher horizontal gradients in the shallow zone as compared to the intermediate zone, which are created by the area behind the Hi-Mill Manufacturing plant which is believed to serve as a point of recharge to the shallow system. Most of the flow within the shallow zone is anticipated to occur within comparatively narrow lenses of higher permeability material such as sands, silty sands, and clayey silts and not within the brown clay itself.

3.5.2.4 Ground-Water Elevation Fluctuations

Presented in Appendix K are composite well hydrographs for the site monitoring wells and piezometers for ground-water data collected in December 1991, and within the first six months of 1992. Annual maximum and minimum potentiometric surface elevations for the shallow, intermediate, and deep zones are not available because a year of ground-water-level data have not yet been collected for a complete year. In general, each monitoring well and piezometer shows an increase in ground-water elevation from January through April and a decrease following the months of May and June, with peaks occurring during the spring. The increase in ground-water elevation is likely the result of spring rains and snowmelt. End-of-the-year data are not yet available so the complete annual cycle of ground-water fluctuations cannot be assessed at this time. After ground-water-elevation data for a full year have been collected, direct comparisons can be made with precipitation data collected for the same time period in order to positively confirm this correlation.

The elevation of the potentiometric surfaces of all three flow systems demonstrates more or less consistent fluctuation patterns over time relative to one another. Some time lag is evident between the peaks and lows in the hydrographs of the deep wells as compared to similar fluctuations in the shallow zone wells. Although not obvious in all cases, this time lag is likely related to minor differences in recharge rates to the two systems. In general, however, the data suggest little temporal variation in recharge to and discharge from the three previously identified flow regimes, suggesting that recharge to the shallow, intermediate, and deep zones is not significantly affected by stratigraphic changes with depth or low vertical permeabilities. When considering the stratigraphy and low vertical permeabilities of the intervening brown clay and upper gray clay horizons, the well hydrographs may suggest a more surficial source of recharge to the intermediate and deep systems. Extrapolation of the intermediate sand unit to the east of Hi-Mill Manufacturing indicates that this layer approaches the surface and may gain surficial expression to the east of the site. This, then, could provide an explanation for the relatively consistent changes in potentiometric pressures in the intermediate sands as compared to the shallow zone.

Further delineation of diurnal (i.e., daily or hourly) variations in the response of each flow system to precipitation events would require continuous daily measurement of ground-water elevations in wells completed in each of the three flow systems. Such tedious monitoring is not believed to be necessary, however, since the behavior of the site flow systems relative to variations in recharge may be adequately defined (relative to the investigation objectives) using the existing monthly monitoring program.

3.5.2.5 Conceptual Ground-Water Flow Model

Presented in this section is a summary of the interpretations of ground-water flow within the flow regimes underlying the Hi-Mill Manufacturing site (a conceptual flow model). The

conceptual flow model incorporates the geologic and hydraulics data collected during both the Phase I and II Remedial Investigations.

A total of five site-specific hydrostratigraphic units has been delineated beneath the Hi-Mill Manufacturing site as a result of the findings of the Phase I and II investigations. The seven stratigraphic units defined from geologic interpretations of boring log data (see Section 3.4.2) have been grouped in accordance with their hydraulic properties in order to define appropriate hydrostratigraphic units which accurately characterize the dynamics of the subsurface flow system. The characteristics of the five hydrostratigraphic units are summarized below:

1. Shallow "Discontinuous" Flow Zone - This unit comprises the upper 10 feet of the subsurface at the Hi-Mill Manufacturing site and generally consists of thin, interbedded layers of brown variegated clay, topsoil, fine sand, silt, clayey silt, and silty clay. The preponderance of flow within this zone is thought to take place within saturated seams of sand, silt, and clayey silt. The mean horizontal hydraulic conductivity of the shallow zone has been estimated at about 2×10^{-4} cm/sec while the mean vertical hydraulic conductivity of the brown clay portions of the unit is approximately 2×10^{-8} cm/sec. Additionally, dry holes advanced during the Phase II investigation are believed to have been completed in the brown clay in areas relatively devoid of transmissive silt and sand seams. This suggests little lateral or vertical flow through the brown clay "matrix" of this horizon. Ground water in this zone flows radially and away from the rear of the Hi-Mill Manufacturing facility, which is believed to represent the main area of recharge to the shallow system owing to the presence of extensive fill material, the presence of the factory septic field, and the preponderance of paved areas around the Hi-Mill Manufacturing facility. Discharge from the shallow system is believed to occur through narrow permeable layers into neighboring Target

Pond and Waterbury Lake as well as the wetland areas lying west of the facility in the Highland State Recreation Area. The shallow zone is best classified as a "discontinuous" phreatic flow system.

2. Upper Gray Clay Aquitard - This unit immediately underlies the shallow "discontinuous" flow zone and ranges from approximately 15 feet to 40 feet in thickness. The upper gray clay appears continuous across the site and represents the hydraulic "bottom" of the shallow flow zone. The upper gray clay generally consists of stiff, blue/gray clay which may contain sand and silt varves indicative of a lacustrine depositional environment. Falling head permeameter analysis of samples collected from the gray clay indicates an overall geometric mean of vertical hydraulic conductivity of about 4×10^{-7} cm/sec. A clear separation in hydraulic potential exists between wells completed in the upper gray clay and those observed in both the overlying shallow flow system and underlying intermediate sand. Vertical hydraulic communication through the gray clay is expected to be tenuous at best based upon low vertical hydraulic conductivity estimates, geologic classification, and determinations of potential leakance.

3. Intermediate Flow Zone - The intermediate sands immediately underlie the upper gray clay and range in thickness from about 25 feet to 30 feet across the site. The intermediate zone chiefly consists of medium-to-coarse-grained outwash sands and fine gravels, which grades to the south and west into a fine silty sand. The geometric mean of horizontal hydraulic conductivity for this unit has been estimated at approximately 3×10^{-3} cm/sec, while the overall mean value of vertical hydraulic conductivity has been estimated at about 9×10^{-3} cm/sec. Comparisons of the horizontal and vertical hydraulic conductivities indicate that this layer is relatively isotropic in hydraulic character but possesses some lateral

heterogeneity. Hydraulic heads within the intermediate zone are generally lower than nearby wells completed within the shallow zone and are not significantly different from wells completed within the deep sands. Hydraulic potentials within intermediate zone wells are usually above the elevation of the upper gray clay. Despite ground-water mounding in the shallow zone attributed to recharge occurring in the area behind the Hi-Mill Manufacturing plant, no such similar mounding effects are evident within the intermediate zone system probably due to the poor hydraulic communication across the upper gray clay. The intermediate zone is best classified as a confined aquifer system. Flow within the intermediate system is generally toward the west.

4. Lower Gray Clay Aquitard - Bounding the bottom of the intermediate flow zone is another stiff, blue/gray layer believed to serve as a partial aquiclude/aquitard between the intermediate and deep sands. The lower gray clay ranges in thickness from less than 1 foot up to about 25 feet. The lower gray clay pinches-out to the south and west promoting hydraulic and physical contact with the deep sands and thickens to the east providing some hydraulic interference with the intermediate flow zone. No wells were completed exclusively in the lower gray clay; however, samples analyzed for vertical hydraulic conductivity yielded an overall mean value of approximately 5×10^{-3} cm/sec, even though some locations possessed vertical permeabilities on the order of 10^{-7} cm/sec (samples collected from thicker zones). Vertical hydraulic communication between the intermediate and deep sands is anticipated to occur to the south and west where the lower gray clay pinches-out and in those areas where the clay is relatively thin.

5. Deep Flow Zone - The deep flow zone underlying the lower gray clay ranges from approximately 5 feet to 20 feet in thickness beneath the site and principally consists of outwash sands similar to the intermediate zone sand horizon. The mean horizontal hydraulic conductivity of the deep sands (not including DW-3)

was estimated at about 9 x 10^{-4} cm/sec, and the vertical hydraulic conductivity was estimated at about 3 x 10^{-3} cm/sec. These results suggest little anisotropy in the deep sands and some minor lateral heterogeneity. The deep zone appears to merge with the intermediate zone sands to the west and south of the site in areas where the lower gray clay pinches-out. Well DW-3 intersects a gray clayey sand which is wholly dissimilar to both the intermediate and deep horizons. This gray clayey sand is interbedded within the lower gray clay unit and exhibits a hydraulic potential which is inconsistent with both the intermediate and deep systems that are both similar to one another. Hydraulic potentials measured within DW-1 and DW-2 are generally consistent with potentials observed within the intermediate system; however, it should be noted that some doubts exist as to the adequacy of the well seal in DW-1. When assessed in conjunction with the intermediate zone wells (i.e., DW-1 and DW-2) and the lithologic data available on the lower gray clay, the deep system flow is probably in a direction which is more or less concurrent with the intermediate zone. In the previous Phase I Remedial Investigation Report, the deep system was analyzed using all three wells, and the overall flow direction was thought to be toward the south. The deep flow zone may be characterized as a leaky, confined aquifer in areas where the lower gray clay is present or, on a larger scale, may be defined in conjunction with the intermediate sands as a large confined aquifer that is interbedded with a thick layer of gray clay.

In addition to the hydrostratigraphic units described above, several other conclusions may be drawn with respect to flow at the Hi-Mill Manufacturing site. An itemized list of conclusions along with interpretations developed in response to several questions raised as a result of the Phase I Remedial Investigation follows:

1. Surface-Water/Shallow Ground-Water Interactions - Examinations of the shallow zone phreatic surface and geologic boring logs suggest that Target Pond, Waterbury Lake, and the North Arm are local discharge zones for shallow ground water through the narrow, permeable lenses of silt, sand, and clayey silt present within the shallow flow system. In general, no recharge to the shallow system from the surface waterbodies is evident, except possibly near SG-5 (entrance to Alderman wetland) where large volumes of stormwater discharged at this location may supply some recharge to the shallow flow system. However, this recharge is believed to be slight since ground water data, collected at times when the surface elevation at SG-5 was above the shallow water table elevation, indicates no change in overall ground-water flow directions. Most of the discharge near SG-5 is expected to flow down the surface channel, following the path of least resistance. The presence of the low permeability upper gray clay, and bottom sediments would appear to preclude any significant hydraulic interaction between the local surface water and the intermediate flow system. Target Pond in particular appears to be perched above the top of the gray clay. It should be noted that water from Target Pond may flow through a portion of the shallow zone into Waterbury Lake just southeast of the site. Thus, it is possible very limited recharge to the shallow system from Target Pond occurs with the ultimate discharge zone being Waterbury Lake. It is also true, however, that several piezometers completed between the two waterbodies in this location were found to be dry.

2. Vertical Gradients and Flow - Vertical gradients at select well clusters indicate that the hydraulic potential between the shallow and intermediate zones and the intermediate and deep zones is generally downward. The lenses of brown variegated clay present in the shallow zone and primarily the upper gray clay

layer, however, preclude significant vertical flow between the shallow and intermediate systems. Evidence for this conclusion are the artesian heads observed in intermediate zone wells (i.e., heads are above the gray clay), the relatively low vertical hydraulic conductivity of the gray clay, the absence of comparable mounding effects (found in the shallow zone) in the intermediate zone, the comparatively low leakage rates of the upper gray clay, and the distinct difference in horizontal hydraulic gradients and flow directions between the intermediate and shallow systems. The lower gray clay, however, was found to thin and then pinch-out to the south and west of the Hi-Mill Manufacturing site. The lower gray clay unit is believed to only locally inhibit hydraulic communication between the intermediate and deep zones where the unit is thickest. Full hydraulic communication between the two flow zones is anticipated to the west of the site where the sands come in contact with one another due to the absence of the lower gray clay. Evidence for the hydraulic interaction of the intermediate and deep horizons includes the similarity in hydraulic potentials for the intermediate and deep systems (except for well DW-3), the thinning of the gray clay toward the west (which results in higher vertical permeabilities), and the total absence of a separating aquiclude to the south and west of the Hi-Mill Manufacturing facility. The rather anomalous hydraulic potential exhibited by Well DW-3 is believed to be due to the fact that this well was screened within a lithologically dissimilar and isolated lense of gray clayey sand which is actually interbedded within the lower gray clay and is not part of either the deep or intermediate systems.

3. Recharge To and Discharge From the Site Flow Regimes - The principal area of recharge to the shallow flow system is believed to occur locally in the low, flat lying area adjacent to the rear of the Hi-Mill Manufacturing facility. Ground-

water mounding is evident in this area based upon inspection of the shallow system phreatic surface. In addition, the abundance of paved areas around the site and the local topography suggest that the locale behind the Hi-Mill Manufacturing plant may be the only potential surficial source for recharge to the shallow flow zone. Areas of recharge to the intermediate and deep flow zones are less certain; however, examinations of the geologic cross sections constructed from boring log data indicate that the intermediate and deep sand units may merge with the ground surface to the east of the site. This may suggest that a possible zone of recharge exists in this location. Discharge from the shallow system is believed to occur at the nearby surface waterbodies of Target Pond, Waterbury Lake, and the North Arm, as well as at the wetland areas located west of the site. Some recharge to the shallow ground-water flow system may occur at the channelway supplying water to Alderman wetland near gauge SG-5. Surface water at this location is likely chiefly derived from stormwater runoff intercepted in the M-59 median and discharged near SG-5 at a drain pipe. It is possible that heavy precipitation events could raise the elevation of the surface water in Target Pond to a level which is higher than the adjacent shallow water table, thus resulting in recharge to the shallow system. However, data collected during Phase I and II indicates this has not occurred during the period of the site investigations. The ultimate discharge locations of the intermediate and deep zones are unknown; however, the two flow systems likely merge to the west and south of Hi-Mill Manufacturing.

4. Overall Horizontal Ground-Water Flow - Flow in the shallow flow zone is generally radial and away from the Hi-Mill Manufacturing facility and is controlled by a ground-water high situated near the ground surface and below the area immediately adjacent to the rear of the site building. Horizontal gradients

in the shallow system steepen toward adjacent Target Pond and Waterbury Lake; discharge to these surface waterbodies likely occurs in the thin, permeable seams of sand, silt, and clayey silt found interbedded with the brown variegated clay. Little flow through the "matrix" of brown clay is expected. Some shallow flow also occurs to the west across M-59. The general direction of ground-water flow in the intermediate system is toward the west and appears to follow the dip of the intermediate sand unit. The originally interpolated flow direction of the deep unit was toward the south; however, a subsequent re-examination of the well construction and boring logs of Wells DW-1, DW-2, and DW-3 suggests that Well DW-3 is completed in a hydraulically isolated and lithologically distinct lens of gray clayey sand interbedded within the lower gray clay. Hydraulic potentials for DW-1 and DW-2 appear consistent with those observed in adjacent intermediate zone wells and, as such, the deep zone flow direction is expected to be similar to that of the intermediate zone. Borings completed west of Hi-Mill Manufacturing on the other side of M-59 suggest that the intermediate and deep sand units merge due to the pinch-out of the lower gray clay layer.

5. Ground-Water/Climate Interactions - Monthly data obtained from the National Oceanic and Atmospheric Administration (NOAA) from 1987 through 1990 have been compiled and discussed in a previous section. Daily measurements of climatological data have also been compiled from NOAA records for 1991. While little correlational ground-water and weather data are available because regular monthly site water levels have only been collected since December 1991, the ongoing ground-water monitoring data will be compared to and analyzed with 1992 climate data once a full year of ground-water elevations and weather information have been completed. However, peaks and lows in the 1992 well hydrographs generally occurred at the times corresponding to wet and dry seasons of the year observed in the climatological data available for the period 1987 through 1991. Ground-water fluctuations in all three flow regimes were found

to be relatively consistent with one another, and no distinct diurnal time lag was observed between differing sets of flow zone monitoring wells. Fluctuations in all three systems are anticipated to be primarily influenced by climatologic events, with spring rains and snowmelt resulting in ground-water highs and the dry season causing drops in the three potentiometric surfaces. Since the observed water-level fluctuations in all three flow regimes are similarly timed, it is believed that recharge to each flow system is likely to occur at or near the surface further suggesting that the intermediate and deep sand units must approach or fully intersect the land surface somewhere east of the study area.

6. Relationship Between Target Pond and Waterbury Lake - Although several dry piezometers were installed within the shallow flow system, enough viable data is available (along with staff gauge data) to interpret the hydraulic relationship between these two surface waterbodies. There does not appear to be any surface flow between Target Pond and Waterbury Lake, although some flow may be possible through a portion of the shallow flow system located southeast of the site. The ground-water high to the rear of the Hi-Mill Manufacturing plant appears to exhibit the main control over the shallow system. It should be noted, however, that several piezometers completed between Target Pond and Waterbury Lake in the zone of potential ground-water communication between the two waterbodies were found to be dry. Flow from this zone is generally radial and away from the facility toward Target Pond and Waterbury Lake.

The characteristics of the conceptual hydrogeologic flow model presented above will be integrated with information on the nature and extent of contamination in Section 5.0 to define the potential fate and transport of ground-water and surface-water impacts. Data gaps identified during the assessment of the Phase I and II Remedial Investigation investigations of the site

ground-water flow systems will be addressed in section 6.0 which presents the summary and conclusions of the Phase I and II studies along with recommendations for future work.

3.5.2.6 Uses of Aquifers

Figure 3.12 depicts the approximate locations of the water supply wells located within a 1-mile radius of the site. The water supply well locations are based on the driller's logs obtained from Michigan Department of Public Health (MDPH). In general, the water supply wells are screened in a range of depths from approximately 40 feet to 120 feet below ground surface (i.e., below the brown clay in the intermediate and deep flow systems). However, several wells are screened in a shallower horizon (i.e., upper intermediate zone) and several others are screened deeper within the glacial materials (i.e., gravel layers below deep flow zone or weathered bedrock horizon). The water supply wells are primarily used for domestic household purposes. Three of the logs indicated that the wells were used for public water supply and several others were used for commercial purposes. None of the wells appears to have been completed in the upper shallow zone, as the shallowest well was completed about 32 feet below ground surface in a "water-bearing sand" zone.

3.6 PAST AND PRESENT LAND USE

This section presents a discussion of the past and present use of the property on which the Hi-Mill Manufacturing facility is currently located as well as the property adjoining the Hi-Mill Manufacturing site. Also provided is a description of processes and activities which may have resulted in impacts to the ground water, surface water, and soil on both the Hi-Mill Manufacturing property and adjacent areas.

The Hi-Mill Manufacturing facility is approximately 4.5 acres and is located along state route M-59 in Highland Township, Oakland County, Michigan. The plant building was completed and went into operation sometime in 1946. Prior to that time, the property and much of the surrounding land were rural and largely undeveloped as it is currently. Since its inception, Hi-Mill Manufacturing has engaged in the fabrication of copper, aluminum, and brass-tubing parts and fittings commonly used in the refrigeration and general appliance industry. The site factory has been expanded several times since the original construction.

Presented in Figure 3.13 are the locations of both current and previous commercial operations in relation to the existing Hi-Mill Manufacturing facility. Examinations of historical photographs and aerial photographs as well as interviews with Hi-Mill Manufacturing employees confirm that a service station was formerly located northwest of the existing Hi-Mill Manufacturing offices in the vicinity of what currently constitutes the M-59 median (Figure 3.13). Hi-Mill Manufacturing purchased the service station after it ceased operations and used the property temporarily to store raw materials used in its manufacturing operations. Hi-Mill Manufacturing traded this parcel of land to the MDNR for property located adjacent to the southwest portion of the Hi-Mill Manufacturing property (Figure 3.13). This allowed Hi-Mill Manufacturing to expand its existing production facilities. The MDNR later relinquished a portion of the former service station property for the construction of the existing four-lane M-59 highway and median.

A small private airfield was previously located on the same side of M-59 and southwest of the Hi-Mill Manufacturing factory (Figure 3.13). The existence of the airfield was confirmed by examinations of aerial photographs taken in 1978. Remnants of the old airfield were still evident in photographs taken in 1985. The airfield was later acquired by the MDNR and incorporated into the Highland State Recreation Area which now envelopes the Hi-Mill Manufacturing site.

Currently, no other manufacturing or commercial enterprises are located within the vicinity of Hi-Mill Manufacturing with the exception of Numatics Inc, a manufacturer of small parts used in air control valves. Numatics is located approximately 1000 feet northeast of Hi-Mill Manufacturing along M-59 (Figure 12). As mentioned previously, Target Pond is located between the Hi-Mill Manufacturing and Numatics plants.

