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PERFORMANCE OF REMEDIAL RESPONSE
ACTIVITIES AT UNCONTROLLED HAZARDOUS
WASTE SITES (REM II)

U.S. EPA CONTRACT NO. 68-01-6939

ADDENDUM TO THE
REMEDIAL INVESTIGATION REPORT
FOR
PRISTINE, INC. SITE
READING, OHIO

REM II

PERFORMANCE OF REMEDIAL RESPONSE ACTIVITIES AT UNCONTROLLED HAZARDOUS WASTE SITES

U.S. EPA CONTRACT NO. 68-01-6939

CDM Federal Programs Corporation
CAMP DRESSER & McKEE INC.
ROY F. WESTON INC.
WOODWARD-CLYDE CONSULTANTS
CLEMENT ASSOCIATES, INC.
ICF INCORPORATED
C.C. JOHNSON & MALHOTRA, P.C.

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ADDENDUM TO THE REMEDIAL INVESTIGATION REPORT FOR PRISTINE, INC. SITE READING, OHIO

EPA Work Assignment No. 15-5L56

REM II Document No. 115-RI2-RT-FNGU-1

Prepared by: ______________________ Date: 12/29/87
Rae Mindock
Site Manager

Approved by: ______________________ Date: 12/29/87
John Schroeter, P.E.
Region V Manager

If you should have any questions, please do not hesitate to contact us directly or the REM II Site Manager, Rae Mindock.

Very truly yours,

CAMP DRESSER & McKEE INC.

John Schroeter
Regional Manager

Attachment

cc: V. Gonzales, Contracting Officer, U.S. EPA
R. Quinn, Project Officer, U.S. EPA
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CDM

environmental engineers, scientists,
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December 28, 1987

Mr. Jonas Dikinis
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U.S. Environmental Protection Agency
230 South Dearborn Street
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Ms. Mary Tyson
Regional Project Manager
U.S. Environmental Protection Agency
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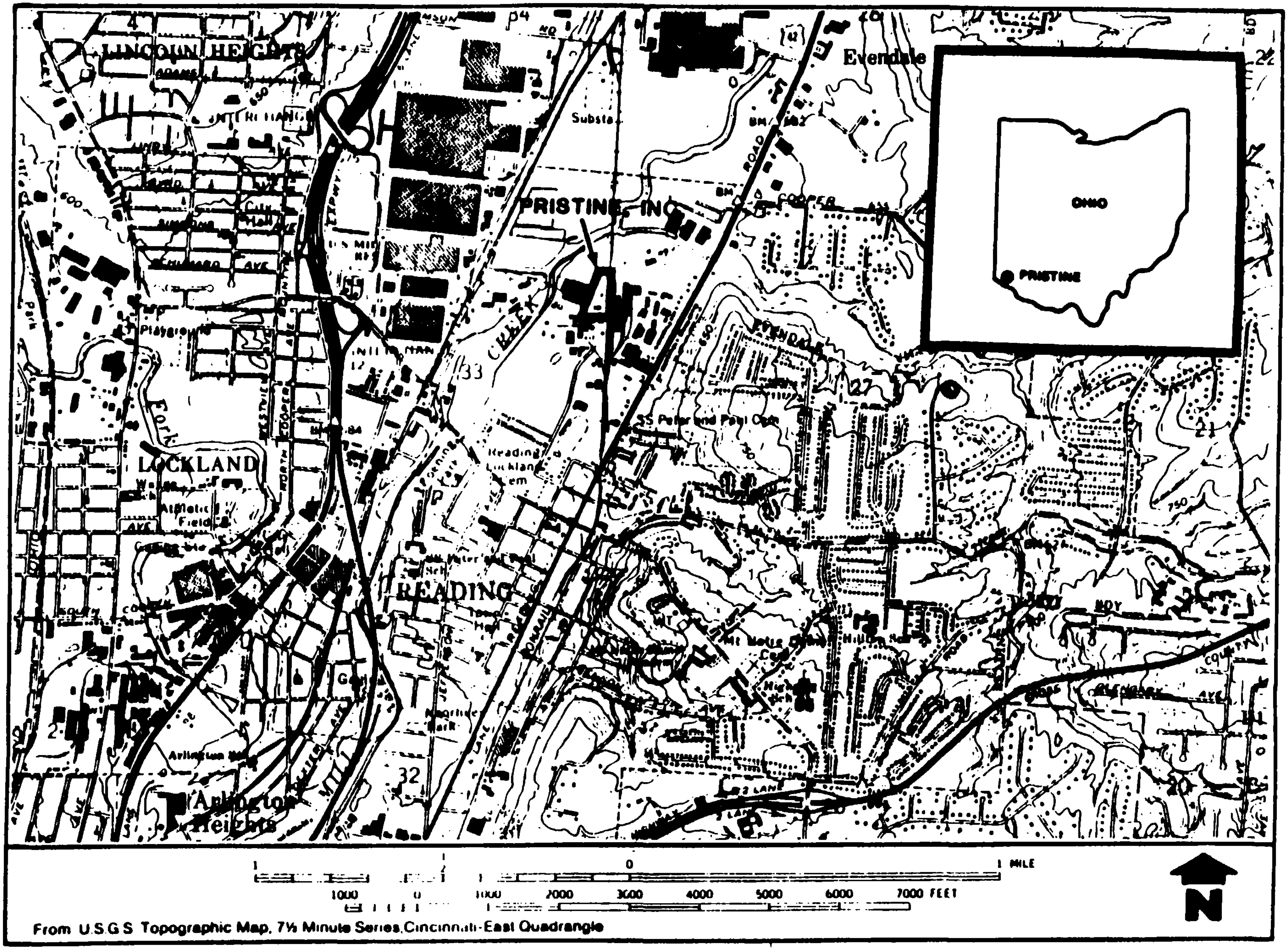
This report presents the results of the Phase 2 Remedial Investigation (RI2) conducted by U.S. EPA at the Pristine, Incorporated site in the City of Reading, Ohio. The addendum to the Remedial Investigation Report has been developed to evaluate data collected during the RI2 field program. This document is intended to be used as a companion document to the Final Remedial Investigation Report, Document No. 115-RI1-RT-CMKQ-1. The RI has several major objectives. The principal objective of a RI is to accurately characterize the site to determine the need for, and extent of any corrective action. In order to determine the need for remedial action, RI activities examine the nature of the site with respect to the types of contamination present, quantities of contamination present, and potential pathways by which contamination may affect public health or environment. Based upon the results of detailed sampling and analysis, a comprehensive evaluation of the actual and potential threat to public health and the environment is conducted. This phase of the RI, referred to as the Public Health Evaluation, examines all available data and assesses the concentration of contaminants and the effect of public exposure via all routes.

Site Description

The Pristine, Inc., site is located in southwestern Ohio in the City of Reading (Population 12,843), a suburb of Cincinnati. The site occupies approximately two acres in the northeast quarter of Section 33, Township 4, Range 1 in Hamilton County Ohio (Figure 1). The site is bordered by residential and industrial areas (Figure 2). Industrial operations owned by Cincinnati Drum Service and Carstab Corporation are located to the west and south of the facility. Cincinnati Drum Service cleans, reclaims, and recycles steel drums. Carstab Corporation manufactures synthetic stabilizers and plasticizers. The immediate eastern limit of the site is bordered by Conrail Railroad right-of-way. On the other side of the tracks, further to the east and southeast, is a grain elevator. Northeast of the site, beyond the railroad is a residential trailer park. The land to the north is owned by the City of Reading. Eight municipal water supply wells, serving the citizens of Reading are approximately 400 feet northwest of the site.

The buildings and facilities which were used during past operations at the Pristine, Inc., site still exist (Figure 2). A concrete pad is present in the area north of the buildings that was used as a mixing area. The site is partially revegetated and shows little evidence of past soil removal activities (May through July, 1984). A lack of vegetation is noted in the southeastern section of the site at the location of the soil trench sampling conducted in June 1985 as part of the RI1 field program. The site is situated on a low terrace that is about ten feet higher than the Mill Creek flood plain immediately to the west of the site. The Pristine, Inc. site does not lie within the



From U.S.G.S Topographic Map, 7½ Minute Series, Cincinnati-East Quadrangle

FIGURE 1
VICINITY MAP
PRISTINE,INC.

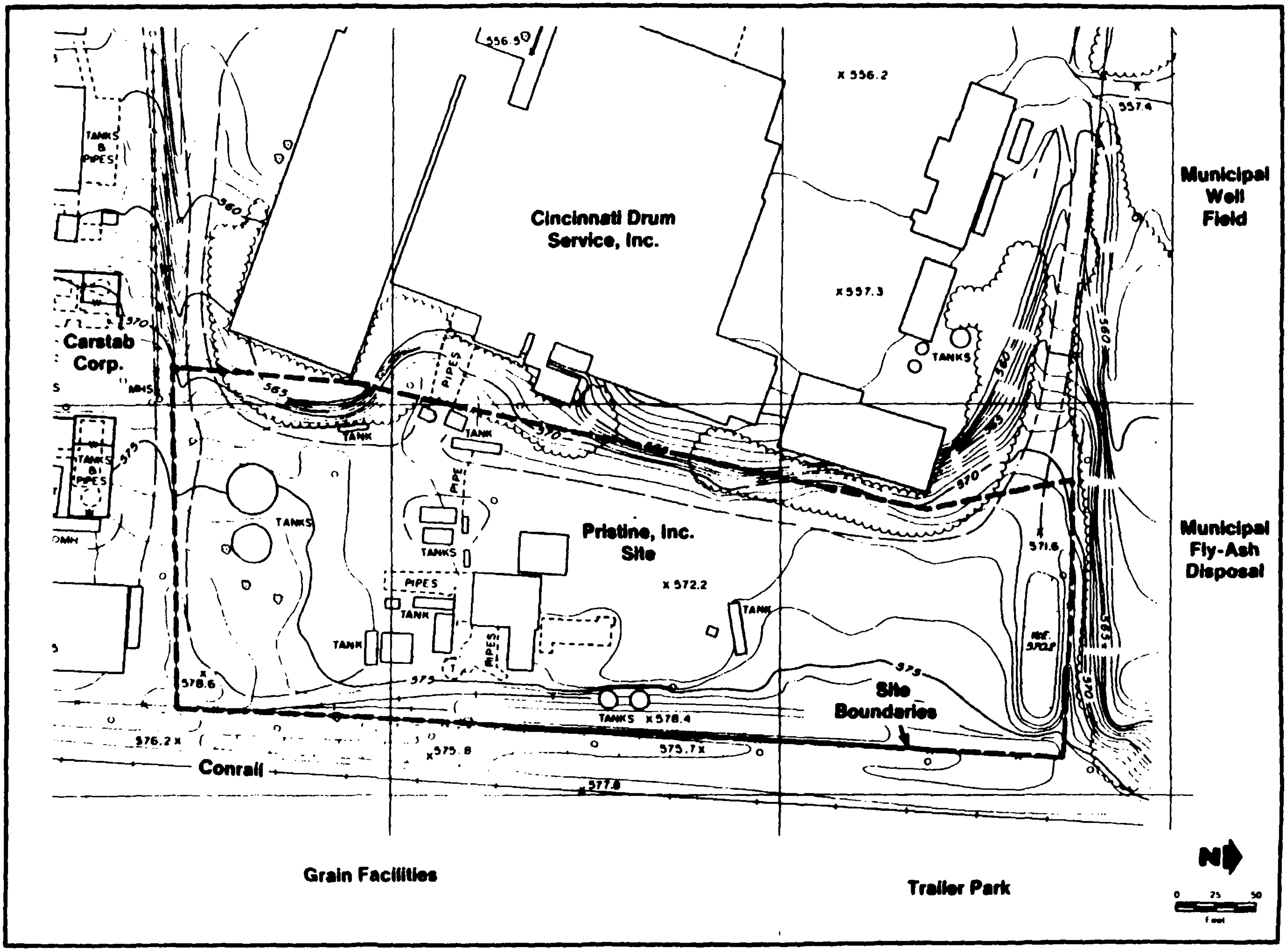


FIGURE 2
SITE MAP
PRISTINE, INC.

100 year flood plain or a designated wetlands. Site surface water runoff generally flows off site toward the Mill Creek.

Site site geology consists of five distinct soil units (Figure 3). The upper most unit consists of zero to ten feet of brown and gray fill. Underlying the fill unit is a sequence of upper lake sediment and outwash deposits. This unit ranges from zero to 46 feet in thickness and consists of three separate outwash lenses within a large lake sediment deposit. The third unit, underlying the lake sediment and outwash sequence, is a glacial till layer ranging from 10 to 45 feet in thickness. Beneath the glacial till is the lower lake sediment unit which is distinctly different from the upper lake sediment unit. The lower lake sediment is absent in the southeastern corner of the site and also southeast of the site. Underlying the lower lake sediments is a lower aquifer. The lower outwash deposit is directly underlain by the lower aquifer at the southeast corner of the site. The thickness of the unit cannot be determined from on-site data. The lower aquifer is the principal regional water supply aquifer. Most notably, the nearby Reading municipal wells, northwest of the site, are completed in the lower aquifer. Results of the field investigation indicate groundwater flow direction in the lower aquifer is toward the northwest.

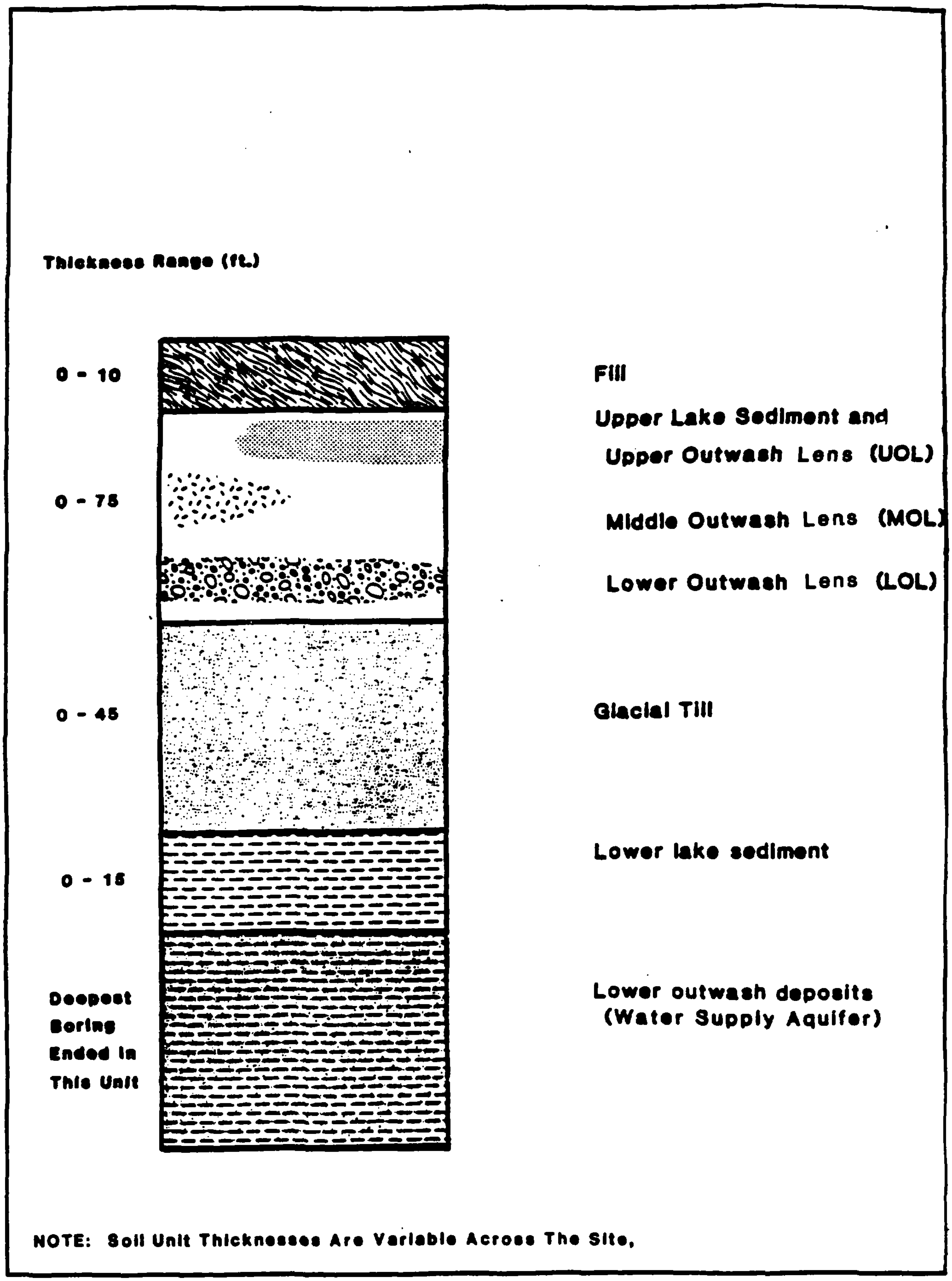
CURRENT SITE STATUS

RESULTS OF THE REMEDIAL INVESTIGATION

Data collected during the Phase 1 Remedial Investigation was reviewed and evaluated. During the evaluation process and during the development of the Feasibility Study several data gaps were identified. Based on review of results of the RI and the identification of data gaps, the RI2 focused on:

- Sampling and analysis of surface soils to determine whether dioxin/furans are present on-site;
- Sampling and analysis of subsurface soils to determine whether an area, referred to as the "magic pit" is a source of contamination for groundwater;
- Sampling and analysis of groundwater to continue the characterization of groundwater contamination both on site and in immediately adjacent, off-site areas;
- A hydrogeological study to determine the extent of the upper outwash lens of the upper aquifer system and to continue the characterization of the lower aquifer.

Results of the RI2 are presented in detail in Sections 1 through 5. Section 1 through 4 present results corresponding to the pathways listed above and should be consulted for detailed review. Section 5 presents the results of the Public Health Evaluation conducted to determine the risk posed by polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. A brief summary of significant results in each of the media sampled is presented in the following paragraphs.



NOTE: Soil Unit Thicknesses Are Variable Across The Site,

FIGURE 3

GENERALIZED COLUMN UNDER THE PRISTINE, INC. SITE

SOIL

Investigation of soil contamination involved collection and analysis of surface soils and collection of subsurface soils through soil borings. Analysis of on-site soils revealed the occurrence of a variety of volatile and semi-volatile organic compounds, pesticides, and dioxin/furan compounds.

Soils contained volatile organic compounds (e.g., 1,2-dichloroethane) in addition to semi-volatile compounds (e.g., phenol). Pesticides and PCBs were detected in the surface soils and borings. Analysis of soils also revealed elevated concentrations of inorganic compounds including cadmium, lead, mercury, and zinc.

GROUNDWATER

Groundwater was investigated through the sampling of 18 monitoring wells and the installation and sampling of five additional monitoring wells. Highly soluble volatile organic compounds (e.g., benzene, vinyl chloride, 1,2-dichloroethane) were the primary contaminants in the groundwater. Semi-volatile compounds and pesticides occurred in relatively lower concentrations. Results of the analysis for inorganic compound revealed elevated concentrations of calcium, iron, magnesium and fluoride.

The direction of groundwater flow in the lower aquifer (water supply aquifer) was re-evaluated during the RI Field Investigation. The direction of groundwater flow was determined to be in a northwesterly direction.

PUBLIC HEALTH EVALUATION

Section 5 is a baseline public health evaluation (PHE) that assesses the potential risks to public health and the environment associated with exposure to polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

Current conditions at the site pose a low hazard from inhaling contaminants with a potential carcinogenic risk of 10^{-14} for both the average and plausible maximum scenarios. Contact with the contaminated soil could constitute a hazard if the length of exposure was on the order of several years and occurred for several hours a day. A potential carcinogenic risk of 10^{-8} and greater than 10^{-6} for the average and plausible maximum scenarios.

Ingestion of site groundwater from a well screened in the lower aquifer at the Pristine, Inc. site, could result in potential upperbound lifetime excess cancer risks of 10^{-8} and 10^{-7} for the average and plausible maximum cases. An individual exposed to contaminants reaching the Reading well field under the average and plausible maximum cases exposure conditions considered in this document would experience lifetime excess cancer risk of 10^{-8} for both cases.

The risks that were determined in the Phase 2 supplemental public health evaluation should be considered additive to those risks determined in the finalized Remedial Investigation Report. The only scenario that would be effected by the addition of the PCDDs/PCDFs as chemical of concern is the dermal contact and incidental ingestion of soils. Adding the potential risk determined in both public health evaluations together, the exposure to on-site soil could result in potential excess lifetime cancer risks (upperbound) of 2×10^{-6} and 3×10^{-4} for the averages and plausible maximum cases, respectively. The potential risks from the other scenarios would remain unchanged.

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U.S. EPA CONTRACT NO. 68-01-6939

ADDENDUM TO THE REMEDIAL INVESTIGATION REPORT FOR PRISTINE, INC. SITE READING, OHIO

EPA Work Assignment No. 15-5L56

REM II Document No. 115-RI2-RT-FNGU-1

Prepared by: ______________________ Date: 12/29/87
Rae Mindock
Site Manager

Approved by: ______________________ Date: 12/29/87
John Schroeter, P.E.
Region V Manager

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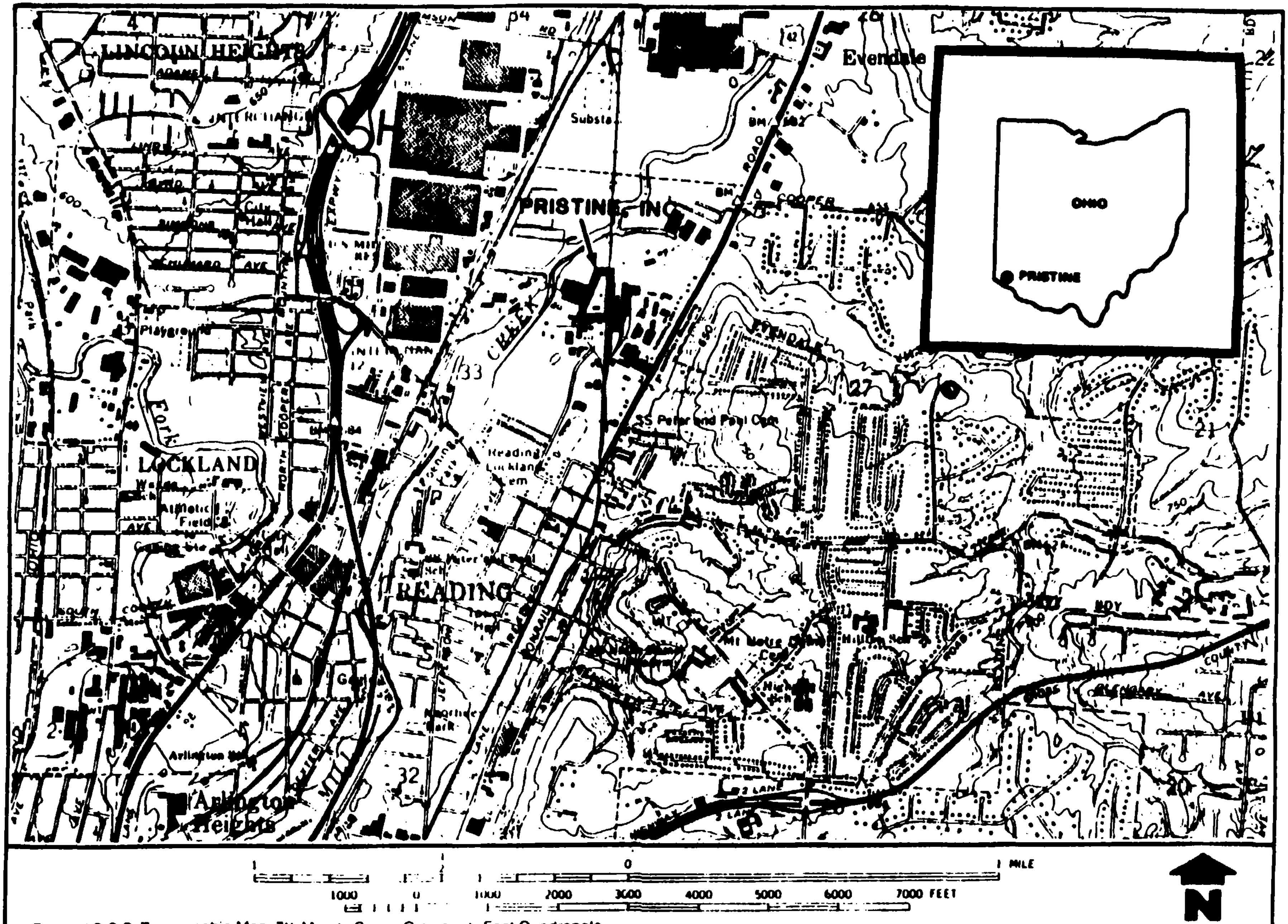

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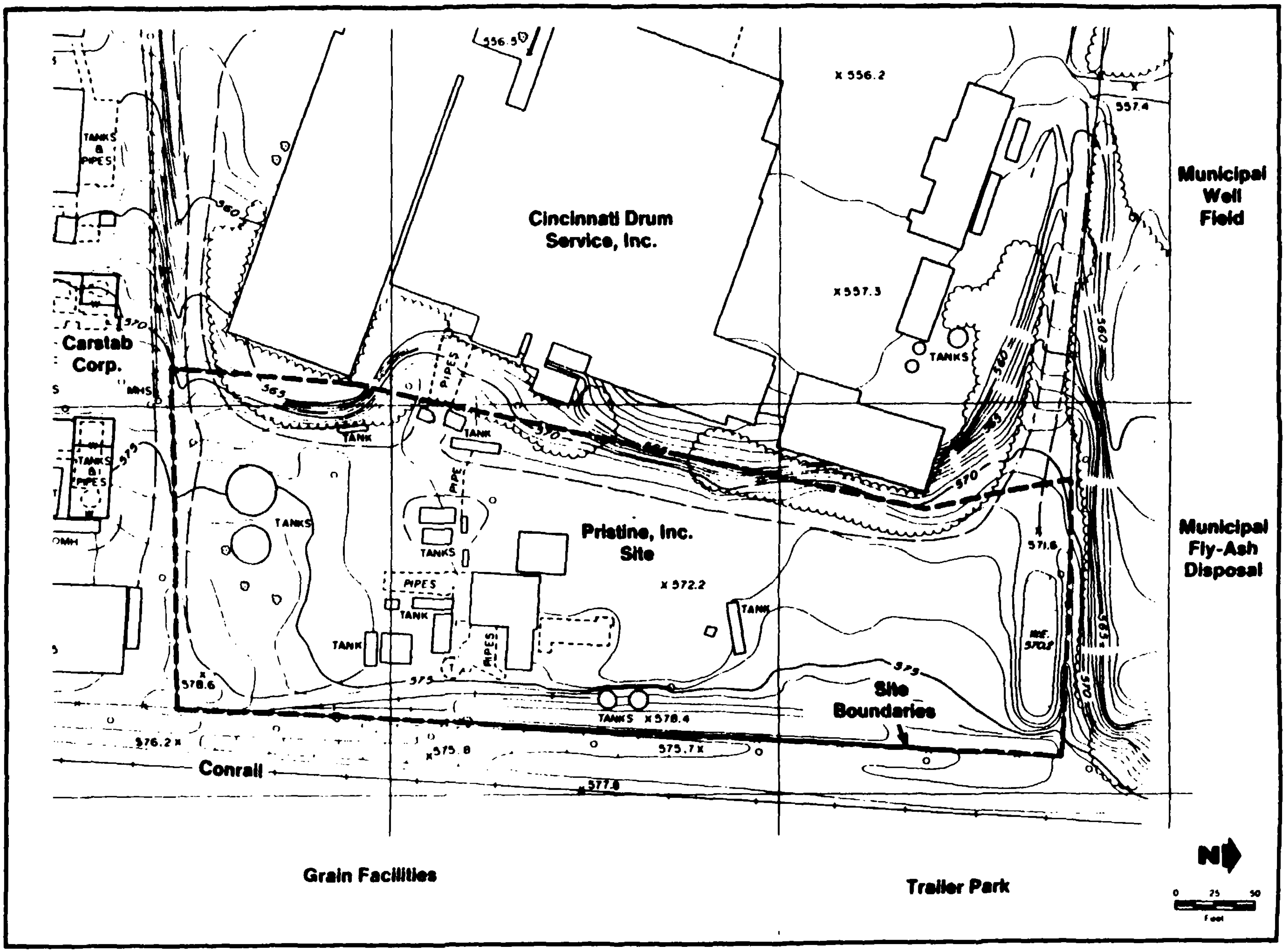

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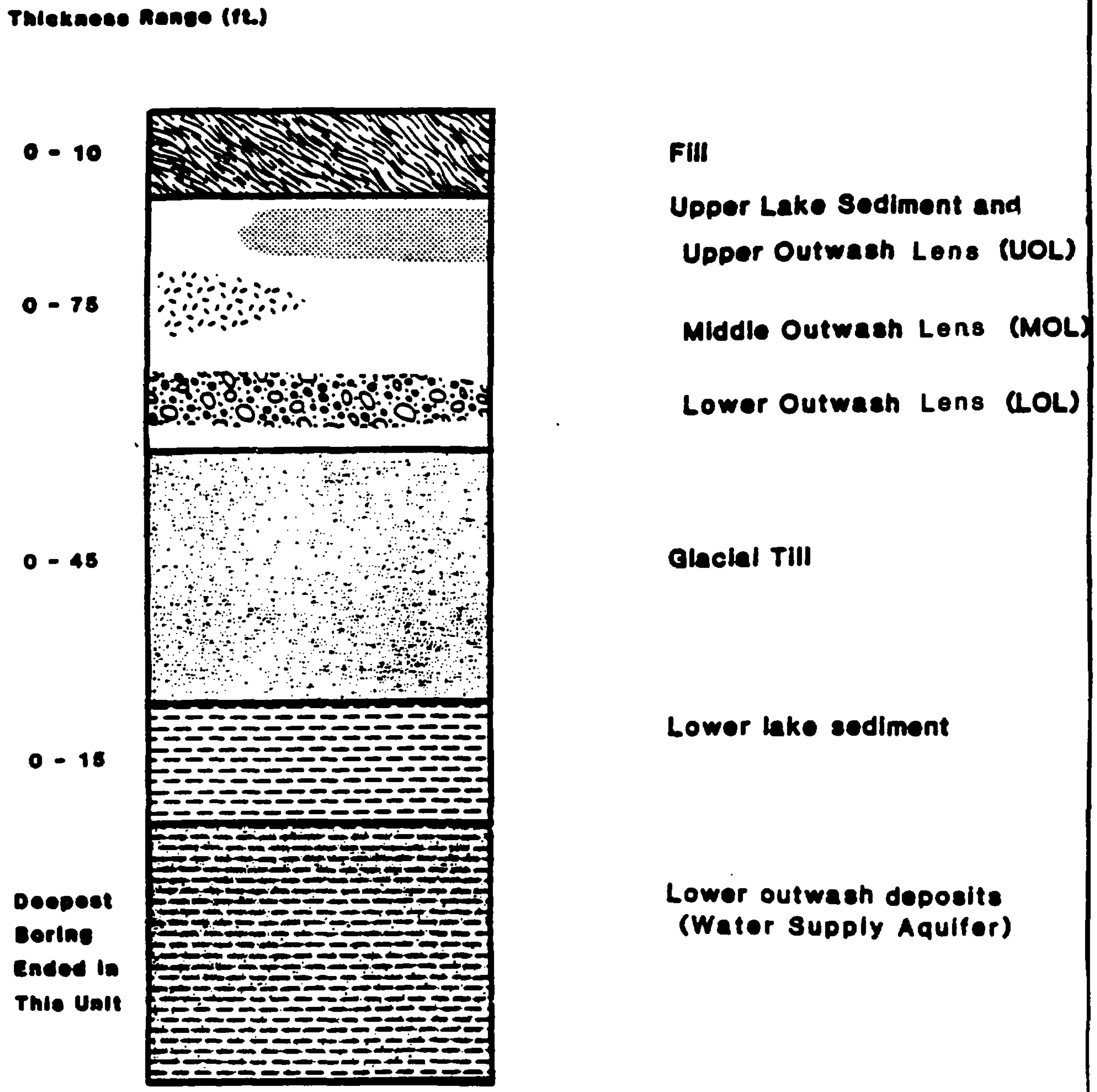

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Appendix

SECTION 1

INTRODUCTION

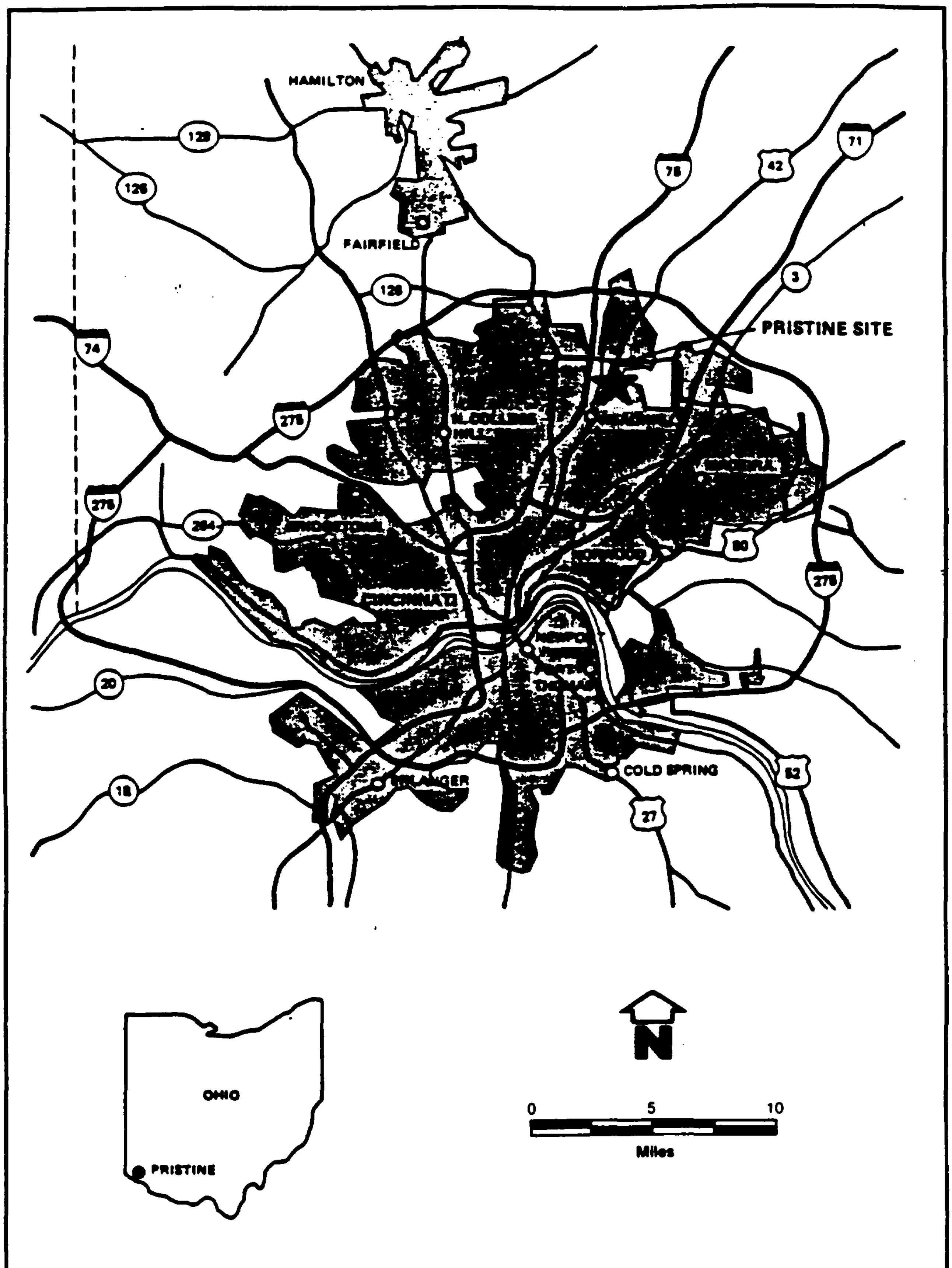
The Pristine, Inc. site is located in the City of Reading, Ohio. The site was previously used for the manufacture of sulfuric acid and later operated as a liquid waste disposal unit. The disposal operations were shut down in September of 1981 in accordance with a State of Ohio Partial Consent Order. The site was added to the U.S. EPA National Priorities List (Group 9), with a ranking of 408, in December of 1982.

In September of 1984 the U.S. EPA initiated a Remedial Investigation/Feasibility Study at the Pristine, Inc. site under the REM II contract. The Remedial Investigation (RI1) field program was conducted from May 1985 to September 1985 to evaluate site conditions as a result of previous waste handling practices. The results of the RI1 investigation were published in the Final Remedial Investigation Report in July 1986.

Data collected during RI1 was reviewed and evaluated in the RI report. During the evaluation process and during the development of the FS, several data gaps were identified. The gaps include lack of chemical data needed to characterize soil and groundwater quality in areas of the site identified as possible sources of contamination. The second phase Remedial Investigation (RI2) was proposed to gather chemical data on soils and groundwater necessary to complete the source characterization. The Addendum to the Remedial Investigation Report has been developed to evaluate data collected during the RI2 field program. This document is intended to be used as a companion document to the Final Remedial Investigation Report, Document No. 115-RI1-RT-CMKQ-1. Additional information on the RI1 investigation is presented in the Executive Summary of the Final Remedial Investigation Report provided in Appendix A.

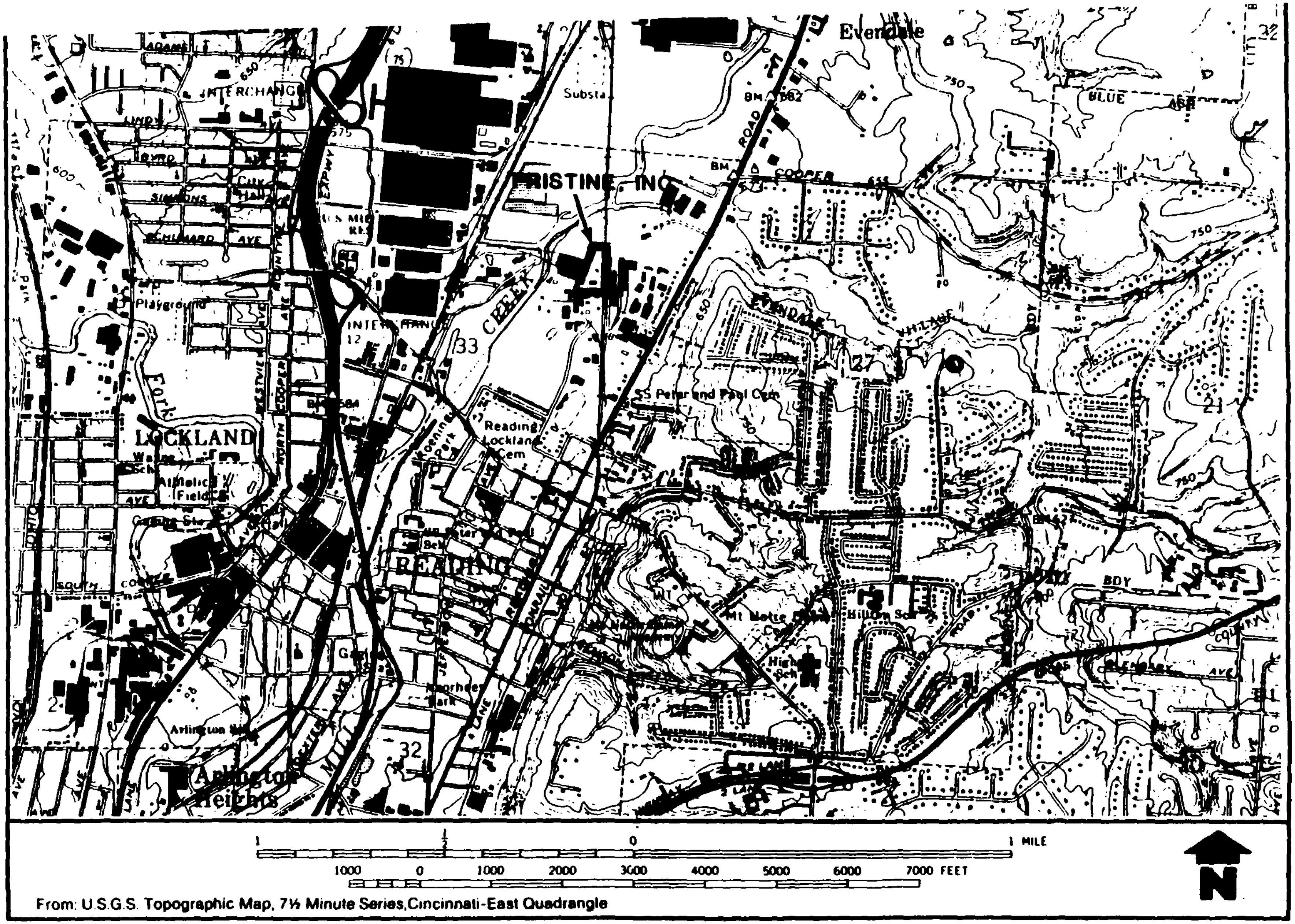
1.1 SITE BACKGROUND

The Pristine, Inc. site occupies approximately two acres of the northeastern quarter of Section 33, Township 4, Range 1 in the City of Reading, Hamilton County, Ohio (Figures 1-1 and 1-2). The site is bordered by industrial and residential areas (Figure 1-3). The land north of the site is owned by the City of Reading. As of September 1987, eight municipal water supply wells, which are about 400 feet from the northwestern corner of the site, are located on this property. All of the well are on line, but are not necessarily operated at one time. Industrial facilities, operated by Cincinnati Drum Service and Carstab Corporation, are located west and south, respectively, of the Pristine, Inc. site. Cincinnati Drum Service cleans, reclaims and recycles steel drums. Carstab Corporation manufactures synthetic stabilizers and plasticizers. The Conrail



Source: RAMP prepared by CH2M HILL November 1983

FIGURE 1-1
SITE LOCATION MAP
PRISTINE, INC.



From: U.S.G.S. Topographic Map, 7½ Minute Series, Cincinnati-East Quadrangle

FIGURE 1-2
VICINITY MAP
PRISTINE, INC.

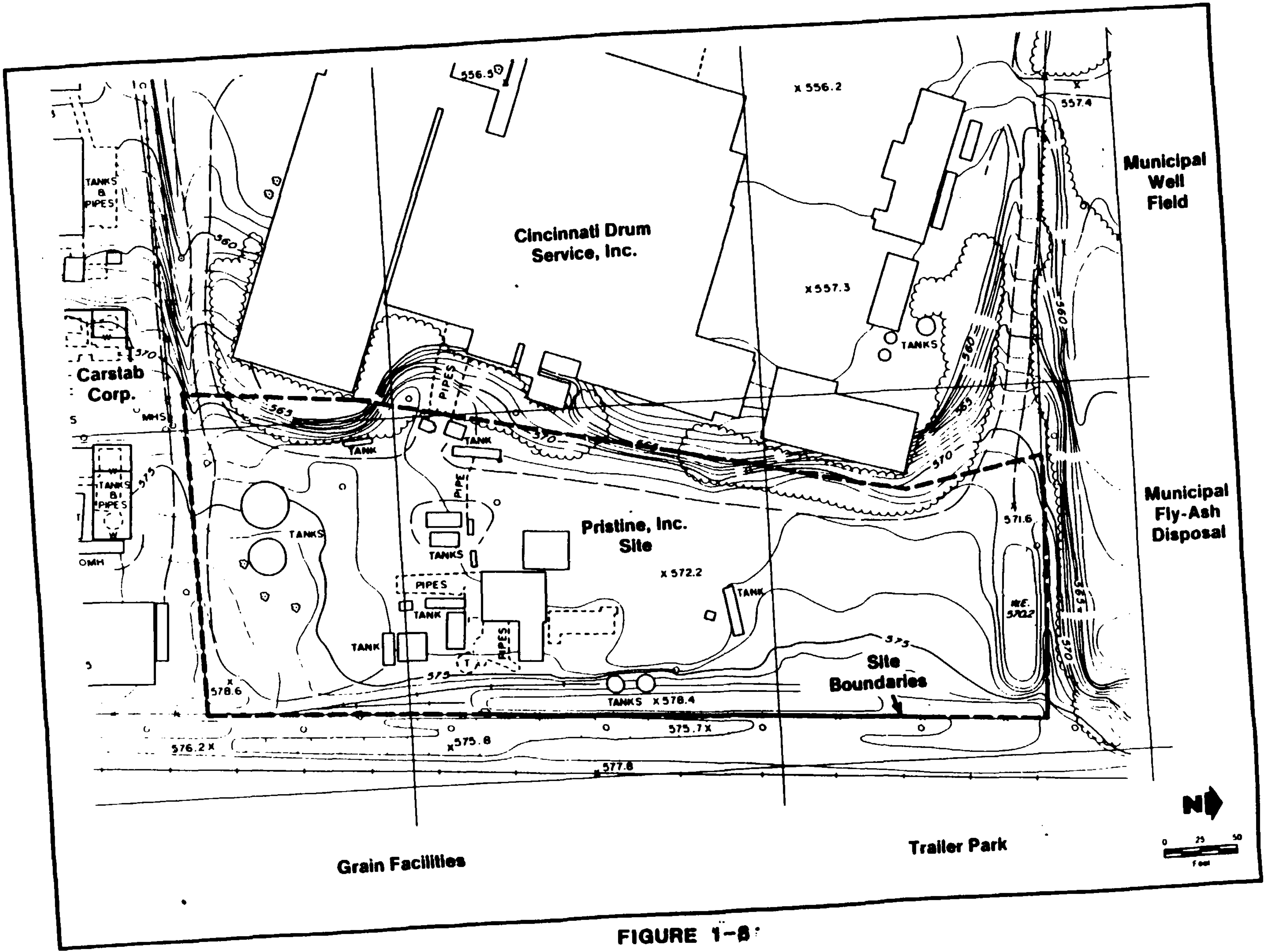


FIGURE 1-8
SITE MAP
PRISTINE, INC.

Railroad runs along the eastern side of the site. On the other side of the tracks, are an industrial facility involved in grain-handling to the east and southeast and a trailer park to the northeast. The site may be reached only from the west, through the Cincinnati Drum Service property, because access to the site is restricted on the north, east and south by chain-link fencing. Additional information on background and previous site waste activities can be found in the Remedial Investigation Report, Section 1.1.3.

1.2 NATURE AND EXTENT OF PROBLEM

1.2.1 Present Site Conditions

The site conditions during the Phase 2 Remedial Investigation (RI2) are basically unchanged from the conditions present during the Phase 1 Remedial Investigation (RI1). The site is partially revegetated and shows little evidence of past soil removal activities (May through July, 1984). A lack of vegetation is noted in the southeastern section of the site at the location of the soil trench sampling conducted in June 1985 as part of the RI1 field program. The buildings and facilities described during Phase 1 still exist but have deteriorated. The buildings and facilities were visually inspected during the RI2 investigation. These structures include an office building, incinerator, a process building, a small laboratory, a cooling tower, various stacks and piping, and 19 tanks of various configurations and volumes. One storage tank is currently being used by Cincinnati Drum, Inc. personnel to store fuel oil. Two semi-trucks, which were not present during the RI1 investigation, are stored on site.

1.2.2 Effects of Contaminants

The results of the monitoring data collected during the Phase 1 Remedial Investigation indicated the presence of contaminants in surface and near surface soils and at depth to 8 feet and in groundwater collected from monitoring wells. The Phase 2 Remedial Investigation (RI2) confirmed these findings. In addition, the RI2 investigation confirmed the presence of dioxins and furans in media that is suspected to be the incinerator residue located in and near the incinerator. The predominant contaminants found at the Pristine, Inc. site were volatile organic compounds and pesticides. A detailed description of the RI1 sampling program is found in Sections 3 and 4 of the Final Remedial Investigation report. A description of the RI2 sampling program is presented in Section 3 of this report.

1.2.3 Future Impacts of Contamination

As stated in the previous section, the predominant contaminants at the Pristine, Inc. site are volatile organics compounds and pesticides. These contaminants are migrating from the site through potential exposure pathways which include soil, air, groundwater, and surface water. The pathways were evaluated in the Public Health Evaluation (PHE), Section 5 of the Final Remedial Investigation Report. As a result of the evaluation, three "complete" pathways were identified: soil, groundwater and surface water. These pathways were identified as routes for contaminant migration from the Pristine, Inc. site. The information gathered during the RI2 supports these conclusions.

1.3 INVESTIGATIVE SUMMARY

1.3.1 Purpose of the Remedial Investigation

The purpose of the Phase 2 Remedial Investigation (RI2) is to more fully evaluate the extent and magnitude of on-site contamination and use this information to evaluate the potential risk to the public health and the environment. The objectives of the RI2 can be characterized by review of the sampling program. The sampling program included:

1. Sampling and analysis of surface soils; conducted to determine whether dioxins/furans are present on site as a result of previous waste handling practices.

2. Sampling and analysis of subsurface soils; conducted to determine whether an area, referred to as the "magic pit," is a source of contamination for groundwater in the lower outwash lens of the upper aquifer system.

3. Sampling and analysis of groundwater; to continue the characterization of off-site groundwater within the upper aquifer system and the on-site groundwater within the lower aquifer system.

4. A hydrogeologic study; conducted to determine the extent of the upper outwash lens of the upper aquifer system and to continue the characterization of the lower aquifer.

A detailed discussion of the objectives and scope of each of the above items is provided in the Work Plan Technical Memo, Section 2, Document No.: 115-RI2-WP-DUHS-1.

1.3.2 Scope of Work

The tasks completed in the RI2 investigation are summarized in a project chronology presented in Appendix B. The RI2 field activities were conducted from June 2, 1987 through August 19, 1987. Sampling for all tasks were performed by a field team consisting of WESTON personnel. The activities were conducted following sampling methods and QA/QC procedures approved by the U.S. EPA and reviewed by the Ohio EPA. The sampling activities are described in the following sections.

Additional information concerning specific QA/QC activities and sampling methods are provided in the Pristine, Inc. Supplemental QA Project Plan (QAPP), Document No. 115-RI2-OP-DQHY-1.

1.3.2.1 Surface Soil Sampling

Surface soil sampling was conducted for two purposes; (1) to determine the presence of dioxin in the soils, and (2) to determine the extent of contaminant of soils surrounding the magic pit. The sampling was conducted during two periods, in June 1987 and July 1987. The sampling activities are described in the following sections.

1.3.2.1.1 Dioxin Analysis

Eleven surface soil, two sediment and two incinerator residue samples were collected on June 2, 1987 to determine whether dioxin/furans are present at the site. The sampling activities were performed as outlined in Section 3.5 of the Pristine, Inc. Supplemental QAPP. Samples of surface soil were collected in eight on-site areas, two off-site samples were collected east of the site along the Conrail railroad tracks and one soil area sample was collected in the municipal well field northwest of the site. Two incinerator residue samples were collected near the incinerator and process building. Two off-site sediment samples were collected in drainage areas between the Pristine, Inc. site and Cincinnati Drum Services, Inc. Within each soil area, soil material was collected at five discrete locations and composited. Soil was taken from 0 to 4 inches at each location. The locations and configurations of these areas and their sample designations are shown in Figure 1-4.

Additional discussion on the objectives and scope of the dioxin sampling program is provided in the Remedial Investigation follow-up Work Plan for the Pristine, Inc. site (TDD-R05-8607-01) prepared on September 3, 1986 by Ecology and Environment. A summary of the dioxin sampling activity is provided in Appendix C. A summary of the sampling program is given in Table C-1. A description of soil area and sediment samples is provided in Table C-2. Analytical results of the dioxin sampling are presented in Section 3.

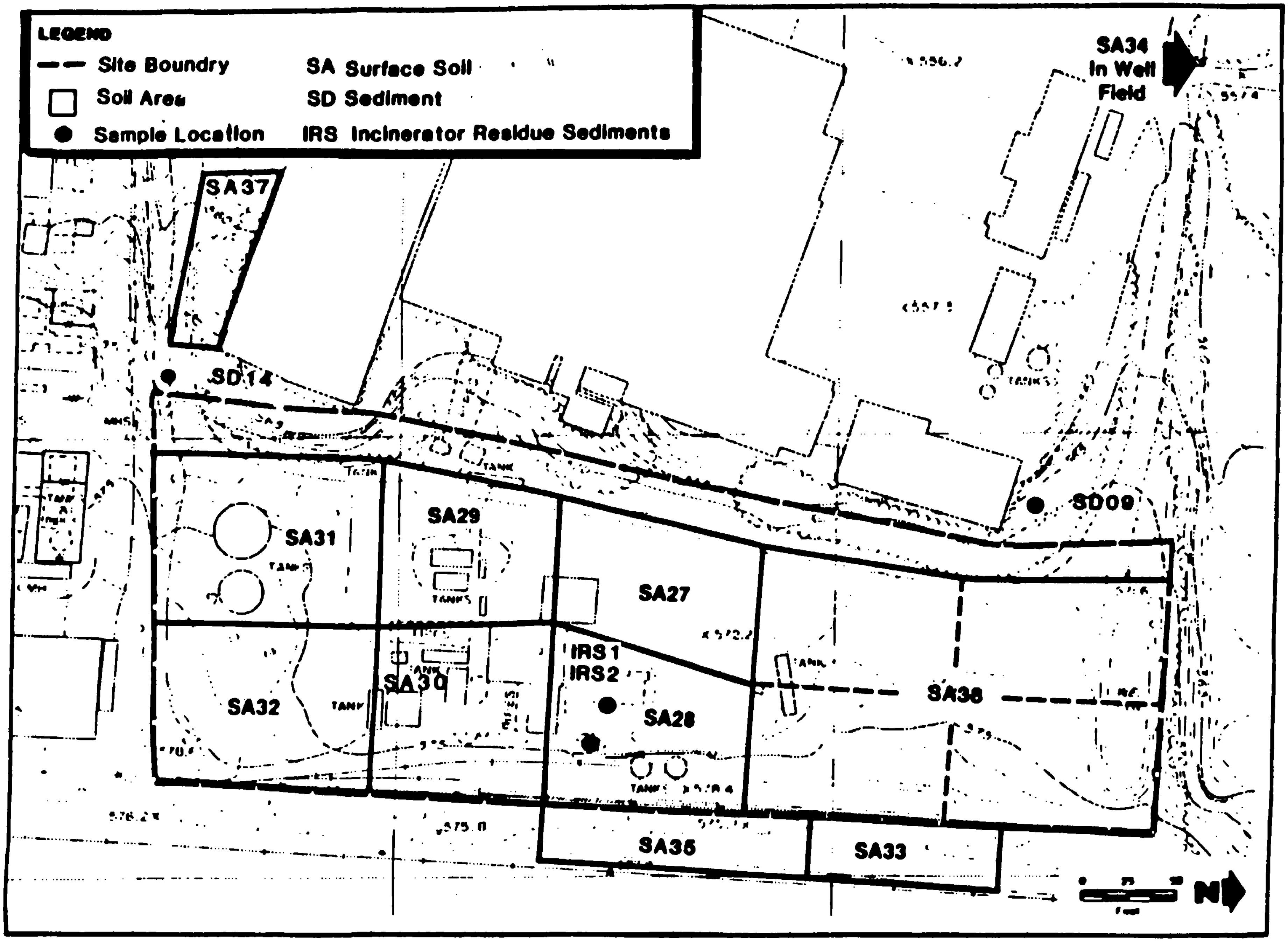


FIGURE 1-4

SOIL AREA, SEDIMENT AND INCINERATOR RESIDUE SAMPLING LOCATIONS

1.3.2.1.2 RAS CLP Analysis

Surface soil sampling at the magic pit for Hazardous Substance List (HSL) analysis was conducted on July 16, 1987. The sampling activities were performed as outlined in Section 3.5 of the Pristine, Inc. Supplemental QAPP. Samples of surface soil material were collected at five on-site locations. The sampling locations are shown in Figure 1-5.

All samples were collected to a depth of six inches using a stainless steel sampling trowel. Surface vegetation, where present, was removed before the sample was taken. The stainless steel trowels were decontaminated in accordance with standard protocol prior to use at each sample location.

A summary of the surface soil sampling activity is provided in Appendix D. A summary of the sampling program is given in Table D-1. Descriptions of the five sampling locations and their corresponding soil samples are presented in Table D-2. Analytical results are presented in Section 3.

1.3.2.2 Subsurface Soil Sampling

Soil boring sampling was conducted on July 22, 24, and August 1, 1987. The sampling activities were performed as outlined in Section 4.6 of the Sampling and Analysis Plan for the Pristine, Inc. site, Document No.: 115-WP1-PS-ALBR-2. (The Sampling and Analysis Plan can also be found in the appendix of the original QA Project Plan for the Pristine, Inc. site, Document No.: 115-WP1-QA-AKYX-2.)

Fourteen soil boring samples were collected at locations shown in Figure 1-6. The borings were advanced using 4.25-inch I.D. hollow stem augers. Soil samples were collected from a 1.5-inch I.D. by 2.0-inch O.D. split spoon sampler. Samples were screened with an organic vapor analyzer (OVA) prior to transfer into individual sample containers and sealed with a Teflon lid. All sampling equipment was decontaminated prior to use at each location, using protocols described in the Quality Assurance Project Plan. The soil boring sampling program is summarized in Table E-1. A description of the samples is presented in Table E-2 and the boring and sampling activity is described in detail in Appendix E. Analytical results of the soil boring sampling are presented in Section 3.

Five soil samples were collected during the drilling of monitoring wells GW63, GW65, GW66 and GW67. Near surface soils were collected for analysis at GW65 and GW66 to determine relative background contaminant concentrations. Samples collected at GW63 and GW67 were taken at lower depths to determine subsurface contamination that could be contributed to contamination migrating in the groundwater. The sampling procedures were followed, as stated above, for soil boring sampling; the results are presented in Appendix E.

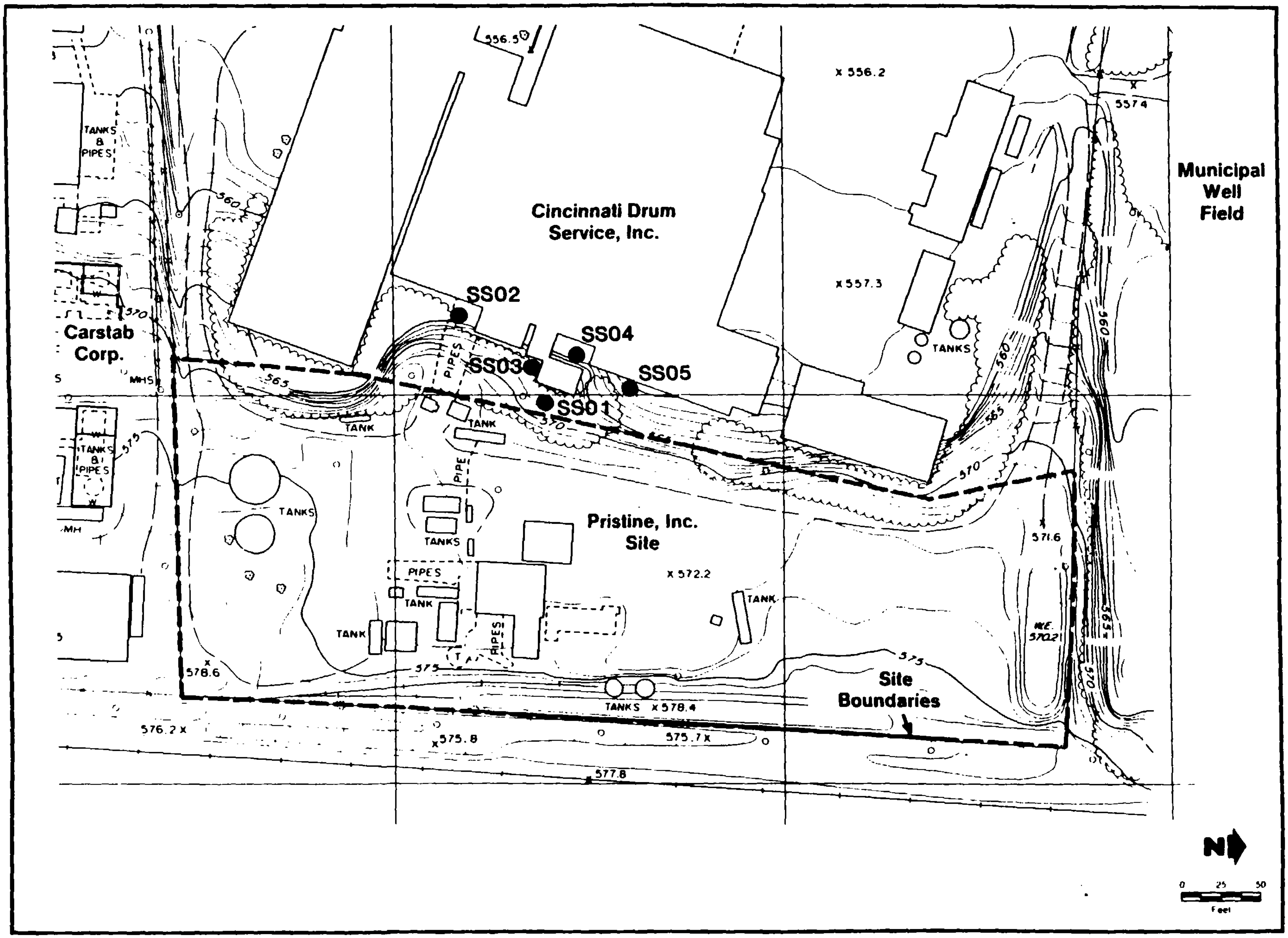


FIGURE 1-5

SURFACE SOIL SAMPLING LOCATIONS

PRISTINE, INC.

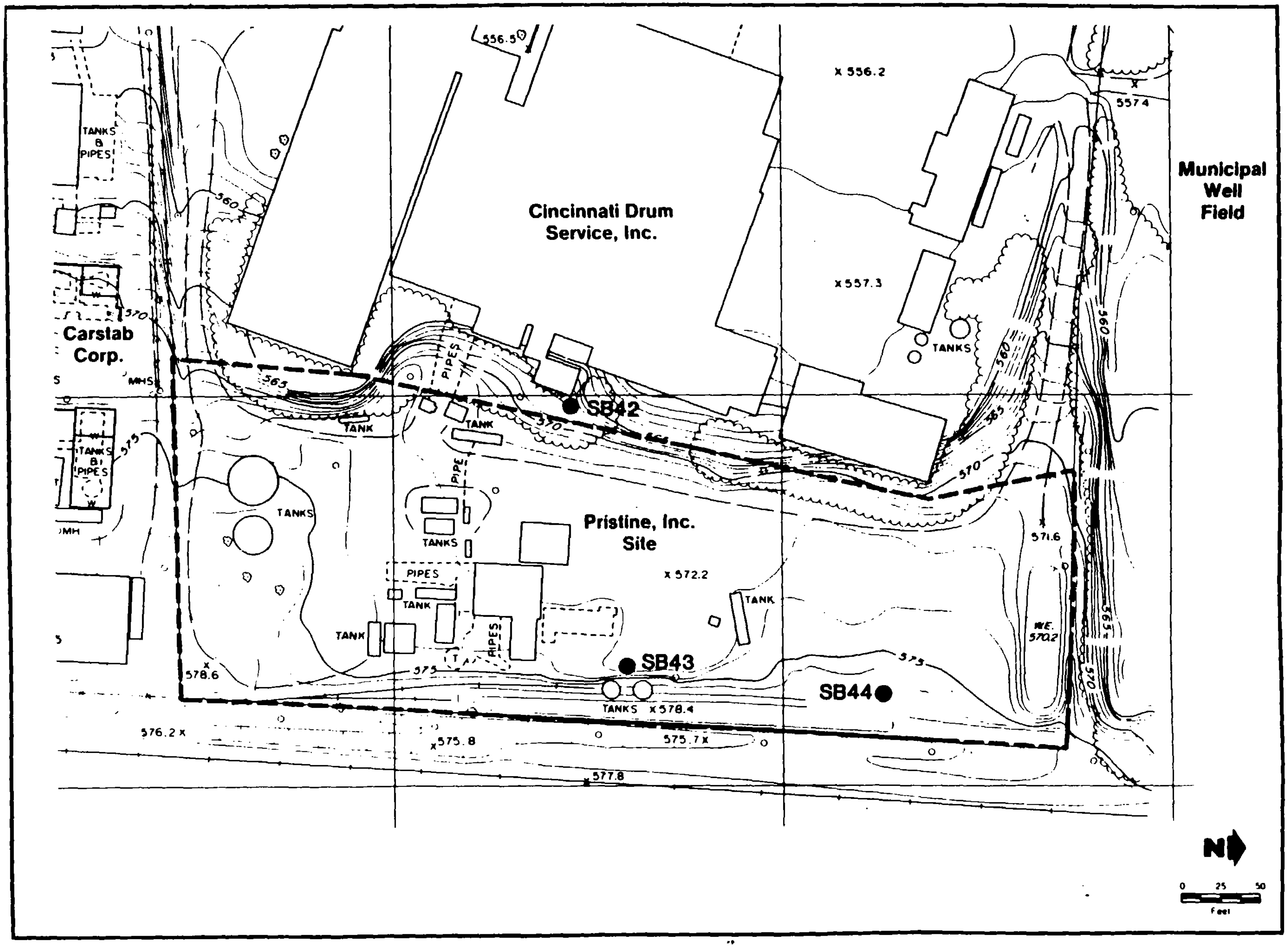


FIGURE 1-6

SOIL BORING LOCATIONS

PRISTINE, INC.

1.3.2.3 Groundwater Sampling

Groundwater sampling was conducted during two rounds on July 16 to August 2, 1987 and August 19, 1987. The groundwater samples were collected from monitoring wells installed using EPA-approved procedures as described in the Quality Assurance Project Plan. The sampling activities were performed as outlined in Section 4.5 of the Pristine, Inc. Sampling Analysis Plan.

Five monitoring wells were installed and sampled during Phase 2 of the Remedial Investigation in addition to the 18 existing wells installed during Phase 1. Two wells were installed on site and three wells were installed off site along the Conrail railroad tracks. The locations and designations of these wells, with respect to the existing wells, are shown in Figure 1-7. Detailed information regarding the installation of the monitoring wells can be found in Appendix F. A summary of the sampling program is given in Table F-1. A summary of field measurements is presented in Table F-2.

1.4 OVERVIEW OF REPORT

1.4.1 Site Features Investigation

Section 2 of this report presents the results of the investigation of the site features. The presentation includes discussion of site geology, and hydrogeology. A discussion of land use, demography, natural resources, climatology, and hydrology of the site is presented in Sections 2.1 through 2.4, and 2.7 of the Final Remedial Investigation Report. No additional data has been collected concerning these topics during the Phase 2 Remedial Investigation, and therefore these sections have not been revised.

Data and information obtained during the Phase 2 Remedial Investigation concerning the extent of the upper aquifer system and the flow direction of the lower aquifer system (water supply aquifer) differs from the findings and conclusions presented in the Final Remedial Investigation Report (see Section 2.6.2, Remedial Investigation Report, Pristine, Inc., 18 July 1986). The results of the RI2 geological and hydrogeologic are presented in Section 2 of this report.

1.4.2 Hydrogeological Investigation

The results of the hydrogeological investigation are presented in Section 3. The section is divided into two major categories: soils and groundwater. The soils analyses includes discussion of surface soil and soil boring analytical data. This data is used to supplement and support the findings and conclusions presented in the Final Remedial Investigation Report. Within the groundwater analyses section, data obtained during the Phase 2 Remedial Investigation is

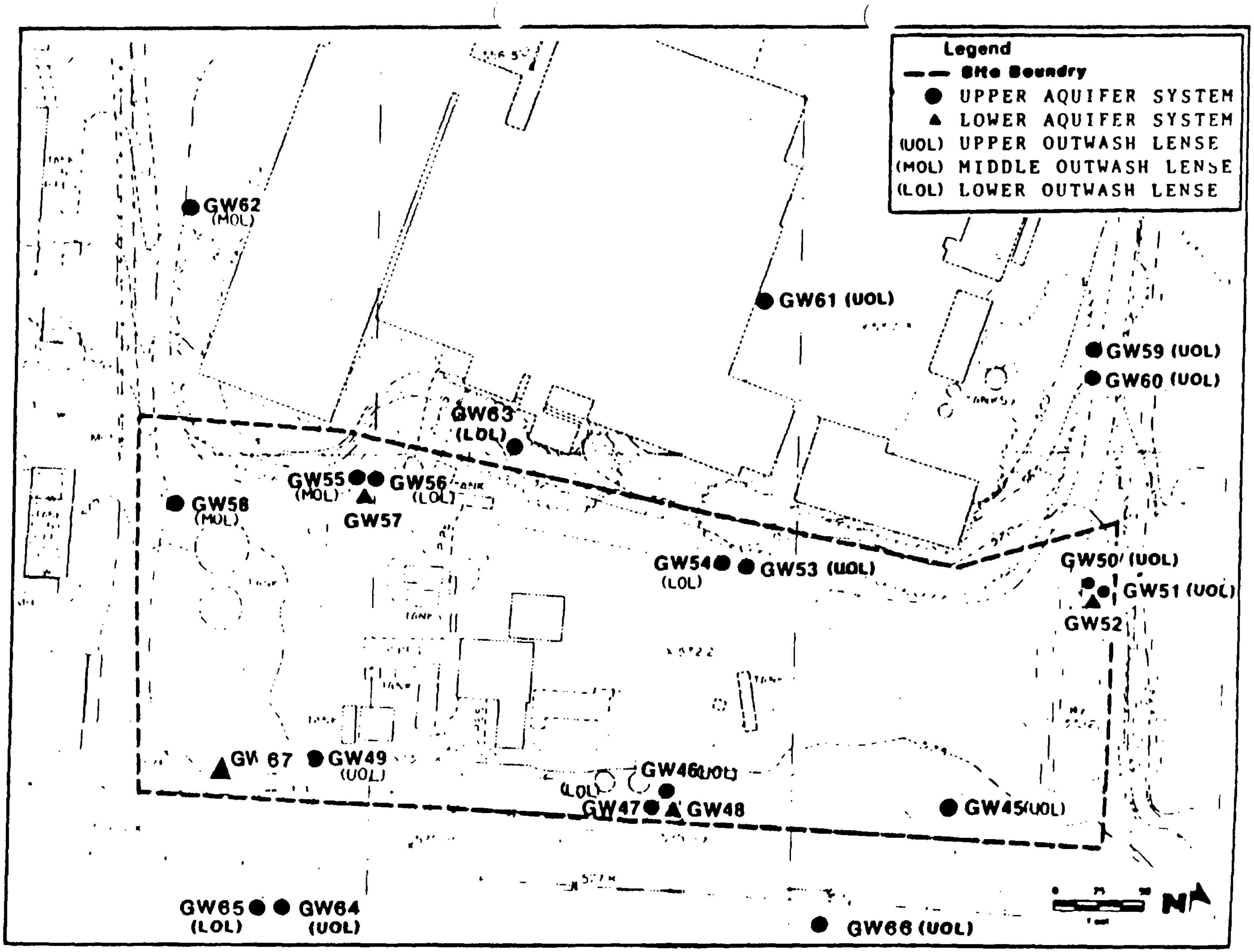


FIGURE 1-7

MONITORING WELL AND GROUNDWATER SAMPLING LOCATIONS

PRISTINE, INC.

used to determine whether an area referred to as the "magic pit" is a source of contamination for groundwater in the lower outwash lens of the upper aquifer system. Also the data is used to supplement and support the findings in the Final Remedial Investigation concerning the characterization of on-site groundwater contamination within the upper aquifer and to continue the characterization of groundwater within the lower aquifer system.

Analytical results of the RI1 Hydrogeological Investigation are presented in Section 3.0 of the Final Remedial Investigation Report for the Pristine, Inc. site.

1.4.3 Public Health and Environmental Concerns

The Public Health Evaluation (PHE) is designed to evaluate the potential risk to public health, welfare and the environment associated with the release of hazardous substances from the Pristine, Inc. site. The PHE was completed with the Final Remedial Investigation Report. The results of the RI2 investigation indicate that the conclusions remain unchanged, with one exception. Dioxin and furan compounds were detected in soil samples collected near the incinerator and identified as incinerator residue samples. An additional PHE was completed to evaluate the risks associated with the dioxin and furan compounds.

SECTION 2

SITE FEATURES INVESTIGATION

This section presents the results of the RI2 investigation of the site features, which includes discussion of geology and soils, and hydrogeology. A discussion of land use, demography, natural resources climatology and hydrology has been presented in Section 2.1 through 2.4, and 2.7 of the Final Remedial Investigation Report.

2.1 GEOLOGY

The Pristine, Inc. site is situated over the buried valley of the Deep Stage Cincinnati River, a glacial-aged river fed by meltwater that eroded several hundred feet into shale and limestone bedrock. Outwash and other glacially derived sediments, which are about 180 feet thick in the vicinity of the site, were subsequently deposited in this valley. The Pristine, Inc. site is situated on a low terrace that is about 10 feet higher than the floodplain of Mill Creek, which now drains the valley. The edge of this terrace is marked by an escarpment which coincides with the western border of the site. The Pristine, Inc. site is not located within the 100 year flood plain, or a wetlands area.

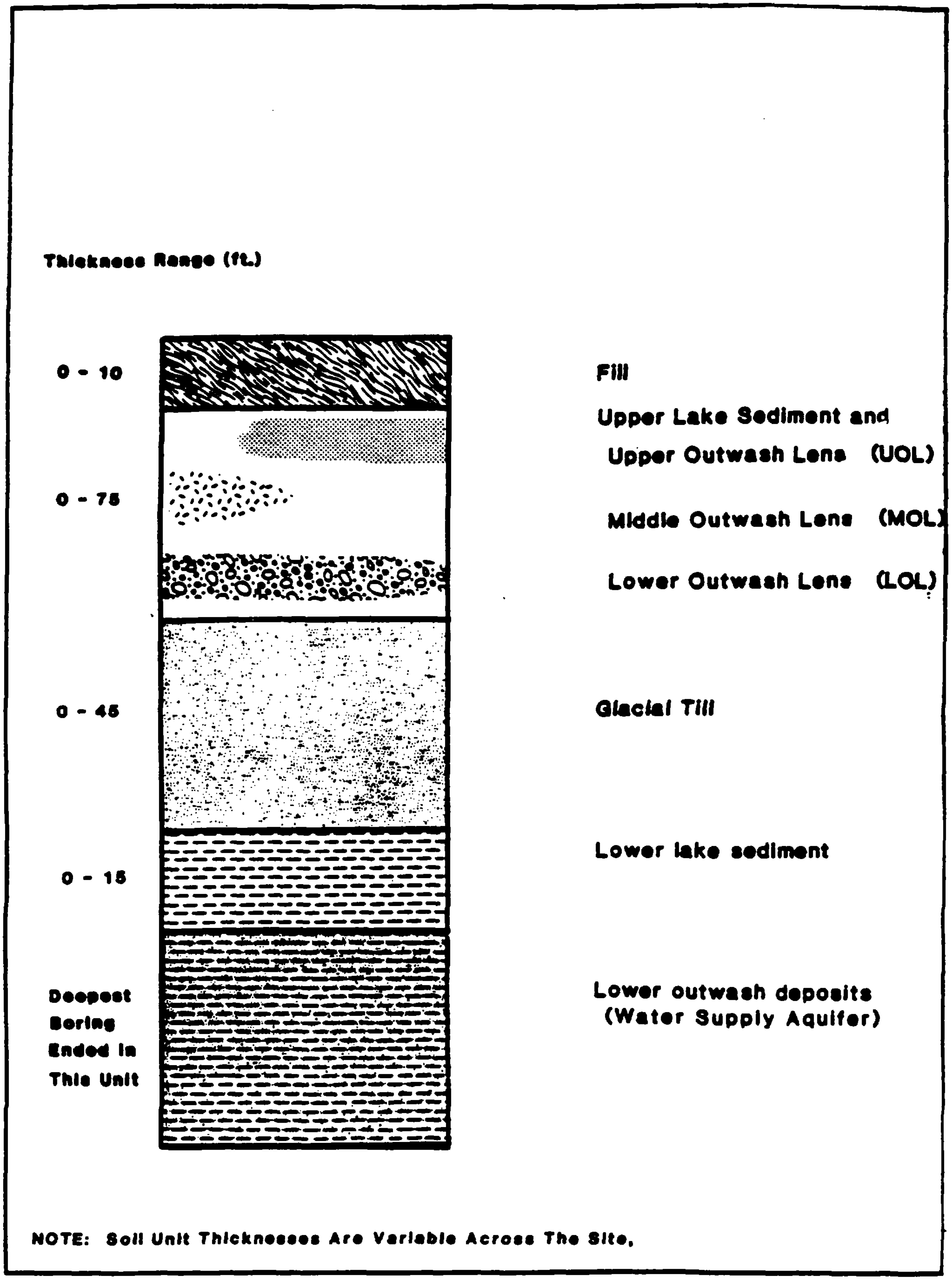
Additional geologic and hydrogeologic data was collected during the second phase remedial investigation (RI 2) at Pristine, Inc. and will supplement the original data. Log sheets, tables, and figures will be presented as appendices of the report. The following appendices are included to present the data:

Appendix G - Hydrogeologic Tables
Appendix H - Boring Logs
Appendix I - Well Installation Data Sheets
Appendix J - Baildown and Slug Test Data

2.1.1 Surficial Materials

The subsurface soil stratigraphy at the Pristine, Inc. site, consists of five distinct soil units, one of which contains more than one soil type (Figure 2-1). From the surface downward, the five soil units are as follows:

- Fill - variously textured soil placed or modified by man's activity. Range in thickness is 0 to 10 feet across the site and up to 15 feet adjacent to the Magic Pit.



NOTE: Soil Unit Thicknesses Are Variable Across The Site.

FIGURE 2-1 GENERALIZED COLUMN UNDER THE PRISTINE INC. SITE

- Upper lake sediment and outwash sequence - predominantly fine-grained, laminated soils containing three, distinct, discontinuous lenses of sandy soil. Range of thickness of the entire unit across the site was 0 to 75 feet, thickening to the southeast and thinning to the west.

- Glacial till - compact, hard, predominantly fine-grained soil, containing substantial amounts of disseminated sand and gravel. Within the study area, the till ranges in thickness from 0 to 45 feet. The glacial till was absent in the southeast corner of the site and off site to the southeast.

- Lower lake sediment deposits - fine-grained, laminated soils. Thickness of this unit ranges from 0 to 15 feet. The lower lake sediment was absent in the southeast corner of the study area and off site to the southeast.

- Lower aquifer outwash deposit - gravely sand soils. Exact thickness of this unit is unknown as no borings completely penetrated deposits.

The stratigraphic relationships and distribution of these soil units at the site are illustrated in the cross-sections presented in Figures 2-2 through 2-9. Each of the soil units is discussed in more detail below.

2.1.1.1 Fill Unit

Fill material at the site ranges from clayey silt to sandy gravel, but is predominantly clayey silt to silty sand with disseminated gravel being common. Asphalt and aggregate backfill materials were observed in borings near or adjacent to the Magic Pit. The fine-grained fill, which is cohesive in nature, is found in the northern third and southwestern corner of the Pristine, Inc. site. The coarser-grained material is found in the south-central part of the site in the vicinity of the buildings and tanks, and also at two monitoring well locations (at the nest of GW59 and GW60, and at GW61) in the northwest section of the Cincinnati Drum Service (CDS) property.

Fill material ranges from 0 to 10 feet in thickness, being absent in the southeastern corner of the site (Figure 2-3). It is thinner (2.5 to 3 feet) along the eastern edge of the site and thicker (5 to 10 feet) along the western edge (Figure 2-1). The fill overlies the upper lake sediment and outwash sequence (lake/outwash sequence). In general, the finer-grained lake sediment occurs beneath the fill but observations made during the drilling of borings SBCP and SB43 indicate that the upper outwash lens may underlie the fill in the central part of the site. At one location on CDS property, GW61, fill directly overlies the glacial till (Figure 2-7).

