Uploaded to the VFC Website

February 2014

This Document has been provided to you courtesy of Veterans-For-Change!

Feel free to pass to any veteran who might be able to use this information!

For thousands more files like this and hundreds of links to useful information, and hundreds of "Frequently Asked Questions, please go to:

Veterans-For-Change

Veterans-For-Change is a A 501(c)(3) Non-Profit Organizaton
Tax ID #27-3820181
CA Incorporation ID #3340400
CA Dept. of Charities ID #: CT-0190794

If Veterans don't help Veterans, who will?

We appreciate all donations to continue to provide information and services to Veterans and their families.

https://www.paypal.com/cgi-bin/webscr?cmd=_s-xclick&hosted_button_id=WGT2M5UTB9A78

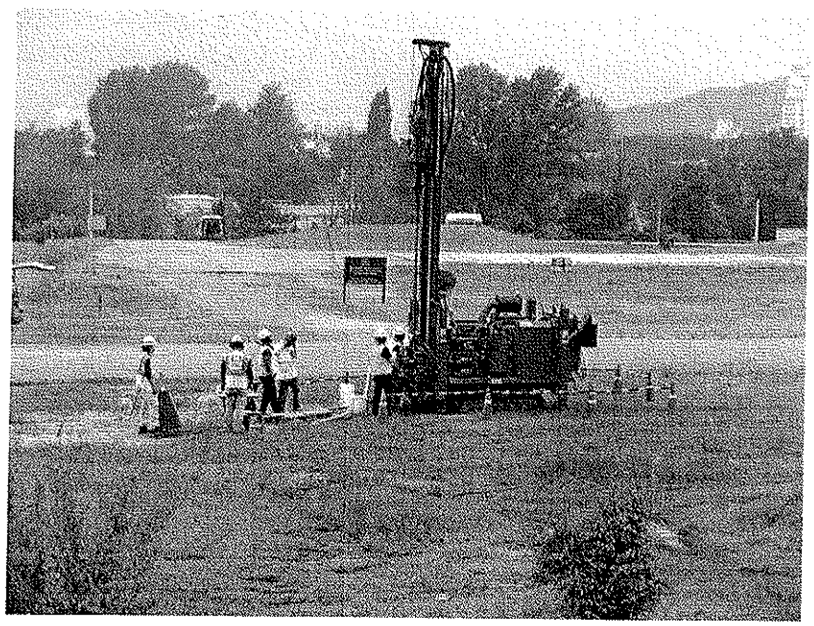
Note: VFC is not liable for source information in this document, it is merely provided as a courtesy to our members & subscribers.

11901 Samuel, Garden Grove, CA 92840-2546

US Army Corps of Engineers
Far East District

Comprehensive Agent Orange Investigation Report

Camp Carroll, Republic of Korea



Submitted to:
Assistant Chief of Staff, Engineers, 8th Army
Bldg 2364, Yongsan Garrison
PSC 303 Box 78, APO AP 96204

Prepared by:
Environmental Section
Geotechnical and Environmental Engineering Branch
US Army Corps of Engineers District, Far East
Unit #15546, APO AP 96205-5546

OCTOBER, 2011

2707

EXECUTIVE SUMMARY

The Installation Management Command-Korea (IMCOM-K) requested that the United States (US) Army Corps of Engineers, Far East District, (FED) perform field investigations related to allegations of Agent Orange burial at Camp Carroll. FED performed the field investigations in basically two strategic phases. The first phase consisted of non-intrusive investigations, specifically geophysical surveys to determine the presence of possible drums within the alleged burial area, and sampling and chemical testing of water recovered from existing monitoring wells and production wells within and adjacent to the investigation area. The second phase consisted of intrusive investigations, specifically the drilling of borings within the alleged burial area and the recovery of soil samples for chemical testing. Boring locations were selected based on results from the non-intrusive investigations, personnel interviews conducted by others, evaluation of historical site imagery, and requirements for subsequent human health risk assessments. Field work, laboratory soil and water testing, and interim report submittals were performed from 2 June to 28 September 2011. Field activities were jointly conducted with staff from FED and the National Institute of Environmental Research of Korea under the Ministry of Environment (MOE).