The nearest residences are located approximately 2000 feet east-southeast of the Hi-Mill Manufacturing facility along Waterbury Road. The property located north-northwest of Hi-Mill Manufacturing across M-59 is owned by the MDNR and is part of the Highland State Recreation Area. In general the area is very sparsely populated.

Known impacts on the local ground water, surface water, and soil may potentially be explained by the activities of several of the past and current property owners located within the Hi-Mill Manufacturing study area. Processes used within the Hi-Mill Manufacturing facility which are of possible concern include the former or current use of nitric and sulfuric acid-brightening solutions, chromic-acid washing, and the degreasing of parts using chlorinated solvents. As discussed in Section 1.2.2, process waters which may have contained diluted acid-brightening solution were formerly discharged into two lagoons located behind the Hi-Mill Manufacturing factory. The lagoons were subsequently excavated and removed in 1983. From 1981 to 1988, a wastewater recycling system replaced the evaporation lagoons. The recycling system consisted of the recycling of rinse waters and the storage of non-recyclable wastewaters in two 1600-gallon concrete underground storage tanks. The wastewater stored within the USTs was neutralized and shipped to a permitted hazardous waste disposal facility. Acid-brightening activities ceased in the fall of 1988. The use of degreasing fluids containing TCE, however, has continued. TCE is utilized inside the Hi-Mill Manufacturing factory in two degreasers used to clean tubular parts following machining. An existing external aboveground 1000-gallon TCE storage tank is present on the southwest end of the building. An aboveground 250-gallon TCE

storage tank, now removed, was formerly situated at the northeast end of the factory. Historically, a pair of aboveground 500-gallon TCE storage tanks were located in the present drum storage area. These storage tanks were moved to the southeast corner of the building in 1973 when the shipping and warehouse area and drum storage area were constructed and remained in operation until 1980.

In addition to potential impacts associated with Hi-Mill Manufacturing, ground-water chemistry data are available that indicate that activities at the former service station previously located on M-59 have resulted in impacts to the ground water and soils within the study area. Activities at the service station that may be of significance include the storage of petroleum-based fuels such as gasoline, the cleaning of automotive parts, and the discharge of waste oil, grease, and other cleaning solutions associated with various repair and service procedures. Anecdotal information on the service station indicates that the UST used for the storage of fuel was punctured during the decommissioning procedure.

A hydrogeologic investigation conducted at the nearby Numatics facility indicates that process waters containing metals have been generated and discharged by Numatics, Inc. Cutting oil is or has been reportedly used at the Numatics plant as are or have been acid-based cleaning solutions. In a report prepared by Keck Consulting Services entitled "Results of Preliminary Hydrogeologic Study, Highland Precision Plant, Section 23, Highland Township, Oakland County, Michigan" (February 1987) on page 5 it is reported that an analysis of soils in the south drain field indicated "significantly high levels of total chromium, total nickel, and hexavalent chromium." Activities at the Numatics facility may have resulted in impacts within the Target Pond/wetland area and on the ground-water flow system because compounds of concern appear to have been discharged by Numatics into a septic field adjacent to the facility, and because the prevailing shallow system phreatic surface (Figure 3.1) suggests that Target Pond is downgradient of Numatics. The full range of compounds and processes employed within the Numatics facility is not known.

Although no specific data are available on the potential impact of the former airfield, there may or may not have been activities conducted on this property that may have impacted local ground water, surface water, or soils. Potential impacts could have arisen from the storage of fuel and/or the repair and maintenance of aircraft.

The results of the investigations into the distribution of chemical compounds within the Hi-Mill Manufacturing study area, and the delineation of potential sources will be discussed in greater detail in Section 4.0.

3.7 ECOLOGY

An Ecological Inventory/Assessment was completed based on information collected by Techna, Geraghty & Miller, and The University of Michigan (Appendix R). Earlier this year, a preliminary draft of the Ecological Inventory/Assessment was submitted to the Quality Assurance Section of the U.S.EPA. To date, no comments have been received by Geraghty & Miller.

The results of the information collected have been interpreted holistically to provide information as to potential terrestrial and aquatic impacts from the activities at the Hi-Mill Manufacturing facility. This section provides a summary of the results and recommendations for further investigation.

3.7.1 Summary of Results

Previous investigations indicated that elevated levels of selected inorganic constituents may be present in surface water and sediment near Hi-Mill Manufacturing. Adverse impacts to the benthic community of Target Pond and trees adjacent to Hi-Mill Manufacturing were

alleged. Information from the 1990 samples of surface water collected from Target Pond was used to assess impacts. These previous results were also used to direct a focused investigation in 1991. Three major activities were conducted in 1991. First, terrestrial and aquatic surveys were completed to assess potential impacts to the flora and fauna. Second, a literature survey was conducted to determine if information was available on the impacts of inorganic constituents on trees. Third, an evaluation of the sediment was completed to determine if the sediment was toxic to a test organism. The physical and chemical characteristics of the sediment were also completed. The conclusions from these activities are summarized in the following subsections.

3.7.1.1 Surface-Water Chemistry

An analysis of surface water samples indicated that natural conditions in Target Pond are different than the background locations. Samples from Target Pond contained higher concentrations of major ions (Al, Ca, Fe, Mg, Mn, K, and Na) and exhibited higher conductivity. It is unlikely that activities at Hi-Mill Manufacturing produced the differences since none of the compounds listed above can be readily associated with the manufacturing process, except for aluminum. These differences probably reflect different land use or soils within the respective watersheds or occur naturally in native soils.

The levels of copper, nickel, and silver in Target Pond were above MDNR Rule 57(2) guidelines. The difference in maximum copper concentrations between Target Pond and the background samples was less than the analytical precision of the laboratory. The maximum concentration of nickel in Target Pond was higher than the background pond; however, this difference was the result of an undetermined bias in analyzing the short list inorganics. The full TAL results do not indicate a difference in nickel levels. The maximum level of silver was higher in the background pond.

The detection of dissolved inorganic constituents in the waters of Target Pond may be due, in part, to former processing activities at the adjacent Hi-Mill Manufacturing facility. However, an inspection of several MDNR reports suggests that the nearby Numatics, Inc. property, located about 800 feet northeast of Hi-Mill Manufacturing, may also act as a potential source of metals to Target Pond since process wastewater is discharged by Numatics into a septic drain field located behind the site building.

3.7.1.2 Ecological Inventory

A terrestrial survey of flora and fauna did not indicate the presence of adverse impacts related to activities at Hi-Mill Manufacturing. Dead trees were observed east of Hi-Mill Manufacturing and at several other locations in the area. Considering the distribution of these dead trees, it is unlikely that activities at Hi-Mill Manufacturing caused their deaths. The size and age of the dead trees near Hi-Mill Manufacturing were not different from a control group.

The aquatic survey did not indicate adverse impacts related to Hi-Mill Manufacturing. Target Pond supported a more numerous and taxonomically diverse assemblage of phytoplankton than the control site. The number of zooplankton in Target Pond was larger and the taxonomic diversity similar to the control site. A diversity of benthic macroinvertebrates was recovered from Target Pond, however, the control site was devoid of these organisms.

The USFWS and MDNR reported that threatened or endangered species are not located within one mile of Hi-Mill Manufacturing.

3.7.1.3 Literature

Two literature surveys were completed and several references were reviewed to determine if they contained information similar to the situation at Hi-Mill Manufacturing. None of the

references contained information that might be useful in evaluating the impacts of inorganics to trees.

3.7.1.4 Sediment Chemistry

The 1990 results indicated that, statistically compared to background, higher levels of aluminum occurred at all of the sampling locations in Target Pond and higher chromium and copper occurred at selected sites. The 1990 results also indicated that the concentration of inorganic constituents was higher in the surficial sediment samples.

The 1991 results indicated that aluminum, barium, chromium, copper, magnesium, and zinc in Target Pond were statistically above background. The percentage solids were higher in Target Pond and the pH and temperature were lower in Target Pond. It should be reiterated that just because a constituent is detected in the sediment does not necessarily mean that it is biologically available and toxic to indigenous organisms. The sediment toxicity tests were used as an indication of this bioavailability and toxicity.

Like the dissolved metals found in the Target Pond surface water, the metals found in the sediments may have their origins in activities at the Hi-Mill Manufacturing site or the adjacent Numatics facility.

3.7.1.5 Sediment Toxicity

The survival of Hyalella was significantly reduced relative to controls in only one sediment sample from Target Pond (TP08). This reduction was likely caused by lower pH or lower percentage solids. A statistically significant relationship existed between sediment toxicity and chromium levels; however, this relationship was not as strong as the pH and percentage

solids of the sediments. For details related to the findings of the Ecological Assessment/Inventory, please refer to Appendix R.

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 SOURCES

The following sections contain a detailed description of potential contaminant sources identified during the numerous field investigations conducted at the Hi-Mill Manufacturing site, historical information obtained from Hi-Mill Manufacturing and other sources, and a physical inspection of the site. Volatile organic sources identified at the site include the aboveground TCE storage tanks and associated filling operations, parts degreasers and associated piping, the accidental release of TCE during the construction of Addition #4, underground heating oil storage, and USTs and service activities associated with a gasoline service station located northwest of the Hi-Mill Manufacturing facility. Inorganic sources include the abandoned wastewater recycling system, the evaporation lagoons located at the rear of the facility, and discharges to Target Pond and the surrounding area resulting from direct releases and dispersal from the evaporation lagoons. Potential off-site sources of inorganics and volatile organics include Numatics Inc. located approximately 1,000 feet northeast of the Hi-Mill Manufacturing site and the former gas station located northwest of the site in the existing M-59 median.

Potential sources involving on-site and off-site USTs can be addressed under CERCLA since CERCLA is concerned with the impact of any contaminant on human health and the environment. Petroleum products associated with USTs could be addressed under CERCLA using cleanup criteria for petroleum-related constituents from other regulatory programs such as ARARs. Additionally, in the case of the former service station, other activities associated with parts degreasing and automotive repairs could have resulted in non-petroleum impacts to the soils and shallow ground-water flow system.

4.1.1 Underground and Aboveground Storage Tanks

Presently, there are no operating UST systems on the Hi-Mill Manufacturing site. However, an abandoned 10,000- gallon capacity #2 fuel oil UST and an abandoned 1,600-gallon capacity wastewater holding USTs are located beneath or near the administrative offices of the Hi-Mill Manufacturing facility (Figure 4.1). The operation of the fuel oil UST was discontinued in 1980 and abandoned by Hi-Mill Manufacturing. The wastewater UST was a component of the wastewater recycling system that was used between 1981 and 1988. The wastewater USTs were constructed of concrete and received non-recycled process wastewaters that were neutralized with caustic soda and shipped approximately every two months to a hazardous waste facility. Laboratory analysis of fluids contained within the wastewater UST detected arsenic, barium, cadmium, trivalent and hexavalent chromium, silver, copper and zinc. The wastewater recycling operation was ceased in 1988 when Hi-Mill Manufacturing terminated all production activities that generated inorganic-bearing wastewater.

Since 1986, an aboveground TCE storage tank, located on the southwest edge of the production building, has been in use at the Hi-Mill Manufacturing site (Figure 4.1). TCE is transferred to degreasing units within the facility via underground piping.

Between 1970 and 1988, a second 250-gallon aboveground TCE storage tank was located near the northeast edge of the production building (Figure 4.1). Underground piping connected the TCE storage tank to a degreaser located in the northeast section of the production facility. According to Hi-Mill Manufacturing personnel, during the construction of an addition to the northeast side of the facility (Addition #4) between 1978 and 1980 (exact date unknown), the underground piping connecting the degreaser to the TCE storage tank was damaged by the construction contractor. The next day the tank was found empty even though the tank had recently been filled and, as such, a maximum volume of 250 gallons of solvent was lost. The

following day the damaged underground piping was replaced with aboveground piping. The original tank, degreaser and associated piping were removed and properly disposed of during the summer of 1988.

Historically, two 500-gallon aboveground TCE tanks were also located in the present oil drum storage area until this area was enclosed in 1973. Then the tanks moved to a location near the southeast corner of the facility. One of the degreasers which is currently in use was moved to the present location about 25 years ago.

4.1.2 Containment and Transport of Process Materials

Presently, TCE is stored in a 1,000-gallon aboveground storage tank located within a diked area at the southwest edge of the Hi-Mill Manufacturing facility. Dextrex Inc. maintains the solvent supply within the aboveground storage tank. Small amounts of solvent have been observed to have been spilled during filling operations. The solvent is transported from the aboveground storage tank to two degreasers within the facility via underground piping. Information regarding the construction and tightness of the piping is not available and, as such, it may be prudent to assess the existing plant operations to determine whether or not active introduction of potential site impacts could be underway.

Wastewater from plant operations was historically discharged to two lagoons located behind the building to the southeast; the former locations are shown in Figure 1.2. Process wastewater consisting chiefly of water, diluted acid-brightening solutions, and dissolved metals and metal cuttings were discharged to the largest of the two site lagoons (which was unlined and approximately 90 feet by 90 feet) prior to 1967 (exact date unknown) until sometime in 1981. The base of this lagoon was reportedly excavated approximately 6 feet into an underlying clay unit. A second, smaller lagoon was constructed in the fall of 1976 south of the existing

wastewater lagoon (Figure 1.2). This second lagoon was constructed to accept overflow from the larger, original lagoon. Although the lagoons were designed to serve as evaporation basins only, it is generally believed that wastewater from these two lagoons was unintentionally spilled into Target Pond into the impoundment area during periods of high rainfall. Between 1981 and 1983, Hi-Mill Manufacturing attempted to dissipate the volume of wastewater effluent more effectively by discharging water contained within the lagoons through spray nozzles located both atop the roof of the production facility and along portions of an eight-foot high fence which surrounds the rear of the property.

In September of 1983, Hi-Mill Manufacturing submitted a request to the MDNR to remove the sludge from the larger of the two lagoons along with adjacent soils and to backfill the area with clean fill. Following approval by the MDNR, the sludge and related soils were removed between November and December 1983 by the General Oil Company of Livonia, Michigan. In addition to the removal of the sludge, soils located along the sides of the lagoon were excavated along with approximately one foot of clay from the bottom to ensure that all contaminated material had been removed. All of the excavated soils and sludge were transported to an appropriate disposal facility. All operations during excavation were monitored by representatives of the MDNR, and the excavated lagoon area was inspected by the MDNR prior to final closure. The smaller lagoon completed in 1976 was not evident during reclamation of the large lagoon and, as such, was not excavated. While the fate of the smaller impoundment is not currently known, it is possible that portions of the lagoon were regraded across the property by either natural and/or proactive means.

As of October 1983, Hi-Mill Manufacturing had installed a recirculation system for process wastewater and had ceased discharge to the lagoons. Waste disposal practices included recycling more of the rinse water and off-site disposal of the remaining waste in a hazardous waste facility. Wastewater was neutralized with caustic soda and stored within a 1,600-gallon

concrete UST until it was transported and disposed of at a hazardous waste facility. The acid-brightening operation was totally eliminated in 1988 and, therefore, the generation, recycling and storage of process wastewaters ceased at that time.

4.1.3 Manufacturing Activities

Since 1946, Hi-Mill Manufacturing has fabricated copper-, aluminum-, and brass-tubing parts and fittings. Manufacturing activities have included the cutting and machining of raw tubing materials followed by the forming, shaping, and soldering of raw tubing and fabricated tubing components. Presently, all soldering operations use silver solder or aluminum- bar brazing. However, tin-lead solder may have been used in discontinued plant operations. Additional processing included sulfuric and nitric acid cleaning and pickling and chromic acid washing of the raw tubing and fabricated tubing components. Prior to 1983, wastewater generated during the acid washing process was disposed of into the lagoons located at the rear of the facility. In late 1983, the lagoon system was replaced with a wastewater recycling system and the shipment of non-recycled hazardous materials to a regulated hazardous waste facility. Prior to the shipping of completed tubing components the parts were degreased by placing them in a parts basket and immersing the basket into a degreasing unit. After removal from the degreaser, the parts were placed under heat lamps to remove any residual solvent from the parts. Any solvents volatilizing from the heating of the parts or the degreasing unit were vented to outside.

4.1.4 Potential Off-Site Sources of Contamination

Prior to at least 1946, a gasoline service station was located across M-59 and northwest of Hi-Mill Manufacturing site. In 1946, Hi-Mill Manufacturing purchased the former gasoline service station for use as a tool storage facility. Prior to Hi-Mill Manufacturing's purchase, the

gasoline USTs had been decommissioned using unknown methods. Hi-Mill Manufacturing used the structure until 1981 when it was deeded to the State of Michigan in exchange for a parcel of land now being used as the southwest parking lot and product shipping area. It is uncertain whether the gasoline USTs are still in place but anecdotal information indicates that the USTs were removed by the Michigan Department of Transportation during the widening of M-59 to a four-lane divided highway. According to Hi-Mill Manufacturing personnel, the USTs were uncovered, pierced, and crushed prior to shipment off the site. Furthermore, the unknown liquid contained within the tanks was spilled directly into the present median of M-59.

Numatics Inc., located approximately 800 feet northeast of the site, manufactures and cleans small stainless steel parts used in air control valves. According to the Michigan Water Resources Commission Permit #M-00090, Numatics is authorized to discharge 12,200 gallons/day of cooling water, 2,000 gallons/day of rinse water, and 800 gallons/day of sanitary sewage to a septic drain field. The spent and concentrated alkali/acid rinse waters are stored on-site in a 5,000-gallon concrete UST until transported to a regulated hazardous waste facility. The 5,000-gallon UST is registered with the State of Michigan Fire Marshall and is constructed of concrete with bare steel piping. According to a hydrogeologic study conducted by Keck Consulting Services in 1987, total chromium and hexavalent chromium were detected in soil samples collected near the septic tanks and drain field. Furthermore, shallow ground water at Numatics flows toward Target Pond approximately 300 feet southeast of the site.

4.2 SOILS AND VADOSE ZONE

During the Phase I Remedial Investigation, an intensive program of soil sampling was conducted both off- and on-site in order to determine the chemical characteristics of the soils. Generally, soil samples were collected from two 20 foot by 40 foot grids, a 60-foot by 60-foot grid, off-grid locations and background locations. Phase I Remedial Investigation soil sampling

included analysis for the occurrence of the SLM; TAL inorganics; Target Compound List (TCL) volatiles; TCL organics; TCL Base, Neutral and Acid Extractables (BNA); TCL Pesticides; and Polychlorinated Biphenyls (PCB). The results of these analyses are discussed in the following sections.

The Phase II soils investigation consisted in the collection of soil samples during soil boring activities from the following locations: IW-6, IW-7, SB-1, SB-2, SB-3, and SB-4. The bottom soil sample and soil samples possessing the highest PID/FID readings were submitted for the laboratory analysis of SLM and TCL volatile organics (Table 2.4). The results of these analyses are discussed below in the following sections.

Prior to evaluating the analytical data, the laboratory data sheets were validated using the "Laboratory Data Validation Functional Guidelines for Evaluating Organics (February 1, 1988) and Inorganics (July 1, 1988) Analysis" prepared by the U.S. EPA Data Review Work Group. Additional information from laboratory and independent professional judgment was also used during the data validation procedure. Laboratory data qualifiers are presented and defined in the analytical data tables. Further discussion regarding the quality of the data generated during the Phase I investigation is presented in the Technical Memorandum provided in Appendix P. The data validation summary for analytical data collected during Phase II is provided in Appendix S.

4.2.1 Inorganics

4.2.1.1 Introduction

Soil samples were collected during the Phase I Remedial Investigation from three grids located on the Hi-Mill Manufacturing property. A total of one hundred twenty-seven samples was collected from a 60 foot by 60 foot grid located on the southwest of the production facility. An additional seventy samples were collected from the 20 foot by 40 foot grids located on the

northeast and southwest sides of the production facility adjacent to the former and present locations of the TCE storage tanks. In general, Phase I Remedial Investigation soil sampling requirements indicated that three soil samples from each soil boring were submitted for laboratory analysis of SLM. Additionally, thirteen soil samples were submitted to an analytical laboratory for the complete TAL. Phase II soil sampling requirements indicated that two samples from each soil boring were submitted for laboratory analysis of the SLM.