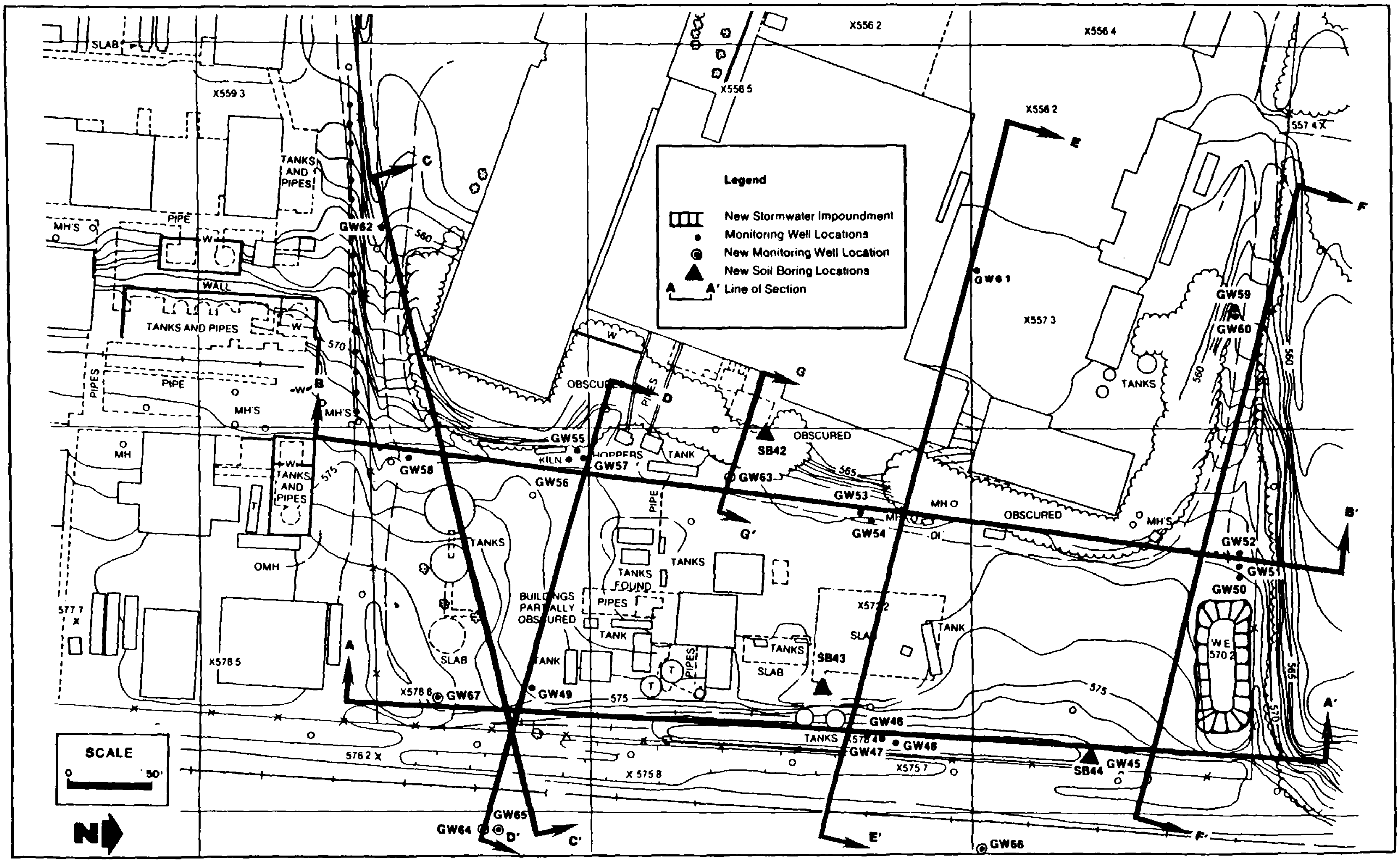


FIGURE 2-2 MONITORING WELL AND SECTION LOCATIONS

PRISTINE, INC. SITE

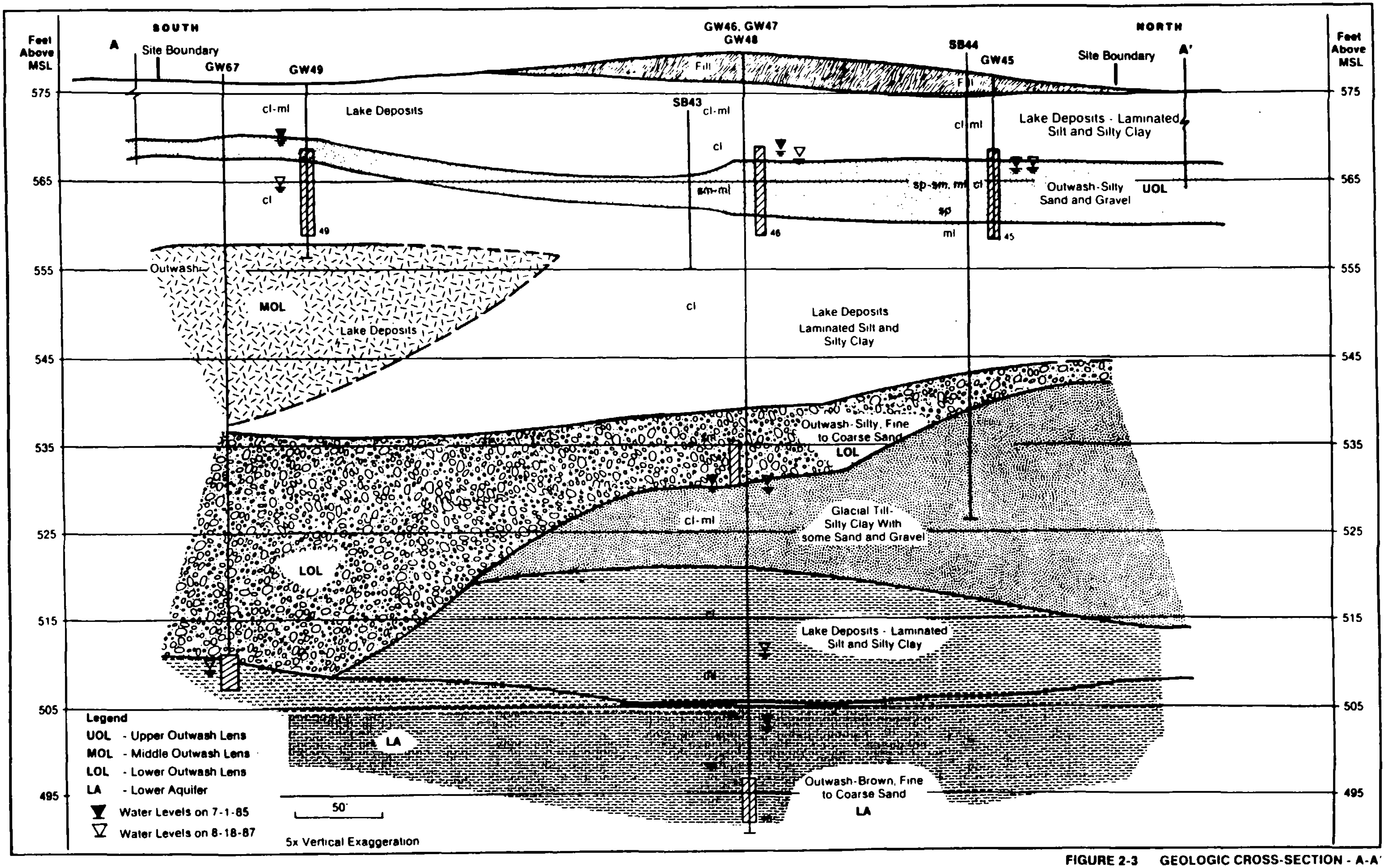


FIGURE 2-3 GEOLOGIC CROSS-SECTION - A-A'

PRISTINE, INC. SITE

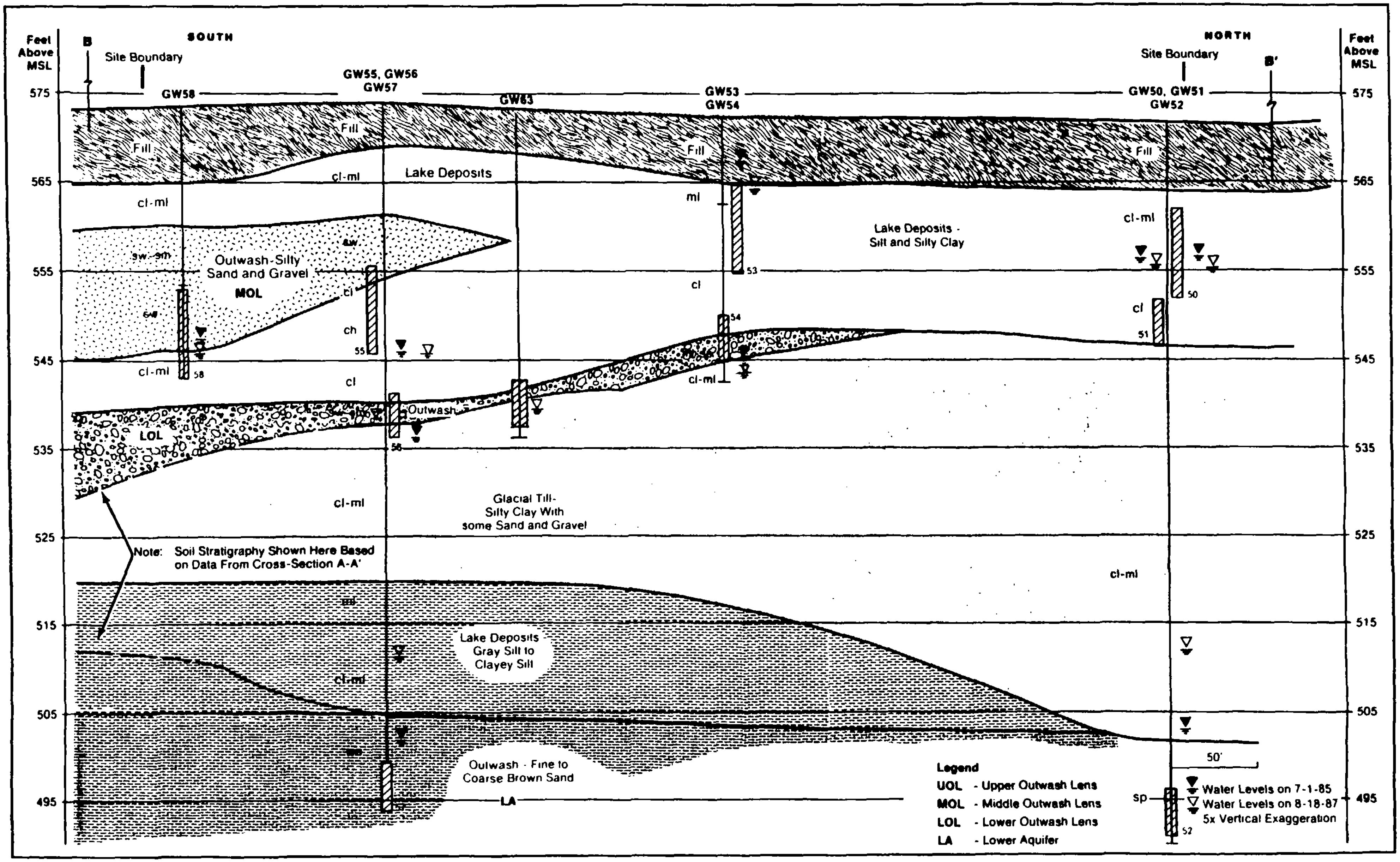


FIGURE 2-4 GEOLOGIC CROSS SECTION - B-B'
PRISTINE, INC. SITE

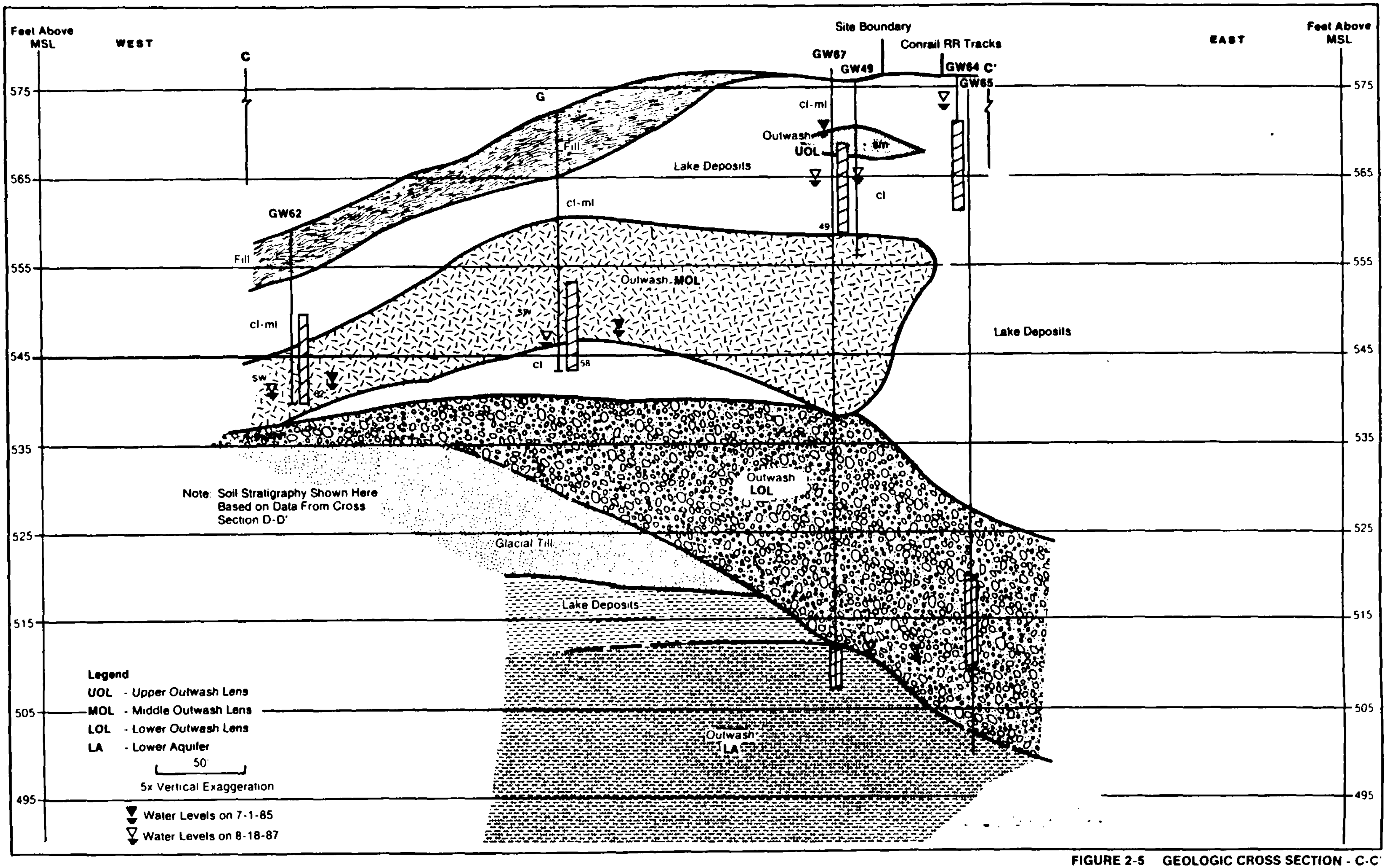


FIGURE 2-5 GEOLOGIC CROSS SECTION - C-C'
PRISTINE, INC. SITE

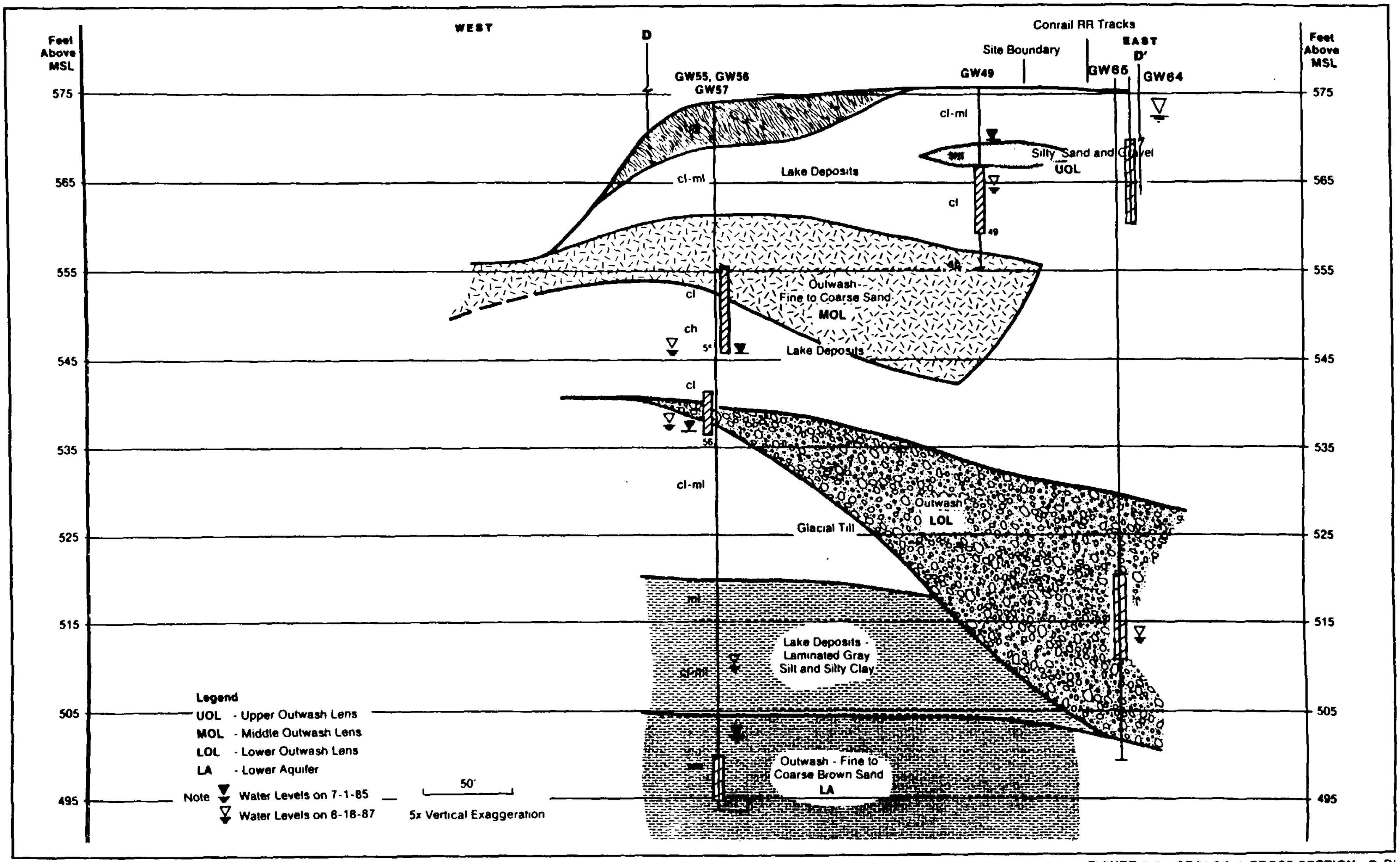


FIGURE 2-6 GEOLOGIC CROSS SECTION - D-D'
PRISTINE, INC. SITE

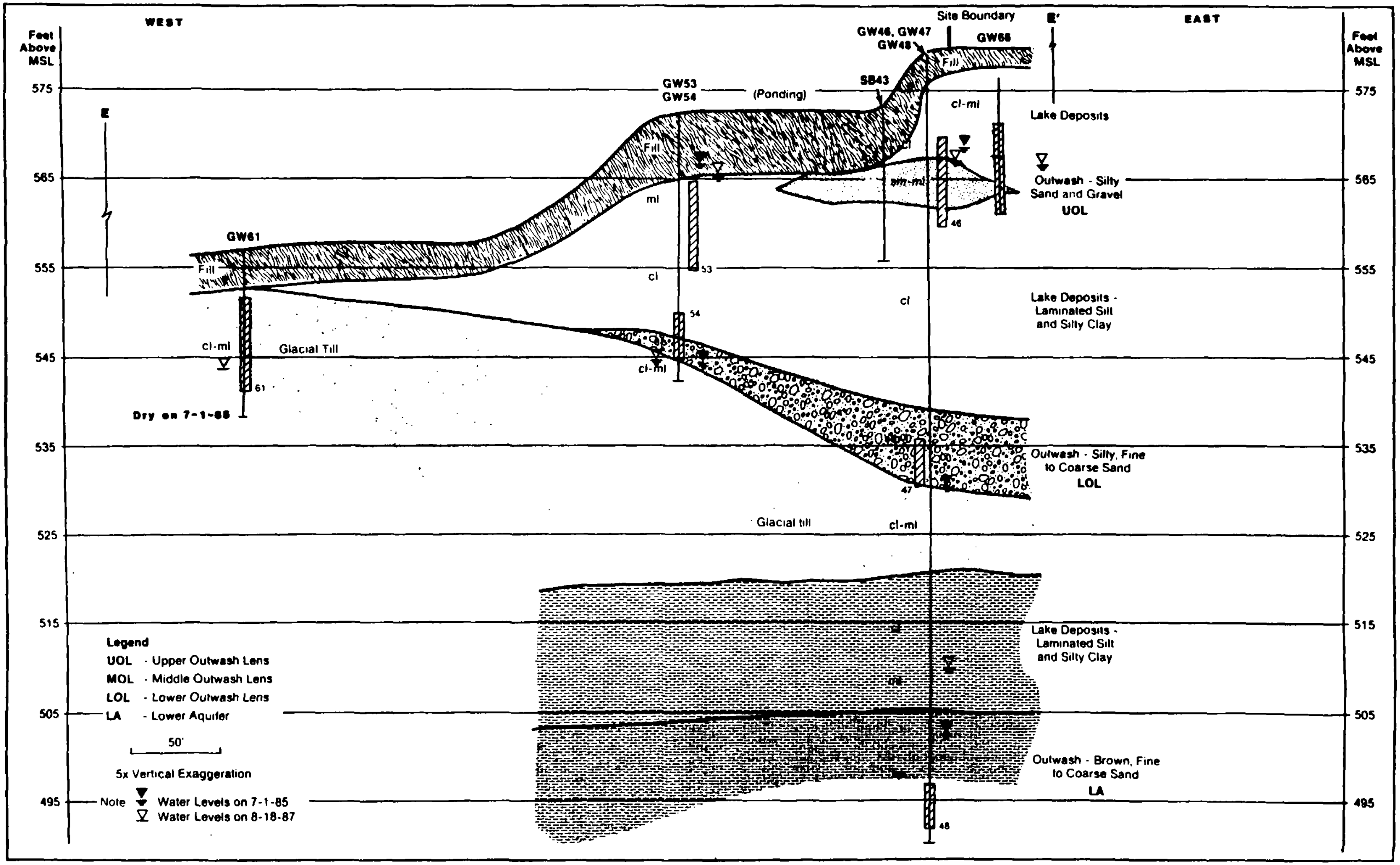


FIGURE 2-7 GEOLOGIC CROSS-SECTION - E-E'
PRISTINE, INC. SITE

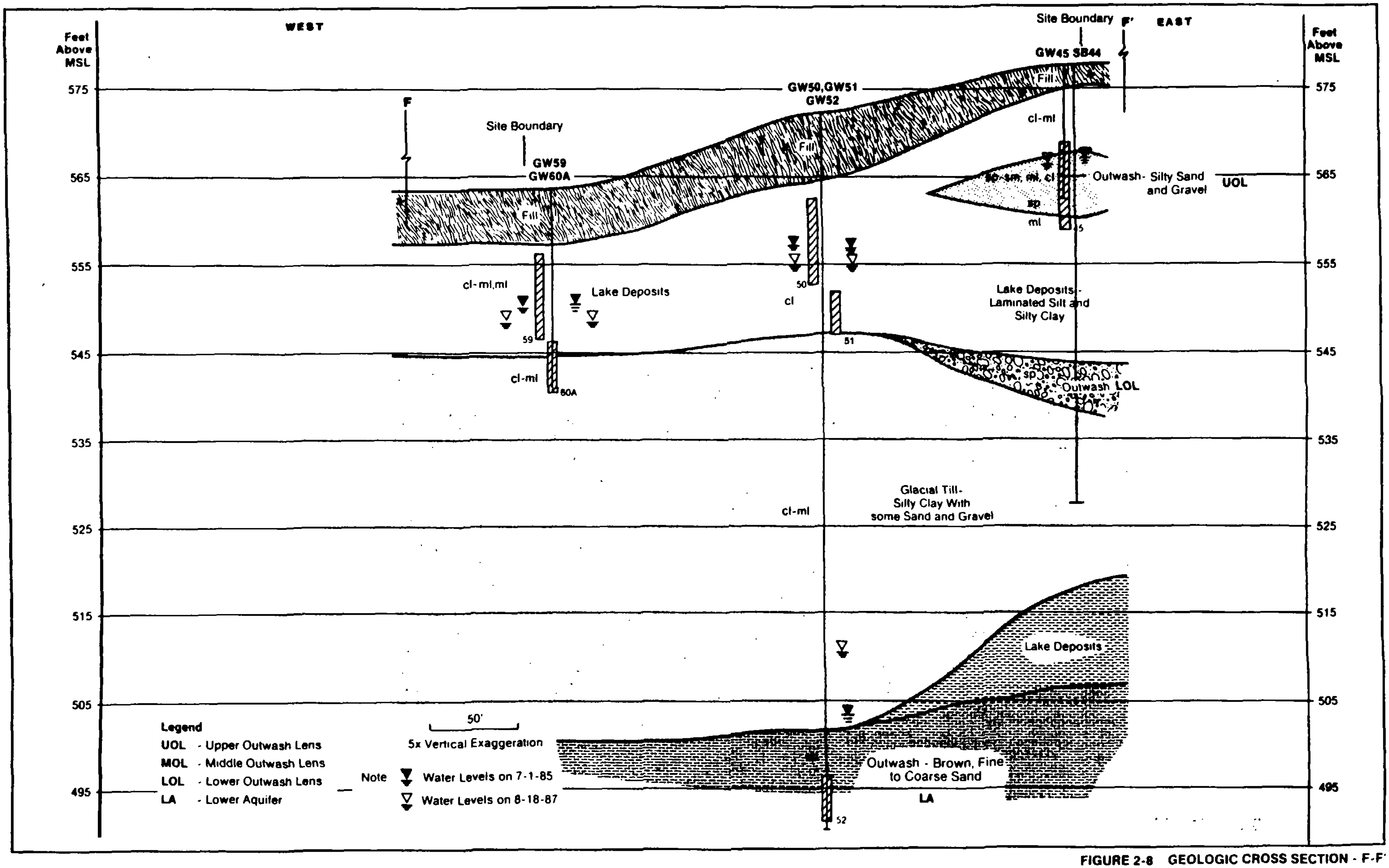


FIGURE 2-8 GEOLOGIC CROSS SECTION - F-F'
PRISTINE, INC. SITE

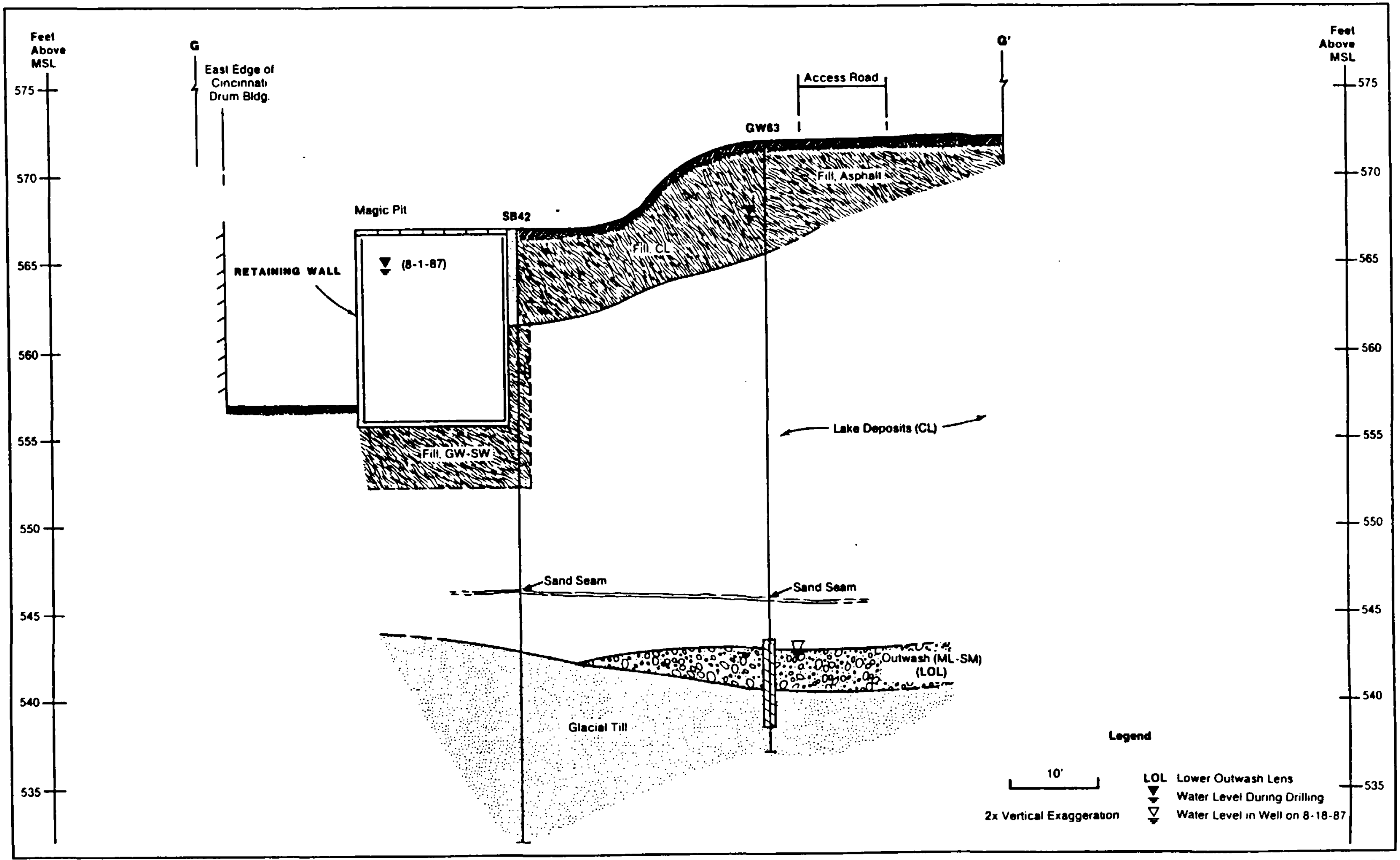


FIGURE 2-9 GEOLOGIC CROSS SECTION G-G'
PRISTINE, INC. SITE

2.1.1.2 Upper Lake/Outwash Sequence

The upper lake sediment and outwash (lake/outwash) sequence consists predominantly of fine-grained deposits. These fine-grained lake soils range from clay to sandy silt, and are typically laminated (i.e., very thinly layered) silty clays and clayey silts that contain a trace to some sand. Within these cohesive soils, interbeds of silt, sandy silt and fine sand are common.

The shallower lake soils, those at depths between about 3 and 18 feet (overlying the upper and middle outwash lenses), tend to be coarser-grained. They are generally clayey silts with faint laminations and sandy interbeds of 0.5 to 6 inches thick.

There are three discontinuous outwash lenses within the lake/outwash sequence as shown on the cross-sections (Figures 2-3 through 2-8). The upper outwash lens ranges from interbedded silty fine sand and silt to fine-to-medium sand that contains a trace of gravel. Most of the upper outwash lens consisted of silty fine sand, and interbeds of silty clay were encountered occasionally. The middle outwash lens is comprised of fine to coarse sand, gravelly sand, and silty sand and gravel. It is predominantly poorly graded medium sand that may contain up to a trace of silt. The lower outwash lens is comprised of silty fine sand, interbedded fine sand and silt, and fine sand that contains a trace to some silt.

The upper lake/outwash sequence ranges from 0 to 75 feet in thickness, being absent at the location of GW61 (Figure 2-7). The sequence is thicker along the eastern and southeastern edge of the site, primarily from the thickening of the middle and lower outwash lenses. The upper lake/outwash sequence becomes thinner to the west (about 15 to 30 feet along the western edge of the site and about 0 to 15 feet off site to the west — beneath Cincinnati Drum Service). The shallower lake soils, those overlying the upper and middle outwash lenses, range from 3 to 13 feet in thickness and are typically 7 to 9 feet thick. The shallower lake soils are thickest in the southwestern corner of the site and off site to the southwest, but no other thickness trends are evident. The deeper lake soils, those underlying the upper and middle outwash lenses, range from 0 to 35 feet in thickness and are typically 14 to 20 feet thick. The deeper lake soils thicken along the eastern edge of the site and are thickest southeast of the site at GW65. However, no lake deposits were observed below the middle outwash lens at GW67. The deep lake deposits become thinner along the western edge of the site.

The upper outwash lens ranges from 3 to 7 feet in thickness and is present only along the eastern edge of the site (Figure 2-3). This lens is thinnest in the southeastern part of the site, becomes thicker to the north, but does not appear to extend off site to the north. This assumption is based on the absence of springs along the slope north of the property fence. The eastern edge of the upper outwash was encountered at GW66, which is 50 feet east of the site. The sandy soils gradate to silty soils such as those found at GW65.

The middle outwash lens ranges from 8 to 20 feet in thickness and is present only in the southern part of the site (Figures 2-5). Based on borings GW55, GW58 and GW67, the middle outwash lens becomes thicker to the south and directly overlies the lower outwash lens in the vicinity of GW67 (southeast corner of the site). This lens extends off site to the west and off site to the south. The middle outwash lens was not encountered off site to the southeast at GW65.

The lower outwash lens ranges from 3 to 26 feet in thickness (Figure 2-5). Based on 11 borings that penetrate through the lower outwash, this lens is present in the central part of the site, is absent off site to the west and absent at the northwestern part of the site. The lower outwash lens thickens and extends off site to the east, south and possibly to the northeast. The lower outwash is directly underlain by the lower aquifer outwash deposit at the southeast corner of the site and off site to the southeast according to findings at GW65 and GW67.

2.1.1.3 Glacial Till Unit

The glacial till is gray with a bluish overtone and ranges from sandy clayey silt that contains a trace of gravel to clayey silt that contains some sand and a trace of gravel. No evidence of vertical fracturing within the till was noted, although a weathered zone of brown glacial till was noted in the upper 6 to 18 inches at SB44 and SB42, respectively. The glacial till was fully penetrated in three boreholes, GW48, GW52 and GW57. At those locations it ranges from 10 to 45 feet in thickness (Figures 2-3 and 2-4). The till is thinnest in the east-central part of the site and thickest in the northwest part. The till unit was absent at GW67, which is in the southeast corner of the site. The till was also absent off site to the southeast at GW65.

The till is estimated to be about 20 feet thick throughout most of the site area, except at locations described above, and may be somewhat thicker off site to the west. The till is overlain by various materials of the lake/outwash sequence, as described above, and by fill at one off-site location (GW61). It is underlain by the lower lake sediment deposits in the southwest and east-central parts of the site, and overlain by the lower outwash deposit in the northwest part of the site. The depth from the ground surface to the top of the glacial till ranges from 25 to 50 feet where encountered on site and 5 to about 20 feet off site to the west.

2.1.1.4 Lower Lake Sediment Unit

The lower lake sediment deposits include silty clay, clayey silt and silt, all of which are distinctly laminated. The lower lake sediments were encountered and fully penetrated in only two borings (Figures 2-6 and 2-7). At both locations, GW48 and GW57, the total thickness of the deposits was about 15 feet. The lower lake sediments were absent off site to the southeast and at the southeast corner of the site, at GW65 and GW67, respectively. The till unit was also absent in these borings, and thus the lower outwash from the upper lake/outwash sequence directly overlies the lower aquifer outwash. In the east-central part of the site, 10 feet of clayey soils overlie 5 feet of silt; whereas in the southwest-central part, 5 feet of silt overlies 10 feet of clayey soils. The lower lake sediment deposits in these areas are overlain by till and underlain by the lower aquifer outwash deposit.

2.1.1.5 Lower Aquifer Outwash Unit (Water Supply Aquifer)

The lower aquifer outwash deposit ranges from coarse sand to silty fine sand and is predominantly composed of fine sand. The coarser-grained soils were found in the northwestern and southeastern part of the site. The borings drilled for this study only penetrated the upper 5 to 15 feet of the lower outwash deposit (Figures 2-3 and 2-4). The thickness of this deposit cannot, therefore, be determined from on-site data. Well logs from an adjacent industrial well and Reading City wells indicate that the lower aquifer is approximately 80 feet in thickness. The depth to the top of the lower outwash deposit at and near the site ranges from 66 to 75 feet based on four on-site borings and one off-site boring. These same borings indicate that the elevation of the top of the outwash deposit ranges from about 500 to 513 feet (MSL).

2.1.1.6 Summary of Soil Stratigraphy

The stratigraphy of the soils beneath the Pristine, Inc. site consists of five major units. The upper-most unit consists of 0 to 10 feet of brown and gray fill. The fill primarily consists of clayey silt to sandy gravel; the clayey variety being fairly cohesive and dense and the sandy variety being loose and less dense.

Underlying the fill unit is a sequence of upper lake sediment and outwash deposits. This unit ranges from 0 to 75 feet in thickness and consists of three separate outwash lenses within a large lake sediment deposit. The outwash lenses within the upper lake sediments are listed below and a brief summary is provided, discussing their thickness, extent of deposition and lithology.

- The upper outwash lens has a maximum thickness of seven feet and is present only along the eastern edge of the site and off site to the east. It consists primarily of silty fine sand; however, interbedded coarser horizons are present. Saturated silts were observed along its margins at the center of the site and off site to the east and southeast. The upper outwash lens appears to terminate off site to the east and off site to the north.

- The middle outwash lens ranges up to 20 feet in thickness and is present only in the southern part of the site. The middle outwash lens appears to thicken to the south and terminates to the east. The middle outwash directly overlies the lower outwash lens at the southeastern corner of the site and possibly off site to the south. The lens consists predominantly of a poorly-graded to well graded medium sand with a trace of silt. Coarser sand and gravelly zones are common.
- The lower outwash lens ranges up to approximately 26 feet in thickness and is the most areally extensive beneath the site, although it does pinch out to the west and northwest. The lower outwash lens thickens to the southeast and is directly underlain by the lower aquifer outwash at the southeast corner of the site and off site to the south and southeast. It is composed of silty fine sand, gravely sand, interbedded fine sand and silt and fine sand that contains a trace of silt.

The third unit, underlying the lake sediment and outwash sequence, is a glacial till layer ranging from 0 to 45 feet in thickness. The till is gray with a bluish overtone varying texturally from a sandy clayey silt to a clayey silt with a trace of scattered gravel. The till unit is absent at the southeastern corner of the site and off site to the southeast.

Beneath the glacial till is the lower lake sediment unit which is distinctly different from the upper lake sediment unit. The lower lake sediment is absent in the southeastern corner of the site and also southeast of the site. The lower lake sediments are characterized by approximately 15 feet of distinctly laminated gray silts, silty clays, and clayey silts.

Underlying the lower lake sediments is a lower outwash unit which is also the municipal and industrial water supply aquifer for the immediate area. The thickness of this unit below the site cannot be determined from on-site data as no boring penetrated the entire deposit. Industrial wells and city wells near the site indicate that the aquifer is approximately 80 feet in thickness. The unit consists predominantly of fine silt with some coarse sand and silty fine sand horizons.

2.1.2 Bedrock Geology

Bedrock was not encountered by any of the borings drilled at the Pristine, Inc. site for this investigation. Data from 14 water supply wells within one mile of the site, including four in the nearby City of Reading well field, indicate that the depth to top of bedrock in this part of the buried valley ranges from 173 to 182 feet (470 to 490 MSL). According to the depth to bedrock data from the nearby municipal and industrial wells, the bedrock valley is oriented somewhat parallel and adjacent to Mill Creek.

Lithologies reported in these well logs included shale and limestone, with shale being the predominant rock type. The shale and limestone encountered in these wells appears to be part of the Kope Formation (previously known as the Latonia Shale) which is Ordovician-aged. They could also be part of the underlying Point Pleasant Formation. Both of these formations are comprised of thinly interbedded shale and limestone.

2.2 HYDROGEOLOGY

From a hydrogeologic perspective, the five soil units identified at the Pristine, Inc. site comprise two aquifer systems partially separated by a confining bed system (Figure 2-10). The upper aquifer system includes the fill and the upper lake sediment and outwash sequence. This sytem extends from the ground surface to the top of the till unit. The confining bed system includes the till and the lower lake sediment deposits. The lower aquifer system includes only the lower outwash deposit and is the same aquifer from which the City of Reading well field obtains water.

The hydrogeologic characteristics (porosity, hydraulic conductivity and velocity) for the units are summarized in Tables 2-2 and 2-3 in Appendix F. The porosity values used were taken from literature (Peck, et. al., 1974) based on soil types observed during the RI1 and RI2. Hydraulic conductivities and velocities were calculated using baildown and slug tests from both the RI1 and RI2 programs. Calculations were performed in reference to "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" (Bouwer and Rice, 1976). All testing procedures, graphs, and calculations used in determining the aquifer characteristics are illustrated in Appendix J.

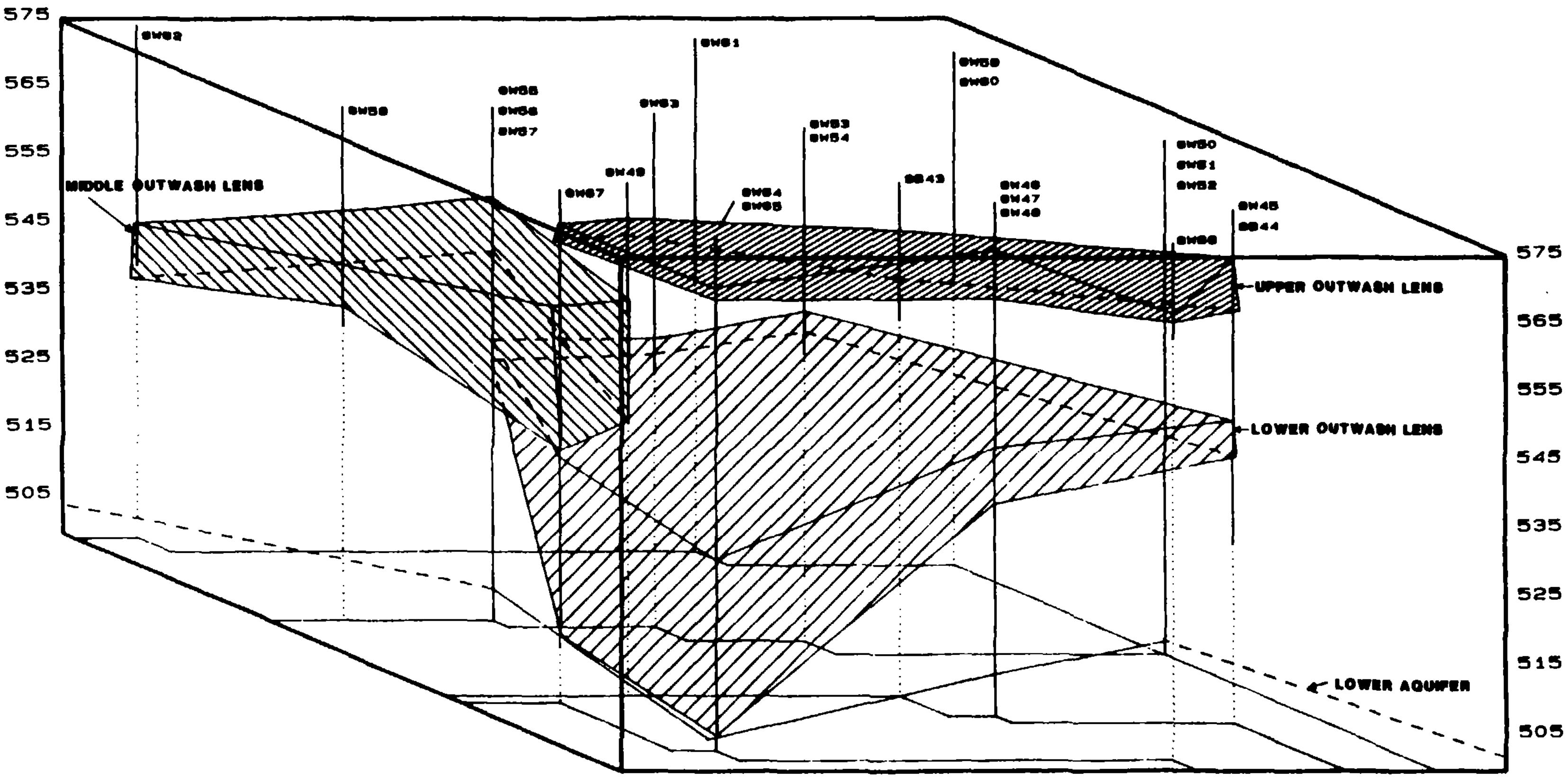
2.2.1 Groundwater - Upper Aquifer System

Groundwater is present in both upper and lower aquifer systems at the Pristine, Inc. site. Groundwater in the upper aquifer system occurs as a series of perched water zones within the lake deposits and outwash lenses. Perched groundwater is defined as water separated

FIGURE 2-10

CONFIGURATION of UPPER AQUIFER in RELATION to LOWER AQUIFER

PRISTINE INC. SITE



from a general zone of saturated groundwater by a layer of unsaturated soil or rock. In this case, groundwater within the upper lake deposit is perched above an unsaturated till having very low permeability.

Groundwater conditions in the upper aquifer system are predominantly controlled by the three outwash lenses. These lenses are linked to each other by vertical leakage through lake sediment deposits or direct drainage in the absence of lake deposits. The three subsystems are as follows:

- Upper perched water table (upper outwash lens)
- Middle perched water table and drainage zone (middle outwash lens)
- Lower drainage zone (lower outwash lens)

Sections 2.3.1.1 through 2.3.1.3 will discuss the groundwater conditions for each of the three outwash lenses listed above. Topics covered include groundwater occurrance, hydrogeologic properties, groundwater flow and drainage patterns.

2.2.1.1 Upper Perched Water Table

This subsystem occurs within the upper outwash lens and near-surface lake sediment. The upper perched water table within the upper outwash lens extends from the southeastern corner and eastern edge of the site, northward across the site. It is absent in the southwestern part of the site. The surface topography decreases rapidly off site to the north, adjacent to the site pond. No springs were noted along this slope off site, and this may be an indication that the upper outwash lens terminates to the north.

Radial groundwater flow occurs within the upper outwash lens due to mounding (Figure 2-11). The mounding is likely due to higher recharge verses discharge of groundwater from the upper lens. The higher recharge is influenced by the overlying, more permeable fill material. The groundwater drains into the surrounding and underlying lake sediments. The flow components are both vertical and horizontal as indicated by monitoring wells adjacent and downgradient of the outwash lens. Actual flow directions will be directly related to the permeability of the soils and the hydraulic gradients at those locations.

Monitoring well GW64 was not used in developing the groundwater contour map for the upper outwash lens. The water level readings from GW64 appear to be influenced by water within the overlying fill material. The fill material is within the screened interval, thus exhibiting higher water level elevations not likely dictating groundwater conditions within the upper outwash lens.

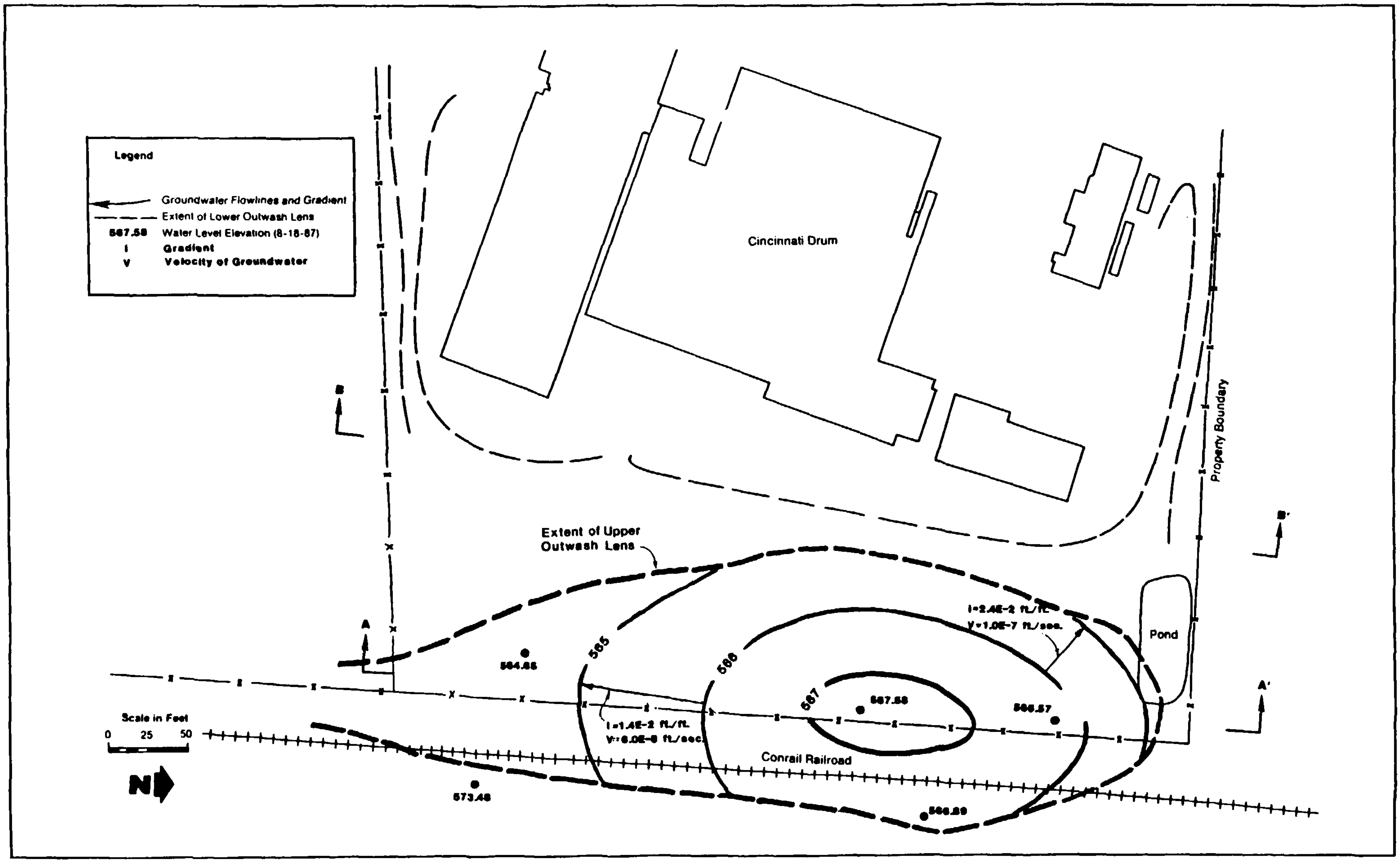


FIGURE 2-11 GROUNDWATER FLOW AND GRADIENTS, UPPER PERCHED WATER SUBSYSTEM
PRISTINE, INC. SITE

It was discovered during the RI2 that the ponding observed in the middle area of the site was caused by broken water lines within an abandoned structure. Within a few days after repair, no ponding was noted in that area. It is likely that water levels within the upper outwash lens may have been effected by the water leak, thus the thickness of saturation within the upper lens may decrease with time.

Horizontal gradients defining the slope of the upper perched water table are shown in Figure 2-11. Gradients within the extent of the upper outwash lens range from 0.014 to 0.024 ft/ft. Horizontal velocities for groundwater flow of the upper outwash lens and upper lake deposits were calculated using the formula $v = Ki/n$, where K is the hydraulic conductivity, i is the gradient and n is the porosity. The calculations are based on the hydraulic conductivity and porosity values presented in Tables 2-2 and 2-3 (Appendix F). Gradients were calculated from contour flow lines shown in Figure 2-10. Based on a porosity of 40 percent (for loose, graded sand) and an average hydraulic conductivity of 1.7×10^{-6} ft/sec, the velocity would range from 6.[illegible] $\times 10^{-8}$ to 1.0×10^{-7} ft/sec (5.2×10^{-3} to 8.8×10^{-3} ft/day), based on the horizontal flow gradients.

2.2.1.2 Middle Drainage Zone and Perched Water Table

This subsystem occurs within the middle outwash lens. The middle perched water table is present in the very southwestern corner of the site. It extends off site to the southwest. The middle drainage zone exists where the outwash lens is essentially unsaturated and underlain by lake sediments. The drainage zone consists of a thin flow zone (one foot or less) along the bottom of the outwash lens and is present in the southern third of the site. Drainage to the lower outwash occurs at the southeast corner of the site, due to the absence of lake deposits between the two subsystems.

Groundwater flow conditions in the middle drainage zone and perched water table are shown in Figure 2-12. Horizontal flow in this subsystem appears to be predominantly to the southwest. The flow direction for the water table shown in the figure is based on the projected shape of the bottom of the middle outwash lens and the probable discharge of this flow subsystem would be to Mill Creek and to the lower outwash lens. The shape of the bottom of the middle outwash lens was projected using data from five borings — GW49, GW55, GW58, GW62 and GW67. Flow directions in the drainage zone are controlled completely by the topography of the bottom of the middle outwash lens. Groundwater flow in the area where the middle outwash lens is underlain by the lower outwash lens and would suggest vertical flow components to the underlying outwash deposits.

Leakage from the middle flow subsystem to the lower drainage zone is also evidenced by the presence of water in GW56, which is screened within the lower drainage zone, and the discontinuous nature of the outwash lenses precluding recharge of the lower lens from shallower off-site sources. The downward leakage, however, between the two outwash lenses also appears to be significant in the area of GW67, where the two lenses are in direct contact with each other.

Horizontal gradients in the middle drainage zone and perched water table are shown in Figure 2-12. Gradients in the drainage zone are the same as the slope of the bottom of the outwash lens and range from 0.119 to 0.500 ft/ft. The gradient calculated for the water table, based on only two water levels and the estimated direction of flow shown in the figure, range from 0.052 to 0.130 ft/ft.
Velocities were calculated as described above, for the upper perched water table subsystem. A porosity of 35 percent (for medium density, graded sand) was used along with an average hydraulic conductivity of 1.5×10^{-6} ft/sec to determine the middle outwash lens velocity. Using these values and gradients of the groundwater in the middle outwash lens, the horizontal velocities would range from 2.2×10^{-7} to 5.6×10^{-7} ft/sec (1.9×10^{-2} to 4.8×10^{-2} ft/day).

2.2.1.3 Lower Drainage Zone

This subsystem occurs in the lower outwash lens. The outwash lens is essentially unsaturated throughout its extent, but there is evidence of a thin (about one to six inches thick) layer of water flowing along the bottom of the outwash zone. The thickness of saturation, however, is greater off site to the southeast where the lower outwash lens dips and is directly underlain by the lower aquifer. The drainage zone is present throughout all but the very northwestern corner of the site.

Groundwater flow conditions in the lower drainage zone are shown in Figure 2-13. Horizontal flow in this subsystem is to the east-southeast and is controlled completely by the topography of the bottom of the lower outwash lens. Horizontal gradients, which are shown in Figure 2-12, are the same as the slope of the bottom of the lens, ranging from 0.100 to 0.250 ft/ft. Vertical leakage from the lower drainage zone to the lower aquifer system occurs throughout the extent of the lower outwash lens. Velocities were calculated as described above for the upper perched water table subsystem. The porosity used for the lower outwash lens will be 30 percent (dense, graded sand) and the average hydraulic conductivity is 7.9×10^{-7} ft/sec. These values and gradients discussed above yield horizontal velocities ranging from 2.6×10^{-7} to $6. \times 10^{-7}$ ft/sec (2.2×10^{-2} to 5.7×10^{-2} ft/day).

2.2.2 Groundwater - Lower Aquifer System

Groundwater conditions in the lower aquifer system are controlled by groundwater withdrawals for municipal and industrial water supply and recharge that occurs by leakage through the overlying confining bed,

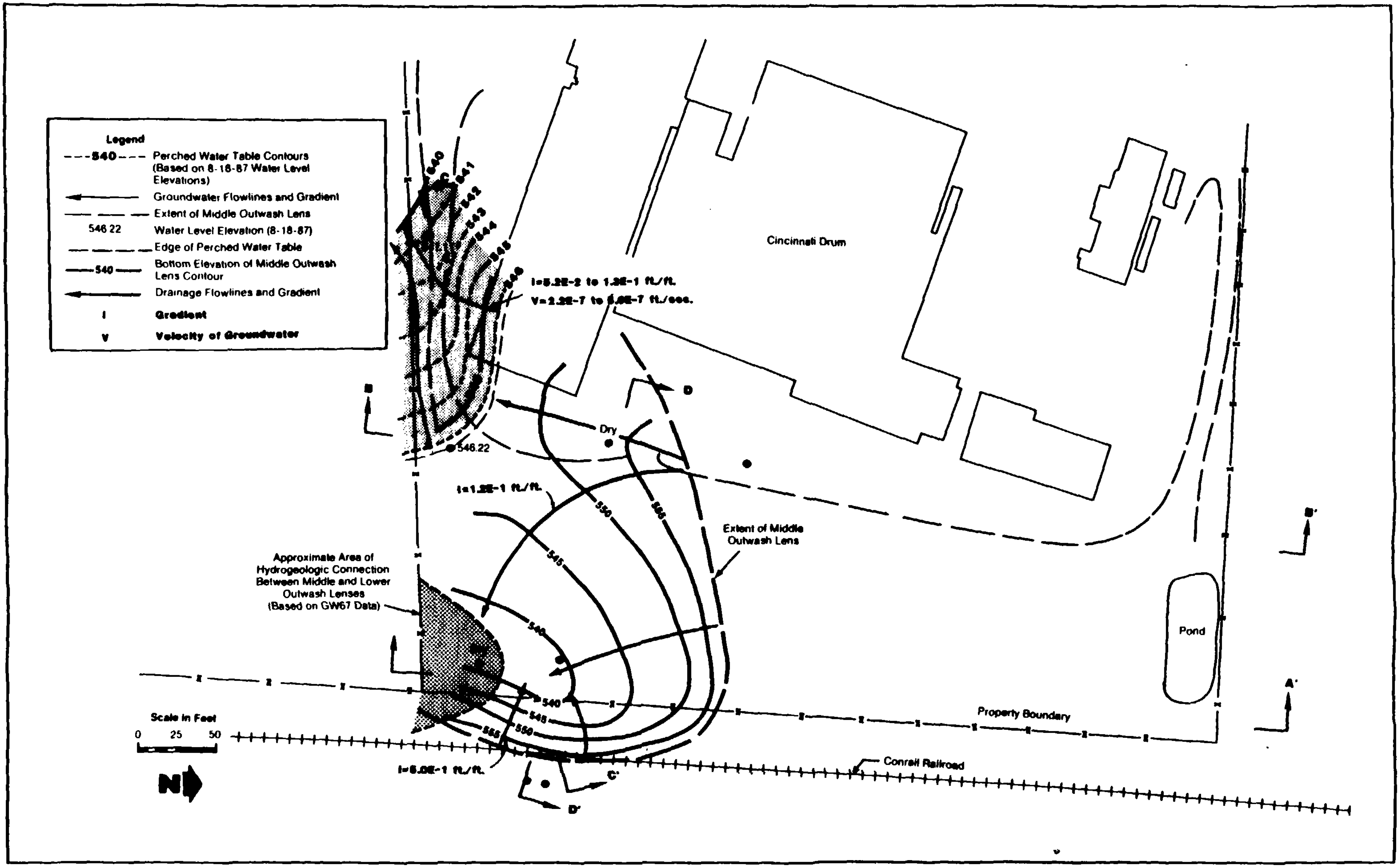


FIGURE 2-12 GROUNDWATER FLOW AND GRADIENTS MIDDLE PERCHED WATER SUBSYSTEM

PRISTINE, INC. SITE

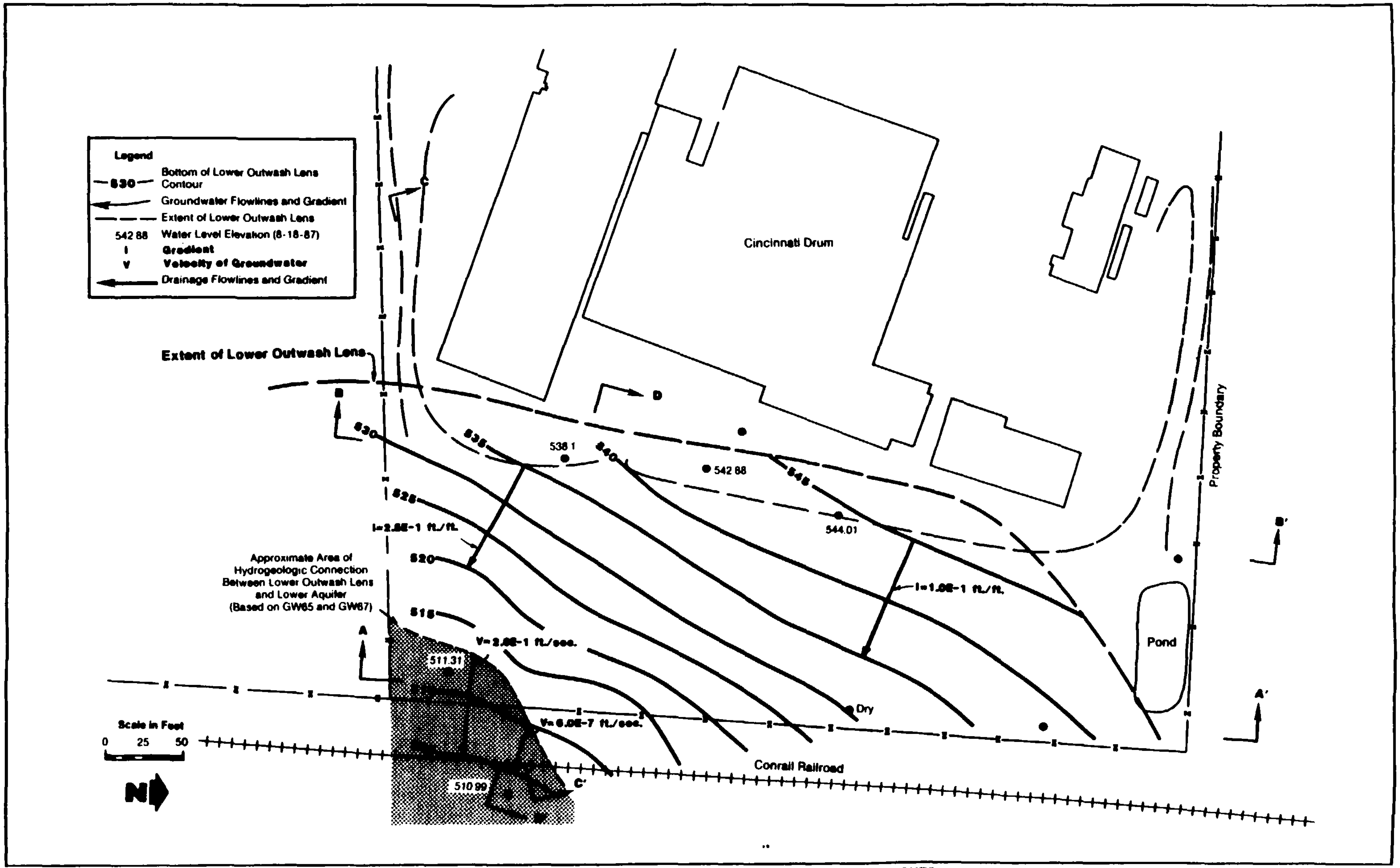


FIGURE 2-13 GROUNDWATER FLOW AND GRADIENTS LOWER DRAINAGE ZONE SUBSYSTEM
PRISTINE, INC. SITE

from other parts of the coarse-grained deposits filling the buried bedrock valley that underlies Mill Creek, and from the bedrock formations cropping out along the walls of the buried valley. The relative locations and magnitudes of the groundwater withdrawals and recharge determine the groundwater flow pattern. According to Fidler (USGS Water Supply Paper 1893, published 1979), significant groundwater utilization began early in the 20th century. Prior to this time, regional groundwater in the Mill Creek valley flowed southward along the valley to discharge at the Ohio River. Reportedly during the period 1900 to 1919, groundwater pumpage from municipal and industrial centers averaged about five million gallons per day (mgd). This increased to about 10 mgd from 1920 to 1942. Groundwater withdrawals during the period 1942 to 1952 were mostly in the cities of Lockland, Reading, Sharonville and Evendale. OEPA records in groundwater pumpage from the General Electric Evendale Plant indicate a design capacity of 14.4 mgd with an average pumpage of 5.7 mgd in 1984.

The groundwater withdrawals have produced a cone of depression which is centered in the Mill Creek Valley and induces flow toward it from all other areas. Groundwater withdrawals due to pumping result in a lowering or drawdown of the water table in the vicinity of the pumping. The drawdown caused by a single well is shaped somewhat like an inverted cone, and is often called a cone of depression. The effects of multiple wells pumping from the same aquifer are additive, and the resulting water table often has a very large cone of depression centered in the area of greatest pumping.

By 1920, drawdowns in Lockland were about 25 feet and those in Reading were about 20 feet. By 1952, these drawdowns had reached 90 feet and 80 feet, respectively. Between 1952 and 1965, the period of reduced groundwater withdrawals, the water table at Lockland had recovered about 10 feet, and the center of the aquifer cone of depression shifted slightly northeastward. In 1985, General Electric ceased pumpage of groundwater from the Mill Creek aquifer and reportedly water levels at the Reading well field have recovered approximately 50 feet since 1965 (Dave Howard, personal communication, April, 1986). The Final Remedial Investigation Report indicated that if the Reading well field remained in use and groundwater withdrawals in other areas continued to decline, the Reading well field could become the greatest pumping center of the aquifer and the cone of depression of the aquifer would be at the well field. This would create a situation where contaminants at the Pristine, Inc. site could potentially migrate to the well field with time. Water level readings taken during the RI2 program from on-site wells indicate that groundwater flow within the lower aquifer is toward the Reading well field. New monitoring wells installed during the RI2 program verify the flow pattern described (Figure 2-14). Several readings were taken along with three survey runs to verify monitoring well and water level elevations, and results were consistent.

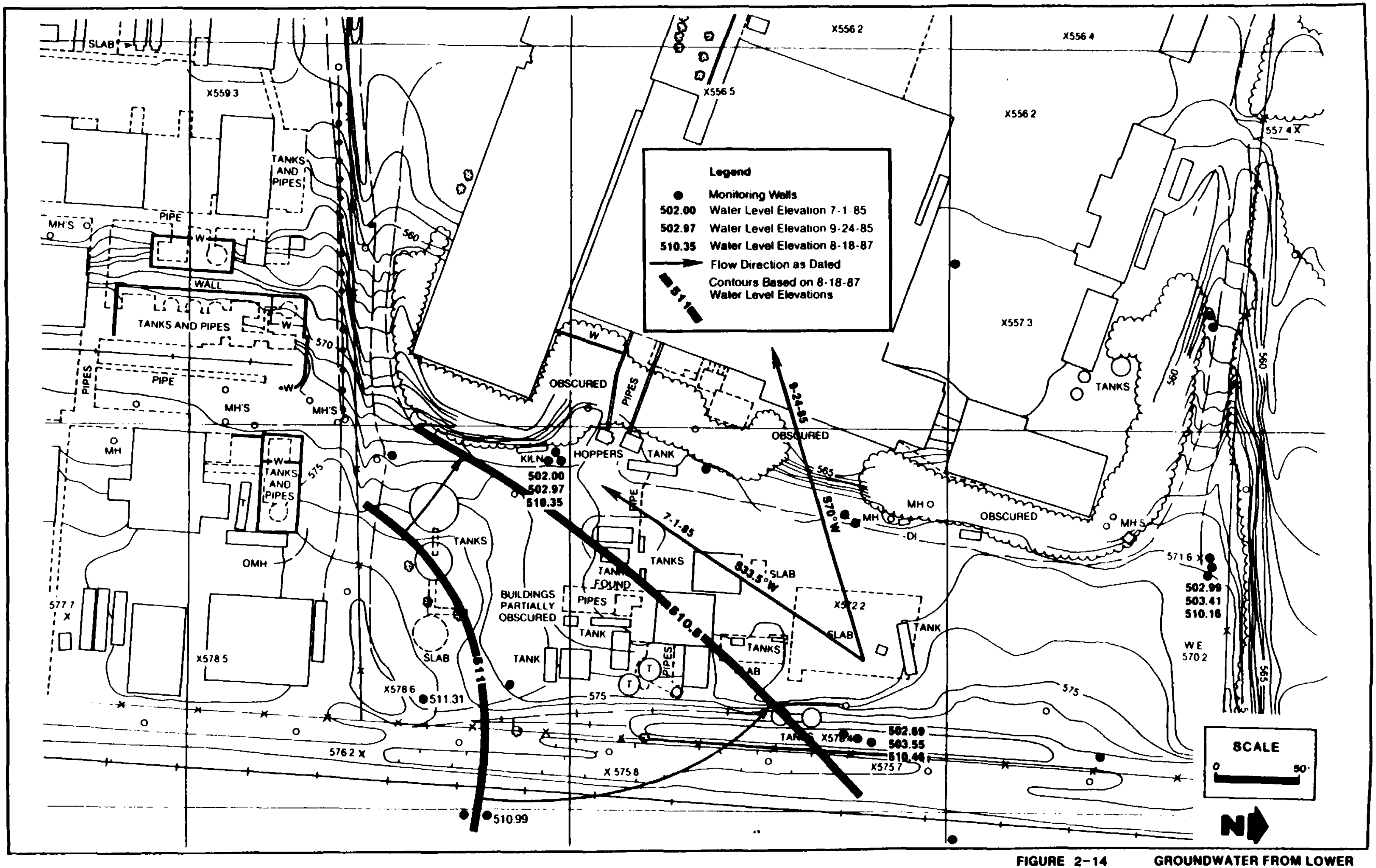


FIGURE 2-14 GROUNDWATER FROM LOWER AQUIFER SYSTEM PRISTINE, INC.

PRISTINE, INC. SITE

Previous water level readings indicated a southwesterly flow across the Pristine, Inc. site. The shift in flow direction is possibly due to a high capacity well placed at the Reading well field adjacent to the site. The well was installed in October of 1986 and withdrawals approximately 700 gpm (personal conversation with Don Shorter, 1987). The gradients calculated for the flow directions were 0.0022 to 0.0081 ft/ft, based on Figure 2-14. Using the average hydraulic conductivity of 4.3×10^{-6} ft/sec and a porosity of 30 percent (dense, graded sand), a flow velocity of 3.2×10^{-8} to 1.2×10^{-7} (ft/sec (2.8×10^{-3} to 1.0×10^{-2} ft/day) can be calculated. At this velocity, water in the upper 0 to 15 feet of the lower outwash deposits (water supply aquifer) would travel up to 3.7 feet in one year. This velocity may not be representative of conditions lower in the aquifer where water supply wells obtain their water.

2.2.3 Summary of Hydrogeology

The hydrogeology can be summarized as follows:

- The upper aquifer system at the site consists of three perched water subsystems coinciding with the three outwash lenses within the upper lake sediment and outwash sequence; These three subsystems lie within the upper lake deposits throughout the site, with the exception of the south to southeast corner of the site. Extensive erosion (scouring) has occurred in this area upon formation of the middle and lower outwash lenses. The middle and lower outwash lens and lower aquifer are directly connected with each other at the southeast corner of the site. The lower outwash lens and lower outwash aquifer are directly connected off site to the southeast.

- The upper outwash lens is almost completely saturated. The middle outwash lens is saturated only in the very southwestern corner of the site. Portions of the middle outwash lens contain a thin layer of water that drains along the bottom contour of the lens. The lower outwash lens contains a thin layer of water that drains along the bottom contour of the lens toward the southeast. The saturation thickness increases where the lower outwash lens intersects the lower aquifer.

- Groundwater flow within the upper aquifer has both a vertical and horizontal flow component. The actual direction of flow depends on which outwash lens or soil deposit is being considered.

- Depth to groundwater in areas where the upper perched (upper outwash lens and upper lake deposits) water table is present ranges from 8 to 12 below the surface.

- The potentiometric surface from the lower aquifer is within the lower lake deposits at some locations, and depths to groundwater range from 63 to 68 feet below the surface.
- Groundwater flow within the upper 10 to 15 feet of the lower aquifer is in a northwesterly direction based on water level readings taken during the RI2. Estimated flow velocities range from 2.8×10^{-3} to 1.0×10^{-2} ft/day (1.0 to 3.7 ft/yr) across the site. These values are based on recovery tests performed on site wells.

Detailed discussion on the hydrogeology of each unit is presented in the following sections. Discussions include groundwater occurrence and their respective flow regimes. The information and data obtained from the RI2 program will be used to supplement the RI1 findings and to further characterize the hydrogeology at the Pristine, Inc. site.

2.3 WATER SUPPLY

Potable water in the Reading area is obtained from the Reading municipal well field consisting of 8 wells located 400 to 1,000 feet northwest of the site on both the western and eastern sides of Mill Creek. Although pumping rates of these wells vary, a combined average of 2.7 million gallons of groundwater are pumped daily from the lower aquifer system, based on withdrawal amounts from the 7 operative wells (Donald Shorter, Reading Water Treatment Plant, personal communication, 1987). The water from individual wells is mixed and treated prior to distribution.

The Lockland well field has four operable wells. Three of them are in Sharonville (about 2.5 miles northeast of Lockland and about 1.5 miles north/northeast of the Pristine site), and the southern well is in Lockland at the treatment plant (about one mile southwest of the Pristine, Inc. site). All four of these wells are screened within the lower aquifer system and withdraw a combined daily average of one million gallons (Rex Brown, OEPA, Groundwater Division, personal communication, September, 1987).

The City of Wyoming has five operative wells located approximately 1.3 miles southwest of the site. Presently, they are withdrawing a combined total of 1.2 million gallons per day from the Mill Creek aquifer (personal communication with Rex Brown, OEPA, September, 1987).

No industrial wells are currently pumping groundwater from the aquifer adjacent to the Pristine, Inc. site. (Personal communication with Donald Shorter, 1987.) Most of the once-used wells have undergone abandonment since 1985. The only nearby industry using the aquifer groundwater is General Electric (GE), which is less than one-half mile west of the site. GE is pumping groundwater for industrial purposes, not for drinking water. (Personal communication with Rex Brown, OEPA, 1987.) Darling and Co. had three wells located west to southwest of the Reading well field, but they do not appear to be presently utilized since the plant is shut down (observation during the RI2, July, 1987).

Based on the hydrogeologic data obtained during the site (RI2) investigation, it appears that the water in the lower aquifer system beneath the Pristine, Inc. site currently flows in a northwesterly direction toward the Reading well field. A detailed discussion of the lower aquifer system is given in Section 2.2.2.

SECTION 3

ANALYTICAL RESULTS OF GEOLOGIC AND HYDROGEOLOGIC INVESTIGATION

The purpose of the geologic and hydrogeologic study is to characterize contamination found in surface soils, subsurface soils, and groundwater at the Pristine, Inc. site. The investigative efforts centered on three major sampling tasks each designed to provide additional information for further characterization of residual contamination. The tasks included sampling and laboratory analysis of surface soils, subsurface soils,and groundwater. All samples were collected in accordance with U.S. EPA guidance and conformed to QA/QC procedures specified in the Quality Assurance Project Plan. All analytical work was provided through the Contract Laboratory Program (CLP). CLP laboratories provided full CLP analysis of 35 volatile organic compounds, 68 semi-volatile organic compounds (base neutral and acid extractables), 27 pesticides and approximately 26 inorganic compounds (the number of parameters analyzed varied with each matrix).

Samples of surficial soil material were collected at the twenty locations. The media sampled included composite soil area samples, grab incinerator residue samples and grab sediment samples. Surface soil sampling was conducted for two reasons; a) to determine the extent of soil contamination surrounding the magic pit, and b) to determine if dioxin/furan contamination exists. Five grab surface soil samples were collected at the magic pit and analyzed for full HSL compounds. The range of constituent organic compound concentration in the soil is presented in Table 3-1. The extent of contaminants in the soils ranged from 0-161,000 ppb for volatile organic compounds, 0 ppb to 94,700 ppb for semi-volatile organic compounds, and from 0 ppb to 10,600 ppb for the pesticide fractions. The concentration of most of inorganic metals detected in the soil area samples were within national average ranges and comparable to the background concentrations, with the exception of barium, cadmium, chromium, lead, mercury, selenium, silver, tin, zinc and cyanide. 2,3,7,8-TCDD was detected in one sample but it was also detected in the laboratory blank. Dioxin and furan compounds were detected in five of the samples.

Three borings were drilled at the site to further assess the vertical distribution of contaminants in the soil. Contaminants in the soil borings ranged in concentration from 0 ppb to 121,990 ppb for volatile organic compounds, 0 ppb to 814 ppb for semi-volatile organic compounds and 0 ppb to 8,600 ppb for pesticides. The concentrations of inorganic metals detected in the soil boring samples were within the national average ranges and comparable to the background concentrations.

Five monitoring wells were installed at four locations on and adjacent to the Pristine, Inc. site. A total of twenty-one groundwater samples

TABLE 3-1

Range of Constituent Organic Compound Concentrations* in Soils and Groundwater Pristine, Inc. Site

	Volatile Analysis	Semi-Volatile Analysis	Pesticide Analysis
	Range	Range	Range
Soil	0-161,000	0-94,700	0-10,600
Soil Borings	0-121,990	0-814	0-8,600
Ground-water	0-317,300	0-6	0- 0.1

All concentrations in ppb.

*Ranges include only RI2 sampling results.

were collected during the initial round of sampling conducted in July 1987. All 21 of the samples were analyzed for volatile organic compounds, while only the five new monitoring wells (GW63, GW64, GW65, GW66 and GW67) were analyzed for volatile organic compounds, semi-volatile organic compounds, pesticide/PCB compounds, and inorganic compounds. The cumulative concentration of contaminants in groundwater samples ranged from 0 ppb to 317,300 ppb for volatile organic compound, 0 to 6 ppb for semi-volatile organic compounds and less than 1 ppb for pesticides. The concentration of inorganic metals detected in the groundwater samples were comparable to water quality standards and criteria.

The following sections describe contamination in each matrix in detail. Section 3.1 discusses criteria and standards used to evaluate the degree of contamination at the Pristine, Inc. site. Section 3.2 discusses contamination in soils and Section 3.3 discusses contamination in the groundwater.

3.1 CRITERIA, STANDARDS, AND AVERAGES

In the evaluation of the concentration of constituents detected at the Pristine, Inc. site, it is necessary to compare contaminant concentrations to existing criteria, standards, and national averages. The criteria and standards have been proposed or enacted to protect human health, welfare and the environment. Criteria necessary to evaluate contaminant constituent concentrations in groundwater and national averages used to evaluate concentrations in soils are discussed in the balance of this section. Criteria used to evaluate data collected during the surface water investigation is presented in Section 4.

3.1.1 Soil

Criteria or standards have not been established to evaluate organic compound concentrations in soils. Therefore, background samples are used as a basis of comparison to determine if soil contamination exists. Background concentrations are indicative of constituent concentrations in soils in the vicinity of the site unaffected by site conditions. The background samples used in this investigation were composite surface soil samples taken in the Reading well field and directly east of the railroad tracks.

Average concentrations of inorganics metals in soils of the United States have been established (Connors and Shacklette, 1975). Background levels of inorganic metals in off-site soils have also been established in this investigation. The background and national average concentrations of inorganic metals of concern at the Pristine, Inc. site are presented in Table 3-2.