Sites investigated are identified as Phase I (western Helipad Area), Phase IIB (eastern Helipad Area), Phase II (Area D and Landfarm), the Slope Area immediately to the south of Phases I and IIB, the Recycling Yard, and Area 41. These locations are referred to in the report as Areas of Concern. Geophysical surveys were conducted in the Phase I, Phase IIB, Phase II, and Slope areas, in that chronological order. Geophysical surveys consisted of Magnetic Gradiometry, Electrical Resistivity Imaging (ERI), and Ground Penetrating Radar (GPR), conducted by SEKO GEO Company under contract and supervised by FED. Geophysical anomalies identified and agreed upon by FED and MOE within Phases I, II, and IIb were then the focus for subsequent intrusive investigations.

Groundwater samples were collected for analysis from 16 existing monitoring wells within and adjacent to Phases I, II, and IIB, 5 existing monitoring wells within Area 41, and 6 existing production wells west of Phase I. Water analyses were performed by SGS-Korea under contract to FED. None of the samples were identified as containing Agent Orange components. Organochlorinated (OC) pesticides such as 4,4'-DDD; 4,4'-DDT; alpha-, beta-, delta-, and gamma-BHCs; dieldrin; and endosulfan sulfate were detected in two of the Area 41 monitoring wells, with concentrations ranging from 0.0544 to 0.467 μg/L. Volatile organic compounds (VOCs) such as PCE, TCE, benzene, 1,2,4-trimethylbenzen, and 1,1,2,2,-tetrachlroethane were detected in some of the groundwater samples. PCE and TCE concentrations as high as 8,390 ug/L and 2,320 ug/L, respectively, were recorded for groundwater below Area 41.

A total of 83 soil borings were performed by direct push technology within the following areas: Phases I, II, and IIB, the Slope Area, and the Recycling Yard. A total of 272 soil samples were collected at various depths within the borings for analysis of Agent Orange components (OC herbicides and dioxins), VOCs, semi-VOCs (SVOCs), OC pesticides, organophosphorous (OP) pesticides, and metals. Soil analyses were performed by SGS-Korea under contract to FED. None of the samples were reported to contain OP-pesticides, OC-herbicides, or SVOCs.

2708

VOCs such as acetone, 2-butanone, methylene iodide, toluene, methylene chloride, PCE, TCE, cis-1,2-dichloroethene, and xylenes were detected in some of the soil samples. The highest detected concentrations of PCE, TCE, toluene, xylenes are 32,300 ug/kg, 117 ug/kg, 21,300 ug/kg, and 1,683 ug/kg, respectively.

OC-pesticides such as 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-BHC, delta-BHC, gamma-BHC (Lindane) and gamma-Chlordane were detected in some soil samples. Gamma-BHC shows the highest concentration among these analytes ((163,000 μg/kg). 4,4'-DDD, 4,4'-DDE and 4,4'-DDT have relatively high concentrations of 13,500 ug/kg, 2,830 ug/kg, and 70,200 ug/kg, respectively.

Three soil samples have measured concentrations of 2,3,7,8-TCDD at levels greater than reporting limits, ranging from 0.502 pg/kg to 7.44 pg/g. The calculated toxic equivalent (TEQ) value for this analyte ranged from 0.00 pg/g to 10.09 pg/g based on the 2005 World Health Organization (WHO) evaluation.

In summary, the non-intrusive and intrusive investigations conducted by FED within the evaluation areas found no evidence for the presence of Agent Orange. Subsurface anomalies detected by the geophysical surveys are attributable to soil and bedrock conditions (e.g. high bedrock and variations in soil moisture) and not to the presence of buried steel drums. Chemical test results for subsurface soil and groundwater samples do not indicate that Agent Orange is present in soil or groundwater at the site. Some soil and groundwater samples do contain OC-pesticides and VOCs.