4.2.1.2 Short List Metals

In order to evaluate the concentration of the SLM and TAL inorganics within the soil on the Hi-Mill Manufacturing property, background soil sampling was conducted to determine the naturally occurring concentrations of inorganic elements of the TAL within the area surrounding the Hi-Mill Manufacturing property. Prior to the initiation of Phase I investigative activities, a total of ten background samples was collected from six locations shown on Figure 2.1. The background locations were selected by Techna and approved by the MDNR and the U.S. EPA. Except for BG-3 and BG-6, two soil samples were collected from each background location and submitted to a laboratory for analysis of TAL inorganics. Due to the proximity of BG-2 to the Hi-Mill Manufacturing facility and the significantly higher concentrations of metals in BG-4-1, the laboratory results for these samples were not used to determine the background criteria for the Hi-Mill Manufacturing site. Background criteria for each analyte was determined by calculating the mean, standard deviation and the mean-plus-two standard deviations. When the concentration of the given analyte was reported as below the detection limit, the value of the detection limit was used in the calculation of the mean concentration. The SLM laboratory results, the mean of the laboratory results, the standard deviation, and the mean-plus-two standard deviations are summarized on Table 4.1. The laboratory results, means, standard deviations, mean-plus-two standard deviations of the remaining TAL inorganics are summarized on Table 4.2.

Upon the completion of the statistical analysis of the background data and development of the background criteria, SLM laboratory data were entered into a database constructed using dBASE 4.0 and compared to the background criteria for each given analyte. Concentrations of the SLM equal to or greater than the background criteria are reported in Table 4.3.

4.2.1.2.1 Surface Soil Samples (0.0 Feet to 1.0 Feet Below Ground Surface

A total of ninety-five surface soil samples was collected and submitted to a laboratory for inorganics analysis during the Phase I Remedial Investigation. Sixty-one of the surface soil samples possessed aluminum concentrations above the aluminum background criteria (i.e., 7,050.1 mg/kg). The aluminum concentrations that exceeded the background criteria ranged from 7,340 mg/kg at Grid Point F7 to 27,100 mg/kg at Grid Point J7.

The concentration of chromium within sixty-seven of the ninety-five surface soil samples exceeded the background criteria of 12.23 mg/kg established for the Hi-Mill Manufacturing site. Chromium concentrations ranged from 12.40 mg/kg at Grid Point A1 to 4420 mg/kg at Grid Point M3. The high chromium concentration measured at Grid Point M3 probably reflects the presence of a metal fragment within the soil sample.

Sixty of the ninety-five surface soil samples contained concentrations of copper that exceeded the copper background criteria of 7.77 mg/kg. Copper concentrations above background ranged from 8 mg/kg at Sample Point OG-3 to 5,010 mg/kg at Grid Point M4. The high concentration of copper measured at Grid Point M4 probably reflects the presence of a metal fragment or fragments within the soil.

The concentration of nickel within sixty-seven of the ninety-five surface soil samples exceeded the nickel background criteria of 8.14 mg/kg. Nickel concentrations above background ranged from 8.20 mg/kg at Grid Points B2, B3 and C5 to 33.3 mg/kg at Grid Point F3.

Four of the ninety-five surface soil samples exceeded the silver background criteria of 3.17 mg/kg. Silver concentrations above background ranged from 3.70 mg/kg at Grid Point B1 to 22.50 mg/kg at Grid Point G5.

The concentration of zinc within the surface soils exceeded the zinc background criteria of 28.53 in eighty-one of the ninety-five surface samples collected. The zinc concentration above background ranged from 31 mg/kg at Grid Point ZY01 to 844 mg/kg at Grid Point K6.

Generally, the highest SLM concentrations that exceeded the background criteria in the shallow soils were concentrated along the western margin of Target Pond and the southeast corner of the Hi-Mill Manufacturing production facility. The western margin of Target Pond is a low-lying wet area that probably received water overflowing from the Hi-Mill Manufacturing lagoons. The higher concentrations of aluminum identified within the soil near the southeast corner of the Hi-Mill Manufacturing facility may have resulted from metals being carried or swept out the doorways located in this part of building. Additionally, the above background metals concentration identified in the area between the northeast corner of the Hi-Mill Manufacturing facility and the western margin can also be attributed to the decommissioned manufacturing equipment stored adjacent to the northeast side of the production building.

In addition to the areas along the margin of Target Pond and the southeast corner of the building, nearly every surface soil sample collected exceeded the background criteria determined for the Hi-Mill Manufacturing site. The above background metals concentrations observed throughout the site likely resulted from either the lagoon-water dispersal program conducted from 1981 to 1983, lagoon overflow or spillage of waste process water, or naturally occurring metals within the clayey soils and silty-clay. Overflow from the lagoons had been noted on several occasions, especially during periods of heavy precipitation. Accidental spillages of waste process water could have also resulted in metals impacts. The dispersal program consisted of

spraying lagoon water from nozzles located on the fence on the east edge of the facility and on the roof of the production facility. The lagoon water dispersal was intended to produce a fine spray of water which would more readily evaporate. However, it may have also accomplished the dispersal of dissolved metals across the entire rear of the Hi-Mill Manufacturing property.

In general, the soils along the margin of Target Pond were logged as silty-clay, organic silty-clay, and peat (Figure 4.2). The organic material within the peat and the organic silty-clay would likely concentrate metals through the absorption of metals to solid organic material (Drever, 1988). The area where the lagoons were located now consists of fill sand, silty sand, and clayey sand, all of which generally contain metals concentrations below the background levels.

4.2.1.2.2 Shallow Soil Samples (1.0 to 3.0 Feet Below Ground Surface)

A total of thirty-four soil samples was collected from a depth of 1 foot to 3 feet below ground surface and submitted to a laboratory for inorganics analysis during the Phase I Remedial Investigation. Twenty-one of the soil samples possessed aluminum concentrations above the aluminum background criteria (i.e., 7,050.1 mg/kg) which ranged from 9,830 mg/kg at Grid Point RS01 to 27,100 mg/kg at Grid Point H7.

The concentration of chromium within twenty-six of the thirty-four shallow soil samples exceeded the background criteria of 12.23 mg/kg established for the Hi-Mill Manufacturing site. Chromium concentrations ranged from 13.40 mg/kg at Grid Points G3/H4 and H4/I5 to 917 mg/kg at Grid Point L3.

Twenty-four of the thirty-four shallow soil samples contained concentrations of copper that exceeded the copper background criteria of 7.77 mg/kg. Copper concentrations above background ranged from 8.40 mg/kg at Sample Point YX01 to 2,500 mg/kg at Grid Point H7.

The concentration of nickel within thirty of the thirty-four shallow soil samples exceeded the nickel background criteria of 8.14 mg/kg. Nickel concentrations above background ranged from 8.40 mg/kg at Grid Point RS01 to 41.50 mg/kg at Grid Point K3.

One of the thirty-four shallow soil samples exceeded the silver background criteria of 3.17 mg/kg. The above background silver concentration was 4.60 mg/kg at Grid Point I5.

The concentration of zinc within the shallow soils exceeded the zinc background criteria of 28.53 in twenty-nine of the thirty-four shallow samples collected. The above background zinc concentration ranged from 28.70 mg/kg at Grid Point WV01 to 244 mg/kg at Grid Point E2.

The soils samples collected from the 1 foot to 3 foot below ground surface horizon show a similar distribution of metals as was observed in the surface soils. Generally, the highest concentrations of metals are located along the western margin of Target Pond. The elevated concentrations of metals observed at the surface near the southeast corner of the production facility are also present at depth within the shallow soils. However, generally, every shallow silty-clay soil sample possesses elevated metals concentration while the more permeable sands, clayey sands, and silty sands generally do not contain metals concentrations above background (Figure 4.3).

The metals concentrations above the background criteria were probably the result of the infiltration of sprayed lagoon waters and the overflow of the wastewater lagoons into the low lying area along the margin of Target Pond. Furthermore, decommissioned manufacturing equipment stored on the northeast edge of the property may have been a source of dissolved metals, either through oxidation of the metal components of the machinery, or if the machinery had residual metal shavings or other residue related to its past service history.

4.2.1.2.3 Intermediate Soils (3.0 to 8.0 Feet Below Ground Surface)

A total of forty soil samples was collected from a depth of 3 feet to 8 feet below ground surface and submitted to a laboratory for inorganics analysis during the Phase I Remedial Investigation. Thirty-one of the soil samples possessed aluminum concentrations above the aluminum background criteria of 7,050.1 mg/kg, and ranged from 7,660 mg/kg at Grid Point I6 to 24,300 mg/kg at Grid Point B3.

The concentration of chromium within thirty-three of the forty intermediate soil samples exceeded the background criteria of 12.23 mg/kg established for the Hi-Mill Manufacturing site. Chromium concentrations ranged from 13.30 mg/kg at Grid Points H6 to 1620 mg/kg at Grid Point I5.

Twenty-two of the forty intermediate soil samples contained concentrations of copper that exceeded the copper background criteria of 7.77 mg/kg. Copper concentrations above background ranged from 10.30 mg/kg at Sample Point A1 to 4440 mg/kg at Grid Point H7.

The concentration of nickel within thirty-six of the forty intermediate soil samples exceeded the nickel background criteria of 8.14 mg/kg. Nickel concentrations above background ranged from 9.00 mg/kg at Grid Point I3 to 32.10 mg/kg at Grid Point B3.

One of the forty intermediate soil samples exceeded the silver background criteria of 3.17 mg/kg. The above background silver concentration was 12.50 mg/kg at Grid Point I5.

The concentration of zinc within the intermediate soils exceeded the zinc background criteria of 28.53 in thirty-one of the forty intermediate soil samples collected. The concentrations of zinc above the background criteria ranged from 28.90 mg/kg at Grid Point WV01 to 101 mg/kg at Grid Point I5.

The soils samples collected from the 3 foot to 8 foot below ground surface horizon show a similar distribution of metals as was observed in the surface and shallow soils. Except for aluminum, the highest metals concentrations were detected within the peat layer at Grid Point I5. Furthermore, generally every soil sample described as organic silty-clay and silty-clay possessed metals concentrations above the background criteria while metals concentrations within soil samples described as clay topsoil, silty-sand, and sand were generally below the background criteria (Figure 4.4). Furthermore, the horizontal variation of the concentration of metals within the silty-clay is probably the result of the natural variation of clay mineralogy and compositions rather than Hi-Mill Manufacturing activities.

4.2.1.2.4 Deep Soils (8.0 to 16.0 Feet Below Ground Surface)

A total of twenty-six soil samples was collected from a depth of 8 feet to 16 feet below ground surface and submitted to a laboratory for inorganics analysis during the Phase I Remedial Investigation. Eighteen of the soil samples possessed aluminum concentrations above the aluminum background criteria ranging from 9,330 mg/kg at Grid Point I3 to 19,000 mg/kg at Grid Point H7.

The concentration of chromium within twenty of the twenty-six deep soil samples exceeded the background criteria of 12.23 mg/kg established for the Hi-Mill Manufacturing site. Chromium concentrations ranged from 16.70 mg/kg at Grid Point I3 to 118 mg/kg at Grid Point G3/H4.

Twelve of the twenty-six deep soil samples contained concentrations of copper that exceeded the copper background criteria of 7.77 mg/kg. The concentration of copper above the background criteria from 9.00 mg/kg at Sample Point WV01 to 615 mg/kg at Grid Point H3/I4.

The concentration of nickel within twenty-one of the twenty-six deep soil samples exceeded the nickel background criteria of 8.14 mg/kg. Nickel concentrations above the background criteria ranged from 9.00 mg/kg at Grid Point G4 to 34.00 mg/kg at Grid Point H7.

None of the twenty-six deep soil samples exceeded the silver background criteria of 3.17 mg/kg.

The concentration of zinc within the deep soils exceeded the zinc background criteria of 28.53 in nineteen of the twenty-six deep soil samples collected. The concentrations of zinc above the background criteria ranged from 41.60 mg/kg at Grid Point I3 to 84.50 mg/kg at Grid Point H7.

The soils samples collected from the 8 foot to 16 foot below ground surface horizon show a similar distribution of metals as was observed in the overlying soils. Except for aluminum, the highest metals concentrations were detected within the silty-clay soils underlying the former lagoons at Grid Points G3/H4 and H3/I4 (Figure 4.5). Furthermore, generally, every soil sample described as silty-clay possessed metals concentrations above the background criteria suggesting that the horizontal variation of the concentration of metals within the silty-clay is probably the result of the natural variation of clay mineralogy and compositions rather than Hi-Mill Manufacturing activities.

4.2.1.2.5 Phase II Soil Sampling

During the Phase II Remedial Investigation, a total of ten soil samples was collected and submitted to a laboratory for analysis of the SLMs. Similar to the Phase I results, the Phase II results were compared to background criteria established prior to the Phase I investigation. Figure 4.6 and Table 4.4 summarize the laboratory results which exceed the background criteria.

Except for zinc at SB-4 -7.5 and aluminum at SB-1-15, SLM concentrations within Soil Borings SB-1, SB-2, SB-3, and SB-4 exceeded the background criteria. The concentration of copper in both samples collected from Soil Borings IW-6 and IW-7 exceeded the copper background criteria. The nickel concentration within Soil Sample IW-7-14' exceeded the background criteria for nickel.

The above discussion of the occurrences of SLMs within the soils at the Hi-Mill Manufacturing site assumed that the background samples were representative of the Hi-Mill Manufacturing soils. However, the background locations chosen by Techna to determine the background criteria may not be representative of the actual background of the Hi-Mill Manufacturing site. In general, the top 2 to 3 feet of the Hi-Mill Manufacturing facility site is covered with a clay-rich material and is classified as an Aquent soil by the United States Department of Agriculture (USDA). Only BG-2 is classified as an Aquent Soil by the USDA. Recall that BG-2 was removed from the background set due to its proximity to the Hi-Mill Manufacturing file. Background samples BG-4, BG-5, and BG-6 are classified as a Tedrow loamy sand, and samples BG-1 and BG-3 are classified as Spinks loamy sand and Kibbie fine sand loam, respectively (Figure 4.10). Figure 4.2, 4.3, 4.4, and 4.5 depict the lithology of the Hi-Mill Manufacturing soils with respect to depth. For comparison, the descriptions of the surficial background samples are included on Figure 4.2. Due to the nature of the clay mineral lattice, numerous naturally occurring metal species will be present including iron, magnesium, manganese, aluminum, chromium, and nickel (Berry and Mason, 1959). As a result of similar ionic radii, copper and zinc may substitute for iron within the clay mineral lattice. The greatest degree of substitution is generally found within chlorite, montmorillionite, and illite clays while little or no substitution occurs within kaolinite (Berry and Mason, 1959). Clay deposits usually contain a mixture of the above-listed clay minerals and would, depending on clay mineralogy, likely contain varying amounts of the SLMs. Therefore, due to the locations and mineralogy of the background samples which are mostly sand, the nature of clay mineralogy and the

preponderance of clayey surficial soils at the site, and the background criteria concentrations are probably significantly lower than would be considered representative of site-specific background concentrations. Thus, the number of soil samples that exceed background criteria may be considerably greater than is actually representative of impacted soils.

4.2.1.3 TAL Inorganics

In order to evaluate the concentration of the TAL inorganics within the soil on the Hi-Mill Manufacturing property, background soil sampling was conducted to determine the naturally occurring concentrations of inorganic elements of the target analyte list within the area surrounding the Hi-Mill Manufacturing property. Prior to the initiation of Phase I investigative activities, a total of ten background samples was collected from six locations shown on Figure 2.1. The background criteria was determined for each analyte using the method described above. Background criteria are summarized on Table 4.2, and laboratory data for the samples analyzed for the full TAL are summarized on Table 4.5.

All measurements of mercury, cyanide, and thallium were either nondetected or below the background criteria for the specific metal. The background criteria for manganese and antimony was exceeded in one sample from HMS-G7-0 and HMS-E5-0, respectively. The metals (arsenic, barium, beryllium, cadmium, calcium, potassium, sodium, vanadium, iron, lead, and magnesium) on the TAL exceeded their respective background criteria in several samples. As discussed above, the concentration of the metals within the soil appear to be associated with specific soil lithologies. For example, six of seven soil samples described as clay or clay topsoil exceeded the background criteria for barium and beryllium. Furthermore, as discussed in the previous section, the background criteria established for the Hi-Mill Manufacturing site do not appear to be representative of the majority of the soil types encountered at the site. As a result of the nonrepresentative background criteria, both commonly occurring (iron, calcium, potassium, and magnesium) and trace metals (lead, barium, cadmium, vanadium, manganese and beryllium) are above background in almost every sample.

4.2.2 Organics

During the Phase I Remedial Investigation, a total of sixteen soil borings was drilled in 20-foot by 40-foot grids on the northeast and southwest sides of the Hi-Mill Manufacturing production building near the former water supply well locations. Soil samples were collected from six additional soil borings located near the present and former TCE storage locations a: north of M-59 during the Phase II Remedial Investigation. Refer to Figure 4.7 for the Phas I and Phase II soil boring locations. In general, Phase I Remedial Investigation sampling requirements indicated that three soil samples from each soil boring were submitted for laboratory analysis of TCL volatile organics for a total of seventy-two TCL volatile organic analyses. During the Phase II Remedial Investigation, two soil samples from each soil boring were submitted for laboratory analysis of TCL volatile organics. Refer to Tables 4.6 and 4.7 for Phase I and Phase II soil analytical results. Soil samples submitted for the analysis of TCL organics, BNA, and PCB/Pesticides included background (BG-1 through BG-5) samples and two selected samples (I4-2 and G4-2) from the 60-foot by 60-foot grid located at the rear of the Hi-Mill Manufacturing facility.

4.2.2.1 TCL Volatiles

Phase I and Phase II TCL volatile organic soil sampling locations, sample depths, and laboratory analytical results are shown on Figure 4.7. Laboratory analytical results are summarized on Tables 4.6 and 4.7. A total of thirteen VOCs was detected in soil samples collected from the Hi-Mill Manufacturing site. Five of the thirteen VOCs detected (1,1,2,2-tetrachloroethane; 1,1,1-trichloroethane; 1,1,2-trichloroethane; ethylbenzene; and xylene) were detected at low-level estimated concentrations below the contract required detection limit (CRDL) ranging from 1 Jμg/kg to 3 J μg/kg. Five additional VOCs (trichloroethene (TCE); 1,2-dichloroethene (DCE); tetrachlorethene; toluene; and chlorobenzene) were detected at

concentrations greater than the CRDL and, in several cases, below the CRDL. Nearly every soil sample analyzed for volatile organics during the Phase I Remedial Investigation and Soil Samples HMS-IW6-100-102 and HMS-SB4-7.5 contained detections of methylene chloride and acetone. All of the soil samples collected during the Phase I were assigned the laboratory qualifier "B" to indicate that methylene chloride and acetone were detected in the method blank. The laboratory qualifier "B" was not assigned to soil samples HMS-IW6-100-102, HMS-IW6-115-117, and HMS-SB4-7.5; however, it is likely that these results are representative of laboratory or field cross contamination rather than the actual existence of these chemical constituents in the soil. The concentrations of organics in all three of the previously mentioned samples were estimated and below and the detection limit of the analysis. Furthermore, there is not any evidence that either methylene chloride or acetone have ever been used on the Hi-Mill Manufacturing site. The compound 2-Butanone was detected in Soil Borings RS23-3-RE, ST01-3DL, ST34-0, ST34-2-RE, WV01-2DL, and YX12-3-RE and was flagged with a laboratory qualifier "B".

TCE and its degradation products were detected at concentrations greater than the CRDL in both of the 20-foot by 40-foot sampling grids located near the former water supply wells. The observed chemical constituents,sample locations, sample depths, and detected concentrations are depicted graphically on Figure 4.7 and are tabulated on Table 4.6. Please note that while the units in Table 4.6 are in mg/kg (ppm) these values were converted to μg/kg (ppb) in Figure 4.7 for correlation to ground-water results which are presented in ppb. In general, the greatest concentrations of TCE within in the soils at the southwest grid occurs beneath the brown/gray variegated (brown clay) clay surface, possibly within silt and sand seams observed within the brown clay during the Phase II drilling and hand-auger boring investigation. TCE was detected within thirteen samples in the southwest grid and ranged in concentration from 2μg/kg to 350 μg/kg. Soil Borings SB-1 and SB-2 were installed adjacent to the aboveground TCE storage tank and contained TCE concentrations ranging from 13μg/kg to 1600 μg/kg. The greatest

concentration of TCE was encountered in the samples collected from 5 feet to 7.5 feet below ground surface and decreased to nondetectable levels of TCE at 15 feet below ground surface in SB-1 and 13 μg/kg at 15 feet below ground surface in SB-2.