TABLE 3-2

National Averages and Background Concentrations of Inorganic Concentrations in Soils Pristine, Inc. Site

	Typical[a] Concentrations		Background[b] Concentrations
	Range	Average	Average
Aluminum	——	7100	7700
Antimony	2-10	5	——
Arsenic	1-50	10	13
Barium	100-3000	430	149
Beryllium	0.1-40	6	0.7
Cadmium	0-0.7	0.06	0.5
Calcium	——	——	53,000
Chromium	1-1000	100	15
Cobalt	1-40	8	7.2
Copper	2-100	30	46
Iron	——	——	17,000
Lead	2-2000	10	22
Magnesium	——	0	14,000
Manganese	20-3000	600	490
Mercury	0.01-0.3	0.03	——
Nickel	5500	100	21
Potassium	——	——	1,200
Selenium	0.1-2	0.5	——
Silver	0.01-5	0.05	——
Sodium	——	——	710
Thallium	——	5	——
Tin	2-2000	10	——
Vanadium	20-500	100	26
Zinc	10-300	50	79
Cyanide	——	0	——
Flouride	——	——	270

ALL CONCENTRATIONS IN PPM

a = CONNOR and SHACKLETTE, 1975

b = OFF-SITE SURFACE SOIL SAMPLE SA34, SB65, AND SB66

3.1.2 Groundwater

The principal criteria by which concentrations of substances in groundwater are evaluated are the Primary and Secondary Drinking Water Standards and cancer risk levels. Drinking water standards are set as maximum contaminant levels (MCLS) and are enforceable standards under the Safe Drinking Water Act (SDWA). Maximum contaminant level goals (MCLGs) are also used to evaluate groundwater but MCLGs are not enforceable. The SDWA and RCRA MCL concentrations for inorganic and organic constituents are shown in Table 3-3. CWA Ambient Water Quality Criteria and SDWA/MCL Goals are also provided in Table 3-3. Both are provided as criteria only, and are not enforceable.

3.2 RESULTS OF SOIL SAMPLING

3.2.1 Surface Soil

3.2.1.1 Dioxin Analysis

Eleven surface soil, two sediment, and two incinerator residue samples were collected to determine whether dioxin/furans are present at the site (Figure 3-1). The samples were collected at the locations used during the RI1 to collect soil area samples, some of the locations were modified. Nine of the surface soil samples and the sediments were analyzed for Routine Analytical Service (RAS) dioxin. Two surface soil samples and the incinerator residue samples were analyzed for Special Analytical Service (SAS) dioxin/furan analysis.

The nine surface soil (RAS) and sediment samples (RAS) were collected to determine whether dioxin contamination existed across the site and in immediate off-site areas. The nine surface soil samples include SA27, SA29, SA31, SA32, SA33, SA34, SA35, SA37 and SA38. Sample SA34 was collected in the Reading well field and analyzed for RAS dioxin to represent background conditions. 2,3,7,8-TCDD was not detected in any of the surface soil or sediment samples. Therefore, based on this data, it can be concluded that off-site migration of dioxin has not occurred.

Two surface soil samples (SAS), SA28 and SA30, and the incinerator residue samples (SAS) were collected in an area suspected of dioxin contamination. Sample SA34 was collected in the Reading Well Field and analyzed for SAS dioxin/furans to represent background conditions. The incinerator residue samples were grab samples collected from the piles of incinerator ash located directly north of the incinerator.

The results of the analysis are presented in Table 3-4. 2,3,7,8-TCDD was detected in one sample, SA30, at 3.392 ppt. The concentrations of 2,3,7,8-TCDD in sample SA30 was qualified by the CLP to indicate the analyte (2,3,7,8-TCDD) was also detected in the laboratory blank. Therefore, based on this data, it can not be determined conclusively

TABLE 3-3

GROUNDWATER CRITERIA
Pristine, Inc. Site

Chemical Name	Maximum Concentration at Pristine, Inc. Site (mg/l) Upper Aquifer	Maximum Concentration at Pristine, Inc. Site (mg/l) Lower Aquifer	Exceeds Standards and Criteria? Upper Aquifer	Exceeds Standards and Criteria? Lower Aquifer	State of Ohio Limits[a] (mg/l)	RCRA Maximum Concentration Limit (MCL) (mg/l)	SDWA Maximum Contaminant Level (MCL) (mg/l)	CWA Ambient Water Quality Criteria for Protection of Aquatic Life: Freshwater Acute/Chronic (mg/l)	CWA Ambient Water Quality Criteria for Protection of Aquatic Life: Marine Acute/Chronic (mg/l)	SDWA/MCL Goal (mg/l)
Aldrin	0.00006	.0007	No	No				3.0E-03[b]	1.3E-03	
Antimony and Compounds	0.092	0.061	No	No				9.0/1.6		
Arsenic and Compounds	0.272	0.079	Yes	Yes		5.0E-02	5.0E-02			
Barium and Compounds	1.390	0.547	Yes	No		1.0	1.0			1.5
Benzene	34	0.008	Yes	No	0.56		5.0E-03	5.3**	5.1**/0.7**	
Beryllium and Compounds	0.017	0.0056	Yes	No				0.1**/5.3E-03**		
Cadmium and Compounds	0.039	0.0094	Yes	Yes	0.002	1.0E-02	1.0E-02	3.9E-03/1.1E-03	4.3E-02/9.3E-03	5.0E-03*
Chlorobenzene (Mono)	1.0	0	Yes	No				0.2**/5.0E-02**	0.1**/0.1**	
Chloroform	56.0	3.9	Yes	No			1.0E-01	2.8E+01**/1.2**		
Chromium III and Compounds	0.226	0.067	Yes	No				1.7/0.2	1.0E+01	
Copper and Compounds	0.340	0.154	Yes	Yes				1.8E-02/1.2E-02	2.9E-03/2.9E-03	1.3*
Dibutyl Phthalate	0.006	0	Yes	No				9.4E-01**/3.0E-03**	2.9**/3.4E-03**	
1,2-Dichlorobenzene	1.3	0	Yes	No						6.2E-01*
1,4-Dichlorobenzene	0.017	0	No	No			7.5E-01			7.5E-01
1,2-Dichloroethane	150.0	0.780	Yes	Yes	3.5		5.0E-03	1.1E+02**/2.0E+01**	1.1E+02	0
1,1-Dichloroethylene	0.270	0	Yes	No			7.0E-03	1.1E+01**	2.2E+02**	7.0E-03
2,4-Dimethylphenol	0.580	0	No	No				2.1**		
Ethylbenzene	3.30	0.056	Yes	No				3.2E+01	4.3E-01**	6.8E-01*
Fluoride	27.0	2.0	Yes	Yes	1.2					
gamma-HCCH (lindane)	0.0009	0	No	No			4.0E-03			2.0E-04*
Hexachloroethane	0.096	0	Yes	No				9.8E-02**/5.4E-02**	9.4E-02**	
Isophorone	0.027	0.030	No	No				1.17E+02**	1.2E+01**	
Lead and Compounds (Inorganic)	0.178	0.148	Yes	Yes	0.03	5.0E-02	5.0E-02	8.2E-03/3.2E-03	0.1/5.6E-03	2.0E-02*
Mercury and Compounds (Inorganic)	0.00044	0.000021	Yes	Yes	0.00002	2.0E-03	2.0E-03	2.4E-03/1.2E-05	2.1E-03/2.5E-05	3.0E-03*
Nickel and Compounds	1.191	0.122	Yes	Yes		1.34E-02		1.8/9.6E-02	0.1/7.1E-03	
Nitrobenzene	1.20	0	No	No				2.7E+01**	6.6	
Pentachlorophenol	0.0266	0	Yes	No				5.5E-02/3.2E-03	5.3E-02/3.4E-04	2.2E-01*
Phenanthrene	0.014	0	No	No					3.0E-01**	
Phenol	4.5	0	Yes	No	0.37			1.0E+01/2.5	5.8	
1,1,2,2-Tetrachloroethane	0.031	0	No	No				2.4**	9.0**	
Tetrachloroethylene	7.5	0	Yes	No	0.073			5.2**/8.4E-01**	1.0E+01**/4.5E-01**	0*
Toluene	160.0	0	Yes	No				1.7E+01**	6.3**/5.0**	2*
1,1,1-Trichloroethane	2.0	0.57	Yes	No			2.0E-01		3.1E+01**	2.0E-01
Trichloroethylene	1.5	0.1	Yes	No			5.0E-03	4.5E+01**/2.1E+01**	2.0**	0
Vinyl Chloride	0.830	0	Yes	No			2.0E-03			0

---

[a] Limits provided by the Ohio EPA Water Quality and Assessment Group, based on toxicity levels.

[b] Notation converts as follows: E-02 = 10^{-2}; E-03 = 10^{-3}; etc.

* Proposed value as of October 1986.

** Lowest observed effect level.

Sources: U.S. EPA, Superfund Public Health Evaluation Manual [illegible] 540/1-[illegible] (OSWER [illegible]ve 9285[illegible]tober [illegible] U.S. E[illegible]ality Cri[illegible]or Wate[illegible] EPA 44[illegible]01, Ma[illegible]51 Fede[illegible]ster 4[illegible]

TABLE 3-4
SUMMARY OF DIOXIN ANALYSIS
PRISTINE, INC. SITE

COMPOUND	SAMPLE LOCATION SA2B03	SA3003	SA3403	IRS1	IRS2
(SAS)					
2378-TCDD (IC)	---	3.392 B	---	---	---
TOTAL TCDD	6.717	99.451	---	0.788	21.261
12378-PCDD	---	8.33	---	---	2.388
TOTAL PCDD	11.028	171.432	0.662	---	14.49
123478-HxCDD	---	8.554	---	---	---
123678-HxCDD	16.092	24.023	---	20.266	6.936
123789-HxCDD	12.889	26.658	---	16.852	---
TOTAL HxCDD	165.938	305.882	---	174.48	34.415
1234678-HpCDD	284.003	292.81	---	353.434	93.394
TOTAL HpCDD	605.444	579.926	40.163	675.281	172.059
OCDD	2490.486	2082.211	454.978	3864.559	609.92
2378-TCDF	43.697	230.999	---	57.015	41.233
TOTAL TCDF	1620.444	1203.283	0.297	484.927	270.222
12378-PCDF	5.303	35.497	---	---	---
23478-PCDF	9.37	62.871	---	24.141	12.197
TOTAL PCDF	75.301	408.21	---	90.428	70.778
123478-HxCDF	16.766	87.387	---	47.77	18.639
123678-HxCDF	9.683	47.36	---	20.833	8.711
234678-HxCDF	8.45	46.872	0.372	---	---
123789-HxCDF	---	---	---	---	---
TOTAL HxCDF	56.846	354.265	1.996	156.668	64.393
1234678-HpCDF	50.414	170.076	---	88.666	38.242
1234789-HpCDF	---	19.513	---	14.836	---
TOTAL HpCDF	108.779	292.861	---	182.804	69.234
OCDF	120.74	179.718	---	170.974	---

All Concentrations Reported in PPT

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
IC = Indicator Chemical

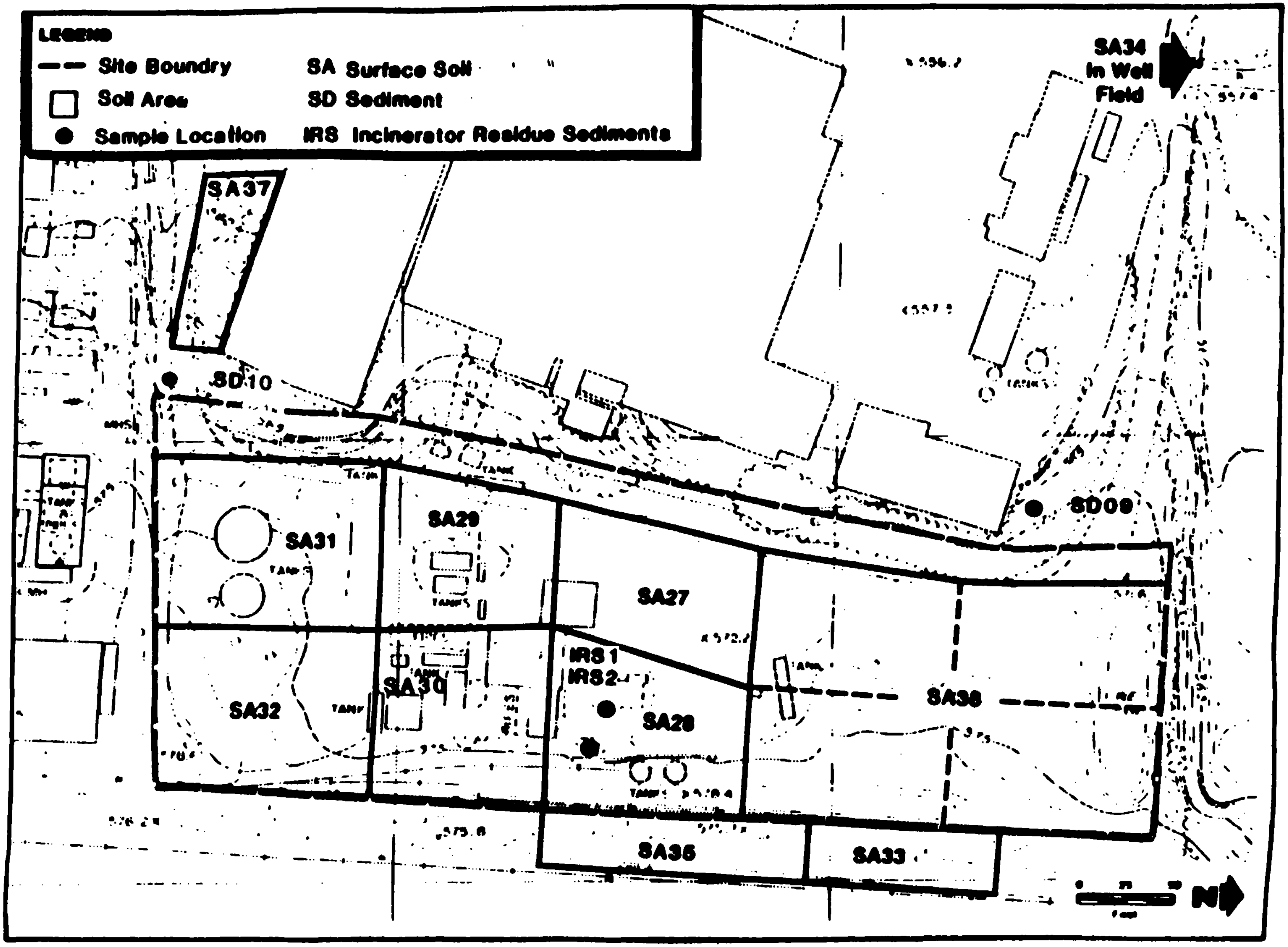


FIGURE 3-1

SOIL AREA, SEDIMENT AND INCINERATOR RESIDUE SAMPLING LOCATIONS that 2,3,7,8-TCDD is present in the sample, but to be protective of public health and the environment, it will be assumed that 2,3,7,8-TCDD was detected in the sample.

Although, 2,3,7,8-TCDD was only detected in one sample, other dioxin compounds and additional furan compounds were detected in the samples. The concentrations of the dioxin and furan compounds are presented in Table 3-4. Sample SA34, collected from the Reading Well Field for a background sample indicates there is some background contamination of the HpCDD and OCDD furan compounds in the soil. In comparison, the other samples contain furan components at concentrations from 1 to 5 orders of magnitude greater than sample SA34. The toxicity of furan compounds are related to 2,3,7,8-TCDD by use of Toxicity Equivalency Factors (TEFs). This analysis is completed in Section 5 of this report, the Public Health Evaluation for dioxin/furan compounds.

3.2.1.2 Surface Soil Samples

Surface soil samples were collected to represent surficial soil contamination at the magic pit. Sample locations are shown on Figure 3-2. Five grab surficial soil samples were collected adjacent to the magic pit. Additional sampling information is presented in Appendix B.

The range of contamination in the surface soil samples is presented in Table 3-5, 3-6, 3-7 and Table 3-8 which summarize the volatile organic, semi-volatile organic compound fraction analysis, pesticide/PCB fraction analysis, and inorganic analysis, respectively.

Cumulative volatile organic compound contamination in the surface samples ranged from 0 to 161,000 ppb. The cumulative value is calculated by summing the concentrations of trans-1,2-dichloroethene, toluene, ethylbenzene, chloroform, 1,2-Dichloroethane and total Xylenes. Although methylene chloride and acetone were detected in the soil samples, the values were not considered in the cumulative concentration calculation. The values for methylene chloride and acetone may be attributed to laboratory contamination, and were not considered in the cumulative totals for RI 1. In addition the compounds were not used to evaluate site conditions in the PHE completed in the final Remedial Investigation Report. This approach was taken because it is recognized that concentrations of methylene chloride and acetone at the site would not affect the ultimate conclusions presented in this report and the ultimate review and selection of preferred remedial alternatives and remedial action.

Toluene, ethylbenzene and total xylenes were detected in one sample, SS02, at concentrations of at 31 ppb, 20 ppb and 110 ppb respectively. Chloroform and 1,2-dichloroethane were detected at less than 20 ppb in

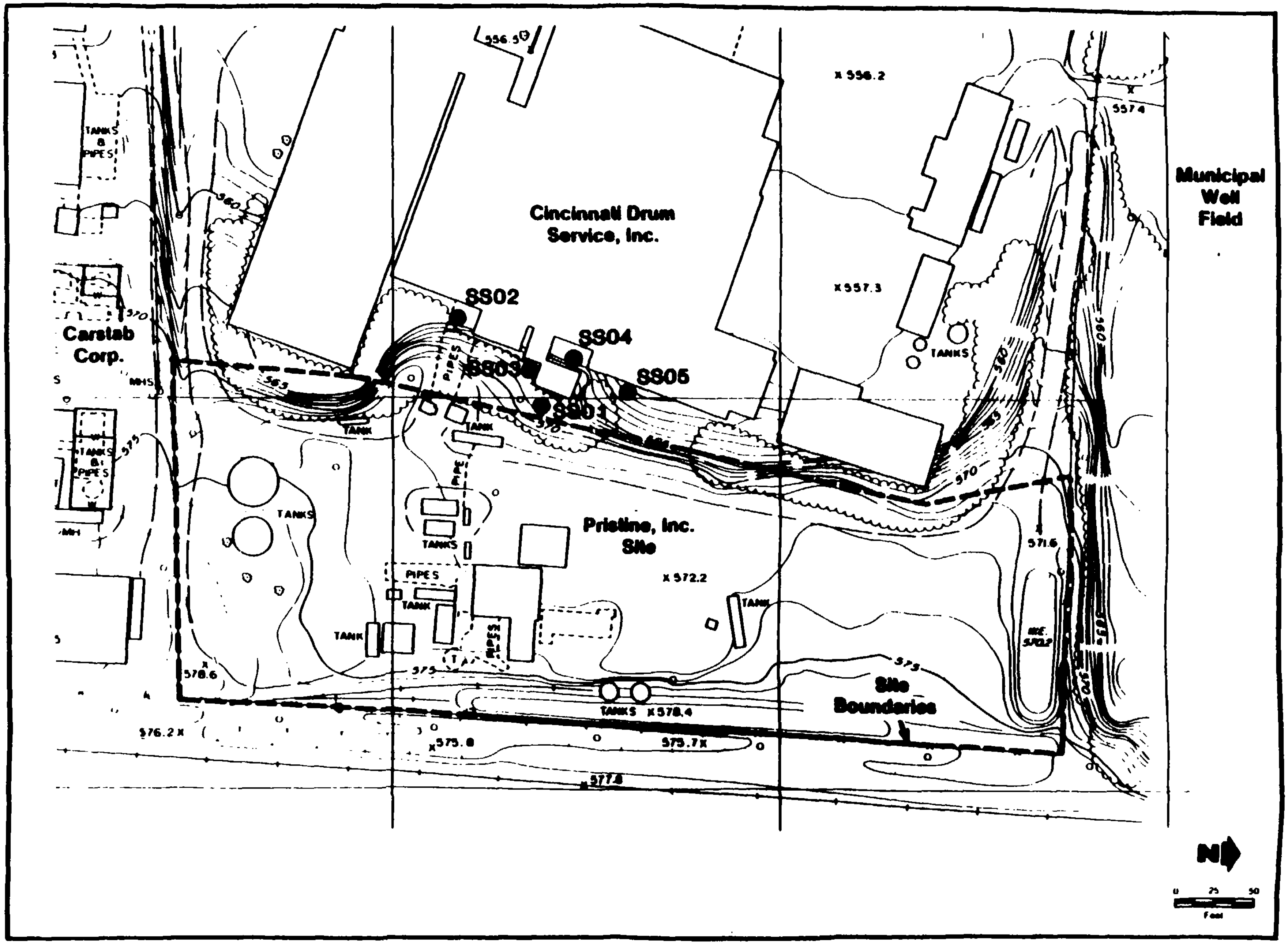


FIGURE 3-2

SURFACE SOIL SAMPLING LOC[illegible]ONS

PRI[illegible]E, IN[illegible]

Table 3-5
Summary of Volatile Organic Compound Analysis
Surface Soil Samples
Pristine, Inc. Site

PARAMETER	Well Location	SS01	SS01DP Duplicate	SS02	SS03	SS04	SS05
	Sampling Round	R3	R3	R3	R3	R3	R3
Chloromethane		---	---	---	---	---	---
Bromomethane		---	---	---	---	---	---
Vinyl Chloride (IC)		---	---	---	---	---	---
Chloroethane		---	---	---	---	---	---
Methylene Chloride		---	7 J	---	---	24	---
Acetone		130	41	310	95	130	83
Carbon Disulfide		---	---	---	---	---	---
1,1-Dichloroethene		---	---	---	---	---	---
1,1-Dichloroethane		---	---	---	---	---	---
trans-1,2-Dichloroethene		---	---	---	---	---	7 J
Chloroform		---	---	---	---	14	---
1,2-Dichloroethane		---	---	---	---	19	---
2-Butanone		---	---	---	---	---	---
1,1,1-Trichloroethane		---	---	---	---	---	---
Carbon Tetrachloride		---	---	---	---	---	---
Vinyl Acetate		---	---	---	---	---	---
Bromodichloromethane		---	---	---	---	---	---
1,2-Dichloropropane		---	---	---	---	---	---
trans-1,3-Dichloropropene		---	---	---	---	---	---
Trichloroethene		---	---	---	---	---	---
Dibromochloromethane		---	---	---	---	---	---
1,1,2-Trichloroethane		---	---	---	---	---	---
Benzene (IC)		---	---	---	---	---	---
cis-1,3-Dichloropropene		---	---	---	---	---	---
2-Chloroethylvinylether		---	---	---	---	---	---
Bromoform		---	---	---	---	---	---
4-Methyl-2-pentanone		---	---	---	---	---	---
2-Hexanone		---	---	---	---	---	---
Tetrachloroethene (IC)		---	---	---	---	---	---
1,1,2,2-Tetrachloroethane		---	---	---	---	---	---
Toluene		---	---	31	---	5 J	---
Chlorobenzene		---	---	---	---	---	---
Ethylbenzene		---	---	20 J	---	---	---
Styrene		---	---	---	---	---	---
Total Xylenes		---	---	110	---	---	---

All Concentrations Reported in ug/kg or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-6
Summary of Semi-volatile Organic Compound Analysis
Surface Soil Samples
Pristine, Inc. Site

	Well Location	SS01	SS01DP Duplicate	SS02	SS03	SS04	SS05
PARAMETER	Sampling Round	R3	R3	R3	R3	R3	R3
Phenol (IC)		---	730	---	3400	11900	---
bis(2-Chloroethyl)ether		---	---	---	---	---	---
2-Chlorophenol		---	---	---	---	---	---
1,3-Dichlorobenzene		---	---	---	---	---	---
1,4-Dichlorobenzene		---	---	---	---	---	---
Benzyl Alcohol		---	---	---	---	---	---
1,2-Dichlorobenzene		---	---	---	---	---	---
2-Methylphenol		---	---	---	---	3700 J	---
bis(2-Chloroisopropyl)Ether		---	---	---	---	---	---
4-Methylphenol		---	80 J	---	---	2700 J	---
N-Nitroso-Di-n-propylamine		---	---	---	---	---	---
Hexachloroethane		---	---	---	---	---	---
Nitrobenzene		---	---	---	---	---	---
Isophorone		---	---	---	140 J	1200 J	---
2-Nitrophenol		---	---	---	---	---	---
2,4-Dimethylphenol		---	---	---	---	1800 J	---
Benzoic Acid		1851 J	940 J	---	---	11000 J	---
bis(2-Chloroethoxy)Methane		---	---	---	---	---	---
2,4-Dichlorophenol		---	---	---	---	---	---
1,2,4-Trichlorobenzene		---	---	---	---	---	---
Napthalene		---	---	---	---	---	---
4-Chloroaniline		---	---	---	---	---	---
Hexachlorobutadiene		---	---	---	---	---	---
4-Chloro-3-methylphenol		---	---	---	---	---	---
2-Methylnapthalene		---	---	---	210 J	---	---
Hexachlorocyclopentadiene		---	---	---	---	---	---
2,4,6-Trichlorophenol		---	---	---	---	---	---
2.4.5-Trichlorophenol		---	---	---	---	---	---
2-Chloronaphthalene		---	---	---	---	---	---
2-Nitroaniline		---	---	---	---	---	---
Dimethyl Phthalate		---	---	---	140 J	---	---
Acenaphthylene		---	80 J	---	---	---	---
3-Nitroaniline		---	---	---	---	---	---
Acenaphthene		---	---	---	---	---	---

All Concentrations Reported in ug/kg or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-6
Summary of Semi-volatile Organic Compound Analysis
Surface Soil Samples
Pristine, Inc. Site

PARAMETER	Well Location	SS01	SS01DP Duplicate	SS02	SS03	SS04	SS05
	Sampling Round	R3	R3	R3	R3	R3	R3
2,4-Dinitrophenol		---	---	---	---	---	---
4-Nitrophenol		---	---	---	---	---	---
Dibenzofuran		---	---	---	85 J	---	---
2,4-Dinitrotoluene		---	---	---	---	---	---
2,6-Dinitrotoluene		---	290 J	---	---	---	---
Diethylphthalate		---	290 J	350 J	---	---	---
4-Chlorophenylphenylether		---	---	---	---	---	---
Fluorene		---	---	---	---	---	---
4-Nitroaniline		---	---	---	---	---	---
4,6-Dinitro-2-Methylphenol		---	---	---	---	---	7100 J
N-nitrosodiphenylamine		---	---	---	---	---	---
4-Bromophenylphenylether		---	---	---	---	---	---
Hexacholorobenzene		---	---	---	---	---	---
Pentachlorophenol		---	---	---	---	---	---
Phenanthrene		240 J	100 J	---	560 J	---	---
Anthracene		150 J	60 J	---	260 J	---	---
Di-n-Butylphthalate		---	1900 B	1900 JB	---	---	---
Fluoranthene		---	220 J	---	650 J	---	---
Pyrene		280 J	150 J	---	---	---	---
Butylbenzylphthalate		---	250 J	3700 J	1200	1400 J	---
3-3'-Dichlorobenzidine		---	---	---	---	---	---
Benzo(a)Anthracene		---	---	---	420 J	---	---
bis(2-Ethylhexyl)Phthalate		---	---	34000	3200	61000	5000 J
Chrysene		---	160 J	---	650 J	---	---
Di-n-Octyl Phthalate		---	---	---	---	---	---
Benzo(b)fluoranthene		---	---	---	---	---	---
Benzo(k)fluoranthene		---	---	---	---	---	---
Benzo(a)pyrene (IC)		---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene		140 J	80 J	---	---	---	---
Dibenz(a,h)Anthracene		---	---	---	---	---	---
Benzo(g,h,i)Perylene		140 J	70 J	---	---	---	---

All Concentrations Reported in ug/kg or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-7
Summary of Pesticide/PCB Analysis
Surface Soil Samples
Pristine, Inc. Site

PARAMETER	Well Location	SS01	SS01DP Duplicate	SS02	SS03	SS04	SS05
	Sampling Round	R3	R3	R3	R3	R3	R3
Alpha-BHC		---	---	---	---	---	---
Beta-BHC		---	---	---	---	---	---
Delta-BHC		---	---	---	---	---	---
Gamma-BHC (Lindane)		---	---	---	---	---	---
Heptachlor		---	---	---	---	---	---
Aldrin		---	---	---	---	---	---
Heptachlor Epoxide		---	---	---	---	---	---
Endosulfan I		---	---	---	---	---	---
Dieldrin (IC)		---	---	---	---	---	---
4,4'-DDE		800 C	---	---	1100 *	---	---
Endrin		---	---	---	---	---	---
Endosulfan II		---	---	---	---	---	---
4,4'-DDD		---	---	---	2400 *	---	---
Endosulfan Sulfate		---	---	---	---	---	---
4,4'-DDT		---	---	---	5000 *	---	---
Methoxychlor		---	---	---	---	---	---
Endrin Ketone		---	---	---	---	---	---
Chlordane		---	---	---	---	---	---
Toxaphene		---	---	---	---	---	---
Aroclor-1016		---	---	---	---	---	---
Aroclor-1221		---	---	---	---	---	---
Aroclor-1232		---	---	---	---	---	---
Aroclor-1242		---	---	---	---	---	---
Aroclor-1248		---	---	---	---	---	---
Aroclor-1254		9800 C	7800 C	---	6600 *	2800 *	1500 *
Aroclor-1260		---	---	---	---	---	---

All Concentrations Reported in ug/kg or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
C = Contract laboratory program qualifier, applies to pesticides where identification has been confirmed by GC/MS.
* = Detected above instrument saturation levels.
IC = Indicator Chemical

Table 3-8
Summary of Inorganic Compound Analysis
Surface Soil Samples
Pristine, Inc. Site

	Well Location	SS01	SS01DP Duplicate	SS02	SS03	SS04	SS05
PARAMETER	Sampling Round	R3	R3	R3	R3	R3	R3
Aluminum		6320	7240	7100	8020	3520	5260
Antimony		---	---	---	[42]	---	---
Arsenic		14	16	7.8	61	[6.9]	---
Barium		164	208	[107]	932	877	[157]
Beryllium		[1]	[1.1]	---	[2]	---	[1]
Cadmium (IC)		7.6	9.6	3.8	51	10	6.6
Calcium		27300 *	38300 *	40800 *	13700 *	69300 *	9550 *
Chromium		79	99	35	856	508	90
Cobalt		---	[8.5]	[9.6]	[11]	[27]	---
Copper		82	111	61	591	386	75
Iron		32100 *	45900 *	23200 *	85200 *	192000 *	34300 *
Lead (IC)		492	712	357	4000	2350	368
Magnesium		6660	8270	9970	[2390]	26700	[2690]
Manganese		495 *R	583 *R	566 *R	454 *R	1680 *R	489 *R
Mercury		2.2	2.2	---	8.2	0.75	1.0
Nickel		[21]	38	[25]	55	200	40
Potassium		[1320]	[1320]	[1270]	[1440]	[329]	[900]
Selenium		5.5	---	7.1	13	---	---
Silver		[4.4]	[7]	---	64	---	---
Sodium		---	---	---	[1180]	---	---
Thallium		---	---	---	---	---	---
Tin		39	59	[24]	318	54	37
Vanadium		[20]	[22]	[19]	[35]	[17]	[19]
Zinc		327 E	448 E	426 E	4010 E	1120 E	242 E
Cyanide		---	0.92	---	6.9	2.9	---

All Concentrations Reported in mg/kg or PPM

--- = Compound was analyzed for, but not detected within detection limits.
J = Contract laboratory program qualifier, indicates an estimated value.
[ ] = Value greater than the instrument detection limit, but less than the contract required detection limit.
* = Duplicate analysis is not within control limits.
R = Spike sample recovery is not within control limits.
E = Estimated value due to the presence of interference.
IC = Indicator Chemical

sample SS04. Low levels of volatile organic compounds in the surface soils is consistent with the results of RI 1.

The cumulative concentration of semi-volatile organic compounds detected ranged from 0 to 94,700 ppb. The cumulative concentration was calculated by summing the concentrations of:

Phenol (IC)
4 Methylphenol
Isophorone
2,4-Dimethylphenol
Benzoic Acid
2-Methlyphenol
Dimethyl Phthalate
Acenaphthylene
2 Methylphenol
2,6-Dinitrotoluene
Diethylphthalate
Dibenzofuran
4,6-Dinitro-2-Methlphenol
Phenanthrene
Anthracene
Di-n-Butylphthalate
Fluoranthene
Pyrene
Butylbenzylphthalate
Benzo(a)Anthracene
bis(2-Ethylexyl)Phthalate
Chrysene
Indeno(1,2,3-cd)Pyrene
Dibenz(a,h)Anthracene
Benzo(g,h,i)Perylene

The majority of these compounds were detected during the RI 1 investigation. Phenol, an indicator chemical was detected in the samples collected directly adjacent to the magic pit. 11,900 ppb of phenol was detected in the sample collected at the base of the magic pit near an intermittent leachate seep.

Pesticides and PCBs were detected in the samples. DDT, DDE, and DDD were detected in sample SS03 at concentrations greater than instrument satration levels. In addition, Aroclor-1254 was detected in all of the samples, with the exception of SS02.

3.2.3 Soil Borings

Two soil borings (SB42, SB43) were drilled at the Pristine, Inc. site to determine the extent of soil contamination at the magic pit and on-site within the upper outwash lens (Figure 3-3). Soil boring SB44 was drilled to confirm the geologic conditions at that locations, and samples were not collected for chemical analysis. Tables 3-9, 3-10, 3-11, and 3-12 summarize the data obtained from the volatile organic compound analysis, semi-volatile organic compound analysis, pesticide analysis, and inorganic analysis, respectively.

Soil boring SB42 was drilled to determine the extent of contamination in the lower outwash lens at the magic pit. Contamination was confirmed within the sandy layers associated with the lower outwash lens. Contaminants detected in groundwater in the lower outwash lens and the lower aquifer were also detected in the samples collected at SB42. The main contaminants of concern include; chloroform, 1,2-dichloroethane, ethyl benzene and total xylenes.

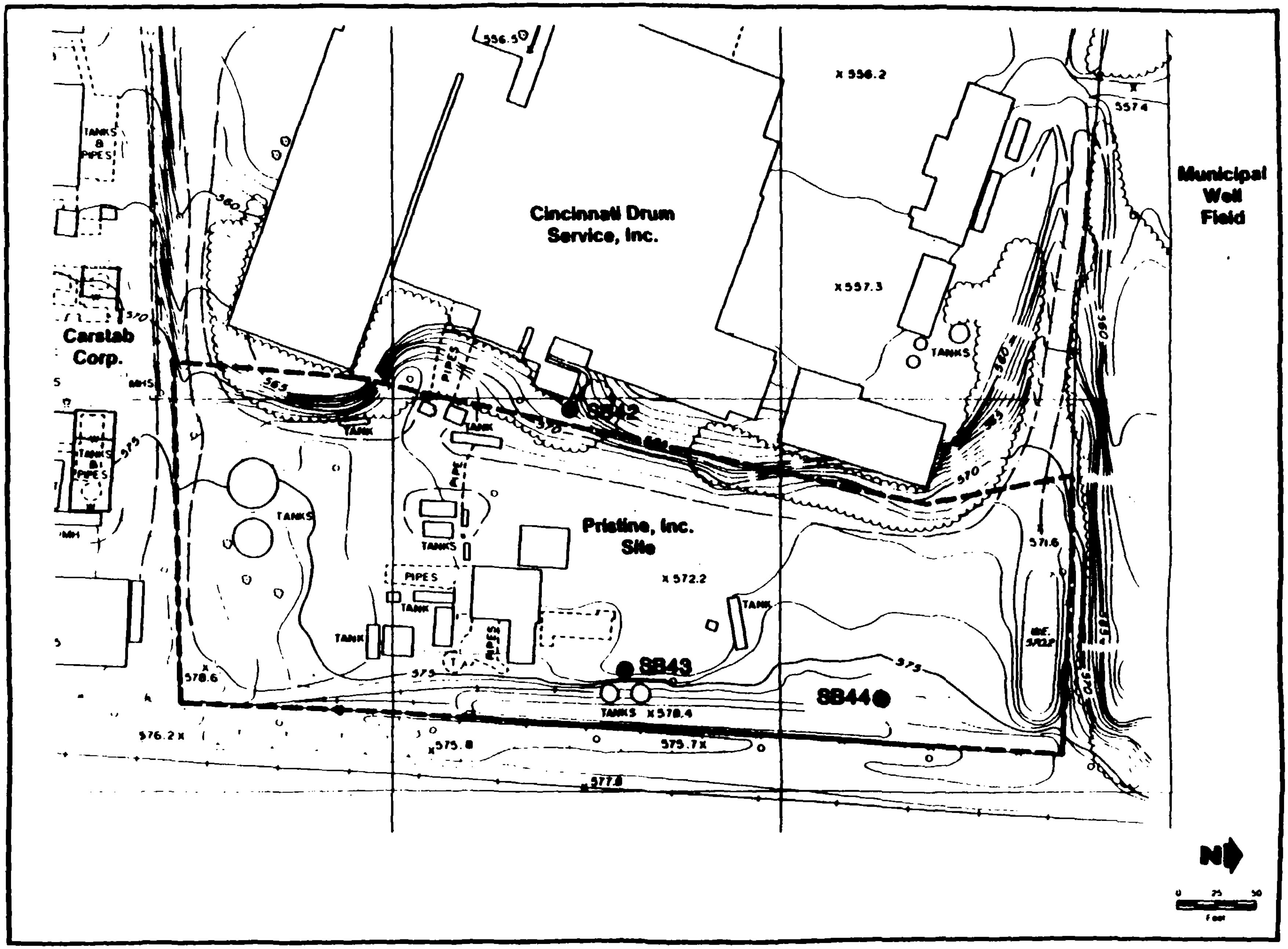


FIGURE 3-3

SOIL BORING LOCATIONS

PRISTINE, INC.

Soil boring SB43 was drilled to determine the vertical extent of contamination within the on-site soils associated with the upper outwash lens. Various contaminants associated with groundwater contamination in the upper outwash lens were detected in the soil boring samples. The highest concentrations of contaminants were detected from eight to twelve feet below the surface. This confirms that the soils associated with the upper outwash lens are a source of contamination.

In addition, to the borings drilled at the site, soil samples were also collected during monitoring well placement. Samples were collected at depth from the soils associated with the lower outwash lens. The contaminants detected in the soils include chloroform, 1,2-dichloroethane, toluene, and total xylenes. This is further evidence of contamination migrating from the magic pit through the lower outwash lens to the lower aquifer.

Minimal semi-volatile contamination was detected in the soil boring samples. Phenol was detected in SB42 from 1800 ppb to 15,000 ppb at depths of 22 to 27 feet beneath the surface. Contamination was detected in SB43 at eight feet below the surface, again these soils are associated with the upper outwash lens. Pesticides were only detected in two soil boring samples, SB42 at 10 feet below the surface and SB43 in the surficial sample.

3.3 GROUNDWATER

3.3.1 Monitoring Wells

Groundwater samples were collected from 21 monitoring wells at the Pristine, Inc. site. During the RI2 phase, five monitoring wells were installed (GW63, GW64, GW65, GW66, and GW67). Locations of the monitoring wells are shown on Figure 3-4. The analytical data for the volatile organic compound fraction, semi-volatile organic compound fraction, pesticide fraction, and inorganic analysis are presented in Tables 3-13, 3-14, 3-15, and 3-16, respectively.

The monitoring wells were installed in three subsystems of the upper aquifer system, and into the lower aquifer system (Figure 3-5). Section 2 describes the characteristics of the aquifers and the subsystems of the upper aquifer. Monitoring wells GW45, GW46, GW49, GW50, GW51, GW53, GW59, GW60, GW61, GW64 and GW66 were installed in the upper outwash lens and the upper perched water table of the upper aquifer system. Wells GW55, GW58 and GW62 were installed in the middle outwash lens of the upper aquifer system. Wells GW47, GW54,GW56, GW63 and GW65 were installed in the lower outwash lens of the upper aquifer system. The wells installed in the lower aquifer (water supply aquifer) include GW48, GW52, GW57 and GW67.

Table 3-9
Summary of Volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

PARAMETER	Well Location	SB4201	SB4202	SB4203	SB4204	SB4205	SB4206	SB4301	SB4302	SB4303	SB4304
	Nominal Depth (ft)	10	20	22	24	27	29	0	2	4	8
	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Chloromethane		---	---	---	---	---	---	---	---	---	---
Bromomethane		---	---	---	---	---	---	---	---	---	---
Vinyl Chloride (IC)		---	---	---	---	---	---	---	---	---	---
Chloroethane		---	---	---	---	---	---	---	---	---	---
Methylene Chloride		---	---	---	---	---	---	---	2 J	---	---
Acetone		---	---	---	---	---	---	---	---	---	---
Carbon Disulfide		---	---	---	---	---	---	6	7	15	---
1,1-Dichloroethene		---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane		---	---	---	---	---	---	3 J	3 J	2 J	---
trans-1,2-Dichloroethene		---	---	---	---	---	---	7	7	5 J	---
Chloroform		4 J	26	52000	13000	7400	510	---	---	---	---
1,2-Dichloroethane		5 J	77	57000	13000	19000	690	---	---	---	---
2-Butanone		---	---	---	---	---	---	---	---	---	11000
1,1,1-Trichloroethane		2 J	---	---	---	---	---	---	---	---	---
Carbon Tetrachloride		---	---	---	---	---	---	---	---	---	---
Vinyl Acetate		---	---	---	---	---	---	---	---	---	---
Bromodichloromethane		---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane		---	---	---	---	---	---	---	---	---	---
trans-1,3-Dichloropropene		---	---	---	---	---	---	---	---	---	---
Trichloroethene		---	---	---	---	---	---	13	27	27	---
Dibromochloromethane		---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane		---	---	---	---	---	11 J	---	---	---	---
Benzene (IC)		---	---	---	---	---	---	---	---	---	1600
cis-1,3-Dichloropropene		---	---	---	---	---	---	---	---	---	---
2-Chloroethylvinylether		---	---	---	---	---	---	---	---	---	---
Bromoform		---	---	---	---	---	---	---	---	---	---
4-Methyl-2-pentanone		---	---	---	---	---	---	---	20	20	1100 J
2-Hexanone		---	---	---	---	---	---	---	---	---	---
Tetrachloroethene (IC)		3 J	---	---	---	---	---	1 J	---	---	---
1,1,2,2-Tetrachloroethane		---	---	---	---	---	---	---	---	---	---
Toluene		47	66	8900	4700	840	78	28	30	190	19000
Chlorobenzene		---	---	---	---	---	---	2 J	3 J	3 J	---
Ethylbenzene		---	23	990 J	5300	---	33 J	5 J	6	8	1500
Styrene		---	---	---	---	---	---	---	---	---	---
Total Xylenes		---	101	3100	24000	420 J	150	10 J	14 J	24 J	7400 J

All Concentrations Reported in ug/kg or PPB

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IC = Indicator Chemical

Table 3-9
Summary of Volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4305	SB4306	SB4307	SB4308	SB6301	SB6302	SB6503	SB65DP	SB6603	SB67
Nominal Depth (ft)	10	12	14	17	29	32	2	2	4	60
								Duplicate		
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Chloromethane	---	---	---	---	---	---	---	---	---	---
Bromomethane	---	---	---	---	---	---	---	---	---	---
Vinyl Chloride (IC)	---	---	---	---	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	---	6	---	---	---	---	---	---	8	13
Acetone	---	240 B	360	55	---	---	---	---	---	---
Carbon Disulfide	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane	180 J	2 J	---	---	---	---	---	2 J	9	---
trans-1,2-Dichloroethene	920	---	---	---	---	---	---	---	---	---
Chloroform	590 JB	6	---	---	6	8	---	---	---	16
1,2-Dichloroethane	640	29	---	---	68	38	---	---	---	6
2-Butanone	3900	42	56	---	---	---	---	---	---	---
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	3 J
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---
Vinyl Acetate	---	---	---	---	---	---	---	---	---	---
Bromodichloromethane	---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---	---	---	---	---
trans-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
Trichloroethene	390 J	---	---	---	---	---	---	---	---	---
Dibromochloromethane	---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	6	---	---	---	---	---
Benzene (IC)	210 J	3 J	3 J	---	---	---	---	---	---	---
cis-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
2-Chloroethylvinylether	---	---	---	---	---	---	---	---	---	---
Bromoform	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-pentanone	1300	---	---	---	---	---	---	---	---	---
2-Hexanone	---	---	---	---	---	---	---	---	---	---
Tetrachloroethene (IC)	---	---	---	---	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane	---	---	---	---	---	---	---	---	---	---
Toluene	3900	9	8 J	2 J	---	2 J	---	---	---	---
Chlorobenzene	---	---	---	---	5 J	3 J	---	---	---	---
Ethylbenzene	---	---	---	---	80	5 J	---	---	---	---
Styrene	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	130 J	52 J	---	---	---	---

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J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-10
Summary of Semi-volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4201	SB4202	SB4203	SB4204	SB4205	SB4206	SB4301	SB4302	SB4303	SB4304
Nominal Depth (ft)	10	20	22	24	27	29	0	2	4	8
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Phenol (IC)	---	---	1800	15000	4500	---	---	---	---	1700
bis(2-Chloroethyl)ether	---	---	---	---	---	---	---	---	---	---
2-Chlorophenol	---	---	---	---	---	---	---	---	---	---
1,3-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---
1,4-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---
Benzyl Alcohol	---	---	---	---	---	---	---	---	---	---
1,2-Dichlorobenzene	---	---	130 J	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	---	---	---	---	---	---	300 J
bis(2-Chloroisopropyl)Ether	---	---	---	---	---	---	---	---	---	---
4-Methylphenol	---	---	---	---	---	---	---	---	---	1700
N-Nitroso-Di-n-propylamine	---	---	---	---	---	---	---	---	---	---
Hexachloroethane	---	---	---	---	---	---	---	---	---	---
Nitrobenzene	---	---	---	---	---	---	---	---	---	---
Isophorone	---	---	---	---	---	---	---	---	---	---
2-Nitrophenol	---	---	---	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---
Benzoic Acid	---	---	---	---	---	---	---	---	---	2400 J
bis(2-Chloroethoxy)Methane	---	---	---	---	---	---	---	---	---	---
2,4-Dichlorophenol	---	---	---	---	---	---	---	---	---	---
1,2,4-Trichlorobenzene	---	---	---	---	---	---	---	---	---	---
Napthalene	---	---	---	---	---	---	---	---	---	---
4-Chloroaniline	---	---	---	---	---	---	---	---	---	---
Hexachlorobutadiene	---	---	---	---	---	---	---	---	---	---
4-Chloro-3-methylphenol	---	---	---	---	---	---	---	---	---	---
2-Methylnapthalene	---	---	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	---	---	---	---	---	---	---	---	---	---
2,4,6-Trichlorophenol	---	---	---	---	---	---	---	---	---	---
2.4.5-Trichlorophenol	---	---	---	---	---	---	---	---	---	---
2-Chloronaphthalene	---	---	---	---	---	---	---	---	---	---
2-Nitroaniline	---	---	---	---	---	---	---	---	---	---
Dimethyl Phthalate	---	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---
3-Nitroaniline	---	---	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---	---	---

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Table 3-10
Summary of Semi-volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4201	SB4202	SB4203	SB4204	SB4205	SB4206	SB4301	SB4302	SB4303	SB4304
Nominal Depth (ft)	10	20	22	24	27	29	0	2	4	8
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
2,4-Dinitrophenol	---	---	---	---	---	---	---	---	---	---
4-Nitrophenol	---	---	---	---	---	---	---	---	---	---
Dibenzofuran	---	---	---	---	---	---	---	---	---	---
2,4-Dinitrotoluene	---	---	---	---	---	---	---	---	---	---
2,6-Dinitrotoluene	---	---	---	---	---	---	---	---	---	---
Diethylphthalate	---	---	---	---	---	---	---	---	---	2500
4-Chlorophenylphenylether	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---
4-Nitroaniline	---	---	---	---	---	---	---	---	---	---
4,6-Dinitro-2-Methylphenol	---	---	---	---	---	---	---	---	---	---
N-nitrosodiphenylamine	---	---	---	---	---	---	---	---	---	---
4-Bromophenylphenylether	---	---	---	---	---	---	---	---	---	---
Hexacholorobenzene	---	---	---	---	---	---	---	---	---	---
Pentachlorophenol	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---	---
Butylbenzylphthalate	---	---	---	---	---	---	---	---	---	---
3-3'-Dichlorobenzidine	---	---	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---	---	---	---	---	---	---
bis(2-Ethylhexyl)Phthalate	---	---	---	---	---	22 JB	590 J	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---	---
Di-n-Octyl Phthalate	---	---	---	---	---	---	---	---	---	---
Benzo(b)fluoranthene	---	---	---	---	---	---	---	---	---	---
Benzo(k)fluoranthene	---	---	---	---	---	---	---	---	---	---
Benzo(a)pyrene (IC)	---	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene	---	---	---	---	---	---	---	---	---	---
Dibenz(a,h)Anthracene	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---	---	---

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Table 3-10
Summary of Semi-volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4305	SB4306	SB4307	SB4308	SB6301	SB6302	SB6503	SB65DP	SB6603	SB6703
Nominal Depth (ft)	10	12	14	17	29	32	2	2	4	60
								Duplicate		
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Phenol (IC)	---	---	---	---	---	---	---	---	---	---
bis(2-Chloroethyl)ether	---	---	---	---	---	---	---	---	---	---
2-Chlorophenol	---	---	---	---	---	---	---	---	---	---
1,3-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---
1,4-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---
Benzyl Alcohol	---	---	---	---	---	---	---	---	---	---
1,2-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	---	---	---	---	---	---	---
bis(2-Chloroisopropyl)Ether	---	---	---	---	---	---	---	---	---	---
4-Methylphenol	---	---	---	---	---	---	---	---	---	---
N-Nitroso-Di-n-propylamine	---	---	---	---	---	---	---	---	---	---
Hexachloroethane	---	---	---	---	---	---	---	---	---	---
Nitrobenzene	---	---	---	---	---	---	---	---	---	---
Isophorone	---	---	---	---	---	---	---	---	---	---
2-Nitrophenol	---	---	---	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---
Benzoic Acid	---	---	---	---	---	---	---	---	---	---
bis(2-Chloroethoxy)Methane	---	---	---	---	---	---	---	---	---	---
2,4-Dichlorophenol	---	---	---	---	---	---	---	---	---	---
1,2,4-Trichlorobenzene	---	---	---	---	---	---	---	---	---	---
Napthalene	---	---	---	---	---	---	---	---	---	---
4-Chloroaniline	---	---	---	---	---	---	---	---	---	---
Hexachlorobutadiene	---	---	---	---	---	---	---	---	---	---
4-Chloro-3-methylphenol	---	---	---	---	---	---	---	---	---	---
2-Methylnapthalene	---	---	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	---	---	---	---	---	---	---	---	---	---
2,4,6-Trichlorophenol	---	---	---	---	---	---	---	---	---	---
2.4.5-Trichlorophenol	---	---	---	---	---	---	---	---	---	---
2-Chloronaphthalene	---	---	---	---	---	---	---	---	---	---
2-Nitroaniline	---	---	---	---	---	---	---	---	---	---
Dimethyl Phthalate	---	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---
3-Nitroaniline	---	---	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---	---	---

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Table 3-10
Summary of Semi-volatile Organic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4305	SB4306	SB4307	SB4308	SB6301	SB6302	SB6503	SB65DP	SB6603	SB6703
Nominal Depth (ft)	10	12	14	17	29	32	2	2	4	60
								Duplicate		
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
2,4-Dinitrophenol	---	---	---	---	---	---	---	---	---	---
4-Nitrophenol	---	---	---	---	---	---	---	---	---	---
Dibenzofuran	---	---	---	---	---	---	---	---	---	---
2,4-Dinitrotoluene	---	---	---	---	---	---	---	---	---	---
2,6-Dinitrotoluene	---	---	---	---	---	---	---	---	---	---
Diethylphthalate	---	---	---	---	---	---	---	---	---	---
4-Chlorophenylphenylether	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---
4-Nitroaniline	---	---	---	---	---	---	---	---	---	---
4,6-Dinitro-2-Methylphenol	---	---	---	---	---	---	---	---	---	---
N-nitrosodiphenylamine	---	---	---	---	---	---	---	---	---	---
4-Bromophenylphenylether	---	---	---	---	---	---	---	---	---	---
Hexacholorobenzene	---	---	---	---	---	---	---	---	---	---
Pentachlorophenol	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---	---
Butylbenzylphthalate	---	---	---	---	---	---	---	---	---	---
3-3'-Dichlorobenzidine	---	---	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---	---	---	---	---	---	---
bis(2-Ethylhexyl)Phthalate	---	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---	---
Di-n-Octyl Phthalate	---	---	---	---	---	---	---	---	---	---
Benzo(b)fluoranthene	---	---	---	---	---	---	---	---	---	---
Benzo(k)fluoranthene	---	---	---	---	---	---	---	---	---	---
Benzo(a)pyrene (IC)	---	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene	---	---	---	---	---	---	---	---	---	---
Dibenz(a,h)Anthracene	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---	---	---

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J = Contract laboratory program qualifier, indicates an estimated value.
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Table 3-11
Summary of Pesticide/PCB Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4201	SB4202	SB4203	SB4204	SB4205	SB4206	SB4301	SB4302	SB4303	SB4304
Nominal Depth (ft)	10	20	22	24	27	29	0	2	4	8
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Alpha-BHC	---	---	---	---	---	---	---	---	---	---
Beta-BHC	---	---	---	---	---	---	---	---	---	---
Delta-BHC	---	---	---	---	---	---	---	---	---	---
Gamma-BHC (Lindane)	---	---	---	---	---	---	---	---	---	---
Heptachlor	---	---	---	---	---	---	---	---	---	---
Aldrin	54	---	---	---	---	---	---	---	---	---
Heptachlor Epoxide	---	---	---	---	---	---	---	---	---	---
Endosulfan I	---	---	---	---	---	---	---	---	---	---
Dieldrin (IC)	---	---	---	---	---	---	---	---	---	---
4,4'-DDE	---	---	---	---	---	---	---	---	---	---
Endrin	---	---	---	---	---	---	---	---	---	---
Endosulfan II	---	---	---	---	---	---	---	---	---	---
4,4'-DDD	---	---	---	---	---	---	---	---	---	---
Endosulfan Sulfate	---	---	---	---	---	---	---	---	---	---
4,4'-DDT	---	---	---	---	---	---	104	---	---	---
Methoxychlor	---	---	---	---	---	---	---	---	---	---
Endrin Ketone	---	---	---	---	---	---	---	---	---	---
Chlordane	---	---	---	---	---	---	---	---	---	---
Toxaphene	---	---	---	---	---	---	---	---	---	---
Aroclor-1016	---	---	---	---	---	---	---	---	---	---
Aroclor-1221	---	---	---	---	---	---	---	---	---	---
Aroclor-1232	---	---	---	---	---	---	---	---	---	---
Aroclor-1242	---	---	---	---	---	---	---	---	---	---
Aroclor-1248	---	---	---	---	---	---	---	---	---	---
Aroclor-1254	760	---	---	---	---	---	---	---	---	---
Aroclor-1260	---	---	---	---	---	---	---	---	---	---

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J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-11
Summary of Pesticide/PCB Analysis
Soil Boring Samples
Pristine, Inc. Site

PARAMETER	Well Location	SB4305	SB4306	SB4307	SB4308	SB6301	SB6302	SB6503	SB65DP	SB6603	SB6703
	Nominal Depth (ft)	10	12	14	17	29	32	2	2	4	60
									Duplicate		
	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Alpha-BHC		---	---	---	---	---	---	---	---	---	---
Beta-BHC		---	---	---	---	---	---	---	---	---	---
Delta-BHC		---	---	---	---	---	---	---	---	---	---
Gamma-BHC (Lindane)		---	---	---	---	---	---	---	---	---	---
Heptachlor		---	---	---	---	---	---	---	---	---	---
Aldrin		---	---	---	---	---	---	---	---	---	---
Heptachlor Epoxide		---	---	---	---	---	---	---	---	---	---
Endosulfan I		---	---	---	---	---	---	---	---	---	---
Dieldrin (IC)		---	---	---	---	---	---	---	---	---	---
4,4'-DDE		---	---	---	---	---	---	---	---	---	---
Endrin		---	---	---	---	---	---	---	---	---	---
Endosulfan II		---	---	---	---	---	---	---	---	---	---
4,4'-DDD		---	---	---	---	---	---	---	---	---	---
Endosulfan Sulfate		---	---	---	---	---	---	---	---	---	---
4,4'-DDT		---	---	---	---	---	---	---	---	---	---
Methoxychlor		---	---	---	---	---	---	---	---	---	---
Endrin Ketone		---	---	---	---	---	---	---	---	---	---
Chlordane		---	---	---	---	---	---	---	---	---	---
Toxaphene		---	---	---	---	---	---	---	---	---	---
Aroclor-1016		---	---	---	---	---	---	---	---	---	---
Aroclor-1221		---	---	---	---	---	---	---	---	---	---
Aroclor-1232		---	---	---	---	---	---	---	---	---	---
Aroclor-1242		---	---	---	---	---	---	---	---	---	---
Aroclor-1248		---	---	---	---	---	---	---	---	---	---
Aroclor-1254		---	---	---	---	---	---	---	---	---	---
Aroclor-1260		---	---	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/kg or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-12
Summary of Inorganic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4201	SB4202	SB4203	SB4204	SB4205	SB4206	SB4301	SB4302	SB4303	SB4304
Nominal Depth (ft)	10	20	22	24	27	29	0	2	4	8
Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
PARAMETER										
Aluminum	2770	6210	13200	6190	6130	7760	7560	11000	5600	7870
Antimony	---	---	---	---	---	---	---	---	---	---
Arsenic	---	7.1	8.7	16	7.8	8	11	13	16	12
Barium	[24]	[91]	[95]	[91]	[29]	[35]	[55]	[88]	[39]	[56]
Beryllium	---	---	[0.67]	---	---	---	---	[0.8]	---	---
Cadmium (IC)	---	---	[2.8]	---	---	---	---	---	---	---
Calcium	97900	108000	73100	141000	130000	123000	74300	60900	80900	119000
Chromium	7.6 *J	15 *J	21 *J	12 *J	9.7 *J	14 *J	16 *J	20 *J	9.8 *J	13 *J
Cobalt	---	[5.6]	[9.8]	---	[7.1]	[10]	[7.7]	[8.8]	[8.1]	[8.3]
Copper	[14]	18	32	19	19	20	38	26	23	20
Iron	9620 *J	35400 *J	26400 *J	21500 *J	18200 *J	21000 *J	26700 *J	37600 *J	20400 *J	24200 *J
Lead (IC)	21 *RJ	42 *RJ	15 *RJ	10 *RJ	9.3 *RJ	10 *RJ	13 *RJ	14 *RJ	11 *RJ	14 *RJ
Magnesium	28700 *J	36100 *J	21200 *J	21700 *J	25300 *J	21400 *J	21800 *J	17700 *J	25800 *J	23800 *J
Manganese	261 *	591 *	499 *	689 *	646 *	608 *	507 *	464 *	380 *	425 *
Mercury	---	0.35 J	---	---	---	---	---	---	---	---
Nickel	[12]	[16]	38	[17]	[16]	[23]	27	34	27	[24]
Potassium	[604]	[966]	[2520]	[1430]	[1130]	[1720]	[1290]	[1800]	[972]	[1570]
Selenium	---	---	---	---	---	---	---	---	3.7	---
Silver	---	---	---	---	---	---	---	---	---	---
Sodium	---	---	---	---	---	---	---	---	---	---
Thallium	---	---	---	---	---	---	---	---	---	---
Tin	---	---	---	---	---	---	---	---	---	---
Vanadium	[7.4]	[17]	[28]	[14]	[13]	[15]	[20]	[28]	[15]	[16]
Zinc	46	73	92	62	46	56	78	90	76	62
Cyanide	---	---	---	---	---	---	---	---	---	---

All Concentrations Reported in mg/kg or PPM

--- = Compound was analyzed for, but not detected within detection limits.
J = Contract laboratory program qualifier, indicates an estimated value.
[ ] = Value greater than the instrument detection limit, but less than the contract required detection limit.
* = Duplicate analysis is not within control limits.
R = Spike sample recovery is not within control limits.
E = Estimated value due to the presence of interference.
IC = Indicator Chemical

Table 3-12
Summary of Inorganic Compound Analysis
Soil Boring Samples
Pristine, Inc. Site

Well Location	SB4305	SB4306	SB4307	SB4308	SB6301	SB6302	SB6503	SB65DP	SB6603	SB6703
Nominal Depth (ft)	10	12	14	17	29	32	2	2 Duplicate	4	60
Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
PARAMETER										
Aluminum	4010	11000	6990	13100	2840	---	7090	9490	10700	2310
Antimony	---	---	---	---	---	---	---	---	---	---
Arsenic	10	7.5	8.9	10	---	---	8.9	14	14	---
Barium	[18]	[52]	[28]	[62]	[31]	---	[47]	[46]	[40]	[illegible]
Beryllium	---	[0.96]	---	[0.95]	---	---	---	[1.2]	---	---
Cadmium (IC)	---	---	---	---	---	---	---	---	---	[2.5]
Calcium	99200	51900	47300	29700	110000	---	118000 E	11100 E	52300 E	257000 E
Chromium	7.7 *J	17 *J	12 *J	20 *J	7 *J	---	11	12	18	16
Cobalt	---	[13]	[8.9]	[13]	---	---	---	[6.3]	[13]	---
Copper	19	28	25	27	[15]	---	[15]	18	24	16
Iron	17600 *J	27900 *J	21800 *J	32800 *J	9840 *J	---	16800	16300	27500	17500
Lead (IC)	10 *RJ	15 *RJ	13 *RJ	16 *RJ	5.9 *RJ	---	11	12	13	20
Magnesium	32000 *J	18100 *J	19000 *J	12000 *J	26400 *J	---	39300	5110	17100	19700
Manganese	490 *	496 *	440 *	512 *	385 *	---	555	470	523	894
Mercury	---	---	---	---	---	---	---	---	---	---
Nickel	[16]	42	[22]	37	[8.8]	---	[17]	[24]	41	[11]
Potassium	[910]	[2380]	[1380]	[2500]	[897]	---	[1310]	[1060]	[2020]	[569]
Selenium	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---
Sodium	---	---	---	---	---	---	---	[737]	---	[illegible]
Thallium	---	---	---	---	---	---	---	---	---	---
Tin	---	---	---	---	---	---	---	---	---	---
Vanadium	[9.5]	[23]	[15]	[26]	[8.4]	---	[17]	[21]	[22]	[8.7]
Zinc	57	88	76	88	40	---	54	140	77	46
Cyanide	---	---	---	---	---	---	---	---	---	---

All Concentrations Reported in mg/kg or PPM

--- = Compound was analyzed for, but not detected within detection limits.
J = Contract laboratory program qualifier, indicates an estimated value.
[ ] = Value greater than the instrument detection limit, but less than the contract required detection limit.
* = Duplicate analysis is not within control limits.
R = Spike sample recovery is not within control limits.
E = Estimated value due to the presence of interference.
IC = Indicator Chemical

Table 3-13
Summary of Volatile Organic Compound Analysis
Groundwater Samples
Pristine, Inc. Site

Well Location	GW45	GW46	GW46BK	GW48	GW49	GW50	GW51	GW52	GW52DP	GW53
	(UDL)	(UDL)	Blank	(LA)	(UDL)	(UDL)	(UDL)	(LA)	Duplicate	(UDL)
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Chloromethane	---	---	---	---	---	---	---	---	---	---
Bromomethane	---	---	---	---	---	---	---	---	---	---
Vinyl Chloride (IC)	---	---	---	---	---	84 J	300	---	---	410
Chloroethane	---	---	---	---	---	410 J	530	---	---	---
Methylene Chloride	13000	30000	21	---	240000	---	40 J	---	---	---
Acetone	---	300000 B	7000 #J	---	---	100000 #J	---	---	---	---
Carbon Disulfide	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane	---	---	---	---	---	860	1700	---	---	---
trans-1,2-Dichloroethene	---	---	---	---	---	---	---	25.	25.	380
Chloroform	---	4300 J	3 J	---	21000	---	---	---	---	---
1,2-Dichloroethane	---	34000	16	21.	22000	---	---	---	---	230
2-Butanone	---	130000	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	---	---	73	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---
Vinyl Acetate	---	---	---	---	---	---	---	---	---	---
Bromodichloromethane	---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---	---	---	---	---
trans-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	103.	103.	---
Dibromochloromethane	---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	---	---	---	---	---	---
Benzene (IC)	5600	27000	16	---	19000	---	34 J	8.	7.	---
cis-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
2-Chloroethylvinylether	---	---	---	---	---	---	---	---	---	---
Bromoform	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-pentanone	---	12000	---	---	---	---	---	---	---	---
2-Hexanone	---	---	---	---	---	---	---	---	---	---
Tetrachloroethene (IC)	---	---	---	---	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane	---	---	---	---	---	---	---	---	---	---
Toluene	120000	110000	70	---	160000	---	---	---	---	---
Chlorobenzene	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	---	---
Styrene	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	8300 J	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
# = *Detected above instrument saturation levels.*
IC = Indicator Chemical

Table 3-13
Summary of Volatile Organic Compound Analysis
Groundwater Samples
Pristine, Inc. Site

Well Location	GW54	GW56	GW56DP	GW57	GW57BK	GW58	GW59	GW60	GW61	GW62
	(LOL)	(LOL)	Duplicate	(LA)	Blank	(MOL)	(UDL)	(UDL)	(UDL)	(MOL
PARAMETER Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3
Chloromethane	---	---	---	---	---	---	---	---	---	---
Bromomethane	---	---	---	---	---	---	---	---	---	---
Vinyl Chloride (IC)	---	---	---	---	---	---	11	---	---	10 J
Chloroethane	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	---	490000 B	440000 B	15.	---	---	1 J	---	---	---
Acetone	---	---	---	---	---	56 J	13	---	---	---
Carbon Disulfide	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane	---	---	---	---	---	---	9	---	---	25
trans-1,2-Dichloroethene	---	---	---	5.4	---	---	5	---	---	27
Chloroform	8	56000	50000	---	---	1500	6	---	7	---
1,2-Dichloroethane	7	150000	130000	20.	---	---	150	100	8	44
2-Butanone	---	---	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	---	---	---	---	---	640	---	---	---	35
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---
Vinyl Acetate	---	---	---	---	---	---	---	---	---	---
Bromodichloromethane	---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---	---	---	---	---
trans-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	9
Dibromochloromethane	---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	---	---	---	---	6	3 J
Benzene (IC)	---	---	---	---	---	---	7	---	---	---
cis-1,3-Dichloropropene	---	---	---	---	---	---	---	---	---	---
2-Chloroethylvinylether	---	---	---	---	---	---	---	---	---	---
Bromoform	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-pentanone	---	---	---	---	---	---	---	---	---	---
2-Hexanone	---	---	---	---	---	---	---	---	---	---
Tetrachloroethene (IC)	---	---	---	---	---	560	---	---	---	8
1,1,2,2-Tetrachloroethane	---	---	---	---	---	---	---	---	---	---
Toluene	---	8800	8300 J	---	---	---	13	---	---	---
Chlorobenzene	---	---	---	---	---	---	4 J	7	---	---
Ethylbenzene	---	2600 J	---	---	---	---	---	---	---	---
Styrene	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	9800	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

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J = Contract laboratory program qualifier, indicates an estimated value.
* = Detected above instrument sat
IC = Indicator Chemical

Table 3-13
Summary of Volatile Organic Compound Analysis
Groundwater Samples
Pristine, Inc. Site

PARAMETER	Well Location Sampling Round	GW63 (LDL) R3	GW63DP Duplicate R3	GW64 (UDL) R3	GW65 (LDL) R3	GW66 (UDL) R3	GW66BK Blank R3	GW67 (LA) R3	GW67DP Duplicate R3	GW67BK Blank R3	GWFH R3
Chloromethane		---	---	---	---	---	---	---	---	---	---
Bromomethane		---	---	---	---	---	---	---	---	---	---
Vinyl Chloride (IC)		---	---	---	---	---	---	---	---	---	---
Chloroethane		---	---	---	---	---	---	---	---	---	---
Methylene Chloride		1900	1300	24	1180	---	---	1460	1690	---	6
Acetone		370 J	---	19	---	---	B J	---	---	17	7 J
Carbon Disulfide		---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene		---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane		---	---	---	---	---	---	40	---	---	---
trans-1,2-Dichloroethene		---	---	---	---	---	---	82	125	---	---
Chloroform		160 J	340	---	100	---	3 J	2650	3860	2 J	---
1,2-Dichloroethane		2300	4400	9	90	---	---	635	780	---	---
2-Butanone		---	---	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane		---	---	---	---	---	---	230	568	3 J	---
Carbon Tetrachloride		---	---	---	---	---	---	---	---	---	---
Vinyl Acetate		---	---	---	---	---	---	---	---	---	---
Bromodichloromethane		---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane		---	---	---	---	---	---	---	---	---	---
trans-1,3-Dichloropropene		---	---	---	---	---	---	---	---	---	---
Trichloroethene		---	---	---	---	---	---	---	---	---	---
Dibromochloromethane		---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane		---	---	---	---	---	---	---	50	---	---
Benzene (IC)		---	---	---	---	---	---	---	---	---	---
cis-1,3-Dichloropropene		---	---	---	---	---	---	---	---	---	---
2-Chloroethylvinylether		---	---	---	---	---	---	---	---	---	---
Bromoform		---	---	---	---	---	---	---	---	---	---
4-Methyl-2-pentanone		---	---	---	---	---	---	---	---	---	---
2-Hexanone		---	---	---	---	---	---	---	---	---	---
Tetrachloroethene (IC)		---	---	---	---	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane		---	---	---	---	---	---	---	---	---	---
Toluene		---	---	---	---	---	3 J	---	---	---	---
Chlorobenzene		---	---	---	---	---	---	---	---	---	---
Ethylbenzene		---	---	---	---	---	---	---	---	---	---
Styrene		---	---	---	---	---	---	---	---	---	---
Total Xylenes		230 J	130 J	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
* = Detected above instrument sat
IC = Indicator Chemical

Table 3-14
Summary of Semi-volatile Organic Compound Analysis
Groundwater Samples
Pristine, Inc. Site

	Well Location	GW63	GW63DP	GW64	GW66	GW66BK	GW67	GW67DP	GW67BK	GWFH
		(LOL)	Duplicate	(UOL)	(UOL)	Blank	(LA)	Duplicate	Blank	
PARAMETER	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3
Phenol (IC)		---	---	---	---	---	---	---	---	---
bis(2-Chloroethyl)ether		---	---	---	---	---	---	---	---	---
2-Chlorophenol		---	---	---	---	---	---	---	---	---
1,3-Dichlorobenzene		---	---	---	---	---	---	---	---	---
1,4-Dichlorobenzene		---	---	---	---	---	---	---	---	---
Benzyl Alcohol		---	---	---	---	---	---	---	---	---
1,2-Dichlorobenzene		---	---	---	---	---	---	---	---	---
2-Methylphenol		---	---	---	---	---	---	---	---	---
bis(2-Chloroisopropyl)Ether		---	---	---	---	---	---	---	---	---
4-Methylphenol		---	---	---	---	---	---	---	---	---
N-Nitroso-Di-n-propylamine		---	---	---	---	---	---	---	---	---
Hexachloroethane		---	---	---	---	---	---	---	---	---
Nitrobenzene		---	---	---	---	---	---	---	---	---
Isophorone		---	---	---	---	---	---	---	---	---
2-Nitrophenol		---	---	---	---	---	---	---	---	---
2,4-Dimethylphenol		---	---	---	---	---	---	---	---	---
Benzoic Acid		---	---	---	---	---	---	---	---	---
bis(2-Chloroethoxy)Methane		---	---	---	---	---	---	---	---	---
2,4-Dichlorophenol		---	---	---	---	---	---	---	---	---
1,2,4-Trichlorobenzene		---	---	---	---	---	---	---	---	---
Napthalene		---	---	---	---	---	---	---	---	---
4-Chloroaniline		---	---	---	---	---	---	---	---	---
Hexachlorobutadiene		---	---	---	---	---	---	---	---	---
4-Chloro-3-methylphenol		---	---	---	---	---	---	---	---	---
2-Methylnapthalene		---	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene		---	---	---	---	---	---	---	---	---
2,4,6-Trichlorophenol		---	---	---	---	---	---	---	---	---
2.4.5-Trichlorophenol		---	---	---	---	---	---	---	---	---
2-Chloronaphthalene		---	---	---	---	---	---	---	---	---
2-Nitroaniline		---	---	---	---	---	---	---	---	---
Dimethyl Phthalate		---	---	---	---	---	---	---	---	---
Acenaphthylene		---	---	---	---	---	---	---	---	---
3-Nitroaniline		---	---	---	---	---	---	---	---	---
Acenaphthene		---	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

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B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-14
Summary of Semi-volatile Organic Compound Analysis
Groundwater Samples
Pristine, Inc. Site

	Well Location	GW63	GW63DP	GW64	GW66	GW66BK	GW67	GW67DP	GW67BK	GWFH
		(LOL)	Duplicate	(UOL)	(UOL)	Blank	(LA)	Duplicate	Blank	
PARAMETER	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3
2,4-Dinitrophenol		---	---	---	---	---	---	---	---	---
4-Nitrophenol		---	---	---	---	---	---	---	---	---
Dibenzofuran		---	---	---	---	---	---	---	---	---
2,4-Dinitrotoluene		---	---	---	---	---	---	---	---	---
2,6-Dinitrotoluene		---	---	---	---	---	---	---	---	---
Diethylphthalate		---	---	---	---	---	---	---	---	---
4-Chlorophenylphenylether		---	---	---	---	---	---	---	---	---
Fluorene		---	---	---	---	---	---	---	---	---
4-Nitroaniline		---	---	---	---	---	---	---	---	---
4,6-Dinitro-2-Methylphenol		---	---	---	---	---	---	---	---	---
N-nitrosodiphenylamine		---	---	---	---	---	---	---	---	---
4-Bromophenylphenylether		---	---	---	---	---	---	---	---	---
Hexacholorobenzene		---	---	---	---	---	---	---	---	---
Pentachlorophenol		---	---	---	---	---	---	---	---	---
Phenanthrene		---	---	---	---	---	---	---	---	---
Anthracene		---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate		---	---	---	---	---	---	---	---	---
Fluoranthene		---	---	---	---	---	---	---	---	---
Pyrene		---	---	---	---	---	---	---	---	---
Butylbenzylphthalate		---	---	---	---	---	---	---	---	---
3-3'-Dichlorobenzidine		---	---	---	---	---	---	---	---	---
Benzo(a)Anthracene		---	---	---	---	---	---	---	---	---
bis(2-Ethylhexyl)Phthalate		---	---	---	---	---	6 J	5 J	3 J	---
Chrysene		---	---	---	---	---	---	---	---	---
Di-n-Octyl Phthalate		---	---	---	---	---	---	---	---	---
Benzo(b)fluoranthene		---	---	---	---	---	---	---	---	---
Benzo(k)fluoranthene		---	---	---	---	---	---	---	---	---
Benzo(a)pyrene (IC)		---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene		---	---	---	---	---	---	---	---	---
Dibenz(a,h)Anthracene		---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene		---	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
IC = Indicator Chemical

Table 3-15
Summary of Pesticide/PCB Analysis
Groundwater Samples
Pristine,Inc. Site

	Well Location	GW63	GW63DP	GW64	GW66	GW66BK	GW67	GW67DP	GW67BK	GWFH
		(LDL)	Duplicate	(UDL)	(UDL)	Blank	(LA)	Duplicate	Blank	
PARAMETER	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3
Alpha-BHC		---	---	---	---	---	---	---	---	---
Beta-BHC		---	---	---	---	---	---	---	---	---
Delta-BHC		---	---	---	---	---	---	---	---	---
Gamma-BHC (Lindane)		---	---	---	---	---	---	---	---	---
Heptachlor		---	---	---	---	---	---	---	---	---
Aldrin		---	---	---	---	---	.07	.06	---	---
Heptachlor Epoxide		---	---	---	---	---	---	---	---	---
Endosulfan I		---	---	---	---	---	---	---	---	---
Dieldrin (IC)		---	---	---	---	---	.17	.15	---	---
4,4'-DDE		---	---	---	---	---	---	---	---	---
Endrin		---	---	---	---	---	---	---	---	---
Endosulfan II		---	---	---	---	---	---	---	---	---
4,4'-DDD		---	---	---	---	---	---	---	---	---
Endosulfan Sulfate		---	---	---	---	---	---	---	---	---
4,4'-DDT		---	---	---	---	---	---	---	---	---
Methoxychlor		---	---	---	---	---	---	---	---	---
Endrin Ketone		---	---	---	---	---	---	---	---	---
Chlordane		---	---	---	---	---	---	---	---	---
Toxaphene		---	---	---	---	---	---	---	---	---
Aroclor-1016		---	---	---	---	---	---	---	---	---
Aroclor-1221		---	---	---	---	---	---	---	---	---
Aroclor-1232		---	---	---	---	---	---	---	---	---
Aroclor-1242		---	---	---	---	---	---	---	---	---
Aroclor-1248		---	---	---	---	---	---	---	---	---
Aroclor-1254		---	---	---	---	---	---	---	---	---
Aroclor-1260		---	---	---	---	---	---	---	---	---

All Concentrations Reported in ug/l or PPB

--- = Compound was analyzed for, but not detected within detection limits.
B = Contract laboratory program qualifier, analyte was found in the lab blank as well as the sample.
J = Contract laboratory program qualifier, indicates an estimated value.
C = Contract laboratory program qualifier, applies to pesticides where identification has been confirmed by GC/MS.
IC = Indicator Chemical

Table 3-16
Summary of Inorganic Compound Analysis
Groundwater Samples
Pristine,Inc. Site

PARAMETER	Well Location	GW63	GW63DP	GW64	GW66	GW66BK	GW67	GW67DP	GW67BK	GWFH
		(LOL)	Duplicate	(UOL)	(UOL)	Blank	(LA)	Duplicate	Blank	
	Sampling Round	R3	R3	R3	R3	R3	R3	R3	R3	R3
Aluminum		[45]	[25]	---	[117]	---	---	---	---	[156]
Antimony		---	---	---	---	---	---	---	---	---
Arsenic		---	---	---	---	---	---	---	---	---
Barium		[80]	[90]	[82]	[36]	---	[55]	[58]	---	[21]
Beryllium		---	---	---	---	---	---	---	---	---
Cadmium (IC)		---	---	---	---	---	---	---	---	---
Calcium		320000	295000	106000	157000	[436]	362000	356000	---	25800
Chromium		[5.2]	[4.5]	---	---	---	---	---	---	---
Cobalt		---	---	---	---	---	---	---	---	---
Copper		[8.5]	[7.4]	---	[6.8]	---	---	---	---	[6]
Iron		[41]	[65]	[28] R	202	---	---	---	---	3270 R
Lead (IC)		---	---	---	---	---	---	---	---	---
Magnesium		92600	82700	26300	51600	---	95000	93600	---	24500
Manganese		3470	3690	360	246	[4.4]	64	63	---	19
Mercury		---	---	---	---	---	---	---	---	---
Nickel		[15]	[15]	---	---	---	---	---	---	---
Potassium		222000	192000	14000	[2310]	---	13700	15100	---	7620
Selenium		---	---	---	---	---	---	---	---	---
Silver		---	---	---	---	---	---	---	---	---
Sodium		77200	71100	22200	9250	---	14700	168000	---	68300
Thallium		---	---	---	---	---	---	---	---	---
Tin		---	---	---	---	---	---	---	---	---
Vanadium		---	---	---	---	---	---	---	---	---
Zinc		[17]	[15]	[14]	[9.7]	[8.6]	---	---	---	22
Cyanide		---	---	---	---	---	---	---	---	14
Fluoride (IC)		300	300	500	200	---	NS	NS	NS	1100

All Concentrations Reported in ug/l or PPB

--- = Compound was analyzed for, but not detected within detection limits.
J = Contract laboratory program qualifier, indicates an estimated value.
[ ] = Value greater than the instrument detection limit, but less than the contract required detection limit.
R = Spike sample recovery is not within control limits.
NS = Not Sampled
IC = Indicator Chemical

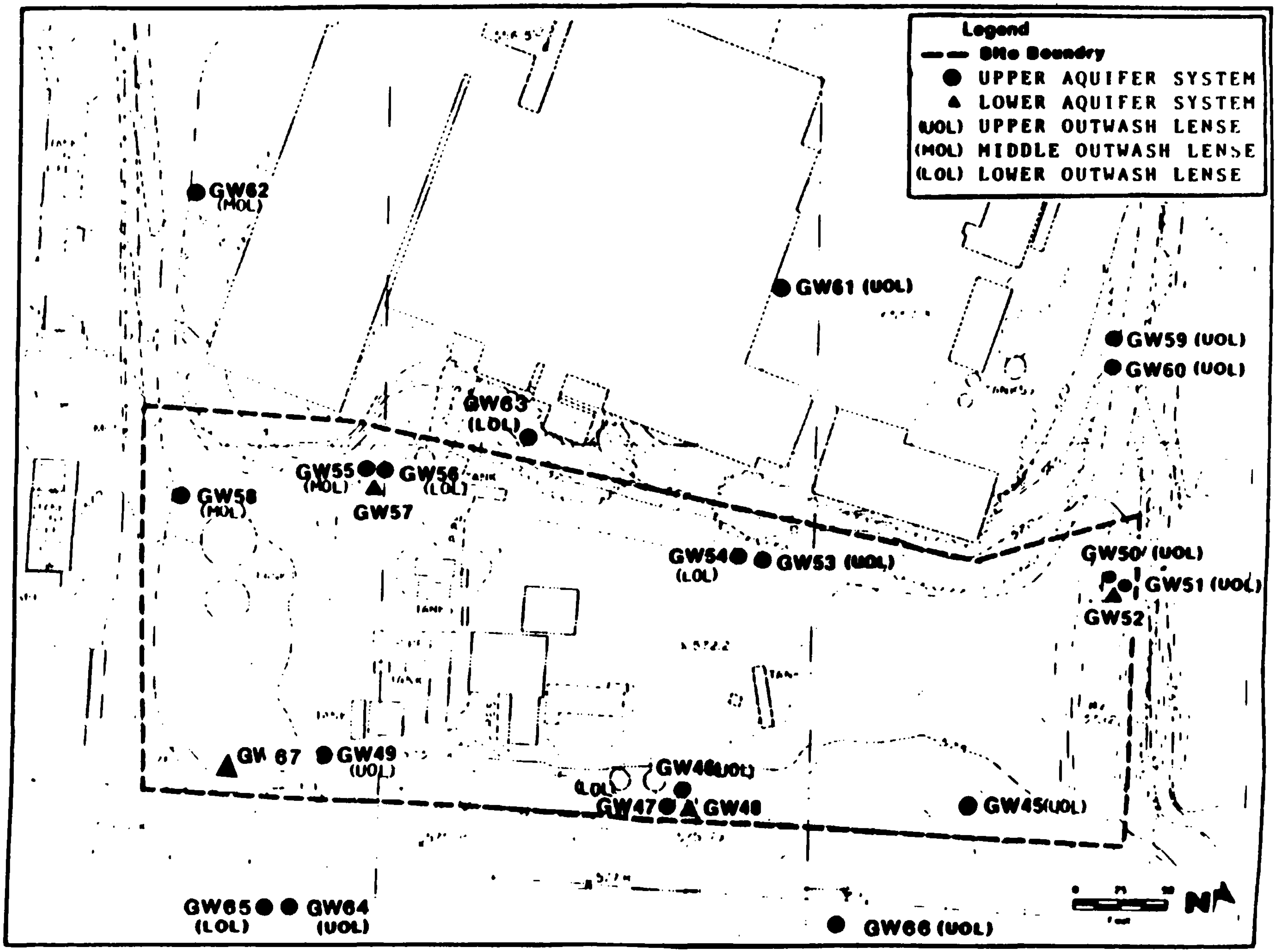


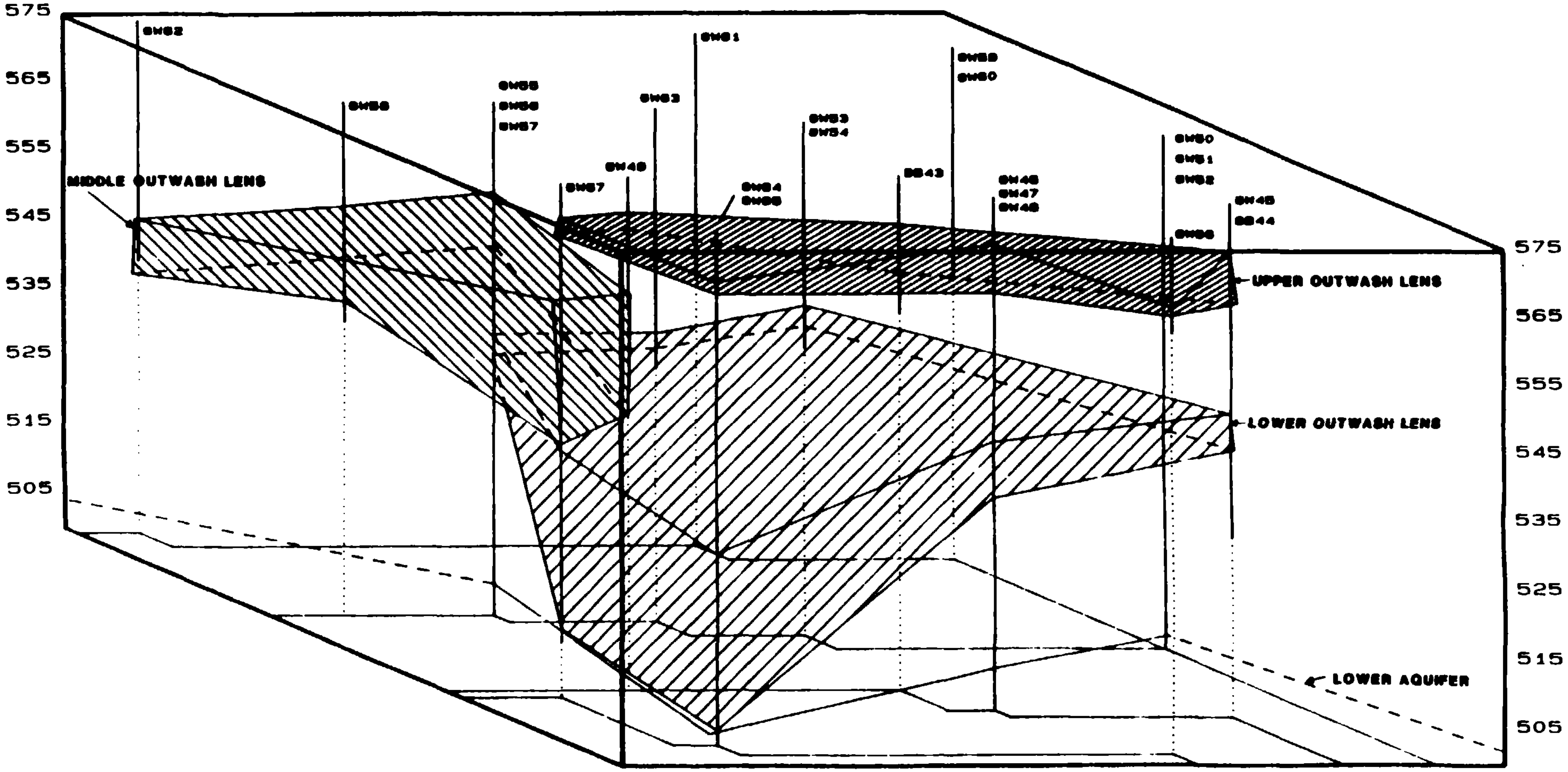
FIGURE 3-4

MONITORING [illegible]LL AND GROUNDWATER SAMPLING [illegible]ATIONS

FIGURE 3-5

CONFIGURATION of UPPER AQUIFER in RELATION to LOWER AQUIFER

PRISTINE INC. SITE



The cumulative volatile organic compound concentrations detected in the groundwater samples are presented in Figure 3-6. The cumulative concentration was calculated by summing the reported concentrations of:

- Vinyl chloride
- Trichloroethene
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- 1,1,2,2-Tetrachloroethane
- Total Xylenes
- Chloroethane
- 1,1,2-Trichloroethane
- Benzene
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene

Methylene chloride and acetone were not considered in the cumulative concentration because a comparison of concentrations of the compounds detected in field blank and duplicate samples was made and the variation of reported concentrations of methylene chloride and acetone in the samples indicated laboratory or field contamination. This approach was taken because it is recognized that concentrations of methylene chloride and acetone at the site will not affect the ultimate conclusions presented in this report and the ultimate review and selection of preferred remedial alternatives and remedial action.