REFERENCES

- EPA/540/G-89/004, OSWER Directive 9355.3-01, Guidance for Conducting Environmental Site Investigations and Feasibility Studies under CERCLA, October 1988.
- EPA Directive No.: 9355.3-01RE1, Getting Ready Scoping the ESI/RE, November 1989.
- EPA Directive No.: 9355.3-01RE2, The Environmental Site Investigation Site Characterization and Treatability Studies, November 1989.
- EPA Directive No.: 9355.3-01RE3, The Remediation Evaluation Development and Screening of Remedial Action Alternatives, November 1989.
- EPA Directive No.: 9355.3-01RE4, The Remediation Evaluation: Detailed Analysis of Remedial Action Alternatives, March 1990.
- FED: Site Assessment of BEQ Hill, Landfarm, Building 565 and Building 326, Camp Carroll, 2004
- FED: Environmental Site Assessment in Support of Landfarm Construction at Camp Carroll, Korea, 2008
- FED: Groundwater Monitoring Well Installation at Landfarm of Camp Carroll, 2007
- Samsung: Camp Carroll Area D and Area 41 Site Investigation, Camp Carroll, Korea, 2004
- Woodward Clyde: Baseline Groundwater Investigation, Camp Carroll, 1992

2710

Table of Contents

References iii
List of table vi
List of figure vi
Appendix vii
Acronyms and abbreviations viii
1. Introduction 1
1.1. Project Objectives and Scope 1
1.2. Camp Carroll Site Description 2
1.3. Areas of Concern 2
1.3.1. Phases I and IIB (Helipad Area) 2
1.3.2. Phase II (Landfarm) 2
1.3.3. Phase II (Area D) 2
1.3.4. Slope Area and Recycling Yard 3
1.3.5. Area 41 3
1.4. Summary of the Previous Investigations 3
1.4.1. Phases I and IIB (Helipad Area), Slope Area, and Recycling Yard 3
1.4.2. Phase II (Area D) 3
1.4.3. Phase II (Landfarm) 3
1.4.4. Area 41 4
1.5. Chemicals of Potential Concern 4
2. Project Activity Overview 11
2.1. Key Personnel and Organization 11
2.2. Project Chronology 11
3. Investigation Methodology 16
3.1. Geophysical survey 16
3.1.1. Magnetic Gradiometry 16
3.1.2. Ground Penetrating Radar 16
3.1.3. Electrical Resistivity Imaging 17
3.2. Geophysical Survey Procedure 17
3.2.1. Magnetic Gradiometry Survey 17
3.2.2. GPR Survey 18
3.2.3. ERI Survey 18
3.3. Soil Borings and Collection of Soil Samples 18
3.3.1. Sampling Plan 18
3.3.2. Soil Boring and Collection of Soil Samples 18
3.3.3. Soil Sampling 19
3.4. Groundwater Sampling 20
3.5. Topographic survey 21
3.6. Investigation Derived Wastes 21
3.7. Site Restoration 21
4. Summary of Investigation Findings 27
4.1. Geophysical Survey Results 27
4.1.1. Phase I 27

2711

4.1.1.1. Magnetic Gradiometry Result 28
4.1.1.2. GPR Result 28
4.1.1.3. ERI Result 28
4.1.1.4. Summary of Phase I Geophysical Survey 28
4.1.2. Phases II/IIB and Slope area 29
4.1.2.1. Magnetic Gradiometry Result 29
4.1.2.2. GPR Result 29
4.1.2.3. ERI Result 30
4.1.2.4. Summary of Phases II/IIB and Slope Area Geophysical Survey 30
4.2. Soil Investigation Result 30
4.2.2. Chemical Analysis Result for Soil Sample 31
4.2.2.1. Phase I Soil Analytical Result 31
4.2.2.2. Phase II/IIB Soil Analytical Result 32
4.3. Groundwater investigation Result 35
4.3.1. Phase I, II, and IIB Groundwater Results 35
4.3.1.1. OC Herbicides 35
4.3.1.2. Dioxins 35
4.3.2. Re-Sampling Result 35
4.3.3. Area 41 Groundwater Result 35
4.3.3.1. Dioxin and Furan, Chlorinated Herbicide 35
4.3.3.2. OC-Pesticide 36
4.3.3.3. OP-Pesticide 36
4.3.3.4. VOC 36
4.3.3.5. SVOC 36
4.3.3.6. Metal 36
4.3.4. Area 41 Re-Sampling Result 36
4.3.4.1. OC- Herbicides 36
4.3.4.2. SVOC 37
5. Summary of Findings 55
5.1. Geophysical Survey 55
5.2. Soil Sampling Result 55
5.3. Groundwater Sampling Result 56