With the exception of WV-01-3 and the resample of YX12-3, TCE was detected in levels ranging from 1 μg/kg to 41 μg/kg in samples collected from the northeast grid. At WV-01-3, an estimated value of 57,000 μg/kg of TCE was detected at a depth of 9.17 feet below groun surface which, according to the boring log, is within the brown clay, and at YX12-3 RE, TCE was detected at 80 μg/kg at a depth of 10 feet, which is also in the brown clay. The remainder of the TCE detections are both within and above the brown clay with the greatest TCE results above the brown clay. Soil Borings SB-3 and SB-4, installed adjacent to the former aboveground TCE storage tank on the north side of the production building, contained detectable levels of toluene and TCE within the gray clay at 15 feet below ground surface. During the drilling of Soil Borings SB-3 and SB-4, a FID (OVA) measured high levels (up to 800 ppm) of volatiles within the hollow- stem augers and soil sample headspace. However, the samples (HMS-SB3-7.5 and HMS-SB4-7.5) possessing highest FID results did not contain detectable levels of TCE or any other compounds on the TCL volatiles list possibly indicating that the high FID readings were due to the occurrence of methane within the subsurface. Table 2.4 lists the FID results from all Phase II Remedial Investigation soil sampling locations. TCE was not detected within the intermediate or deep zones during soil sampling, with the exception of two samples collected from IW-6 at depths of 100 feet below ground surface (2.8 μg/kg) and 115 feet below ground surface (2.0 μg/kg).

The high concentrations of TCE detected at soil sample location WV-01-3 (57,000 μg/kg) may be indicative of the presence of impacts beneath the Hi-Mill building itself. The damage of a product delivery line beneath an existing portion of the building undoubtedly resulted in the deposition of solvents beneath the facility. It is also possible that free-product dense non-

aqueous phase liquids (DNAPLs) may be present beneath the building in either the form of lenses or residual ganglia trapped between mineral grains in the soil. This information may be critical during the design and implementation of a remedial system or during any future investigatory work. Information derived from Cherry (1991) suggests that direct extraction of DNAPL is not usually advised, especially by aggressive pumping techniques, since research has shown that such activities often result in the further mobilization of otherwise comparatively stable occurrences of free-product. Therefore, care must be exercised during any remedial design or future investigatory activities to prevent further migration of DNAPL related compounds.

The compound DCE was detected in five samples collected during the Phase I Remedial Investigation and one sample collected during the Phase II Remedial Investigation. During the Phase I investigation DCE results ranged from 13 μg/kg to 41 μg/kg and the Phase II detection was 49 μg/kg at Soil Boring SB-1. Five of the six DCE detections were located on the southwest side of the production facility at a depth of 4 feet to 7.5 feet below ground surface.

Chlorinated solvent 1,1,1-Trichloroethane (1,1,1-TCA) was detected in five samples collected during the Phase I investigation and ranged from 2 J μg/kg to 140 μg/kg. No 1,1,1-TCA was detected in the soil samples collected during the Phase II investigation. Soil Boring RS34 contained two detections of 1,1,1-TCA at 1 foot and 3 feet below ground surface of 140 μg/kg and 110 μg/kg, respectively. An estimated concentration of 2 J μg/kg of 1,1,1-TCA was detected at Soil Boring RS23 at 0.75 foot and 6 feet. Several single detections of compounds possibly related to solvent impurities or different grades of industrial solvent have been encountered during the Phase I and Phase II soil sampling including tetrachloroethene in SB1-7.5 of 68 μg/kg, 1,1,2,2-tetrachloroethane in WV01-3 at 2 J μg/kg and 1,1,2-trichlorethane at 2 J μg/kg.

Eleven soil samples collected during the Phase I Remedial Investigation contained detectable levels of toluene ranging from 3 μg/kg to 7 μg/kg. Nine of these eleven detections estimated values are assigned the "J" laboratory qualifier. Five toluene detections, ranging from 2.2 μg/kg to 37 μg/kg, were reported in soil samples collected during the Phase II investigation; two of the five toluene detections were estimated values and were assigned a "J" laboratory qualifier. The greatest number of toluene detections were found within the samples collected from the northeast sampling grid which is approximately 100 feet east of the former #2 fuel oil tank and adjacent to an area of the production facility in which cutting oils are used during the processing of raw tubing. However, the source of the toluene is uncertain, it may be the result of either impurities within the TCE supply, the potential of chlorinated solvents to "mobilize" heavier, less mobile petroleum hydrocarbons, the former service station, or laboratory contamination. Toluene was also detected at depths of 100 feet below ground surface (3.3μg/kg) and 115 feet below ground surface (2.2 μg/kg) in Boring IW-6.

During the Phase I investigation, xylenes were detected in levels ranging from 1 J μg/kg to 2 J μg/kg in samples collected from soil borings located within the southwest grid. All of the xylene results are estimated as shown by the "J" laboratory qualifier. Several other compounds possibly related to petroleum hydrocarbons include the 14 μg/kg of chlorobenzene in RS23-1, and the 2J μg/kg of ethylbenzene in RS23-1 and ST12-1.

The distribution of TCE, 1,1,1 TCA, and DCE results within the soil on the southwest side of the production building suggests that the main source of dissolved TCE is not the aboveground storage tank but may instead be related to either the piping connecting the TCE storage tank with the presently operating degreasing units or the degreasing units. Furthermore, nondetectable and near nondetectable levels of TCE were encountered with depth in Soil Borings SB-1 and SB-2 suggesting that the brown clay in this area impedes the vertical migration of VOCs. The results of the Phase I grid sampling and soil sampling at Soil Borings SB-3 and SB-

4 on the north side of the building indicate that the former aboveground storage tank was not the source of TCE but rather that the underground piping, the degreaser, or possibility accidental spills contributed to the occurrence of TCE within the soil. The detection of 57,000 μg/kg within Soil Sample WV-01-3 and the detection of high concentrations of volatiles and vinyl chloride gas within the borehole of VP-1 suggests that the solvent release that occurred as a result of the product delivery line damage has impacted the brown clay and the upper portions of the gray clay. The greatest extent of TCE soil impacts is near the edge of the building and likely extends beneath the Hi-Mill Manufacturing facility.

An inspection of the facility manufacturing operation including piping, drains, and degreasing units should be conducted prior to commencement of the feasibility study to insure that no ongoing potential sources of impacts are present. As discussed previously, the damage of a solvent delivery line between 1978 and 1980 under the existing Addition #4 portion of the building may have resulted in the introduction of compounds of concern beneath the existing structure. Care must therefore be exercised in the design of a remedial system to address the possible presence of chlorinated solvents beneath the building, or in any future investigatory work to prevent the further migration of compounds of concern.

4.2.2.2 TCL Organics (BNA,PCB,PEST)

Ten soil samples were submitted to an analytical laboratory for the analysis of TCL organics. An additional two samples were also submitted for the analysis of TCL BNA and TCL PEST/PCBs. The samples submitted were collected at the Background Locations BG-1 through BG-5 and Grid Intersections I-4 and G-4. Samples submitted for TCL BNA and PEST/PCBs were surface samples collected at BG-2 and BG-5. Sample locations are shown on Figure 2.1 and analytical results are found on Table 4.8.

A total of thirteen semi-volatile organic compounds (SVOC) was detected in soil samples collected from the Hi-Mill Manufacturing site. Twelve of the thirteen SVOCs detected (benzo(a) anthracene, benzo(b) fluoranthene, benzo(g,h,i) perylene, butyl benzyl phthalate, chrysene,

dibenzo(a,h) anthracene, di-n-octyl phthalate, indeno(1,2,3-cd) pyrene, phenanthrene and pyrene) were detected at low-level estimated concentrations below the CRDL ranging from 0.049 J to 0.44 J μg/kg. Two SVOCs, fluoranthene and bis(2-Ethylhexyl) phthalate were detected at a concentration greater than the CRDL. All of the above compounds were detected a surface soil sample collected at BG-2 which is located near the former #2 fuel oil UST. Except for the three phthalates (bis(2-Ethylhexyl) phthalate, di-n-octyl phthalate, Butyl benzyl phthalate), the detected compounds are indicative of fuel oil and are probably related to overfills of the UST. Bis(2-ethylhexyl) phthalate was detected at BG2-0, BG3-1 and I4-2 ranging from 0.15 to 0.59 μg/kg. Di-n-butyl phthalate was detected at BG2-0, BG5-0, and I4-2 ranging from 0.049 to 0.14 μg/kg. Butyl benzyl phthalate was detected at BG2-0 at a concentration of 0.049 μg/kg. Except for the 0.59 μg/kg result at BG3-1, all of the phthalates levels are below the CRDL and are therefore qualified as estimated.

Neither of the samples submitted for TCL PEST/PCBs analysis contained detectable concentrations of PCBs or pesticides.

4.3 SURFACE WATER AND SEDIMENTS

The following sections contain a discussion of the results of the sampling and analysis of surface water and sediment samples collected during the Phase I investigation of Target Pond, Waterbury Lake, and the background pond, and during the Phase II investigation of Target Pond and Waterbury Lake. The Phase I work was originally performed by Techna and was presented to the U.S. EPA and the MDNR in the Phase I Remedial Investigation Report submitted in 1990. The results of the analysis presented by Techna were validated by Geraghty & Miller in the Final Technical Memorandum submitted to the U.S. EPA and the MDNR in 1991 and are presented in complete form in Appendix P. The Phase II sampling was conducted by Geraghty & Miller in 1991.

4.3.1 Background Pond

Techna reportedly collected four surface-water and four sediment samples (labeled "BP") from a background pond located approximately 1000 feet southwest of Waterbury Lake. These samples were analyzed for SLM and TAL inorganics; the results are presented in Tables 4.9 and 4.10. The sediment and surface-water sample analyses were also re-examined in the Phase II Ecological Assessment and Inventory Report provided in Appendix R.

4.3.1.1 Surface Water

Four surface-water samples were collected at more or less equally spaced stations within the background pond. These samples were analyzed to determine what the likely local background concentrations of inorganics were adjacent to the Hi-Mill Manufacturing facility. Techna (1990) used these results to determine whether or not Target Pond had likely been affected by previous activities at the Hi-Mill Manufacturing site.

Copper was detected in only one sample (BP-1) at a concentration of 19.5 ppb. Chromium was detected in Sample BP-4 at a concentration of 9.3 ppb, which was less than the contract detection limit. Nickel was also detected at concentrations below the contract detection limit at locations BP-1 and BP-3 (13.8 ppb and 17.8 ppb, respectively). Silver was detected in Samples BP-2 and BP-4 at concentrations of 12.5 ppb and 9 ppb respectively, while zinc was detected in BP-1 and BP-4 at concentrations of 11.8 ppb and 12.4 ppb respectively. No hexavalent chromium was detected in the background pond surface water. Ammonia nitrogen concentrations ranged from 50 ppb (BP-4) up to 160 ppb (BP-1). Nitrate/nitrite nitrogen concentrations ranged from 70 ppb (BP-4) up to 180 ppb (BP-1).

The surface-water sampling results obtained from the background pond were not used during the Phase II Ecological Assessment and Inventory for comparisons of Target Pond water-quality impacts. New samples were collected from Waterbury Lake in 1991 for use as background criteria for Target Pond. For details related to the assessment of Target Pond, please refer to the Ecological Assessment and Inventory presented in Appendix R.

4.3.1.2 Sediments

A total of four sediment samples was collected from the background pond by Techna at the same locations as those used to obtain surface-water samples. These samples were analyzed for SLM and TAL inorganic compounds. These results were presented by Techna in the Phase I Remedial Investigation Report (1990), by Geraghty & Miller in the Technical Memorandum (1991) (see Appendix P), and again in the Phase II Ecological Assessment and Inventory provided in Appendix R.

Aluminum in the background pond sediments ranged from 946 ppm (BP-2) up to 3610 ppm (BP-4). Chromium was detected in Samples BP-1 (22.9 ppb, B) and BP-4 (37.1 ppm). Copper was detected in only one sample (BP-3) at a concentration of 34.8 ppm (B). Nickel was not detected in any of the background pond sediment samples, nor was silver. Zinc was detected in BP-3 and BP-4 at concentrations of 71.6 ppm and 122 ppm, respectively. Hexavalent chromium was detected in Sample BP-4 only at a concentration of 1.6 ppm.

The Ecological Assessment and Inventory presented in Appendix R discusses the background pond sediment analyses in greater detail and also compares these results to samples collected from Target Pond and Waterbury Lake during the Phase I investigation.

4.3.2 Target Pond

Presented in the following section is a brief discussion of the distribution of compounds within the Target Pond surface water and sediments based upon comparisons to the background pond and U.S. EPA and MDNR criteria (in the case of water). For details of the distribution of inorganics in the site waterbodies, please refer to the Ecological Assessment and Inventory Report presented in Appendix R. Also refer to Table 4.9 and 4.10 for summaries of the results of analyses performed on the Target Pond surface water and sediments.

4.3.2.1 Surface Water

A total of sixteen surface-water samples was collected from Target Pond during the Phase I investigation (Techna, 1990) and analyzed for TAL inorganics, SLM, hexavalent chromium, ammonia, and nitrate plus nitrite. These results are presented in the Ecological Assessment and Inventory presented in Appendix R.

The 1990 Techna results suggested that the surface water of Target Pond has not been adversely impacted by previous site activities because the concentrations of inorganic constituents in Target Pond were generally less than or nearly equal to the U.S. EPA and MDNR water-quality criteria or the samples collected from the background pond. Copper, nickel, and silver were all detected at concentrations in excess of the U.S. EPA and MDNR criteria. However, silver was also detected at levels above the water-quality criteria within the background pond. In fact, silver concentrations in the background pond were greater than those detected for Target Pond.

The 1991 Geraghty & Miller sampling of the Target Pond surface water revealed that the concentration of aluminum, calcium, iron, magnesium, manganese, potassium, and sodium were

all above background. Concentrations of chromium, nickel, and silver were above MDNR Rule 57(2) Guidelines.

For details relating to the assessment of surface-water-quality data collected from Target Pond, please refer to the Ecological Assessment and Inventory Report presented in Appendix R.

4.3.2.2 Sediments

A total of 20 sediment samples was collected in Target Pond by Techna (1990). The results of this sampling and analysis were originally presented in the Phase I Remedial Investigation Report (Techna, 1990), in the Technical Memorandum prepared by Geraghty & Miller (1991) (see Appendix P), and in the Phase II Ecological Assessment and Inventory provided in Appendix R. The samples were analyzed for TAL inorganics, SLM, ammonia, hexavalent chromium, nitrate plus nitrite, percentage solids, and cyanide.

The levels of aluminum, chromium, copper, and zinc in the Target Pond sediments were all statistically above observed concentrations in the background pond. The results suggest that the sediments in Target Pond may have been impacted by the discharge of metal-laden process wastewaters from the Hi-Mill Manufacturing plant into two lagoons (located at the rear of the factory) which in turn overflowed into Target Pond. It should be noted, however, that information on the nearby Numatics, Inc. facility suggests that current or past activities there may have also contributed to the impacts on the Target Pond sediments. Metals discharged to the pond were likely retained within the bottom sediments, owing to higher concentrations of organic carbon.

An additional four sediment samples were collected in 1991 by Geraghty & Miller during the Phase II investigation; the results are presented in the Ecological Assessment and Inventory presented in Appendix R. These samples were analyzed for aluminum, barium, chromium, copper, magnesium, vanadium, and zinc as well as percentage solids and pH. Two additional sediment samples were collected from Waterbury Lake to use as background for comparison to the Target Pond results. Of the compounds examined in Target Pond, all were above the Waterbury Lake sediment concentrations with the exception of vanadium. These results provided further evidence that the sediments in Target Pond may have been impacted by activities at either the Hi-Mill Manufacturing site and/or the adjacent Numatics, Inc. facility.

For details on the migration of metals into Target Pond, please refer to Section 5.0. For details on the assessment of the sediment chemistry results, refer to the Ecological Assessment and Inventory Report presented in Appendix R.

4.3.3 Waterbury Lake

Presented in the following section is a brief discussion of the distribution of compounds within the Waterbury Lake surface water and sediments based upon comparisons to the background pond and U.S. EPA and MDNR criteria (in the case of water). For details of the distribution of inorganics in the site waterbodies, please refer to the Ecological Assessment and Inventory Report presented in Appendix R. Also refer to Table 4.9 and 4.10 for summaries of the results of analyses performed on the Waterbury Lake surface water and sediments.

4.3.3.1 Surface Water

Of the surface water samples collected by Techna from Waterbury Lake, only nickel and silver were detected at concentrations in excess of the water-quality criteria established by U.S.

EPA and MDNR. Only silver was actually higher than the background pond samples. For details of the assessment of the surface-water-quality results obtained from Waterbury Lake, please refer to the Ecological Assessment and Inventory Report presented in Appendix R.

4.3.3.2 Sediments

Sediment samples collected from Waterbury Lake by Techna (1990) demonstrated that the levels of chromium and copper exceeded the concentrations of the sediment concentrations observed in the background pond for Sample WL-1. Geraghty & Miller collected two additional sediment samples from Waterbury Lake in 1991; the results are presented in Appendix R. The samples were used as background for comparisons of the concentrations determined in the Target Pond sediments during the Phase II investigation. The compounds analyzed included aluminum, barium, chromium, copper, magnesium, vanadium, zinc, percentage solids, and pH. For details of the sediment sampling results in Waterbury Lake, please refer to the Ecological Assessment and Inventory Report presented in Appendix R.

4.4 GROUND WATER

Two ground-water sampling rounds have been conducted at the Hi-Mill Manufacturing site. The first sampling round was conducted in March 1990 by Techna in which a total of thirty-two monitoring wells was sampled. During the initial sampling round, twenty samples were analyzed for TCL VOCs (not including blanks, duplicates, and spikes), seven samples were analyzed for TAL inorganics, three semi-volatiles analyses were performed (not including blanks and duplicates), thirty-one samples were analyzed for SLM (not including duplicates and blanks), and twenty-three samples were analyzed for ammonia and total nitrogen (not including duplicates and blanks). The second sampling round, conducted by Geraghty & Miller, Inc. in February 1992, consisted of sampling eighteen shallow monitoring wells, nine intermediate monitoring wells and three deep monitoring wells. All of the samples collected were submitted for analysis of SLM and TCL VOC. Measurement of field parameters (pH and conductivity) was completed

immediately following the sample collection. Additionally, the Phase II investigation involved the drilling of a total forty-eight hand-auger borings and the collection of water samples from the open boreholes. The water samples collected from the hand-auger boreholes were analyzed using a field GC for the volatile organics TCE; 1,1-DCE; 1,2-DCE; and vinyl chloride, and four sample splits were submitted to a laboratory for TCL volatiles analysis. Eight of the water samples collected from the hand-auger borings were also analyzed for BTEX. The results of chemical analysis from the Phase I and Phase II sampling round are discussed below. Field GC data sheets are found within Appendix N. The location of the monitoring wells and hand-auger borings are shown on Figures 2.1 and 4.8, respectively.

Prior to evaluating the analytical data, the laboratory data sheets were validated using the "Laboratory Data Validation Functional Guidelines for Evaluating Organics (February 1, 1988) and Inorganics (July 1, 1988) Analysis" prepared by the U.S. EPA Data Review Work Group. Additional information from laboratory and independent professional judgement was also used during the data validation procedure. Laboratory data qualifiers are presented and defined in the analytical data tables. Further discussion regarding the quality of the data generated during the Phase I and Phase II sample collection and analysis activities are presented in the Technical Memorandum provided in Appendices P and S, respectively.

4.4.1 Inorganics

Ground-water samples were collected during the Phase I and Phase II Remedial Investigations. During the Phase II Remedial Investigation, thirty ground-water samples were submitted for SLM analysis. During Phase I Remedial Investigation sampling event, seven samples were analyzed for TAL in addition to thirty-two samples for SLM. Tables 4.11 and 4.12 summarize the Phase I Remedial Investigation analytical results for the SLM and TAL inorganics, respectively. Table 4.13 summarizes the SLM analytical results from the Phase II

Remedial Investigation, and Figure 4.9 summarizes the SLM results above the MDNR Background Ground-Water Survey Concentrations.

4.4.1.1 Short List Metals

SLM results were compared to ground-water background values obtained from the MDNR/WMD Guidance Document, May 1988. SLM above background are summarized on Table 4.14. Six monitoring wells, sampled during the Phase II investigation, contained dissolved aluminum concentration above the MDNR background criteria. Dissolved aluminum concentrations above background ranged from 58.8 μg/L at Monitoring Well SW-18 to 392 μg/L at SW-1. Five of the six monitoring wells that contained above background levels of dissolved aluminum were screened in a clay horizon suggesting that the possible source of the aluminum is naturally occurring aluminum. Furthermore, Hem (1986) concluded that aluminum-bearing gibbsite crystals near 0.10 μm in diameter possess considerable physical and chemical stability and will pass through most water filters. Therefore, the probable presence of gibbsite within the ground water will result in elevated levels of dissolved aluminum in the ground water. One Monitoring Well SW-5 contained nickel concentrations above the background criteria. During the Phase I sampling event, four monitoring wells contained nickel concentrations above the background criteria. The nickel concentrations ranged from 129 μg/L at SW-11 to 149 μg/L at SW-15. Resampling the monitoring wells during the Phase II investigation resulted in nondetected or below background levels of nickel in the monitoring wells.