The extent of volatile organic compound concentrations detected during the Phase 2 investigation is consistent with data obtained during the RI 1 investigation. The extent of the upper outwash lens has been defined during the RI 2. It has been concluded that off-site contamination in the upper outwash lens is minimal (GW64) or nonexistent (GW66).

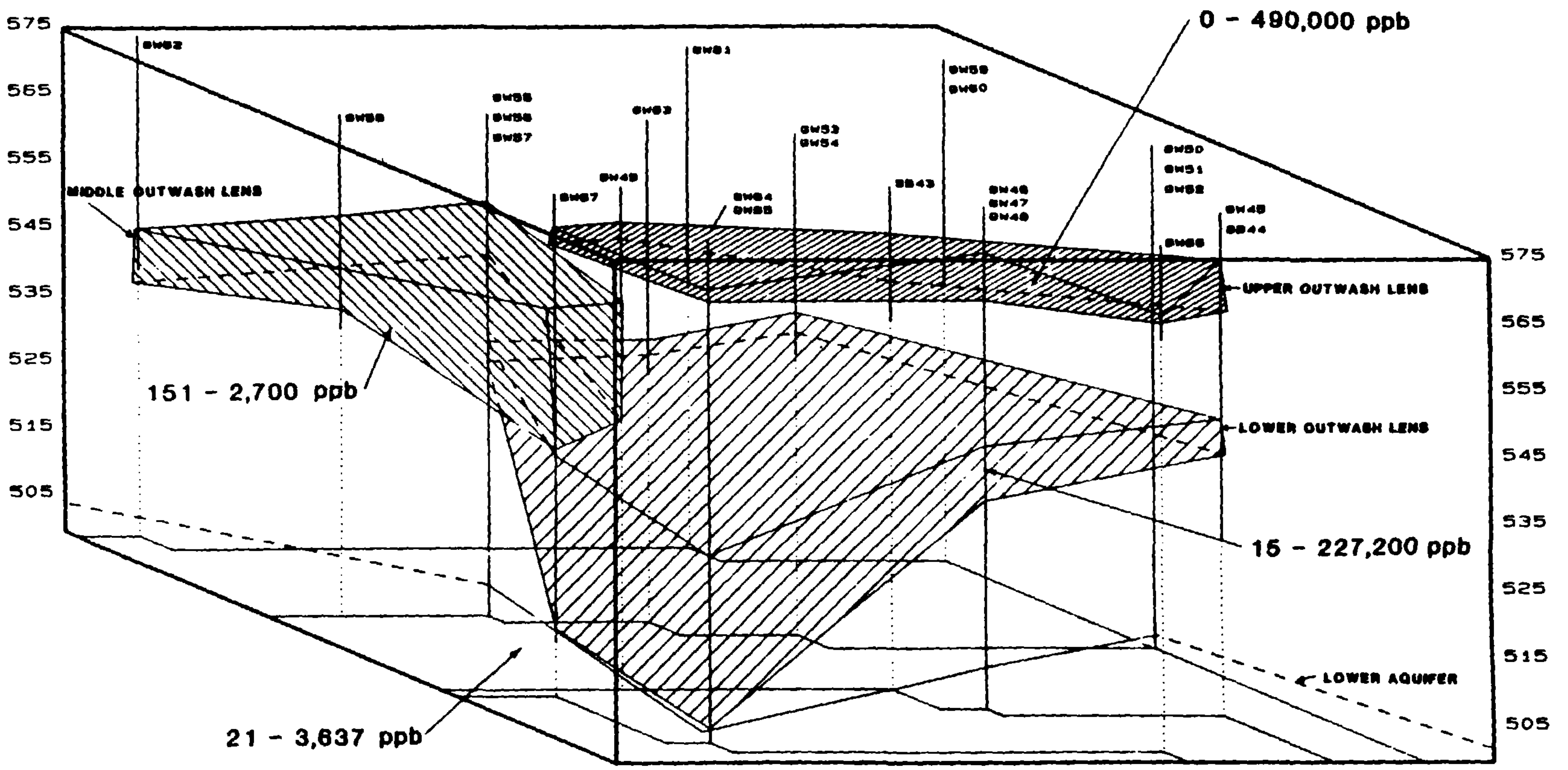
Contamination in the lower outwash lens and the lower aquifer has been further defined. Migration of contaminants can be tracked from soils and groundwater in the lower outwash lens to the groundwater in the lower aquifer. Monitoring GW67, which is placed at the location where the upper outwash lens interconnects which the lower aquifer contains chloroform, 1,2-dichloroethane and 2-butanone. These components are also detected in GW56 which is placed in the lower outwash lens, downgradient from the magic pit.

The five monitoring wells (GW63, GW64, GW65, GW66, GW67) installed during RI 2 were sampled for semi-volatile organic components and pesticide/PCB compounds. Bis(2-ethylhexyl)Phthalate was the only semi-volatile compound detected. Aldrin and dieldrin were the only two pesticides detected. All three of the compounds were detected at low levels in monitoring well GW67, which again, is located at the interface of the lower outwash lens and the lower aquifer.

FIGURE 3-6

Cummulative Concentration of Volatile Organic Compounds in the Upper and Lower Aquifer Systems

PRISTINE INC. SITE



SECTION 4

DEFINITION OF AREAS OF CONTAMINATION

The purpose of the Phase 2 Remedial Investigation is to more fully evaluate the potential extent and magnitude of contamination and evaluate the potential risk to the environment, the public health and welfare at the Pristine, Inc. site. In this section the extent and volumes of contaminated soil will be defined.

The extent of vertical soil contamination has been defined at the magic pit and in the upper outwash lens. Soil boring SB42 was drilled at the magic pit; the contamination in the soils was located at depths from approximately 20 to 30 feet below the surface. Soil boring SB43 was drilled in the central portion of the site through the upper outwash lens. The contamination (~ 10 ppm volatile organic compounds) found in the samples collected at depths of 8 to 12 feet below the surface is an example of soil contamination within the upper outwash lens. The results at both soil boring locations indicate that the soils are sources of contamination at the site and remediation of the magic pit area and of the upper outwash lens is necessary. Based on the data obtained in both RI1 and RI2, and calculated target risk concentrations, two remedial action soil removal strategies have been developed. The two remediation strategies which were developed for the Feasibility Study are further defined in this report. Soil Remediation Strategy I defines the quantity of soil that poses a risk based on direct contact and incidental ingestion only. Soil Remediation Strategy II defines the quantity of soil that poses a risk associated with direct contact and incidental ingestion of soil and contributes to risk associated with ingestion of groundwater based on leaching of contaminants from the soil.

4.1 SOIL REMEDIATION STRATEGY I

The Phase I Remedial Investigation revealed that a large number of contaminants were present in the surface soils, soil trenches, and soil borings. As part of the Public Health Evaluation (RI1), a subset of these chemicals (indicator chemicals) were selected to evaluate the potential risks to human health from the Pristine, Inc. Site. The Superfund Public Health Evaluation Manual (EPA 1986) recommends the re-evaluation of the indicator chemicals for the Feasibility Study to ensure that all classes of chemicals are considered and can therefore be evaluated as to the applicability of the remedial options considered. Additionally the manual advises that the initial focus of the evaluation be on the potential carcinogens since they will generally drive the final design.

There are two approaches that may be used to translate the total risk levels at the site into target concentrations for individual chemicals. The first method is to select one or two potential carcinogens to drive the design process. The second approach is to allow the total number of potential carcinogenic compounds or a subset of the carcinogenic chemicals to drive the design process. In this case eleven compounds were chosen based on frequency, concentration and potential threat. The eleven compounds include:

- Aldrin
- Benzene
- Chloroform
- DDT
- 1,2-Dichloroethane
- 1,1-Dichloroethene
- Dieldrin
- PAHs
- 2,3,7,8-TCDD (Dioxin)
- Tetrachloroethylene
- Trichloroethylene

Based on these eleven compounds, and a total target risk level of 10^{-6}, the resulting apportioned (individual) target risk level of 9.1×10^{-8} for each potential carcinogen was calculated. Once the target intake is calculated the corresponding individual intake concentration could be calculated. The target intake is determined using the following formula.

Potential Carcinogenic Risk = (Chronic DI) (Potency Factor)

DI = Daily Intake

This concentration was based on exposure to contaminated soil by direct contact and incidental ingestion. Table 4-1 presents the results of the calculation to determine the chronic daily intake for each of the compounds of concern.

Soil Remediation Strategy I was developed to remediate all soils which contributed a 10^{-6} cancer risk based on the calculated daily intake. Concentrations in the surface soil of 7 of the 11 target compounds listed in Table 4-1 are greater than the target risk concentrations and dictate that soil remediation is necessary. The compounds include aldrin, benzene, DDT, 1,2-dichloroethane, dieldrin tetrachloroethylene, and PAHs.

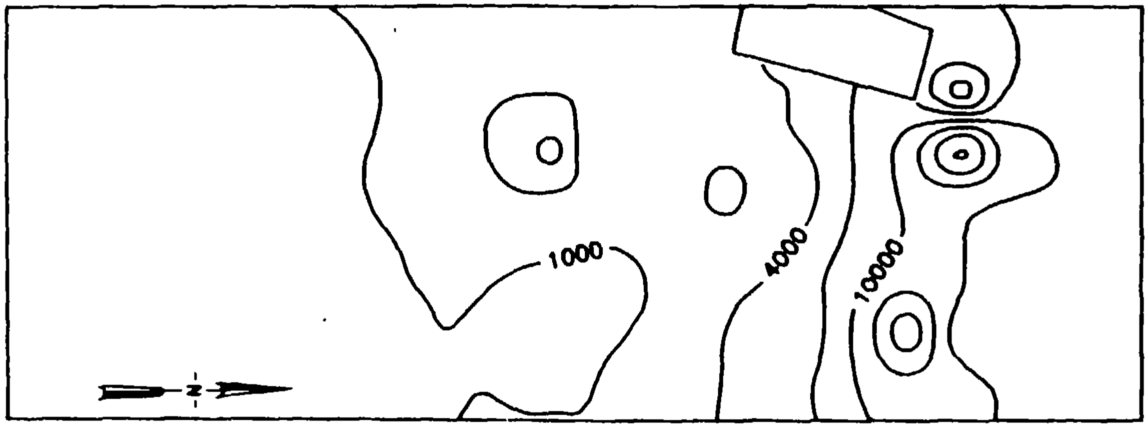
Three of the seven compounds diedrin, DDT, and benzene, dominate the soil remediation strategy. The target soil concentrations for dieldrin and DDT are 6 ppb and 487 ppb, respectively. Figure 4-1 presents the area (to a depth of 1 foot) in which concentrations of dieldrin and DDT are greater than the respective target soil concentrations. Removal of 1 foot of soil in the area presented in Figure 4-1 will eliminate the risk associated with direct contact and incidental ingestion of dieldrin and DDT, and also the risk associated

TABLE 4-1

TARGET SOIL CONCENTRATIONS
PRISTINE, INC. SITE

Chemical Name	Target Intake Concentration in Soil (ug/kg) or ppb
Aldrin	15
Benzene	3182
Chloroform	2043
DDT	487
1,2-Dichloroethane	1818
1,1-Dichloroethylene	285
Dieldrin	6
PAHs	14
2,3,7,8-TCDD (Dioxin)	0
Tetrachloroethylene	3244
Trichloroethylene	15,041

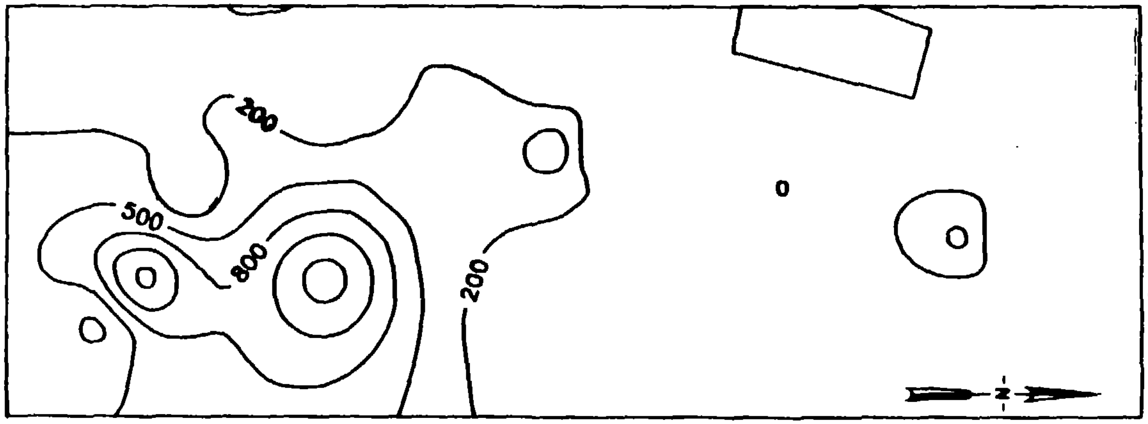
4,4' DDT – Surface



Target Risk Level = 487 ppb

Concentrations in ug/Kg (ppb)

Dieldrin – Surface



Target Risk Level = 6 ppb

Concentrations in ug/Kg (ppb)

FIGURE 4-1
EXTENT OF DIELDRIN AND DDT CONTAMINATION
PRISTINE, INC. SITE

with 1,2-dichloroethane, tetrachloroethylene, aldrin and PAHs. This area (to a depth of 1 foot across the site) represents a volume of 3598 cubic yards of soil.

The soil target concentration for benzene is 3182 ppb. The area (to a depth of 2 feet across 50% of the site) in which concentration of benzene is greater that the target soil concentration is presented in Figure 4-2. This area (from a depth of 1 foot to 2 feet below the surface) represents a volume of 1799 cubic yards of soil. Remediation of the additional volume of soil, from 1 foot to 2 feet below the surface, in the area presented in Figure 4-2 will eliminate the risk associated with direct contact and incidental ingestion of benzene.

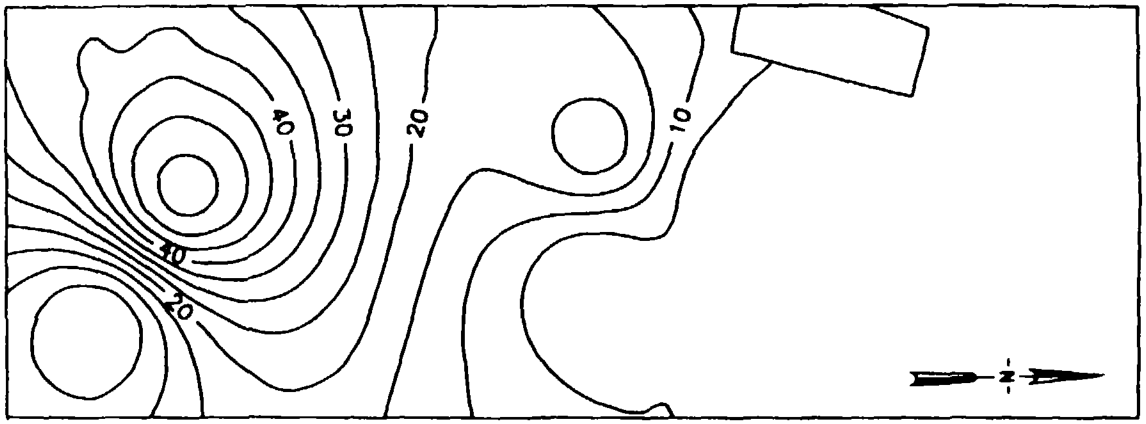
Soil Remediation Strategy I, developed to eliminate the risk associated with direct contact and incidental ingestion, combines the areas (and associated volumes) presented in Figure 4-1 and 4-2. Figure 4-3 presents the volume of soil remediation defined by Strategy I. This area represents a volume of approximately 5400 cubic yards of soil. Sediment samples are defined as contaminated media based on concentrations of aldrin, DDT, dieldrin, PAHs, and 1,2-dichloroethane. The volume of contaminated sediments is estimated to be 600 cubic yards. Subsurface soil in the magic pit area are also defined as contaminated based on the concentration of 1,2- dichloroethane. The volume of soil remediation necessary at the magic pit is calculated to be approximately 1,125 cubic yards based on data obtained from soil boring SB42. Therefore, the volume of soil remediation for Soil Remediation Strategy I included the volume of surface soils (5400 cubic yards), sediments (600 cubic yards) and subsurface magic pit soil (1,125 cubic) for a combined volume of 7,125 cubic yards of contaminated media.

4.2 SOIL REMEDIATION STRATEGY II

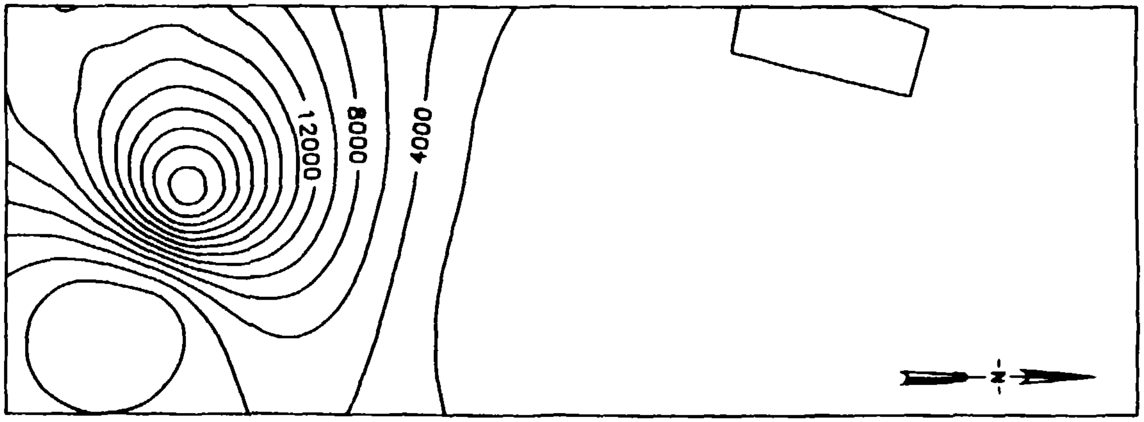
Contaminants remaining in the soil following a site cleanup may, over time, leach into groundwater. A model was developed to calculate contaminant concentrations in groundwater at the Pristine, Inc. site that would predict concentrations that could be expected in the lower aquifer overtime. This model is conservative in that it assumes that all of the contamination reaches this aquifer and is only diluted with infiltrating rainwater. It is assumed that the other groundwater lenses do not exist.

The model assumes that a certain percentage of the rainfall at the site will infiltrate the site and desorb contaminants from the soil based on equilibrium soil-water partitioning. The infiltrating rainwater will act to dilute and transport the mobilized contaminants. Once the infiltrating water reaches the aquifer it is further assumed that it will mix completely with the groundwater below the site, resulting in an equilibrium groundwater concentration.

Benzene - One ft. below the surface



Benzene - Two ft. below the surface



Target Risk Level = 3182 ppb

Concentrations in ug/Kg (ppb)

FIGURE 4-2

EXTENT OF BENZENE CONTAMINATION

PRISTINE, INC. SITE

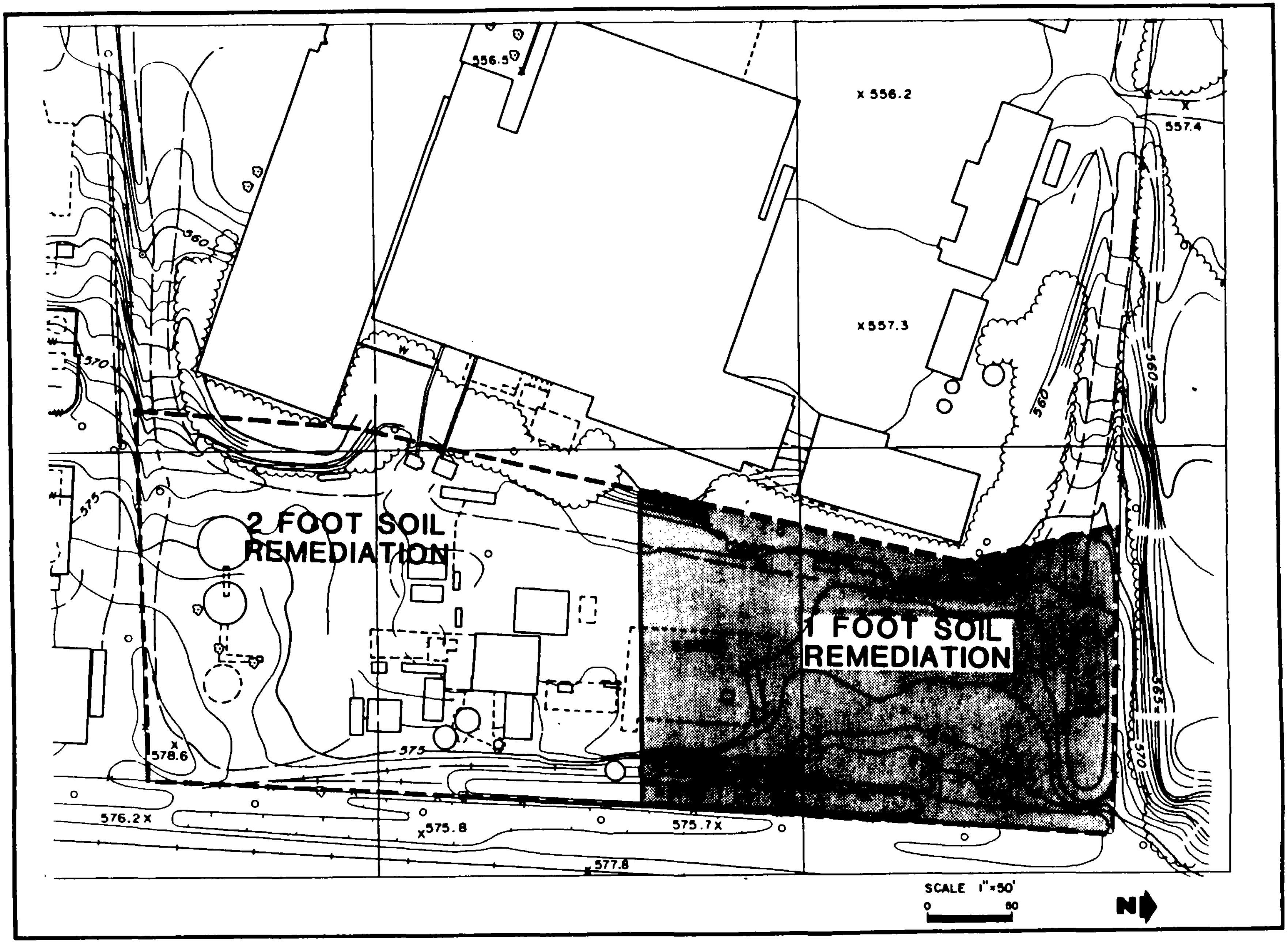


FIGURE 4-3
SOIL REMEDIATION STRATEGY I
PRISTINE, INC. SITE

The mixing of groundwater and infiltrating water and the resultant contaminant concentrations in groundwater are related as follows (Summers et al. 1980):

$$C_{gw} = \frac{Q_P C_P}{Q_P + Qgw}$$

Where

C_{gw} = contaminant concentration in the groundwater (ug/l);
Q_p = volumetric flow rate of infiltration (soil pore water) into the groundwater (ft^3/day);
C_p = contaminant concentration in the infiltration; and
Q_{gw} = volumetric flow rate of groundwater (ft^3/day).

The volumetric flow rate of infiltration, Q_p, is derived from the percentage of the total rainfall from the site (reported as approximately 40 inches in the RI report) that is attributed to recharge to groundwater flow systems or 15 percent (Fidler 1979) or approximately 6 inches per year. This quantity of rain is assumed to fall over the entire area of the site or 120,000 square feet corresponding to a volumetric infiltration rate of 164 ft^3/day. The volumetric flow rate of groundwater, Q_{gw}, is estimated as the average linear groundwater velocity times the area of the aquifer perpendicular to the groundwater flow across the contaminated area of the site:

$$Q_{gw} = (K)(i)(l)(d)$$

Where

K = hydraulic conductivity (1x0 ft/day),
i = hydraulic gradient (0.00245 ft/ft),
l = length of the site perpendicular to flow (600 ft); and
d = depth of the aquifer or mixing zone (43.3 ft).

The hydraulic conductivity is based on regional pumping tests (Fidler 1970). The depth of the mixing zone is taken to be one-third the depth that the Reading municipal wells are screened. The gradient and length of the site are taken from the Pristine RI report. The volumetric groundwater flow rate is calculated to be 8900 ft^3/day. The ratio of Q_p to Q_{gw} plus Q_p (0.018) is used to estimate concentrations of the organic compounds detected in the soil that would be expected to be in the groundwater.

The concentration in the infiltrating groundwater, C_p, can be predicted using a soil-water partitioning model, expressed as:

$$C_s = (K_d)(C_p)$$

Where

C_s = soil concentration (ug/kg);
K_d = soil water equilibrium partition coefficient (liter/kg); and
C_p = concentration in infiltration (ug/liter).

Partition coefficients, K_d, were derived by multiplying the organic carbon water partition coefficient, K_{oc}, by the fraction of organic carbon, f_{oc}, as seen by

$$K_d = (K_{oc}) \quad (f_{oc})$$

where

K_d = soil-water equilibrium partition coefficient (liter/kg);
K_{oc} = organic carbon partition coefficient (liter/kg); and
f_{oc} = fraction of organic carbon (0.005).

The fraction of organic carbon is assumed to be 0.5% based on the descriptions of the soil presented in the RI report. The presence of greater amounts of organic carbon in the soil would retard the movement of the organic compounds present at Pristine, Inc. site. Thus this model could overestimate the migration potential of the organic compounds from the Pristine, Inc. site soils to the groundwater.

The model assumes an equilibrium partitioning of the contaminant between the soil and the soil pore water. The model does not account for attenuation of the contaminants in the unsaturated zone. It further assumes that all of the contamination reaches the lower aquifer.

In the public health evaluation of the Pristine RI, it was assumed that the groundwater from the site contributed 12% to the overall amount of groundwater reaching the Reading well field. This assumption is used to calculate the related contaminants at the well field.

Table 4-2 presents the predicted groundwater concentrations at the site and at the Reading well field. The associated health risk predicted at the well field is also presented in Table 4-2.

The predicted groundwater concentrations presented in Table 4-2 need to be compared to applicable requirements to verify the predicted concentrations are below required limits. Maximum Contaminant Levels (MCLs) is one of the required limits for groundwater contaminants. Based on the comparison of target groundwater concentrations and MCLs, it is predicted that the leached concentrations of three compounds would be greater than the MCLs. To eliminate this predicted risk to groundwater, a reverse calculation was used to calculate the

TABLE 4-2

CONCENTRATION OF CONTAMINANTS IN THE SOIL AND PREDICTED GROUNDWATER CONCENTRATIONS PRISTINE, INC. SITE

Chemical Name	Concentration in Groundwater Site Boundary (ug/l)	Concentration in Groundwater Well Field (ug/l)	Risk (Upperbound at Well Field)
Aldrin	5.4E-04	6.5E-05	2E-08
Benzene	1.4E+02	1.7E+01	8E-05
Chloroform	2.4E-03	2.9E-04	7E-10
DDT	7.2E-03	8.7E-04	8E-09
1,2-Dichloroethane	4.7E+02	5.6E+01	1E-04
1,1-Dichloroethylene	1.6E+01	1.9E+00	3E-05
Dieldrin	1.2E-02	1.4E-03	1E-06
PAHs	3.2E-05	3.9E-06	1E-09
2,3,7,8-TCDD (Dioxin)	1.2E-09	1.4E-10	6E-10
Tetrachloroethylene	3.2E+01	3.9E+00	6E-06
Trichloroethylene	4.3E+02	5.16E-01	2E-05
Total			3E-04

TABLE 4-3

TARGET SOIL CONCENTRATIONS WITH PREDICTED GROUNDWATER CONCENTRATIONS AT MCL'S PRISTINE, INC. SITE

Chemical Name	Target Soil Concentration (ppb)
Benzene	116
1,2-Dichloroethane	19
Trichloroethylene	175

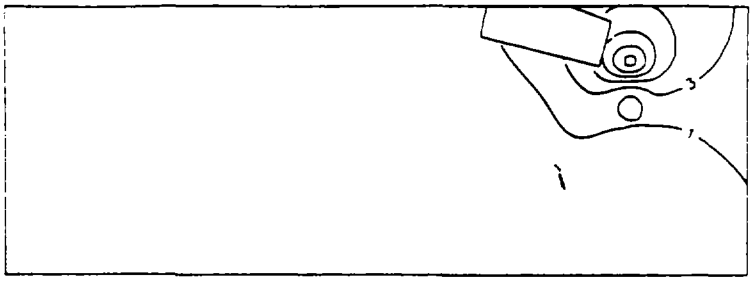
concentration of benzene, 1,2-dichloroethane, and trichloroethylene that could remain in the soil and not pose a threat due to potential leaching. The results are presented in Table 4-3.

Soil Remediation Strategy II was developed to remediate all soils that pose a risk associated with direct contact and incidental ingestion of soil, and contribute to risk associated with ingestion of groundwater based on leaching of contaminants from the soil. Concentration in the subsurface soil of 2 of the 3 target compounds listed in Table 4-2 are greater than the target risk concentrations and dictate the soil remediation strategy. The target concentration of benzene and 1,2-dichlorethane are, 116 ppb and 19 ppb respectively. Figure 4-4 and 4-5 present the concentrations of benzene and 1,2-dichlorethane at depths from the surface to eight feet below the surface. This area represents the partial extent of soil remediation to necessary eliminate the risk associated with the leaching of contaminants from the soil to the groundwater.

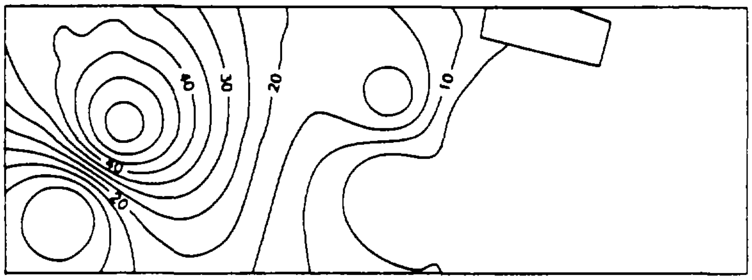
Data collected during RI2 confirms that the soil within the upper outwash lens is also a source of contamination. The concentrations of 1,2- dichloroethane, trichloroethelyene, and benzene in soil boring SB43 are greater than the target soil concentrations to depths of 12 feet below the surface. The extent of the upper outwash lens has been estimated to include up to 50% of the on-site area (Figure 4-6). This has not been confirmed and additional work in the remedial design phase has been recommended to define the extent of the lens.

Soil Remediation Strategy II, developed to eliminate the risk associated with direct contact and incidental ingestion, and the potential to produce leachate, combines the areas (and associated volumes) presented in Figures 4-4, 4-5, and 4-6. Based on the concentration of contaminants and the extent of contamination, (8 feet across the entire site, 12 feet across 50% of the site), the recommended volume of soil for remediation to an average of 10 feet is 35,980 cubic yards. Figure 4-7 presents the area of soil remediation defined by Strategy II. As described in Section 4.1, the volume contaminated sediments (600 cubic yards) and subsurface soils at the magic pit (1,125 cubic yards) should also be included. Therefore, the volume of soil to be remediated for Soil Remediation Strategy II is 37,700 cubic yards.

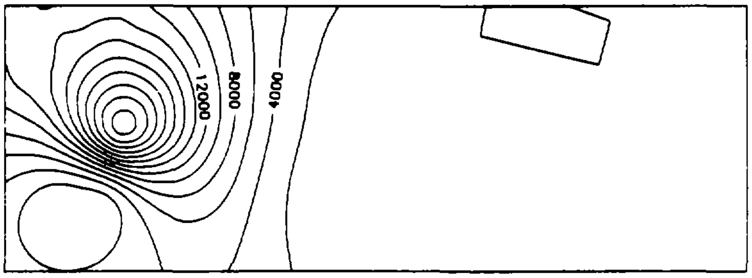
Benzene – Surface



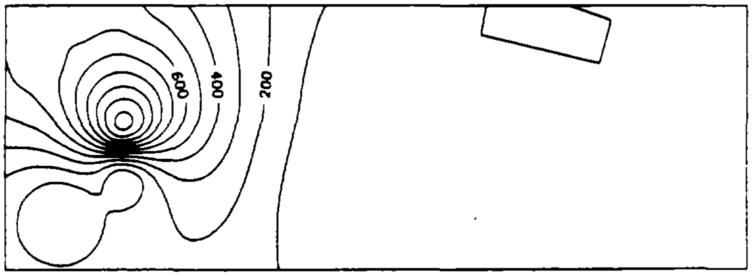
Benzene – One ft. below the surface



Benzene – Two ft. below the surface



Benzene – Four ft. below the surface



Benzene – Eight ft. below the surface

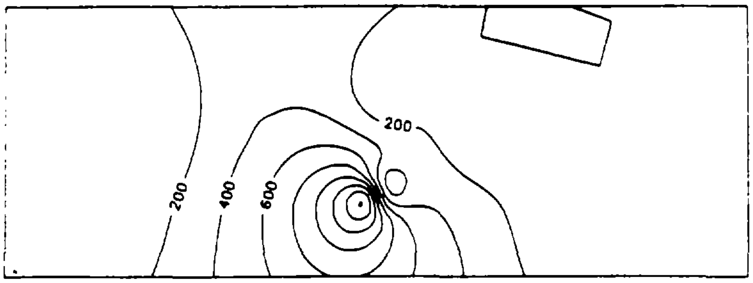


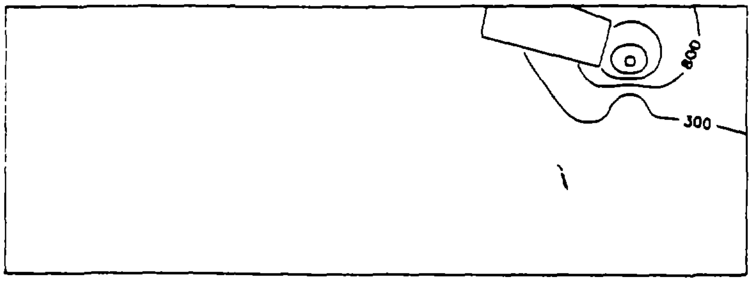
FIGURE 4-4
EXTENT OF BENZENE CONTAMINATION

PRISTINE, INC. SITE

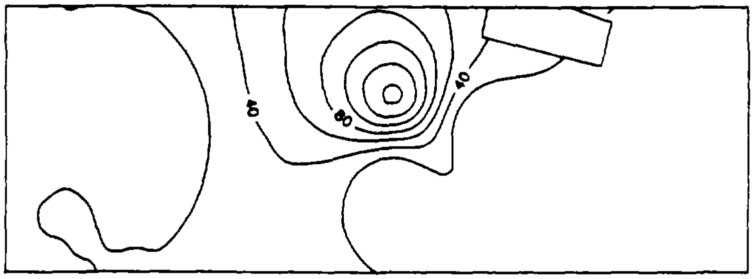
Target Risk Level = 116 ppb

Concentrations in ug/Kg (ppb)

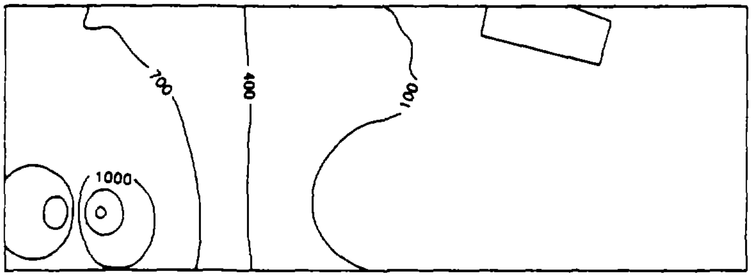
1,2–Dichloroethane – Surface



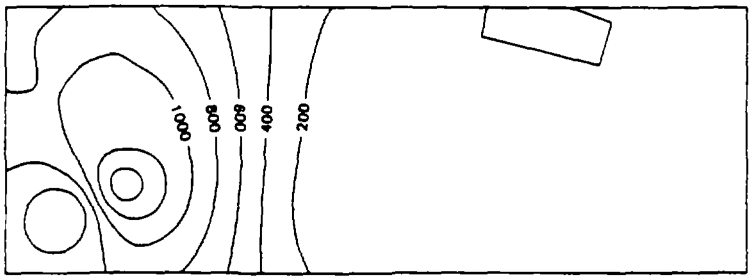
1,2–Dichloroethane – One ft. below the surface



1,2–Dichloroethane – Two ft. below the surface



1,2–Dichloroethane – Four ft. below the surface



1,2–Dichloroethane – Eight ft. below the surface

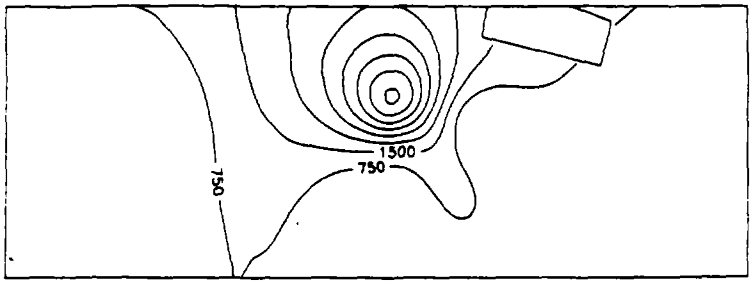


FIGURE 4-5

EXTENT OF 1,2-DICHLOROETHANE CONTAMINATION

PRISTINE, INC. SITE

Target Risk Level = 19 ppb

Concentrations in ug/Kg (ppb)

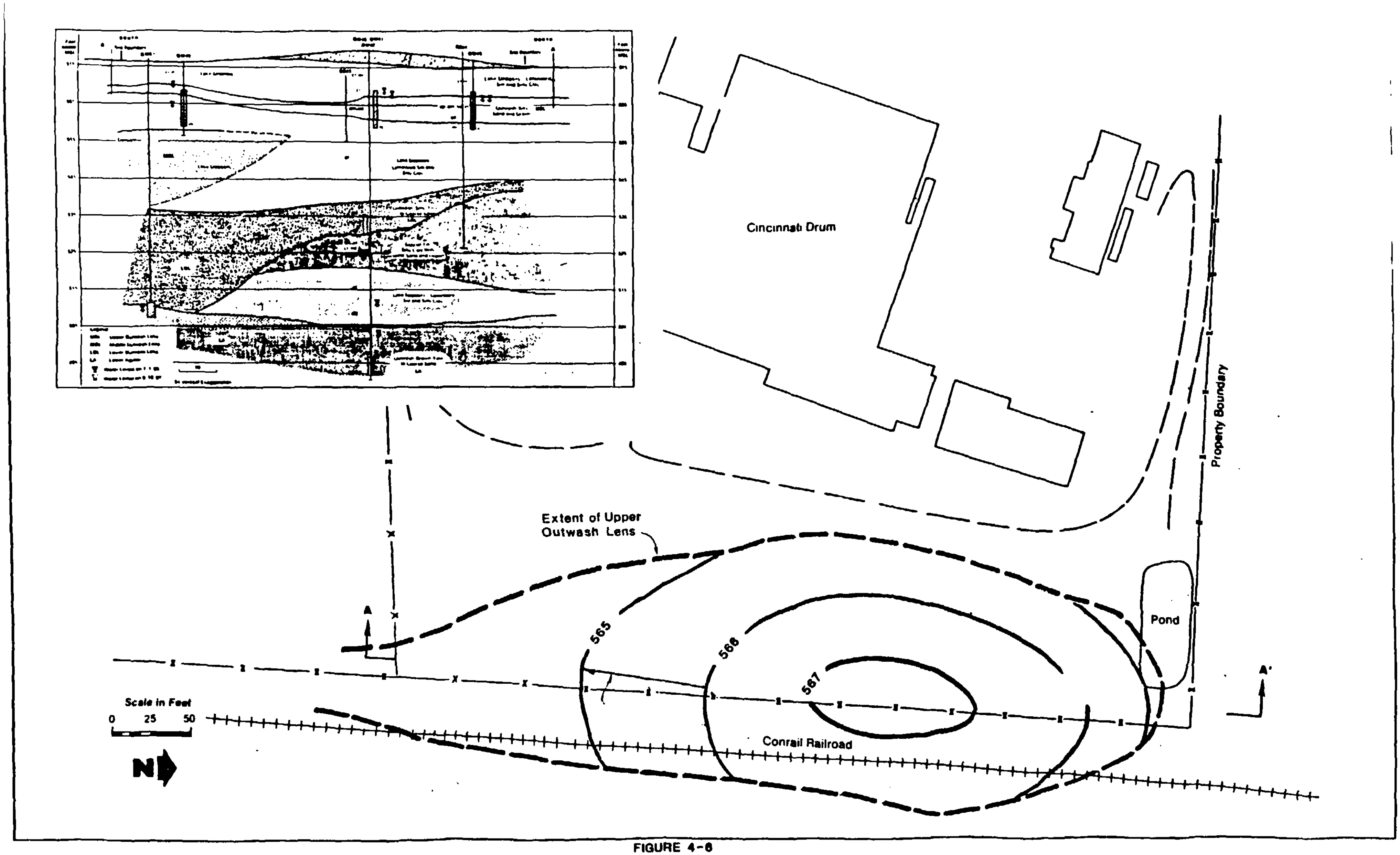


FIGURE 4-6
Extent of Upper Outwash Lens
Pristine, Inc. Site

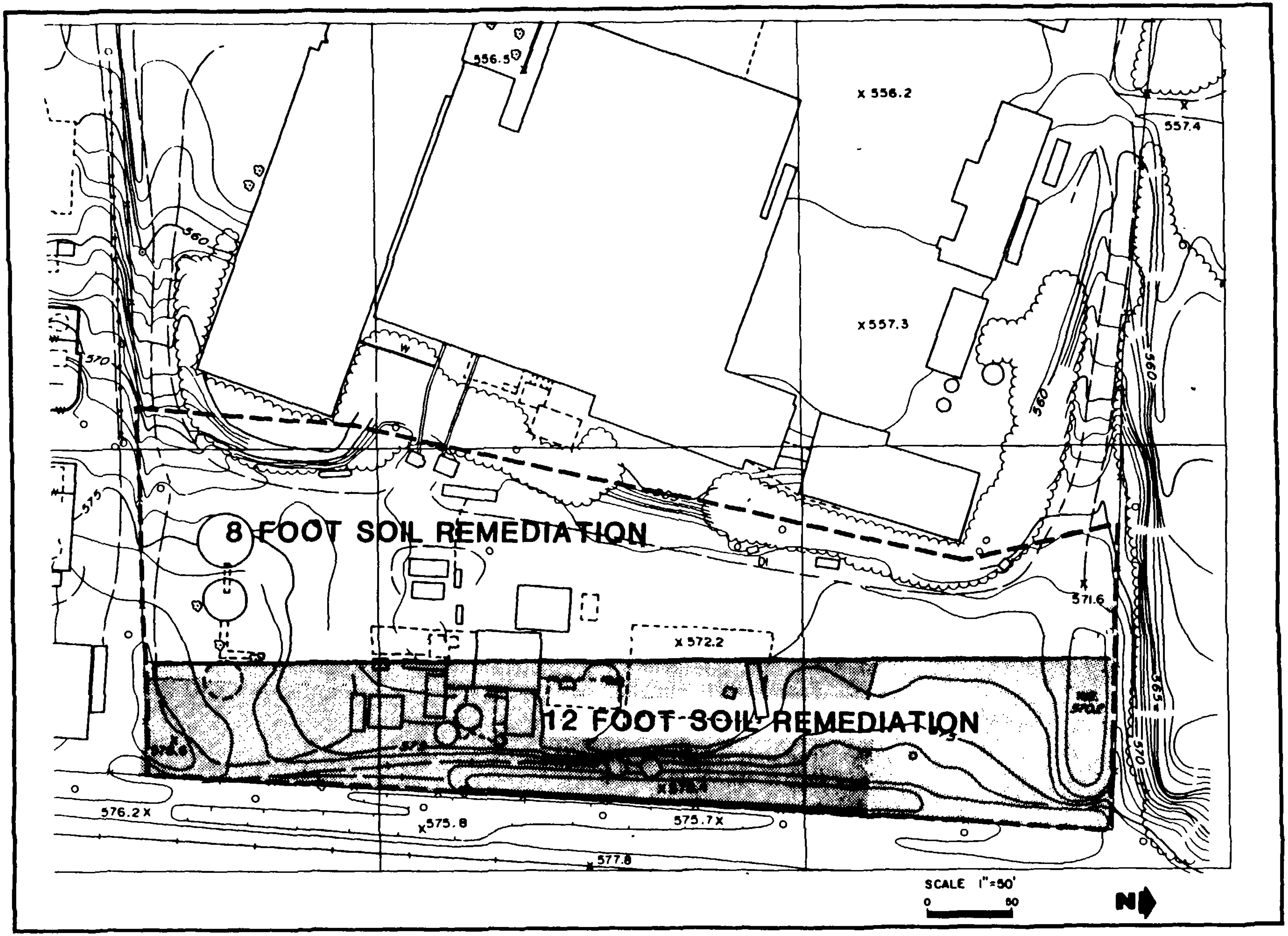


FIGURE 4- 7

SOIL REMEDIATION STRATEGY II

PRISTINE, INC. SITE

SECTION 5

PUBLIC HEALTH EVALUATION

A public health evaluation (PHE) is an estimation of the magnitude and probability of actual or potential harm to public health or the environment caused by a threatened or actual release of a hazardous substance. It is a site-specific risk assessment performed as part of the Remedial Investigation/Feasibility Study (RI/FS) performed under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and its successor the Superfund Amendments and Reauthorization Act of 1986 (SARA). This is a supplemental public health evaluation designed to address the new data collected as part of the Phase 2 RI. This public health evaluation is designed to be a companion to the previous public health evaluation and should not be used to replace the original public health evaluation which considers all of the chemicals detected at the Pristine, Inc., site.

One of the primary objectives of the Phase 2 RI was to determine whether or not polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were present in the soils at the Pristine, Inc. site. A number of these compounds were detected near the structures on the Pristine, Inc. site as seen in Figure 5-1. The purpose of this supplemental public health evaluation is to determine whether or not the presence of the PCDDs and PCDFs pose a risk to human health or the environment.

This public health evaluation which is consistent with guidelines from the Office of Emergency and Remedial Response (USEPA 1986a) and federal guidelines for risk assessments (USEPA 1986b,c,d) is organized as follows: First, in Section 5.1, a brief chemical description of the PCDD and PCDF classes of compounds is presented. The second Section 5.2, will present a brief overview of the toxicological properties of the PCDDs and PCDFs. The potential for migration of the PCDDs an PCDFs from the Pristine, Inc. site is then discussed in Section 5.3 together with the exposure pathways that are related to the migration routes and that may be present under current- and future-use scenarios will then be evaluated assuming that the current-use patterns remain unchanged. Each section will discuss the relevant exposure pathways and the concentrations of the PCDDs and PCDFs at the points of exposure, and the potential effect of exposure via each of the exposure pathways. The PHE will use the information developed for the Public Health Evaluation, Chapter 5, of the Remedial Investigation Report.

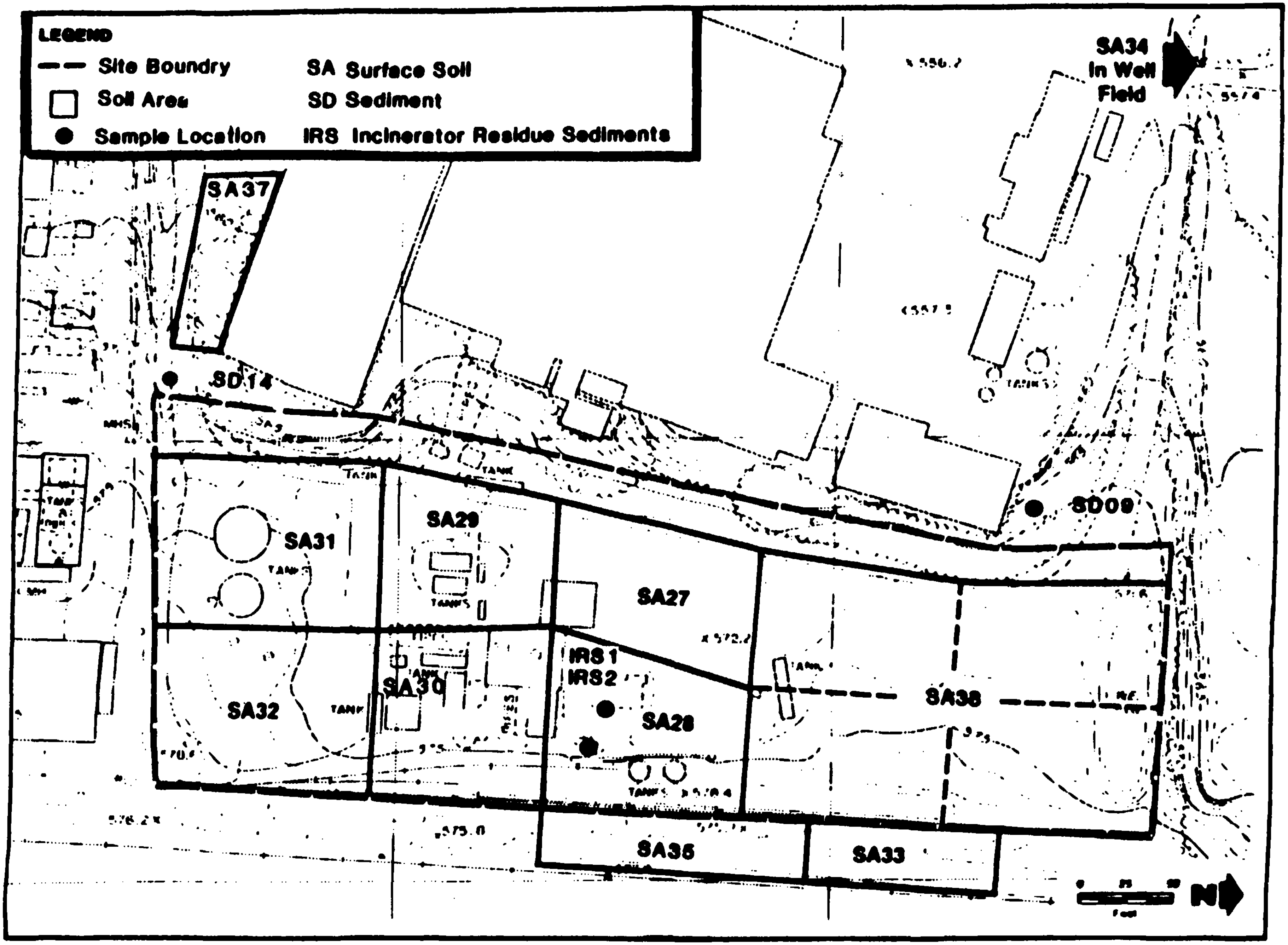


FIGURE 5-1

SOIL AREA, SEDIMENT AND INCINERATOR RESIDUE SAMPLING LOCATIONS

PRISTINE INC. SITE

5.1 CHEMICALS OF POTENTIAL CONCERN

The polychlorinated dibenxo-p-dioxins (PCDDs) comprise a family of 75 congeners, each of which is an isomer of one of eight homologue classes (CDDs), which have varying degrees of chlorination. Specific isomers are identified by numbers representing the positions of chlorination, e.g. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Congeners with 4 to 7 chlorines are often divided into two subclasses, comprising those congeners with and without chlorine substitutions in the 2,3,7 and 8 positions. Thus, the data are often presented as, for example, 2,3,7,8-TCDD and total TCDDs to make this distinction. Most information in the literature, with respect to environmental fate, pertains to the 2,3,7,8-TCDD congener, since this compound is considered to be the most toxic. Limited information is available on the other dioxin congeners, and chemical properties for them are for the most part estimated.

The polychlorinated dibenzofurans (PCDFs) comprise a family of 135 congeners in 8 homologues (CDFs) with varying degrees of chlorination. They are structurally similar to the PCDDs, and thus are similar in chemical and biological properties. The same system of abbreviations is used to designate isomers, homologues, and subclasses of PCDFs as is used for PCDDs.

5.2 HAZARD ASSESSMENT

For hazard assessment purposes, individual pollutants are separated into two categories of chemical toxicity depending on whether they exhibit noncarcinogenic or carcinogenic effects. Classification into these categories is related to fundamentally different views of the mechanisms of action involved in the two cases. Since the chemicals of concern for this public health evaluation are the PCDDs and PCDFs which are classified as potential carcinogens, as seen below, only the effects of potential carcinogens will be discussed herein.

In the case of chemicals exhibiting carcinogenic effects, most authorities recognize that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is recognized to be a non-threshold mechanism since there is essentially no level of exposure (i.e., a threshold) for a carcinogen which does not result in some finite possibility of generating the disease.

EPA's Carcinogen Assessment Group (CAG) has developed cancer potency factors for estimating the upperbound excess lifetime cancer risks associated with various levels of lifetime exposure to potential human carcinogens. In practice, cancer potency factors are derived from the results of human epidemiology studies or chronic animal bioassays. The data from animal studies are fitted to the linearized multistage model and a dose-response curve is obtained. The low-dose slope of the dose-response is subjected to various adjustments and an interspecies scaling factor is applied to derive the cancer potency factor for humans. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an ad hoc basis. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. While the actual risk is unlikely to be higher than the estimated risk, it could considerably lower.

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are two families of compounds believed to share a common mechanism of action, with individual congeners differing widely in potency. Toxicity profiles of these two classes of compounds are found in Appendix K. The most biologically active congeners tend to be chlorinated at the 2,3,7,8-position. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) is commonly considered to be the most potent of the PCDD/PCDF compounds and as a result, is the most thoroughly studied. For regulatory purposes, the relative potencies of the other PCDDs/PCDFs are often based on a comparison with that of 2,3,7,8-TCDD.

2,3,7,8-TCDD has been shown to be carcinogenic when administered orally or dermally to mice or rats (Kociba et al. 1978; NTP 1982a,b). EPA's CAG calculated the 2,3,7,8-TCDD cancer potency factor, which is the 95th percentile confidence limit on the slope of the line relating response to dose (or risk to exposure), to be 1.6×10^{5} $(mg/kg/day)^{-1}$. It should be noted that the actual mechanism of carcinogenic action of 2,3,7,8-TCDD is under debate. However, at this time it is appropriate to use the EPA's CAG cancer potency factor in site-specific risk assessments involving 2,3,7,8-TCDD.

Although a considerable amount of data is available on 2,3,7,8-TCDD, less information is available on other PCDD/PCDFs. For this reason, EPA (Bellin and Barnes 1986) has established interim procedures for estimating risks associated with exposure to PCDDs/PCDFs, based on their potency relative to that of 2,3,7,8-TCDD. The toxicity equivalence factors (TEFs) derived using a comparison of relative potencies are presented in Table 5-1. To estimate the potency of complex PCDD or PCDF mixtures, the concentrations of the congeners in each congener group are multiplied by an appropriate TEF. For example, to derive a potency factor for a mixture of heptachlorodibenzodioxins (HpCDDs), the quantity of HpCDDs chlorinated at the 2,3, 7, and 8 positions would be multiplied by a factor of 0.001, and the remaining quantity of HpCDDs would be multiplied by 0.00001 to obtain a TEF. Thus, according to the EPA toxicity ranking scheme, HpCDDs are considered to be 1000 to 100,000 times less potent than TCDD.

5.3 EXPOSURE ASSESSMENT

The potential pathways by which human populations could be exposed to contaminants at or originating form the Pristine, Inc. site will be

TABLE 5-1

EPA INTERIM PROCEDURES FOR DEVELOPING TOXICITY EQUIVALENT FACTORS FOR CHLORINATED DIBENZODIOXINS AND DIBENZOFURANS[a]

COMPOUND	TOXICITY FACTOR (relative to 2,3,7,8-TCDD)
<u>Chlorinated Dibenzodioxins (PCDDs)</u>	
Monochlorodibenzodioxins	0
through Trichlorodibenzodioxins	0
2,3,7,8 TCDDs	1
Other TCDDs	0.01
2,3,7,8 Penta CDDs [b]	0.5
Other Penta CDDs	0.005
2,3,7,8 Hexa CDDs [b]	0.04
Other Hexa CDDs	0.0004
2,3,7,8 Hepta CDDs[b]	0.001
Other Hepta CDDs	0.00001
Octa CDDs	0
<u>Chlorinated Dibenxofurans (PCDFs)</u>	
2,3,7,8 Tetra CDFs	0.1
Other Tetra CDFs	0.001
2,3,7,8 Penta CDFs[b]	0.1
Other Penta CDFs	0.001
2,3,7,8 Hexa CDFs[b]	0.01
Other Hexa CDFs	0.0001
2,3,7,8 Hepta CDFs[b]	0.001
Other Hepta CDFs	0.00001

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[a] This methodology for deriving Toxicity Equipment Factors is currently under discussion at EPA. It does not constitute Agency poloicy at this time.

[b] This terminology is used to refer to chlorination at positions 2, 3 7, and 8. Since the molecule may contain 5 (penta), 6 (hexa), or 7 (hepta) chlorines, other positions will be chlorinated as well.

addressed based on the site and surrounding area under both current- and future-use scenarios. In addition, in order to estimate exposures of potentially exposed populations concentrations of chemicals of potential concern in environmental media at points of potential exposure are estimated.

An important step in identifying exposure pathways is to determine the mechanisms by which PCDDs and PCDFs may migrate in the environment. The potential for migration is influenced by the environmental chemistry of the compounds which will influence their fate and transport. This will first be discussed in the context of the Pristine, Inc. site. The next section will be a determination of the exposure pathways which will be evaluated in this assessment.

5.3.1 Environmental Fate and Transport

In general, the migration of any organic compound through the soil is governed by the water solubility of the compound and its propensity to bind to soil organic matter. The organic carbon/water partition coefficient, K_{oc}, describes the extent to which an organic chemical partitions itself between the organic carbon in soil and water. Chemicals with high K_{oc}s have a high propensity to bind to soil and not to readily become dissolved in water. Table 5-2 presents the physicochemical properties of some PCDDs and PCDFs, including their K_{oc}s.

The PCDDs and PCDFs have low solubilities, as seen in Table 5-2, which limits their vertical mobility through soils, particularly those with a high organic carbon content. It has been estimated that for a soil with 1% organic carbon (per dry weight of soil) and 30% water by volume, about 99.99% of the 2,3,7,8-TCDD will be sorbed on the soil at equilibrium (Podoll et al. 1986). Migration of PCDDs and PCDFs sorbed onto surface soil or sediment could occur due to storm events, tracking, wind dispersion, or natural surface water cycling.

While 2,3,7,8-tetrachlorodibenzo-p-dioxin will preferentially bind to the soils at the site, a small fraction (0.01% as discussed above) will become solubilized and migrate through the soils. Thus, it is possible that some of the PCDDs and PCDFs will reach the lower aquifer at Pristine, Inc. and migrate towards the Reading well field.

The soils can act as a source of PCDDs and PCDFs to the on-site pond or Mill Creek as the result of surface water transport during a storm. Once in these surface water bodies, volatilization of these compounds could occur. Additionally, volatilization from the soils themselves could occur.

The volatilization of dissolved PCDDs from a surface water body may occur in the environment. Podoll et al. (1986) estimated volatilization of 2,3,7,8-TCDD from a "model" pond and river by the

TABLE 5-2

PHYSIOCOCHEMICAL PROPERTIES OF SOME POLYCHLORINATED DIBENZO-p-DIOXINS AND FURANS

	2,3,7,8-TCDD[f]	PeCDD[f]	HxCDD[f]	2,3,7,8-TCDF[f]
Molecular Weight	321.9	356.5	390.9	
Vapor Pressure, (mm Hg) at 25°C and 1 Atm	[a] $1.7\text{x}10^{06}$ [a] $1.0\text{x}10^{-6}$	NA	NA	[e] $2.0\text{x}10^{-6}$
Water Solubility (mg/l) at 25°C	[a] 0.2 [b] 0.019	[a] 0.04	[a] 0.008	
Kow	[a] $1.4\text{x}10^{6}$ [a] $6.9\text{x}10^{6}$ [a] $1.9\text{x}10^{7}$ [a] $1.4\text{x}10^{6}$ [c] $4.24\text{x}10^{6}$ [d] $1.04\text{x}10^{7}$	[a] $7\text{x}10^{7}$	$4.2\text{x}10^{7}$	[d,e] $6.6\text{x}10^{5}$
Koc	[a] $9.9\text{x}10^{5}$ [a] $3.3\text{x}10^{6}$	[a] $5\text{x}10^{6}$	[a] $3\text{x}10^{7}$	

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[a] USEPA 1985a.
[b] Marple, Brunck, and Throop 1986, measured at 22°C.
[c] Marple, Berridge, and Throop 1986; average value.
[d] Burkhard and Kuehl 1986.
[e] USEPA 1986e.
[f] 2,3,7,8-TCDD = 2,3,7,8-tetrachloradibenzo-p-dioxin, PeCDD = pentachlorodibenzodioxin, HxCDD = hexachlorodibenzodioxin, 2,3,7,8-TCDF = 2,3,7,8-tetrachlorodibenzofuran.

two-film method. The authors calculated relatively short half-lives of 32 days for a pond and 16 days for a river; such estimations are valuable for they indicate that volatilization may occur, but it must be stressed that these half-lives depend greatly on site specific parameters such as depth of the water, turbulence of air and water phases, and the amount of suspended solid in the water body. A similar calculation using the model EXAMs and incorporating sorption of TCDD onto both suspended and bottom sediment resulted in half-lives from a pond and lake on the order of 5 and 12 years, respectively (USEPA 1985a).

Volatilization of PCDDs in dry soils can be expected to occur in proportion to its attenuated vapor pressure in the sorbed state (Podoll et al. 1986). In Seveso, TCDD diminished rapidly in soil during the first six months after the ICMESA accident; after this period, no further decreases were noted i.e. half-life greater than 10 years (di Domenico et al.1984). The authors hypothesized that the levels of TCDD decreased at a rate which ultimately reached steady state and attributed the initial decrease to a combination of volatilization, photolysis, and vertical movement through the soil by heavy rains.

Several processes could contribute to the removal of PCDDs and PCDFs from the Pristine, Inc. site soils. These include photolysis, biodegradation, and biouptake, which will be discussed below.

PCDDs and PCDFs are capable of undergoing photolytic changes under ambient conditions; the importance of this process with respect to the degradation of PCDDs and PCDFs may well depend on the media they are found. Although significant photolytic degradation of TCDD has occurred on a precoated silica plate, many studies have indicated that negligible decomposition occurs on soil (USEPA 1985a).

PCDDs and PCDFs are believed to be resistent to metabolism by soil microorganisms, and biogradation is not considered to be an important transformation process for PCDDs as a chemical class (USEPA 1985a).

The high K_{ow} values of PCDDs and PCDFs indicate that bioaccumulation is likely to occur, although such partitioning will be species specific and dependent upon rates of metabolism. The half-life of 2,3,7,8-TCDD in a single exposed primate is reported as approximately one year (Weerasinghe et al. 1985).

5.3.2 Identification of Exposure Pathways

An exposure pathway is defined by four elements: (1) a source and mechanism of chemical release to the environment, (2) an envriornmental transport medium for the released chemical, (3) a point of potential exposure by the receptor with the contaminated medium, and (4) a route of exposure. A pathway is considered "complete" if all four elements are present. The first two elements of an exposure pathway have been addressed above in the discussion of the environment fate and transport of PCDDs and PCDFs.

During the previous RI, it was determined that potentially significant complete exposure pathways included direct contact, ingestion, or inhalation of contaminants present in or released from the soil, surface water, or groundwater. As part of the current, supplemental RI, only exposure pathways dependent upon releases of PCDDs and PCDFs from the soil will be evaluated since pcdds and PCDFs were analyzed only in this medium. Thus, the exposure scenarios that will be considered here under current-use scenarios are direct contact with soils, volatilization from soils, ingestion of groundwater at the Reading well field contaminated by compounds originating in the soils and under the future-use scenario ingestion of groundwater at the Pristine, Inc. site and surface water runoff to Mill Creek.

For each of the complete pathways presented in the public health evaluation of the main RI, exposure scenarios were developed. For each scenario that applies here, as discussed above, two exposure cases—an average case and a plausible maximum case, are considered. For the average exposure case, the geometric mean of the PCDD/PCDF concentrations, expressed as 2,3,7,8-TCDD equivalents, is used with what are considered to be the most likely (although conservative) exposure conditions. For the plausible maximum case, the highest measured PCDD/PCDF concentration is used together with high estimates of the range of potential exposure parameters relating to frequency and duration of exposure and the quantity of contaminated media contacted.

5.3.3 Estimation of Exposure Point Concentrations—Current-Use Scenario

Data collected during the supplemental RI will be used to estimate the concentrations of contaminants that might reach potentially exposed populations. The estimated concentrations will be determined using the methodology presented in the original RI.

5.3.3.1 Direct Contact with Contaminated Soil

Human populations can be exposed to the PCDDs/PCDFs in the surface soils adjacent to the buildings on the site. One method of exposure to contaminated soils is through dermal contact and subsequent incidental ingestion. The site is fenced on three side, with direct access available only through the Cincinnati Drum Service facility. Any individuals coming into contact with the soils on the site would be potentially exposed to the PCDDs/PCDFs present in them. Table 5-3 summarizes the concentrations of the congeners detected in the soil as well as calculating the TEF for each. The total concentration for each sample location was used to calculate the geometric mean

TABLE 5-3
SUMMARY OF DIOXIN EQUIVALENCIES
PRISTINE, INC. SITE

SAMPLE LOCATION

		SA2803		SA3003		SA3403		IRS103		IRS203	
COMPOUND	TEFs	CONC.	TEF	CONC.	TEF	CONC.	TEF	CONC.	TEF	CONC.	TEF
2378-TCDD	1	ND	0.000	3.392	3.392	ND	0	ND	0	ND	0
TOTAL TCDD	0.01	6.717	0.067	99.451	0.995	ND	0	0.788	0.008	21.261	0.213
12378-PCDD	0.5	ND	0.000	8.33	4.165	ND	0	ND	0	2.388	1.194
TOTAL PCDD		11.028	0.000	171.432	0.000	0.662	0.000	ND	0	14.49	0.000
123478-HxCDD	0.04	ND	0.000	8.554	0.342	ND	0	ND	0	ND	0
123678-HxCDD	0.04	16.092	0.644	24.023	0.961	ND	0	20.266	0.811	6.936	0.277
123789-HxCDD	0.04	12.889	0.516	26.658	1.066	ND	0	16.852	0.674	ND	0
TOTAL HxCDD		165.938	0.000	305.882	0.000	ND	0	174.48	0.000	34.415	0.000
1234678-HpCDD	0.001	284.003	0.284	292.81	0.293	ND	0	353.434	0.353	93.394	0.093
TOTAL HpCDD		605.444	0.000	579.926	0.000	40.163	0.000	675.281	0.000	172.059	0.000
OCDD	0	2490.486	0.000	2082.211	0.000	454.978	0.000	3864.559	0.000	609.92	0.000
2378-TCDF	0.1	43.697	4.370	230.999	23.100	ND	0	57.015	5.702	41.233	4.123
TOTAL TCDF		1620.444	0.000	1203.283	0.000	0.297	0.000	484.927	0.000	270.222	0.000
12378-PCDF	0.1	5.303	0.530	35.497	3.550	ND	0	ND	0	ND	0
23478-PCDF	0.1	9.37	0.937	62.871	6.287	ND	0	24.141	2.414	12.197	1.220
TOTAL PCDF		75.301	0.000	408.21	0.000	ND	0	90.428	0.000	70.778	0.000
123478-HxCDF	0.01	16.766	0.168	87.387	0.874	ND	0	47.77	0.478	18.639	0.186
123678-HxCDF	0.01	9.683	0.097	47.36	0.474	ND	0	20.833	0.208	8.711	0.087
234678-HxCDF	0.01	8.45	0.084	46.872	0.469	0.372	0.004	ND	0	ND	0
123789-HxCDF	0.01	ND	0.000	ND	0.000	ND	0	ND	0	ND	0
TOTAL HxCDF		56.846	0.000	354.265	0.000	1.996	0.000	156.668	0	64.393	0.000
1234678-HpCDF	0.001	50.414	0.050	170.076	0.170	ND	0	88.666	0.089	38.242	0.038
1234789-HpCDF	0.001	ND	0.000	19.513	0.020	ND	0	14.836	0.015	ND	0
TOTAL HpCDF		108.779	0.000	292.861	0.000	ND	0	182.804	0.000	69.234	0.000
OCDF	0	120.74	0.000	179.718	0.000	ND	0	170.974	0.000	ND	0
TOTAL 2378-TCDD EQUIVALENTS			7.746817		46.156		0.004		10.751		7.432

concentration, 14.31 ng/kg, for the average case scenario. The maximum concentration is 48.79 ng/kg.

5.3.3.2 Exposure via the Air Pathway

The air exposure pathway is defined by the volatilization of PCDDs/PCDFs from the soil to the air. The importance of this pathway has been discussed in Section 5.3.1 of this chapter. The model used in the public health evaluation in the RI is used for this assessment.

The model described by Shen (1982) was used to estimate the air emission rates from soils at the Pristine, Inc. site. The model estimates volatilization as a function of the chemical and physical properties of the compound and the properties of the soil such as poposity, soil density, and depth.

The air-related fate of volatile organic chemicals is dependent upon soil conditions. Highly organic soils retard diffusion and mass transport because of the sorptive interactions between the soil particles and the PCDDs/PCDFs. Highly porous and dry soils have a higher diffusion rate because there is more air space through which the PCDDs/PCDFs can move. The soils at the Pristine, Inc. site were assumed to have a soil porosity of 0.35.

The concentration of a contaminant released to the air spaces within the soil is defined as:

$$C_{sa} = \frac{C_i I_i MW_i}{RT}$$

where

C_{sa} = concentration in air spaces of soil (g/cm^3);

C_i = concentration in the soil (weight fraction, ng/ng);

P_i = vapor pressure (1.70×10^{-6} mm Hg);

MW_i = molecular weight (322 g/mole);

R = gas constant (6.24×10^4 cm^3-mm Hg/mol-K); and

T = absolute temperature (298 K).

The emission rate from the soil is calculated by:

$$E_i = \frac{C_{sa} D_i A O_T^{4/3}}{Z}$$

where

E_i = emission rate of a compound (g/sec);

D_i = diffusion coeficient (0.05303 cm^2/sec;

A = exposed area (1.21×10^8 cm^2);

O_T = total soil porosity (0.35); and

Z = effective depth of soil cover (30.5 cm).

The emission rate are estimated for two cases: an average case calculated using the mean PCDDs/PCDFs concentration in the soil and the plausible maximum case calculated using the maximum PCDDs/PCDFs concentration.

The emission model predicts the rate at which the PCDDs/PCDFs diffuse through the soil to the surface. Once the chemicals are released, they will be transported downwind to the potential receptors. The emission rate calculated above can be used in an atmospheric transport model to predict the concentration at the downwind receptors. A simple box model rather than a Gaussian dispersion model is used for the Pristine, Inc. site because the downwind receptors are less than one-eighth of a mile from the site.