2712

LIST OF TABLE

Table 2-1. Key Project Personnel and Contact Information........ 11
Table 2-2. Chronological Summary of Camp Carroll Agent Orange Project........ 12
Table 3-1 Analytical Methods, Holding Time and Preservation of Soil Samples........ 22
Table 3-2 Analytical Methods, Holding Time and Preservation of Groundwater Samples........ 23
Table 3-3 Coordinates for Borehole in the Vicinity of Helipad of Camp Carroll........ 24
Table 3-4 Coordinates for Supply and Monitoring Wells Utilized in the Project at Camp Carroll. 25
Table 4-1 Soil Sample Information of Phase I at the Helipad of Camp Carroll........ 38
Table 4-2 Soil Sample Information of Phase II/IIB at Camp Carroll........ 39
Table 4-3 Groundwater Parameters Measured During Investigation in the Vicinity of Helipad Area at Camp Carroll........ 40
Table 4-4 Groundwater Parameters Measured at Area 41 of Camp Carroll........ 41

LIST OF FIGURE

Figure 1-1. Location of Camp Carroll........ 6
Figure 1-2. Areas of Concern within Camp Carroll........ 7
Figure 1-3. Detail Areas of Concern in the Vicinity of Helipad Area at Camp Carroll........ 8
Figure 1-4. Detail Location of Area 41 at Camp Carroll........ 9
Figure 4-1 Borehole Location of Phase I in Western Helipad Area of Camp Carroll........ 42
Figure 4-2 Borehole Location of Phase II/IIB at Helipad, Landfarm and Area D of Camp Carroll. 43
Figure 4-3 Magnetic Gradiometry Survey Result at Phase I of Helipad Area........ 44
Figure 4-4 GPR Survey Result at Phase I of Helipad Area........ 45
Figure 4-5 ERI Survey Result at Phase I of Helipad Area........ 46
Figure 4-6 Combined Geophysical Survey Results Showing Subsurface Anomaly at Phase I of Helipad Area........ 47
Figure 4-7 Magnetic Gradiometry Survey Result at Phase II/IIB Area........ 48
Figure 4-8 GPR Survey Result at Phase II/IIB Area........ 49
Figure 4-9 ERI Survey Result at Phase II/IIB Area........ 50
Figure 4-10 Combined Geophysical Survey Results Showing Subsurface Anomaly at Phase II/IIB Area........ 51
Figure 4-11 Location of Monitoring and Supply Wells in the Vicinity of Helipad Area........ 52
Figure 4-12 Location of Monitoring Well at Area 41........ 53
Figure 5-1 Summary of Geophysical Survey Results and Location of 2,3,7,8-TCDD Reported within the Investigation Area, Camp Carroll........ 57

APPENDIX

Appendix I	Phase I Geophysical Report
Appendix II	Phase II/IIB and Slope-Recycling Yard Geophysical Reports
Appendix III	Phase I, II, IIB Soil Sampling Plan
Appendix IV	Soil Boring Logs
Appendix V	Soil Descriptive Summary
Appendix VI	Phase I Soil Sample Test Result
Appendix VII	Phase II/IIB Soil Sample Test Result
Appendix VIII	Phase I, II, IIB Groundwater Sample Test Result
Appendix IX	Phase I, II, IIB Groundwater Re-Sample Test Result
Appendix X	Area 41 Groundwater Sample Test Result
Appendix XI	Area 41 Groundwater Re-Sample Test Result

ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).
2,4,5-T: 2,4,5-trichlorophenoxyacetic acid
2,4-D: 2,4-dichlorophenoxyacetic acid
AoC: Area of Concern
BEC: Beautiful Environmental Construction
Bgs: below ground surface
BHC: Benzene Hexachloride
CD: Compact Disc
CoPC: Chemicals of Potential Concern
DCE: Dichlorinated ethylene
DDD: Dichlorodiphenyldichloroethane
DDDK: Defense Distribution Depot Korea (DDDK)
DDE: Dichlorodiphenyldichloroethylene,
DDT: Dichlorodiphenyltrichloroethane
DEHP: Bis(2-ethylhexyl)phthalate (DEHP)
DO: dissolved oxygen
DRO: Diesel Range Organic
DVD: Dissociated Vertical Deviation
ERT: Electrical Resistivity Tomography
ESA: Environmental Site Assessment
ESI: Environmental site investigation
FED: Far East District
GC/MS: Gas Chromatography/Mass Spectrometer
GHz: Giga Hertz
GPR: Ground Penetrating Radar
GRO: Gasoline Range Organic
HRGC/HRMS: High-resolution Gas Chromatography/High Resolution Mass Spectrometry
IDIQ: Indefinite Delivery and Indefinite Quality
IDW: Investigation-Derived Wastes
IMCOM-K: Installation Management Command-Korea
MHz: Mega Hertz
MOE: Ministry of Environmental
MW: Monitoring wells
nT per meter (nT/m)
nT: nanotesla (nT)
OC: Organochlorinated
Ohm-m: ohm-meters
ORP: oxidation/reduction potential
PCDDs: Polychlorinated Dibenzo-p-dioxins
PCDF: Polychlorinated Dibenzofurans (PCDF)
PCE: Tetrachlorinated ethylene
PHC: Public Health Commander
POL: Petroleum Oil Lubricant

PPE: Personal Protective Equipment
PRG: Preliminary Remedial Goal
PVC: Poly Vinyl Chloride
RCRA: Resource Conservation and Recovery Act
ROK: Republic of Korea
RRO: Residual Range Organic
SOFA: Status of Forces Agreement
SVOCs: Semi VOCs
TCE: Trichlorinated ethylene
TEQ: Toxic Equivalent
TPH: Total Petroleum Hydrocarbons
US: United
USAG: US Army Garrison
USEPA: US Environmental Protection Agency
USFK: United States Forces in Korea
UTM: Universal Transverse Mercator
VOCs: Volatile Organic Carbons
VSP: Visual Sample Plan
WGS: World Geodetic System
WHO: World health Organization

2716

This page intentionally left blank

2717

1. INTRODUCTION

Allegations were made that a large number of 55-gallon drums containing the tactical herbicide known as 'Agent Orange' were buried at Camp Carroll (Figure 1-1) at locations designated as Phase I (western Helipad area), Phase IIB (eastern Helipad area), Phase II (Area D and Landfarm), the Slope Area immediately south of Phases I and IIB, the Recycling Yard, and Area 41. Figure 1-2 presents the site locations in the vicinity of the Helipad and Area 41. This Report provides the results of investigations conducted by the US Army Corps of Engineers, Far East District (FED) to look for physical and chemical evidence of Agent Orange presence in soil and groundwater at Camp Carroll.

FED performed the field investigations in basically two strategic phases. The first phase consisted of non-intrusive investigations, conducting geophysical surveys to determine the presence of possible drums within the alleged burial area, and sampling and chemical testing of water recovered from existing monitoring wells and production wells within and adjacent to the investigation area. The second phase consisted of intrusive investigations, drilling borings within the alleged burial area and recovering soil samples for chemical testing. Boring locations were selected based on results from the non-intrusive investigations, personnel interviews conducted by others, evaluation of historical site imagery, and requirements for subsequent human health risk assessments. Field work, laboratory soil and water testing, and interim report submittals were performed from 2 June to 28 September 2011. Field activities were jointly conducted with staff from FED and the National Institute of Environmental Research of Korea under the Ministry of Environment (MOE).

FED was supported in these investigations by Beautiful Environmental Construction (BEC) Company for direct push soil borings, their subcontractor SEKO GEO Company for geophysical surveys, and SGS Testing Korea for analytical laboratory services. All contractors are under an Indefinite Delivery and Indefinite Quality (IDIQ) contract with FED. All field work was conducted jointly with personnel from FED and the National Institute of Environmental Research of Korea under the Ministry of Environment (MOE).