4.4.1.2 Target Analyte List

Table 4.12 summarizes the Phase I laboratory analytical results for the ground-water samples analyzed for TAL inorganics. No information was located relating to whether the TAL laboratory analytical results were filtered or non-filtered samples. No ground-water samples

were submitted for the complete TAL inorganics during the Phase II Remedial Investigation. Antimony, arsenic, beryllium, cadmium, mercury, thallium, and cyanide were nondetected in all samples submitted for the complete TAL analysis. The common major element constituents of most naturally occurring ground water (calcium, magnesium, manganese, sodium, potassium and iron) were detected in almost every sample. In general, the concentration of iron was higher within intermediate aquifer ground-water samples than shallow saturated zone ground-water samples. The concentration of calcium, magnesium, and manganese was higher in shallow saturated zone samples (SW-2, SW-22, SW-5 and SW-8) than samples from the intermediate aquifer (IW-1, IW-3, IW-5). Except for ground-water Sample HMW-IW-5, vanadium and barium were non-detected. The concentrations of both vanadium and barium within the ground-water Sample HMW-IW5 are both within the range of concentrations observed in naturally occurring ground water (Hem, 1986).

4.4.2 Organics

An evaluation of the volatile organic chemical results indicates that a total of fifteen VOCs was detected during the Phase II investigation. Nearly every sample had concentrations less than the CRDL, minor QA failures, or dilution uncertainties requiring that the concentrations be flagged as estimated with the laboratory qualifier "J". Four of the fifteen compounds detected including acetone, methylene chloride, 2-butanone, and chloroform are probably the result of laboratory or field contamination. Nine of remaining eleven compounds including TCE, 1,2-dichloroethylene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), 1,1,1-trichloroethane (1,1,1-TCA), vinyl chloride, benzene, toluene, ethyl benzene, and xylenes are probably indicative of the impacts to the ground water. The remaining compounds (4-methyl-2-pentanone, and bromodichloromethane) occur at a concentration of 1J μg/L and are likely laboratory artifacts.

The following sections will divide the discussion of the volatile results detected during Phase II investigation into three sections: shallow perched zone, intermediate flow system, and deep flow system. Included within the discussion of the shallow zone will be a narrative of the results of the hand-auger boring investigation. The section dealing with the intermediate system will include a discussion of the results of the vertical profiling conducted during the Phase II investigation. Furthermore, the Phase II VOC results will be compared and contrasted with the Phase I VOC results in order to elucidate the sources and any potential migration pathways at the Hi-Mill Manufacturing site.

4.4.2.1 Shallow "Discontinuous" Flow System

4.4.2.1.1 Monitoring Well Sampling

During the Phase II ground-water sampling, VOCs were detected in water samples from ten shallow monitoring wells. VOCs not related to laboratory or field contamination including TCE; 1,2-DCE; 1,1-DCA; 1,1,1-TCA; vinyl chloride; and toluene were detected at levels ranging from 2 J μg/L to 6700 J μg/L. Table 4.15 and Table 4.16 list all of the VOCs detected during the Phase I and Phase II sampling events, respectively. Figure 4.7 depicts the locations of the monitoring wells and concentrations of the VOCs detected during the Phase II sampling event.

During the Phase II water sampling, TCE was detected within samples from SW-1 (6700 J μg/L), SW-11 (18 μg/L), SW-12 (2 J μg/L), and SW-7 (4 J μg/L). During the Phase I ground-water sampling, TCE was detected within samples from two monitoring wells, SW-1 (1100 μg/L) and SW-3 (140 μg/L). During the Phase I and Phase II water-sampling events TCE was detected above the CRDL at Monitoring Well SW-1 which is located southeast of the aboveground storage tank and southwest of the degreasers located within the Hi-Mill Manufacturing facility. Furthermore, Monitoring Well SW-1 is screened within the upper gray clay and possibly across two silt/fine sand seams. Phase I laboratory analytical results indicate

that significant levels of TCE were detected above the CRDL at Monitoring Well SW-3 which is near the location of the former aboveground TCE storage tank and degreaser. However, during the subsequent Phase II sampling event, TCE was not detected at Monitoring Well SW-3 nor were greater concentrations of TCE biodegradation daughter products detected (see below) suggesting possible migration of TCE away from the area surrounding SW-3. TCE was also detected hydraulically down- or side-gradient at Monitoring Well SW-11 which is screened across the gray clay and a fine sand/silt seam possibly hydraulically connected with the sand seam observed at Monitoring Well SW-1.

The compound 1,2-dichloroethylene (1,2-DCE) was detected during the Phase II sampling event in ground-water samples from Monitoring Wells SW-1 (1400 J μg/L), SW-3 (4 J μg/L), SW-5 (130 J μg/L), SW-7 (4 J μg/L), SW-10 (7 J μg/L), and SW-11 (2 J μg/L). An evaluation of the Phase I water-sampling results indicates that 1,2-DCE was detected at Monitoring Wells SW-1 (360 μg/L), SW-3 (100 μg/L), SW-5 (75 μg/L), and SW-10 (30 μg/L). Similar to the occurrence of TCE, the greatest concentration of 1,2-DCE was detected at Monitoring Well SW-1 with lesser estimated concentrations detected hydraulically downgradient of the Hi-Mill Manufacturing facility. Except for SW-3, the Phase I water-sampling results are similar with respect to 1,2-DCE concentration and the affected wells. Monitoring Well SW-3 shows a considerable decrease in the concentration of 1,2-DCE from the Phase I to Phase II sampling events possibly the result of migration and biodegradation of 1,2-DCE.

Vinyl chloride was detected at Monitoring Well SW-3 (39 J μg/L) during the Phase II sampling event and within Monitoring Wells SW-1 (60 JB μg/L), SW-3 (60 JB μg/L), and SW-5 (4 J μg/L) during Phase II sampling event. The concentrations observed during the Phase I and Phase II sampling events are probably the result of the biodegradation of 1,2-DCE to vinyl chloride near the Hi-Mill Manufacturing facility. The high levels of TCE and 1,2-DCE and low levels of vinyl chloride (nondetected during the Phase II sampling) observed at Monitoring Well SW-1 likely represents a more recent solvent release rather than an older release near northeast side of the production facility.

Chlorinated solvent 1,1,1-trichloroethane (1,1,1-TCA) was detected in Monitoring Well SW-1 (100 J μg/L) during the Phase II sampling event. 1,1,1-TCA was not detected during the Phase I sampling round. The occurrence of 1,1,1-TCA is likely the result of impurities within the solvent used by Hi-Mill Manufacturing.

At Monitoring Well SW-9A, toluene was detected at concentration below the CRDL of 2 J μg/L. During the Phase I sampling, Monitoring Well SW-4 contained a detection of toluene below the CRDL. Due to the low estimated toluene concentration within Monitoring Well SW-9A and SW-4, the toluene detections may represent either laboratory contamination or more likely contamination resulting from the use of a gasoline powered water pump during purging of the monitoring well.

4.4.2.1.2 Hand-Auger Boring Water Sampling

Hand-auger borings were drilled around the Hi-Mill Manufacturing facility, within the median of M-59 and north of M-59. Water samples were collected from the open boreholes and submitted for analysis by a field GC. Four splits of hand-auger-boring water samples were submitted to ENSECO for TCL volatile organic analysis. Sampling locations are depicted on Figure 4.8, while results are presented in Figures 4.11 through 4.14. Field GC results are depicted on Table 4.17. Laboratory data sheets and field GC data sheets are located within Appendix N.

TCE was detected within water samples from twenty-six hand-auger borings drilled within the M-59 median, north of M-59, and around the Hi-Mill Manufacturing facility. The concentration of TCE ranged from 5 μg/L to 55,000 μg/L with the greatest concentrations identified located within the median of M-59 at SBM-15 (55,000 μg/L), SBM-13 (11,000 μg/L), SBM-14 (4,000 μg/L), and near Hi-Mill Manufacturing at HAB-8 (8,500 μg/L). The approximate lateral extent of TCE occurrence is depicted on Figure 4.11.

In addition, 1,2-DCE was detected within water samples from eighteen hand-auger borings drilled within the M-59 median and around the Hi-Mill Manufacturing facility. The concentration of 1,2-DCE ranged from 3 μg/L to 3,500 μg/L. The highest 1,2-DCE concentration identified during the hand-auger-boring water sampling was located adjacent to the Hi-Mill Manufacturing facility at HAB-8 (3,500 μg/L) and HAB-6 (3,000 μg/L). The approximate lateral extent of 1,2-DCE is shown on Figure 4.12.

Six detections of 1,1-DCE were identified within water samples collected from hand-auger borings drilled on the Hi-Mill Manufacturing site and within the M-59 median. 1,1-DCE results ranged from 3 μg/L to 23 μg/L with the greatest concentrations located at HAB-6 (23 μg/L) and HAB-8 (20 μg/L); this correlates with the greatest concentrations of 1,2-DCE results.

Vinyl chloride was detected within nine water samples collected from hand-auger borings on the Hi-Mill Manufacturing site and within the M-59 median. Vinyl chloride results ranged from 6 μg/L to 436 μg/L. The greatest concentration of vinyl chloride was encountered at HAB-6 (436 μg/L) and HAB-8 (38 μg/L). The approximate extent of vinyl chloride occurrences are depicted on Figure 4.13.

Based on the apparent shallow aquifer ground-water flow direction and the distribution of TCE/DCE/Vinyl chloride detections, dissolved TCE appears to be migrating northwest within the surficial perched ground water toward the M-59 median away from a source located on the Hi-Mill Manufacturing site. Furthermore, based on the information related to the solvent release discussed in section 4.1.2, the most likely source of dissolved TCE within the shallow ground water is the occurrence of free product beneath the Hi-Mill Manufacturing site resulting from the break in the product delivery line that occurred between 1978 and 1980. The northwesterly migration continues until the dissolved VOCs encounter the utility trench within the median of M-59. The coarse-grained backfill materials within the utility trench tend to channel the flow

of the shallow ground water and dissolved VOCs toward the southwest. The preferential flow pathway along the utility trench is shown by several low VOC detections and several nondetections north of the utility trench and M-59 at SBM-27, SBM-22, SBM-26, SBM-7, and SBM-12. The low TCE detection at SBM-18 (11 μg/L) may represent cross contamination from an incompletely decontaminated hand auger because resampling at the same location (SBM-18R) yielded nondetections for TCE, DCE, and vinyl chloride. Although the precise location of the previous sample collected with the auger used at SBM-18 is not known, several impacted locations were sampled prior to SBM-18. Air emissions from the plant could have also resulted in some minor cross-contamination as well.

VOCs detected on the south side of the Hi-Mill Manufacturing production facility at HAB-6 and HAB-7 may represent an older biodegraded release as shown by the greater concentrations of DCE and vinyl chloride with respect to the concentration of TCE. Furthermore, HAB-6 is located within the nearly flat mound of perched shallow ground-water located at the rear of the Hi-Mill Manufacturing facility. The shallow ground-water and VOCs identified near HAB-6 will migrate slowly toward the northeast.

Seven water samples and one soil sample were collected from the hand-auger borings drilled in the area of the former gasoline service station located within the present median of M-59. Using the field GC, the soil samples were analyzed for benzene, toluene, ethyl-benzene, xylenes (BTEX), TCE, DCE, and vinyl chloride. The location of the hand-auger borings and the GC results are shown on Figure 4.14. Field GC analytical results are summarized on Table 4.18; field GC data sheets are located within Appendix N.

BTEX compounds were detected within five water samples and one soil sample from the hand-auger borings drilled in the M-59 median. Total BTEX concentrations ranged from 115 μg/L at SBM-32 to 21,222 μg/L at SBM-24. In general, xylenes are the largest component of

total BTEX concentrations detected within the samples. Since xylenes are the least soluble of the BTEX compounds, the elevated xylenes to total BTEX ratio is indicative of an older release of gasoline. An older gasoline release is consistent with the information that the gasoline service station has not operated since approximately 1946 and that the USTs were likely removed during the road construction and widening of M-59 in the 1980s.

4.4.2.2 Intermediate Flow System

During the Phase II Remedial Investigation, the occurrence of volatile organics was investigated within the intermediate aquifer by conducting vertical profiling activities at four locations, installing monitoring wells if volatile organics were detected, and sampling all monitoring wells to determine if volatile organics were present within the intermediate zone. Two of the vertical profiles (IW-6 and VP-3) extended through the intermediate and deep flow zones because the silty-clay unit that usually separates the deep flow zone from the intermediate flow zone was not encountered at those locations. The Phase I investigation of the intermediate aquifer consisted of installing eight intermediate monitoring wells and sampling for TCL volatile organics.

4.4.2.2.1 Vertical Profiling

Four vertical profiles were advanced through the intermediate aquifer until the bottom of the aquifer was encountered. Two of the vertical profiles (IW-6 and VP-3) extended through the intermediate and deep flow zones because the silty-clay unit that separates the deep flow zone from the intermediate flow zone was not encountered at the above listed locations. Water samples were collected and submitted for analysis of 1,1-DCE; 1,2-DCE; TCE; and vinyl chloride using a field GC. Field GC results, field parameters (pH, conductivity, and temperature) and sampling depths are summarized on Table 4.19.

Except for a water sample collected at 55 feet to 56 feet below ground surface from Vertical Profile VP-1, all vertical-profile samples had nondetectable levels of 1,1-DCE; 1,2-DCE; TCE; and vinyl chloride. TCE was detected at a concentration of 11 μg/L in Water Sample HMW-VP1-55-56' collected from a depth of 55 feet to 56 feet below ground surface at Vertical Profile VP-1. In response to the TCE detection, a monitoring well was installed within the borehole with the well screen intersecting the zone where the TCE was detected. Since the installation of Monitoring Well VP-1, water samples have been collected on January 28, 1992, and February 12, 1992, and submitted to an analytical laboratory for analysis of TCL volatile organics. An evaluation of the analytical results indicates that no volatile organics were detected within either water sample. The laboratory analytical results suggest that the TCE encountered during vertical profiling may be the result of drag down of TCE-contaminated water during augering or during the collection of water samples using the drive-screen sampling system.

During the advance of Boring VP-1, vinyl chloride gas was encountered below the water table between 10 feet and 15 feet below ground surface. While the origins of this gas are not precisely known, it may have been produced when dissolved vinyl chloride was exposed to the atmosphere. It should be noted that the gas was actually encountered above the intermediate sand horizon.

4.4.2.2.2 Monitoring Well Sampling

During the Phase II ground-water sampling, VOCs were detected in water samples from three intermediate monitoring wells. No VOCs not related to laboratory or field contamination were detected. Table 4.16 lists all of the VOCs detected, and Figure 4.7 depicts the locations of the monitoring wells and concentrations of the detected VOCs. Except for SW-17, acetone was detected within the water samples from Monitoring Wells IW-2 (58 J μg/L) and IW-5 (2

J μg/L). Besides being a common laboratory contaminant, acetone has never been used for any production processes at the Hi-Mill Manufacturing facility.

Due to the detection of TCE (3 μg/L), toluene (3 μg/L) and xylene (3 μg/L) in a water sample from the hydraulically upgradient Monitoring Well SW-17, a second water sample was collected to either confirm or disprove the detection of the above-listed volatile organics. Monitoring well SW-17 was resampled on April 8, 1992, and laboratory analytical results indicate that no volatile organics not related to laboratory contamination were detected.

During the Phase I ground-water sampling event, methylene chloride, acetone, 2-butanone, and toluene were detected in water samples collected from the intermediate aquifer. All of the above-listed compounds are common laboratory contaminants that occurred within the sample's method blank. Phase I laboratory analytical results are summarized on Table 4.15.

4.4.2.3 Deep Flow System

During the Phase II ground-water sampling, no VOCs not related to laboratory or field contamination were detected. Table 4.16 lists all of the VOCs detected, and Figure 4.7 depicts the locations of the monitoring wells and concentrations of the detected VOCs. During the Phase I ground-water sampling event, methylene chloride, acetone, 2-butanone, and toluene were detected in water samples collected from the deep system. All of the above-listed compounds are common laboratory contaminants that occurred within the sample's method blank. Phase I laboratory analytical results are summarized on Table 4.15.

4.4.3 Base Neutral and Acid Extractable Compounds

Select ground-water samples were collected from Wells SW-2, SW-5, SW-8, and IW-1 for analysis of BNA concentrations during the Phase I investigation; the results are presented in Table 4.20. Only one detection of Di-n-butyl phthalate (0.008 mg/L) was observed in all the

analytical results. This compound was detected in Well SW-2 which was completed within the shallow perched flow system. Although the origins of this compound cannot be positively identified, it is anticipated that the detection may be the result of cross contamination by laboratory or sampling equipment constructed of plastics or latex, such as the disposable sampling gloves often used by field personnel.

4.5 AIR

No specific data suggest that the ambient air space around Hi-Mill Manufacturing has been impacted by VOCs. Volatile gases were only in discovered in one instance, during the drilling of Profile VP-1. Vinyl chloride gas was detected using an air sampling tube between 10 feet and 15 feet below ground surface, below the water table and above the intermediate flow zone. This gas was likely produced when vinyl chloride dissolved in ground water vaporized upon exposure to the atmosphere. It is possible that the gas may have already been present in the site vadose zone and, thus, could have migrated up through the hole during drilling. In either case, however, no ongoing impacts to the site atmosphere are believed to be likely (based on monitoring with field FID/PID equipment) unless the shallow site soils and ground water are disturbed through some type of human activity.

5.0 CONTAMINANT FATE AND TRANSPORT

5.1 POTENTIAL MIGRATION PATHWAYS

5.1.1 General

This section discusses the potential migration pathways which may exist at the Hi-Mill Manufacturing site which could facilitate the transport of the various compounds of concern identified during the Phase I and II Remedial Investigations. Compounds of concern constitute both organic and inorganic compounds as discussed previously in Section 4.0. Also presented in this section is a summary of potential receptors for the compounds present in various site media such as soils, ground water, and surface water as well as a general discussion of the persistence of the chemical species identified during the sampling and analysis of these media. Transport routes of potential migration include both actual movement of a compound or compounds within a given medium or transfer between media types. For example, the transport of organic compounds may be confined almost exclusively to the ground-water flow regime unless a surface waterbody such as a river or pond accepts discharge from the ground-water flow system. In the latter case, the constituent of interest would be transferred from one medium to another whereas, in the former example, compound transport would involve translocation within a given medium (i.e., ground water). The potential for such transference between media will be examined in Section 5.3.

The following discussion presented on the migration, fate, and transport of compounds at the Hi-Mill Manufacturing site is based upon the results of the hydrogeologic and geologic data interpretations performed for Phase I and II as well as actual analytical results from soil, ground water, and surface water. The principal potential migration pathways identified during

the Phase I and II investigations include soils, surface water, and ground water. A brief discussion of air as a potential route of contaminant transport is also provided in Section 5.1.5.

The principal VOCs of concern identified during the Phase I and II investigations include but are not limited to TCE; 1,2 dichloroethene (1,2 DCE); and, vinyl chloride. Although some small concentrations of 1,1, dichloroethene (1,1 DCE) were detected in some of the GC analyses of HAB water samples, it is difficult to differentiate 1,1 DCE from 1,2 DCE using the instruments employed. Thus, in the absence of other data, 1,1,DCE has not been included as a compound of concern. VOCs were identified in both the site soils and shallow ground-water systems. Potential sources for these VOCs (discussed in detail in Section 4.1) include existing and former aboveground TCE storage tanks; a 200+ gallon spill of TCE degreasing fluid between 1978 and 1980 which occurred during the construction of an addition to the site factory; incidental spillage of degreaser during the servicing of aboveground tanks; leaks in the plant infrastructure (e.g., cracked flooring, leaky pipes); and other forms of incidental dispersal that might be associated with the manufacturing process. Other potential sources of the VOCs detected in site ground water and soils include a UST previously used to store heating oil, a gasoline station which was formerly located west of Hi-Mill Manufacturing at the current site of the M-59 median which had fuel storage USTs, and a repair shop which may have acted as a source of VOCs as a result of the cleaning of automotive parts.