The box model adapted from Hanna et al. (1982) assumes that there are no reductions in concentrations as a result of meteorological effects (e.g., dispersion) or topographical features (e.g., trees and shrubs). These assumptions are valid for the Pristine, Inc. site , although slightly conservative. The air path from the site to the trailer park (the nearest downwind receptor) is clear until the row of trees on the edge of the trailer park alongside the railroad tracks. The average concentration of each contaminant in the air is calculated using the emission rate, E_i, calculated above as follows:

$$C_{air} = \frac{E_i}{r\ U\ 1}$$

where

r = atmospheric mixing zone (400 m) (USEPA 1972);

U = average wind speed (4.1 m/sec) (NOAA 1984); and

l = length of soil area (164 m).

The concentration of the PCDDs/PCDFs is calculated for the average and plausible maximum cases. The concentrations calculated were 4.87×10^{-22} g/m^3 and 1.67×10^{-21} g/m^3 for the average and plausible maximum cases, respectively. Because the box model assumes no dispersion, estimates of on-site exposure to the PCDDs/PCDFs will be the same.

5.3.3.3 Groundwater

The hydrogeology beneath the Pristine, Inc. site is complex, although some generalizations can be made concerning contaminant transport. The primary concern is contaminant transport into the lower aquifer which is used regionally as a water supply. The groundwater was not analyzed for PCDDs/PCDFs during the Phase 2 RI field work, as a result, a model can be used to predict the concentration on the TEFs that will reach the groundwater and the Reading well field.

A model was developed to calculate contaminant concentrations in groundwater at the Pristine, Inc. site that would predict concentrations that could be expected in the lower outwash aquifer over time. This model is conservative in that it assumes that all of the contamination in the soils reaches this aquifer and is only diluted with infiltrating rainwater. It is assumed that the other groundwater lenses do not exist.

The model assumes that a certain percentage of the rainfall at the site will infiltrate the site and desorb contaminants from the soil based on a equilibrium soil-water partitioning. It is further assumed that this contaminated infiltration will mix completely with the groundwater below the site, resulting in an equilibrium groundwater concentration.

The mixing of groundwater and infiltration and the resultant contaminant concentrations in groundwater are related as follows (Summers et al. 1980):

$$C_{gw} = \frac{Q_p C_p}{Q_p + Q_{gw}}$$

where

C_{gw} = contaminant concentration in the groundwater (ug/l);

Q_p = volumetric flow rate of infiltration (soil pore water) into the groundwater (ft^3/day);

Q_{gw} = volumetric flow rate of groundwater (ft^3/day; and

C_p = contaminant concentration in the infiltration.

The volumetric flow rate of infiltration, Q_p, is derived from the percentage of the total rainfall from the site (reported as approximately 40 inches in the RI report) that is attributed to recharge to groundwater flow systems or 15 percent (Fidler 1970) or approximately 6 inches per year. This quantity of rain is assumed to fall over the entire area of the site or 120,000 square feet corresponding to a volumetric infiltration rate of 164 ft^3/day. The volumetric flow rate of groundwater, Q_{gw}, is estimated as the average linear groundwater velocity times the area of the aquifer perpendicular to the groundwater flow across the contaminated area of the site:

$$Q_{gw} = (V)(L)$$

where

V = groundwater velocity = (k)(h),

where

k = hydraulic permeability (140 ft/day)
h = hydraulic gradient (0.00245 ft/ft); and

L = length of the site perpendicular to flow (600 ft); and

D = depth of the aquifer or mixing zone (43.3 ft).

The depth of the mixing zone is taken to be one-third the depth that the Reading municipal wells are screened. The other parameters listed above are taken from the Pristine, Inc. site RI report. The volumetric groundwater flow rate is calculated to be 8900 ft^3/day. The ratio of Q_p to Q_{gw} plus Q_p (0.018) is used to estimate concentrations in the groundwater of the organic compounds detected in the soil.

The concentration in the infiltrating groundwater, C_p, can be predicted using a soil-water partitioning model, expressed as:

$$C_p = C_s/K_d$$

where

C_s = soil concentration (ug/kg);

Cp = concentration in infiltration (ug/liter); and

K_s = soil-water equilibrium partition coefficient (liter/kg).

The soil data considered in this evaluation are those taken during the Phase 2 RI, and discussed above. Partition coefficients, K_d, were derived by multiplying the organic carbon partition coefficient, K_{oc}, by the fraction of organic carbon, f_{oc}, as seen by

$$K_d = K_{oc} * f_{oc}$$

where

K_d = soil-water equilibrium partition coefficient (liter/kg);

K_{oc} = organic carbon partition coefficient (2.95×10^6 liter/kg); and

f_{oc} = fraction of organic carbon (0.005)

The fraction of organic carbon is assumed to be 0.5% based on the descriptions of the soil presented in the RI report. The presence of greater amounts of organic carbon in the soil would retard the movement of the organic compounds present at the Pristine, Inc. site. Thus this model could overestimate the migration potential of the PCDDs/PCDFs from the Pristine, Inc. soils to the groundwater.

The model assumes an equilibrium partitioning of the contaminant between the soil and the soil pore water, which may occur after a long period of time. The model, therefore, probably overestimates the concentration in groundwater associated with an actual soil concentration. It is assumed that the entire site is the source of PCDDs/PCDFs rather than the localized area where it was detected. The model does not account for attenuation of the contaminants in the unsaturated zone. It further assumes that all of the contamination reaches the lower outwash aquifer. The presence of the groundwater aquifer lenses would act to further dilute and possibly attenuate the contaminants released from the site. The predicted concentrations of PCDDs/PCDFs in the lower aquifer at the Pristine, Inc. site are 1.75×10^{-11} mg/liter for the average case and 5.96×10^{-11} mg/liter for the plausible maximum case.

In the public health evaluation of the Pristine, Inc. site RI, it was assumed that the groundwater from the site contributed 12% to the overall amount of groundwater reaching the Reading well field. This assumption is used to calculate the concentration of site related contaminants at the well field. The predicted groundwater concentrations at the Reading well field are 2.1 x 10^{-12} mg/liter and 7.2 x 10^{-12} mg/liter for the average and plausible maximum cases, respectively.

5.3.4 Estimation of Exposure Point Concentrations--Future-Use Scenario

5.3.4.1 Groundwater

In the absence of institution controls limiting access or future uses of the Pristine, Inc. site, the ingestion of groundwater originating from a drinking water well installed in the lower aquifer at the site must be evaluated. Since groundwater measurements were not taken for PCDDs/PCDFs, the groundwater model presented in section 5.3.3.3 can be used to predict the concentrations of PCDDs/PCDFs reaching the lower aquifer.

It is assumed that the concentration of PCDDs/PCDFs in the soil remains constant over time. This is a reasonable assumption since di Domenico et al. (1984) found that in the first six months after the ICMESA accident, the levels Of TCDD reached a steady state. At Pristine, Inc. the incinerator (the likely source of PCDDs/PCDFs) has been inoperative for a number of years an hence the concentrations of these compounds in the soil are likely to remain constant. Thus, using the groundwater leaching model, the concentration of PCDDs/PCDFs in the groundwater is predicted to be 1.8 x 10^{-11} mg/liter for the average case and 6.0 x 10^{-11} mg/liter for the plausible maximum case.

5.3.4.2 Surface Water

In the public health evaluation under future-use conditions, one route of exposure was the transport of contaminants via the drainage ditches to Mill Creek. This is still a complete pathway, however it is unlikely to contribute significantly to the offsite transport of the PCDDs/PCDFs from the Pristine, Inc. site. The PCDD/PCDF soil contamination is concentrated in the areas surrounding the buildings. PCDDs/PCDFs were not found elsewhere at the Pristine, Inc. site. Thus, it does not appear as if the PCDD/PCDF contaminated soil is being transported across the site toward the drainage ditches and ultimately to Mill Creek. As a result, this pathway will not be quantified in this public health evaluation.

5.4 RISK CHARACTERIZATION

In this section, information on the potential levels of exposure to PCDDs/PCDFs is combined with information on the toxicity of these compounds to determine the health risks to individuals living near or working near the Pristine, Inc. site. In Section 5.4.1, the general toxicological principles and assumptions used in evaluating potential human health risks are discussed. Potential exposures and associated human health risks under current- and future-use conditions are discussed in Sections 5.4.2 and 5.4.3, respectively.

5.4.1 General Principles

5.4.1.1 Comparison to Applicable or Relevant and Appropriate Requirements

Guidance provided in the Superfund Public Health Evaluation Manual (USEPA 1986a) directs that concentrations or contaminants at exposure points should be compared with applicable or relevant and appropriate requirements (ARARs). There are no ARARs available for the PCDDs and PCDFs. The Centers for Disease Control (CDC) has set a guidance level of 1 ug/kg 2,3,7,8-TCDD in residential soils and 5 ug/kg 2,3,7,8-TCDD in commercial areas (Kimbrough et al.1984). Since ARARs are not available, a quantitative exposure and risk assessment must be performed (USEPA 1986a).

5.4.1.2 Quantitative Risk Assessment

Evaluation of the risks associated with oral, inhalation, and dermal exposure to PCDDs/PCDFs at the Pristine, Inc. site is based primarily on a comparison of the estimated chemical intakes with appropriate guidelines for the protection of human health.

Human exposures to PCDDs/PCDFs for the Pristine, Inc. site are determined using conservative assumptions for exposure assessment. Conservative assumptions tend to overestimate exposure so that the final estimate of exposure will be near to or higher than the upper end of the range of actual exposures. Human exposure is expressed in terms of intake, which is the amount of a substance taken into the body per unit body weight per unit time, or mg/kg/day. A chronic daily intake (CDI) is averaged over a lifetime for carcinogens (USEPA 1986b). The CDI is calculated separately for each exposure pathway, since different populations at risk may be affected by the individual pathways.

For chemicals exhibiting carcinogenic effects, lifetime excess cancer risks (upperbound) are estimated. The cumulative dose received during the period of exposure and averaged over the lifetime of the exposed individual (CDI) is multiplied by the cancer potency factor (PF) to yield the upperbound lifetime excess risk : Risk = CDI x PF, for risk levels of 10^{-2} or less. Regulatory agencies have proposed risk management decisions for potential carcinogens based on estimated risk levels ranging from 10^{-7} to 10^{-4}. A risk level of 10^{-6}, representing an upperbound probability that one excess cancer case in 1,000,000 individuals might result from exposure to the potential carcinogen, is often used as a benchmark by regulatory agencies. Accordingly, 10^{-6} will be the target level expressed in this report.

5.4.2 Estimation of Exposure and Assessment of Risk Under Current Conditions

In this section, exposure point concentrations are used to estimate the extent of human exposure to PCDDs/PCDFs at the Pristine, Inc. site. As has been discussed previously, there are three exposure pathways that may have a potential impact on human health under current land use conditions. These are exposure via direct contact with soil, volatilization of PCDDs/PCDFs from soil, and leaching of PCDDs/PCDFs from soils to groundwater reaching the Reading well field.

5.4.2.1 Soil

The direct ingestion of contaminated soil is a potentially significant route of exposure, especially for children who constitute the most sensitive population for this exposure. Young children may ingest contaminated dirt by normal mouthing of soiled objects and of their hands, or by pica, the direct consumption of dirt. Older children are less likely to eat soil or to mouth soiled objects, but they may inadvertently ingest dirt from their hands. In the following assessment, it is assumed that older children 6 to 11 years old play in the soil on the site. As additional assumption is that dermal exposure is the same for older children and adults.

Two exposure scenarios are considered in this assessment. The average case assumes that older children are on the site two times a week during the warmer months of the year (May to September). The geometric mean concentration of PCDDs/PCDFs in the surface soils was used in this scenario. The plausible maximum case assumes that children visit the site five times a week during the warmer months or 100 times a year and are exposed to the maximum concentration of PCDDs/PCDFs in the soil. The basis for estimating the amount of soil contacting the skin and the amount of soil inadvertently consumed per day by older children is given below and in Appendix L.

Average and plausible maximum incidental soil ingestion rates for children are 50 and 250 mg/visit, respectively. The derivation of these rates is discussed in Appendix L, and was based primarily on the work of Binder et al. (1986), van Wijnen et al (1986), and Hawley (1985).

Absorption factors were established for exposure resulting from incidental ingestion of outdoor soil to address the potential bioavailability of the PCDDs/PCDFs when absorbed on soil particles. The absorption factors for the PCDDs/PCDFs were derived from several studies on the gastrointestinal absorption of soil-adsorbed 2,3,7,8-TCDD (Poiger and Schlatter 1980, McConnel et al. 1984, Lucier et al. 1986). The experimental evidence indicates that PCDDs/PCDFs are less readily absorbed through the gastrointestinal tract when adsorbed on soil. The fraction that became bioavailable was dependent in part on the composition of the soil matrix (e.g., amount of organic carbon) and the length of contact between the soil and the chemical. A value of 35% was used for the average case and 50% was used for plausible maximum case to reflect this diminished bioavailability based on physicochemical properties and the studies mentioned above.

Values of 1 g/day and 5 g/day are used as the average and plausible maximum estimates of soil contact rates of dermal exposure for children. These values are contact rates for each exposure event and are based on a consideration of contact rates in mg soil/cm^2 skin (0.5-1.5 mg/cm^2) from Schaum (1984), surface area of parts of the body that are likely to be in contact with soil (e.g., approximately 250 cm^2 for the palms of the hands) from EPA (1985b), and of certain subjective factors (i.e., children have less surface area than adults but are more likely to play in soil). These are reasonable values, but hey are another source of uncertainty in the risk calculation.

Poigner and Schlatter (1980) noted that approximately 5% of the TCDD applied to rat skin was absorbed from a soil and water paste. Direct analogy to the Poigner and Schlatter study probably overestimates absorption through human skin because rodent skin is much more permeable than human skin (Feldman and Maibach 1974), absorption is likely to be higher from a soil and water paste than from drier soil, and TCDD was added to the paste only 10-15 hours before application and therefore was not fully adsorbed. Based on a consideration of the available data and the bioavailability of PCDDs/PCDFs from soil, a value of 0.3% will be used for the average dermal absorption rate and a value of 3% will be used for the plausible maximum dermal absorption rate.

Table 5-4 summarizes the assumptions used in the direct contact with soil exposure scenarios. Using these assumptions, the chronic daily intake for children exposed to PCDDs/PCDFs in soil by direct ingestion of the soil and by dermal absorption of PCDDs/PCDFs from the soil can be calculated by the following:

$$CDIs = DI_I + DI_A$$

where

CDI_S = chronic daily intake from soil (mg/kg/day);

DI_I = daily intake via ingestion; and

DI_A = daily intake form dermal absorption.

TABLE 5-4

ASSUMPTIONS USED IN ESTIMATING EXPOSURE VIA T CONTACT WITH SOILS AT THE PRISTINE, INC. E

Parameter	Average Case	Plausible Maximum Case
1. Frequency of contact	40 visits/year (2 visits/week for 20 weeks)	100 visits/year (5 visits/week for 20 weeks)
2. Ages of children exposed	6 - 11 years	6 - 11 years
3. Average weight over period of exposure	30 kg	30 kg
4. Years of exposure	6	6
5. Incidental ingestion of contaminated soil	50 mg/visit	250 mg/visit
6. Fraction absorbed due to ingestion	0.35	0.50
7. Quantity of soil coming into contact with skin per exposure event	1 g	5 g
8. Fraction absorbed through skin	0.003	0.03
9. Concentration of PCDDs/PCDFs	14.3 ng/kg	48.8 ng/kg

The chronic daily intake of PCDDs/PCDFs for the incidental ingestion of soil can be calculated by:

$$DI_I = \frac{(C_s)(I)(AI)(E)(YR)(X)}{(BW)(D)\ (LT)}$$

where

DI_I = daily intake via ingestion (mg/kg/day);

C_s = concentration of 2,3,7,8-TCDD TEF in soil (mg/kg);

I = amount of soil ingested (mg/event);

AI = differential absorption factor;

E = number of exposure events (event/year);

YR = years of exposure (years);

X = conversion factor (kg/10^6 mg);

BW = average body weight (kg); and

LT = years in a lifetime (70 years); and

D = days in a year (365 day/year).

The average and plausible maximum daily intakes due to incidental soil ingestion are 7.8×10^{-14} mg/kg/day and 4.8×10^{-12} mg/kg/day, respectively.

Intake estimates for dermal absorption of PCDDs/PCDFs are estimated as follows:

$$DI_A = \frac{(C_s)(CD)(E)(YR)(Z)(ABS)}{(BW)(D)\ (LT)}$$

where

DI_A = daily intake from dermal absoroption (mg/kg/day);

C_s = concentration of 2,3,7,8-TCDD TEF in soil (mg/kg);

CD = contact rate for soil (g/event);

ABS = dermal absorption factor;

E = number of exposure events (event/year);

YR = years of exposure (years);

Z = conversion factor (kg/1000 g);

BW = average body weight (kg);

LT = years in a lifetime (70 years); and

D = days in a year (365 days/year).

The average daily intakes due to dermal absorption are 1.3×10^{-14} mg/kg/day for the average exposure scenario and 5.7×10^{-12} mg/kg/day for the plausible maximum exposure scenario.

The chronic daily intake for PCDDs/PCDFs expressed as 2,3,7,8-TCDD equivalents prorated over a 70 year lifetime would then correspond to 9.2×10^{-14} mg/kg/day and 1.0×10^{-11} mg/kg/day for the average and plausible maximum cases, respectively. The lifetime excess cancer risk (upperbound) associated with direct contact with soils at the Pristine, Inc. site under the average exposure scenario is 1×10^{-8}. Under the conditions and assumptions of the plausible maximum exposure scenario, the lifetime excess cancer risk (upperbound) associated with exposure to PCDDs/PCDFs in soils is 2×10^{-6}.

5.4.2.2 Air

The air exposure pathway has been described previously and the concentrations derived in section 5.3.3.2 can be used to estimate the risks associated with the volatilization of PCDDs/PCDFs from the soils at the Pristine, Inc. site. During the public health evaluation for the RI, it was determined that exposure via the inhalation of dust would be minimal due to the fact that the site was becoming revegetated with grasses.

The chronic daily intake for exposure to PCDDs/PCDFs released to the air can be calculated using the following equation:

$$CDI_a = \frac{(C_{air})(IR)}{BW}$$

where

CDI_a = chronic daily intake from air (mg/kg/day)

C_{air} = concentration in air (mg/day);

IR = inhalation rate (20 m^3/day); and

BW = body weight (70 kg).

The exposure point concentrations, C_{air}, were presented in section 5.3.3.2. The chronic daily intakes are 1.4×10^{-19} mg/kg/day for the average exposure scenario and 4.8×10^{-19} mg/kg/day for the plausible maximum exposure scenario. The corresponding upperbound excess lifetime cancer risks associated with daily exposure over a 70 year lifetime are 2×10^{-14} and 8×10^{-14} for the average and plausible maximum exposure scenarios, respectively.

5.4.2.3 Exposure to Groundwater

Exposure to chemicals in groundwater occurs primarily by ingesting the water. The chronic daily intakes for the ingestion of groundwater can be calculated by assuming that a 70 kg individual drinks 2 liters of groundwater originating at the Reading well field every day for a lifetime using the following equation:

$$CDI_w = \frac{(C_w)(I)}{BW}$$

where

CDI_w = chronic daily intake due to groundwater exposure (mg/kg/day);

C_w = concentration of PCDDs/PCDFs in water (mg/liter);

I = quantity of water ingested (2 liters/day); and

BW = body weight (70 kg).

The daily intakes resulting from exposure to groundwater are 6.0×10^{-14} mg/kg/day and 2.0×10^{-13} mg/kg/day for the average and plausible maximum exposure scenarios, respectively. The corresponding upperbound excess lifetime cancer risks are 1×10^{-8} for the average case and 3×10^{-8} for the plausible maximum case.

5.4.3 Estimation of Exposure and Assessment of Risk Under Future Conditions

In the absence of future remedial actions and institutional actions limiting access to the Pristine, Inc. site, the routes of exposure quantified above for the current-use scenarios would also apply in the future. Quantification of these exposure scenarios will not be repeated in this section.

Use of the groundwater at the Pristine, Inc. site as a household or industrial tap water supply could occur in the future. Under this future use scenario, individuals may be exposed to PCDDs/PCDFs in the groundwater by direct ingestion of tap water.

5.4.3.1 Ingestion of Groundwater

Under this scenario, the average individual is assumed to weigh 70 kg and drink 2 liters of water each day for 70 years. Based on these assumptions and the predicted concentrations of PCDDs/PCDFs in the lower aquifer at the Pristine, Inc. site chronic daily intakes were derived using the equation presented in Section 5.4.2.3 for groundwater ingestion under current-use conditions. For the average exposure case, the chronic daily intake was calculated to be 5.0×10^{-13} mg/kg/day. The upperbound excess cancer risk associated with this chronic daily intake is 8×10^{-8}. The chronic daily intake for the plausible maximum case was determined to be 1.7×10^{-12} mg/kg/day. The corresponding upperbound excess cancer risk is 3×10^{-7}.

5.4.4 Uncertainties in Risk Assessment

The procedures and inputs used to assess potential human health risks in this public health evaluation are subject to a wide variety of uncertainties. In general, there are six main sources of uncertainty:

- Environmental chemistry sampling and analysis
- Environmental parameter measurement
- Fate and transport modeling
- Exposure parameter estimation
- Toxicological data
- Errors through combinations of the above

Below is a general discussion for these areas of uncertainty.

Environmental chemistry sampling and analysis errors can stem from the error inherent in the procedures, from a failure to take an adequate number of samples to arrive at sufficient areal resolution, from mistakes on the part of the sampler, or from the heterogeneity of the matrix being sampled. One of the most effective ways of minimizing procedural or systematic error is to subject the data to a strict quality control review. Even with all data rigorously quality assured, however, there is still error inherent in all analytical procedures, and it is still not possible to definitively determine if the sample is truly representative of site conditions.

The absence of environmental parameter measurements also contributes to uncertainly. Lack of site-specific measurements dictates that estimates must be made based on literature values, regression equations, extrapolations, and/or best professional judgment.

Modeling errors can stem from a lack of validation or verification of the models. Typically, an order of magnitude result is considered to be satisfactory for most complex modeling scenarios.

There are inherent uncertainties in determining the exposure parameters that are combined with toxicological information to assess risk. For example, there are a number of uncertainties regarding assumptions in estimating the likelihood that an individual would come into contact with contaminants originating at the site, the concentration of compounds in the environmental medium of concern and period of time over which the exposures would occur. Conservative assumptions regarding constant concentrations of contaminants over time have been made in this assessment; however, neither biodegradation or dispersion have been considered.

Toxicological data error is probably the largest source of uncertainty in his risk assessment. As EPA noted in its Guidelines for Carcinogenic Risk Assessment. (USEPA 1986b):

> There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to geometric constitution, diet, occupational and home environment, activity patterns, and other cultural factors.

All of these individual errors from different sources may be propagated into larger errors by mathematical combination in the risk assessment. For purposes of evaluating remedial alternatives under Superfund, however, risk assessments provide a useful decision-making tool despite the uncertainties. Risk assessments provide a method to compare various exposure routes, which can then be used to determine if and how remedial actions should be taken.

5.5 CONCLUSIONS

This supplemental public health evaluation for the Pristine, Inc. site is a baseline assessment, which evaluates potential impacts to human health in the absence of remedial action under both current- and future-use scenarios. This assessment evaluated exposure to human populations to the polychlorinated dibenzo-p-dioxins and the polychlorinated dibenzofurans, expressed as 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalents (2,3,7,8-TCDD TEFs). The findings are summarized below. It should be noted that this public health evaluation is designed to be a companion to the previous public health evaluation and should not be used to replace the original public health evaluation which considered all of the chemicals detected at the Pristine, Inc. site.

Under current land-use conditions at the Pristine, Inc. site, the principal exposure pathways by which human receptors could potentially be exposed to PCDDs/PCDFs were:

- Direct contact with surface soils;
- Inhalation of PCDDs/PCDFs volatilized from soils; and
- Ingestion of PCDDs/PCDFs in groundwater originating at the Reading well field.

Average and plausible maximum exposure scenarios were developed for each of these pathways. The exposure point concentrations of the PCDDs/PCDFs were estimated for the potentially exposed populations. Human health risks were assessed based on these estimates of exposure and a quantitative description of the toxicity of 2,3,7,8-TCDD. The major conclusions of this assessment are summarized below:

- Exposure of children to on-site soil through dermal contact and incidental ingestion could result in potential excess lifetime cancer risks (upperbound) of 1×10^{-8} and 2×10^{-6} for the average and plausible maximum scenarios, respectively.
- Inhalation of PCDDs/PCDFs released from soil via volatilization by nearby residents or on-site receptors could result in potential excess lifetime cancer risks (upperbound) of 2×10^{-14} for the average case scenario and 8×10^{-14} for the plausible maximum scenario.
- Ingestion of groundwater at the Reading well field assuming a 12% contribution from the Pristine, Inc. site could result in a potential upperbound excess lifetime cancer risk of 1×10^{-8} and 3×10^{-6} for the average and plausible maximum cases, respectively,

The exposure scenarios described above would apply for possible future land-use conditions. In addition, an exposure pathway related to groundwater use of the lower aquifer at the Pristine, Inc. site was considered. Average and plausible maximum exposure scenarios for the ingestion of this water were developed. The conclusions can be summarized below:

- Ingestion of groundwater from a well screened in the lower aquifer at the Pristine, Inc. site, could result in potential upperbound lifetime excess cancer risks of 8×10^{-8} and 3×10^{-7} for the average and plausible maximum cases.

The risks that were determined in this supplemental public health evaluation should be considered additive to those risks determined in the finalized Remedial Investigation Report. The only scenario that would be effected by the addition of the PCDDs/PCDFs as chemical of concern is the dermal contact and incidental ingestion of soils. Adding the potential risk determined in both public health evaluations together, the exposure to on-site soil could result in potential excess lifetime cancer risks (upperbound) of 2×10^{-6} and 3×10^{-4} for the average and plausible maximum cases, respectively. The potential risks from the other scenarios would remain unchanged.

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ADDENDUM

REMEDIAL INVESTIGATION REPORT
FOR
PRISTINE, INC. SITE
READING, OHIO

APPENDICES

DOCUMENT NO.: 115-RI2-RT-FNGU-1

APPENDIX A

EXECUTIVE SUMMARY
FINAL REMEDIAL INVESTIGATION REPORT

EXECUTIVE SUMMARY

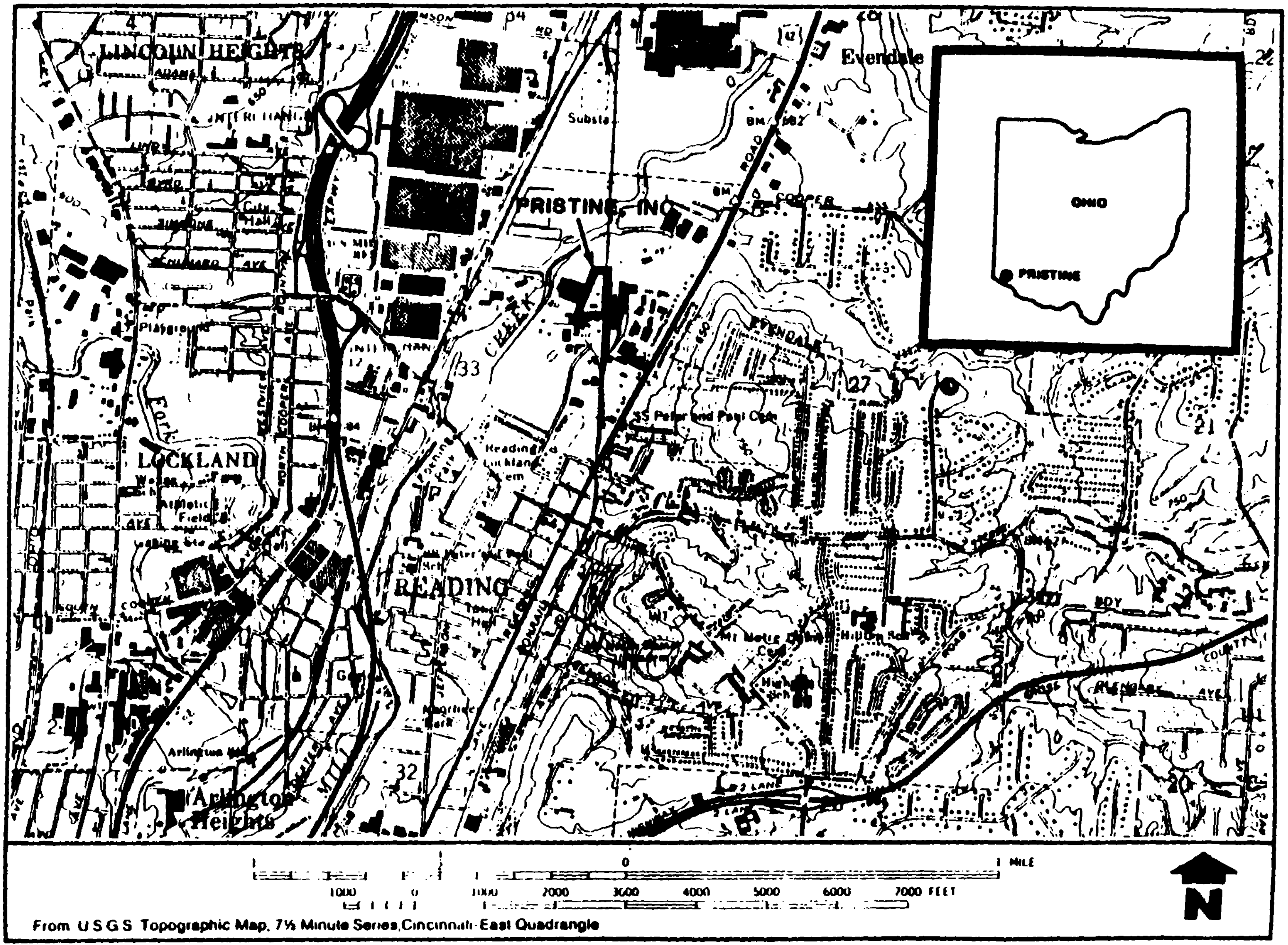
Overview of the RI Process and Objectives

This report presents the results of the Remedial Investigation (RI) conducted by U.S. EPA at the Pristine, Incorporated site in the City of Reading, Ohio. The Remedial Investigation was conducted under the authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or more commonly, "Superfund"). Remedial Investigations are conducted at all sites listed on the National Priorities List (NPL) of uncontrolled hazardous waste sites. These investigations provided the initial basis for the ultimate design and implementation of corrective, remedial actions. The RI, therefore, has several major objectives. The principal objective of a RI is to accurately characterize the site to determine the need for, and extent of any corrective action. In order to determine the need for remedial action, RI activities examine the nature of the site with respect to the types of contamination present, quantities of contamination present, and potential pathways by which contamination may affect public health or environment. Based upon the results of detailed sampling and analysis, a comprehensive evaluation of the actual and potential threat to public health and the environment is conducted. This phase of the RI, referred to as the Public Health Evaluation, examines all available data and assesses the concentration of contaminants and the effect of public exposure via all routes.

In general terms, the final outcome of a Remedial Investigation is a compilation of detailed data on site conditions, contaminant types and quantities and an evaluation of the degree of actual and potential public health threat. The final RI report presents the results of all field and analytical activities and provides the basis for development of remedial cleanup alternatives. Remedial alternatives, if warranted, are identified and evaluated during the next stage of the process -- the Feasibility Study (FS).

Site Description

The Pristine, Inc., site is located in southwestern Ohio in the City of Reading (population 12,843), a suburb of Cincinnati. The site occupies approximately five acres in the northeast quarter of Section 33, Township 4, Range 1 in Hamilton County Ohio (Figure 1). The site is bordered by residential and industrial areas (Figure 2). Industrial operations owned by Cincinnati Drum Service and Carstab Corporation are located to the west and south of the facility. Cincinnati Drum Service cleans, reclaims, and recycles steel drums. Carstab Corporation manufactures synthetic stabilizers and plasticizers. The immediate eastern limit of the site is bordered by Conrail Railroad right-of-way. On the other side of the tracks, further to the east and southeast, is a grain elevator. Northeast of the site, beyond the railroad is a residential trailer park. The land to the north is owned by the City of Reading. Three municipal water supply wells, serving the citizens of Reading are approximately 300 feet northwest of the site.



From USGS Topographic Map, 7½ Minute Series, Cincinnati-East Quadrangle

FIGURE 1
VICINITY MAP
PRISTINE,INC.

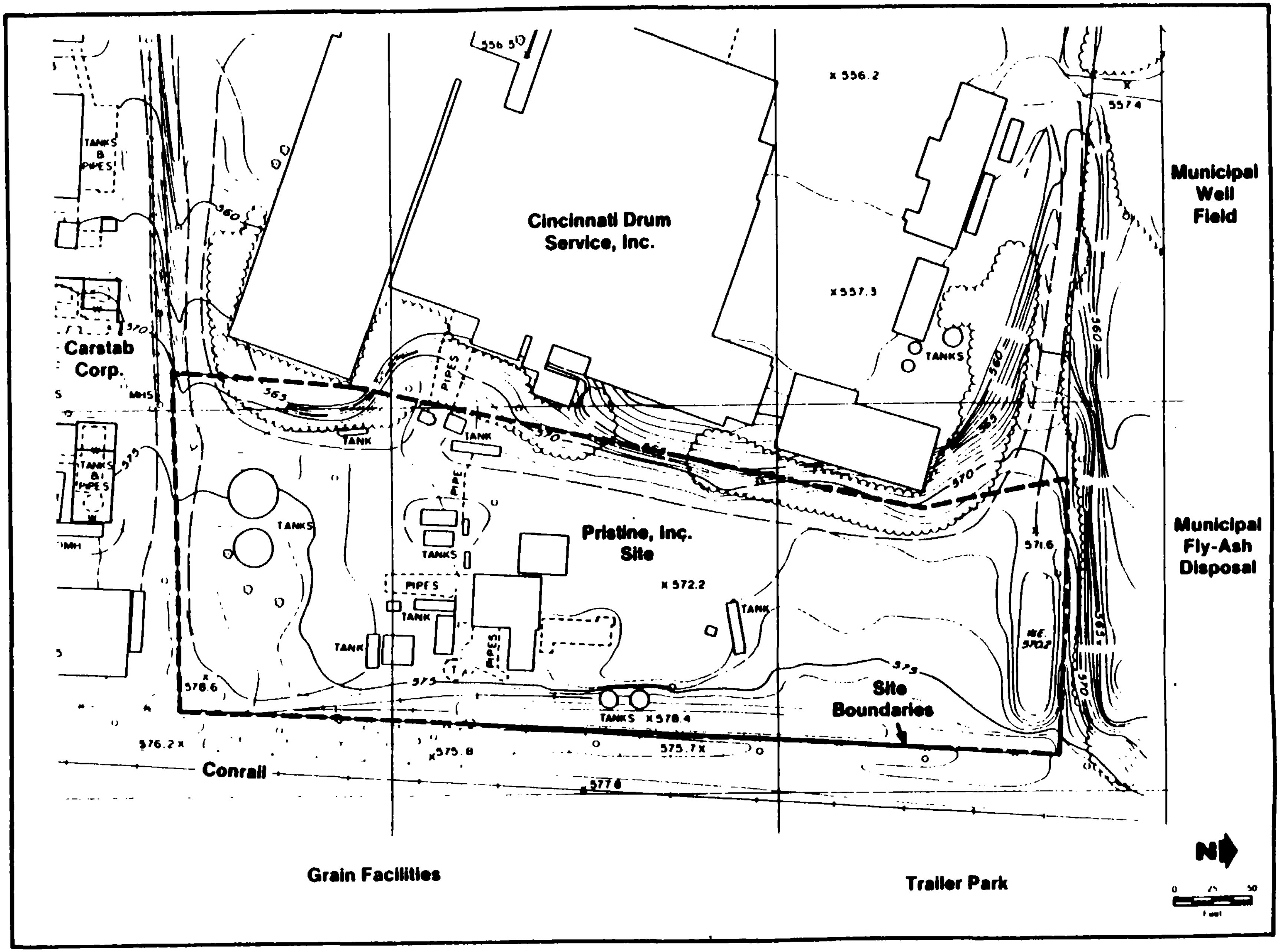


FIGURE 2
SITE MAP
PRISTINE, INC.

The buildings and facilities which were used during past operations at the Pristine, Inc., site still exist (Figure 2). A concrete pad is present in the area north of the buildings that was used as a mixing area. The pad is uneven, cracked, and intermittently ponds water during rainfall events. Much of the site is unvegetated and shows evidence of soil removal activities undertaken during May through July of 1984. The site is situated on a low terrace that is about ten feet higher than the Mill Creek flood plain immediately to the west of the site. The Pristine, Inc. site does not lie within the 100 year flood plain or a designated wetlands. Site surface water runoff generally flows off site toward the Mill Creek.

The site geology consists of five distinct soil units (Figure 3). The upper most unit consists of zero to ten feet of brown and gray fill. Underlying the fill unit is a sequence of upper lake sediment and outwash deposits. This unit ranges from zero to 46 feet in thickness and consists of three separate outwash lenses within a large lake sediment deposit. The third unit, underlying the lake sediment and outwash sequence, is a glacial till layer ranging from 10 to 45 feet in thickness. Beneath the glacial till is the lower lake sediment unit which is distinctly different from the upper lake sediment unit. The lower lake sediments are approximately 15 feet thick. Underlying the lower lake sediments is a lower outwash unit. The thickness of the unit cannot be determined from on-site data. The lower outwash aquifer is the principal regional water supply aquifer. Most notably, the nearby Reading municipal wells, northwest of the site, are completed in the lower outwash deposit. Results of the field investigation indicate groundwater flow direction in the lower water supply aquifer is toward the southwest.

Site History

Pristine, Inc. began liquid waste disposal operations at the site in November 1974. Prior to this, the site had been used for the manufacturing of sulfuric acid. In the spring of 1977, Pristine Inc. obtained a permit to operate a liquid waste incinerator. In April 1979, as many as 8,000 to 10,000 drums and several hundred thousand gallons of bulk liquids were on site, consisting of acids, solvents, pesticides, PCB's and other, chemicals. Disposal operations were ordered shut down in September, 1981, in accord with a partial consent order with the State of Ohio. In August 1982, the Hazard Ranking System (HRS) was used to review the site. In accordance with procedures established under Subpart F, Section 300.66 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), the Pristine, Inc. site was added to the National Priorities List (NPL) in December 1982.

From June 1980 to November 1983, much of the waste at the site was removed in accordance with consent decree between Pristine, Inc. and the Ohio EPA. Some of the wastes stored, and subsequently removed from the site during this period, included paint sludges, lab packs, flammable solvents, cyanide wastes, pesticides, chlorinated solvent sludge, DDT, "neutralized" acid sludge, PCB-contaminated soils,

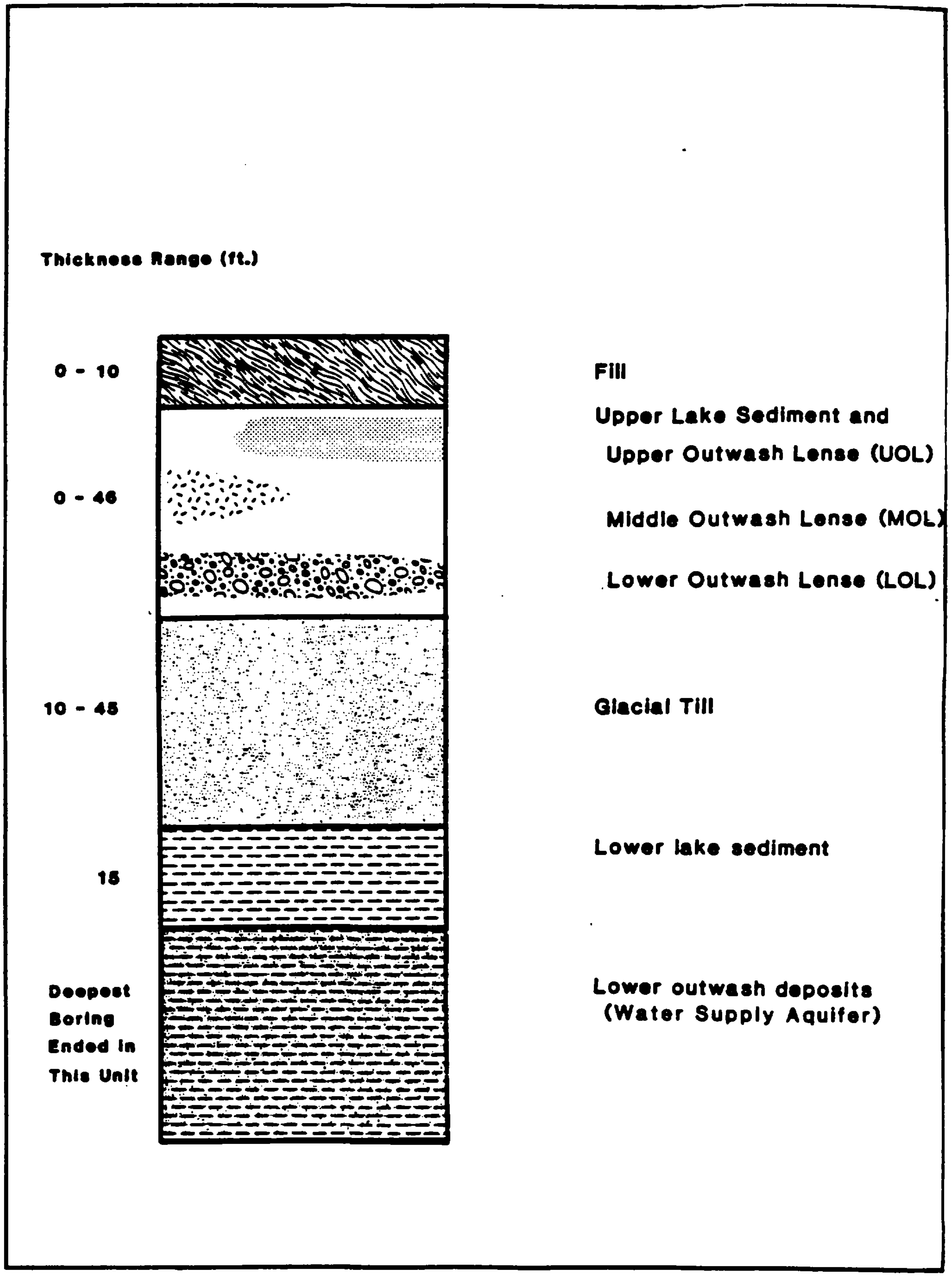


FIGURE 3

GENERALIZED STRATIGRAPHY

PRISTINE, INC. SITE

incinerator ash, solvent/sludge mixture and unknown waste mixtures, Between March 1984 and July 1984, additional follow-up waste removal and surficial cleanup activities were performed by some of the potentially responsible parties under authority of a CERCLA 106 (a) administrative order. During this period, sludges from several tanks and pits were removed. In addition, approximately 500 cubic yards of contaminated soils and sludges from the collection pond were removed. The collection pond was subsequently relined. The cleanup activities undertaken between 1980 and 1984 addressed immediate hazardous or dangerous site conditions. The activities did not, however address the long term risks attributed to the site.

In May 1985, the U.S. EPA initiated a field Remedial Investigation designed to document, define, and characterize the actual and potential threats to the public health and the environment. The RI field effort was completed in September 1985 and this report presents and summarizes the results.

CURRENT SITE STATUS

RESULTS OF THE REMEDIAL INVESTIGATION

Based on review of historical practices at the site and data compiled from state and federal files regarding the site, the RI focused on:

- Sampling and analysis of soils to determine the presence, character, and extent of residual contamination in the near-surface soils;
- Sampling and analysis of groundwater to determine the presence, character, and magnitude of groundwater contamination both on site and in immediately adjacent, off-site areas;
- Sampling and analysis of water supply wells to determine whether groundwater currently being pumped by the municipal or industrial water supply wells in the immediate vicinity is contaminated; and,
- Sampling and analysis of surface water, sediments, and stormwater to determine whether contamination has migrated from the site.

Results of the RI are presented in detail in Sections 1 through 5. Section 1 through 4 present results corresponding to the pathways listed above and should be consulted for detailed review. Section 5 presents the results of the Public Health Evaluation. A summary of the range of concentrations of some of the organic and inorganic compounds detected at the Pristine, Inc. site is presented in Table 1. Investigative samples were collected from locations shown in Figure 4. A brief summary of significant results in each of the media sampled is presented in the following paragraphs.

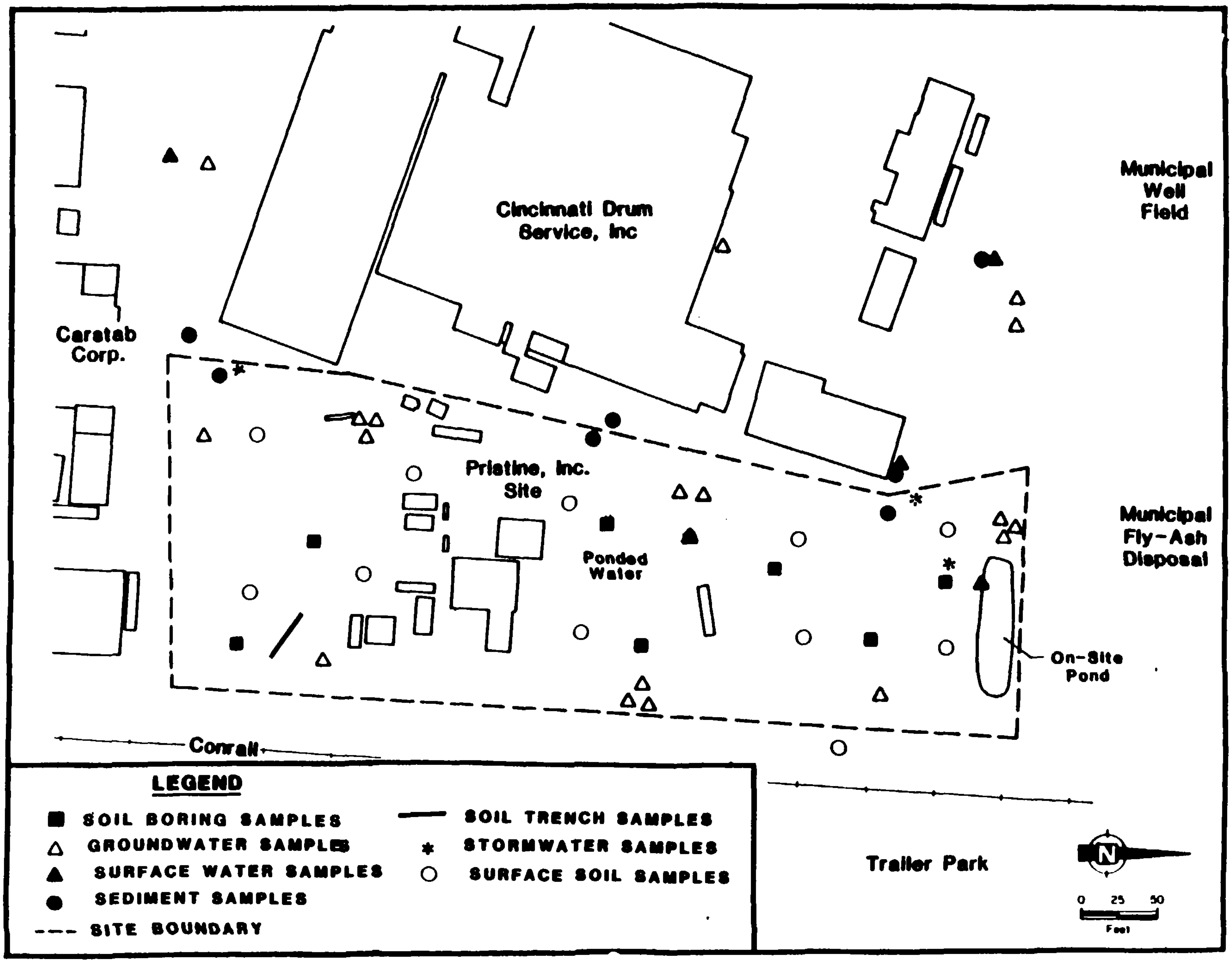


FIGURE 4 SAMPLING LOCATIONS PRISTINE, INC. SITE

TABLE 1

RANGE OF CHEMICAL CONSTITUENTS DETECTED AT PRISTINE, INC. IN PPB

CHEMICAL CONSTITUENTS	SOIL AREA SAMPLES (Surficial Soils)	SOIL TRENCH SAMPLES (Subsurface Soils)	SOIL BORING SAMPLES (Subsurface soils)	MONITORING WELL SAMPLES		WATER SUPPLY SAMPLES (Lower Aquifer)	SURFACE WATER SAMPLES	SEDIMENT SAMPLES	STORM-WATER SAMPLES
				(Upper Aquifer)	(Lower Aquifer)				
<u>ORGANIC COMPOUNDS</u>									
VINYL CHLORIDE	0	0	0	0-830	0	0	0	0	0
TETRACHLOROETHENE	0-120,000	0	0-430	0-7,500	0	0	0-250	0-504	0
BENZENE	0	0-1,200	0-27,000	0-34,000	0-3	0-9.5	0-9.3	0-12	0
1,2-DICHLOROETHANE	0-110	0-3,500	0-6,200	0-41,000	0-750	0-170	0-6,200	0-2,400	0
PHENOL	0-470	410-6,200	0-18,000	0-4,500	0	0	0-230	0-987	0
BENZO(a)PYRENE	0-640	0-200	0	0	0	0	0	0	0
DIELDRIN	0-1,500	0	0-74	0	0	0	0	0-75	0-0.2
4,4'-DDE	0-3,000	0	0-370	0	0	0	0-0.86	0-1,800	0-0.06
4,4'-DDD	0-1,600	0	0-2,100	0-0.14	0	0	0-0.78	0-1,700	0-0.24
4,4'-DDT	0-10,000	0	0-18,000	0	0	0	0-1.82	0-21,000	0-1.5
<u>INORGANIC COMPOUNDS</u>									
CADMIUM	0-26,000	0	0-8,500	0-39	0-9.4	0-6.44	0-136	0-45,000	6.1-20
FLUORIDE	202,000-470,000	NOT ANALYZED	0-476,000	170-27,000	100-2,000	0-400	0-3,400	NOT ANALYZED	820-2000
LEAD	23,000-2,560,000	10,000-77,000	0-258,000	0-178	0-148	0-4.6	0-383	0-2,410,000	59-768
MERCURY	0-8,000	0-160	0-980	0-0.44	0-0.021	0-0.1	0-1.1	0-15,000	0-6.6

SOIL

Investigation of on-site soil contamination involved collection and analysis of surface soils, and collection of subsurface soils through soil borings and excavation of a test trench. Analysis of on-site soils revealed the occurrence of a variety of volatile and semi-volatile organic compounds as well as pesticides. Principal contaminants in surface soils were pesticides (e.g., dieldrin and DDT).

Subsurface soils from the trench excavation and borings contained volatile organic compounds (e.g., tetrachloroethene and benzene) in addition to semi-volatile compounds (e.g., phenol and 1,2-Dichlorobenzene). There were no pesticides detected in the soil trench samples, but pesticides were detected in the borings (e.g., dieldrin and DDT). Analysis of on-site soils also revealed elevated concentrations of inorganic compounds including cadmium, lead, mercury, and zinc.

GROUNDWATER

Groundwater was investigated through the installation of 18 monitoring wells and collection of 30 groundwater samples during two seasons. Highly soluble volatile organic compounds (e.g., benzene, vinyl chloride, tetrachloroethene) were the primary contaminants in the groundwater. Semi-volatile compounds and pesticides occurred in relatively lower concentrations. Results of the analysis for inorganic compound revealed elevated concentrations of iron, lead, magnesium and fluoride.

Eight water supply wells, situated northwest of the site which provide potable water to residents of Reading were sampled. Low levels of volatile organic compounds were detected in the municipal wells during both sampling rounds. The Agency for Toxic Substances and Disease Registry (ATSDR) reviewed the data and concluded the trace levels of organics present in some of the wells do not present immediate health concerns; however, their presence in the water indicates that the groundwater quality in the vicinity is compromised. Elevated levels of iron and manganese exceed the Secondary Drinking Water Regulation levels. The levels of iron and manganese are aesthetically based for taste and odor and, consequently, their presence in the water risk of no known human health concern.

The direction of groundwater flow in the lower aquifer (water supply aquifer) was determined during the RI Field Investigation. The direction of groundwater flow was determined to be in a south to southwesterly direction; and, it was determined that the conditions at the site do not appear to currently affect groundwater quality in the Reading well field. It is possible that future municipal and industrial pumping will influence the direction of groundwater flow and that changes that are presently occurring in the pumping centers of the area will alter the direction of groundwater flow at some time in the future.

SURFACE WATER AND SEDIMENTS

Evaluation of surface waters, sediments associated with surface water bodies and stormwater runoff was conducted. Results indicate that surface water were contaminated with volatile and semi-volatile organic compounds and low concentrations of pesticides (i.e., trans-1,2-dichloroethene, phenol, and DDT). Results of inorganic analysis indicated elevated levels of arsenic, cadmium, copper, lead, and silver in the surface water. Sediments associated with surface water were found to contain a variety of volatile organic compounds, semi-volatile organic compounds and pesticides. Elevated levels of inorganic compounds (i.e., cadmium, chromium, copper, magnesium, and mercury) were detected in the sediment samples. Experimental collection of stormwater runoff during period of rainfall determined that very low concentrations of contaminants were detected in stormwater runoff. The contaminants were primarily pesticides (i.e., dieldrin and DDT) at concentrations of less than one ppb. Elevated levels of inorganic compounds were not detected.

PUBLIC HEALTH EVALUATION

Section 5 is a baseline public health evaluation (PHE) that assesses the potential risks to public health and the environment associated with exposure to contaminants from the Pristine, Inc. site.

A subset of 9 of the more than 90 compounds detected in the soil, sediment, surface water, groundwater, and stormwater runoff at the Pristine, Inc. sit under present site conditions were selected as indicator chemicals. The indicator chemicals were chosen so that they represented the most highly concentrated, toxic, mobile, widely distributed, or persistent compounds at the site and, therefore, pose the greatest potential risk to human health and the environment. The indicator chemicals were benzo(a)pyrene, benzene, cadmium, dieldrin, fluoride, lead, phenol, tetrachloroethene, and vinyl chloride.

Several potential exposure pathways considered to pose a threat to human health and the environment were evaluated. These included skin contact and incidental swallowing of soil, drinking of groundwater from the Reading water supply wells, assuming these wells intercept groundwater from the site some time in the future, and inhaling volatile chemicals emitted from soils and surface water. In addition, assuming Mill Creek is used for recreational use in the future, skin contact and incidental swallowing of water in Mill Creek that had been contaminated by stormwater runoff was considered.

Current conditions at the site pose a low hazard from inhaling contaminants with a potential carcinogenic risk of 10^{-9} and 10^{-7} for most probable and worst case conditions. A 10^{-9} risk corresponds to the chance that one excess cancer case in 1,000,000,000 individuals might result from a lifetime exposure under most probable case conditions. Contact with the contaminated soil could constitute a hazard if the length of exposure was on the order of several years and occurred for several hours a day. A potential carcinogenic risk of 10^{-6} and greater then 10^{-4} for the most probable and for the worst case has been considered. A 10^{-6} risk corresponds to the chance that one excess cancer case in 1,000,000 individuals might result from a lifetime exposure under most probable case conditions. Ingestion of site groundwater, if it is intercepted by the Reading well field, will represent the greatest risk or potential hazard. An individual exposed to contaminants reaching the Reading well field under the most probable and worst-case exposure conditions considered this document would experience lifetime excess cancer risk 10^{-4} and 10^{-2}, respectively. A 10^{-4} risk is the chance that one excess cancer case in 10,000 individuals might result from a lifetime exposure under most-probable case conditions should the Pristine, Inc. water intersect the Reading well field.

Based upon the results of the Remedial Investigation including the evaluation of public health threats, the U.S. EPA will be proceeding with a Feasibility Study. The Feasibility Study will focus on identifying remedial alternatives to mitigate actual and potential health and environmental threats. Remedial alternatives will be reviewed in accordance with technical, institutional, health, environmental, and economic criteria specified in November 1985 revision of the National Contingency Plan (400 CFR Subpart F 300.68) and in accord with all laws that are applicable or relevant and appropriate to the Pristine, Inc. site.

APPENDIX B

PROJECT ACTIVITIES AND MILESTONES

WASTE TREATMENT, STORAGE AND DISPOSAL OPERATIONS

This part of the site chronology covers the period from November 1974, when Pristine, Inc. began its liquid waste disposal operations, to June 11, 1980, when a complaint and partial consent decree relating to conditions at and operation of the site were filed by the Ohio Attorney General's Office.

November 1974 — Pristine, Inc. begins liquid waste disposal operations.

February 11, 1977 — Ohio EPA issues Pristine, Inc. a permit to operate a liquid waste incinerator effective March 28, 1977; the permit is good for three years.

1977 to 1979 — Ohio EPA, division of Air Pollution Control records numerous and repeated violations of Ohio's air pollution regulation relative to organic vapor emissions and excessive smoke from the incinerator.

April 4, 1979 — Ohio EPA conducts a site inspection. Between 8,000 and 10,000 drums of waste and 13 bulk storage tanks containing several hundred thousand gallons of waste each are found on site. Gross contamination of the surface soils, due to leakage from the drums and tanks, is noted.

April to August, 1979 — Additional air pollution violation are logged by the Ohio EPA, including fumes from neutralization or adipoyl chloride.

August to December 1979 — Ohio EPA prepares modifications to the terms and conditions of Pristine, Inc.'s permit to operate the incinerator. Air pollution violations continue to occur.

December 4, 1979 — Ohio EPA issues modifications to Pristine, Inc.'s permit to operate methods and use of control equipment, permissible waste types and sampling of incoming wastes, and maintenance and malfunction records.

January 22, 1980 — City of Reading Fire Chief orders Pristine, Inc. to discontinue operations for failure to correct fire code violations documented in August 1979.

February 19, 1980 — Pristine, Inc. allowed to re-open and operate if done so within a new set of guidelines. Two days later, an air pollution violation is logged.

March 4, 1980 — In accordance with modified permit to operate, Pristine, Inc. was to be required to reduce waste inventory to 2,000 drum equivalents by this date; this requirement was not met.

March 21, 1980 — Ohio EPA's efforts to achieve compliance with the modified permit to operate at Pristine, Inc. are referred to the Ohio Attorney General's office.

April 10, 1980 — U.S. EPA personnel conduct a SPCC inspection of the Pristine, Inc. site and issue a Notice of Violation for failure to comply with the regulations. An enforcement sampling survey is conducted at the same time in conjunction with Ohio EPA personnel.

June 11, 1980 — Ohio Attorney General's Office, representing Ohio EPA, files a complaint in Court of Common Pleas, Hamilton County, Ohio, requesting improvement of site compliance with applicable rules and regulation pertaining to the Pristine, Inc. site. A partial consent decree is filed at the same time, enjoining Pristine, Inc. to cease operation of its incinerator and discontinue receipt of wastes, except to the extent that such actions are in full compliance with the provisions of the consent decree.

REMEDIAL RESPONSE ACTIONS

This section covers the period from June 11, 1980, to October 9, 1984. During this period, the activities at the site were primarily directed toward improving environmental conditions at the site. This section includes activities performed by Pristine, Inc. as well as those performed by the U.S. EPA.

June 16, 1980 — Per partial consent decree: Pristine, Inc. to submit a SPCC plan in compliance with and including provisions of consent decree (plan submitted, not acceptable).

June 30, 1980 — Per partial consent decree: all wastes to be removed from within buildings (not completed), pumps and sumps to be installed to make the incinerator's wet scrubber system a closed loop (completed), interlock between fuel feed and scrubber water pressure to be installed (not completed), continuous temperature recording to be installed on incinerator (completed), plan for characterizing incoming wastes to be submitted (not completed).

July 15, 1980 — Per partial consent decree: plan for sampling containers of unknown waste to be submitted (completed), plan for disposal of contents of large storage tank (#1) to be submitted (completed).

September 15, 1980 — Per partial consent decree: on-site drum inventory to be reduced to 1,000 drums (not completed), contents of second large storage tank (#2) to be properly disposed of (not completed), leaking or open drums to be repaired or covered (not completed), all activities at open neutralization pit to cease (not completed), certain specified wastes (>5 ppm PCB, >5% halogenated hydrocarbons, cyanides, insecticides, pesticides, herbicides, rodenticides) to be removed from site (not completed).

October 1, 1980 — Ohio EPA conducts site inspection to document status of compliance with partial consent decree; a total of 4,615 drums are counted and the total volume of wastes in 8 bulk storage tanks is estimated to be 154,479 gallons.

November 1980 — Several site inspections are made to determine the status of compliance with consent decree.

December 4, 1980 — State of Ohio files contempt charges for noncompliance with provisions of partial consent decree of June 11, 1980.

December 23, 1980 — Per partial consent decree: total inventory to be reduced to 55,000 gallons (not completed), all storage areas to consist of curbed concrete pads (not completed), new caustic scrubber system to be installed (not completed), trial burns and stack testing to be performed (not completed).

January 31, 1981 — Per partial consent decree, Pristine, Inc. to have complied with all provisions of the consent decree; continued operation of the incinerator dependent on compliance status (Pristine not in compliance). State of Ohio files to find Pristine, Inc. in contempt for failure to comply.

May 6, 1981 — A Nunc Pro Tunc order is filed finding Pristine, Inc. in contempt of court for failure to comply with the partial consent order of June 11, 1980; Pristine ordered to purge itself of contempt by complying with provisions of original order in accordance with a revised schedule.

May 20, 1981 — Site inspection by Ohio EPA personnel reveals that approximately 20 to 30 drums have been punctured with a pick-axe and allowed to drain into the soil.

June 20, 1981 — Following the filing of additional contempt charges, a second Nunc Pro Tunc order is filed, extending the compliance schedule again.

August 19, 1981 — An Interim Status inspection is conducted; 59 violations are noted.

September 8, 1981 — Ohio Attorney General's Office files a motion for determination of Pristine's failure to purge itself of contempt, and for a temporary restraining order, which is granted, to cease all incineration and neutralization activities on site and restrict waste activities to removal.

October 8, 1981 — Pristine, Inc. is denied approval for a Hazardous Waste Facility Installation and Operation Permit by the Hazardous Waste Facility Approval Board.

March 22, 1982 — Ohio EPA Southwest District Office receives scoping document from U.S. EPA (Technical Assistance Team) for planned removal action at Pristine, Inc., incorporating results of site status inspection conducted on March 2, 1982. Inspection showed the waste inventory to consist of approximately 300 drum equivalents of paint sludge and contaminated soil contained in three open dumpsters; about 870 drums containing paint sludges, acid sludges, acid, DDT, fatty acids, lab packs, flammable solvents, cyanides, and chlorinated solvent sludge; and about 187,000 gallons of liquids and sludges, predominantly acids and solvents, in 12 bulk storage tanks.

March 1982 — Pristine, Inc. hires Ny-Trex, Inc. of Richfield, Ohio to perform cleanup activities at the site. Over the next several months, approximately 500 cubic yards of bulked contaminated sludges and soils, about 15,600 gallons of bulked drum and tank wastes composed of solvents, acids and PCB-contaminated liquids, and 42 intact drums were removed from the site. At the end of this activity, most of the drummed wastes had been removed from the site.

November 15, 1982 — In a letter to U.S. EPA Region V, Ohio EPA requests that Pristine, Inc. be made eligible for planned removal actions and commits to the required 10% state matching of costs. The detailed scope of the needed removal actions are presented in this submittal.

December 31, 1982 — Pristine, Inc. to have obtained contractor to perform remaining cleanup activities.

January 31, 1983 — Ecolotech, Inc. to have obtained contractor to perform remaining cleanup activities.

February to October 1983 — Ohio EPA continues efforts to get remaining cleanup done by Pristine, Inc. through cooperative and consent agreements. Site visit by CH_2M Hill personnel preparing a RAMP for the site conducted in April 1983.

November 1983 — 33,000 gallons of contaminated water and 3,100 gallons of chlorinated solvents removed.

December 1983 to February 1984 — Efforts to complete cleanup pursued under CERCLA.

March 13, 1984 — A Unilateral Administrative Order was issued under authority of Section 106 (A) of CERCLA to Pristine, Inc. requiring removal of the contents of six tanks, three pits, and visibly contaminated soil. If not performed by the responsible parties, these activities would be done by the U.S. EPA as an emergency removal.

April 3, 1984 — Meeting held between Pristine, Inc. and U.S. EPA to discuss terms of consent order to comply with Administrative Order. The tank contents have been removed, but no other actions have been taken. Deadlines for repair of the runoff collection system and removal of contaminated soil are extended to April 30, 1984 and June 30, 1984, respectively.

April 26, 1984 — Repair work on runoff collection system undertaken. The activated carbon filters were subsequently found to be incompletely removing organic contamination from collection pond discharge.

April 30, 1984 — U.S. EPA and five respondents execute a Consent Order pursuant to Section 106 of CERCLA. The respondents are Pristine, Inc. Riley Kinman, an officer and Principal Manager of Pristine, Inc., and Oren Long, Pauline Long and Jane Long, owners of the site on which the facility is located. The Consent Order provided an extension of time, until June 30, 1984, to complete soil removal and removal of contents of a collection pit, as required in the March 3, 1984 Unilateral Administrative Order.

April 30 to May 10, 1984 — Soil removal activities undertaken. A total of 240 to 300 cubic yards of soil was excavated and taken to licensed off-site disposal facilities.

June 4, 1984 — Pristine, Inc. notifies U.S. EPA of verbal approval of Metropolitan Sewerage District to discharge water from collection pond to nearby sanitary sewers on a temporary basis.

June 27, to July 3, 1984 — Sludge removal activities at the runoff collection pond are undertaken. A total of 180 to 225 cubic yards of contaminated sludge were excavated and taken to a licensed off-site disposal facility.

July 11, 1984 — Samples collected from the bottom of the pond excavation to confirm that enough sludge/soil was removed.

August 20, 1984 — Based on a verbal report of contaminated concentrations found at the bottom of the pond excavation, U.S. EPA decides that the most prudent course of action with respect to the Section 106 Order is to allow partial backfilling and relining of the collection pond.

October 9-10, 1984 — Representatives of the REM II project team meet on site with Ohio and U.S. EPA personnel to review site history, waste disposal and storage practices, and past remedial activities; and to examine the current status of the site.

REMEDIAL INVESTIGATION ACTIVITIES AND MILESTONES

This part of the site chronology covers the period from September 1984 to October 1985 while the field activities of the remedial investigation were being performed.

September 4, 1984 — Work assignment for Pristine, Inc. authorized by U.S. EPA.

September 17, 1984 — Work Plan Memorandum submitted to U.S. EPA.

October 9-10, 1984 — Conducted site visit with Ohio EPA personnel.

October 25, 1984 — Existing Condition Memorandum submitted to U.S. EPA.

November 6, 1984 — Compiled Site Plan submitted to U.S. EPA.

November 15, 1984 — QAPP and Sampling and Analysis Plan submitted to U.S. EPA.

December 4, 1984 — Site Management Plan submitted to REM II and U.S. EPA.

January 8, 1985 — Draft Work Plan submitted to U.S. EPA.

January 28, 1985 — Revised QAPP submitted to U.S. EPA.

February 26, 1985 — Revised QAPP submitted to REM II and U.S. EPA.

March 1, 1985 — Revised Work Plan submitted to U.S. EPA.

April 19, 1985 — Final QAPP sent to REM II and U.S. EPA.

April 23, 1985 — Work Plan approved by U.S. EPA RPM.

April 24, 1985 — Work Plan approved by U.S. EPA, Region V. Mobilization Plan for field work initiated.

April 25, 1985 — Phased feasibility study Plan submitted to U.S. EPA.

May 15, 1985 — Drilling subcontractor was selected.

May 20, 1985 - Mobilization of field facilities began and completed on May 23, 1985.

May 24, 1985 — Six soil samples collected from trench located on the southeast corner of the site. Samples identification numbers include: PI-ST41-01, PI-ST41-DP, PI-ST42-01, PI-ST43-01, PI-ST44-01, PI-ST44-MS.

May 29, 1985 — Seven sediment samples collected from various locations at the site. Sample identification numbers include: PI-SD08-01, PI-SD09-01, PI-SD10-01, PI-SD11-01, PI-SD11-DP, PI-SD12-01, and PI-SD14-MS.

May 30, 1985 — Six surface water samples collected. Sample location and identification number include: collection pond (PI-SF04-01), ditch on the north end of the building (PI-SF05-01), ditch on the north end downstream (PI-SF06-01), pond near road (PI-SF07-01), and (PI-SF07-DP and PI-SF01-BK).

June 3, 1985 — Four stormwater samples collected. Sample location and identification number include: north end swale (PI-SR02-01 and PI-SR02-DP), south end swale (PI-SR03-01 and PI-SR03-02).

June 4, 1985 — Began drilling monitoring well GW52 and completed on June 6, 1985.

June 7, 1985 — Monitoring well GW51 drilled and installed.

June 8, 1958 — Monitoring well GW50 drilled and installed.

June 10, 1985 — Eight water supply samples collected from the Reading well field. Sample location and identification number include: Well #2 (PI-WS15-01), Well #3 (PI-WS16-01), Well #4 (PI-WS17-01), Well #12 (PI-WS18-01), Well #9 (PI-WS19-01), Well #10 (PI-WS20-01), Well #7 (PI-WS21-01), and Well #1 (PI-WS22-01) monitoring well GW53 and GW54 drilled and installed.

June 11, 1985 — Drilled and installed monitoring well GW45.

June 12, 1985 — Drilled and installed monitoring well GW55 and GW56. Eight soil area samples collected from various areas at the site. Sample identification numbers are: PI-SA23-01, PI-SA24-01, PI-SA25-01, PI-SA26-01, PI-SA27-01, PI-SA28-01, PI-SA29-01, and PI-SA30-01.

June 13, 1985 — Drilled and installed monitoring well GW58. Eight soil samples collected from various areas. Sample identification numbers are: PI-SA31-01, PI-SA32-01, PI-SA33-01, PI-SA33-MS, PI-SA33-02, PI-SA34-01, PI-SA34-DP and PI-SA34-02.

June 14, 1985 — Three soil boring areas sampled. Sample identification numbers include: PI-SB35-01 through 05, PI-SB36-01 through 05, PI-SB37-01 through 05.

June 17, 1985 — Drilled and installed monitoring well GW47. Also collected water supply from General Electric Co. wells sample number PI-WSGE-01.

June 18, 1985 — Drilled and installed monitoring well GW46.

June 19, 1985 — Drilled and installed monitoring well GW49. Drilling of monitoring well GW57 began and completed on June 21, 1985.

June 20, 1985 — Drilled and installed monitoring well GW60.

June 21, 1985 — Drilled and installed monitoring wells GW59, GW60A and GW61. Drilling began on monitoring well GW48 and completed on June 24, 1985.

June 22, 1985 — Drilled and installed monitoring well GW62.

June 24, 1985 — Groundwater monitoring wells installation completed.

June 25, 1985 — Groundwater samples from monitoring wells GW50, GW51, and GW52 were collected. Sample identification numbers are: PI-GW52-01, PI-GW51-01, PI-GW50-01 and PI-GW51-DP.

June 26, 1985 — Groundwater samples from monitoring wells GW45, GW46, GW49, GW53, GW57, and GW58 were collected. Sample identification numbers include: PI-GW45-01, PI-GW46-01 and DP, PI-GW49-01, PI-GW53-01, PI-GW57-01, and PI-GW58-01.

June 27, 1985 — Groundwater samples from monitoring wells GW47, GW48, GW55, GW56, GW59, GW60, GW62, and surface water from the tile drain along south access road were collected. Sample identification numbers include: PI-GW47-01, PI-GW48-01, PI-GW55-01, PI-GW56-01, PI-GW59-01, PI-GW60-01, PI-GW62-01, and PI-SFDT-01.

June 28, 1985 — Demobilization of field facilities initiated.

July 1, 1985 — Demobilization completed.

July 31, 1985 — Technical memorandum regarding soil trench, surface water, sediment and water supply submitted to U.S. EPA RPM.

August 16, 1985 — Soil Area and Soil Boring Technical Memorandum was submitted.

August 29, 1985 — Technical memorandum on stormwater and groundwater submitted to U.S. EPA RPM.

September 23, 1985 — Mobilization for second round of groundwater sampling initiated.

September 24, 1985 — Measured water level in all monitoring wells.

September 25, 1985 — Conducted baildown testing on wells GW50, GW51, GW52, GW53, GW56, GW57, GW58, GW59, GW60, and GW62.

September 26, 1985 — Conducted baildown testing on wells GW45, GW-46, GW48, and GW49, collected groundwater samples from wells GW51 and GW52.

September 27, 1985 — Groundwater samples collected from wells GW53, GW56, GW57, GW58, GW59, GW60, GW61, and GW62.

September 29, 1985 — Groundwater samples collected from wells GW-45, GW46, GW48, GW49, and GW50.

October 1, 1985 — Demobilization of second round sampling completed.

This part of the site chronology covers the period from July 1986 to August 1987, while the second phase field activities of the remedial investigation were being performed.

July 17, 1986 — Final RI submitted to U.S. EPA.

December 17, 1986 — Draft Supplemental QAPP for Phase II submitted to U.S. EPA.

December 29, 1986 — Work Plan Tech Memo submitted to U.S. EPA.

January 23, 1987 — Revised Supplemental QAPP submitted to U.S. EPA.

March 17, 1987 — Work Plan Amendment submitted to U.S. EPA.

April 17, 1987 — Draft Request for Applicable, Relevant, and Appropriate Remedial Alternatives submitted to U.S. EPA.

May 18, 1987 — Revised Supplemental Health and Safety Plan submitted to U.S. EPA.

May 19, 1987 — Invitation for Bids submitted to potential drilling subcontractors.

May 20, 1987 — Supplemental QAPP approved by U.S. EPA.

May 28, 1987 — Mobilization for dioxin sampling initiated and completed on June 1, 1987.

June 1, 1987 — Final Supplemental Health and Safety Plan approved by U.S. EPA.

June 2, 1987 — Samples of surface soil were collected at eight on-site and three off-site areas. Two incinerator residue samples were collected near the incinerator building. Two off-site sediment samples were collected west of the site. Sample identification numbers include: PR-SA27-03, PR-SA28-03, PR-SA29-03, PR-SA30-03, PR-SA31-03, PR-SA32-03, PR-SA33-03, PR-SA34-03, PR-SA35-03, PR-SA37-03, PR-SA38-03, PR-SD09-03, PR-SD10-03, PR-IRS1-03, and PR-IRS2-03.

June 3, 1987 — Demobilization completed

July 9, 1987 — Drilling subcontractor was selected.

July 9, 1987 — Mobilization of field facilities began and completed on July 13, 1987.

July 14, 1987 — Water levels were taken to further characterize the direction of flow of the lower aquifer.

July 16, 1987 — Surface soil samples collected near the magic pit. Sample identification numbers include: PR-SS01-03, PR-SS02-03, PR-SS03-03, PR-SS04-03, and PR-SS05-03. One groundwater sample collected from an existing well (GW52).

July 17, 1987 — Two groundwater samples collected from existing wells. Sample identification numbers are GW48 and GW57.

July 20, 1987 — Three groundwater samples collected from existing wells. Sample identification numbers are GW59, GW60, and GW61.

July 21, 1987 — Four groundwater samples collected from existing wells. Sample identification numbers are GW54, GW56, GW58, and GW62.

July 22, 1987 — Drilled and sampled soil boring SB43. Groundwater samples were collected from two existing wells. Sample identification numbers are PR-SB-43-01 to PR-SB-43-08; PR-GW45-03 and PR-GW46-03.

July 23, 1987 — Drilled and installed monitoring well GW63. Subsurface soil samples taken during well installation. Groundwater samples taken from three existing wells. Sample identification numbers are PR-SB63-01, PR-SB63-02, PR-GW50-03, PR-GW51-03, and PR-GW53-03.

July 24, 1987 — Drilled and sampled soil boring SB42. Sample identification numbers are PR-SB42-01 to PR-SB42-06.

July 25, 1987 — Baildown tests performed on monitoring wells GW50 and GW59. Structures and tanks were measured and inspected.

July 27, 1987 — Drilled and installed monitoring well GW66. Subsurface soil samples were taken during well installation (sample identification number PR-SB6603). Baildown tests performed on monitoring well GW50, GW51, GW52, GW54, GW57, GW60, and GW62.

July 28, 1987 — Drilled and installed monitoring well GW65. Subsurface soil samples were taken during well installation (sample identification number PR-SB65-03). Baildown tests performed on monitoring well GW45, GW46, GW48, GW49, GW58, GW61, and GW66.

July 29, 1987 — Groundwater samples collected from GW66.

July 30, 1987 — Drilled and installed monitoring wells GW64 and GW67. Subsurface soil samples were taken during the installation of GW67 (sample identification number PR-SB67-03). Groundwater samples collected from GW63.

August 1, 1987 — Conducted baildown tests on GW64 and GW67. Sampled water from on-site fire hydrant (sample identification number PR-GWFH-03). Drilled soil boring SB44 (did not sample).

August 2, 1987 — Collected samples from monitoring well GW64. Began site demobilization.

August 3, 1987 — Demobilization of Phase 2 sampling completed.

August 18, 1987 — Remobilized to collect two groundwater samples from Phase 2 wells and collect water level readings.

August 19, 1987 — Collected samples from monitoring wells GW65 and GW67 and demobilized.

APPENDIX C

SURFACE SOIL SAMPLING SUMMARY - DIOXIN ANALYSES

SURFACE SOIL SAMPLES COLLECTED FOR DIOXIN ANALYSES

Samples of surface soil were collected in eight on-site areas (SA27, SA28, SA29, SA30, SA31, SA32, SA37 and SA38). Two off-site soil area samples were collected east of the site along the Conrail railroad tracks (SA33 and SA35). One soil area sample was collected in the municipal well field northwest of the site (SA34). Two incinerator residue samples were collected near the incinerator building. Two off-site sediment samples (SD09, SD10) were collected in low drainage areas between the Pristine, Inc. site and Cincinnati Drum Services, Inc. A duplicate sample was taken at soil area SA35 and of sediment sample SD09. The surface soil samples were collected at locations identified as soil areas in the RI1. The sediment samples were also collected at locations identified in the RI1. The locations and configurations of these areas and their sample designations are shown in Figure 1-4. A summary of the sampling program is given in Table C-1.

Within each soil area, soil material was collected at five discrete locations with a disposable scoop and composited in a disposable aluminum pan. Soil was taken from 0 to 4 inches at each location. After being thoroughly mixed in the aluminum pan with the sampling scoop, the composite sample was placed in 8-oz. glass sampling bottles and sealed with a Teflon-lined cap. The sampling scoops, aluminum trays, and other disposables were discarded in a steel drum and sealed.

All samples were packed and shipped according to EPA protocol for medium hazard samples along with a performance sample and two blanks which were provided by the CRL (Region V). The samples were analyzed for 2, 3, 7, 8-dioxin and 2, 3, 7, 8-TCDY/TCDF by CLP RAS/SAS. The rationale for the sampling program is provided in Section 2.2.3.1 of the Work Plan Technical Memo; Document No.: 115-RI2-WP-DUHS-1. Addition discussion on the objectives and scope of the dioxin sampling program is provided in the Remedial Investigation follow-up work plan for the Pristine, Inc. site (TDD-R05-8607-01) prepared on September 3, 1986 by Ecology and Environment. The scope prepared in the follow-up Work Plan has been modified as requested by the U.S. EPA Remedial Project Manager. The modifications include the reduction of the number of sediment samples collected and the eliminationof the sample of dust collected from the Cincinnati Drum Service, Inc. Baghouse.