1.1. PROJECT OBJECTIVES AND SCOPE

The overall objective of the project was to acquire sufficient environmental data for subsurface soils and groundwater to determine if there was any trace of chemicals that were originally present in Agent Orange at the alleged burial sites. The investigations included geophysical surveys to determine if buried steel drums, possibly containing Agent Orange, were present below the sites. The collected data were also used to support human health risk assessments being conducted by the Public Health Command. The scope of the project included a review of available background information, including historical site imagery, a review of geophysical survey results to develop a sample collection strategy, borings to collect subsurface soil samples, collecting groundwater samples from existing production and monitoring wells, and laboratory analyses.

1.2. CAMP CARROLL SITE DESCRIPTION

US Army Garrison (USAG)-Daegu Camp Carroll (hereafter Camp Carroll) is located in Chilgok-Gun, Gyeongsanbuk-Do, adjacent to the city of Waegwan in the south-central portion of the ROK (Figure 1-1). Camp Carroll serves as the Headquarters, U.S. Army Material Support Center and functions as a staging ground for U.S. military operations on the Korean Peninsula. The primary mission of the installation is to serve as a staging facility and a storage and maintenance depot. Urban areas bound the installation to the northwest, west and southwest. Hilly, forested areas bound the installation to the north and east. Agricultural fields (mostly rice paddies) border the camp on the northeast and the south. The Naktong River flows from north to south approximately 0.5 kilometers west of Camp Carroll.

1.3. AREAS OF CONCERN

The areas of concern for the current investigation are based upon the allegations of former US service members that Agent Orange was buried at Camp Carroll during late 1970s. These are the areas of concern which were investigated by FED: Phase I (western Helipad area); Phase IIB (eastern Helipad area); Phase II (Area D and Landfarm), the Slope Area immediately south of Phases I and IIB, the Recycling Yard, and Area 41. There were no specific allegations of Agent Orange burial at Area 41. Area 41 was a later addition to the FED investigation due to it being an initial staging ground for hazardous materials subsequently transferred to Area D, and due to the presence high concentrations of volatile organic compounds (VOCs) in soil and groundwater detected in previous FED site investigations. Figure 1-3 shows the detail project areas in the vicinity of Helipad Area at Camp Carroll.

1.3.1. Phases I and IIB (Helipad Area)

The Helipad site is located in the southeastern portion of Camp Carroll near the installation's eastern boundary (inlet figure at Figure 1-2). There is no documentation for waste disposal occurring within the Helipad Area, other than the unsubstantiated allegations by one former US soldier of a drum burial trench being located at some position within Phase I or the immediately adjoining Slope Area or Recycling Yard. Phase I was the initial investigation area worked by FED, performed on the basis of these burial allegations.

1.3.2. Phase II (Landfarm)

The Camp Carroll Landfarm located at the eastern end of the installation, next to the Helipad Area, consists of three engineered units for treatment of contaminated soil. Two of the units are treatment beds, referred to as Bed #1and Bed #2, accompanied by a water retention pond (Figure 1-2). The dimensions of each treatment bed, which is bounded by a berm, are approximately 70 meters by 30 meters. The dimensions of the water retention pond are approximately 30 meters by 20 meters. The third unit is a biopile facility. This unit was also approximately 70 meters by 30 meters. The biopile facility was removed during this investigation because it significantly interfered with the geophysical survey. The total Landfarm facility remaining is approximately 9,100 square meters.

1.3.3. Phase II (Area D)

Area D is a former hazardous waste disposal area. Numerous hazardous materials were disposed in this area between the years of 1977 and 1982. Personnel interviews indicated that numerous drums of hazardous materials were transported to Area D from Area 41. The drums contained a variety of chemicals including pesticides (including DDT), herbicides, solvents, and over 100 other detected chemicals. The location of Area D is shown in Figure 1-3.

Reportedly, much of the disposal area material and surrounding soil was excavated between 1982 and 1983 and placed into 55-gallon drums. Despite the removal activity, residual amounts of contaminated material may have remained. No visual evidence of hazardous waste disposal, such as soil discoloration, dead vegetation, or hummocky terrain, was observed during a 1992 site inspection performed by a Woodward-Clyde Consultants field team.

1.3.4. Slope Area and Recycling Yard

The Slope Area and Recycling Yard are situated south of the Helipad and Area D. This location was the last area investigated on account of changing drum burial allegations made on site by a former US service member.