Several so called SLM were also detected in the ground water, soils, surface water, and surface-water sediments of the site; in particular, aluminum, chromium, copper, nickel, and zinc. Metals were detected above background concentrations in site soils (particularly at the rear of the factory), in nearby Target Pond (in the surface water and bottom sediments), and in site monitoring wells (i.e., ground water).

5.1.2 Soils

Movement of compounds through the zone of unsaturated soil (vadose zone) can occur as a result of the action of wind, surface water, human, or animal activities. The tendency of a compound to migrate through the vadose zone is dependent upon the type(s) of chemical species involved as well as various properties of the soil.

5.1.2.1 Inorganics

In the case of inorganic compounds, some of the critical soil properties which control the migration of metals include the cation exchange potential; soil type (available surface area); pH conditions; the oxidation state of the metals; and whether or not the compound has been complexed with other anions such as chlorine. Variations in vadose zone conditions such as pH are not only dependent upon the characteristics of the native soil but the chemistry of infiltrating waters. At Hi-Mill Manufacturing, metals were introduced to the site soils chiefly by the expulsion of process wastewater into the two lagoons formerly located at the rear of the facility (Figure 1.2). These solutions were a mixture of water, chromic acid, and residual metals. Some wastewater was also discharged via a network of spray dispersal heads located at the top of the plant and along the adjacent fencing. Although this practice of process water disposal was discontinued in 1981 due to the adoption of recycling, it is anticipated that some quantifiable concentrations of metals were introduced into the site soils. Additionally, despite the excavation and backfilling of the former disposal lagoons, metals were still detected at concentrations above the site background levels in other site soils (see Section 4.2.1). After the initiation of recycling activities, waste process water which could not be recycled was pumped to an underground concrete holding tank at the location shown in Figure 4.1. Once the tank was full, any remaining water was transported by a licensed waste hauler to a permitted hazardous waste treatment facility. The wastewater recycling system was abandoned in 1988 because Hi-Mill

Manufacturing had terminated all production activities that resulted in the production of metal-containing process water.

The presence of water and acid-based compounds in the process wastewater may have facilitated transport to the shallow ground-water flow system by increasing the solubility of inorganic constituents. At some of the Techna soil sampling locations, actual metal cuttings were discovered in the shallow soils. These fragments would undoubtedly contribute to the high concentrations of metals observed in the soil sample analyses. The mobility of metal-laden waters through the site vadose zone would be dependent upon the driving head of the waste stream (i.e., the shear volume of standing water), the vertical permeability of the shallow soils (also dependent upon effective porosity), and the ability of the soils to hold some of the dissolved metal constituents (see relevant soil properties listed above). Actual metal cuttings would probably not be translocated to the shallow ground-water system except by some man- or animal-induced action.

Initially, metals held within the matrix of shallow site soils would remain relatively immobile unless percolating surface waters possessed chemical characteristics which resulted in the increased solubility of the said metals such that the compounds of interest would once again enter solution. Wind and surface erosion are also potential methods by which metal-laden soils could be transported away from the initial site of deposition. However, the bulk of the Hi-Mill Manufacturing site, which is unpaved, is well vegetated with grass and trees. Much of the waste-water originally transferred to the former disposal lagoons traveled via narrow surface drainages to adjacent Target Pond, thereby transferring inorganic constituents from the shallow site soils (in part) to a surface-water medium. Since Target Pond is believed to sit atop a sequence of relatively impermeable clays (see Section 3.5.2.1), and because the hydrogeologic data indicate that Target Pond is a zone of discharge from the shallow flow system, not a source of recharge, most of the metals introduced to Target Pond are believed to have been trapped

within the thick bottom sediments of the pond. Data collected during the Ecological Assessment and Inventory (see Section 4.3) indicate that the pond sediments have likely been affected by the discharge of waste process water. Other potential forms of transport of metals in the vadose zone would include animal and, especially, human contact. It should be noted, however, that there is evidence that the Target Pond and wetland area may have been impacted by inorganics from other sites. Available data on the Numatics, Inc. facility located north of Hi-Mill Manufacturing and Target Pond (Figure 3.13) may have formerly or currently discharged metal-laden process waters on their property. Examinations of local topography and shallow ground-water flow (Figure 3.1) suggest that transport via ground-water and/or surficial runoff from Numatics to Target Pond is possible. Therefore, the impacts observed within Target Pond may not be wholly the result of activities at the Hi-Mill Manufacturing facility.

To summarize, the chief mechanisms for transport through the vadose zone are anticipated to be the leaching of metals from site soils by percolating waters which may ultimately result in the introduction of inorganics to the shallow ground-water system and displacement by way of direct human contact with affected soils. In general, the remobilization of metals bound to shallow site soils is expected to result in only minor continued migration of inorganic compounds. Human contact with affected soils is considered to be the principal transport mechanism of concern, owing to the potential risks to human health and safety.

Trans-media migration pathways are expected to include transport of inorganic compounds from the soil to the ground water via percolation of infiltrating water; surficial erosion of metal affected soils by surface runoff into Target Pond (following site topography); and migration of dissolved metals (mobilized by percolating water) to the shallow ground-water flow system which, in turn, would flow to Target Pond in accordance with the flow directions depicted in the phreatic surface map presented as Figure 3.1. Metals transported to Target Pond would likely be deposited in lake bottom sediments. The preponderance of inorganic compound

migration to the adjacent pond and wetland areas is believed to have occurred during the period prior to 1981 when process waters were discharged to the former lagoons. The migration potential of inorganics in surface water and ground water will be discussed in greater detail in Sections 5.1.3 and 5.1.4 respectively.

5.1.2.2 Organics

The primary physical characteristics which are anticipated to affect the migration of organics through the vadose zone are organic compound solubility (includes density characteristics); the vapor pressure of the compounds of interest; and the biodegradation of organics to form other compounds either by purely biological or biochemical reactions. The principal potential routes of migration are expected to include direct downward infiltration of liquid organics, possibly to the shallow ground-water flow system; removal of soil-bound organics by percolating waters and/or surface runoff; and human contact. The downward migration of organics through the vadose zone is controlled not only by the characteristics of the compounds of interest but of the medium as well. Medium characteristics of potential importance include the vertical permeability of the soil; the porosity of the soil; the surface area and type of soil affected; and the driving head (standing volume) of the discharged organic liquid.

As discussed in detail in Section 4.0, potential sources of the organics found in site soils include the accidental spillage of over 200 gallons of TCE-based degreasing fluid; potential leaks from any of the former or existing aboveground TCE storage tanks or associated piping; accidental spills around the aboveground tanks which could have occurred during routine servicing; and leaks in the factory infrastructure associated with either the degreasing units or the building itself (e.g., cracked flooring). The 200+ gallon spill of TCE occurring between 1978 and 1980 is expected to be responsible for the plume delineated in the M-59 median west

of the Hi-Mill Manufacturing facility. Although identified through portable GC analysis of shallow ground water, migration in the shallow flow system is anticipated to have been initiated by downward infiltration of degreaser through the site vadose zone. Residual ganglia may possibly reside in the unsaturated soil surrounding the site of the spill.

Further propagation of chlorinated solvents in the vadose zone may also be occurring in the form of soil gas. Vinyl chloride gas was encountered during the drilling of Vertical Profile VP-1 between approximately 10 feet and 15 feet below ground surface. Although this gas was encountered at a depth below the water table (which is at about 3 feet to 5 feet below ground surface), it is uncertain as to whether the gas originated within the vadose zone itself or was the result of exposure of dissolved vinyl chloride to the atmosphere. If soil gas is present in the vadose zone, it may migrate through the shallow unsaturated zone and may further contribute to the spread of TCE and related daughter products, DCE and vinyl chloride, by direct contact with the shallow phreatic surface.

TCE, DCE, and vinyl chloride were also detected in site soils during both the Techna and Geraghty & Miller investigations. These solvents were found in both unsaturated soils and in shallow ground water around former and existing degreaser storage tanks (Figure 4.7). The presence of these compounds may be indicative of occasional accidental spillage or small persistent leaks. Existing soil impacts are expected to include residual chlorinated compounds held within the matrix of shallow soils as residual ganglia. Certainly, some of the spill degreasing liquid migrated downward toward the shallow ground-water flow system. Further adulteration of shallow ground water may occur due to the percolation of infiltrating waters.

Animal, wind, and erosional activity are not expected to exert a major influence in the transport of residual soil organics through the vadose zone. Human contact and translocation of organic compounds is a potential mode of transport due to incidental worker exposure to site

soils. The shallowest site soils (i.e., upper 3 feet), however, may no longer contain significant quantities of VOCs due to the volatilization and evaporation of light fractions.

To summarize, the major mechanisms of transport of organics in the vadose zone (i.e., migration pathways) include downward migration due to the percolation of infiltrating waters and incidental human contact and exposure. Soil gas migration may also play a part in the migration of organics; however, the available data do not suggest the clear presence of soil gas in the site vadose zone. The biodegradation of TCE to 1,1 DCE, 1,2 DCE, and vinyl chloride can affect the transport of soil organics since the degradation products of TCE can have vastly different chemical properties (e.g., vinyl chloride vapor pressure). For example, the eventual breakdown of TCE to vinyl chloride can result in significant transport of vinyl chloride in the vadose zone as soil gas.

As in the case of the inorganics, trans-media migration of organic compounds is likely at the Hi-Mill Manufacturing site. The migration of organics to different media includes downward infiltration of organics to the shallow ground-water flow system; production and transport of soil gas may impart detectable quantities of organics to the ground water via direct contact with the water table and capillary fringe; organics imparted to ground water via soil gas and/or downward infiltration may be ultimately discharged to local surface waterbodies such as Target Pond, Waterbury Lake, or the wetlands located west of M-59 (see shallow phreatic surface map in Figure 3.1); and some surface erosion of impacted soil is possible, which could result in the translocation of organics to surface waterbodies via runoff or enhance incidental human or animal contact. If significant quantities of shallow soil gas are produced, some of this gas could be imparted to the atmosphere, especially if the ground surface is disturbed by human activities. Of the potential migration pathways discussed, migration to ground water via infiltration/leaching of residual ganglia and soil gas development are considered most significant.

5.1.3 Surface Water

The surface waterbodies located adjacent to the site do not appear to have any surficial form of drainage. The North Arm of Waterbury Lake was originally thought to drain under M-59 to a creek and wetland area on the west-northwest side of M-59. However, close inspection of this area suggests that no direct surface hydraulic contact exists between the two surface waterbodies, and the creek on the west side of M-59 appears to receive discharge from only the storm water sewers completed within the M-59 median and perhaps some base flow from the shallow flow system. Staff gauge data from the wetland area located immediately west of Target Pond suggest that flow may occur under M-59 through a drainage box toward Target Pond. As discussed previously, Target Pond and Waterbury Lake do not appear to provide recharge to the bulk of the site ground-water flow systems and, generally, act as zones of discharge only (see the phreatic surface map in Figure 3.1). However, some flow from the North Arm may occur through the shallow system beneath M-59 with the ultimate discharge point being the entrance to Alderman wetland. Some flow may also occur between Target Pond and Waterbury Lake through a narrow intervening portion of the shallow system. It should be noted, however, that several piezometers located in this area were dry. Target Pond is underlain by two sequences of relatively vertically impermeable clays (most notably the upper gray clay), and discharge to both Target Pond and Waterbury Lake is believed to occur from the shallow system via narrow lenses of silty, sand, and clayey silt, interbedded within the brown clays.

Thus, Target Pond and Waterbury Lake are expected to accept discharges containing both inorganic and organic constituents from the shallow ground-water flow system and surficial runoff. Although not specifically indicated by the data, some form of shallow soil gas migration (of organic compounds) in the site vadose zone cannot be ruled out. The wetland areas west of M-59 may accept impacted discharge from the shallow ground-water flow system; however,

while no specific data on the quality of these waters are available, delineation of shallow organic ground-water impacts would suggest such discharge has not yet occurred. Conversely, there appear to be no major receptors or outward paths of migration from Target Pond, with the possible exception of animal and/or incidental human contact or the possible ground-water connection to Waterbury Lake. The bulk of inorganic constituents are believed to have been introduced into Target Pond during the period prior to 1981 when the former wastewater lagoons were active. Most of the inorganics introduced into Target Pond are anticipated to have been trapped by thick bottom sediments owing to the high organic carbon content of these sediments and the comparatively high specific gravities of the compounds involved. Target Pond is a predominately reducing environment and, as such, the low pH conditions present in the lake would tend to reduce metals solubilities and thus diminish their mobility. No specific analyses for VOCs were performed on the surface water or bottom sediments during either the Phase I or II Remedial Investigations.

Soils and ground-water data collected from the adjacent Numatics, Inc. facility, taken in conjunction with available shallow ground-water data, would suggest that the Numatics facility may have also contributed inorganic compounds to the Target Pond and wetland area. Surficial runoff and shallow ground-water gradients indicate that flow from the Numatics property is, at least in part, toward Target Pond.

In summary, although the adjacent surface waterbodies are likely receptors of impacted water (especially inorganics) there appear to be minimal external discharge paths for these compounds from either Target Pond, Waterbury Lake, or the North Arm of Waterbury Lake. Possible discharge paths from Target Pond, Waterbury Lake, and the North Arm include discharge from the North Arm into the shallow flow system which, in turn, may discharge into Alderman wetland; discharge from Target Pond to Waterbury Lake through a narrow portion of the shallow flow system; and discharge from Waterbury Lake to the North Arm via ground

water through a small levee separating the two waterbodies. It should be noted, however, that several of the HABs advanced in the area between Target Pond and Waterbury Lake were found to be dry, and that inspection of the phreatic surface map suggests that a "stagnant" zone (relatively flat water table) may exist in this area (although this could change with fluctuations in the surface water and ground-water table). In addition, data on the lateral extent of TCE suggests that shallow ground-water impacts have not likely reached the potential surface water receptors of Waterbury Lake or the North Arm. Some of the wetland areas west of M-59 may possess external migration routes; however, data on the lateral extent of the shallow ground-water plume indicate that these compounds probably have not yet reached any of these potential receptors. The main avenue of migration out of Target Pond is incidental contact with humans and/or exposure by various local flora and fauna (see the Ecological Assessment and Inventory in Appendix R).

5.1.4 Ground Water

Ground water is the principal migration pathway of both inorganic and organic compounds. A wide variety of volatile organic species and dissolved metals have been detected in the ground-water flow regime at Hi-Mill Manufacturing. In general, inorganic and organic constituents are expected to migrate downgradient in the direction of ground-water flow at a rate which is equal to or less than the ground-water seepage velocity. Migration through the ground-water flow system is dependent upon such physical factors as aquifer hydraulic conductivity; both total and effective porosity; tortuosity of the interconnected pores; hydraulic gradient; lithologic variations; and the driving head involved during initial introduction into the system. Relevant chemical characteristics include solubilities; vapor pressure; density; oxidation state; cation exchange potential; pH conditions; the retardation factor; and anion complexing.

The preponderance of ground-water impacts have been discovered in the shallow flow system. The phreatic surface map of the shallow system depicted in Figure 3.1 illustrates the approximate direction of transport. Transport of inorganic compounds in ground water may be arrested if water chemistry conditions fluctuate in a manner conducive to the reduction of the solubility of those compounds. VOCs may be retarded by adsorbing onto the sides of pore spaces within the shallow site soils and/or by a phenomenon referred to as matrix diffusion, whereby molecules of an organic compound diffuse into the matrix (or mineral grains) of a soil or rock and then gradually diffuse back into active pore spaces over time. The tendency of an inorganic or organic compound to remain trapped within a saturated medium is dependent upon both the physical properties of the medium and the chemical characteristics of the compound in question. So-called "conservative solutes" (such as chlorine) will totally dissolve in ground water and will remain in solution traveling at nearly the same rate as the ground-water medium. Hence, when metals are complexed with an anion like chlorine, their solubility and, thus, mobility may be increased substantially. With regard to organic compounds, the tendency of an organic substance to be slowed during transport due to chemical or physical properties may be expressed by a value known as the retardation factor. For reference, the retardation factor of a conservative solute is equal to 1.

The approximate lateral distribution of VOCs in the shallow flow system as delineated during the Phase II investigation at Hi-Mill Manufacturing is presented in Figure 4.7. Similarly, the distribution of dissolved metals in ground water, found at concentrations above published background levels, is provided in Figure 4.9 (from Phase II) (mostly aluminum an one detection of nickel).

Comparisons of the distribution of VOCs in the shallow ground water clearly illustrates migration of the combined TCE, DCE, and vinyl chloride plume downgradient to the west-southwest and away from the Hi-Mill Manufacturing facility. This migration pattern may be explained by examining the gradients and ground-water flow directions within the shallow flow system, which is presented as Figure 3.1. Based upon the shape of this plume and the known

ground-water flow directions, the point of origin of the TCE appears to be located in the same approximate vicinity as Addition #4 of the Hi-Mill Manufacturing plant building. Recall that a TCE spill of approximately 250 gallons occurred near this area in the late 1970s when a pipeline carrying degreaser was accidently damaged during the construction of Addition #4. If the phreatic system gradients remain similar to those shown in Figure 3.1 over time, then one would expect continued migration of TCE, DCE, and vinyl chloride to the west and southwest of Hi-Mill Manufacturing at a rate ranging from approximately to 15 to 800 ft/year (depending upon gradient; assumes no retardation and an effective porosity of 33 percent, see Section 3.5.2.3 for seepage velocity calculations). Typically, however, the chlorinated solvents possess retardation factors on the order of about 2; which indicates that such compounds will move at only about half the rate of a conservative solute. There are also many uncertainties with regard to actual effective porosity and dispersivity.

Some isolated detections of VOCs were also discovered which may be associated with smaller source areas not related to the major spill (e.g., minor spillage/leakage around former and existing TCE tanks). These VOC detections are also presented in Figure 4.7. It should be noted that with the exception of some unusual detections believed to be related to laboratory cross contamination, no VOCs were detected in the intermediate or deep zones, either by sampling of existing monitoring wells or the completion of vertical profiles (water sampling). One exception was a single sample collected from Profile VP-1 which indicated the presence of 11 ppb of TCE. Two subsequent sampling events of the well installed in VP-1, however, failed to confirm the presence of VOCs. Trace concentrations of TCE and toluene were detected in the intermediate zone at levels lower than the quantifiable detection limit within soil samples collected from Vertical Profile IW-6, at depths of 100 feet to 102 feet below ground surface and 115 feet to 117 feet below ground surface. Although the precise origins of these compounds are unknown, the concentrations are low enough that cross contamination, either by direct contact or by air emissions from the Hi-Mill Manufacturing factory, is a possibility. These data tend

to conflict with other ground-water data available for the immediate vicinity. While ground-water flow is generally 3-dimensional in nature, the upper gray clay separating the shallow zone from the intermediate and deep flow zones is believed to be of sufficiently low permeability to preclude downward migration of volatiles (and inorganics). Phreatic surface data and topographic maps do suggest however, that ground water within the shallow zone may discharge to surface-water and/or wetland features located within the Highland State Recreation Area. Thus, although currently limited in lateral extent, VOCs may eventually find surficial receptors if remedial containment and/or clean-up measures are not implemented in a ely manner.

Presented in Figure 4.9 is a map depicting the distribution of dissolved metals in ground water at levels in excess of published background levels. Virtually all such detections are for the metal aluminum (and one which is nickel). All such detections (dissolved metals) were within wells completed in the shallow flow system with the exception of a 58.8 ppb detection in Well SW-18 (intermediate flow zone). These data cannot be reliably contoured to demonstrate potential migration patterns, although transport is expected to be in the same general direction as phreatic surface flow. These metals may appear to be positive confirmation of inorganic impacts to the ground-water flow system due to the lack of any site/area-specific background ground-water data or because of anomalously high natural concentrations of these metals in nearby soils. In other words, some or all of the detections observed above published background concentrations may not, in fact, be the result of previous site activities. Migration of aluminum through the subsurface flow system is not felt to be of major concern at the Hi-Mill Manufacturing site. The data do not suggest at this time that ground-water impacts may have reached other surface receptors as of the date of this report.