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	~~OTR #~~ DIOXIN	~~ITR #~~ SAS	TAG #	QC LOT #
7405 RAS	PA-SA27-03	87RT01 S01	SL	MED	06/02/87	06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 04		5-101551	F6115 122
SAS	PA-SA28-03	87RT01 S02				06/04/87	TRIANGLE	3501324252	13757-58	5-08941		3414E-01	5-101552	F6349 104
7405 RAS	PA-SA29-03	87RT01 S03				06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 05		5-101553	F6115 122
SAS	PA-SA30-03	87RT01 S04				06/04/87	TRIANGLE	3501329252	13757-58	5-08941		3414E-02	5-101554	F6349 104
7405 RAS	PA-SA31-03	87RT01 S05				06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 06		5-101555	F6115 122
7405 RAS	PA-SA32-03	87RT01 S06				06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 07		5-101556	F6115 122
7405 RAS	PA-SA33-03	87RT01 S07				06/03/87	K.C.S	3501329241	13753-54	5-08944	DF 0A72 08		5-101557	F6115 122
7405 RAS	PA-SA34-03	87RT01 S08				06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 09		5-101558	F6115 122
SAS	"	87RT01 S08				06/04/87	TRIANGLE	3501329252	13757-58	5-08941		3414E-03	5-101559	F6349 104
7405 RAS	PA-SA35-03	87RT01 S09				06/03/87	K.C.S	3501329241	13753-54	5-08944	DF 0A72 10		5-101560	F6115 122
7405 RAS	" -D3	87RT01 D09				06/03/87	K.C.S	3501329241	13753-54	5-08944	DF 0A72 11		5-101561	F6349 104
7405 RAS	PA-SA37-03	87RT01 S10				06/03/87	K.C.S.	3501329241	13753-54	5-08944	DF 0A72 12		5-101562	F6349 104
7405 RAS	PA-SA38-03	87RT01 S11				06/03/87	K.C.S	3501329241	13753-54	5-08944	DF 0A72 13		5-101563	F6349 104

RAS = SHIPPED TO KANSAS CITY SCIENTIFIC

TABLE C-1

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	~~OTR #~~ DIOXIN	~~ITR #~~ SAS	TAG #	DC LOT #
7405 RAS	PR-SD09-03	87RT01 S12	SL	MED	[illegible]	06/03/87	K.C.S	3501329241	13753-54	5-08444	DE 027214		5-101564	F6329 [illegible]
7405 RAS	" -D3	87RT01 D12	↓		↓	06/03/87	K.C.S	3501329241	13753-54	5-08444	DE 027215		5-101565	F6329 [illegible]
7405 RAS	PR-SD10-03	87RT01 S13	↓		↓	06/03/87	K.C.S	3501329241	13753-54	5-08444	DE 027216		5-101566	F6329 [illegible]
SAS	PR-IAS1-01	87RT01 S14	SL		[illegible]	06/04/87	TRIANGLE	3501329252	13757-58	5-08441		3014E-04	5-101567	F6329 [illegible]
SAS	PR-IAS2-01	87RT01 S15	↓		↓	06/04/87	TRIANGLE	3501329252	13757-58	5-08441		3014E-05	5-101568	F6329 [illegible]
7405 RAS	PR-PE01-03	87RT01	SL		06/04/87	06/04/87	K.C.S.	3501329241	13753-54	5-08444	DE 027201		5-101569	[illegible]
7405 RAS	PR-RD01-03	87RT01	SL		06/04/87	06/04/87	K C S	3501329241	13753-54	5-08444	DE 027202		5-101570	[illegible]
7405 RAS	PR-RD02-03	87RT01	SL	↓	06/02/87	06/02/87	K.C.S.	3501329241	13753-54	5-08445	DE 027203		5-101571	[illegible]

TABLE C-1 (CONT.)

APPENDIX D

SURFACE SOIL SAMPLING SUMMARY - RAS CLP ANALYSES

SURFACE SOIL SAMPLES FOR HSL ANALYSES

Samples of surface soil material were collected at five on-site locations. The sampling locations are shown in Figure 1-5. A summary of the sampling program is given in Table D-1. A description of the soil sample location and sample description is provided in Table D-2.

All samples were collected to a depth of six inches using a stainless steel sampling trowel. Surface vegetation, where present, was removed before the sample was taken. The soil was placed in a labeled glass, capped with a Teflon-lined lid. The stainless steel trowels were decontaminated in accordance with standard EPA protocol prior to use at each sample location.

The samples were packed and shipped in accordance with EPA protocol and analyzed for volatile organics, extractable organics, including priority pollutants, pesticides/PCBs, cyanide, and metals.

Descriptions of the five sampling locations and their corresponding soil samples are presented in Table D-2. The rationale for the sampling program is provided in Section 2.2.2.2 of the Work Plan Technical Memo for the Pristine, Inc. Site.

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	DTR #	ITR #	TAG #	QC LOT #
7644	PR-5501-03	87RT01542	Soil	Low	7/14/87	7/17/87	GCA	4905751756	13760-61	5-09502	EM 007	—	5-77798	F6211072
												—	5-77795	"
												—	5-77796	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 946	5-77793	F6211072
	PR-5501-D3	87RT01D42					GCA	4905751756	13760-61	5-09502	EM 008	—	5-77794	F6211072
												—	5-77799	"
												—	5-77800	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 947	5-77797	F6211072
	PR-5502-03	87RT01543					GCA	4905751756	13760-61	5-09502	EM 009	—	5-77802	F6211072
												—	5-77803	"
												—	5-77804	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 948	5-77801	F6211072
	PR-5503-03	87RT01544					GCA	4905751756	13760-61	5-09502	EM 010	—	5-77806	"
												—	5-77808	"
												—	5-77807	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 949	5-77805	F6211072
	PR5504-03	87RT01545					GCA	4905751756	13760-61	5-09502	EM 011	—	5-77810	
												—	5-77811	
												—	5-77812	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 950	5-77809	F6211072
	PR5505-03	87RT01546					GCA	4905751756	13760-61	5-09502	EM 012	—	5-77815	
												—	5-77814	
												—	5-77816	45171092
							RMAL	3501329171	13762-63	5-08943	—	MEL 951	5-77813	F6211072

TABLE D-1

TABLE D-2

DESCRIPTION OF SOIL SAMPLING LOCATIONS AND SAMPLES

Sample Number	Location Descriptions	Sample Descriptions	OVA Reading (ppm)
PR-SS01-03 and PR-SS01-03	SE of magic pit near corrugated drain tile	Brown gravelly soil; very moist	0
PR-SS02-03	SE of compressor room at Cincinnati Drum, Inc. side of magic pit	Dark brown oil soil	30-50
PR-SS03-03	Immediately adjacent to SW wall of magic pit	Dark brown soil	0
PR-SS04-03	Immediately adjacent to NW wall of magic pit	Dark brown oily soil some water	0
PR-SS05-03	25 feet north of magic pit	Brown gravelly soil; very moist	0.3-0.5

D — Duplicate Sample
OVA — Organic Vapor Analyzer

APPENDIX E

SOIL BORING AND WELL CONSTRUCTION SOIL SAMPLING SUMMARY

SOIL BORINGS

A total of eight (8) borings were drilled during the RI, Phase 2 program. The purpose of the borings was to obtain additional hydrogeologic data and to access the vertical distribution of contaminants in the soil. Figure 1-6 illustrates the location of the borings placed during the RI, Phase 2 program. A summary of the sampling program is presented in Table E-1. A summary of the soil sample borings is presented in Table E-2.

All soil borings were drilled using Standard Penetration Testing (SPT) methods in accordance with ASTM D-1586. The boreholes were advanced by use of 4.25 inch I.D. hollow stem augers. Soil samples were collected from 1.5 inch I.D. by 2.0 inch O.D. split spoon samples, driven by a 140 pound hammer. The sampling intervals were variable for the borings, depending on field situations (e.g., soils encountered, field screening results, etc.) and purpose of sampling. The final depths for the soil borings were based on the contaminant levels found in the soil samples (using the HNu or OVA instruments). The boring logs are attached in Appendix H.

As mentioned in the preceding paragraph, soil samples were field screened by use of a Photoionization Meter (HNu) with a 10.2 eV lamp, and an Organic Vapor Analyzer (OVA). These instruments are capable of detecting volatile organic compounds (VOCs) in units of parts per million (ppm). Samples were screened by either a qualified geologist or engineer. A selected number of samples were obtained for laboratory analysis as to represent the contaminant profile, primarily at SB42 and SB43.

To prevent or minimize cross-contamination between sampling intervals, the split spoon samplers were decontaminated. The decontamination method consisted of steam cleaning to remove the residual soils, followed by a hexane rinse and distilled water rinse. All sampling equipment and tooling were also decontaminated prior to mobilizing for the next boring location. The drill rig and tooling was also cleaned prior to and after completion of the drilling program.

SOIL SAMPLES COLLECTED DURING WELL CONSTRUCTION

Near surface soils were collected for analysis at GW65 and GW66 to determine relative background contaminant concentrations. Soil samples were also screened with the OVA for the duration of the drilling, but no additional samples were collected for analysis. At monitoring wells GW63 and GW67, soil samples were collected and analyzed in the saturated sandy soils corresponding to the lower outwash lense and lower aquifer outwash, respectively. Refer to Table E-3 which lists the sample designation, depths and descriptions. No other soil samples were taken for analytical purposes, but continuous screening was performed with the OVA during drilling operations.

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7672	PR-SB42-01	87RT01551	soil	low	072487	072487	U. of Iowa	4905751874	12843-44	5-09512	EI 984	——	5-77901	F6211032
												——	5-77902	U611132
							↓	↓	↓	↓	↓	——	5-77903	"
	↓	↓					RMAL	4905751885	12841-42	5-08927	——	MEL 962	5-77904	F6211032
	PR-SB42-02	87RT01552					U. of IA	4905751874	12843-44	5-09512	EI 985	——	5-77905	F6329112
												——	5-77906	D611322
							↓	↓	↓	↓	↓	——	5-77907	"
	↓	↓					RMAL	4905751885	12841-42	5-08927	——	MEL 963	5-77908	F6329112
	PR-SB42-03	87RT01553					U. of IA.	4905751874	12843-44	5-09512	EI 986	——	5-77909	"
												——	5-77910	D611328
							↓	↓	↓	↓	↓	——	5-77911	"
	↓	↓					RMAL	4905751885	12841-42	5-08927	——	MEL 964	5-77912	F6329102
	PR-SB42-04	87RT01554					U. of Iowa	4905751874	12843-44	5-09512	EI 987	——	5-77913	"
												——	5-77914	D6332112
							↓	↓	↓	↓	↓	——	5-77915	"
	↓	↓					RMAL	4905751885	12841-42	5-08927	——	MEL 965	5-77916	F6329102
	PR-SB42-05	87RT01555					U. of Iowa	4905751874	12843-44	5-09512	EI 988	——	5-77917	"
												——	5-77918	D6112192
							↓	↓	↓	↓	↓	——	5-77919	"
	↓	↓					RMAL	4905751845	12841-42	5-08927	——	MEL 966	5-77920	F6329112
	PR-SB42-06	87RT01556					U. of IA	4905751874	12843-44	5-09512	EI 989	——	5-77921	F6329102
												——	5-77922	4517 1192
							↓	↓	↓	↓	↓	——	5-77923	"
	↓	↓			↓		RMAL	4905751885	12841-42	5-08927	——	MEL 967	5-77924	F6322012
	PR-SB43-01	87RT01561			072887		SWRI	4905751900	12865-66	5-09509	EL 974	——	5-77861	F6115102
												——	5-77862	4513[illegible]
							↓	↓	↓	↓	↓	——	5-77863	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	——	MEL 952	5-77864	F6115102
	PR-SB43-02	87RT01562					SWRI	4905751900	12865-66	5-09509	EL 975	——	5-77865	"
												——	5-77866	4513[illegible]
							↓	↓	↓	↓	↓	——	5-77867	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	——	MEL 953	5-77868	F6115102
	PR-SB43-03	87RT01563					SWRI	4905751900	12865-66	5-09509	EL 976	——	5-77869	F6115112
												——	5-77870	4513[illegible]
							↓	↓	↓	↓	↓	——	5-77871	"
↓	↓	↓	↓	↓	↓	↓	RMAL	4905751896	12862-63	5-09511	——	MEL 954	5-77872	F6115112

TABLE E-1

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	DC LOT
7672	PR-SB43-04	87RT01564	SOIL	LOW	072387	072487	SWRI	4905751900	12865-66	5-09509	EL977	—	5-77873	F611511..
												—	5-77874	4512342..
							↓	↓	↓	↓	↓	—	5-77875	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	—	MEL955	5-77876	F611511 2
	PR-SB43-05	87RT01565					SWRI	4905751900	12865-66	5-09509	EL978	—	5-77877	"
												—	5-77878	4512342..
							↓	↓	↓	↓	↓	—	5-77879	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	—	MEL956	5-77880	F611511 2
	PR-SB43-06	87RT01566					SWRI	4905751900	12865-66	5-09510	EL979	—	5-77881	"
												—	5-77882	4512392..
							↓	↓	↓	↓	↓	—	5-77883	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	—	MEL957	5-77884	F611511 2
	PR-SB43-07	87RT01567					SWRI	4905751900	12865-66	5-09510	EL980	—	5-77885	F6219..
												—	5-77886	D61322..
							↓	↓	↓	↓	↓	—	5-77887	
	↓	↓					RMAL	4905751896	12862-63	5-09511	—	MEL958	5-77888	F6212..
	PR-SB43-08	87RT01568					SWRI	4905751900	12865-66	5-09510	EL981	—	5-77889	"
												—	5-77890	D6132..
							↓	↓	↓	↓	↓	—	5-77891	"
	↓	↓					RMAL	4905751896	12862-63	5-09511	—	MEL959	5-77892	F6212..
	PR-SB63-01	87RT01569			072387		SWRI	4905751900	12865-66	5-09510	EL982	—	5-77893	"
												—	5-77894	D6112..
							↓	↓	↓	↓	↓	—	5-77895	"
	↓	↓					RMAL	4905751896	12862-63	5-0954	—	MEL960	5-77896	F6211..
	PR-SB63-02	87RT01570					SWRI	4905751900	12865-66	5-09510	EL983	—	5-77897	"
↓	"	"	↓	↓	↓	↓	"	"	"	"	"	—	5-77898	D611222..
—	NO INORGA	NIC SAMPLE	TA	KEN										
—	PR-SB64-01	NOT SAMPLED												
—	----													
—	↓	↓												
7672	PR-SB65-0	87RT01558	SOIL	LOW	072887	073187	SWRI	4905751820	22307-08	5-21696	EE809	—	5-77948	F6328..
												—	5-77949	D6132..
							↓	↓	↓	↓	↓	—	5-77950	"
	↓	↓					RMAL	4905751852	12856-57	5-15069	—	MEL060	5-77945	F6328..
	PR-SB65-D3	87RT01558					SWRI	4905751820	22307-08	5-21696	EE813	—	5-77929	"
												—	5-77930	D6132..
							↓	↓	↓	↓	↓	—	5-77931	"
↓	↓	↓	↓	↓	↓	↓	RMAL	4905751852	12856-57	5-15069	—	MEL061	5-77932	F632..

TABLE E-1 (CONT.)

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7672	PR-SB66-02	87RT01 557	SOIL	LOW	072787	073107	SWRI	4905751820	27307-08	5-21696	EE 808	—	5-77925	F6326910
												—	5-77926	D6132142
												—	5-77927	45171092
							RMAL	4905751852	12856-57	5-15069	—	MEL058	5-77928	F6329102
	PR-SB67-02	87RT01 559			073087		SWRI	4905751820	27307-08	5-21696	EE 814	—	5-77933	"
												—	5-77934	D6104102
												—	5-77935	"
							RMAL	4905751852	12856-57	5-15069	—	MEL059	5-77936	F6115101

TABLE E-1 (CONT.)

TABLE E-2

SUMMARY OF SOIL BORING SAMPLES

Sample Number	Depth (feet)	Description	OVA (ppm)
PR-SB42-01	1.0-2.5	Brown and black silty clay fill	0.2
PR-SB42-02	8.5-12.5	Coarse to fine sand, saturated	0-0.2
PR-SB42-03	16.0-17.5	Brown silty clay with coarse-fine sand, moist clay seams	0-0.2
PR-SB42-04	18.5-20.0	Brown silty clay (mottled), some coarse-fine sand, gravel; moist clay seams	0-0.2
PR-SB42-05	21.0-22.5	Gray-brown silty clay, some fine sand	10-40
PR-SB42-06	23.5-25	Brown weathered silty clay till; sheen in seam from 24 feet	40-70
PR-SB42-07	26.0-27.5	Gray silty clay till; coarse-fine sand; occasional coarse-fine gravel; hard, moist clay	100-400
PR-SB42-08	28.5-30.0	Same as PRSB42-07, except with extremely hard clay	0.5-1
PR-SD43-01	0.10	Fill material; elemental sulfur and resins noted	0
PR-SB43-02	1.0-2.5	Dark gray silty clay; some sand and fill; moist clay	0
PR-SB43-03	3.5-5.0	Olive brown and black silty clay; trace sand	ND
PR-SB43-04	6.0-7.5	Saturated silty-fine sand; black and brown silty clay	2
PR-SB43-05	8.5-10.0	Dark gray silt; fine sand; trace clay; saturated	3.5
PR-SB43-06	4.0-12.5	Gray clayey silt	3
PR-SB43-07	13.5-15.0	Gray clayey silt	2.2
SB44		Not Sampled (geotechnical purposes only)	

TABLE E-3

SUMMARY OF WELL CONSTRUCTION SOIL SAMPLES

Sample Number	Depth (feet)	Description	OVA (ppm)
PR-SB63-01	28.5-30.0	Brown silt and fine sand; saturated	0
PR-SB63-02	31.0-32.5	Brown weathered silty clay; some sand; occasional gravel; hard, low plast. moist clay	0
SB64		Not Sampled (field screened for organic vapors; converted to monitoring well GW-64)	
PR-SB65-01	1.0-2.5	Black and brown sandy fill; wet	0
PR-SB66-01	1.0-5.0	Sandy fill; olive-brown silty clay; trace sand, moist	0
PR-SB67-01	58.5-60.0	Light-brown coarse-fine sand; traces of fine gravel and silt; dry	2.5-3.0

OVA — Organic Vapor Analyzer.

APPENDIX F

GROUNDWATER SAMPLING SUMMARY

GROUNDWATER SAMPLING

Five monitoring wells were installed and sampled during Phase 2 of the Remedial Investigation in addition to the sampling of 18 existing wells installed during Phase 1. Two wells were installed on site and three wells were installed off site along the Conrail railroad tracks. The locations and designations of these wells, with respect to the existing wells, are shown in Figure 1-7. Detailed information regarding the installation of the monitoring wells (e.g., drilling methods, soil stratigraphy, well construction and well development) can be found in Appendices H, I and J. A summary of the sampling program is given in Table E-1. A summary of field measurements is presented in Table E-2 and E-3.

Sixteen of the 18 existing wells were sampled for volatile organic analysis. Monitoring wells GW-47 and GW-55 did not contain enough water to allow even partial sample collection at the time of sampling. Five wells installed during Phase 2 were collected and analyzed for volatile organic compounds, extractable organics, filtered metals, cyanide, and fluoride. Monitoring well GW-65 was only sampled for volatile organic analysis due to a low water level and slow recharging after well purging. Monitoring wells GW-65 and GW-67 were not analyzed for fluoride. An on-site fire hydrant was also sampled and analyzed for all parameters listed above. The water supply from the hydrant was used in the drilling process and for preliminary decontamination of equipment; therefore, it provides a background level for which all Phase 2 analytical data can be compared.

The following procedure was used for monitoring well sampling:

- Upon initially opening the well caps of the existing wells, the well mouths were screened for organic vapors with a photoionization detector (HNu^R with a 10.2 eV lamp) or a flame ionization detector (OVA). Benzene levels were screened using a benzene-specific detector tube (Draeger^R). Refer to Table C-3.

- Water levels and well depths were measured using an electronic water level indicator to an accuracy of 0.01 feet. Using this information, static volumes of water in the wells were calculated.

- The wells were purged dry or until three to five volumes of water were collected using a Teflon bailer. The wells were allowed to recharge prior to sampling.

- Groundwater samples were collected using a Teflon bailer. The bailer was lowered into the static water column in the well with a nylon or polyethylene cord. Because the volume of the bailer was about 750 ml, it was necessary to lower, fill, and retrieve the bailer about nine times for each sample collected. The general sequence of sample bottle filling was as follows: volatile organics, metals (to be filtered), cyanide, fluoride, and extractable organics. Bottles for volatile organic analysis were filled first

- Field measurements of pH, specific conductivity, and temperature were taken using a portion of the sampled water in a glass jar.
- Samples collected for metal analysis were filtered prior to preservation and shipment. Filtering was performed using a disposable, 150-ml filtering unit with a 0.45-micron filter and a hand vacuum pump. The filtrate was transferred into a bottle and the original bottle was discarded. New filter apparatus was used for each sample and whenever the filter in use could not be satisfactorily rinsed of sediment (using deionized water administered in a squeeze bottle). Cyanide and fluoride samples were not filtered.
- All samples were preserved, packed, and shipped according to EPA protocol.
- Bailers used for well purging and sampling were decontaminated using standard protocol prior to use at each well. Rope used to lower the bailers was discarded and replaced by new rope at each well.

Duplicate samples were taken at monitoring wells GW52, GW56, GW63 and GW67. Field blanks using deionized water were taken at monitoring wells GW57, GW66 and GW67. All duplicates and field blanks were sampled, preserved, and shipped using identical procedures as used for environmental samples.

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7672	PR-GW45-03	87R101-S24	GW	LOW	072387	072387	ACUREX	3501329703	12168-69	S-09506	EM 013		S-77817	87091161
	"	"											S-77818	
	PR-GW46-03	87R101-S25									EM 014		S-77819	
	"	"									"		S-77820	
	PR-GW46-R3	87R101-R25									EM 015		S-77821	
	"	"									"		S-77822	
DRY	PR-GW47-03	87R101-S26	NOT		SAMPLED									
7648	PR-GW48-03	87R101-S27	GW	LOW	071787	071787	GCA	4905751756	13760-61	S-09503	EM 017		S-77825	87091161
"	"	"			"	"	"	"	"	"	"		S-77826	
7672	PR-GW49-03	87R101-S28			072387	072387	ACUREX	3501329263	12168-69	S-09506	EM 018		S-77827	
	"	"								"	"		S-77828	
	PR-GW50-03	87R101-S29								S-09507	EM 019		S-77829	
	"	"									"		S-77830	
	PR-GW51-03	87R101-S30									EL 959		S-77831	
	"	"									"		S-77832	
7648	PR-GW52-03	87R101-S31			071787	071787	GCA	4905751756	13760-61	S-09503	ET 960		S-77833	
	"	"									"		S-77834	
	PR-GW52-D3	87R101-D31									ET 961		S-77835	
	"	"									"		S-77836	
	PR-GW53-03	87R101-S32			072387	072387	ACUREX	3501329263	12168-69	S-09507	EL 962		S-77837	
	"	"			"	"		"	"	"	"		S-77838	
	PR-GW54-03	87R101-S33			072187	072187		4905751760	12070-71	S-09504	ET 963		S-77839	
	"	"			"	"		"	"	"	"		S-77840	
	PR-GW55-02	87R101-S34	NOT		SAMPLED									
7672	PR-GW56-03	87R101-S35	GW	LOW	072187	072187	ACUREX	4905751760	12070-71	S-09504	ET 965		S-77843	87091161
	"	"									"		S-77844	
	PR-GW56-D3	87R101-D35									ET 966		S-77846	
	"	"									"		S-77845	
7648	PR-GW57-03	87R101-S36			071787	071787	GCA	4905751756	13760-61	S-09503	ET 967		S-77847	
	"	"									"		S-77848	
	PR-GW57-R3	87R101-R36									ET 968		S-77849	
	"	"									"		S-77850	
	PR-GW58-03	87R101-S37			072187	072187	ACUREX	4905751760	12070-71	S-09504	ET 969		S-77851	
	"	"			"						"		S-77852	
	PR-GW59-03	87R101-S38			072087						ET 970		S-77853	
	"	"			"						"		S-77854	

TABLE F-1

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7672	PR-GW60-03	07R701539	GW	LOW	072087	072187	ACURAY	4905751760	12870,71	5-09504	EJ 971		5-77855	8707 1161
	"	"									"		5-77856	
	PR-GW61-03	87R701540									EJ 972		5-77857	
	"	"									"		5-77858	
	PR-GW62-03	87R701541			072187						EJ 973		5-77859	
	"	"			"						"		5-77860	
	PR-GW63-03	87R701520			072087	072187	PEI	HAND DELIVERED	12860,61	5-08928	EM 001	—	5-77751	A7117052
												—	5-77752	
												—	5-77753	8709 1161
												—	5-77754	
							RMAL	4905751812	12856-57	5-15062	—	MEL 940	5-77756	C7180012
							"	"	"	"	—	"	5-77757	
						080187	WILSON	3501229182	12850-51	5-21699	—	SAID 8487-01	5-119851	
	PR-GW63-D3	87R701D20					PEI	HAND DELIVERED	12860,61	5-08928	EM 002	—	5-77760	A7117052
												—	5-77761	"
												—	5-77762	8709 1161
												—	5-77763	"
							RMAL	4905751852	12856-57	5-15061	—	MEL 941	5-77758	C7180012
							"	"	"	"	—	"	5-77759	
						080187	WILSON	3501229102	12850-51	5-21699	—	SAID 8487-02	5-119852	
	PR-GW64-03	87R701521			080287	080387	PEI	HAND DELIVERED	12858-59	5-15071	EM 003	—	5-77768	A7117052
												—	5-77769	"
												—	5-77770	8709 1161
												—	5-77771	"
							RMAL	4905751771	12852-53	5-15100	—	MEL 942	5-77766	C7180012
							"	"	"	"	—	"	5-77767	
						080487	WILSON	3501329182	12850-51	5-21699	—	SAID 8487-03	5-119852	
7904	PR-GW65-03	87R701522			081987	081987	SWOK	4905752316	13601-02	5-02258	EJ 616	—	5-62689	5 [illegible]
					"	"	"	"	"	"	"	—	5-64685	"
					VOA's ONLY ;			NO EXTRACTABLE		ORGANIC	OR	INORGANICS		TAKEN
	PR-GW66-03	87R701223			072987	072187	PEI	HAND DELIVERED	12854-55	5-08929	EM 005		5-77779	A7117052
													5-77790	
													5-77791	
													5-77782	
													5-77783	

TABLE F-1 (CONT.)

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7672	PR-GW66-03	87RT01 S23	water	low	072987	073187	PEI	HAND DELIVERED	12854-55	5-04929	EM 005	—	5-77784	[illegible]
												—	5-77785	87041161
												—	5-77786	
												—	5-77787	
												—	5-77788	
												—	5-77789	
												—	5-77790	
							AMAL	4905751852	12856-57	5-15069	—	MEL 944	5-77791	[illegible]
							"	"	"	"	—	"	5-77792	
						080487	WILSON	3501329182	12850-51	5-21694	—	[illegible]	5-119854	
	PR-GW66-R3	87RT01 R23					PEI	HAND DELIVERED	12860-61	5-04964	EM 006	—	5-77941	[illegible]
												—	5-77942	"
												—	5-77943	[illegible]
												—	5-77946	"
							AMAL	4905751852	12856-57	5-15069	—	MEL 945	5-77947	[illegible]
								"	"	"	—	"	5-77792	
						080487	WILSON	3501329182	12850-51	5-21699	—	[illegible]	5-119855	
7304	PR-GW67-03	87RT01-SB1			081987	081987	SWOK	4907752216	13613, 12	5-02257	CJ 613	—	5-69660	[illegible]
												—	5-69661	
												—	5-69662	
												—	5-69663	
												—	5-69664	
												—	5-69665	
												—	5-69651	[illegible]
												—	5-69652	
												—	5-69653	
												—	5-69654	[illegible]
												—	5-69655	
												—	5-69656	
												—	5-69657	
												—	5-69658	
												—	5-69659	
							SPECTRUM	4905752320	13614, 15	5-02262	—	MEJ 941	5-69666	[illegible]
							"	"	"	"	—	"	5-69667	"
	PR-GW67-D3	87RT01-DB1					SWOK	4905752216	13601, 602	5-02250	GJ 614	—	5-69069	[illegible]
												—	5-69670	
												—	5-69671	
												—	5-69672	[illegible]
												—	5-69673	"

TABLE F-1 (CONT.)

CASE #	SAMPLE #	CRL #	MATRIX	CONC.	SAMPLE DATE	SHIPPING DATE	LAB	FEDERAL EXPRESS #	CUSTODY SEAL	C-O-C	OTR #	ITR #	TAG #	QC LOT #
7709	PR-GW67-D3	87R701-D01	WATER	LOW	091187	091487	SPECTRIX	4905752320	13614-15	5-02262	—	MEJ 942	5-69675	[illegible]
	"	"					"	"	"	"	—		5-69676	"
	PR-GW67-R3	87R701-RB1					SWOK	4905752316	13601-02	5-02258	EJ 615	—	5-69677	[illegible]
												—	5-69678	
												—	5-69679	
												—	5-69680	[illegible]
												—	5-69681	"
							SPECTRIX	4905752320	13614-15	5-02262	—	MEJ 943	5-69682	[illegible]
							"	"	"		—		5-69683	"
7672	PR-GWFH-03	87R701-371			090187	090387	P.E.I.	HAND DELIVERED	12058-59	5-15071	EE 816	—	5-77230	[illegible]
												—	5-77231	"
												—	5-77232	[illegible]
												—	5-77233	"
							RMAL	4905751771	12052-53	5-15100	—	MEL 943	5-78234	[illegible]
							"	"	"	"	—	"	5-78235	
						090187	WILSON	3501323182	12050-51	5-21699	—	[illegible]	5-119856	

TABLE F-1 (CONT.)

TABLE F-2

SUMMARY OF FIELD PARAMETERS

Well Number	pH	Specific Conduc. (umhos)	Temperature (°C)
GW45	6.76	2,800	27
GW46	7.42	4,800	28
GW47	Not Sampled		
GW48	6.82	2,400	17
GW49	6.7	2,000	27.5
GW50	6.2	6,000	20.8
GW51	6.22	5,000	29
GW52	7.03	1,210	22
GW53	6.86	2,200	26
GW54	7.09 7.10	3,000	26
GW55	Not Sampled		
GW56	6.57 6.59	4,450	26
GW57	7.04	1,900	23
GW58	6.53 6.53	3,100	37
GW59	6.51	600	28
GW60	6.78	600	28.5
GW61	6.82	2,700	28.5
GW62	6.12 6.12	1,200	30
GW63	6.86	3,000	28
GW64	—	—	—
GW65	6.80	480	18.5
GW66	7.02	1,050	32
GW66R	7.30	5	31
GW67	6.45 6.59	1,850 1,650	21.0 23.5
GW67R	6.71	0	28

R — Blank sample (deionized water).

TABLE F-3

ORGANIC VAPOR SCREENING OF PHASE 1 WELLS

Well Number	OVA at Well Mouth (ppm)	Detector Tube at Well Mouth-- Benzene (ppm)*
GW45	700	10, ND
GW46	2	ND
GW47	ND	ND
GW48	—	—
GW49	40	0.8, 5.0
GW50	7	ND
GW51	15	0.8-1.0, ND
GW52	—	—
GW53	2	ND
GW54	2.5	ND
GW55	1	ND
GW56	1	ND
GW57	—	—
GW58	2	ND
GW59	ND	ND
GW60	—	—
GW61	ND	ND
GW62	3	ND

OVA -- Organic Vapor Analyzer.
ND -- Screened but not detected.
* -- Draeger^{R} detector tube; benzene specific tube type:
Range: 0.5-10 ppm
Note: Other aromatic compounds (e.g., toluene, zylene, ethylbenzene) are indicated with approximately the same sensitivity as benzene.

APPENDIX G

HYDROGEOLOGIC TABLES

TABLE G-1

UNIFIED SOIL CLASSIFICATION SYSTEM

COARSE-GRAINED SOILS

CLEAN GRAVELS (LITTLE OR NO FINES)	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
	GC	CLAYEY GRAVELS GRAVEL-SAND-CLAY MIXTURES
CLEAN SANDS (LITTLE OR NO FINES)	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES
	SC	CLAYEY SANDS, SAND-CLAY MIXTURES

FINE-GRAINED/HIGHLY ORGANIC SOILS

SILTS AND CLAYS LIQUID LIMIT (LESS THAN 50)	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
SILTS AND CLAYS LIQUID LIMIT (GREATER THAN 50)	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS
	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
	OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS	PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

*THE PLASTIC INDEX IS THE DIFFERENCE BETWEEN THE LIQUID LIMIT AS DETERMINED IN ATTERBERG LIMITS TESTING (ASTM D 4318-83)

TABLE G-2

SUMMARY OF HYDROGEOLOGIC PROPERTIES OF SOILS
PRISTINE, INC. SITE

Soil Unit	Hydraulic Conductivity (ft/sec)	Explanation	Porosity (%)	Explanation
Upper outwash lens	1.66×10^{-6}	Based on baildown recovery and slug test data	40	Based on grain size distribution and literature
Upper lake deposit	2.04×10^{-7}	Based on baildown recovery and slug test data	55	Based on grain size distribution and literature
Middle outwash lens	1.45×10^{-6}	Based on baildown recovery and slug test data	35	Based on grain size distribution and literature
Lower outwash lens	7.89×10^{-7}	Based on baildown recovery and slug test data	30	Based on grain size distribution and literature
Till	10^{-7} to 10^{-9}	Based on literature for similar soil types	25	Based on literature
Lower aquifer	4.29×10^{-6}	Based on baildown recovery and slug test data	30	Based on grain size distribution and literature

Note: Hydraulic conductivities showing one value are based on mathematical average of wells screened in same soil unit.

TABLE B-3
SLUG TEST AND BAILDOWN DATA
FOR DETERMINING HYDRAULIC CONDUCTIVITY
PRISTINE, INC. SITE

WELL NO.	H (feet)	rc (feet)	rw (feet)	H/r_w	ln H/r_w	D (feet)	L (feet)	L/r_w	A	B	C	$(D-H)/r_w$	$\ln(D-H)/r_w$	$\ln(R/r_w)$	slope (/sec)	K (ft/sec)	K (ft/day)
GW-45	8.00	0.08300	0.08300	96.39	4.57	8.00	8.00	96.39	---	---	4.00			3.54	0.00307	4.68E-06	0.40457
GW-46	9.17	0.08300	0.18000	50.94	3.93	9.17	9.17	50.94	---	---	2.70	---	---	3.00	0.00038	4.32E-07	0.03734
GW-48	12.64	0.08300	0.08300	152.29	5.03	12.64	5.00	60.24	---	---	3.00	---	---	3.72	0.00080	2.05E-06	0.17723
GW-49	8.02	0.08300	0.18000	44.56	3.80	8.02	8.02	44.56	---	---	2.40	---	---	2.91	0.00007	8.75E-08	0.00756
GW-50	3.30	0.08300	0.18000	18.33	2.91	3.30	3.30	18.33	---	---	1.80	---	---	2.10	0.00034	7.45E-07	0.06437
GW-51	7.95	0.08300	0.18000	44.17	3.79	7.95	5.00	27.78	---	---	1.90	---	---	2.79	0.00065	1.25E-06	0.10783
GW-52	19.03	0.08300	0.08300	229.28	5.43	19.03	5.00	60.24	---	---	3.00	---	---	3.97	0.01700	4.64E-05	4.01221
GW-53	12.52	0.08300	0.18000	69.56	4.24	12.52	10.00	55.56	---	---	2.85	---	---	3.22	0.00010	1.15E-07	0.00996
GW-54	0.24	0.08300	0.18000	1.33	0.29	0.24	0.24	1.33	---	---	1.20	---	---	0.21	0.00034	1.04E-06	0.08978
GW-56	2.00	0.08300	0.18000	11.11	2.41	2.00	2.00	11.11	---	---	1.65	---	---	1.65	0.00062	1.77E-06	0.15315
GW-57	8.00	0.08300	0.08300	96.39	4.57	8.00	5.00	60.24	---	---	3.00	---	---	3.44	---	---	---
GW-58	3.33	0.08300	0.08300	40.12	3.69	3.33	3.33	40.12	---	---	2.30	---	---	2.81	0.00037	1.08E-06	0.09307
GW-59	3.76	0.08300	0.18000	20.89	3.04	3.76	3.76	20.89	---	---	1.80	---	---	2.23	0.00001	1.84E-08	0.00159
GW-60A	9.41	0.08300	0.18000	52.28	3.96	9.41	6.00	33.33	---	---	2.20	---	---	2.91	0.00053	8.84E-07	0.07642
GW-61	2.01	0.08300	0.18000	11.17	2.41	2.01	2.01	11.17	---	---	1.65	---	---	1.66	0.00009	2.56E-07	0.02208
GW-62	1.73	0.08300	0.08300	20.84	3.04	1.73	1.73	20.84	---	---	1.80	---	---	2.23	0.00044	1.95E-06	0.16875
GW-63	3.89	0.08300	0.18000	21.61	3.07	3.89	3.89	21.61	---	---	1.80	---	---	2.27	0.00120	2.41E-06	0.20807
GW-64	11.88	0.08300	0.18000	66.00	4.19	11.88	10.00	55.56	---	---	2.85	---	---	3.19	0.00426	4.68E-06	0.40395
GW-66	6.71	0.08300	0.18000	37.28	3.62	6.71	6.71	37.28	---	---	2.25	---	---	2.74	0.00057	8.00E-07	0.06914
GW-67	5.00	0.08300	0.08300	60.24	4.10	5.00	5.00	60.24	---	---	3.00	---	---	3.14	0.00026	5.72E-07	0.04938

NOTES:
Baildown method used for all wells except GW52 and GW60A. Slug tests were used on these wells.
Refer to paper by Bouwer and Rice, " A Slug Test for Determining Hydraulic Conductivity
of Unconfined Aquifers with Completely or Partially Penetrating Wells. "
The paper provides definitions for the variables shown on Table 2-3 and equations used for computations.

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TABLE 6-4
MONITORING WELL WATER LEVEL MEASUREMENTS
PRISTINE, INC. SITE

WELL NO.	TOTAL DEPTH	CASING ELEV	6 - 25 - 85		7 - 1 - 85		9 - 24 - 85		8 - 18 - 87	
			DEPTH	ELEV	DEPTH	ELEV	DEPTH	ELEV	DEPTH	ELEV
GW-45	21.09	578.79	11.03	567.76	12.19	566.60	12.51	566.28	12.22	566.57
GW-46	22.95	580.53	11.81	568.72	12.19	568.34	13.21	567.32	12.95	567.58
GW-47	51.66	580.25	49.04	531.21	50.34	529.91	50.70	529.55	DRY	------
GW-48	91.76	580.86	DRY	------	78.17	502.69	77.31	503.55	70.40	510.46
GW-49	19.48	577.05	7.44	569.61	7.50	569.55	10.93	566.12	12.40	564.65
GW-50	22.63	574.15	18.24	555.91	17.69	556.46	19.77	554.38	18.70	555.45
GW-51	28.21	573.79	17.94	555.85	17.43	556.36	20.17	553.62	18.38	555.41
GW-52	85.31	573.81	71.00	502.81	70.82	502.99	70.40	503.41	63.65	510.16
GW-53	21.28	574.15	7.34	566.81	7.24	566.91	7.99	566.16	9.15	565.00
GW-54	30.62	574.39	30.25	544.14	30.53	543.86	DRY	------	30.38	544.01
GW-55	30.82	575.57	28.69	546.88	30.80	544.77	30.35	545.22	DRY	------
GW-56	40.22	575.88	39.44	536.44	39.24	536.64	38.60	537.28	37.78	538.10
GW-57	82.21	575.79	73.84	501.95	73.79	502.00	72.82	502.97	65.44	510.35
GW-58	33.68	574.78	27.59	547.19	27.66	547.12	30.08	544.70	28.56	546.22
GW-59	19.60	564.53	13.83	550.70	14.59	549.94	15.80	548.73	15.47	549.06
GW-60A	25.30	564.93	14.31	550.62	14.85	550.08	16.31	548.62	15.92	549.01
GW-61	17.38	558.64	DRY	------	DRY	------	16.71	541.93	15.26	543.38
GW-62	19.17	558.11	15.62	542.49	16.15	541.96	15.56	542.55	17.00	541.11
GW-63	33.50	574.43	------	------	------	------	------	------	31.55	542.88
GW-64	15.00	576.94	------	------	------	------	------	------	3.46	573.48
GW-65	66.50	576.89	------	------	------	------	------	------	65.90	510.99
GW-66	15.00	575.38	------	------	------	------	------	------	8.49	566.89
GW-67	70.00	577.56	------	------	------	------	------	------	66.25	511.31

NOTE:
Monitoring wells GW63 through GW67 installed in July, 1987.

APPENDIX H

BORING LOGS

DRILLING LOG

WELL NUMBER: SB42
LOCATION: 1' from northeast corner of Magic Pit
SURFACE ELEVATION: ~567
OWNER: Pristine, Inc
ADDRESS: Reading, Ohio
TOTAL DEPTH: 35.0'
WATER LEVEL: 6.5' (during drill)
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/24/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. VanAllen

SKETCH MAP

NOTES: Water level @ 6.5' below grade during drilling. Grouted w/ cement/bentonite slurry

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					Brown & black silty clay fill (from access road) (CL)
1.0		01	SS	2 3 3	Brown to orange brown clayey silt to silty clay fill, some sand, moist (CL) Qu* < 1.0 tsf
		02	SS	5 3 6	
5.5		03	SS	1 1 0	Granular fill, coarse to fine sand, coarse to fine gravel, very loose, saturated (GW-SW)
		04	SS	1 0 0	
		05	SS	2 2 3	
		06	SS	3 2 5	
14.7		07	SS	10 14 12	Brown mottled silty clay, some coarse to fine sand, seams of coarse to fine sand @ 16-17.5', moist (CL, SW)
		08	SS	6 4 6	

* ASTM D1586

SHEET 1 OF 2

WW ENGINEERING CONSULTANTS

DRILLING LOG

WELL NUMBER SB12
LOCATION 1' from Northeast corner of Magic Pit
SURFACE ELEVATION ~ 567
DRILLING COMPANY ATEC
DRILLER Ray West
LOG BY: K Van Allen

OWNER: Pristine, Inc
ADDRESS Reading, Ohio
TOTAL DEPTH 35.0'
WATER LEVEL 6.5' (during drill)
DRILLING METHOD HSA
DATE DRILLED 7/24/87
HELPER Jim

SKETCH MAP

NOTES See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
20		09	SS	3 5 5	Brown mottled silty clay, some coarse to fine sand, tr. gravel, moist (CL)
23.0					Gray to brown silty clay, tr. sand, sand seam @ 23.5-23.6', medium, medium plasticity, moist (CL)
4.0		10	SS	16 21 30	Brown weathered silty clay till, little coarse to fine sand, occ gravel, very hard, medium plasticity, moist (CL)
25.5		11	SS	12 13 20	Gray silty clay till, little coarse to fine sand, occ gravel, very hard, medium plasticity, moist (CL)
		12	SS	18 21 37	
		13	SS	12 17 23	
5					End of boring @ 35.0

DRILLING LOG

WELL NUMBER: SB43
OWNER: Pristine Inc.
LOCATION: Aprox 45' Southwest of GW46
ADDRESS: Reading, Ohio
TOTAL DEPTH: 17.5'
SURFACE ELEVATION: ~572.5
WATER LEVEL: ~9.5' (during drill.)
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/22/07
DRILLER: Ray West
HELPER: Jim
LOG BY: K. vanAllen

SKETCH MAP

NOTES water level 9' below grade during drilling. Grouted w/ cement/bentonite slurry.

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0		01	SS	5 3 4	Drk gray silty clay Fill, some sand, medium plasticity, moist (CL) Qu* = 1.0 tsf
4.0		02	SS	5 6 11	olive brown & black silty clay Fill, tr. sand, medium plasticity, moist. (CL) Qu* = 4.0 tsf
		03	SS	4 10 10	
7.0					Gray silty fine sand, poorly graded, saturated (ML-SM)
7.3		04	SS	8 9 9	Drk gray silt, fine sand, tr. clay, poorly graded, saturated (ML) Qu* = 2.0 tsf
10.5		05	SS	5 7 7	Drk gray clayey silt interbedded w/ silty clay, tr. sand, saturated (ML, CL) Qu* = 1.5 tsf
		07	SS	3 2 3	
.5		08	SS	2 2 4	Gray silty clay, tr. fine sand, medium, medium plasticity, moist to wet (CL) Qu* = 1.0 tsf
17.5					End of boring @ 17.5'

* ASTM D-1586

SHEET 1 OF 1

DRILLING LOG

WELL NUMBER	SB44	OWNER:	Pristine, Inc.
LOCATION	Aprox 15' South of GW45	ADDRESS	Reading, Ohio
		TOTAL DEPTH	50.0'
SURFACE ELEVATION	~577	WATER LEVEL:	
DRILLING COMPANY	ATEC	DRILLING METHOD	HSA
DATE DRILLED	8/1/87		
DRILLER	Ray West	HELPER	Jim
LOG BY:	Skip Richetts		

SKETCH MAP

NOTES No sampling until 23.5' below grade.
Water level @ 28.5' during drilling. Grouted w/ cement/bent.

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
20					Gray silty clay, tr. fine sand, stiff, medium plasticity, moist. (CL)
		01	SS	4 5 6	
		02	SS	3 6 7	
					Orange brown silty clay, tr. fine sand, medium plasticity, moist. (CL)
4.0		03	SS	10 19 27	Brown medium sand, poorly graded, dense, moist. (SP)
39.0		04	SS	33 27 29	Gray clayey silt, occ sand, occ gravel, extremely dense, dry to moist (ML)

* ASTM D1586

SHEET 1 OF 2

DRILLING LOG

WELL NUMBER: SB44
LOCATION: 15' South of GW45
OWNER: Pristine, Inc.
ADDRESS: Reading, Ohio
TOTAL DEPTH: 50.0'
SURFACE ELEVATION: ~577
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 8/1/87
DRILLER: Ray West
HELPER: Jim
LOG BY: Skip Ricketts

SKETCH MAP

NOTES: See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
40					Gray clayey silt, occ. sand, occ. gravel, extremely dense, non plastic, moist (ML)
		05	SS	15 35 50/1	
49.0 49.5		06	SS	34 38 50/1	Brown weathered silty clay till, little sand, occ. gravel, very hard, medium plasticity, moist. (CL)
50.0					Gray silty clay till, little sand, occ. gravel, very hard, medium plasticity, moist (CL)
					End of boring @ 50.0' (auger refusal)

* ASTM D1586

SHEET 2 OF 2

DRILLING LOG

WELL NUMBER: GW64
OWNER: Pristine, Inc.
LOCATION: 10' south of GW65
ADDRESS: Reading, OH
TOTAL DEPTH: 15.0'
SURFACE ELEVATION: 576.60
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/30/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					Black & brown coarse to fine sand, little silt, loose, fill, wet (SM)
.0					Olive and brown silty clay, some coarse to fine sand, occ. gravel, very stiff, med. plasticity, moist (CL)
.3					Gray clayey silt, loose to med. dense, saturated (ML)
.7					Gray clayey silt, tr. fine sand, med. dense, moist (ML)
.0					End of boring @15.0'

* ASTM D1586

SHEET 1 OF 1

DRILLING LOG

WELL NUMBER: GW65
LOCATION: 75' north, 50' east of SEx of property fence, along RR tracks
SURFACE ELEVATION: 576.35
OWNER: Pristine, Inc.
ADDRESS: Reading, Ohio
TOTAL DEPTH: 77.0'
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/28/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES: water level @ 2' below grade during drilling. Converted to monitoring well.

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					Black & brown coarse to fine sand, little silt, loose, fill, wet (SM)
		01	SS	3 3 1	
		02	SS	5 7 13	
6.0		03	SS	10 11 14	Olive & brown silty clay, some coarse to fine sand, occ gravel, very stiff, medium plasticity, moist (CL) Qu* = 4.5 tsf
		04	SS	5 13 14	
9.3					Gray clayey silt, loose to medium dense, saturated (ML) Qu* = 1.0 tsf
		05	SS	3 2 4	
13.7		06	SS	5 7 9	Gray clayey silt, tr fine sand, medium dense, moist (ML) Qu* = 2.0 tsf
		07	SS	5 7 9	
18.0					Gray clayey silt, medium dense, saturated (ML) Qu* = 1.3 tsf
		08	SS	5 6 7	
20					

*ASTM D1586

SHEET 1 OF 4

DRILLING LOG

WELL NUMBER GW65

OWNER: Pristine, Inc

LOCATION 75' north, 50' east of SEx of property fence, along RR tracks

ADDRESS: Reading, Ohio

TOTAL DEPTH 77.0'

SURFACE ELEVATION 576.35

WATER LEVEL

DRILLING COMPANY ATEC

DRILLING METHOD HSA

DATE DRILLED 7/28/87

DRILLER Ray West

HELPER Jim

LOG BY: K. Van Allen

SKETCH MAP

NOTES See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
20					Gray silty clay, tr. fine sand, stiff, medium plasticity, moist. (CL) Qu*= 1.2 tsf
		09	SS	5 6 8	
		10	SS	5 5 7	
		11	SS	5 5 7	
		12	SS	5 5 7	
		13	SS	4 6 6	
		14	SS	5 6 6	
		15	SS	4 5 6	
		16	SS	3 5 7	
		17	SS	4 5 6	
		18	SS	4 6 6	
40		19	SS	5 6 7	

DRILLING LOG

WELL NUMBER: GW65
LOCATION: 75' North, 50' east of SE× of property Fence, along RR tracks
SURFACE ELEVATION: 576.75
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/28/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K.Van Allen

OWNER: Pristine, Inc
ADDRESS: Reading, Ohio
TOTAL DEPTH: 77.0'
WATER LEVEL:

SKETCH MAP

NOTES: See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
40					
		20	SS	5 5 7	Gray silty clay, tr. fine sand, stiff, medium plasticity, moist. (CL) Qu*=1.2 tsf
		21	SS	5 5 6	
		22	SS	3 6 7	
		23	SS	4 6 8	
		24	SS	6 6 8	
		25	SS	6 9 9	
49.5		26	SS	6 9 13	Gray clayey silt, tr. coarse to fine sand, medium dense, wet. (ML) Qu*=1.5 tsf
50.8 51.0		27	SS	7 7 11	Gray clayey silty fine sand, poorly graded, medium dense, moist to wet (SC-SM)
		28	SS	14 19 24	Gray silty clay, tr. fine sand, interbedded with brown medium to fine sand, moist (CL, SP)
5.5		29	SS	20 32 24	Brown silty medium to fine sand, occ coarse sand, poorly graded, very dense, moist. (SM)
58.0		30	SS	15 17 15	Brown fine sand, tr. silt, poorly graded, dense, moist (SP)

*ASTM D1586

DRILLING LOG

WELL NUMBER: GW65
OWNER: Pristine, Inc
LOCATION: 75' north, 50' east of SEx of property fence, along RR. Tracks
ADDRESS: Reading, Ohio
TOTAL DEPTH: 77.0'
SURFACE ELEVATION: 576.35
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/28/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES: Water level @ 2' below grade during drilling. Dropped to 39.5' after taking SS-37, stabilized @ 39.5' below grade

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
60					Brown fine sand interbedded w/ gray silty clay, moist (SP, CL)
		31	SS	7 21 36	
62.5					Brown coarse to fine sand, little silt, well graded, extremely dense, moist to wet (SM)
		32	SS		
▼					
		33	SS		
		34	SS		
		35	SS		
71.5					Brown silty fine sand, poorly graded, very dense, wet (SM)
5.0					Brown silty coarse to fine sand w/ coarse to fine gravel, well graded, very dense, wet (SM-GM) End of boring @ 77.0'
7.0					
0					

* ASTM D1586

SHEET 4 OF 4

DRILLING LOG

WELL NUMBER: GW63
OWNER: Pristine, Inc
LOCATION: Apros 35' east of magic pit
ADDRESS: Reading, Ohio
TOTAL DEPTH: 35'
SURFACE ELEVATION: ~572
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/23/87
DRILLER: Tony West
HELPER: Jim
LOG BY: K.VanAllen

SKETCH MAP

NOTES: Water level @ 4' below grade during drilling. Converted to monitoring well.

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					Aspalt, aggregate, fill, saturated
		01	SS	3 3 3	
7.0					Brown silty clay, tr. sand, tr. gravel, very stiff, medium plasticity, moist (CL) Qu* = 2.2 tsf
		02	SS	6 8 10	
12.0					Gray silty clay, tr sand, very stiff, medium plasticity, moist (CL) Qu* = 1.5 tsf
		03	SS	4 5 6	
		04	SS	3 4 5	
		05	SS	4 6 6	

* ASTM D1586

SHEET 1 OF 2

DRILLING LOG

WELL NUMBER GW63
LOCATION Aprox 35' east of magic pit
SURFACE ELEVATION ~572

OWNER Pristine Inc.
ADDRESS Reading, Oh.
TOTAL DEPTH
WATER LEVEL

DRILLING COMPANY ATEC
DRILLING METHOD HSA
DATE DRILLED 7/23/87
DRILLER Ray West
HELPER Jim

LOG BY: K VanAllen

SKETCH MAP

NOTES See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
		06	SS	4 6 6	Gray silty clay, tr. sand, stiff, medium plasticity, moist (CL) Qu* = 1.2 tsf
		07	SS	6 6 6	
		08	SS	4 8 13	½" sand seam, fine sand & silt, moist (SM) @ 27.2'
29.0		09	SS	7 10 18	Brown silt & fine sand, poorly graded, saturated (ML-SM)
31.3		10	SS	30 34 52	Brown weathered silty clay till, some coarse to fine sand, occ gravel, very hard, medium plasticity, moist (CL) Qu* = 4.5+ tsf
		11	SS	18 34 51	
5					End of boring @ 35.0'

*ASTM D-1586

SHEET 2 OF 2

DRILLING LOG

WELL NUMBER: GW66
LOCATION: 150' south, 50' east of NE ~~x~~ of property fence, along RR tracks
SURFACE ELEVATION: 575.58
OWNER: Pristine Inc.
ADDRESS: Reading, Ohio
TOTAL DEPTH: 15.0'
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/27/07
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES: Water level @ 12.5' below grade after taking SS-6. Converted to monitoring well.

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					Silty coarse to fine sand, fill, wet (SW-SM)
1.5		01	SS	3 4 5	Olive & brown silty clay, tr. sand, very stiff, medium plasticity, moist. (CL) Qu* = 2.5 tsf
		02	SS	3 5 7	
6.0		03	SS	3 8 11	Gray clayey silt, occ. fine sand seams, moist (ML, SP)
8.5		04	SS	7 12 15	Gray clayey silt to silty clay, some coarse to fine sand, very stiff, medium plasticity, moist. (CL-ML)
9.8					Gray clayey silt, tr. sand, medium dense, saturated (ML)
		05	SS	12 10 11	
12.0					Brown coarse to fine sand, little silt, saturated (SW-SM)
12.3					Gray clayey silt, tr sand, medium dense, saturated (ML)
		06	SS	11 14 15	
					End of boring @ 15.0'

* ASTM D1586

SHEET 1 OF 1

DRILLING LOG

WELL NUMBER: GW 67
OWNER: Pristine Inc.
LOCATION: Aprox. 50' South of GW49
ADDRESS: Reading, OH.
TOTAL DEPTH: 70.0'
SURFACE ELEVATION: 576.87
WATER LEVEL:
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/30/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES:

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0					No sampling between 0 - 30', advanced augers to 38.5 before sampling.

* ASTM D1586

SHEET 1 OF 4

DRILLING LOG

WELL NUMBER: GW57
LOCATION: Aprx. 50' South of GW49
SURFACE ELEVATION: 576.87
OWNER: Pristine, Inc.
ADDRESS: Reading, Ohio
TOTAL DEPTH: 70.0'
WATER LEVEL: 66' during drilling
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/30/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES: No Sampling until 38.5'
Encountered MOL about 20',
remain in sand until 55'
Converted into monitoring well

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
20					Orange brown medium sand, poorly graded, medium dense, damp (SP)
39.0		01	SS	11 18 19	Light brown coarse to fine sand, tr. fine gravel, tr. silt, dense, well graded, damp (SW)
40					

*ASTM D1586

SHEET 2 OF 4

DRILLING LOG

WELL NUMBER: GW67
OWNER: Pristine Inc.
LOCATION: Aprox 50' South of GW49
ADDRESS: Reading, Ohio
TOTAL DEPTH: 70.0'
SURFACE ELEVATION: 576.87
WATER LEVEL: 66' during drilling
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/30/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Alten

SKETCH MAP

NOTES: See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
					Light brown coarse to fine sand, tr. fine gravel, tr. silt, well graded, medium dense to dense, damp (SW)
		02	ss	10 9 12	
		03	ss	12 17 18	
		04	ss	12 17 19	
		05	ss	10 15 18	

*ASTM D1586

SHEET 3 OF 4

WESTON

DRILLING LOG

WELL NUMBER: GW67
OWNER: Pristine Inc.
LOCATION: Aprox. 50' South of GW49
ADDRESS: Reading, Ohio
TOTAL DEPTH: 70.0'
SURFACE ELEVATION: 576.87
WATER LEVEL: 66' during drilling
DRILLING COMPANY: ATEC
DRILLING METHOD: HSA
DATE DRILLED: 7/30/87
DRILLER: Ray West
HELPER: Jim
LOG BY: K. Van Allen

SKETCH MAP

NOTES: See page 1

DEPTH (FEET)	GRAPHIC LOG	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE BLOWS*	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
60					Light brown coarse to fine sand, tr. fine gravel, tr. silt, well graded, dense, damp. (SW)
66.0					Brown coarse to fine gravel, & coarse to fine sand, tr. silt, well graded, very dense, saturated (GW)
		06	SS	37 53 50/3	
70.0					End of boring @ 70.0'

* ASTM D1586

SHEET 4 OF 4

APPENDIX I

WELL INSTALLATION DATA SHEETS

Well ___

Well Construction Summary

Location or Coords Aprox 65' north, 50' east of SE of property fence, along RR tracks

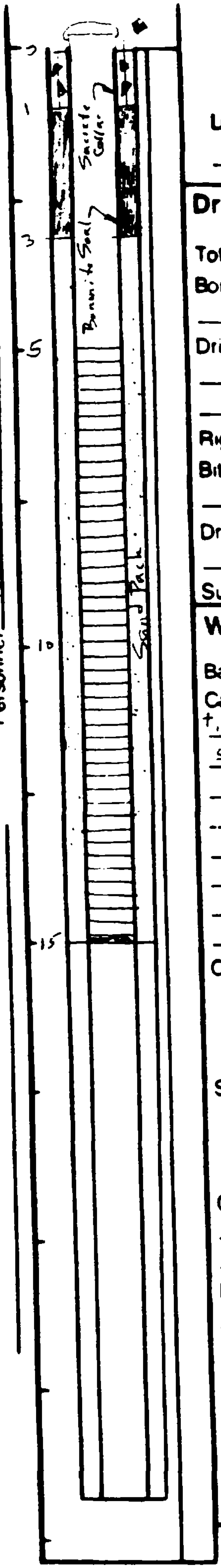
Elevation Ground Level 576.40

Top of Casing (PVC) 576.74

Location 'Reading, Ohio

Personnel K. Van Allen

Project Tristate Inc. KIZ



Drilling Summary:

Total Depth 15'

Borehole Diameter 8"

Driller ATEC

Rig Mobil B-61

Bit(s) 4 1/4" ID x 7 3/4" OD HSA

Drilling Fluid None

Surface Casing ___

Well Design:

Basis Geologic Log ✓ Geophysical Log ___

Casing String(s) C = Casing S = Screen

+.4' -	5'	C
5' -	15'	S

Casing C1 2" Ø Sch. 40 PVC riser, flush joint

C2 ___

Screen. S1 2" Ø Sch. 40 PVC screen, 0.010" slotted openings

S2 ___

Centralizers ___

Filter Material Ottawa Silica Sand, sorted, medium grain

Cement None

Other Wyoming bentonite pellets Sacrete

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
No sampling	7/30	1030	7/30	1115
Well Const.	7/30	1115	7/30	1230
Geophys Logging				
Casing				
Filter Placement	7/30	1130	7/30	125
Cementing				
Development	8/1	1200	8/1	1400
Other				
Seal placement	7/30	1200	7/30	1230
Sacrete	7/31	-	7/31	-

Well Development:

Bailed well for aprox. 2 hrs., recovery good Used surging action for removal of fines from the screened interval

Comments:

Performed buildup test, recovered in 2hrs See results, for addl. data

WESTON

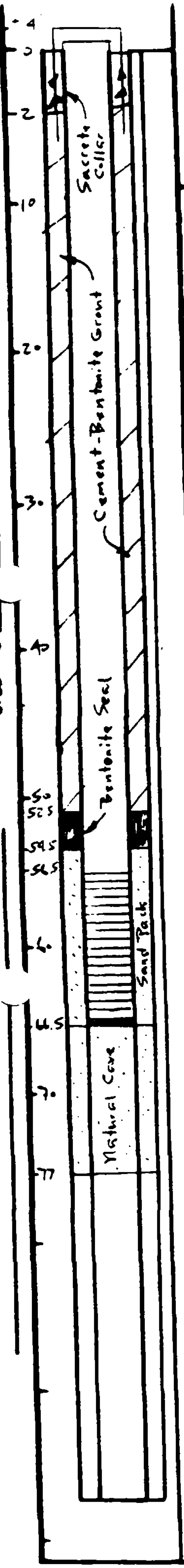
Well 3-6

Well Construction Summary

Project Pristine Inc. KJ2

Location Ke... ...

Personnel K VanAllen



Location or Coords Aprox 75' North 50' east of SE~ of property fence, along RR tracks.

Elevation Ground Level 576.35

Top of Casing (PVC) 576.19

Drilling Summary:

Total Depth 77.0'

Borehole Diameter 8"

Driller ATEC

Rig Mobil B-61

Bit(s) 4 1/4" ID x 7 3/4" OD HSA

Drilling Fluid Clear water, See comments

Surface Casing

Well Design:

Basis Geologic Log ✓ Geophysical Log

Casing String(s) C = Casing S = Screen

+.6' - 56.5'	C	
56.5' - 66.5'	S	

Casing C1 2" Ø Sch 40 PVC riser, flush jointed

C2

Screen S1 2" Ø Sch 40 PVC Screen, 0.010" slotted openings

S2

Centralizers

Filter Material Ottawa Silica Sand, Sorted, medium grain

Cement Portland, type I

Other Benseal bentonite powder
Wyoming bentonite pellets
Sacrete

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Sampling	7/28	0900	7/29	0900
Well Const.	7/29	1000	7/29	1930
Geophys Logging				
Casing				
Filter Placement	7/29	1400	7/29	1600
Cementing	7/29	1800	7/29	1930
Development	8/1	1100	8/1	1200
Other				
Seal placement	7/29	1600	7/29	1700
Sacrete	7/30	–	7/30	

Well Development:

Bailed well dry on 7/30 and on 8/1. Well recovered to 577' (top PVC) on 7/30 Well recovery on 8/1 very poor.

Comments:

Clear water was used to flush muds from augers. Aprox 300 gal used for flushing.
Probable that water infiltrated into the gravely zone @ 75.5-77'

WESTON DESIGNERS CONSULTANTS

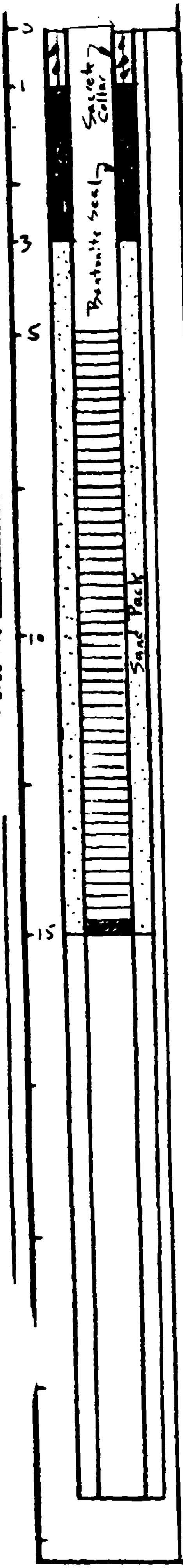
Well GW 66

Well Construction Summary

Location or Coords 150' South, 50' east of NE x of property Fence, along RR tracks

Elevation Ground Level ~576

Top of Casing ~576.3



Personnel K. Van Allen

Drilling Summary:

Total Depth 15.0'

Borehole Diameter 8"

Driller ATEC

Rig Mobil B-61

Bit(s) 4 1/4" ID x 7 3/4" OD HSA

Drilling Fluid None

Surface Casing

Well Design:

Basis Geologic Log ✓ Geophysical Log

Casing String(s) C = Casing S = Screen

+.2' - 5' C

5' - 15' S

Casing C1 2" ϕ Sch 40 PVC Riser, flush jointed

C2

Screen S1 2" ϕ Sch 40 PVC Screen, 0.010" slotted openings

S2

Centralizers

Filter Material Ottawa Silica Sand Sorted, medium grain

Cement

Other Wyoming bentonite pellets Sacrete

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Sampling	7/27	0930	7/27	1100
Well Const.	7/27	1200	7/27	1500
Geophys Logging				
Casing				
Filter Placement	7/27	1230	7/27	1400
Cementing				
Development	7/28	1430	7/28	1700
Other				
Seal Placement	7/27	1400	7/27	1500
Sacrete	7/28	-	7/28	-

Well Development:

Bailed well dry about 4 times, allowing it to recover. Surging action used for removing fines from screened interval. Spent aprox. 2 1/2 hrs for development.

Comments:

Some silts or clays in water from well, but development improved it. Recovery fair

Baildown test performed, see results for addl. data.

WESTON

Well [illegible]

Well Construction Summary

Location or Coords: Aprox 50' South of GW 49

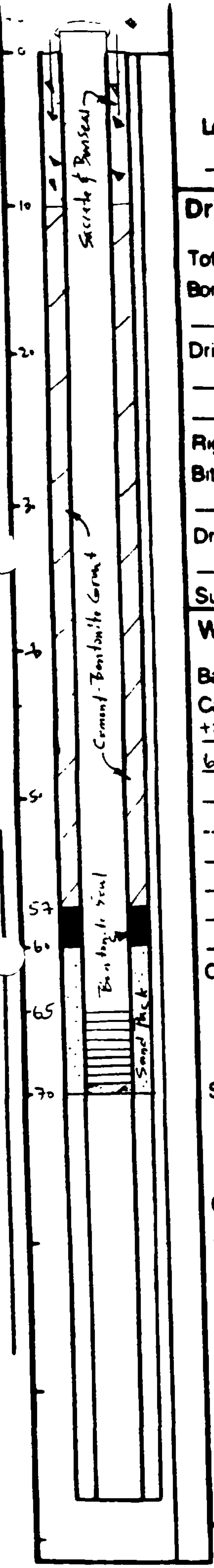
Elevation Ground Level: 576.87

Top of Casing (PVC): 577.36

Location: Reading, Ohio

Personnel: Kim Allen

Project: Pristine, Inc. RI c



Drilling Summary:

Total Depth: 70.0'

Borehole Diameter: 8"

Driller: ATEC

Rig: Mobil B-61

Bit(s): 4 1/4" ID x 7 3/4" OD HSA

Drilling Fluid: Clear water, see comments.

Surface Casing:

Well Design:

Basis: Geologic Log ✓ Geophysical Log

Casing String(s): C = Casing S = Screen

+2'	65'	C
65'	70'	S

Casing C1: 2" Ø Sch 40 PVC riser, flush joint

C2:

Screen S1: 2" Ø Sch. 40 PVC screen, 0.010" slotted openings

S2:

Centralizers:

Filter Material: Ottawa Silica Sand sorted medium grain

Cement: Portland, type I

Other: Benseal bentonite powder Wyoming bentonite pellets Secrete

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Sampling	7/30	1530	7/31	0930
Well Const.	7/31	0930	7/31	1550
Geophys Logging				
Casing				
Filter Placement	7/31	1030	7/31	1200
Cementing	7/31	1400	7/31	1550
Development	8/1	1300	8/1	1400
Other				
Seal Placement	7/31	1330	7/31	1400

Well Development:

Bailed well for aprox. 1 hr. using surging action for removal of fines

Removed about 17 gal

Comments:

Water silty, turbid, but became less turbid w/ development. Recovery fair

Performed baildown test, see results for addl. data.

Well Sw 63

Well Construction Summary

Location or Coords Aprox 35' east of magic pit

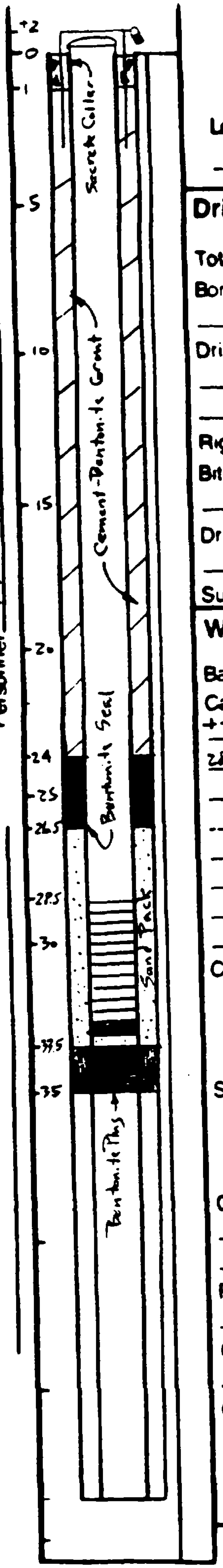
Elevation Ground Level ~ 572

Top of Casing ~ 574

Location Reading, OH

Personnel K. VanAllen

Project Pristine Inc, RI2



Drilling Summary:

Total Depth 35.0'

Borehole Diameter 8"

Driller ATEC

Rig Mobil B-61

Bit(s) 4 1/4" ID x 7 3/4" OD HSA

Drilling Fluid Clear water, see comments.

Surface Casing

Well Design:

Basis Geologic Log ✓ Geophysical Log

Casing String(s) C = Casing S = Screen

+2' - 28.5' C

28.5' - 33.5' S

Casing C1 2" φ Sch. 40 PVC riser, flush jointed

C2

Screen. S1 2" φ Sch. 40 PVC screen, 0.010" slotted openings

S2

Centralizers

Filter Material Ottawa silica sand, sorted medium grain

Cement Portland, type I

Other Benseal bentonite powder

Wyoming bentonite pellets

Sacrete

Construction Time Log:

Task	Start		Finish	
	Date	Time	Date	Time
Drilling				
Sampling	7/23	0930	7/23	1030
Well Const.	7/23	1030	7/23	1515
Geophys Logging				
Casing				
Filter Placement	7/23	1100	7/23	1200
Cementing	7/23	1330	7/23	1430
Development	7/25	0900	7/25	1200
Other				
Seal Placement	7/23	1200	7/23	1230
Sacrete	7/24	-	7/24	-

Well Development:

Bailed well dry about four times, using surging action for removal of fines from sand pack. Spent aprox. three (3) hours for development. Slow recovery due to lithology (silt) of saturated zone.

Comments:

Used clear water to flush soil cuttings from inside augers, allowing proper settlement of well screen sand pack and pellets. Used aprox. 150 gal. water and majority of water was discharged from augers.

Very little water infiltrated into materials due to low permeability of screened soils.

Recovery fairly slow.

Performed buildown test see results for addl. data

APPENDIX J

BAILDOWN AND SLUG TEST DATA

A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells

HERMAN BOUWER AND R. C. RICE

U.S. Water Conservation Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Phoenix, Arizona 85040

A procedure is presented for calculating the hydraulic conductivity of an aquifer near a well from the rate of rise of the water level in the well after a certain volume of water is suddenly removed. The calculation is based on the Thiem equation of steady state flow to a well. The effective radius R_e over which the head difference between the equilibrium water table in the aquifer and the water level in the well is dissipated was evaluated with a resistance network analog for a wide range of system geometries. An empirical equation relating R_e to the geometry of the well and aquifer was derived. The technique is applicable to completely or partially penetrating wells in unconfined aquifers. It can also be used for confined aquifers that receive water from the upper confining layer. The method's results are compatible with those obtained by other techniques for overlapping geometries.

With the slug test the hydraulic conductivity or transmissibility of an aquifer is determined from the rate of rise of the water level in a well after a certain volume or 'slug' of water is suddenly removed from the well. The slug test is simpler and quicker than the Theis pumping test because observation wells and pumping the well are not needed. With the slug test the portion of the aquifer 'sampled' for hydraulic conductivity is smaller than that for the pumping test even though with the latter, most of the head loss also occurs within a relatively small distance of the pumped well and the resulting transmissibility primarily reflects the aquifer conditions near the pumped well.

Essentially instantaneous lowering of the water level in a well can be achieved by quickly removing water with a bailer or by partially or completely submerging an object in the water, letting the water level reach equilibrium, and then quickly removing the object. If the aquifer is very permeable, the water level in the well may rise very rapidly. Such rapid rises can be measured with sensitive pressure transducers and fast-response strip chart recorders or *x-y* plotters. Also it may be possible to isolate portions of the perforated or screened section of the well with special packers for the slug test. This not only reduces the inflow and hence the rate of rise of the water level in the well, but it also makes it possible to determine the vertical distribution of the hydraulic conductivity. Special packer techniques may have to be developed to obtain a good seal, especially for rough casings or perforations. Effective sealing may be achieved with relatively long sections of inflatable stoppers or tubing. The use of long sections of these materials would also reduce leakage flow from the rest of the well to the isolated section between packers. This flow can occur through gravel envelopes or other permeable zones surrounding the casing. Sections of inflatable tubing may have to be long enough to block off the entire part of the well not used for the slug test. High inflation pressures should be used to minimize volume changes in the tubing due to changing water pressures in the isolated section when the head is lowered.

So far, solutions for the slug test have been developed only for completely penetrating wells in confined aquifers. *Cooper et al.* [1967] derived an equation for the rise or fall of the water level in a well after sudden lowering or raising, respectively. Their equation was based on nonsteady flow to a pumped, completely penetrating well, and the solution was expressed as a series of 'type curves' against which observed rates of water level rises were matched. Values for the transmissibility and storage coefficient were then evaluated from the curve parameter and horizontal-scale position of the type curve showing the best fit with the experimental data. *Skibitzke* [1958] developed an equation for calculating transmissibility from the recovery of the water level in a well that was repeatedly bailed. The technique is limited to wells in confined aquifers with sufficiently shallow water levels to permit short time intervals between bailing cycles [*Lohman*, 1972].

To use the slug test for partially penetrating or partially perforated wells in confined or unconfined aquifers, some solutions developed for the auger hole and piezometer techniques to measure soil hydraulic conductivity [*Bouwer and Jackson*, 1974] may be employed. However, the geometry of most groundwater wells is outside the range in geometry covered by the existing equations or tables for the auger hole or piezometer methods. For this reason, theory and equations are presented in this paper for slug tests on partially or completely penetrating wells in unconfined aquifers for a wide range of geometry conditions. The wells may be partially or completely perforated, screened, or otherwise open along their periphery. While the solutions are developed for unconfined aquifers, they may also be used for slug tests on wells in confined aquifers if water enters the aquifer from the upper confining layer through compression or leakage.

THEORY

Geometry and symbols of a well in an unconfined aquifer are shown in Figure 1. For the slug test the water level in the well is suddenly lowered, and the rate of rise of the water level is measured. The flow into the well at a particular value of y can be calculated by modifying the Thiem equation to

$$Q = 2\pi KL \frac{y}{\ln (R_e/r_w)} \tag{1}$$

where Q is the flow into the well (length^3/time), K is the hydraulic conductivity of the aquifer (length/time), L is the height of the portion of well through which water enters (height of screen or perforated zone or of uncased portion of well), y is the vertical distance between water level in well and equilibrium water table in aquifer, R_e is the effective radius over which y is dissipated, and r_w is the horizontal distance

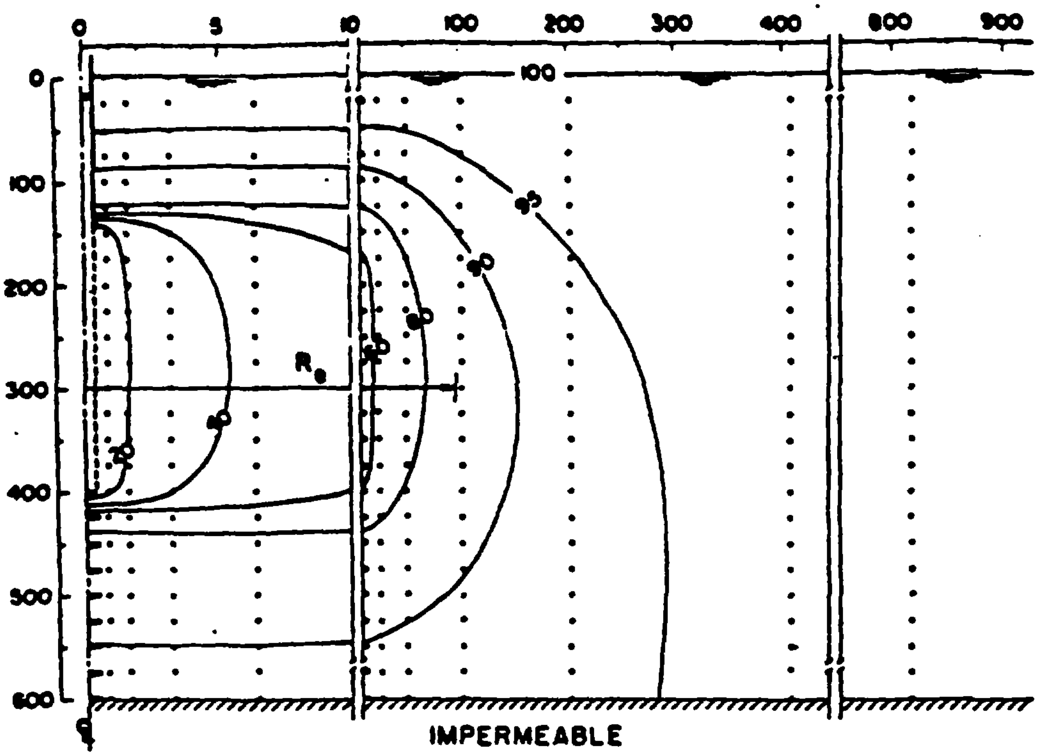


Fig. 2. Node arrangement (dots) for resistance network analog and potential distribution (indicated as percentages on equipotentials) for system with $L/r_w = 625$, $H/r_w = 1000$, and $D/r_w = 1500$. The numbers on the left and at the top of the figure are arbitrary length units (note breaks in horizontal scale).

less than the flow when the layer is taken as being infinitely permeable. The average of the two flows can then be taken as a good estimate of the flow that would occur if the aquifer were represented on the analog as being uniform to infinite depth [*Bouwer*, 1967]. This average flow was used to calculate R_e for $D = \infty$.

The analog analyses were performed by simulating a system with certain values of r_w, H, and D. The electrical current entering the 'well' was then measured for different values of L, ranging from near H to near 0. This was repeated for other values of r_w, H, and D. The condition where $L = H$ could not be simulated on the analog because it would mean a short between the water table as the source and the well as the sink. The electrical current flow in the analog was converted to volume per day, and ln R_e/r_w was evaluated with (1) for each combination of r_w, H, L, and D used in the analog.

For a given geometry described by r_w, H, and D, the current flow Q_i into the simulated well varied essentially linearly with L and could be described by the equation

$$Q_i = mL + n \tag{7}$$

Because of the linearity between Q_i and L the results of the analyses could be extrapolated to the condition $L = H$. The values of m in (7) appeared to vary inversely with ln H/r_w. The values of n varied approximately linearly with ln $[(D - H)/r_w]$, the slope A and intercept B in these relations being a function of L/r_w. This enabled the derivation of the following empirical equation relating ln R_e/r_w to the geometry of the system:

$$\ln \frac{R_e}{r_w} = \left[\frac{1.1}{\ln (H/r_w)} + \frac{A + B \ln [(D - H)/r_w]}{L/r_w}\right]^{-1} \tag{8}$$

In this equation, A and B are dimensionless coefficients that are functions of L/r_w, as shown in Figure 3. If $D >> H$, an increase in D has no measurable effect on ln R_e/r_w. The analog results indicated that the effective upper limit of ln $[(D - H)/r_w]$ is 6. Thus if D is considered infinity or $(D - H)/r_w$ is so large that ln $[(D - H)/r_w]$ is greater than 6, a value of 6 should still be used for the term ln $[(D - H)/r_w]$ in (8).