1.3.5. Area 41

The Area 41 site is located close to the southern installation boundary of Camp Carroll, next to the Defense Distribution Depot Korea (DDDK) office. Figure 1-4 presents the site location of Area 41 within Camp Carroll. Area 41 has been identified as a former drum storage area, and drummed (or otherwise containerized) hazardous materials were stored in Area 41 (Samsung 2004). The drums contained a variety of chemicals including pesticides (including DDT), herbicides, solvents, vehicle fluids (battery acid and antifreeze), POLs, other hydrocarbons, and chemicals. Numerous spill events reportedly occurred in this area between 1976 and 1981. Eye-witness accounts describing soil discoloration and localized ponding of liquids indicate that a significant amount of leakage and spillage of materials likely occurred in the vicinity of stored containers.

1.4. SUMMARY OF THE PREVIOUS INVESTIGATIONS

1.4.1. Phases I and IIB (Helipad Area), Slope Area, and Recycling Yard

There are no relevant historical environmental investigation reports for these areas.

1.4.2. Phase II (Area D)

A previous environmental site investigation (ESI) (Samsung, 2004) reported that the site soil contained concentrations of various contaminants including total petroleum hydrocarbons (TPH) of gasoline range organic (GRO), diesel range organic (DRO), and residual range organic (RRO), VOCs, SVOCs, pesticides, metals and dioxins. Concentrations of several soil contaminants exceeded EPA Region IX preliminary remedial goal (PRG) screening criteria.

1.4.3. Phase II (Landfarm)

FED conducted an environmental site assessment (ESA) at the Landfarm area in 2004. Results of soil sampling indicated the presence of VOCs in site soils. Most of the detected VOCs were solvent-related chemicals. VOC contamination was detected as deep as 6 to 8 meters below ground surface. A few pesticide, metal, and dioxin/furan compounds were also detected in site soils. Arsenic was detected in one soil sample at a concentration greater than the

2720

EPA guidance level for protection of ground water. Preliminary findings indicate that VOC and arsenic contamination exist in site soils and the levels could contribute to the contamination of the underlying groundwater.

Site investigation results of soil and groundwater by FED in 2007 revealed that the treatment beds are not a source of soil or groundwater contamination. Soil sampling indicates that concentrations of VOCs, mostly solvent-related chemicals including tetrachlorinated ethylene (PCE) and trichlorinated ethylene (TCE), exceeded EPA Region IX Preliminary Remediation Goals (PRGs) for residential soil and for tap water. Concentrations of organochlorinated (OC)-pesticides exceeded EPA Region IX PRGs for residential soil. Mixed TPH, consisting of JP-8, diesel, and oil, was identified from one soil boring with a concentration of 10,000 mg/kg. Groundwater sampling results indicate that concentrations of VOCs including PCE and TCE exceeded USEPA PRGs for tap water. Concentrations of arsenic, lead and OC-pesticide were detected in groundwater samples exceeding USEPA PRGs for tap water.

During soil excavation in support of new the treatment bed construction in 2008, approximately 2,200 cubic meters of contaminated soils with various chemicals were excavated and stockpiled within the Landfarm facility. In associated with the contaminated soil, tons of buried materials were uncovered such as 55gallon drums, 5 gallon cans and construction debris. Most 55 gallon drums were crushed and empty, while one of them contained a POL-like liquid but was not tested. The 5-gallon cans contained a white, odorless powder which was identified as calcium carbonate by subsequent laboratory analysis. Despite the removal and excavation activities, residual amounts of contaminated material may remain.