Some of the shallow monitoring wells located immediately adjacent to Target Pond and downgradient of the Hi-Mill plant show small estimated concentrations of select VOCs (e.g., SW-7, SW-9A, and SW-10) (Figure 4.7). While others show no such detections (e.g., SW-4,

SW-9, SW-14, and SW-22). Of those wells showing VOC impacts in shallow ground water near Target Pond, the highest concentrations of TCE, DCE, and toluene detected were 4 ppb (SW-7), 7 ppb (SW-10), and 2 ppb (SW-9A) respectively (See Figure 4.7). To determine a reasonably accurate potential concentration of VOCs in Target Pond at this time would be extremely difficult owing to the high number of variable factors involved such as volatilization, biodegradation, and varying inflow of water into the pond. However, based upon the available data, it is not anticipated that concentrations of the VOCs listed above entering the pond would be any higher than that described above (i.e., TCE = 4ppb; DCE = 7 ppb; toluene = 2 ppb). In fact, it is expected that actual concentrations would be considerably lower (perhaps nondetects) owing to retardation and adsorption prior to entering the pond, and volatilization and biodegradation after entering the surface water receptor. In addition, the comparatively large volume of water present within Target Pond relative to the low concentrations which may be entering, would likely result in no significant detections. However, the most efficient and expeditious way to confirm or refute these conclusions would be to collect surface water samples of Target Pond.

In summary, the shallow ground-water flow system is felt to serve as the primary migration pathway for the transport of VOCs. Transport of inorganics (namely aluminum) at levels in excess of published background concentrations is not felt to be of great concern. VOC migration appears to be confined to the upper 10 feet of the shallow flow system. Heretofore, no evidence is currently available which would suggest that either the intermediate or deep flow zones have been affected nor are any data available which would indicate that local surface water has been impacted. The wetland areas west of Hi-Mill Manufacturing and M-59 may eventually act as receptors for the TCE, DCE, and vinyl chloride plume discovered beneath M-59 if remedial measures are not implemented. The source of the primary VOC plume appears to have been the TCE-based degreaser spill which occurred in the late 1970s during the construction of Addition #4. Other isolated "pockets" of VOC-affected water were found adjacent to former

and existing degreaser storage tank locations. All VOC-impacted water is expected to move in the general direction of shallow phreatic flow as depicted in Figure 3.1. As stated in previous sections, contributions of VOCs and, to a lessor degree, inorganics may be ongoing with trans-media (i.e., to ground water) migration occurring by the leaching of residual compounds from the vadose zone via infiltrating waters and by contact between the water table and soil gas. While surface water may act ultimately as a receptor for VOCs and dissolved metals, data on the hydraulics and chemistry of the shallow ground water suggest that such propagation out of the shallow flow zone has not yet occurred.

The migration potential of organics and inorganics to humans and animals from site ground water is expected to be minimal since no known water supply wells have been completed locally in the shallow system. The yield and permeability of the shallow zone is not believed adequate to serve as a potential source of potable water. Deeper wells, such as the two formerly located near the Hi-Mill Manufacturing facility (Figure 1.2) may potentially pull contaminants from the shallow zone into the intermediate or deep systems by dragging down compounds along the sides of improperly sealed casings or by overcoming limited permeabilities in the intervening gray clay layer by establishing very strong downward vertical gradients. Some problems were encountered in the previous site supply wells when small concentrations of VOCs were detected in the plant water (see Section 1.2.2). The potential for migration of VOCs to human or animal populations is much more likely if sufficient time is given for the existing shallow impacted ground water to reach surface-water receptors.

5.1.5 Air

Migration of compounds via the atmosphere is only feasible if organic compounds possessing adequate chemical properties to permit volatilization are exposed to the atmosphere. Dust particles of metal-impacted soils may be picked up and transported by winds; however, this

is not considered to be a significant factor in compound transport since the site is either well vegetated or paved. Volatile fractions of organic compounds discharged at the surface of the plant site are expected to have been dissipated soon after a spill may have occurred. The major mechanism by which organic constituents may be introduced into the atmosphere is by the release of soil gas. During the completion of Vertical Profile and Well VP-1 (Figure 2.1), a pocket of gas was encountered during drilling. The gas was tentatively identified by a Drager tube as vinyl chloride. No other data on the escape of organics to the atmosphere are available for the Hi-Mill Manufacturing site; however, the phenomenon observed during the boring of VP-1 suggests that some type of man-induced displacement of surface soils would be necessary in order to result in a significant release of soil gas from the site vadose zone. Therefore, air as a migration pathway is not deemed significant in the absence of human disturbance of site soils.

5.2 CONTAMINANT PERSISTENCE

Among the inorganic constituents detected in site soils and ground water which were in excess of either site-specific or published background criteria, a total of five compounds of concern was identified during the Phase I and II investigations; these included aluminum, chromium, copper, nickel and zinc. Similarly, of the organic compounds detected in site soils and ground water during the Phase I and II investigations, the primary compounds of concern identified were 1,1,1 TCA; 1,2 DCE; TCE; and vinyl chloride. Other volatiles detected which cannot be readily explained as laboratory contaminants included toluene and tetrachloroethene. This section presents a discussion of the potential persistence of the inorganics and organics described above.

5.2.1 Inorganics

The metals mentioned above are anticipated to persist in the shallow site soils unless dissolved and transported by water. As discussed previously in Section 5.1.2, the factors which would likely influence inorganic solubility include the soil type and available surface area; the

cation exchange potential; the pH conditions of the soil and infiltrating waters; the oxidation state of the metals; and the availability of anions which could form complexes with the resident metals. Metals are frequently immobilized in soils as a result of fixation within the soil grains themselves or adsorption onto the surface of the soil minerals within available pore spaces. Fixation mechanisms may include chemisorption; solid state diffusion; and precipitation of minerals. Cation adsorption, most commonly associated with the organic compounds, is known to occur for the five identified metals of concern. As reported by Dragun in "The Soil Chemistry of Hazardous Materials", the observed range of adsorption coefficients (or Kd's) for trivalent chromium, copper, and zinc are 470 to 150,000 ppm; 1.4 to 333 ppm; and, 0.1 to 8,000 ppm, respectively. Once becoming mobile, these metals may be transported by surface water, ground water, or surface runoff/interflow for some distance until either a static receptor is reached by the transport medium or until soil and/or water conditions vary in a manner which reduces compound solubility and permits fixation within a different locale in the soil horizon.

5.2.2 Organics

Although biodegradation of subsurface organics and volatilization of light organic fractions at the surface are factors which may reduce the persistence of the identified VOCs of concern, organic compounds at the Hi-Mill Manufacturing site are expected to persist (especially at greater depths) for a sufficient length of time to permit migration away from the facility. However, evidence of the biodegradation of TCE into related daughter products 1,1 DCE; 1,2 DCE; and vinyl chloride is present. This process of biodegradation occurs when microbes living within the soil and ground water strip chlorine atoms from chlorinated solvents, thus, gradually altering their molecular structures and creating different compounds. The typical degradation sequence for TCE may be summarized as follows TCE to 1,2 DCE (total) to vinyl chloride. While the end-product of this sequence (vinyl chloride) is not thought to degrade rapidly by micro-organisms, it is susceptible to hydrolysis and has a high volatility and, thus, may rapidly

vaporize when exposed to the atmosphere. The rapid vaporization of vinyl chloride is not anticipated to represent a primary method of reducing the compounds persistence at the Hi-Mill Manufacturing site unless the native soil is disturbed by some type of human-induced activity. Each of the identified volatile organics of concern will readily be adsorbed to soil particles, especially in the presence of organic carbon. Adsorption of organics is anticipated in the shallow site vadose zone and in strata where free-phase product may be present.

5.3 CONTAMINANT MIGRATION

Presented in the following sections is a discussion of the known and suspected potential migration of the identified compounds of concern at the Hi-Mill Manufacturing site. This section has been delineated into individual summaries of migration in the principally identified media; that is soil, surface water, ground water, and air.

5.3.1 Soils

The preponderance of migration of compounds through the shallow site vadose zone (unsaturated soils) at the Hi-Mill Manufacturing site is anticipated to occur in the form of downward transport to the shallow ground-water flow system. In some cases, such as the 200+ gallon spill of TCE near Addition #4, downward migration of compounds likely occurred initially as a result of the saturation of the vadose zone by degreaser beneath the spill location and the shear driving head of the fluid. Similarly, the downward transport of metals may have occurred due to the saturation of the shallow zone by acid-containing wastewater solutions containing heavy metals which were discharged to the rear of the plant into two unlined retention lagoons. Other sites of soil adulteration, such as the areas around the former and existing TCE tanks, may not have had sufficient hydraulic impetus to create immediate vertical transport of compounds to the shallow perched zone. Rather, in these cases, transport may have been

accomplished by means of infiltrating waters which dissolved some of the inorganic and organic compounds and thus, carried them to the phreatic surface. Shallow site soils were also impacted by the discharge of plant process water via a network of spray heads located at the top of the site building and along adjacent fencing.

Other possible forms of migration through the soil medium include surface-water runoff, which could have been rather significant if precipitation events occurred soon after a recent spill; wind-blown transport of affected soil, which is not considered to be highly significant due to the abundance of vegetated and paved areas around the site; and human interference. Another potential mechanism for migration of organics through the vadose zone is soil gas migration, particularly with regard to vinyl chloride. This gas was encountered during the completion of Vertical Profile VP-1, suggesting that soil gas may exist beneath portions of the site. However, the gas was encountered while drilling below the water table (between about 10 feet to 15 feet below ground surface). Consequently, it is unknown as to whether the vinyl chloride was actual soil gas or the result of the volatilization of high concentrations of the compound upon exposure to the atmosphere. This was the only such encounter during the investigation and, as such, while by no means certain, the potential for soil gas migration in the vadose zone cannot be ruled out.

Of the compounds of concern identified, the inorganics (metals) are anticipated to be least mobile within the vadose zone, owing to generally poor solubilities and the tendency of the identified metals to adsorb to the surface of mineral grains especially when native soils are high in organic carbon content. If ganglia of residual organics are trapped within pore spaces of the vadose zone and if an adequate supply of percolating waters is available then organic residuum may act as a persistent source of compounds which can migrate downward to the shallow water table.

The available data collected during the Phase I and II Remedial Investigations suggest that trans-media migration of soil impacts has occurred at the Hi-Mill Manufacturing site. Trans-

media migration involves the migration or transport of impacts from one medium (such as soil) to another (such as ground water). Undoubtedly, the analytical results obtained from the site monitoring wells for both organic and inorganic compounds indicate that chemical species have in fact migrated downward through the vadose zone into the shallow ground-water flow regime. Further migration of inorganic transport to local surface waterbodies has also occurred in the form of surface runoff (especially from the former lagoons into Target Pond). Organics may have also been transferred to the air (e.g., venting of vinyl chloride during drilling) and potentially to ground water via soil gas migration. Direct soil gas transfer to the atmosphere is not anticipated to be likely, at present, unless through the disturbance of shallow site soils by human activity. The potential impact to surface water from organic constituents present in the soil is unknown. Analysis of the hydrogeologic and geologic data collected during the Remedial Investigation indicate that further migration of inorganics into the shallow or intermediate ground-water flow regimes is not likely due to the presence of low permeability clays underlying Target Pond. Inorganics were probably trapped, in most cases, within the organic bottom sediments of the pond.

Once entering the ground water from the soil medium, shallow impacts are expected to move in the same general direction as the phreatic surface flow shown in Figure 3.1. With the exception of two soil analytical results collected during the drilling of location IW-6, no significant impacts were detected in the intermediate or deep flow zones. If impacts were later discovered within these systems, migration would likely be in a more-or-less westerly direction toward the Highland State Recreation Area. Further discussion will be devoted to surface-water and ground-water migration in the following sections.

5.3.2 Surface Water

Overflow from the former wastewater lagoons likely occurred in the past with the bulk of the flow and metal-laden waters transferred to adjacent Target Pond. Metals contained within this process wastewater were trapped in thick organic bottom sediments. Some of the metals

transported to Target Pond may have temporarily remained in solution due to the acidity of the wastewater. Inorganics which were initially in solution likely settled to the bottom due a change in solubility brought on by the neutralization of the acidic water by the reducing environment of the pond. Since no discharge from the pond to the shallow ground water is evident based upon examinations of hydrogeologic and geologic data, metals-impacted sediments in Target Pond will not likely be subjected to migration unless it is induced by human activities. Although it is possible that some discharge into a small portion of the shallow system between Target Pond and Waterbury Lake is possible, the available data indicate that much of this zone may be dry, and water levels collected in March of 1992 suggest the water table may be relatively flat in this area if it is partially saturated. Similarly, staff gauge data collected from Target Pond and the wetland area located west of M-59, suggest that surface flow is from the wetland area towards Target Pond, precluding surface-water transport away from the Hi-Mill Manufacturing site. No data are available as to whether or not the surface water and bottom sediments of Target Pond have been impacted by any of the identified organic compounds of concern (e.g., TCE, DCE, vinyl chloride).

Transference of inorganic compounds to the flora and fauna of Target Pond is possible; the impact is discussed in detail in the Ecological Assessment and Inventory provided in Appendix R.

5.3.3 Ground Water

Migration of both inorganic and organic compounds into the shallow ground-water flow system has occurred at the Hi-Mill Manufacturing site. Further transport of these compounds through the ground-water flow system has also occurred as delineated in Section 4.0. Organic constituents may have also migrated into a portion of the intermediate flow system; however, the data in this regard are unclear since the preponderance of intermediate zone monitoring-well

and vertical-profile data indicate no such impacts. The only indication of potential affects on the deeper flow regime come from the analysis of two soil samples collected from the intermediate zone in Boring IW-6. These detections were at concentrations which were well below the quantifiable detection limits set for the compounds of concern and may have been the result of cross contamination via air or direct contact with the samples. It is anticipated that migration into the shallow ground-water flow system took place principally as a result of the downward migration of compounds through the unsaturated shallow soil zone.

5.3.3.1 Inorganics

The mechanism by which the bulk of the inorganic compounds were introduced into the site ground water is believed to have originated from the discharge of acidic metal-laden wastewater at the rear of the Hi-Mill Manufacturing facility. The metals contained within the discharged water were believed to have been at least partially dissolved due to the acidity of the waste process water. Since the phreatic surface in this area is so shallow (generally only 3 feet to 4 feet below ground surface) and since such large volumes of water were discharged from the plant, it is anticipated that at least some quantity of this water did manage to infiltrate downward into the shallow flow system. Differences in the physical and chemical characteristics of the medium may have allowed much of the inorganic compounds to become fixed within the vadose zone and/or saturated site soils. Those metals which did remain in solution however, are expected to be transported in a direction consistent with that of the shallow ground-water flow system (Figure 3.1). Comparisons between the results of the ground-water sampling event conducted at the end of Phase II and the published MDNR background concentrations for the SLM in ground water indicate that, for the most part, only aluminum has been detected in the Hi-Mill Manufacturing ground-water flow system at levels above background. One sample from Well SW-5 did reveal the presence of nickel at elevated concentrations (Figure 4.9). Since the ground-water metals concentrations cannot be readily contoured, there is some question as to

whether the background concentrations used are actually appropriate for the site. However, in general, transport of dissolved metals is not expected to be wholly dissimilar from those of organic compounds, as stated previously.

The bulk of ground-water transport of inorganic compounds is expected to be in either a west-northwest direction toward the Highland State Recreation Area property located west of M-59, or toward Target Pond, with discharge ultimately occurring as baseflow from narrow lenses of sand, silt, and clayey silt located within the shallow flow zone. Shallow ground water may eventually reach a surface-water receptor on the west side of M-59 which may accept dissolved metals from the Hi-Mill Manufacturing facility. The laboratory analytical data of ground water do not indicate the presence of elevated metals in the subsurface flow regime west of M-59 and Hi-Mill Manufacturing. In general, the highest ground-water concentrations of inorganic compounds may be found in wells located at the rear of the Hi-Mill Manufacturing plant, which is consistent with the former discharge locations of the waste process water. Further elevation of ground-water concentrations of dissolved metals may be associated with the deposition of metal cuttings in the process wastewater, which could act as small-scale sources of elevated metals concentrations and may not be directly related to the initial introduction of impacted factory water into the shallow ground-water flow system.

The only non-shallow zone monitoring well to exhibit elevated levels of dissolved metals at concentrations above published background is Well SW-18 (Figure 4.9), which was completed in the intermediate zone. The reason for elevated levels of aluminum in this well is not fully understood (given the prevailing ground-water gradients); however, this location may be downgradient of the nearby Numatics, Inc. facility located north of Hi-Mill Manufacturing. However, examinations of the shallow phreatic surface map (Figure 3.1) are inconclusive since insufficient data are available to clarify whether SW-18 is actually downgradient or sidegradient relative to Numatics. Another well, not actually on the Hi-Mill Manufacturing property (SW-20),

also exhibited elevated levels of aluminum (in the shallow zone). This well location, too, is downgradient of the Numatics, Inc. facility. Examinations of reports received through the Freedom of Information Act on the production activities at the Numatics facility suggest that either past or existing practices on the property may have or are currently contributing to the transport of metals in the ground-water flow regime, surface water, and soils. Thus, detections at SW-20 and SW-18 may be due entirely, or in part, to activities at Numatics and may not be wholly reflective of the transport characteristics of the flow regime underlying Hi-Mill Manufacturing and the adjacent areas.

5.3.3.2 Organics

Organic compounds were likely introduced into the ground-water flow regime from multiple sources; however, of those discussed previously in Section 5.1.1, the most significant source of these compounds is anticipated to be the accidental release of degreaser during the construction of Addition #4. Introduction of chlorinated solvents into the ground water as a result of this spill likely occurred due to the driving head of the standing fluid which was anticipated to have saturated the shallow unsaturated soils and migrated downward to the shallow phreatic system. As the impacted portions of the vadose zone gradually drained, residual ganglia of the degreaser were probably left behind as retained product trapped within the pore spaces and mineral grains of the underlying soil. Further leaching of this residual material is expected to be minimal since the area of the spill was covered completely by the new building structure, thus precluding the percolation through the impacted area by infiltrating waters. Compounds from the spill which reached the shallow water table then migrated in a westerly direction away from the plant in a manner consistent with the phreatic system flow direction. The lateral extent of this plume was delineated during the Phase II investigation and is depicted in Figure 4.7. Discharge from the shallow system may occur in the wetland areas located west of the plant across M-59, although the investigation conducted in and around M-59 indicates that product has not likely reached these areas.

Incidental spills associated with the servicing of existing and former aboveground degreasing tanks would not likely infiltrate rapidly to the shallow ground-water flow system. It is anticipated that light volatile fractions would evaporate at the surface and that some residual product would become trapped within the upper site vadose zone. These areas, since they are exposed to the elements, could be subject to leaching of organics by infiltrating waters. Dissolved organics in these areas could then migrate to the shallow phreatic system. Data on the chemistry of soils and ground water at the north and south ends of the building where most of the tanks are or were formerly located suggest that impacts to both mediums (i.e., soil and ground water) have occurred (Figure 4.7). Migration of dissolved organics derived from these source areas will be in the same general direction as shallow ground-water flow in accordance with the prevailing gradients in the area of the spill.

In order to predict the potential future rate and distance of migration of TCE in the shallow flow system, a numerical ground-water flow and transport simulation would have to be performed. Data which would be required in order to perform such a simulation would include (but not necessarily be limited to) hydraulic conductivity, effective saturated aquifer thickness, storativity, effective porosity, retardation of TCE (or other compounds in question), hydraulic gradients within and beyond the study area, hydraulic boundaries, and seepage velocities beyond the current study area. Dispersivities would have to be determined during calibration of the solute transport portion of the model, and calculations would have to be performed to estimate the effects of matrix diffusion. In addition, a multi-phase transport model (few of which are available) might be advisable if the presence of free-product is confirmed or strongly suspected. Much of the information described above is not currently available. Thus, specific quantification of migration rates cannot be reliably determined at this time.

While the collection of considerable additional data would make such a modeling effort more feasible, the loss of time involved in such a collection and modeling effort would

undoubtedly delay the implementation of remedial measures considerably. Therefore, the most expedient use of the time and funds available would be better employed on the design and implementation of an appropriate remedial system to halt and reverse the current migration of ground water impacts.

All organic compound transport within the ground-water flow system is expected to be subject to retardation owing to the chemistry of the individual compounds and the physical characteristics of the water-bearing soils. The persistence of the organic compounds of concern in ground water was presented previously in Section 5.2.

There is no definitive proof of migration of organic compounds into the intermediate or deep flow systems. The bulk of the data derived from monitoring well sampling and vertical profiling indicates that no such impacts have occurred. The geologic and hydrogeologic data indicate that the upper gray clay possesses sufficiently low hydraulic conductivities and lithologic characteristics to preclude the downward migration of compounds. However, soil samples collected from Boring IW-6 (Figure 4.7) located west of M-59 indicated the presence of low concentrations of some VOCs. It is possible that these samples were cross contaminated during their collection, most notably by contact with affected air emanating from the Hi-Mill Manufacturing plant. It is worthwhile to note that no evidence of intermediate zone impacts were detected in holes and wells located immediately adjacent to suspected source areas.