If $D = H$, the term ln $[(D - H)/r_w]$ in (8) cannot be used. The analog results indicated that for this condition, which is the case of a fully penetrating well, (8) should be modified to

$$\ln R_e/r_w = \left(\frac{1.1}{\ln (H/r_w)} + \frac{C}{L/r_w}\right)^{-1} \tag{9}$$

where C is a dimensionless parameter that is a function of L/r_w as shown in Figure 3.

Equations (8) and (9) yield values of ln R_e/r_w that are within 10% of the actual value as evaluated by analog if $L > 0.4H$ and within 25% if $L << H$ (for example, $L = 0.1H$).

The analog analyses were performed for wells that were closed at the bottom. Occasionally, however, wells with open bottoms were also simulated. The flow through the bottom appeared to be negligible for all values of r_w and L used in the analyses. If L is not much greater than r_w (for example, $L/r_w << 4$), the system geometry approaches that of a piezometer cavity [*Bouwer and Jackson*, 1974], in which case the bottom flow can be significant. Equations (8) and (9) can also be used to evaluate ln R_e/r_w if a portion of the perforated or otherwise open part of the well is isolated with packers for the slug test.

Equipotentials for the flow system around a partially penetrating, partially perforated well in an unconfined aquifer after lowering the water level in the well are shown in Figure 2. The numbers along the symmetry axis and the water table represent arbitrary length units. The numbers on the equipotentials indicate the potential as a percentage of the total head difference between the water table (100%) and the open portion of the well (0%) shown as a dashed line.

The value of R_e for the case in Figure 2 is 96.7 length units. As shown in the figure, this corresponds approximately to the ometer method at the lower values of L/r_w. With the ezometer method a cavity is augered out in the soil below a ezometer tube. The water level in the tube is abruptly ered, and K of the soil around the cavity is calculated from rate of rise of the water level in the tube [*Bouwer and* *ackson*, 1974]. The equation for K is

$$K = \frac{\pi r_c^2}{A_Y}\frac{1}{t}\ln\frac{y_0}{y_t} \tag{12}$$

here A_Y is a geometry factor with dimension of length. Val- of A_Y were evaluated with an electrolytic tank analog by *ungs* [1968], whose results were expressed in tabular form as $_Y/r_w$ for different values of L/r_w (ranging between 0 and 8), $- L)/r_w$, and $(D - H)/r_w$.

Taking a hypothetical case where $L/r_w = 8$, $H/r_w = 12$, and $/r_w = 16$, K calculated with (5) is 18% below K calculated ith (12). This is more than the 10% error normally expected th (8) and (9) for the L/H value of 0.67 in this case. The rger discrepancy may be due to the difference in method- ology, or to the fact that the L/r_w value is close to the lower nit of the range covered on the resistance network analog.

An approximate equation for calculating K with the pie- ometer method was presented by *Hvorslev* [1951]. The equa- ion, which is based on the assumptions of an ellipsoidal cavity well screen and infinite vertical extent (upward and down- ard) of the flow system, contains a term $[1 + (L/2r_w)^2]^{1/2}$. For most well-slug-test geometries, $L/2r_w$ will be sufficiently rge to permit replacement of this term by $L/2r_w$. In that case, owever, Hvorslev's equation for Q yields $R_e = L$, which is not true. In reality, R_e is considerably less than L. For example, if $L = 40$ m, $r_w = 0.4$ m, $H = 80$ m, and $D = \infty$, (8) shows that $R_e = 11.9$ m, which is much less than the value of 40 m ndicated by Hvorslev's equation. However, since the calcu- lation of K is based on ln (R_e/r_w) as shown by (5), the error in is less than the error in R_e (i.e., 36 and 236%, respectively, in his case).

If, for the above example, the top of the well screen or cavity had been taken at the same level as the water table ($H = 40$ m), R_e would have been 8.6 m and Hvorslev's equation would have yielded a K value that is 50% higher than K given by (5). The larger error is probably due to Hvorslev's assumption of infinite vertical (upward) extent of the flow system, which is not met when the cavity is immediately below the water table. Using Hvorslev's equation for cavities immediately below a confining layer would increase the error to 73%, but this, of course, is due to the fact that a water table is not a solid boundary. Hvorslev's equation for the confining layer case can be shown to yield $R_e = 2L$.

Auger hole method. The analog analyses for (8) and (9) and Figure 3 were performed for $L < H$, because short circuiting between the water table and the well prevented simulation of the case where $L = H$. If the analog results are extrapolated to $L = H$, however, the geometry of the system in Figure 1 becomes similar to that of the auger hole technique, for which a number of equations and graphs have been developed to calculate K from the rise of the water level in the well [*Bouwer and Jackson*, 1974]. *Boast and Kirkham* [1971], for example, developed the equation

$$K = C_{BK}\frac{\Delta y}{\Delta t} \tag{13}$$

where C_{BK} was determined mathematically and expressed in tabular form for various values of L/r_w, $(D - H)/r_w$, and y/H. Since the rate of rise of the water level in the hole after the removal of a slug of water decreases with decreasing y, $\Delta y/\Delta t$ is not a constant and the value of K obtained with this procedure depends on the magnitude of Δy used in the field measurements. The general rule is that Δy should be relatively small.

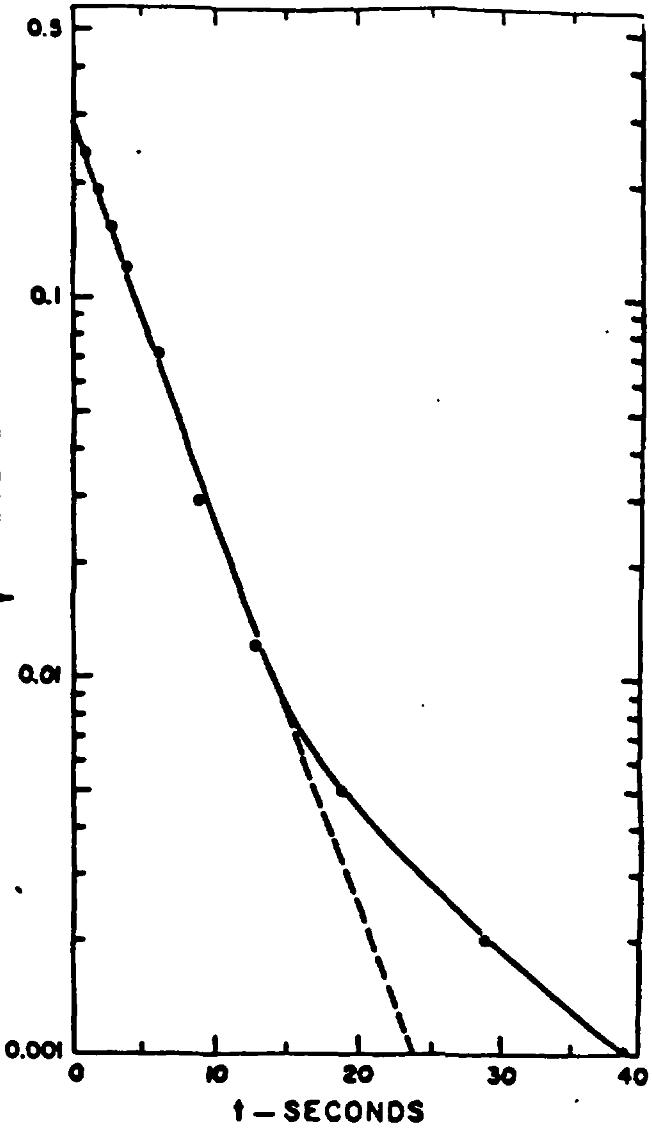
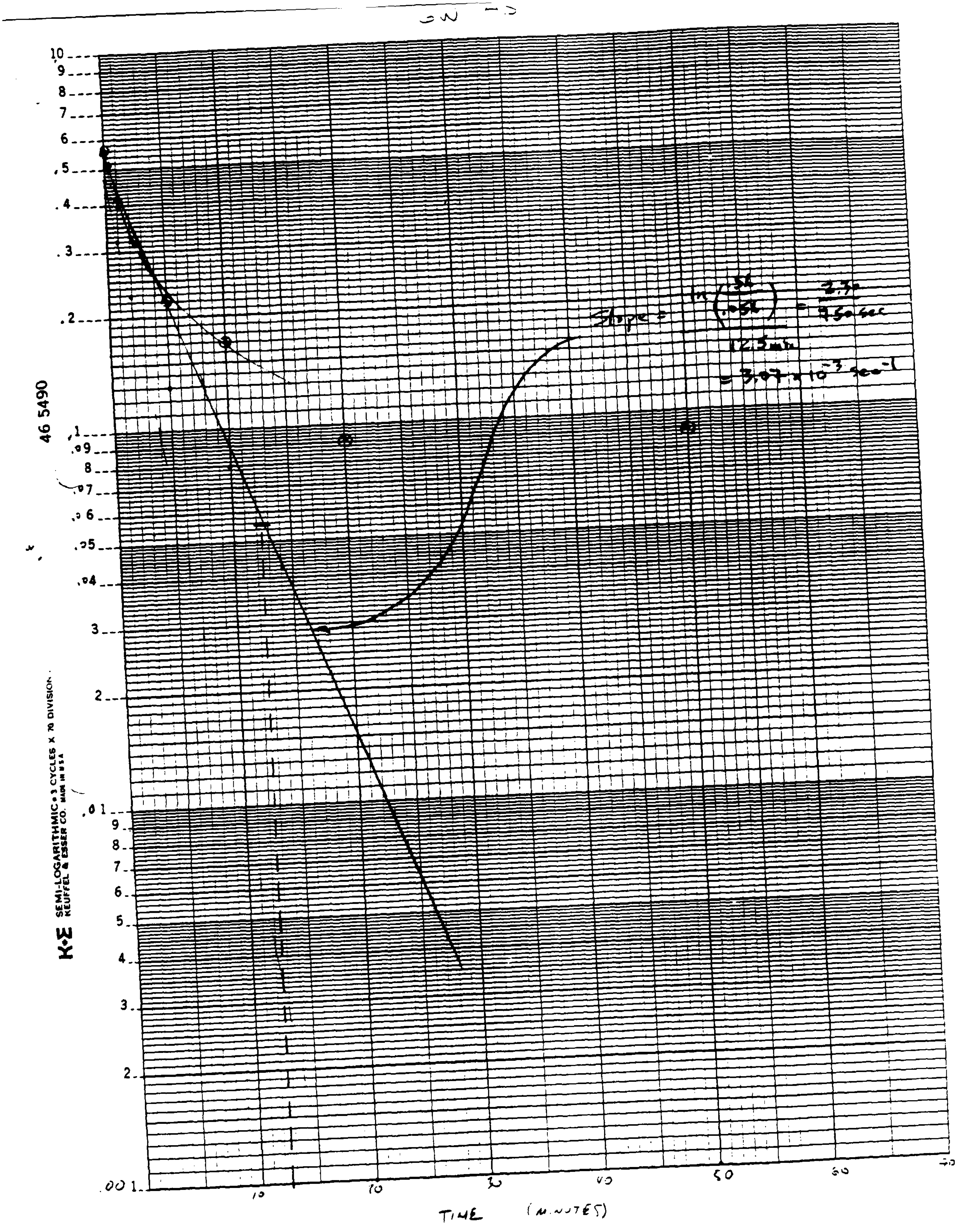


Fig. 4. Plot of y versus t for slug test on east well.

Taking a hypothetical case where $y_0 = 2.5$ m, $y_t = 2.4$ m, $\Delta t = 10$ s, $L = H = 5$ m, $D = 6$ m, and $r_w = 0.1$ m, (5) yields a K value that is 36% lower than K calculated with (13). However, if y_t is taken as 0.5 m, which should give $\Delta t = 394$ s according to the theory that $(1/t)$ ln y_0/y_t is constant, the K value yielded by (5) is 26% higher than K obtained with (13). If y_t is taken as 0.9 m, (5) and (13) give identical results.

Slug test on wells in confined aquifers. The confined aquifer for which the slug test by *Cooper et al.* [1967] was developed is an aquifer with an internal water source, for example, recharge through aquitards or compression of confining layers or other material. This situation is similar to that of the unconfined aquifer presented in this paper because the water table is considered horizontal, like the upper boundary of a confined aquifer, and the water table is a plane source. Thus K or T calculated with (5) or (6) should be of the same order as K calculated with the procedure of *Cooper et al.* [1967], which involves plotting the rise of the water level in the well and finding the best fit on a family of type curves. *Cooper et al.* [1967] presented an example of the calculation of T for a well


10
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7
6
.5
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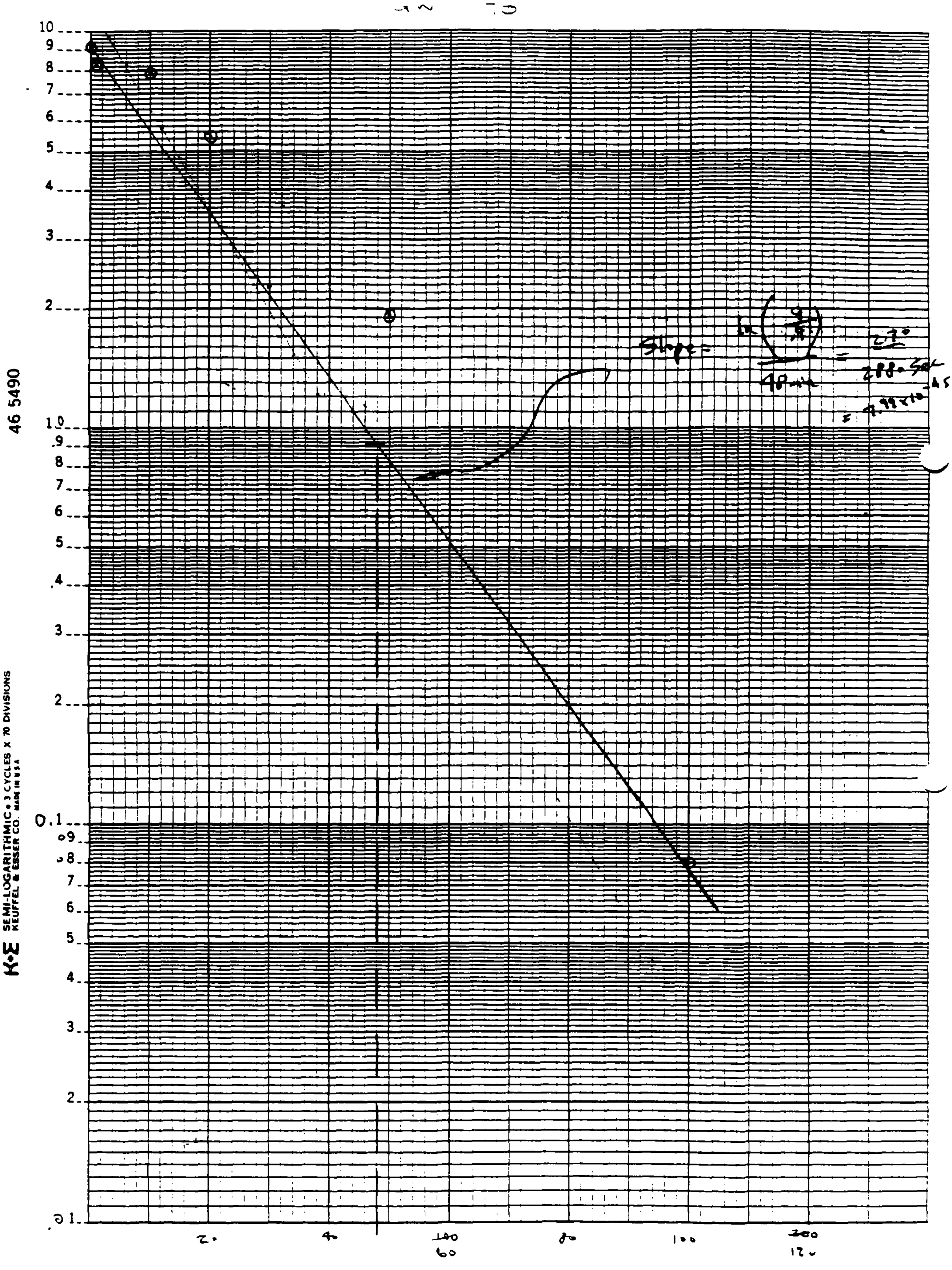
.3
.2
.1
.09
8
.07
.06
.05
.04
3
2
.01
9
8
7
6
5
4
3
2
.001
10
20
30
40
50
60
70
TIME (MINUTES)
Slope = ln(.56/.056) / 12.5 min = 2.30/750 sec
= 3.07 x 10^-3 sec^-1
46 5490
K•E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISION
KEUFFEL & ESSER CO. MADE IN U.S.A.


10
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1.0
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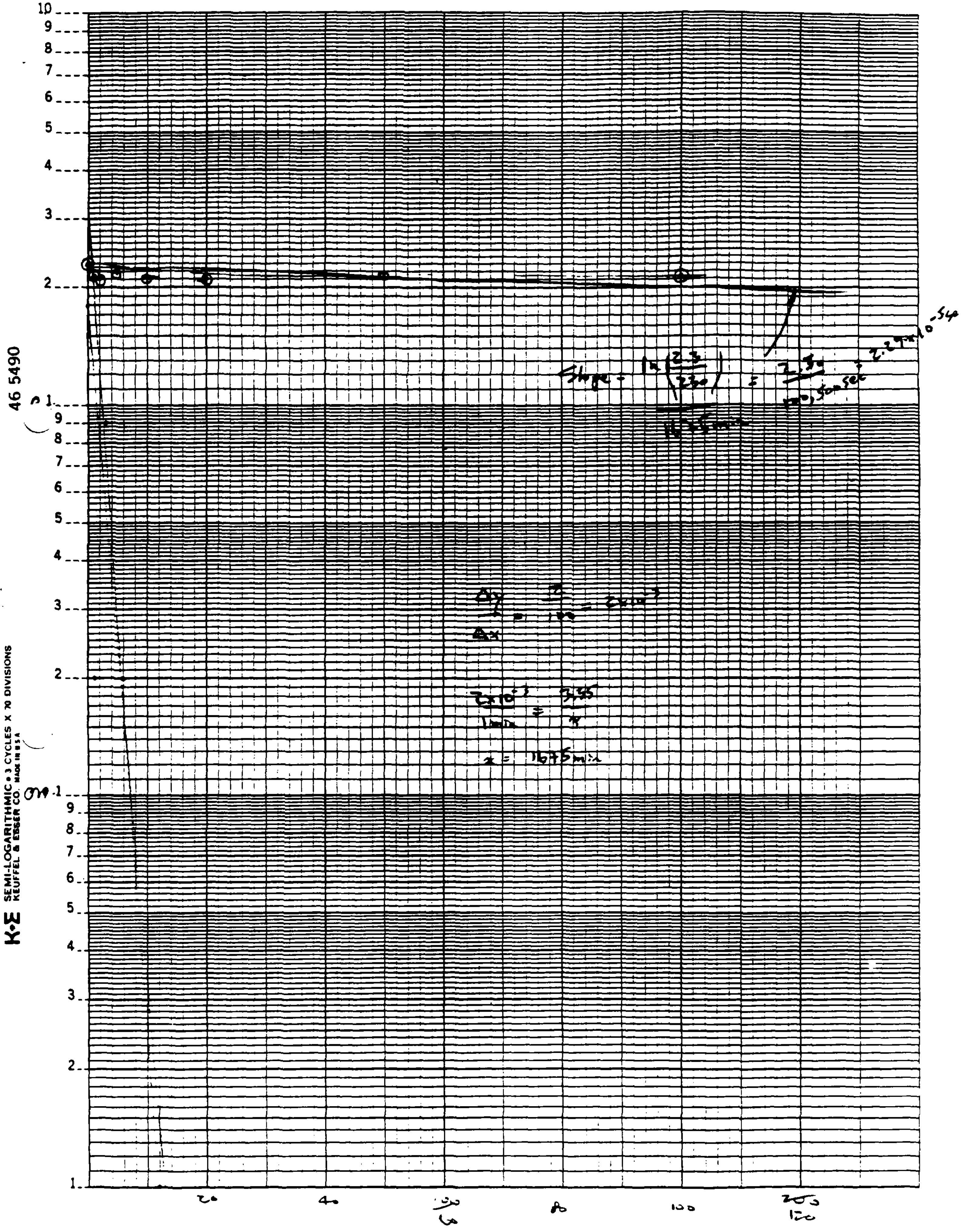
0.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
20
40
100
60
80
100
200
120
Slope = ln(9/.8)/48 min = 2.70/2880 sec
= 9.99×10^-4 sec^-1
46 5490
K·E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

GW30



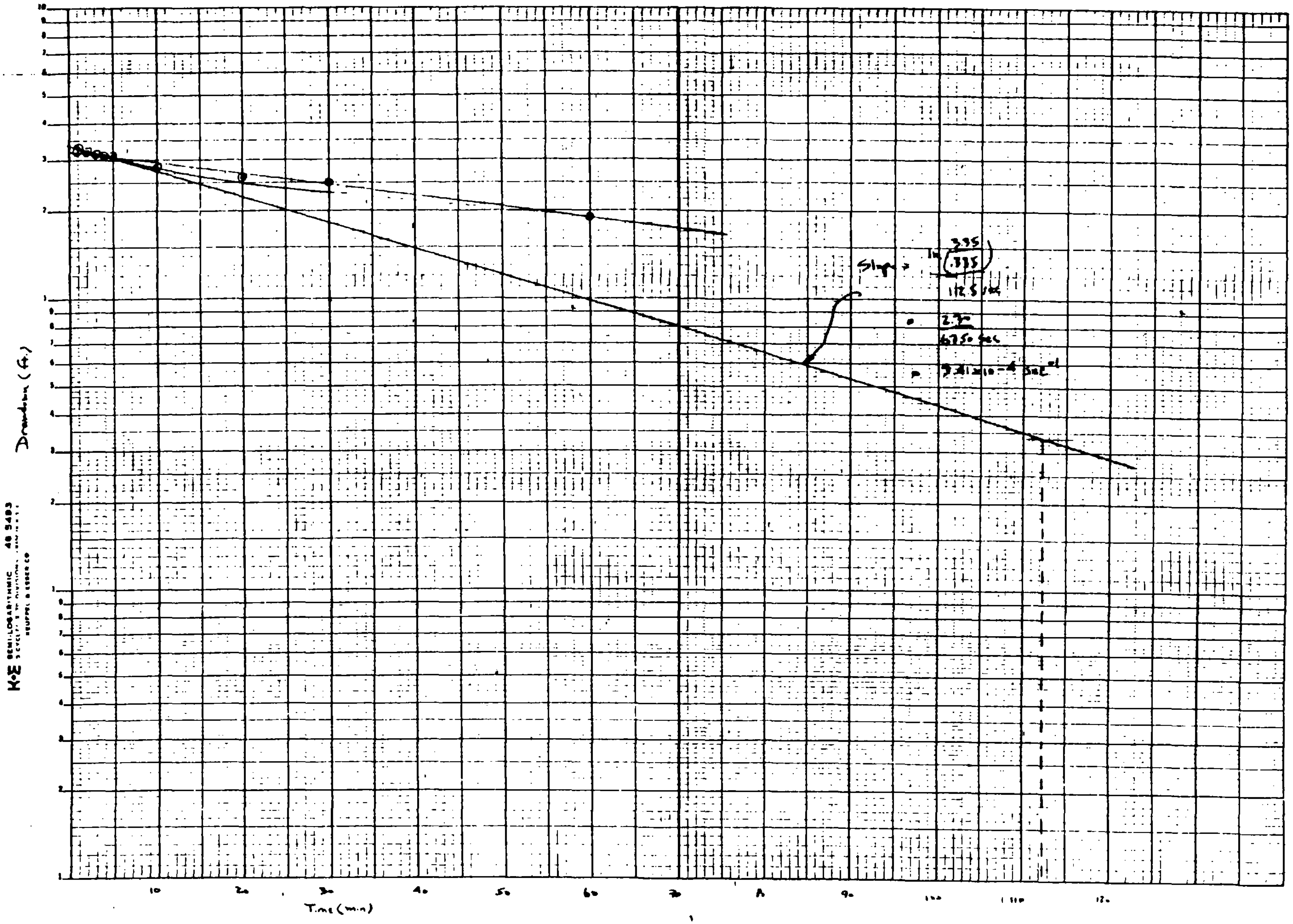
Slope = $\frac{\ln\left(\frac{2.3}{2.30}\right)}{1675\,\text{min}} = \frac{2.30}{100{,}500\,\text{sec}} = 2.29\times10^{-54}$

$\frac{\Delta y}{\Delta x} = \frac{.2}{100} = 2\times10^{-3}$

$\frac{2\times10^{-3}}{1\,\text{min}} = \frac{3.35}{x}$

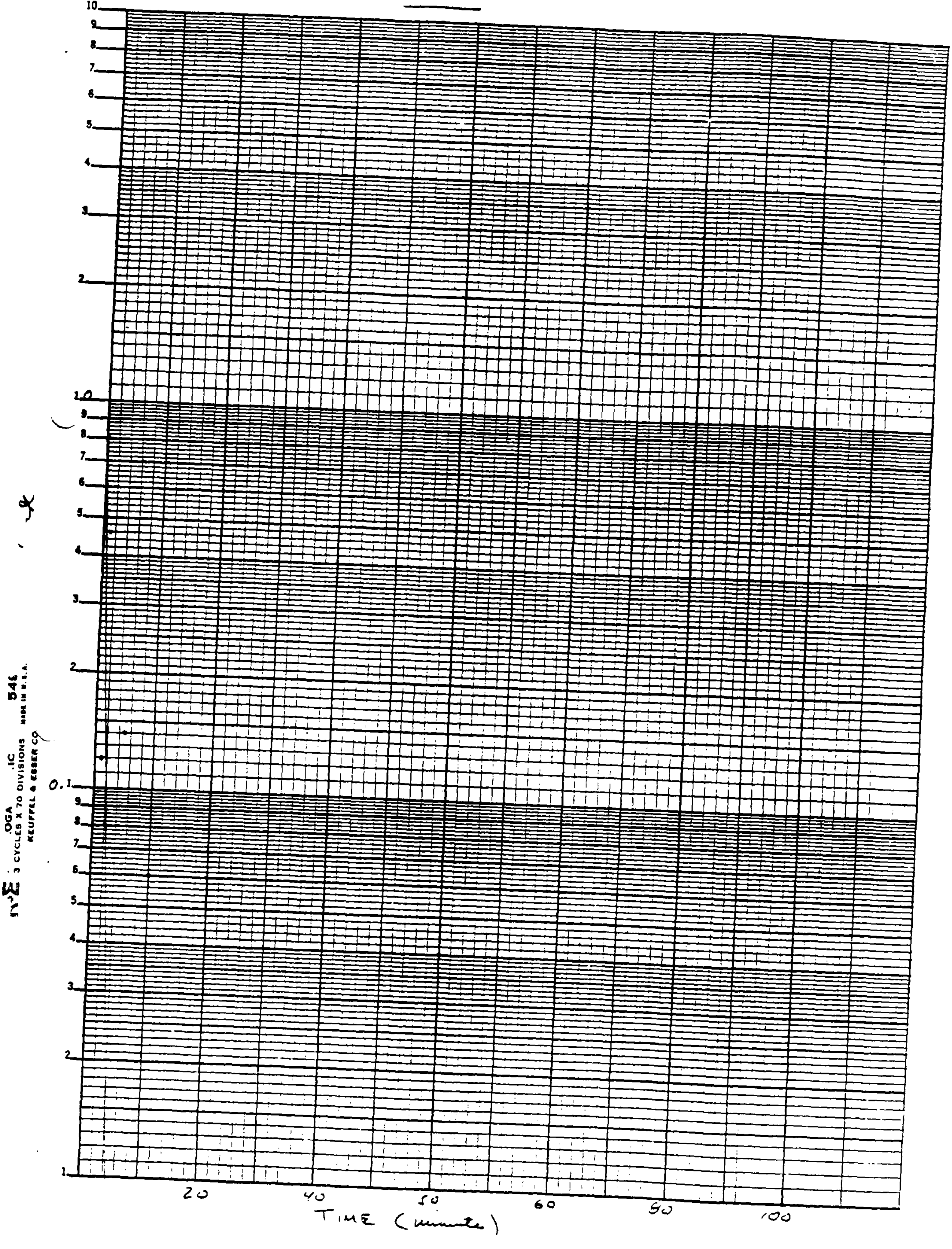
$x = 1675\,\text{min}$

GW 50



$$\text{Slope} = \frac{\ln\left(\frac{3.35}{.335}\right)}{112.5 \text{ min}} = \frac{2.30}{6750 \text{ sec}} = 3.41 \times 10^{-4} \text{ sec}^{-1}$$

GW 32


10
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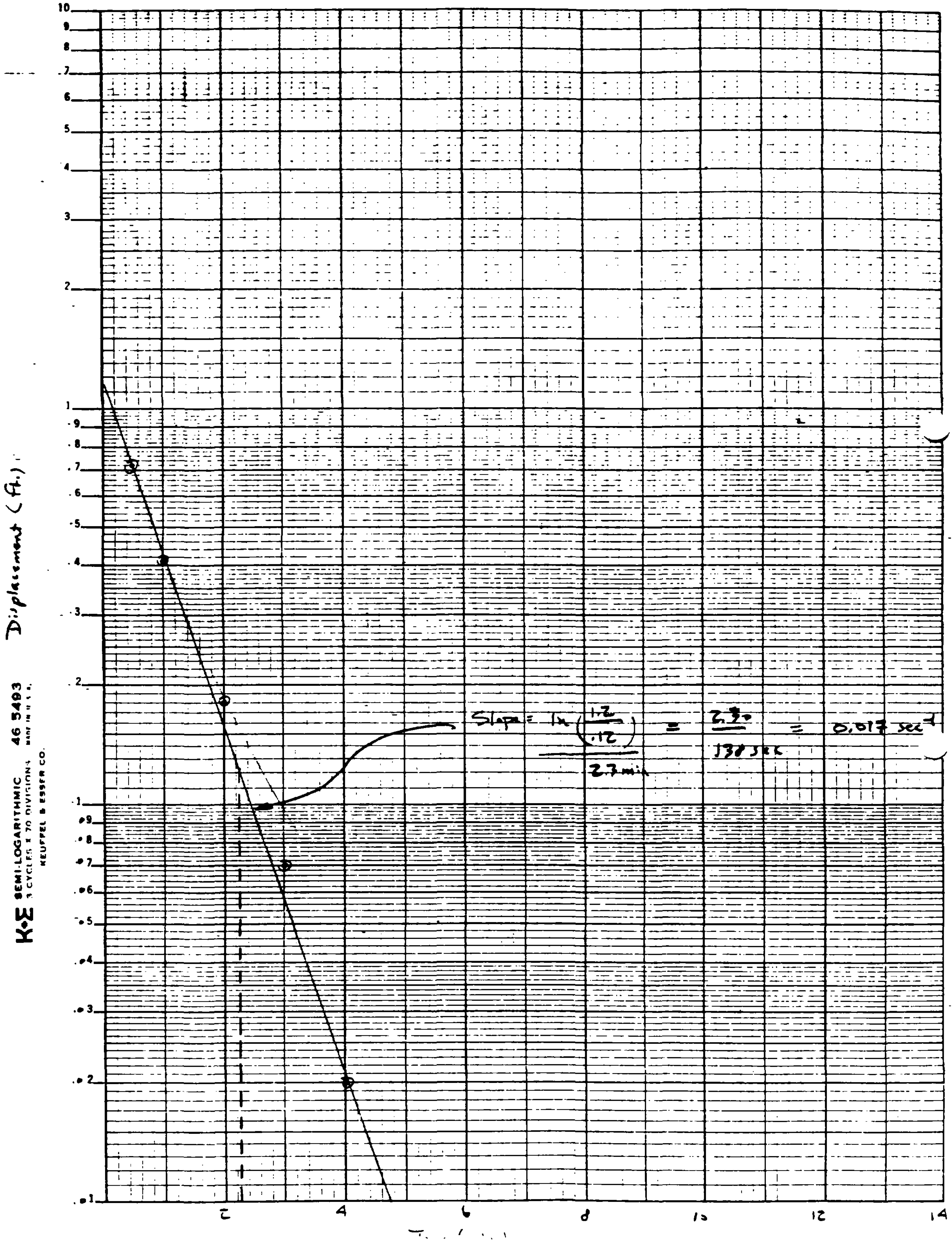
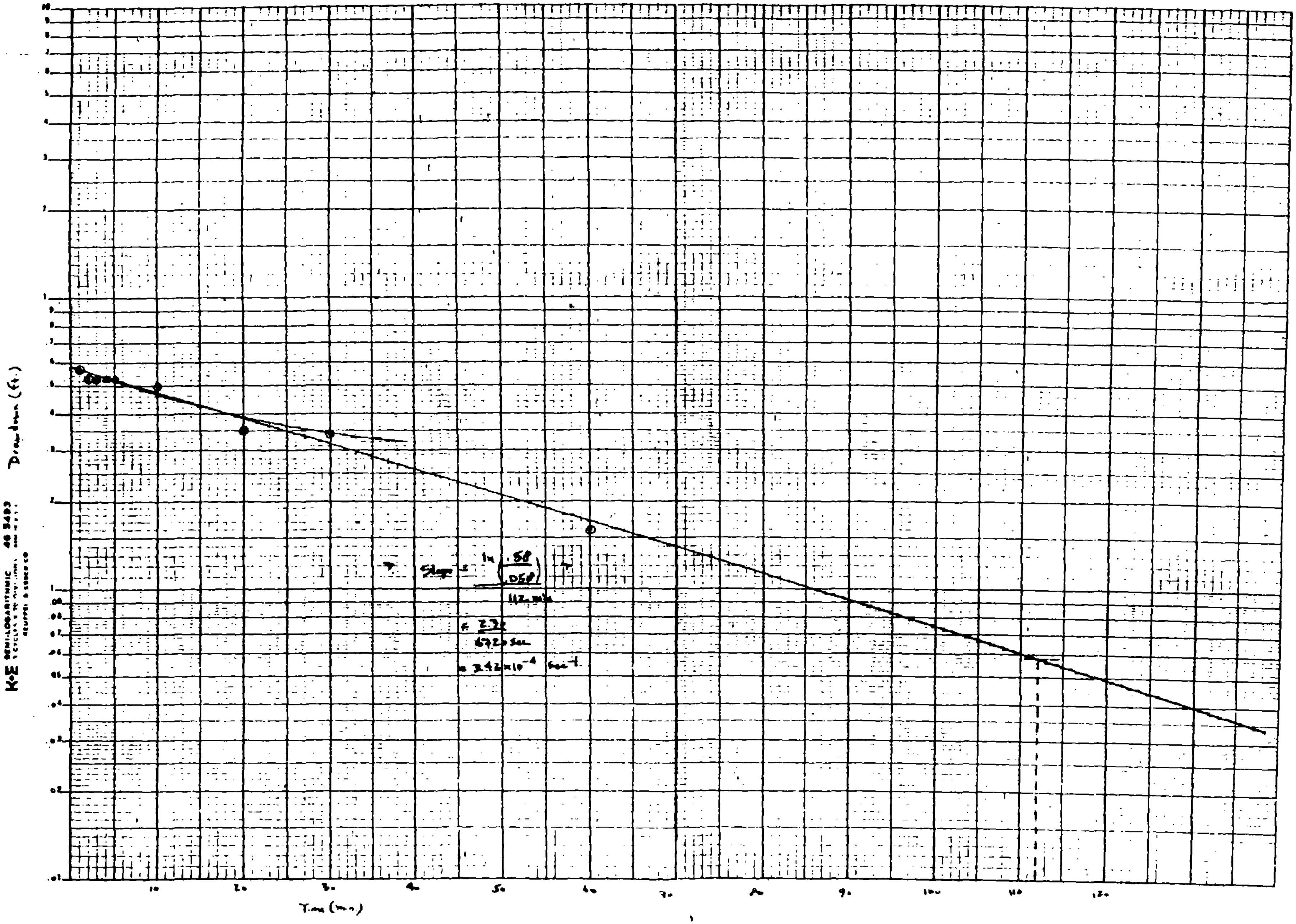
5
4
3
2
1.0
9
8
7
6
5
4
3
2
0.1
9
8
7
6
5
4
3
2
1
s
20
40
50
60
80
100
TIME (minutes)
LOGARITHMIC
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
546
MADE IN U.S.A.

GW52 (Slug Test)

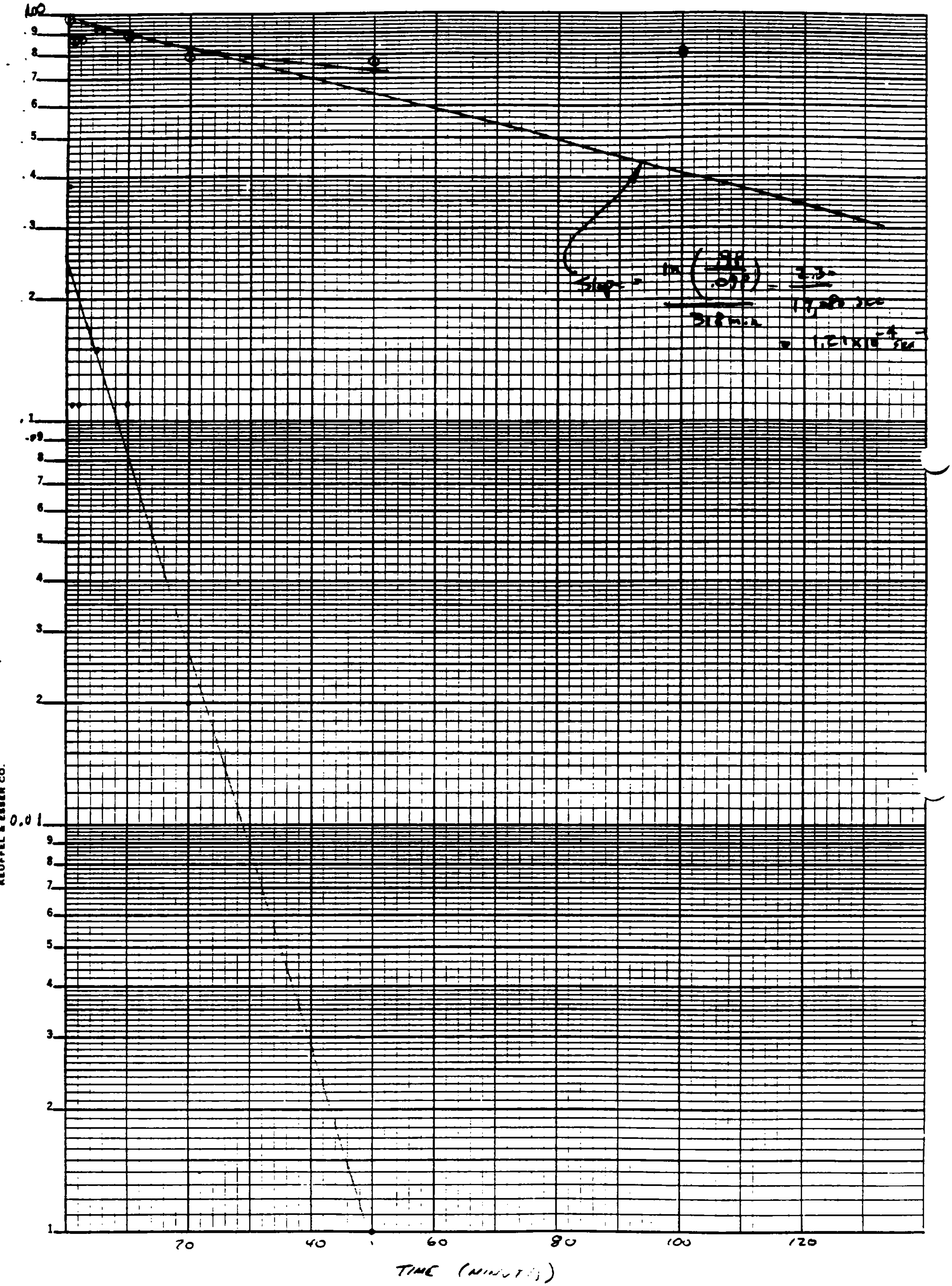


$$\text{Slope} = \frac{\ln\left(\frac{1.2}{.12}\right)}{2.3\ \text{min}} = \frac{2.30}{138\ \text{sec}} = 0.017\ \text{sec}^{-1}$$



$$\text{Slope} = \frac{\ln\left(\frac{.58}{.058}\right)}{112\ \text{min}} = \frac{2.32}{6720\ \text{sec}} = 3.42 \times 10^{-4}\ \text{sec}^{-1}$$

GW 50


1.0
.9
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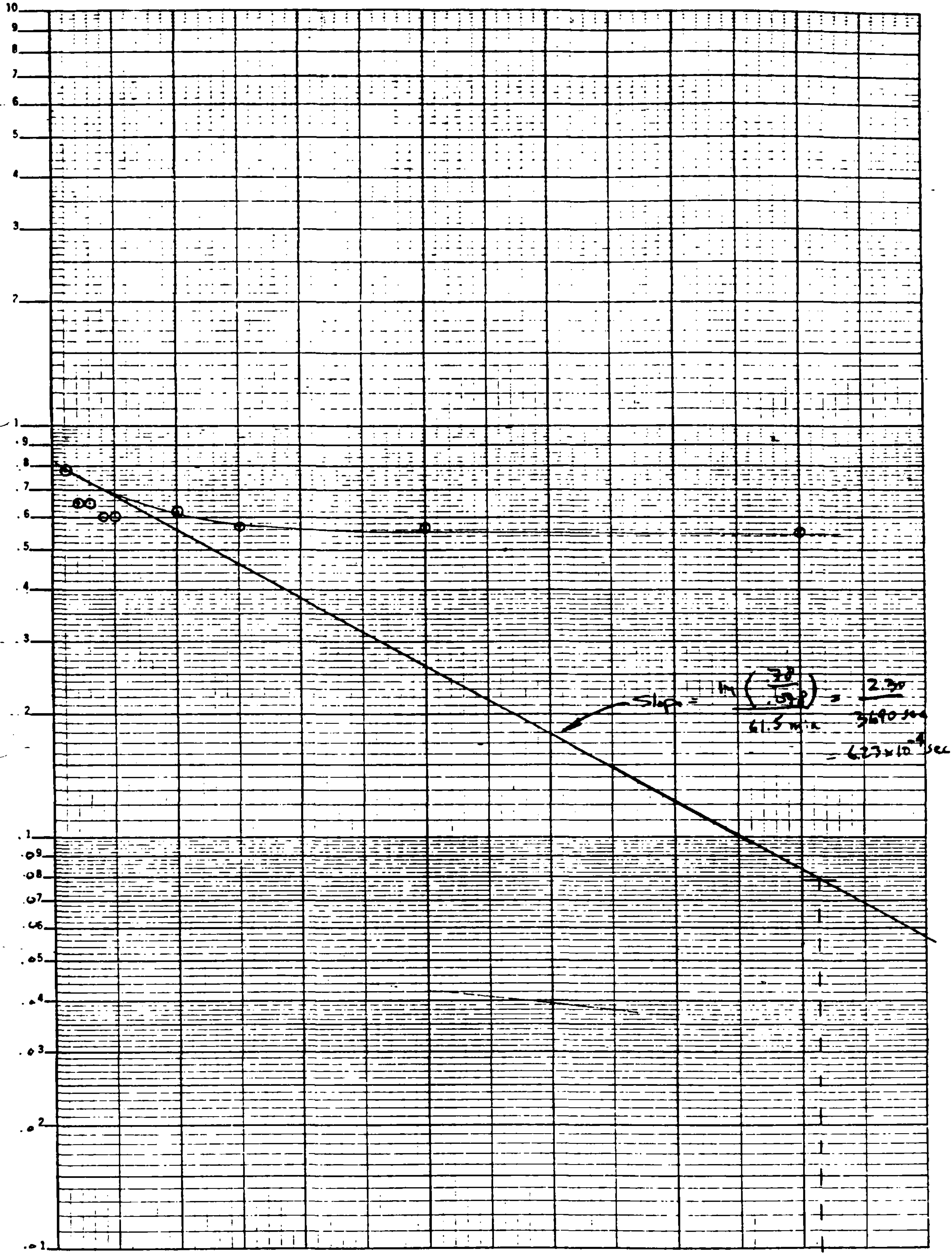
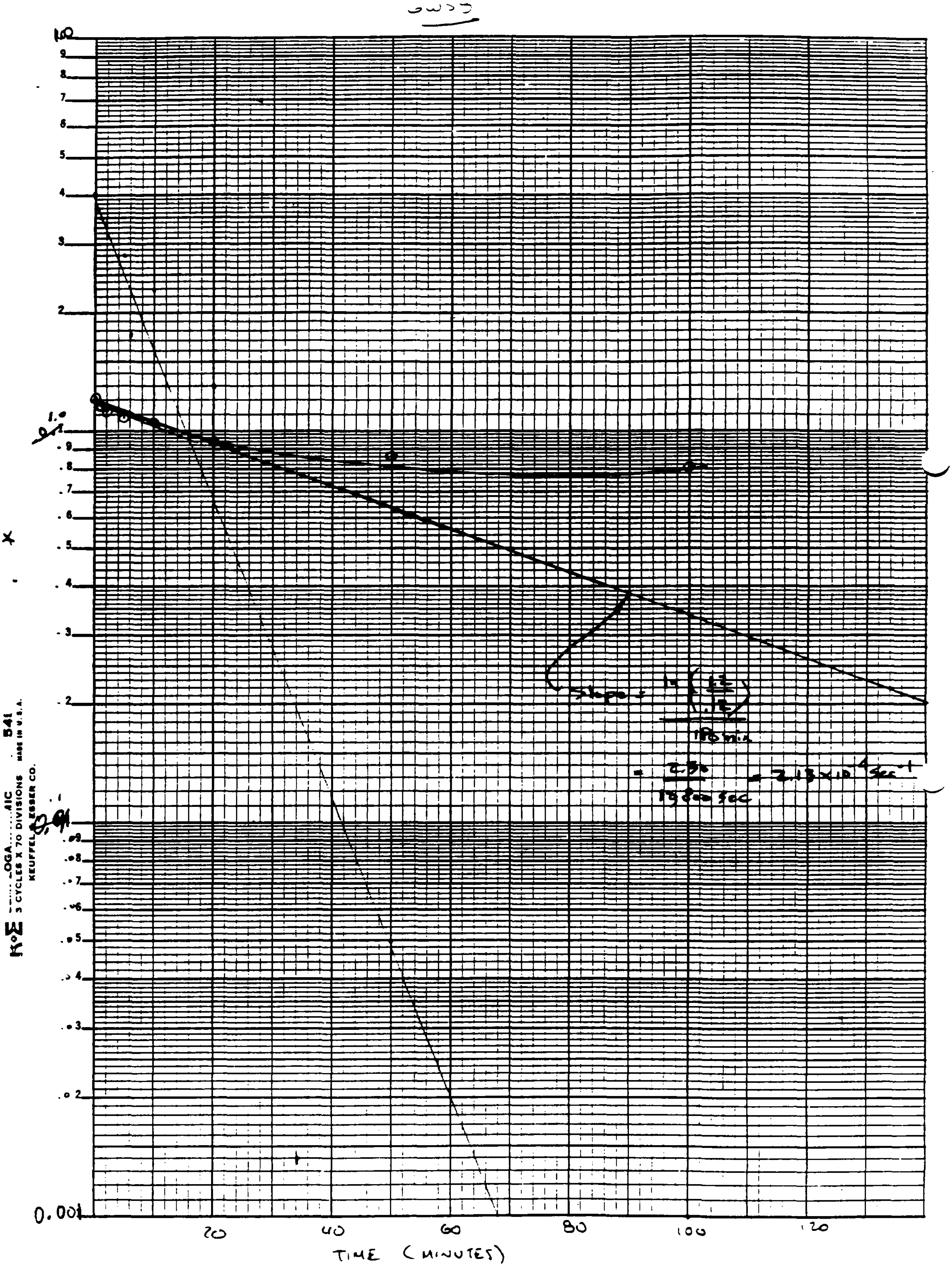
.7
.6
.5
.4
.3
.2
.1
.09
.8
.7
.6
.5
.4
.3
.2
0.01
9
8
7
6
5
4
3
2
1
20
40
60
80
100
120
TIME (MINUTES)
Slope = ln(.98/.098) / 318 min = 2.30 / 19,080 sec
= 1.21×10⁻⁴ sec⁻¹
LOGA 11C 546
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

GW56

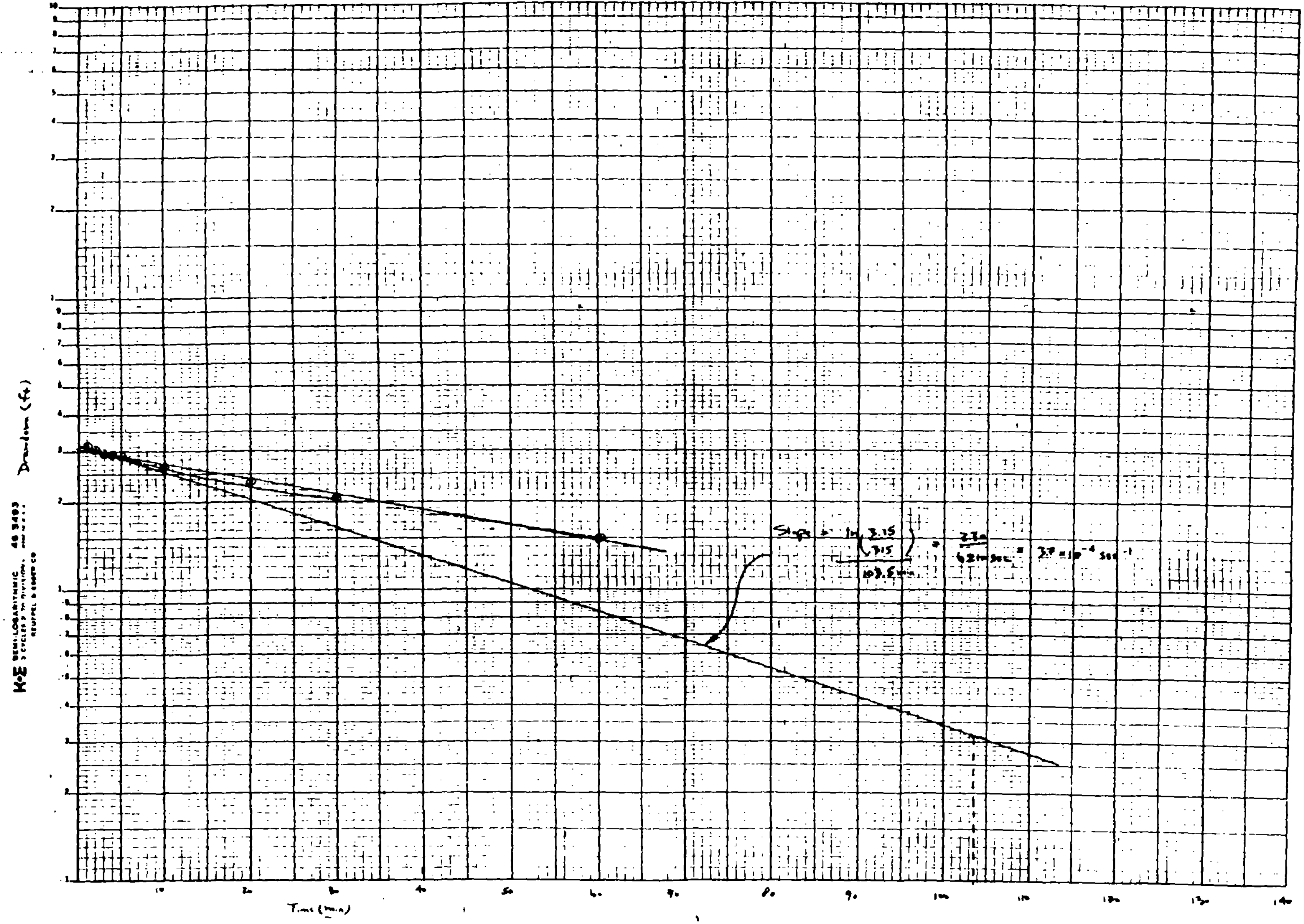


$$\text{Slope} = \frac{\ln\left(\frac{.78}{.078}\right)}{61.5\ \text{min}} = \frac{2.30}{3690\ \text{sec}}$$

$$= 6.23\times10^{-4}\ \text{sec}^{-1}$$

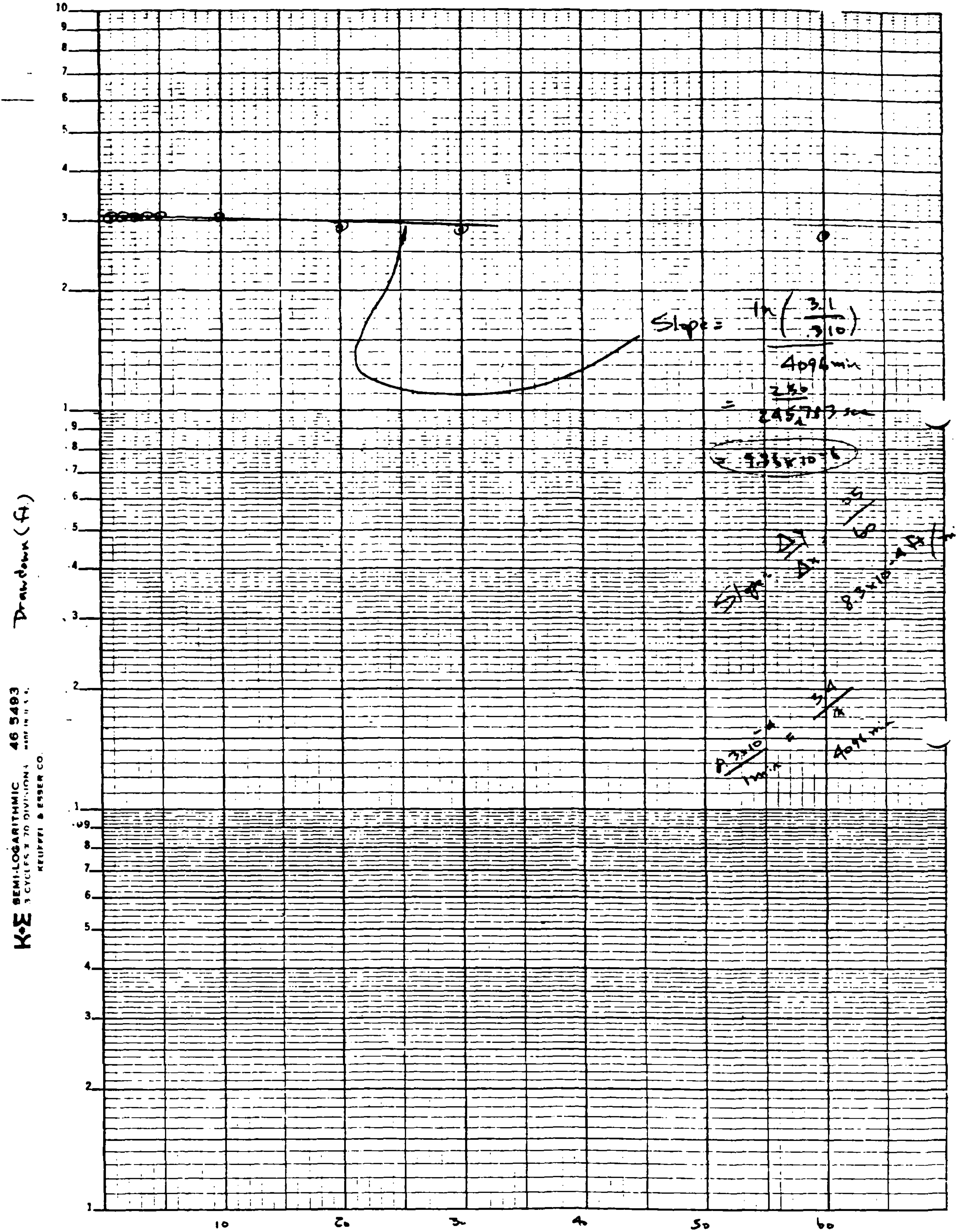
GW33
X
TIME (MINUTES)
20
40
60
80
100
120
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.01
.09
.08
.07
.06
.05
.04
.03
.02
0.001
Slope = ln(1.2/.12) / 180 min
= 2.30 / 10800 sec = 2.13×10^-4 sec^-1
K&E LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
541 MADE IN U.S.A.

Gw 58



$$\text{Slope} = \frac{\ln\left(\frac{3.15}{.315}\right)}{103.5\,\text{min}} = \frac{2.30}{6210\,\text{sec}} = 3.7 \times 10^{-4}\,\text{sec}^{-1}$$

GW 59



Slope = $\frac{\ln\left(\frac{3.1}{.310}\right)}{4096\text{ min}}$

= $\frac{2.30}{245{,}760\text{ sec}}$

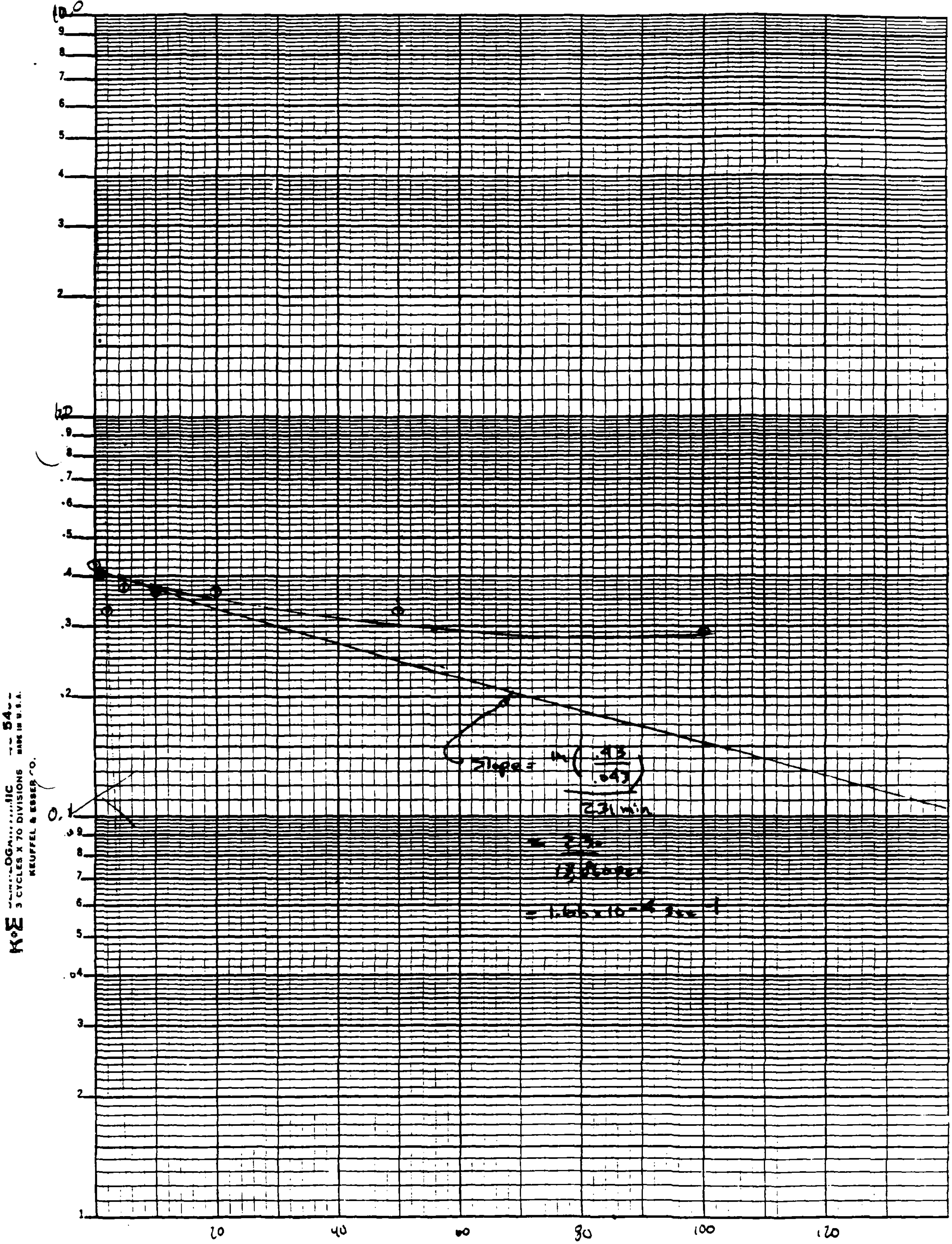
= 9.35×10^{-6}

Slope = $\frac{\Delta y}{\Delta x}$ = $\frac{.55}{60}$ = 8.3×10^{-4} ft/min

$\frac{8.3 \times 10^{-4}}{1\text{ min}}$ = $\frac{3.4\text{ ft}}{4096\text{ min}}$

K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

SW 60


10.0
9
8
7
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3
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1.0
.9
.8
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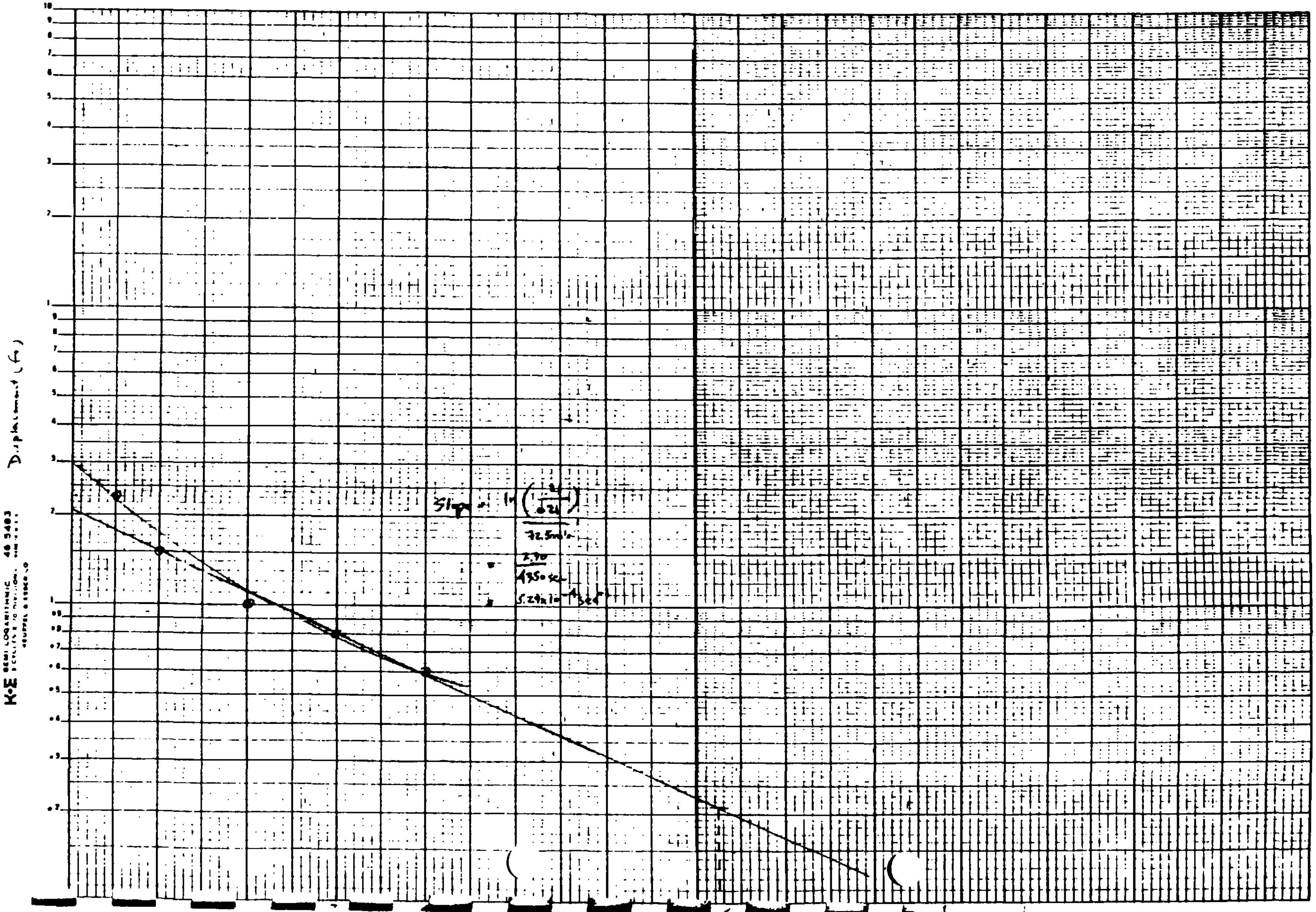
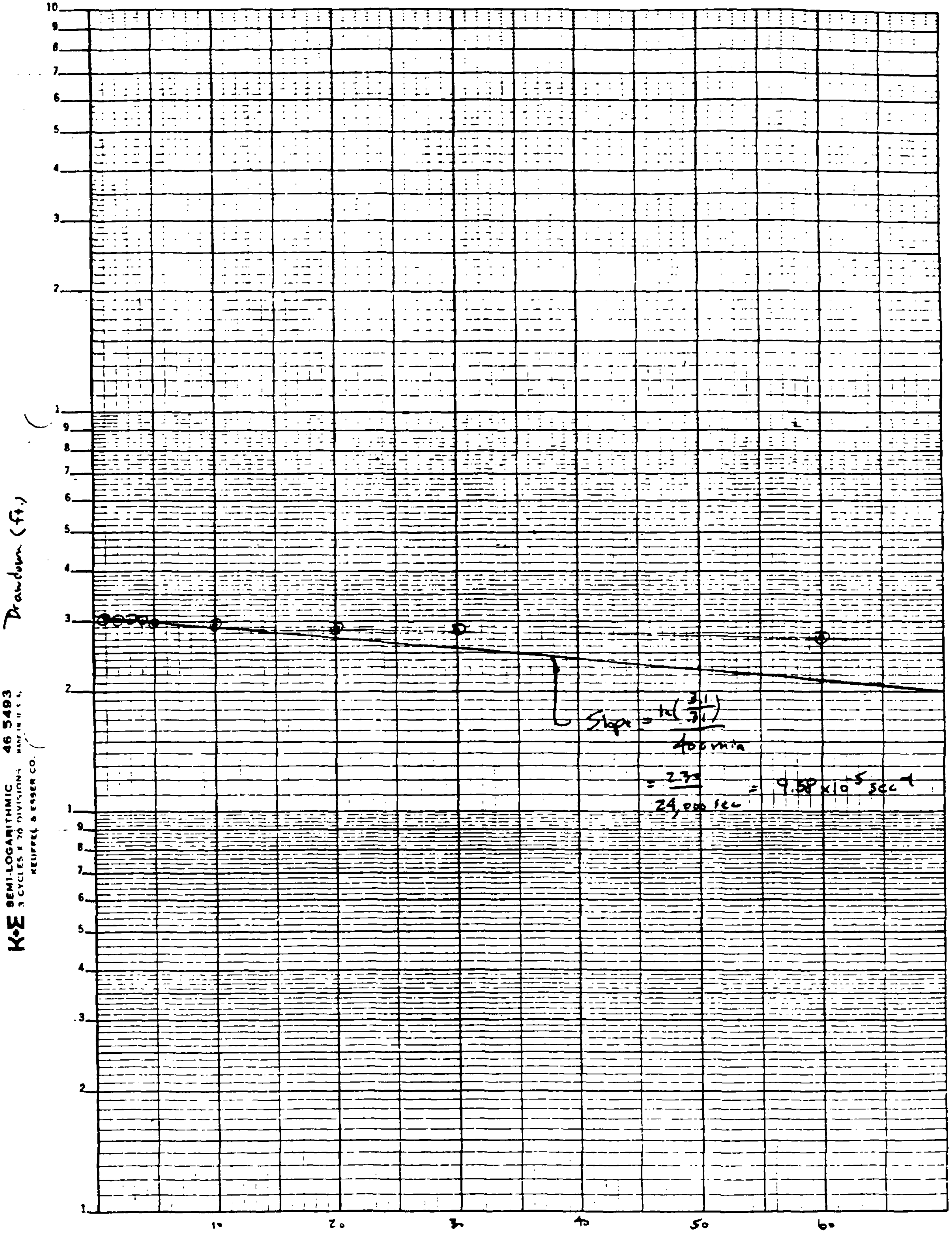
.6
.5
.4
.3
.2
0.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
20
40
60
80
100
120
K+E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.
Slope = ln(.413/.043) / 231 min
= 2.3 / 13,860 sec
= 1.66 x 10^-4 sec^-1

GW-6o (Slug Test)

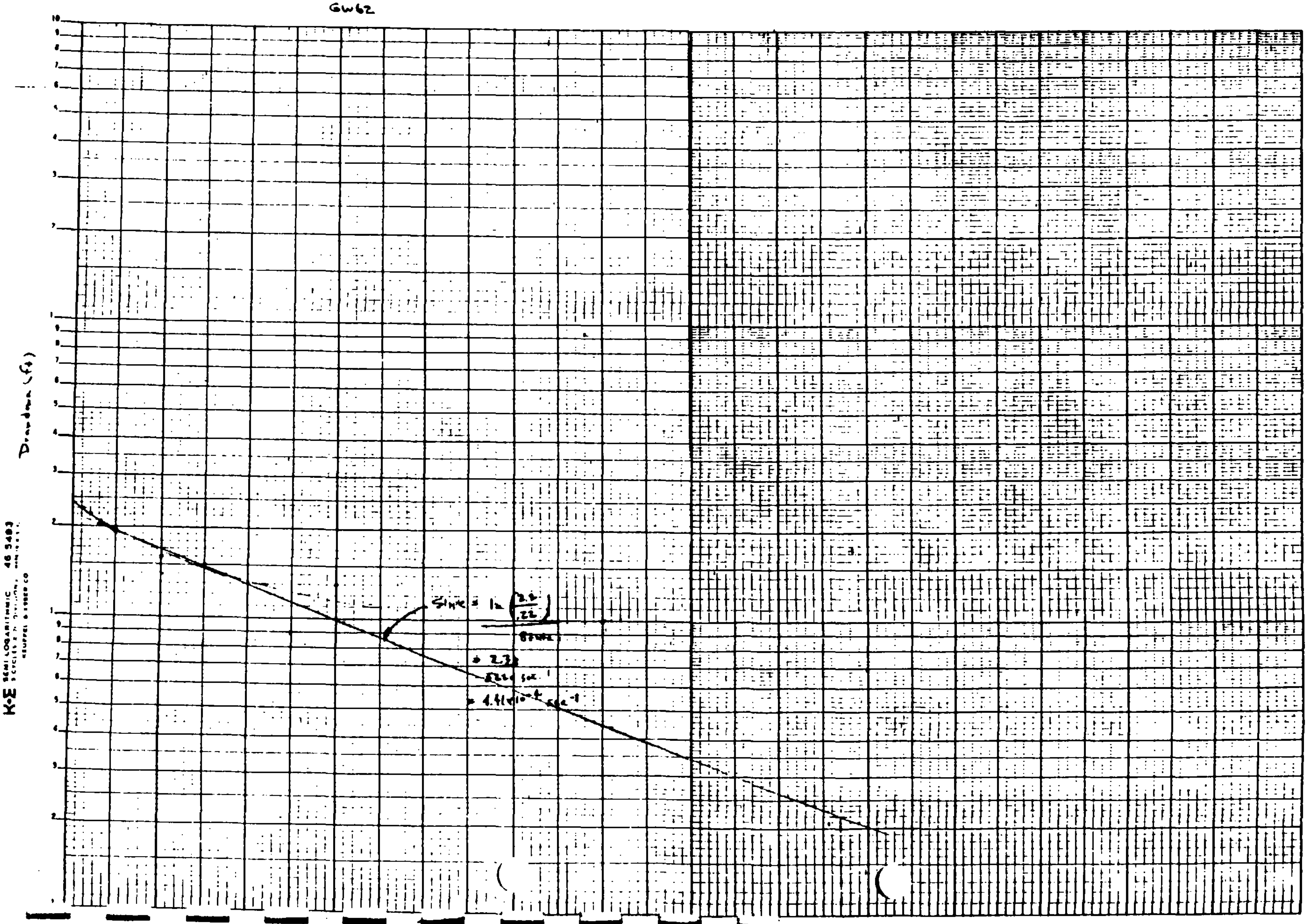


$$\text{Slope} = \frac{\ln\left(\frac{2.4}{.24}\right)}{72.5\text{ min}} = \frac{2.30}{4350\text{ sec}} = 5.29\times10^{-4}\text{ sec}^{-1}$$

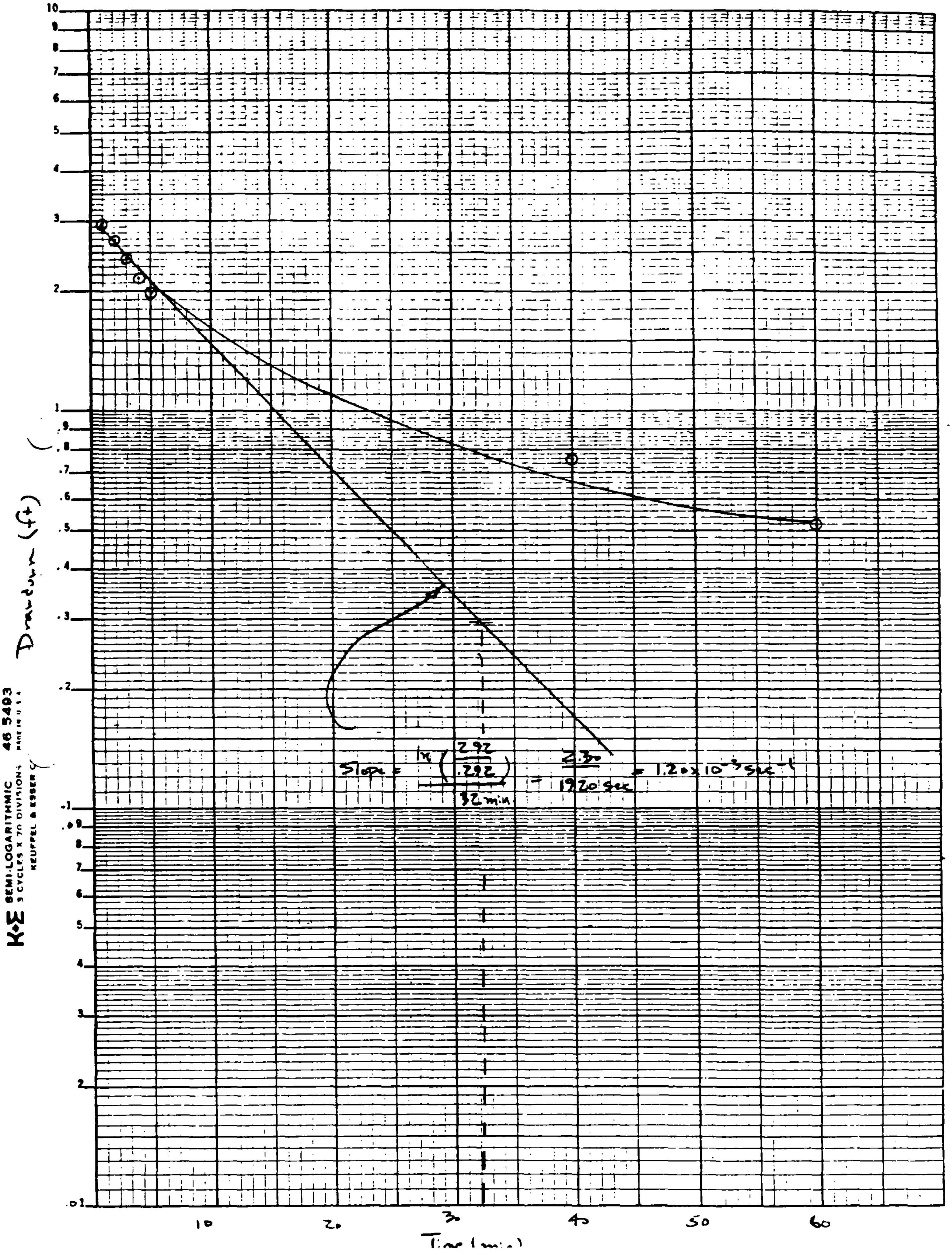
GW61



Drawdown (ft.)
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
.3
2
1
10
20
30
40
50
60
Slope = ln(3.1/2.1) / 400 min
= 2.3 / 24,000 sec = 9.58 x 10^-5 sec^-1
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

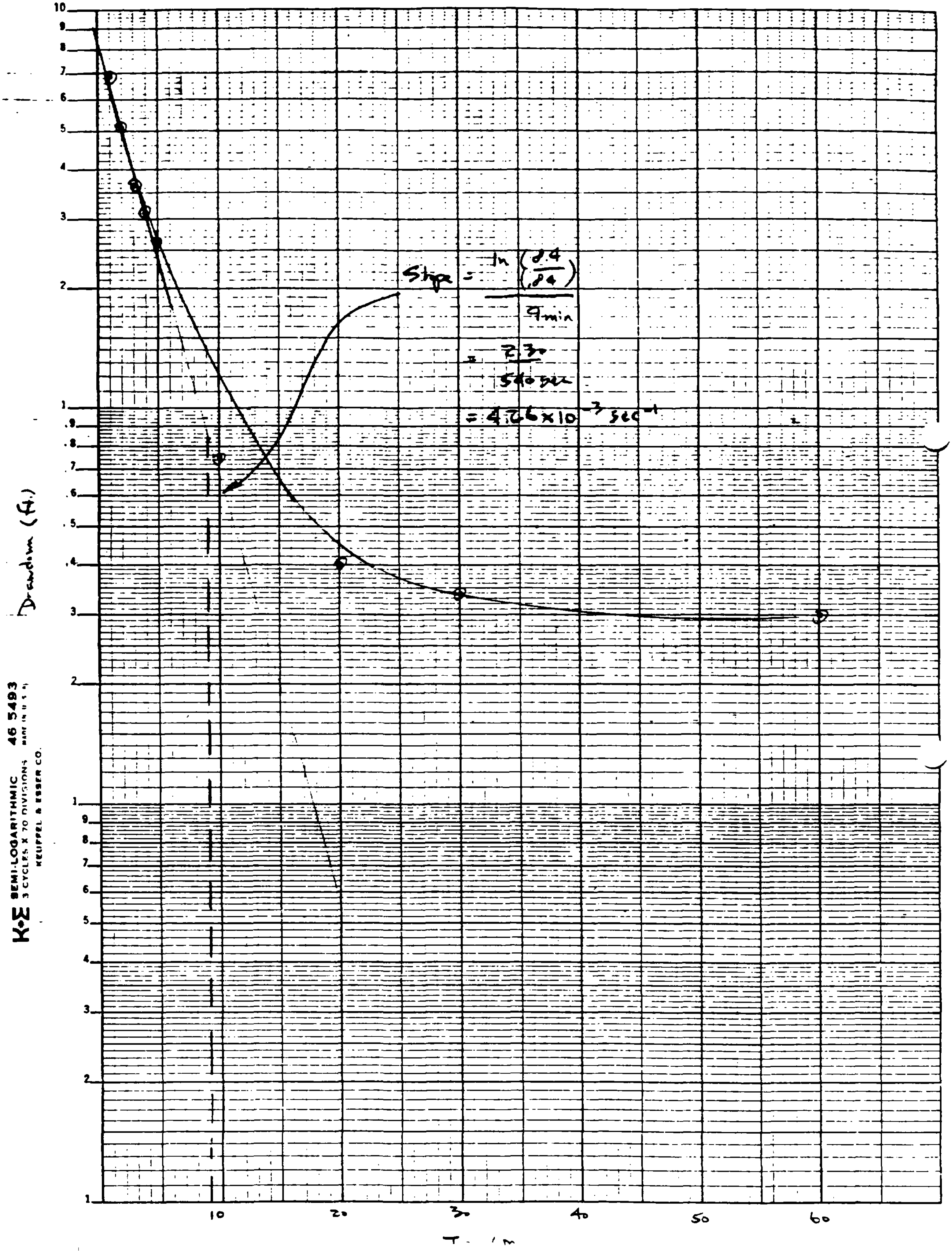

GW62
Drawdown (ft)
Slope = ln(2.2/.22) / 5220 sec
= 2.3 / 5220 sec⁻¹
= 4.41×10⁻⁴ sec⁻¹
K+E SEMI-LOGARITHMIC 46 5483
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

GW63

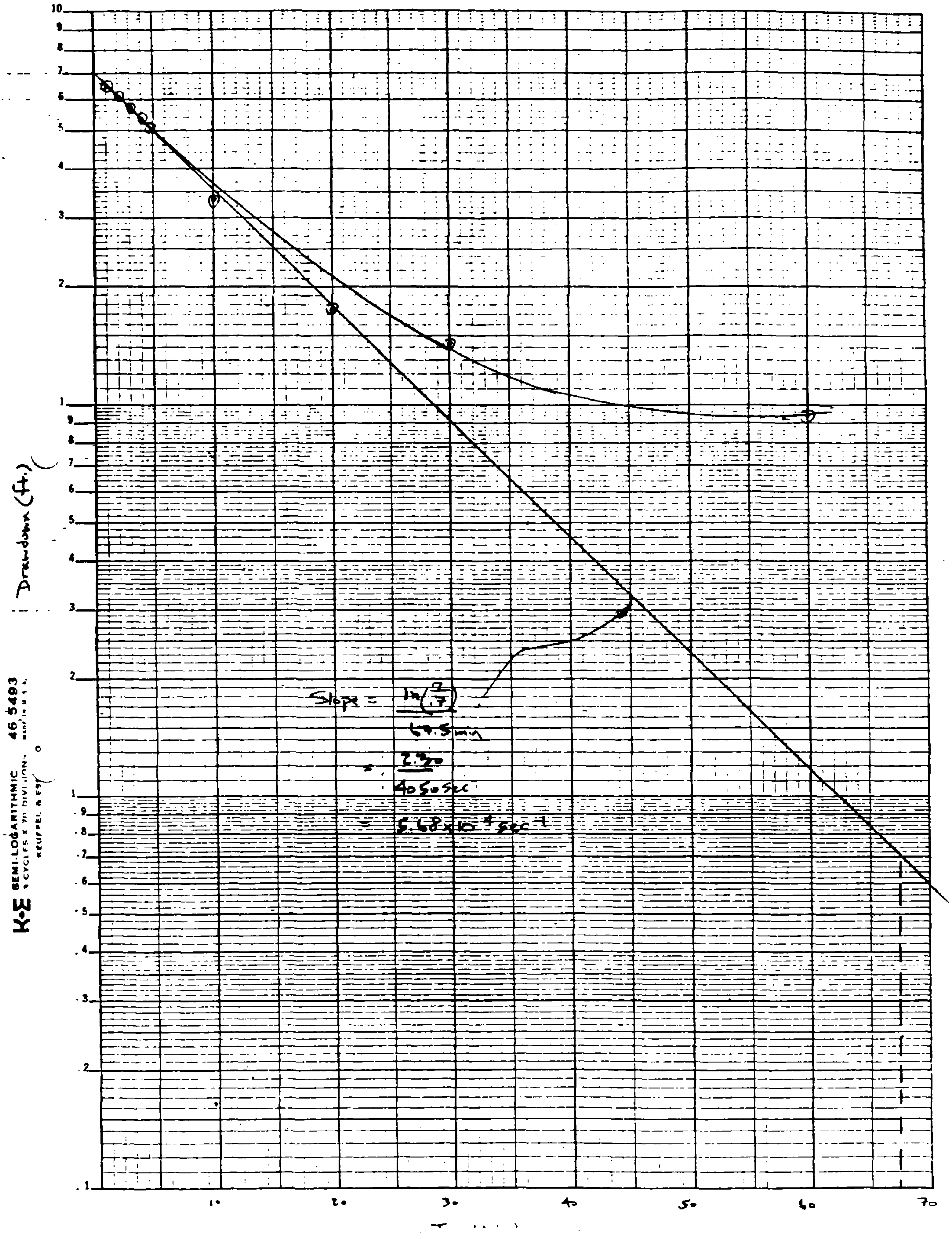


$$\text{Slope} = \frac{\ln\left(\frac{2.92}{.292}\right)}{32\text{ min}} = \frac{2.30}{1920\text{ sec}} = 1.20 \times 10^{-3}\text{ sec}^{-1}$$

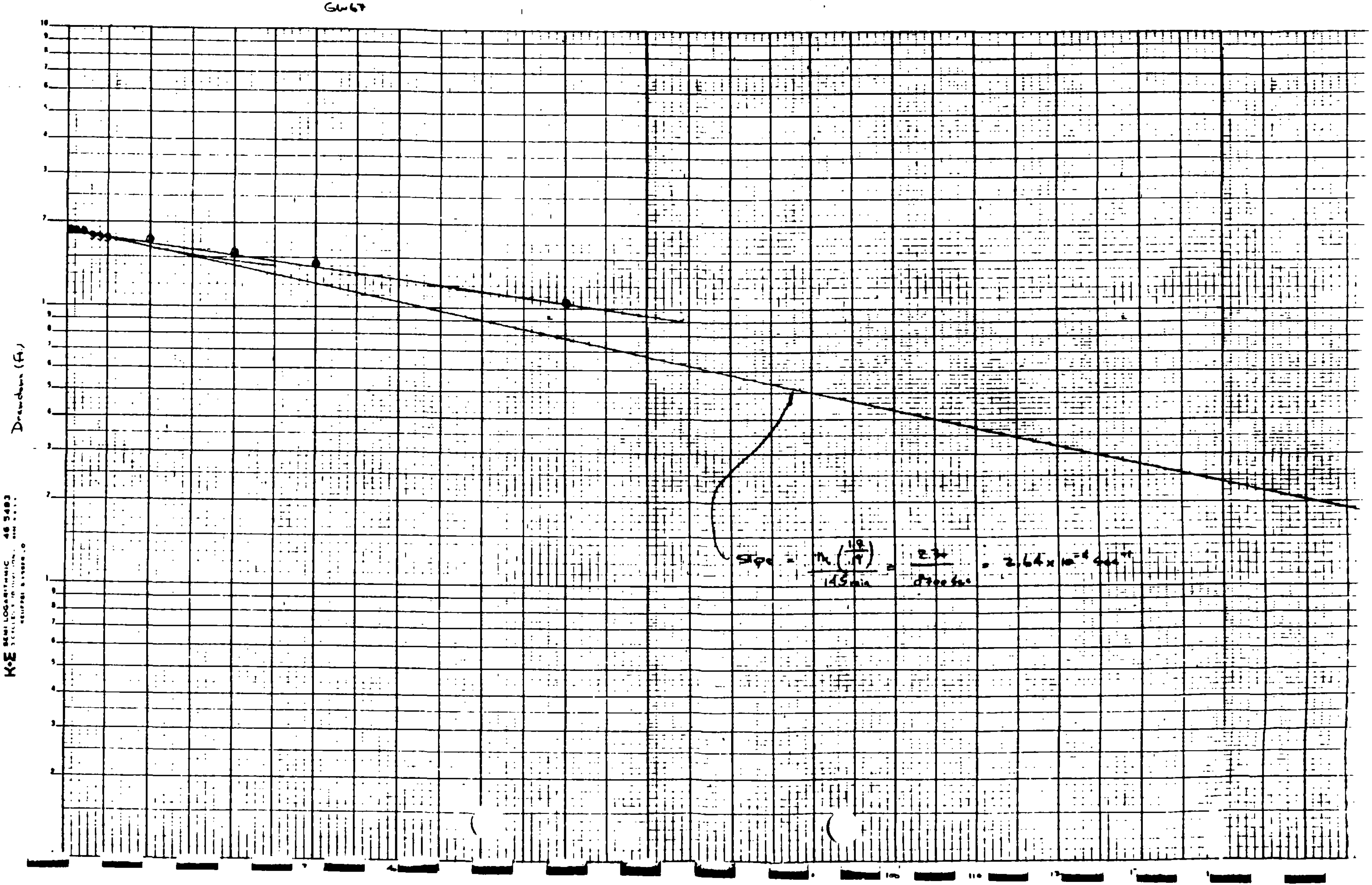
GW64



$$\text{Slope} = \frac{\ln\left(\frac{8.4}{.84}\right)}{9\,\text{min}} = \frac{2.30}{540\,\text{sec}} = 4.26\times10^{-3}\,\text{sec}^{-1}$$



$$\text{Slope} = \frac{\ln\left(\frac{7}{.7}\right)}{67.5\,\text{min}} = \frac{2.30}{4050\,\text{sec}} = 5.68\times10^{-4}\,\text{sec}^{-1}$$


Gw67
Drawdown (ft.)
Slope = $\frac{\ln\left(\frac{1.9}{.19}\right)}{145\,\text{min}} = \frac{2.3}{8700\,\text{sec}} = 2.64 \times 10^{-4}\,\text{sec}^{-1}$
K+E SEMI-LOGARITHMIC 46 5493

APPENDIX K

HUMAN HEALTH TOXICITY PROFILES

POLYCHLORINATED DIBENZO-p-DIOXINS

INTRODUCTION

The polychlorinated dibenzo-p-dioxins (PCDDs) comprise a family of 75 congeners, each of which is an isomer of one of eight homologues (CDDs) with varying degrees of chlorination. For simplicity, the homologues are abbreviated as follows:

Number of Chlorines	Abbreviation
1	M1CDD
2	D2CDD
3	T3CDD
4	T4CDD
5	P5CDD
6	H6CDD
7	H7CDD
8	O8CDD

Specific isomers are identified by numbers representing the positions of chlorination, e.g., 2,3,7,8-T4CDD. Congeners with 4-7 chlorine substitutions are often divided into two subclasses, comprising those congeners with and without chlorine substitutions in the 2,3,7, and 8 positions.