However, because it is theoretically possible for VOCs to eventually migrate downward into the intermediate system through the upper gray clay (i.e., after several decades), prompt remedial measures should be employed in an expedient manner. In the event that free-product is present beneath the site building in the form of dense non-aqueous phase liquids (DNAPLs), care must be exercised in employing any remedial system to prevent remobilization of a DNAPL plume. It has also been recommended by numerous authors on the subject of DNAPL, that

extreme care must be exercised during investigatory work to avoid the further migration of free-product (Cherry, 1991; Villaume, 1985; U.S.EPA, 1992).

5.3.4 Air

Very little data on the transport of the compounds of concern through the atmosphere is available and, thus, conclusions related to this form of migration are qualitative. As mentioned previously, however, some vinyl chloride gas was identified during the advancement of Vertical Profile VP-1 between 10 feet to 15 feet below ground surface. It is unknown whether this gas was actual vadose zone soil gas, or whether the gas was created following the volatilization of vinyl chloride dissolved in ground water upon exposure to the atmosphere. The gas was encountered while drilling below the water table. It is believed that organics will not migrate into the atmosphere and be subsequently transported unless affected soil and ground water is disturbed by human activities such as drilling. The potential for such difficulties must be taken into consideration during the design and implementation of any remedial alternatives (to minimize risks to workers) and during any further investigatory work which could result in the release of hazardous gases.

6.0 SUMMARY AND CONCLUSIONS

6.1 SUMMARY

The following sections contain a summary of the findings of the Phase I and II Remedial Investigations with regard to the distribution and migration of soil, ground water, and surface water impacts at the Hi-Mill Manufacturing site.

6.1.1 Nature and Extent of Contamination

1) Several potential sources of VOCs are present at the Hi-Mill Manufacturing including the degreaser units, solvent storage tanks and associated piping. The most prominent source of VOCs is the past release of approximately 250 gallons of chlorinated solvents from the piping associated with the solvent storage tank located on the north side of the Hi-Mill Manufacturing production building.

2) The potential sources of metals occurring at the Hi-Mill Manufacturing site include the wastewater lagoons located at the rear of the Hi-Mill Manufacturing facility, waste-acid solutions stored within concrete USTs and fragments and chips of metal associated with Hi-Mill Manufacturing's manufacturing process.

3) Several potential off-site sources have been identified in the region surrounding the Hi-Mill Manufacturing facility including Numatics Inc. and a former service station, which are located northeast and northwest of Hi-Mill Manufacturing, respectively. Dissolved gasoline compounds identified within the soil near the location of the former service station is likely the result of improper decommissioning and removal of the USTs during the widening of M-59. If

extensive automotive repair was conducted at the service station, then this former site could be a source of solvents which may have been used to clean parts. Numatics Inc. disposes of process wastewater through a septic field located adjacent to the Numatics production facility. Local shallow hydraulic gradients indicate that the water discharged to the septic field will flow toward Target Pond.

4) Soil samples collected during the Phase I and Phase II investigations were analyzed to determine the concentration of the SLM occurring within the soil. A large percentage of soil samples exceeded the background criteria established prior to the initiation of the Phase I Remedial Investigation. However, based on a review of the background and grid-sample descriptions, the background samples do not appear to representative of the soil conditions present on the site. Background samples of soils more representative of site soil types could be collected off-site at a non-impacted location.

5) Volatile organic analysis of soil samples collected during the Phase I and Phase II Remedial Investigation indicated that elevated levels of chlorinated solvents are present within the soil on the north side of the building near the former solvent storage area. Significantly lower concentrations of VOCs were detected in the soil on the southwest of the Hi-Mill Manufacturing facility and appeared to be limited to samples collected from the upper brown clay.

6) Surface water and sediment samples collected from Target Pond during the Phase I and Phase II investigations suggested that the Target Pond sediments may have been impacted by aluminum, chromium, copper, and zinc as a result of previous or current activities at the Hi-Mill Manufacturing and/or nearby Numatics

facilities. The surface water of Target Pond, however, does not appear to have been significantly impacted.

7) The laboratory results of the Phase I ground-water sampling event indicated that only dissolved aluminum and nickel above the MDNR background criteria were present within the ground water at Hi-Mill Manufacturing. The resampling of the monitoring wells during the Phase II Remedial Investigation indicated that the nickel detected within the monitoring wells during Phase I was no longer present at levels above background. However, aluminum concentrations above background were detected during the Phase II Remedial Investigation ground-water sampling event.

8) Elevated concentrations of VOCs were detected during the hand-auger boring investigation and both the Phase I and Phase II ground-water sampling. Phase I water sampling results indicated that the shallow saturated zone was impacted with chlorinated solvents. The highest VOC concentrations were detected on the north and southwest sides of the Hi-Mill Manufacturing facility adjacent to the past and present solvent storage tanks. Phase II ground-water sampling results indicated that elevated levels of VOCs present on the north side of the facility had decreased significantly. However, VOC concentrations on the south west side of the facility increased significantly between the Phase I and Phase II sampling events. The hand-auger boring investigation conducted during the Phase II Remedial Investigation in and around M-59 delineated the extent of chlorinated solvents within the shallow saturated zone in the M-59 median area. The delineated plume is believed to have been caused by the accidental discharge of degreaser during the construction of Addition #4. The highest VOC concentrations detected during the hand-auger boring investigation were located

within the median of M-59 and appeared to extend to a source located on the Hi-Mill Manufacturing facility corresponding to the site of the aforementioned spill. Benzene, toluene, ethylbenzene, and xylenes were detected near the location of the former service station. The detection of elevated BTEX within the M-59 median is probably the result of the reported improper decommissioning and removal of the USTs during the construction of M-59.

9) In general, the ground-water samples analyzed from Vertical Profiles VP-1, VP-2, VP-3, and IW-6, detected no VOCs by portable GC analysis, suggesting that no impacts to the intermediate flow system by organics have occurred. One exception was an 11 ppb detection of TCE at the bottom of VP-1. However, two subsequent samplings and analyses of this interval failed to confirm the presence of VOCs.

10) Analysis of two soil samples collected from the intermediate zone on Boring IW-6 indicates low levels of VOCs. It is suspected, however, these detections may have been the result of cross contamination.

11) Vinyl chloride gas which was discovered below the water table during the drilling of Profile VP-1 may have been produced as a result of the exposure of dissolved vinyl chloride above the intermediate zone to the atmosphere or may have already been present in the gaseous state in the vadose zone.

6.1.2 Fate and Transport

Presented below is a brief summary of the conclusions drawn from the assessment of the fate and transport of inorganic and organic compounds:

1. Metals were chiefly introduced into the ground-water flow system and adjacent Target Pond by the discharge of water containing diluted acid-brightening solution laden with metals to the two former collection lagoons;

2. Metals were deposited in the site soils by the discharge of waste process water and those which did not remain in solution were fixed within the shallow site soils;

3. Inorganics discharged to Target Pond were deposited within the bottom organic sediments where they became fixed due to changes in solubility and the organic carbon content of the sediments;

4. Dissolved inorganics will generally move in the same direction as shallow ground-water flow;

5. Organics discharged by the accidental release of 200+ gallons of TCE-based degreaser were introduced into the site vadose zone and shallow ground water. Residual ganglia were likely left behind following the spill but are not subject to further leaching due to the prevention of infiltration over this area by the completion of Addition #4. Organics reaching the shallow water table dissolved and the lateral extent of these constituents has been determined using a combination of hand-auger borings and GC analysis of water samples. Based upon the concentrations of TCE observed during the HAB investigation, and the nature of this spill, it is possible that DNAPL is present beneath or adjacent to the site building in the form of either pools or small lenses, or more likely, as trapped residual ganglia. This possibility should be taken into account when planning remedial alternatives, and care should be exercised to avoid directly contacting or intersecting potential free-product during further investigation.

6. Organic compounds spilled around former and existing tank areas were at least partially volatilized at the surface. While some residual was left in the unsaturated soils, infiltrating waters were the probable mechanism for dissolution and transport to the shallow ground-water flow system;

7. The detections of organic compounds found in site ground water may be moving toward Target Pond. No data are available on the organic concentrations of the Target Pond surface water or sediments;

8. Organics introduced into the shallow ground-water flow system are traveling in the general direction of ground-water flow; however, their transport has likely been retarded by the chemical properties of the compounds and the physical characteristics of the medium;

9. Vinyl chloride gas was encountered during the drilling of Vertical Profile VP-1, below the water table at a depth between 10 feet to 15 feet below ground surface. The gas may have developed when dissolved vinyl chloride in the ground water was exposed to the atmosphere. While no data are available which indicate the presence of soil gas in the vadose zone, this transport mechanism cannot be completely ruled out;

10. None of the data suggest that VOCs transported by ground water have been discharged to potential surface-water receptors located west of M-59. However, two soil samples collected from Boring IW-6 did indicate the presence of low levels of VOCs. These samples may have been cross contaminated. Except for the results obtained from IW-6, no other data suggest that the intermediate or deep flow zones have been affected by organics;

11. Inorganics at concentrations above background levels were detected in the intermediate aquifer at Well SW-18; however, this well is downgradient of the Numatics, Inc. facility which is a suspected source of metals for both the ground-water and surface-water flow systems;

12. Inorganics above background were detected in Shallow Well SW-20 which is downgradient of Numatics, Inc. not Hi-Mill Manufacturing. Thus, the detections in this well are believed to be the result of migration of metals from Numatics toward Target Pond;

13. The only inorganics discovered at concentrations above background within the intermediate flow zone were found at boring IW-6 (i.e., copper). The cause of these elevated metals concentrations is unknown; however, downward migration seems unlikely due to the distribution of metals near the source areas. The reliability of the background soil-sample locations is in some question, however, and as such may not be wholly appropriate for all site conditions. The location corresponding to IW-6 may represent a natural zone of anomalous concentrations of these metals;

14. Currently, the principal method of migration and transport of metals fixed within subsurface soils is believed to be incidental human contact with shallow impacted material. Flora and fauna may also be subject to contact, especially in Target Pond;

15. Wind-blown erosion and transport of soils affected by either organic or inorganic compounds is anticipated to be a minor mechanism of migration. Organics occurring at or near the surface are believed to have volatilized and evaporated

soon after deposition. In addition, much of the site is either vegetated or paved, thereby inhibiting such a phenomenon;

16. Compounds which are either currently entering or have entered Target Pond by ground-water baseflow, surficial runoff, or wind-blown erosion are not anticipated to travel to any other medium. There is, however, a possibility that some discharge from Target Pond may occur to a narrow portion of the shallow flow system between Target Pond and Waterbury Lake. However, several HABs advanced in this area were dry, and available ground-water data suggests that a "static" or "flat" water table may exist here if portions of the shallow system are saturated. Target Pond appears to be underlain by relatively impermeable clays and is not believed to represent a source of recharge to any subsurface flow system. In addition, surface topography indicates that all runoff in the area of the pond is toward the waterbody, not away. Staff- gauge data from Target Pond and the wetland areas across M-59 suggest that surface flow is toward Target Pond and under the roadway in the form of surface runoff from the M-59 median diverted into drainage grates into a drain pipe which emerges at the entrance to Alderman wetland. The overall decrease in metals concentrations in Target Pond between the Phase I and II investigations could be due to either a large variability in concentrations in sediments from location to location; sediment deposition and resuspension; differences in laboratory analysis and improved QA/QC during Phase II; or some combination of the above; and

17. Surface runoff may transport affected soils toward Target Pond, however, organics which were deposited initially in surface soils are believed to have largely volatilized.

6.2 CONCLUSIONS

The following sections present the data limitations of the Phase II investigation and recommendations for future work. Also presented are the conclusions of the Phase I and II investigations as they relate to future potential remedial action objectives.

6.2.1 Data Limitations and Recommendations for Future Work

6.2.1.1 Data Limitations

Provided below is a summary list of the limitations of the data collected and analyzed during the Phase II investigation. Limitations of the Phase I investigation are not directly discussed since the Phase II investigation was designed to address gaps identified following the Phase I study. Limitations to the Phase II data may be summarized as follows:

1. Background soil samples collected during Phase I and reanalyzed statistically during Phase II may not wholly reflect the actual background concentrations of metals in site soils since the soil types collected (predominantly sands) are not completely representative of all available soil types. In particular, no clays were used in establishing metals background concentrations. Clayey soils tend to have a much higher natural content of metals than do sands or silts, and clays are fairly widespread across the site as shown in Figure 4.2. Thus, the potential exists that the background concentrations used to delineate the extent and nature of inorganic impacts may be lower than the actual natural conditions and, as such, may result in the implication that soils have been impacted to a greater degree than they actually have.

2. Published MDNR background ground-water concentrations (WMD/MDNR Guidance Doc., 1988) were used to determine the degree to which local ground water may have been impacted by inorganic compounds associated with prior site-related activities. These background concentrations may or may not be accurate for the site since they are based upon regionally determined data and are not site specific.

3. There exists some uncertainty as to why there is such a significant difference in the biological diversity of Target Pond in comparison to nearby Waterbury Lake. Although these two waterbodies may be representative of wholly dissimilar habitats (i.e., a lake versus a pond/wetland), Target Pond has greater diversity than does Waterbury Lake and, thus, in the absence of complete water-chemistry data, does leave the question open with regard to the lack of species within Waterbury Lake. Since the Phase I investigation did address the issue of dissolved inorganics in both waterbodies, and also the concentrations of metals within the lake and pond bottom sediments, only organic water-quality data are absent in the assessment of the Target Pond and wetland area.

4. If Target Pond and Waterbury Lake are indeed fundamentally different habitats then comparisons using Waterbury Lake as background may not be wholly appropriate. However, Geraghty & Miller worked closely with the U.S.EPA in developing the work plan for the Ecological Inventory and Assessment. Target Pond and Waterbury Lake were used during Phase I for comparisons and Phase II merely expanded these comparisons. The fact that it has been concluded that the waterbodies are dissimilar habitats is a conclusion based upon the data collected and not on a prior assumption.

5. Detections of VOCs in the two soil samples collected from the intermediate/deep sands at Boring IW-6 may be indicative of either cross contamination during sampling, or actual impacts to the deeper flow systems. No other data are available which would indicate impacts to the deeper zones.

6. Horizontal hydraulic conductivity estimates derived from the analysis of slug test data collected from several site wells may not be wholly adequate for the design of some remedial systems.

7. Although the presence of soil gas has not been confirmed, some gas was discovered during the drilling of Profile VP-1 and, as such, soil gas cannot be completely ruled out. No site-specific data on the potential presence and migration of soil gas are available.

8. The discharge area(s) of the shallow flow system west of M-59 is not clearly understood. Data from the wetlands and ponds located west of M-59 would be useful in delineating this relationship.

6.2.1.2 Recommendations for Future Work

Based upon the results of the Phase I and II investigations and the data limitations described above, the following items are recommended for future investigation of the Hi-Mill Manufacturing site:

1. An amended background soil-sampling grid should be devised which incorporates samples and analyses of clayey soil types collected from non-impacted areas of the site and adjacent areas. The revised background concentrations should be used to re-assess the potential impacts to site soils.

2. A monitoring well should be installed in a portion of the shallow aquifer which has not been impacted by previous site activities for the purpose of establishing background concentrations of metals in the area's ground water. These site-specific background concentrations should then be used to determine whether shallow ground water has been affected by the previous discharge of metal-laden process waste water. It is not believed that existing site wells could be reliably used for background concentrations of dissolved metals due to past site activities and activities at the adjacent Numatics facility.

3. Surface water samples and bottom sediment should be collected from Target Pond and analyzed for VOC concentrations to determine if this waterbody has been impacted by the release of chlorinated solvents.

4. Water chemistry, macroinvertebrate, phytoplankton, zooplankton, and conventional water-quality parameter (i.e., temperature, pH, conductivity, etc.) samples should be obtained from a pond and/or wetland area which is more representative of the Target Pond habitat. These new data should be used in comparison to the results of the Phase II Ecological Assessment and Inventory to determine what effect, if any, prior site activities have had on Target Pond.

5. A ground-water monitoring well should be installed in a location adjacent to Vertical Profile IW-6 and later sampled for VOCs and dissolved metals. The screen should be placed between 100 feet and 115 feet below ground surface to determine if this zone was actually impacted by compounds emanating from the site or whether the soil sample results originally obtained from this interval were cross contaminated. The hydraulic-head data collected from this new well would also be useful in defining flow in the western margin of the intermediate/deep flow systems.

6. A limited survey of the site vadose zone ought to be conducted using surficial or shallow soil gas monitoring devices (such a flux-chamber). The survey should be conducted in areas adjacent to the former and existing degreaser tank locations at the north and south ends of the building to determine the likelihood of the presence of soil gas. Of particular interest is whether or not any gas may be presently escaping from the vadose zone into the atmosphere. Such data will be useful for the Risk Assessment. This work should be completed prior to the completion of the Risk Assessment. A soil gas survey would be conducted in order to determine whether or not soil gas is present in the vadose zone, and if it is, to determine the composition and extent of that gas. Information derived from a soil gas survey would be used to design an appropriate remedial system and to determine if any risks may be present to workers implementing either a remedial system or performing additional investigatory work.

7. The installation of staff gauges in one or more of the surface waterbodies located west of Hi-Mill Manufacturing and M-59 would be useful in determining whether or not shallow ground water from the perched system could be discharging to this location. Such a determination could be useful in assessing whether or not the shallow TCE plume depicted in Figure 4.16 is a potential long-term risk to human health and safety. This work should be conducted prior to the completion of the Risk Assessment.

8. If during the Feasibility Study, the available hydraulic-conductivity data are found to be insufficient for the purpose of assessing and implementing various remedial designs then further testing of the shallow flow system is recommended.

6.2.2 Recommended Remedial Action Objectives

Presented in this section is a preliminary assessment of the recommended objectives of a Remedial Action/Remedial Design Study. This information is intended for use in the structuring of the Feasibility Study. The remedial alternatives and objectives examined during the Feasibility Study should take into account reasonably determined risks to human health and safety based upon the results of the Risk Assessment. Therefore, the final remedial action objectives should be determined upon realistic risks as determined during the Risk Assessment. The recommended objectives may be summarized as follows:

1. Due to the low hydraulic conductivity and limited lateral and vertical extent of the impacted portions of the shallow flow system, it is unlikely that an aggressive pump-and-treat program will be effective in remediating the shallow ground water. If the Risk Assessment determines that significant risks to human health and safety due to exposure to the shallow ground water do exist then possible objectives in this regard might include a soil vapor extraction system; a passive interceptor trench or drains; sheet piling driven around the affected area and keyed into the upper gray clay; in-situ bioremediation; or some combination of the above. Another passive approach could involve the capping or paving of the rear of the Hi-Mill Manufacturing facility which is believed to represent the main zone of recharge to the shallow system. By installing such a cap, the reduced influx of water into the shallow system could halt transport of compounds in the shallow ground water by reducing hydraulic gradients. It should be noted, however, that the shallow zone is not an aquifer and as such, the use of this zone as a viable water supply is impractical and unlikely. In addition, consideration should also be given to the role the former service station, previously located in the existing M-59 median, may have played in the organic impacts observed in site soils and ground water.

2. Since the bottom sediments of Target Pond have likely been impacted by metals, access restriction of this area to limit potential exposure to sediments should be examined. Because there is no surficial or subsurface hydraulic outlet to Target Pond, migration of these impacted sediments by surface- or ground-water action is not deemed significant. Confirmation should also be sought prior to the initiation of any remedial action studies as to the role activities at the adjacent Numatics, Inc. facility may have played in the impact to Target Pond and the shallow ground-water flow system.

3. Pending the re-assessment of the background concentrations of inorganics in site soils and ground water, remedial action of metals in site soils and ground water may not be necessary. Under the existing background criteria, impacts to the ground water do not appear to be significant. Impacted soil could either be capped behind the Hi-Mill Manufacturing facility or excavated if the Risk Assessment determines that the risks to human beings due to incidental exposure are significant. However, it is highly recommended that the existing background sample set be re-evaluated before setting any such objectives and prior to the completion of the Risk Assessment.

4. Pending the results of the assessment of whether soil gas is present in the site vadose zone, if the gas is present, emphasis should be given to the installation of a soil vapor extraction system to control/remediate soil gas.

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