The toxicity of PCDDs, particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-T4CDD), has been critically reviewed many times in recent years. EPA recently prepared an Ambient Water Quality Criteria Document (1984a), a Health Assessment Document (1985a), and a Drinking Water Criteria Document (1985b). Other recent reviews include those by the Ontario Ministry of the Environment (1985), Kimbrough et al. (1984), and by Clement Associates for the Veterans Administration (Clement Associates, 1983, 1985, 1986).

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

MECHANISMS OF ACTION

2,3,7,8-T4CDD (and other PCDDs) is known to act by a distinctive mechanism that is probably responsible for its exceptionally high toxicity and its unusual spectrum of toxic effects (McKinney and McConnell 1982, Poland and Knutson 1982, Poland et al. 1983, Safe 1983, Vickers et al. 1985). 2,3,7,8-T4CDD binds selectively to a high affinity "receptor" protein in the cytosol of mammalian cells (Poland et al. 1976, Carlstedt-Duke 1979, Roberts et al. 1985). The T4CDD-receptor complex is translocated to the nucleus of the cell where it binds to DNA and alters gene expression as indicated by increased mRNA synthesis (Carlstedt-Duke et al. 1981, 1982). Receptor binding is associated with the induction of aryl hydrocarbon hydroxylase (AHH) and a variety of other enzymes (Parkinson and Safe 1981). This induction has been demonstrated in a number of different tissues, but is particularly marked in the liver, kidney, thymus, and skin, which are important target organs for 2,3,7,8-T4CDD toxicity. The affinity of the cytosolic receptor for 2,3,7,8-T4CDD varies widely among and within species. At least in mice, this variability is genetically controlled and is associated with the Ah gene locus (Poland et al. 1976a, 1983), a locus that is also associated with induction of AHH. A number of researchers have recently determined that the sensitivity of experimental animals to many of the biological effects of 2,3,7,8-T4CDD is associated with AHH inducibility and segregates with the Ah locus during cross-breeding experiments in mice (Kouri et al. 1978, Poland et al. 1976a, 1982, Dencker and Pratt 1981, Poland and Glover 1980, Knutson and Poland 1980, 1982, Jones and Sweeney 1980, Vecchi et al. 1983b, Clark et al. 1983). These findings are important for risk assessment because they show genetic variability in susceptibility to the biological effects of 2,3,7,8-T4CDD. Especially wide variations in susceptibility are expected in a genetically heterogeneous species such as the human species.

MAJOR TOXIC EFFECTS OF 2,3,7,8-T4CDD

Lethality: Toxic Signs

2,3,7,8-T4CDD is an exceptionally potent toxin in several animal species. The single-dose oral LD_{50} ranges from 0.6 to 2.1 µg/kg in male guinea pigs (Schwetz et al. 1973, McConnell et al. 1978a) through 20 to 70 µg/kg in rats and rhesus monkeys (Schwetz et al. 1973, McConnell et al. 1978b) and 100 to 450 µg/kg in mice (Smith et al. 1981, McConnell et al. 1978a) to about 5,000 µg/kg in hamsters (Henck et al. 1981). Most animals die 20 to 40 days after exposure in a "wasting syndrome," which involves progressive loss of up to 50% of body weight and leads to death without clearly identifiable lethal pathological lesions.

Effects on Lymphoid Tissues

One of the most consistent signs of acute or chronic 2,3,7,8- T4CDD toxicity is hypoplasia or atrophy of the thymus gland. This has been observed in most species tested (Allen et al. 1977, McConnell et al. 1978a, Schwetz et al. 1973, Henck et al. 1981). Other effects have been observed primarily in the more sensitive species such as the rhesus monkey, guinea pig, mouse, and chicken (McConnell et al. 1978a, Allen et al. 1977, Schwetz et al. 1973, Norback and Allen 1973).

Skin and Gastrointestinal Lesions

Acute or chronic exposure of rhesus monkeys to 2,3,7,8-T4CDD leads to a characteristic spectrum of skin and gastrointestinal lesions (Allen et al. 1977, McConnell et al. 1978b, McNulty et al. 1982). These include loss of hair and eyelashes, acne-like eruptions, accentuated hair follicles, hyperkeratosis of the skin, and hyperplasia and dysplasia of the gastric mucosa. These effects were seen in monkeys after chronic exposure to 2,3,7,8-T4CDD in the diet at concentrations as low as 50 parts per trillion (ppt) (Schantz et al. 1979). The skin lesions in rhesus monkeys are commonly regarded as a good model for the human disease chloracne (Allen et al. 1977, McConnell et al. 1978b, McNulty 1985).

Reproductive Toxicity

Many studies have demonstrated that 2,3,7,8-T4CDD interferes with reproduction or causes birth defects in experimental animals (reviews and summaries can be found in EPA 1984a,b, 1985a, and in Nisbet and Paxton 1982). These reproductive studies involved a wide range of species and several routes of administration. In rodents, kidney anomalies appear to be the most frequent defect seen. Defects of the palate are also frequently seen in mice. Many studies have also shown increased resorptions and decreased live births (Courtney 1976, Neubert and Dillman 1972, Smith et al. 1976, Murray et al. 1979, Khera and Ruddick 1973, Allen et al. 1977, 1979, McNulty et al. 1982).

Immunotoxicity

Many studies have shown that 2,3,7,8-T4CDD is immunosuppressive in experimental animals (Vos et al. 1973, 1977, 1978, Vos and Moore 1974, Thigpen et al. 1975, Thomas and Hinsdill 1979, Sharma and Gehring 1979, Dean et al. 1981, Clark et al. 1981, 1983, Vecchi et al. 1983a,b, Nagarkatti et al. 1984, Luster et al. 1979, 1982, Faith and Moore 1977, Faith and Luster 1979). 2,3,7,8-T4CDD appears to have a broad-spectrum immunosuppressive effect that includes hypoplasia or atrophy of the thymus, spleen, and bone marrow, and interference with cell-mediated and antibody-mediated immune functions. One important aspect of this effect is that 2,3,7,8-T4CDD appears to depress the generation of cytotoxic T-lymphocytes at doses lower than those known to cause other biological effects in intact animals (Clark et al. 1983).

Carcinogenicity

Three experiments have shown that 2,3,7,8-T4CDD increases the frequency of cancer in rats and mice exposed to it for most or all of their lifetimes (Kociba et al. 1978, NTP 1982a,b). Two other studies (Van Miller et al. 1977, Toth et al. 1979) yielded similar but less definitive results. These studies indicated that the liver is an important target site for the carcinogenic action of 2,3,7,8-T4CDD when it is administered orally. However, neoplastic responses were also seen in the thyroid, lymphatic system, lung, adrenal cortex, tongue, and hard palate and nasal turbinates in one or more studies. At least four studies (Van Miller et al. 1977, NTP 1982a, and NTP 1982b in both mice and rats) showed a suggestive increase in soft-tissue tumors of histologic types similar to those reported in workers presumptively exposed to 2,3,7,8-T4CDD. Thus, 2,3,7,8-T4CDD appears to have a broad-spectrum neoplastic effect in at least two species, rats and mice.

In addition to increasing tumor frequency when administered alone, 2,3,7,8-TCDD can promote or inhibit the effect of other cancer initiators. A number of studies of interactions between 2,3,7,8-T4CDD and known carcinogenic initiators have been reviewed by DiGiovanni (1984). In one study of a two-stage carcinogenesis system in rat liver, 2,3,7,8-T4CDD acted as a potent promoter of tumors initiated by diethylnitrosamine (Pitot et al. 1980). In mouse skin, 2,3,7,8-T4CDD did not act as a promoter in two studies (Berry et al. 1978, NTP 1982a) although it did so in the susceptible hairless strain (Poland et al. 1982). In other studies in mouse skin, 2,3,7,8-T4CDD acted as a cocarcinogen when administered simultaneously with carcinogenic polynuclear aromatic hydrocarbons but as a potent inhibitor when administered one to three days earlier (Cohen et al. 1979, DiGiovanni et al. 1979, 1980). These results suggest that tumor production and inhibition in mice by 2,3,7,8-T4CDD may be genetically controlled and are probably related to the sensitivity to AHH induction and/or sensitivity to epidermal proliferation.

Other Toxic Effects in Animals

The liver is a major target organ for the toxicity of 2,3,7,8-T4CDD in rodents (Kociba and Schwetz 1982). A number of studies have demonstrated that 2,3,7,8-T4CDD interferes with porphyrin metabolism by inhibiting hepatic uroporphyrinogen decarboxylase (Goldstein et al. 1973, 1982, Sweeney et al. 1979, Smith et al. 1981, Kociba et al. 1976, 1978, Cantoni et al. 1981, 1984a,b,c). Liver toxicity and porphyria are less prominent in rhesus monkeys and guinea pigs. 2,3,7,8-T4CDD also causes pathological changes in the kidney.

EVIDENCE FOR TOXICITY IN HUMANS

Studies of the possible effects of 2,3,7,8-T4CDD and other polychlorinated dibenzo-p-dioxins (PCDDs) in humans have involved groups putatively exposed as a result of industrial accidents, through occupational exposure to phenoxy herbicides or chlorophenols, through exposure to herbicides while serving in Vietnam, or through residence near areas where phenoxy herbicides or chlorophenols were manufactured. In no case was there any quantitative characterization of exposure, and in most cases even qualitative characterization of exposure was incomplete. Persons exposed as a result of industrial accidents may have been exposed to a variety of chemicals in addition to 2,3,7,8-T4CDD. Persons exposed to phenoxy herbicides and chlorophenols may also have been exposed to other toxic chemicals and the extent of their exposure to PCDDs is conjectural. Most studies of the general population, of Vietnam veterans, and some studies of workers probably included many individuals with little or no exposure even to phenoxy herbicides. Many studies were also limited by small sample sizes, by inadequate controls, and by inadequate duration of follow-up. These factors severely limit the conclusions that can be drawn about the effects of 2,3,7,8-T4CDD on humans. Likewise, they invalidate the claims that are sometimes made that epidemiological studies have shown that humans are insensitive to the effects of 2,3,7,8-T4CDD.

Chloracne

The most consistently observed consequence of acute or subacute exposure to PCDDs is the skin disease chloracne. Chloracne is characterized by acneform eruptions, enlarged comedones, and in some cases hyperpigmentation and hirsutism (Crow 1981). Chloracne develops several days to months after exposure to PCDDs and may persist for as long as 29 years after exposure (Moses et al. 1984). Chloracne has been reported in most or all cases of occupational exposure associated with poor hygiene or industrial accidents (Bleiberg et al. 1964, Poland et al. 1971, Moses et al. 1984, Goldmann 1972, 1973, Vos et al. 1977, Jirasek et al. 1974, Pazderova-Vejlupkova et al. 1981, Cook 1981, May 1973, 1982, Oliver 1975, Suskind and Herzberg 1984), and was also observed in individuals (primarily children) exposed in the environment following the accident at Seveso, Italy (Crow 1981, Caramaschi et al. 1981, Del Corno et al. 1982). A consistent feature of reports of chloracne is that only a proportion of the workers subject to exposure developed chloracne, suggesting variable susceptibility.

Porphyria and Effects on Other Liver Enzymes

Porphyria cutanea tarda has been reported in workers exposed in three industrial accidents (Bleiberg 1964, Pazderova-Vejlupkova et al. 1981, Moses et al. 1984) but not in other occupationally-exposed cohorts (Moses et al. 1984, Suskind and Herzberg 1984). In addition, there have been several case reports of porphyria cutanea tarda in individuals who may have been exposed to 2,3,7,8-T4CDD as a result of experimental contamination (Doss et al. 1984, Hope et al. 1984). A number of persons exposed to 2,3,7,8-T4CDD at Seveso, Italy showed abnormal patterns of porphyrin excretion without clinical signs of porphyria cutanea tarda (Doss et al. 1984). The available evidence is not adequate to establish a relationship between exposure to 2,3,7,8-T4CDD and porphyria cutanea tarda in humans. Animal evidence, however, clearly indicates that 2,3,7,8-T4CDD inhibits uroporphyria decarboxylase; it may be that 2,3,7,8-T4CDD alters the pattern of porphyria excretion in humans and triggers porphyria cutanea tarda in susceptible individuals.

Several studies of individuals exposed to 2,3,7,8-T4CDD have shown elevated serum levels of gamma-glutamyl transpeptidase (GGT) (May 1982, Moses et al. 1984, Mocarelli et al. 1984) or elevated urinary excretion of d-glucaric acid (May 1982, Ideo et al. 1982). The health significance of these findings is unclear, but both are thought to reflect the induction of cytochrome P-450 in the liver.

Effects on Lipid Metabolism and the Cardiovascular System

Several studies of occupationally exposed workers have shown elevated serum levels of triglycerides, and in some cases other lipids (reviewed by Moses et al. 1984). Two recent studies of a population exposed at Nitro, West Virginia, indicated serum lipid alterations among workers with a history of chloracne (Moses et al. 1984, Suskind and Hertzberg 1984). These lipid

TABLE 1

LOWEST EFFECT LEVELS FOR THE TOXIC EFFECTS OF TCDD IN EXPERIMENTAL ANIMALS

Effect	Species	Dose or Concentration and Duration	Reference and Comments
Acute lethality (single dose LD_{50})	Guinea pig	2.0 µg/kg	McConnell et al. 1978b; McNulty et al. 1982
Acute systemic toxicity	Rhesus monkey	1.0 µg/kg	McNulty 1977
Induction of AHH (benzo(a)pyrene hydroxylase)	Sprague-Dawley rat	2.0 ng/kg (single dose p.o.)	Kitchin and Woods 1979 (0.6 ng/kg = no effect level)
Immunosuppression (decreased generation of CTLs)	C57Bl/6 mouse	1 ng/kg/wk for 4 weeks intraperitoneally	Clark et al. 1983
Chronic lethality	Rhesus monkey	500 ppt in diet for 9 months (ca. 12 ng/kg/day)	Allen et al. 1977
		2 ppb in diet for 61 days (ca. 100 ng/kg/day)[a]	McNulty 1977
Chronic toxicity (hair loss, hyperkeratosis, weight loss, blood changes)	Rhesus monkey	50 ppt in diet for 20 months (ca. 1.5 ng/kg/day)[a]	Schantz et al. 1979
Cancer	Sprague-Dawley rat	10 ng/kg/day for 2 years in diet	Kociba et al. 1978
Cancer	Osborne-Mendel rat	5 ng/kg/day for 2 years in diet	NTP 1982a
Cancer promotion	Charles River rat	280 ng/kg/wk for 32 weeks p.o.	Pitot et al. 1980
Reproductive toxicity			
o spontaneous abortions and impairment of conception	Rhesus monkey	50 ppt in diet for 7 months (ca. 1.5 ng/kg/day)[a]	Allen et al. 1979
o 3 generations (fetal toxicity and kidney anomalies)[b]	Sprague-Dawley rat	1 ng/kg/day in diet	Murray et al. 1979
Porphyrin metabolism	Sprague-Dawley rat	10 ng/kg/day for 2 years in diet	Kociba et al. 1978
Histopathological alterations in liver and thymus	Sprague-Dawley rat	1 ng/kg/day for 2 years in diet	Kociba et al. 1978

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[a] These monkeys were also exposed to small quantities of PCBs as a result of accidental dietary contamination, but data on the toxicity of PCBs to rhesus monkeys indicate that they would not contribute significantly to the observed effects (Van Miller 1981, pp. 86-87)

[b] Interpretation of fetal toxicity is complicated by variations in fertility (Kimbrough et al. 1984), but effects [illegible] and kidney abnormalities were significant (Nisbet and Paxton 1982)

abnormalities, together with scattered reports of cardiovascular disease among exposed workers, have suggested an association between exposure to 2,3,7,8-T4CDD and heart disease, but other recent studies have failed to support this hypothesis (Bond et al. 1983, Moses et al. 1984, Suskind and Hertzberg 1984).

Effects on the Gastrointestinal System

Two recent studies of occupationally exposed populations have shown an association between exposure to 2,3,7,8-T4CDD and gastrointestinal disease. Bond et al. (1983) found significantly increased incidences of x-ray-proved ulcers and morbidity due to diseases of the gastrointestinal system (excluding the liver). Suskind and Hertzberg (1984) found a significant excess of workers who reported a history of gastrointestinal ulcers in the 2,3,7,8-T4CDD-exposed group. These findings, in combination with animal data (see above) and the excess stomach cancers in exposed workers reported by Thiess et al. (1982) (see below), suggest that the stomach may be an important target organ for 2,3,7,8-T4CDD in humans.

Effects on the Immune System

In a clinical study of 154 former residents of a mobile home park (Quail Run, Missouri) where the soil was contaminated with 2,3,7,8-T4CDD, Hoffman et al. (1986) reported a significant reduction in delayed hypersensitivity responses to standard antigens among a subgroup of 51 residents, compared with 93 controls. Measures of T-cell functioning were also depressed, although not significantly, among the residents. These results suggest an association between impairment of the immune system and exposure to 2,3,7,8-T4CDD, but such exposure was not documented or measured.

Reproductive Effects

A number of studies have attempted to investigate reproductive outcomes in human populations putatively exposed to 2,3,7,8-T4CDD, but these studies are severely compromised by difficulties in documenting exposure and in establishing rates of adverse reproductive outcomes in comparison populations.

Lathrop et al. (1984) found significant increases in spontaneous abortions and in birth defects among wives of personnel directly involved in spraying "Agent Orange" in Southeast Asia. Hanify et al. (1981) found a statistical association between incidence of birth defects (heart defects and talipes) and wide-area spraying of 2,4,5-T. Several other studies have suggested a possible increase in spontaneous abortions among putatively exposed populations (Bruzzi et al. 1981, Matheson et al. 1981, Australian Veterans Health Studies 1983). A recent case-control study of birth defects in the Atlanta area suggested that Vietnam veterans who had been exposed to "Agent Orange" had increased risks of fathering babies with spina bifida and cleft lip (Erickson et al. 1984). However, these findings were scattered among the results of studies that investigated many possible adverse outcomes, so it is possible that most or all could have arisen by chance ("false positive" results). Overall, therefore, the evidence for an association between exposure to 2,3,7,8-T4CDD and adverse reproductive outcomes is inconclusive.

Evidence for Carcinogenicity

Several Swedish epidemiological studies have reported an association between occupational exposure to phenoxy acid herbicides or chlorophenols and increased incidence of certain cancers, including soft tissue sarcomas, non-Hodgkin's lymphomas, and nasopharyngeal cancers (Hardell and Sundstrom 1979, Hardell et al. 1981, 1982, Erikson et al. 1981). The presumptive link between these exposures and cancer is the presence of 2,3,7,8-T4CDD or other PCDDs as impurities in phenoxy acids and chlorophenols.

A case-control study of similar design in New Zealand failed to demonstrate a significantly increased relative risk for soft tissue sarcoma among individuals exposed to phenoxy herbicides or chlorophenols (Smith et al. 1982, 1983, 1984). Two case-control studies investigating possible relationships between the occurrence of soft-tissue sarcomas and prior military service in Vietnam have yielded conflicting results (Greenwald et al. 1984, Kogan and Clapp 1985). Lynge (1985) reported excess incidences of soft-tissue sarcomas among Danish workers employed in the manufacture of phenoxy herbicides, but most of the herbicides involved were not contaminated with 2,3,7,8-T4CDD. There have been several case reports of soft-tissue sarcomas among

U.S. workers exposed to phenoxy acids and/or PCDDs (Cook 1981, Zack and Suskind 1980, Zack and Gaffey 1983, Johnson et al. 1981, Moses and Selikoff 1981, Hope et al. 1984). However, Fingerhut et al. (1984) showed that some of these reports were based on erroneous pathological diagnoses. In a small but well-controlled study, Thiess et al. (1982) reported a significant excess of stomach cancers among workers presumptively exposed to 2,3,7,8-T4CDD in a chemical reactor accident 23 years earlier. Other cancer studies have been inadequate to show either positive or negative results. Although some of these results suggest a possible association between exposure to 2,3,7,8-T4CDD and increased risk of cancer, the evidence taken as a whole is inconclusive.

FACTORS QUALIFYING INTERPRETATION OF DATA ON TOXICITY

Several factors complicate the interpretation of the toxic effects of 2,3,7,8-T4CDD, especially the extrapolation of animal data to predict likely effects in humans.

Incomplete Human Exposure Data

The previous section noted that no studies of the toxicity of 2,3,7,8-T4CDD in humans included adequate characterization of exposure. Many studies were of human populations exposed to phenoxy acids or chlorophenols, in which contamination with 2,3,7,8-T4CDD is likely but was not verified or measured. In several studies of industrial accidents, 2,3,7,8-T4CDD was identified in the chemical residues, but other chemicals, including chlorophenols, were doubtless present. In none of the studies was there any quantitative characterization of exposure. Thus, the human data are useful only for qualitative comparison with the animal data. Both qualitative and quantitative inferences of risk must be based primarily on the animal data.

Comparative Persistence in Different Species

2,3,7,8-T4CDD is relatively persistent in the environment and in many living systems. Its persistence in animal tissues is probably responsible in part for its exceptionally high chronic toxicity (Kimbrough 1980).

The metabolism and pharmacokinetics of 2,3,7,8-T4CDD have been reviewed by Neal et al. (1982). 2,3,7,8-T4CDD is readily absorbed after oral administration and is well absorbed through the skin. McConnell et al. (1984) and Bonaccorsi et al. (1983) have shown that it is readily adsorbed even after long-term residence on soil particles, although a study by Umbreit et al. (1986) suggested substantially lower absorption from another soil sample. It is concentrated in the fat and liver in most species. After lifetime exposure of rats to a diet containing 22 parts per trillion (ppt) 2,3,7,8-T4CDD, the average concentrations of 2,3,7,8-T4CDD in both fat and liver were 540 ppt, showing magnification by a factor of 25 (Kociba et al. 1978). 2,3,7,8-T4CDD is eliminated slowly in the form of hydroxylated metabolites from the bodies of small rodents, in which its biological half-life ranges from 10 to 43 days. However, McNulty et al. (1982) reported much longer persistence in the tissues of a rhesus monkey; in this species, the biological half-life is probably greater than one year. The persistence of 2,3,7,8-T4CDD in humans is not known. However, the closely related compounds 2,3,7,8-tetrachlorodibenzofuran and 2,3,4,7,8-pentachlorodibenzofuran appear to persist for many years in human tissues (Nagayama et al. 1977, 1983). Thus, it is likely that 2,3,7,8-T4CDD is also retained for long periods in humans. This would be expected to result in relatively high chronic toxicity.

Inter- and Intra-Species Variations in Toxic Response

Toxic responses to 2,3,7,8-T4CDD vary widely among and within species. Guinea pigs, rhesus monkeys, and chickens are extremely sensitive to the acute toxic effects of 2,3,7,8-T4CDD; rats and mice are intermediate in sensitivity; and hamsters are relatively insensitive. Some of this variability probably results from variations in the abilities of different species to metabolize and eliminate 2,3,7,8-T4CDD, whereas some may result from variations in the distribution of the cytosolic receptor protein. However, not all of the interspecies variability can be explained by these factors (Poland and Knutson 1982, Neal 1984). For example, guinea pigs are much more sensitive to the acute lethal effects of 2,4,7,8-T4CDD than are hamsters or rats, yet 2,3,7,8-T4CDD does not induce AHH activity in guinea pigs, and guinea pigs metabolize and excrete 2,3,7,8-T4CDD as rapidly as do rats (Neal 1985).

However, susceptibility of mice to most of the toxic effects of 2,3,7,8-T4CDD is genetically controlled and is associated with the Ah locus. Intraspecies variability has not been investigated extensively in other species, but it might be expected that susceptibility would vary in parallel to variations in AHH inducibility (Poland and Knutson 1982). The significance of intraspecies variability is that some individuals may be much more susceptible than others, requiring the use of large safety factors to protect the most sensitive individuals.

Qualitative Inference of Hazards to Humans

Among the toxic effects of 2,3,7,8-T4CDD observed in animals, chloracne, porphyria, enzyme induction, and effects on lipid metabolism and the gastrointestinal tract have been observed in presumptively exposed human populations. In addition, there is some suggestive, but inconclusive, evidence of immunotoxicity and increased risk of cancer, and limited evidence for reproductive impairment and induction of birth defects; this evidence has been summarized in previous sections. The fact that 2,3,7,8-T4CDD is carcinogenic in experimental animals leads to a presumption that it would increase the risk of cancer in humans exposed under appropriate circumstances (IRLG 1979). Human chloracne is similar to that induced by 2,3,7,8-T4CDD in a susceptible species, the rhesus monkey. Furthermore, two studies have shown that 2,3,7,8-T4CDD is a potent inducer of AHH and related enzymes in human cells in vitro (Nagayama et al. 1983, Hudson et al. 1983). Thus, it is reasonable to infer that 2,3,7,8-T4CDD has the potential to cause adverse health effects in humans under appropriate circumstances of exposure.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

RELATIVE SUSCEPTIBILITY OF HUMANS AND ANIMALS TO 2,3,7,8-T4CDD

The relative susceptibility of humans and animals to the toxic effects of 2,3,7,8-T4CDD is not known. However, five observations cited above are pertinent:

1. Human chloracne is similar to that elicited by 2,3,7,8-T4CDD in the rhesus monkey, a susceptible species.

2. 2,3,7,8-T4CDD is a potent inducer of AHH in human cells in vitro, and the susceptibility of human cells to 7-ethoxycoumarin O-deethylase induction was of the same order of magnitude as that of cells from susceptible mouse strains (Hudson et al. 1983). However, the concentrations of the cystolic receptor protein in human lung tissue were well below those reported for rat and mouse tissues (Roberts et al. 1985).

3. Closely related chlorinated dibenzofurans are very persistent in human tissues.

4. In many incidents of presumptive human exposure, only a proportion of the exposed individuals developed chloracne or other toxic signs.

5. In addition, the susceptibility of human cells to enzyme induction by 2,3,7,8-T4CDD is known to vary widely among individual subjects (Hudson et al. 1983) as is the concentration of the cystolic receptor protein (Roberts et al. 1985).

These observations support two inferences. First, observations 4 and 5 suggest that individual susceptibility to the toxic effects of 2,3,7,8-T4CDD is likely to be widely variable among humans. Second, observations 1, 2, and 3 suggest that at least some individuals are likely to be highly susceptible (at least as susceptible as rhesus monkeys).

NONCARCINOGENIC EFFECTS OF 2,3,7,8-T4CDD

A number of toxic effects of 2,3,7,8-T4CDD have been observed at low dose levels (Table 1). At least six different effects in three different species have been observed at dose rates in the range of 1 to 2 ng/kg/day, and a significant reduction in the generation of cytotoxic T-lymphocytes has been reported in mice following four weekly doses of 1 ng/kg 2,3,7,8-T4CDD (Clark et al. 1983). It is clear from the data in Table 1 that a lowest-observed-adverse-effect level (LOAEL) for chronic exposure to 2,3,7,8-T4CDD would not exceed 1 ng/kg/day. Significant AHH induction has been observed in rats following a single dose of 2 ng/kg (Kitchin and Woods 1979). Although induction of certain liver enzymes (those associated with cytochrome P-450) is often considered an adaptive response rather than a significant adverse effect, induction of AHH (and other enzymes associated with cytochrome P-448) is associated with a wide range of serious toxic effects (Parkinson and Safe 1981). Accordingly, 2 ng/kg represents a LOAEL for acute exposure to 2,3,7,8-T4CDD.

Applying an uncertainty factor of 1,000 to the subchronic LOAEL of 1 µg/kg/day, EPA (1985b) derived a reference dose (RfD) of 1 pg/kg/day for 2,3,7,8-T4CDD. This value was used as a 10-day "Health Advisory" for subchronic exposure of children and as a chronic "Adjusted Acceptable Daily Intake" for lifetime exposure of adults (EPA 1985b). A chronic RfD for 2,3,7,8-T4CDD has not been established, but should probably be lower than 1 pg/kg/day. An acute RfD for 2,3,7,8-T4CDD has not been established, but a value of 2 pg/kg would be appropriate, based on the same uncertainty factor of 1,000.

CARCINOGENIC EFFECTS OF 2,3,7,8-T4CDD

For 2,3,7,8-T4CDD, EPA (1985a) calculated a low-level cancer potency factor based on a feeding study in female rats that induced a statistically significant increased incidence of tumors in the liver, lungs, hard palate, and nasal turbinates (Kociba et al. 1978). The data on tumor incidence in the rat study were used in the linearized multistage model to calculate 95% upper confidence limits on risk. The risks determined using this approach are unlikely to underestimate the actual risks posed by exposure to low levels of 2,3,7,8-T4CDD in the environment, and may overestimate risk. The carcinogenic potency factor for lifetime exposure to 2,3,7,8-T4CDD is 1.56×10^{5} $(mg/kg/day)^{-1}$, indicating that a risk of 1.56×10^{-1} (upper bound) is associated with continuous lifetime exposure to a dose of 1 ng/kg/day. EPA (1985c) classified the weight of evidence for carcinogenicity as B2, based on sufficient evidence from animal bioassays and inadequate evidence from studies in humans.

TOXIC EQUIVALENCY FACTORS FOR OTHER PCDDS

Specific criteria for risk assessment for PCDDs other than 2,3,7,8-T4CDD have not been developed, except that EPA (1985a) defined chronic and subchronic NOAELs and LOAELs and a cancer potency factor for a mixture of H6CDDs. The cancer potency factor for this mixture was 6.2×10^3 $(mg/kg/day)^{-1}$, i.e., about one-twenty-fifth of that of 2,3,7,8-T4CDD, and the weight of evidence for carcinogenicity was classified as B2, based on sufficient evidence from animal bioassays and inadequate evidence from studies in humans.

In the absence of specific risk criteria for PCDDs other than 2,3,7,8-T4CDD, both regulatory agencies and scientific committees have proposed an approach to risk assessment based on "toxicity equivalency factors" (TEF) (Eadon et al. 1982, State of California 1983, USDHHS 1983, Ontario Government 1985, EPA 1986). The basis of this approach is the similarity in mechanisms of action and toxic effects of the PCDDs, as documented in the references cited above and in other scientific reviews (Poland and Knutson 1982, McKinney and McConnell 1982, Safe 1983). In the TEF approach, it is assumed that each PCDD congener acts by a similar mechanism, and that its potency can be characterized relative to that of 2,3,7,8-T4CDD. To implement this approach, a TEF is assigned to each individual PCDD congener, or to subclassess of PCDDs, and it is assumed that a quantity q_i of the ith subclass is equivalent in toxic potency to a quantity $q_i t_i$ of 2,3,7,8-T4CDD, where t_i is the TEF for the ith subclass. A further assumption is made that the potencies of different subclasses are additive. The basis for this approach is discussed in Appendix B. As discussed in Appendix B and in the toxicity profile for PCDFs, the same approach can be used for risk assessment for PCDFs.

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POLYCHLORINATED DIBENZOFURANS

INTRODUCTION

The polychlorinated dibenzofurans (PCDFs) comprise a family of 135 isomers of 8 homologues (CDFs) with varying degrees of chlorination. They are structurally similar to the PCDDs and appear to be similar to the PCDDs in chemical and biological properties. The same system of abbreviations is used to designate isomers, homologues, and subclasses of PCDFs as is used for PCDDs.

Most toxicological studies of PCDFs have been conducted with 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-T4CDF) or with poorly characterized mixtures. Several reviews of the toxicity of PCDFs in humans and animals have been published (Kuratsune and Shapiro 1984, Kikuchi 1984, Okumura 1984, Goldstein 1980, Parkinson and Safe 1981, Poland and Knutson 1982, Safe et al. 1983, EPA 1986, NRCC 1984, Ontario Government 1985). This profile summarizes the most important information available on PCDFs and lays the basis for the development of estimated risk criteria.

QUALITATIVE DESCRIPTION OF HEALTH EFFECTS

HUMAN DATA

PCDFs have been implicated in poisonings of large numbers of people in Japan in 1968 and in Taiwan in 1978. These poisoning incidents are frequently referred to as "Yusho" and "Yu-Cheng," respectively, and resulted from the leakage of chemicals containing PCDFs (along with PCBs and polychlorinated quaterphenyls or PCQs) from a heat exchanger used in processing rice oil. The ingestion of the contaminated rice oil led to the poisonings; although PCBs were originally implicated as the causative agents, there is now strong evidence that PCDFs were the primary cause of the poisonings (Masuda and Yoshimura 1984, Kunita et al. 1984, Bandiera et al. 1984). Although the two incidents have some differences, they demonstrate remarkably similar patterns of PCDF toxicity; the Yusho incident will be used as the primary basis for this report because it has been widely studied and reported (see summaries by Kuratsune and Shapiro 1984, Kikuchi 1984, and Okumura 1984).

Forty PCDF isomers have been identified in Yusho oil, but only 10 were present above detection limits in the blood of patients when analyzed some years later (Rappe et al. 1979). The isomers retained in the blood were primarily two tetra-, two penta-, and two hexaCDFs; none of these isomers contained two adjacent, unsubstituted positions. These authors concluded that PCDFs with two vicinal hydrogens were most likely to be metabolized and eliminated. These results were similar to those obtained by Masuda et al. (1983).

The average intake of PCDFs during the period of exposure appears to have been 3.4 mg (Hayabuchi et al. 1979). The average latent period (period from the initiation of intake until the appearance of symptoms) was found to be 71 days; the length of the latent period correlated well with the rate of oil consumption per day per kilogram.

Among the 1,665 known victims of Yusho poisoning, 51 persons have been reported as having died since 1968. Autopsies of several revealed the causes of death to include: malignant neoplasms of the stomach, liver, lung, and breast; cerebrovascular lesions; pneumonia; myocardial degeneration; cirrhosis of the liver; amyloidoses; and osteodystrophia fibrosa (Urabe et al. 1979). However, no systematic study of deaths among Yusho victims has been reported.

In addition to the dermal and ocular effects that were most characteristic of Yusho disease, early signs of toxicity in the Yusho victims included fatigue, nausea, vomiting, and swelling of the extremities. Later findings were anorexia, numbness, joint pain, and edema of the extremities (Higuchi 1976). Kasuda (1971) found that 60% of the Yusho women studied had irregular menstrual cycles; other reported effects included myocardial damage (Urabe et al. 1979); chronic bronchitis (Shigematsu et al. 1971); bursitis (Kaibarna et al. 1981); and persistent headaches in 58% of patients (Shibasaki 1981).

The ocular signs of Yusho disease were usually the first to be found, followed in 2 to 3 months by dermal signs. Ocular signs and symptoms included discharge from the eyelids, swelling of the upper lids and meibomian glands, and pigmentation of the conjunctive and corneal ring (Higuchi 1976). These signs occurred in more than two-thirds of the patients. In addition, there was a burning sensation in the eyes and transient visual disturbances caused by clouding of the cornea with fluid (Ikui et al. 1969).

Dermal reactions included acneiform eruptions which occurred in 113 of the 138 patients who were initially diagnosed by Goto and Higuchi (1969). The characteristic lesion was a greenish white to wheat-colored cyst ranging from pinhead- to pea-sized. When this lesion was secondarily infected, there was a local inflammatory reaction. The most frequent areas affected were the pinna of the ear, the postauricular region, and the outer ear canal. In children, there was a tendency to develop even-shaped pimples on the chin, each with a black spot in the center. There was also a marked drying of the skin in children, similar to juvenile eczema. Pigmentation of toenails and fingernails, flattening of the nails, especially the thumb; and pigmentation of the oral mucosa, especially the lips were also observed in many patients (Urabe and Asahi 1984).

Fetuses born to Yusho women frequently had reduced birth weights along with transient pigmentation of the skin (Funatsu et al. 1971, 1972). Stillbirths and cardiac anomalies have also been reported (Kikuchi et al. 1977). Reduced growth rates were reported by Yoshimura (1971) in children who consumed Yusho oil. Yusho disease has been reported in babies who were breast-fed by mothers who were diagnosed as Yusho victims (Yoshimura 1974).

The "Yu-Cheng" poisoning incident appears to have been closely parallel to the Yusho incident (for recent review and four-year followup, see Hsu et al. 1984). Based on data reported by Chen et al. (1984), Kunita et al. (1984), and Hsu et al. (1984), the average cumulative doses ingested by Yu-Cheng victims were about 1.3 g of PCBs and 3 mg of PCDFs. Signs and symptoms of poisoning were similar to those observed in Yusho, except that gastrointestinal and respiratory symptoms were less prominent in Yu-Cheng, and that immunological abnormalities and reduced nerve conduction velocities were clearly documented in Yu-Cheng victims (Hsu et al. 1984, Lu and Wu 1985, Lu and Wong 1984). Hsu et al. (1984) reported high frequencies of infant mortality and deaths from liver diseases, but no systemic mortality study has been reported.

TOXIC EFFECTS REPORTED IN ANIMALS

The toxicity of PCDFs in animals has been reviewed by a number of authors, including Goldstein (1980), Parkinson and Safe (1981), Poland and Knutson (1982), Safe et al. (1983), EPA (1983a,b, 1986), NRCC (1984), and Ontario Government (1985). These reviewers have drawn attention to the close similarity between the biological activity of PCDFs and that of the structurally similar PCDDs. The most toxic PCDFs appear to be 2,3,7,8-T4CDF and 2,3,4,7,8-P5CDF, which are almost as biologically active as 2,3,7,8-T4CDD. They resemble 2,3,7,8-T4CDD in binding to the same cytosolic receptor protein, inducing aryl hydrocarbon hydroxylase (AHH), and causing the same spectrum of toxic effects (Parkinson and Safe 1981, Poland and Knutson 1982). Structure-activity relationships among the PCDFs appear to be the same as those among the PCDDs; the most active compounds are those with chlorine substitutions in the 2, 3, 7, and 8 positions that have no more than one chlorine substitution in the 1, 4, 6 or 9 position (Goldstein 1980).

The acute oral LD_{50} for various PCDFs ranges from 3-10 ug/kg for 2,3,4,7,8-P5CDF in guinea pigs (Moore et al. 1979) to 200,000 to 400,000 ug/kg for a PCDF mixture in male and female CF mice, respectively (Nishizumi 1978). Signs of toxicity generally include: slight growth retardation (Saeki et al. 1977); "wasting syndrome"; lymphoid depletion in the thymus, spleen, and bone marrow; renal hyperplasia; hyperkeratosis of the skin; thymic atrophy; and hepatomegaly (Moore et al. 1976, 1979).

Moore et al. (1979) reported only slight effects in C57Bl mice exposed to 22 oral doses of up to 300 ug/kg 2,3,7,8-T4CDF over a 30-day period (cumulative doses of up to 6.6 mg/kg). No clinical signs of toxicity were observed, and the only pathological changes found were reductions in the weight of the thymus and increases in liver weight.

In contrast, Nagayama et al. (1979) reported marked effects on the skin of CF1 mice exposed to a mixture of T4CDFs and P5CDFs at a concentration of 0.6 ppm in the diet for 10 weeks (cumulative dose, about 5 mg/kg). Effects included hyperkeratosis of the dermal epithelium and dilation of the follicles. It is not clear whether the differences between the results of these experiments are attributable to the different strain of mice, the exposure to P5CDFs, or the longer exposure period in this study.

Oishi et al. (1978) exposed groups of 10 Sprague-Dawley rats to PCDFs at concentrations of 1 or 10 ppm in the diet for 4 weeks. The PCDF mixture was prepared by chlorination of dibenzofuran, and it contained 2 T4CDF, 4 P5CDF, and 4 H6CDF components. Rats exposed to 10 ppm developed "chloracne-like" lesions on the ears within 3 weeks. Rats exposed to either dose showed increased liver weight, decreased thymus weight, decreased hemoglobin and hematocrit values, increased serum cholesterol and cholinesterase activity, decreased serum triglycerides, decreased SGPT, and increased SGOT levels.

Few studies on the effect of PCDFs on the immune system have been reported. Luster et al. (1979a,b) exposed groups of 4-8 female Hartley guinea pigs to six weekly oral doses of 0, 0.05, 0.17, 0.5, or 1.0 ug/kg of 2,3,7,8-T4CDF (stated to be more than 98% pure). Thymus-to-body-weight ratios were reduced in the two or three highest dose groups, but spleen weights did not decline significantly. Exposure to the two highest dose levels significantly depressed cell-mediated immune functions, as indicated by decreased lymphocyte blastogenesis when cultured with T-mitogens, delayed hypersensitivity reactions, and reduced productions of the macrophage inhibitor factor. Effects at the two lower doses were not statistically significant. No significant effects on humoral immunity, as indicated by serum IgG levels and antibody response following immunization with bovine gamma globulin, were observed. The effects were similar both qualitatively and quantitatively to those induced by 2,3,7,8-T4CDD under similar circumstances (Vos et al. 1973). The authors pointed out that neither 2,3,7,8-T4CDF nor 2,3,7,8-T4CDD induced severe immunotoxic effects in adult guinea pigs, but the effects of 2,3,7,8-T4CDD were much more severe in young animals.

Vecchi et al. (1983a,b) compared the immunosuppressive effects of 2,3,7,8-T4CDF and 2,3,7,8-T4CDD in strains of mice that are "responsive" (C57Bl/6) and "nonresponsive" (DBA/2) to AHH induction. 2,3,7,8-T4CDF (purity unstated) was dissolved in corn oil and administered to groups of 7-8 mice by intraperitoneal injection or gavage in single doses of 0, 5, 11, 22.5, 45, 90, 180, or 900 ug/kg. Thymus weights and spleen cell counts fell significantly in animals given the two highest dose levels. Humoral antibody production, as indicated by the number of spleen hemolytic plaque-forming cells in response to a challenge with sheep red blood cells, was significantly reduced in "responsive" mice at all doses from 11.5 ug/kg upwards. The effect was much smaller in "nonresponsive" mice (37% versus 85% inhibition at a dose of 180 ug/kg). The authors stated that the effects of 2,3,7,8-T4CDF were similar to those produced by 2,3,7,8-T4CDD at doses 30 times smaller. However, their data indicate that the ratio of effective doses was actually about 1:100. The effects of 2,3,7,8-T4CDF had almost disappeared 42 days after treatment, in contrast to those of 2,3,7,8-T4CDD, which were only slightly reduced after 42 days. In an experiment with cynomolgus monkeys by Hori et al. (1982), administration of a mixture of PCBs (about 2.0 mg/kg/day) and PCDFs (about 0.8 ug/kg/day) to one monkey caused severe immunosuppression within 4 weeks. However, the effects were almost as severe when the PCB mixture was administered alone at about 1.7 mg/kg/day; hence, attribution of the effect to PCDFs is doubtful.

Schoeny (1982) tested five CDFs for their ability to induce point mutations in the Ames test. The chemicals tested were dibenzofuran, 2,8-D2CDF, 3,6-D2CDF, 2,3,7,8-T4CDF, and O8CDF. Concentrations tested ranged from 0.1 up to 4 or 10 ug/plate. The 2,8-D2CDF was stated to be 95-99% pure, the 2,3,7,8-T4CDF was reported to have two minor contaminants (probably T3CDFs and P5CDFs), and the other chemicals were stated to be 99% pure, but no specific analyses were reported. The chemicals were tested in up to 11 strains of Salmonella, usually with and without metabolic activation with S9 (rat liver microsomes induced with various chemicals, including Aroclor 1254 or 2,3,7,8-T4CDF). None of the CDFs induced a significant increase in revertant colonies. This study appears to have been carefully conducted according to standard protocols for the Ames test, and its negative results appear valid.

Two teratology studies with 2,3,7,8-T4CDF have been reported. Weber et al. (1984) treated groups of 6 pregnant C57Bl/6N mice by gavage with 0, 250, 500, or 1,000 ug/kg 2,3,7,8-T4CDF on day 10 of gestation and groups of 8 to 11 pregnant mice with 0, 10, 30, 50, or 100 ug/kg/day on days 10 to 13 of gestation. The females were sacrificed on day 18 of gestation; the numbers of resorbed, dead, and live fetuses were counted, and the fetuses were examined for soft tissue anomalies. The only suggestion of maternal toxicity was increased liver weight in the high-dose group in each dosage regimen. A dose-related increase in fetal mortality was found in the groups receiving a single treatment. Both the singly and multiply treated groups showed dose-related increases in cleft palate and in kidney changes (largely hydronephrosis) on both a litter and a fetus basis. In the high-dose groups receiving either the single or multiple treatments, 100% of the fetuses had kidney changes; and this effect was significantly higher on a fetus basis in all treatment groups. The authors noted, however, that these effects are likely to be reversible with further development. Although the control group for the single treatments had no fetal mortality or kidney changes, nearly 12% of the fetuses in the other control group were affected by each of these end points. No cleft palates were observed, however, in any of the control litters. The incidence of cleft palate was significantly higher after maternal treatment with one dose of 1,000 ug/kg (87% of fetuses, 100% of litters) or four treatments of 50 ug/kg/day (16% of fetuses, 67% of litters).

Despite the variability between the control groups and the possibility that the kidney changes may be transient, this experiment demonstrates that 2,3,7,8-T4CDF can produce a clear teratogenic response when given to mice at doses of 50 ug/kg/day on days 10 to 13 of gestation or produce fetal loss when given as a single dose of 250 ug/kg on day 10. Comparing the results of this experiment with those of Moore et al. (1973), who used an almost identical protocol, the doses of 2,3,7,8-T4CDF and 2,3,7,8-T4CDD required to cause cleft palate in 50% of the litters when administered on days 10 to 13 were about 40 ug/kg and 2 ug/kg, respectively. Thus, 2,3,7,8-T4CDF produces a similar teratogenic response to that of 2,3,7,8-T4CDD, but is about 20 times less potent.

Hassoun et al. (1984) also treated pregnant C57Bl mice with 2,3,7,8-T4CDF (analyzed by gas chromatography and found to be only 90% pure, with 8% hexachloroterphenyls as the major impurity). Groups of 5 to 11 females were given single intraperitoneal injections of 100-800 ug/kg of 2,3,7,8-T4CDF in dioxane or of dioxane alone on day 10, 11, 12, or 13 of gestation and were sacrificed on day 16 or 17. The treatment-related increases in resorption, fetal death, hydrops, thymic atrophy, hydronephrosis, and cleft palate were similar to the findings following gestational treatment with 2,3,7,8-T4CDD.

Poland et al. (1982, 1983) reported that 2,3,7,8-T4CDF was a potent promoter of skin tumors in HRS/J hairless mice. A group of 20 female HRS/J mice was given a single skin application of a tumor initiator (N-methyl-N'-nitro-N-nitroso-guanidine or MNNG; 5 umol) and was then exposed to applications of 1 ug 2,3,7,8-T4CDF in acetone, twice weekly for 20 weeks. All of the 19 surviving mice developed papillomas, with an average multiplicity of 4.9 tumors/mouse. None of the 23 mice treated with MNNG only, and 1/20 mice treated with 2,3,7,8-T4CDF only, developed tumors. This appears to be the only report of testing of PCDFs for carcinogenicity.

The only chronic toxicity studies with PCDFs reported to date are several studies in monkeys. McNulty et al. (1981, 1982) exposed groups of three male rhesus monkeys to 2,3,7,8-T4CDF in the diet at concentrations of 5 or 50 ppb for periods of 2-6 or 1-2 months, respectively. Daily intakes of 2,3,7,8-T4CDF were about 0.5 ug/kg/day for the low-dose group and 5 ug/kg/day for the high-dose group. One high-dose and two low-dose monkeys died after progressive weight loss, but no specific cause of death could be identified. Clinical signs included swelling of the eyelids, loss of nails and hair, and dry and scaly skin. Autopsies showed generalized squamous metaplasia of the sebaceous glands, hyperkeratosis of the nail beds, atrophy of the thymus, metaplasia of the stomach mucosa, and hypoplasia of the bile duct mucosa and the bone marrow. These effects were clinically and morphologically similar to those produced by exposure to 2,3,7,8-T4CDD or PCBs. 2,3,7,8-T4CDF appeared to be roughly 0.01-0.1 times as active as 2,3,7,8-T4CDD. Surviving monkeys had clinically recovered within 1-2 months after cessation of exposure to 2,3,7,8-T4CDF.

Hori et al. (1982) reported a study designed to explore the relative toxicity of PCBs, PCQs, and PCDFs as found in Yusho oil. As part of this study, three cynomolgus monkeys were exposed to mixtures of PCBs and PCDFs similar (but not identical) to those found in Yusho oil; one monkey was exposed to the same mixture after removal of PCDFs, and two monkeys served as controls. Weight loss, dermal and ocular lesions, immunosuppression, death, liver and kidney pathology were among the toxic effects reported. Kunita et al. (1984) subsequently reported on 3 monkeys exposed to the PCDF mixture alone at a dose rate of 8 ug/kg/day for 80-113 days. The mixture containing PCBs and PCDFs was the most toxic, causing severe weight loss; death at the higher dose rate; skin and ocular lesions; severe immunosuppression; and pathological changes in the skin, meibomian gland, liver, and kidney. The mixture without PCDFs had considerably less severe effects than the mixture with PCDFs at the same dose rate, except that the former's effect on the immune response to a challenge by sheep red blood cells was almost as great. The PCDFs by themselves caused weight loss and skin lesions but no deaths; other effects were not investigated. The results of this study are limited by the low chemical specificity and the sample sizes of only 1-3 animals, but they suggest that the PCDF mixture tested was primarily responsible for the skin, ocular, liver, and kidney lesions. The fact that the PCB/PCDF mixture was more toxic than a higher dose of the PCDF mixture suggests the possibility of additive or synergistic toxicity. With simultaneous feeding of Yusho-type PCBs, hair loss was first noted after a cumulative dose of about 10 ug/kg of the PCDF mixture, immunosuppression after a cumulative dose of about 20 ug/kg, and deaths after cumulative doses of about 36 and 75 ug/kg, although the low-dose monkey survived a cumulative dose of about 100 ug/kg. However, without simultaneous feeding of PCBs, the 3 monkeys exposed to PCDFs alone appear to have survived cumulative doses of 550-750 ug/kg. The poor design and reporting of these experiments make it difficult to draw definitive conclusions.

Yoshihara et al. (1979) and Yoshimura et al. (1981) reported on the effects of PCDFs on rhesus and crab-eating monkeys. The chemicals tested were Kanechlor 400 and a mixture of T4CDFs and P5CDFs. The PCDFs were incorporated in the diet to achieve daily doses of 0.625, 1.25, or 2.5 ug/kg/day, usually in combination with Kanechlor 400 at daily doses of 0.125, 0.25, or 0.5 mg/kg/day, respectively (a ratio of 1:200). Some monkeys were exposed to Kanechlor 400 alone. Exposure was intermittent, taking place for 5-6 days each week during months 1-8, 22-23, and 28-30 of the experiment; all animals received different doses and/or different mixtures during the three exposure periods. Most animals were given cholestyramine, liquid paraffin, or glutathione during parts of the periods of dosage. Two monkeys received 0.625 ug/kg/day of PCDFs alone during months 1-8; but one of these received cholestyramine during months 9-10; and both received 0.5 mg/kg/day of Kanechlor 400 during months 22-23.

The clinical and pathological signs in the monkeys exposed to PCDFs alone were generally similar to those observed in rhesus monkeys exposed to Aroclor 1248 (Allen et al. 1979) or 2,3,7,8-T4CDF (McNulty et al. 1981), except that no monkeys died and acne was not observed. Additional findings included hypertriglyceridemia, induction of AHH and DT-diaphorase in the liver, keratinous cysts of the meibomian glands, and bleeding of the gingiva with hyperkeratosis and proliferative invasion of the epithelium. Effects were generally less severe in the crab-eating monkeys than in the rhesus monkeys. The rhesus monkeys fed 0.625 ug/kg/day of PCDFs alone showed less severe ocular signs than those fed 0.25 mg/kg/day of Kanechlor 400. Monkeys exposed to a mixture of PCDFs and Kanechlor 400 showed greater proliferation of the smooth endoplasmic reticulum than those fed either mixture alone. After cessation of exposure to PCDFs, liver enzyme levels returned to normal after 6-9 months.

These studies are difficult to interpret because of the incomplete characterization of the tested mixtures, the complicated protocol and dosage schedule, and the incomplete categorization (in the English abstract) of the effects according to exposure group. However, the effects were generally similar to those reported in other studies of monkeys exposed to PCBs (Allen and

Norback 1976, McNulty et al. 1980), 2,3,7,8-T4CDD (Allen et al. 1977, 1979), and 2,3,7,8-T4CDF (McNulty et al. 1981). The studies suggested that the toxicity of the PCDF mixture tested was between 200 and 400 times that of Kanechlor 400. However, this result is limited to ocular effects and contrasts strongly with that of Hori et al. (1982), which suggested that (purified) Kanechlor 400 did not cause ocular effects in cynomolgus monkeys at a dose 2,500 times higher than the effective dose for a PCDF mixture. Cumulative doses of PCDFs in the experiment of Yoshimura et al. (1981) were in the range of 76 to 110 ug/kg; hair loss and enzyme induction were noted after cumulative doses of about 30 ug/kg.

QUANTITATIVE DESCRIPTION OF HEALTH EFFECTS

Table 1 summarizes estimates of the cumulative doses of PCDFs that have been reported to cause toxic effects in humans and two species of monkeys. In both humans and monkeys, the effects are qualitatively similar, at least at low doses (see above). The data in Table 1 suggest that the effects are also quantitatively similar in that the minimum effective doses are similar in all three species. These comparisons are only approximate, because both humans and some groups of monkeys were exposed to incompletely characterized mixtures of PCDFs and the human dosages were estimated retrospectively. However, the data in Table 1 constitute a substantial basis for the assumption that data on rhesus monkeys (a relatively susceptible species) can be used as the basis for risk assessment for humans. Because of the similarity in the toxic effects of PCDFs and PCDDs, it is reasonable to extend this assumption to PCDDs, including 2,3,7,8-T4CDD.

Specific risk criteria have not yet been developed for PCDFs, even in the most comprehensive criteria documents recently published by NRCC (1984) and Ontario Government (1985). Instead, these and other scientific committees and regulatory agencies (Eadon et al. 1982, State of California 1983, EPA 1986) have proposed an approach based on "toxic equivalency factors" (TEFs). The basis for this approach is the similarity in mechanisms of action and toxic effects of PCDFs to those of the PCDDs. Accordingly, PCDFs are included in the same TEF scheme for risk assessment as PCDDs.

TABLE 1

EFFECTIVE DOSES OF PCDFs IN HUMANS AND MONKEYS

		Estimated Cumulative Intake (ug/kg)			
Species	Mixture Ingested	Mild Effects	Severe Effects	Deaths	Reference
Human[a]	Yusho oil	10	60	?	Hayabuchi et al. 1979
Human[a]	Yu-Cheng oil	16	50	--	Hsu et al. 1984
Rhesus monkey	2,3,7,8-TCDF	13[b]	90	24,88, 310	McNulty et al. 1981, 1982
Rhesus monkey	2,3,7,8-TCDF	31[c]	--	--	Birnbaum et al. 1981
Rhesus monkey	Mixture	30[b]	76-110	107, 112[d]	Yoshimura et al. 1981
Cynomolgus monkey	Yusho-like mixture with PCBs	10[b]	20-100	36,75	Hori et al. 1982
Cynomolgus monkey	Yusho-like mixture without PCBs	--	550-750	--	Kunita et al. 1984

[a] Assumed average body-weight 60 kg

[b] First reported signs of toxicity

[c] Single dose

[d] Killed when moribund

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APPENDIX L

ESTIMATED SOIL INGESTION RATES

ESTIMATED SOIL INGESTION RATES
FOR USE IN RISK ASSESSMENT

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SHORT TITLE: ESTIMATED SOIL INGESTION RATES

Summary

Assessing the risks to human health posed by contaminants present in soil requires an estimate of likely soil ingestion rates. In the past, direct measurements of soil ingestion were not available and risk assessors were forced to estimate soil ingestion rates based on observations of mouthing behavior and measurements of soil on hands. Recently, empirical data on soil ingestion rates have become available from two sources (Binder et al.(1) 1986 and Clausing et al.(2) 1987). Although preliminary, these data can be used to derive better estimates of soil ingestion rates for use in risk assessments.

Estimates of average soil ingestion rates derived in this paper range from 25 to 100 mg/day, depending on the age of the individual at risk. Maximum soil ingestion rates that are unlikely to underestimate exposure, range from 100 to 500 mg. A value of 5,000 mg/day is considered a reasonable estimate of a maximum single-day exposure for a child with habitual pica.

Key Words: Soil Ingestion Rates; Risk Assessment; Soil Contamination

Introduction

Scientists attempting to evaluate the risks posed by contamination from a hazardous waste site generally must examine several routes of exposure. For some of these exposure pathways, estimates of intake rates for environmental media (i.e., liters of water consumed per day; liters of air inhaled per hour) are available based on empirical data. However, only limited information on such intake rates is available for other potential routes of exposure. Recently, two pilot studies presenting empirical data on soil ingestion rates in children were reported in the literature. This paper uses information from these two studies to estimate soil ingestion rates for use in exposure and risk assessments.

Previous Estimates of Soil Ingestion Rates

Exposure to contaminants via ingestion of soil[1] can occur by inadvertant consumption of soil on the hands of food items, mouthing of objects, consumption of nonfood items (pica[2]), or a combination of these pathways. Although direct information on soil ingestion rates was not available, several authors have used information on exposure via the above pathways to attempt to quantify the amount of soil ingested by children. Estimates made by these researchers, together with brief descriptions of their methods, are presented in Table I.

TABLE I

ESTIMATED LEVELS OF SOIL INGESTION REPORTED IN THE LITERATURE

Reference	Age	Level (mg/day)	Comments
Lepow et al. 1974,(3) 1975(4)	4.3 years (mean)	100	Based on observations of mouthing behavior and amount of soil on hands
Day et al. 1975(5)	1-3 years	10-1,000	Based on ingestion of soil on candy
Duggan and Williams 1977(6)	2-6 years	25	Based on mouthing behavior and amount of soil on hands
Mahaffey 1977(7)	1-3 years	140-430	Based on estimate of paint consumption by children with pica
Schaum 1984(8)	2-6 years	100-5,000	Based on Lepow et al.(4) and on observations by Chisholm on children with habitual pica
Kimbrough et al. 1984(9)	0-9 months	0	Based on estimates of mouthing behavior and amount of soil on hands
	9-18 months	1,000	
	1.5-3.5 years	10,000	
	3.5-5 years	1,000	
	Over 5 years	100	
Hawley 1985(10)	2.5 years	165	Based on estimated ingestion of both soil and dust
	6 years	24	
	Adults	61	

Empirical Data on Soil Ingestion Rates

Empirical data on soil ingestion rates in young children have recently become available. Binder et al.(1) and Clausing et al.(2) each conducted a pilot study on the use of trace elements of estimating soil ingestion rates in children. Binder et al.(1) estimated soil ingestion rates for 59 children 1 to 3 years old, in East Helena, Montana. Clausing et al.(2) estimated soil ingestion rates for 18 nursery school children and 6 hospitalized children, 2 to 4 years old, in the Netherlands.

Binder et al.(1) measured the trace elements silicon, aluminum, and titanium, all of which are present at high concentrations in soil and none of which are absorbed to a great degree by humans, in the soil and in fecal samples from 59 children 1 to 3 years old. The concentrations of the elements in the soil and in daily fecal samples were then compared to estimated daily soil ingestion. Binder et al.(1) also calculated soil ingestion rates using the minimum value method in which the lowest soil ingestion rate for each child is averaged.

Binder et al.'s(1) soil ingestion values are presented in Table II. As can be seen from this table, estimates of soil ingestion rates are similar for aluminum and silicon, and differ only slightly for values obtained using the minimum value method. The estimated soil ingestion rate obtained using titanium as a tracer metal is considerably higher than the values obtained using the other methods. Binder et al.(1)

TABLE II

SOIL INGESTION RATES (mg/day) BY CHILDREN 1 TO 3 YEARS OLD AS ESTIMATED BY BINDER ET AL.(1)

Basis for Estimate	Arithmetic Mean	Geometric Mean	Standard Deviation	Upper 95th Percentile
Aluminum	181	128	203	584
Silicon	184	130	175	578
Titanium	1,834	401	3,091	9,590
Minimum[a]	108	65	121	386

[a] The minimum value approach involves determining the lowest soil ingestion rate for each child predicted by any one of the three tracer metals and combining these minimum values.

SOURCE: Binder et al.(1)

were unable to determine the cause of this difference. However, an examination of the distribution of the soil ingestion rates indicates that the distribution is similar for silicon and aluminum as indicators, and when using the minimum value methods, but for titanium the distribution is essentially bimodal, with peaks at around 150 mg/day and at over 1,000 mg/day. This type of distribution suggests that some of the children may have been ingesting titanium from another source.

Clausing et al.(2) measured the acid insoluble residue (AIR) and the trace elements aluminum and titanium in the soil and in 27 fecal samples from 18 nursery school children 2 to 4 years old and in 8 samples from 6 hospitalized children (age unspecified; assumed to be 2 to 4 years old). Clausing et al.(2) also used the minimum value method (which they referred to as the maximum soil ingestion method) to estimate soil ingestion rates. The hospitalized children, who were unlikely to ingest soil, were used as estimators of background (non-soil) exposure.

Soil ingestion values determined by Clausing et al.(2) are presented in Table III. The authors noted that titanium gave a wide range of values but that a much smaller range was obtained using the aluminum and AIR methods. They also noted that the estimates obtained using the minimum value method were almost normally distributed.

In order for the methods employed by Binder et al.(1) and Clausing et al.(2) to provide reliable estimates of soil

TABLE III

SOIL INGESTION RATES (mg/day) BY CHILDREN 2 TO 4 YEARS OLD AS ESTIMATED BY CLAUSING ET AL.(2)

Basis for Estimate	Nursery School Children		Hospitalized Children	
	Arithmetic Mean	Standard Deviation	Arithmetic Mean	Standard Deviation
Aluminum	232	263	56	24
Titanium	1,431	3,015	2,293	2,456
Acid Insoluble Residue	129	69	--	--
Minimum	105	67	49	22

SOURCE: Clausing et al.(2)

ingestion rates, the following conditions are necessary: (1) tracer intake from other sources should be low, (2) tracer absorption from the gut should be low, and (3) tracer concentrations in soil should be high and not too variable. In addition to these conditions, Binder et al.(1) assumed that daily stool output averaged 15 g per child, while Clausing et al.(2) assumed that daily stool output averaged 10 g per child. Binder et al.(1) attempted to quantify the effects of their assumptions on the estimated soil ingestion rates. Clausing et al.(2) attempted to account for tracer intake from the other sources. Based on information presented in these two papers, a semi-quantitative analysis of the effects of the assumptions can be made.

As noted by Binder and her colleagues,(1) failure to account for dietary sources of the tracers leads to an overestimation of soil ingestion rates. Calculating rates using the minimum value method for estimation should decrease this bias somewhat, but dietary sources can be more completely accounted for by obtaining ingestion rate values for a control population (not exposed to soil) and subtracting values estimated for this population from those for the soil-exposed population. This method was employed by Clausing et al.(2). By comparison to estimates from the minimum value method, the silicon and aluminum methods give values that are higher by between 40% and 50%. The background values calculated by Clausing et al.(2) suggest that even the minimum value method estimates may be too high by about 50%. Based on these considerations alone, the actual average amount of soil ingested daily by children in the two studies was probably between 50 and 110 mg/day.

The effect of not accounting for absorption will lead to underestimating exposure. However, the effect is likely to be relatively minor, for two reasons. First, each percent absorbed only yields a single percent change in the estimate and absorption is known to be low. Second, a fraction of any absorbed material may be excreted in the urine or feces and subsequently collected by the researchers from diapers; none of the tracers is known to accumulate over long periods in the body, so excretion and absorption may be in balance.

Variability in soil concentrations of tracers may lead to either over- or underestimation of soil ingestion rates. However, in the Binder et al.(1) study, the means, medians, and geometric means of the aluminum and silicon concentrations in soil (N=59) are very close (Al: mean = 67 mg/g; median = 67 mg/g; geometric mean = 66 mg/g; Si: mean = 303 mg/g; median = 302 mg/g; geometric mean = 302 mg/g) suggesting that the data are normally distributed and that variations are unlikely to have significant effects on the estimates.

Binder et al.(1) used 15 g as an average for daily fecal output. By comparison to either the value used by Clausing et al.(2) (10 g/day) or to the average value of 7.3 g/day (geometric mean = 6.6 g/day; median value = 6.7 g/day) calculated from their own study, this value appears to be too high. Use of 15 g/day as the value for mean fecal mass therefore appears likely to lead to an overestimation of soil ingestion rates, possibly by as much as 50%.

The soil ingestion rates estimated by Binder et al.(1) and by Clausing et al.(2) using the minimum value method are in close agreement (103 ± 121 mg/day and 105 ± 67 mg/day, respectively). They currently represent the best available values on which to base conservative (unlikely to underestimate ingestion rates) estimates of soil ingestion rates. Based on these data, a value of 100 mg/day can be used as the soil ingestion rate for the average child between 1 and 4 years old.

The 99th percentile upper confidence limits on the soil ingestion rate derived using the minimum value method are 507 mg/day for the Binder et al.(1) study and 306 from the Clausing et al.(2) study. Because of the preliminary nature of the two studies, it is prudent to use a value close to the higher of these two numbers, 500 mg/day, as the estimate of soil ingestion rates for the maximally exposed child between 1 and 4 years old.

Estimation of Soil Ingestion Rates

Soil ingestion can occur at any age but is most prevalent in young children. Baltrop as cited in Mahaffey(7) reported that over 75% of children 1 to 3 years old mouthed small objects and that 35% ingestion them. The author also noted that the prevalence of these activities decreased with age; only 33% of children 4 to 5 years old mouthed objects, and only 6% had pica. Mahaffey(7) further reported that other estimates indicate that approximately one-half of all children 1 to 3 years old have pica. Mahaffey and Annest(11) reported that pica is most prevalent in children 6 months to 3 years old, and it is significantly more common in children from lower income families.

As noted above, older children are less likely to exhibit pica. However, Lepow et al.(3,4) observed children 2 to 6 years old mouthing objects, and it is prudent to use this value of 500 mg/day as an estimate of maximum soil ingestion for children 1 to 6 years old. Using the same reasoning, the value of 100 mg/day can be used as an estimate of the average soil ingestion rate for children in this age group.

Children less than 1 year old are not likely to come into direct contact with soil regularly. However, very young children may be exposed to contaminated house dust. No specific information is available on ingestion of dust by children in this age group, and we suggest a value of half the previous value, or 250 mg/day, as a reasonable estimate of maximum ingestion levels. Similarly, 50 mg/day can be used as an estimate of the average dust ingestion rate for children in this age group.

No empirical information on older children is available, but Mahaffey(7) reported that mouthing of objects decreased in most children more than 4 years old. Based on this information, we assume that almost all children 6 to 11 years old would have reduced their soil ingestion by at least 50%. Consequently, we suggest the use of 250 mg/day as an estimate of the maximum ingestion rate and 50 mg/day as an estimate of average soil ingestion rate by children in this age group.

For children more than 11 years old and adults, the value of 100 mg/day recommended by Kimbrough et al.(9) appears to be a reasonable maximum estimate of daily soil ingestion based on the assumption that mouthing behavior will decrease further. Based on Hawley's(10) assumptions, 50 mg/day can be used as an estimate of the average soil ingestion rate for people who have frequent hand-to-mouth contact (e.g., smokers), or who are in direct contact with contaminated soil (e.g., construction workers, gardeners). A value of half this number (25 mg/day) appears to be a reasonable estimate of the average soil ingestion rates for adults under most conditions.

As noted earlier, certain individuals exhibit pica habitually, i.e., they eat nonfood items regularly, even daily. The values for soil ingestion reported above may underestimate exposure for people exhibiting this type of behavior. The upper limit on soil ingestion of 5,000 mg/day recommended by Schaum(8) could be used as a maximum estimate of soil ingestion by a person with habitual pica.

Our estimates of soil ingestion by persons in different age groups are presented in Table IV. These values fall within the range of soil ingestion levels suggested by Schaum,(8) and are in general agreement with the estimated levels of soil ingestion presented in Table I.

TABLE IV

ESTIMATES OF SOIL INGESTION RATES

Age	Average Weight[a] (kg)	Maximum Case[b] (mg/day)	Average Case (mg/day)
0-1 year	10	250	50
1-6 years	15	500	100
6-11 years	30	250	50
Over 11 years	70	100	25[c]

[a] USEPA(12)

[b] This does not include individuals who exhibit, habital pica. For them, the upper value presented in Schaum(8) of 5,000 mg/day would be more appropriate.

[c] A value of 50 mg/day is probably a more reasonable estimate of soil ingestion rates for adults who exhibit frequent hand-to-mouth activity (e.g., most smokers) and regularly engage in outdoor activities.

Discussion/Conclusions

No single value will accurately reflect daily soil ingestion rates for all individuals. Too many factors can influence contact with soil and consequently affect the quantity of soil ingested. However, risk assessors or managers often need to estimate average and maximum soil ingestion rates in order to assess potential exposure to soil-bound contaminants. Large scale studies on soil ingestion rates are being planned in both the United States and the Netherlands, but the results of these studies will most likely not be available for several years. The values for soil ingestion rates presented in this paper have been derived using the best information currently available. We feel that these values are unlikely to underestimate soil ingestion levels and are therefore prudent estimates for use in assessing ingestion exposure to contaminated soil. As such, they provide reasonable, yet conservative (unlikely to underestimate exposure), estimates for use in the risk assessment process.

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FOOTNOTES

[1] Although several authors distinguish between soil and dust in their assessments, the data do not appear to be complete enough to allow this type of differentiation. In addition, soil commonly makes up a major portion of indoor dust.(10) Consequently, the term "soil" will be used in this discussion to refer to soil and dust combined.

[2] The term "pica" refers to both normal mouthing with subsequent ingestion of nonfood items, which is quite common among children at certain ages, and the unnatural craving for and habitual ingestion of nonfood items. The latter is an uncommon condition that is generally associated with medical conditions such as malnutrition, certain neurobehavioral disorders, and iron deficiency anemia, or, less often, with a particular cultural background. The term "habitual pica" will be used in this paper to refer to this unusual type of ingestion of nonfood items. The term "pica" will be used for the normal ingestion of nonfood items common in children at certain ages.

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