1.4.4. Area 41

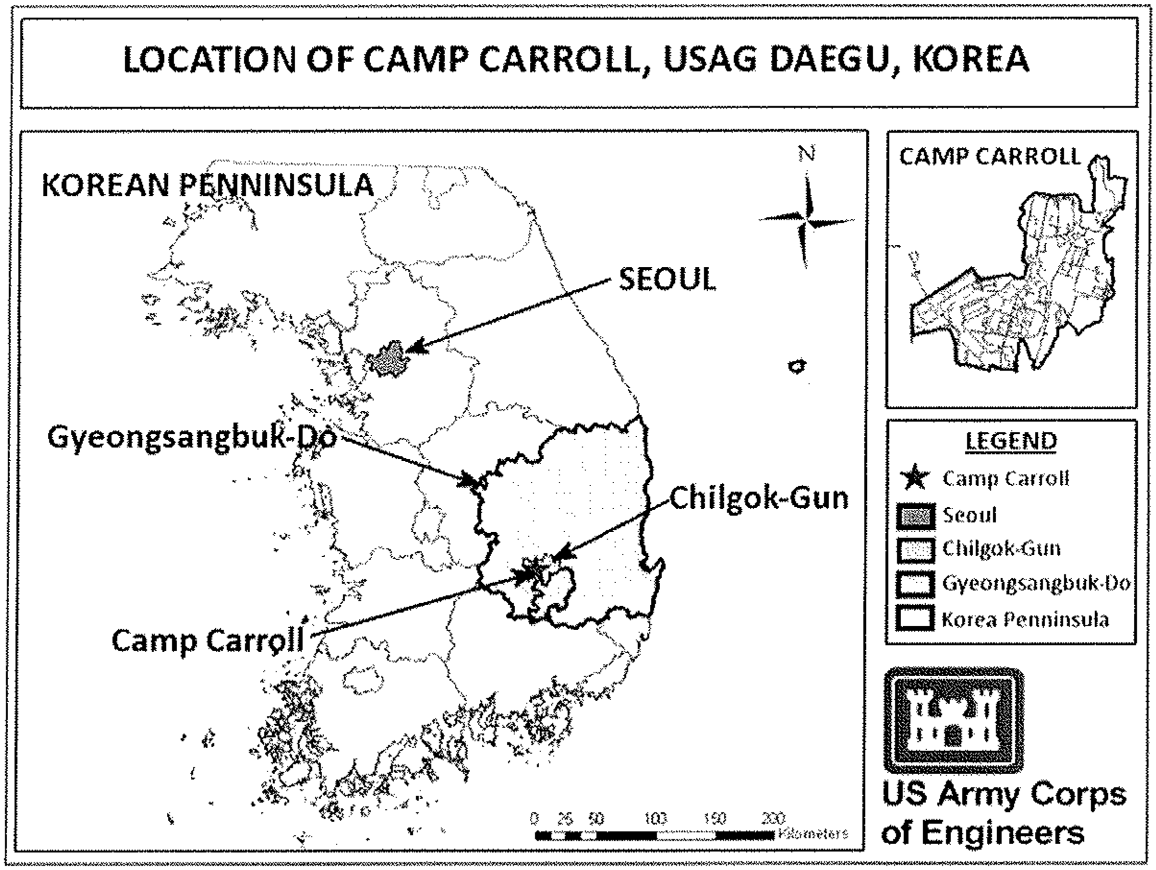
Area 41 has been previously evaluated for environmental conditions during an ESA(Samsung 2004). Samsung conducted an ESA, as an FED IDIQ contractor, at Area 41, and reported that the soil contained numerous contaminants including TPH-GRO, -DRO, -RRO, VOCs, SVOCs, pesticides, metals and dioxins. Several soil contaminant concentrations exceeded EPA Region IX PRG screening criteria. Groundwater samples obtained from Area 41 monitoring wells contained concentrations of some VOCs including PCE,TCE, and 1,2-dichlorinated ethylene (DCE).

1.5. CHEMICALS OF POTENTIAL CONCERN

Agent Orange was a tactical herbicide developed for use in combat situations. It was a 1:1 mixture of two herbicides: – 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). During manufacturing, the 2,4,5-T was contaminated with trace amounts of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). These are the major chemicals of potential concern (CoPC) for this investigation. A full suite of chemicals would also be of concern in order to assess the human health risk not only by Agent Orange but also by possible chemicals released from the historic activities. A full suite of chemicals include total petroleum hydrocarbons (TPH), VOCs, semi VOCs, organochlorinated (OC) pesticides, dioxins, organophosphorous (OP) herbicides , OC-herbicides and metals.

2721

Figure 1-1. Location of Camp Carroll



2723

Figure 1-2. Areas of Concern within Camp Carroll.

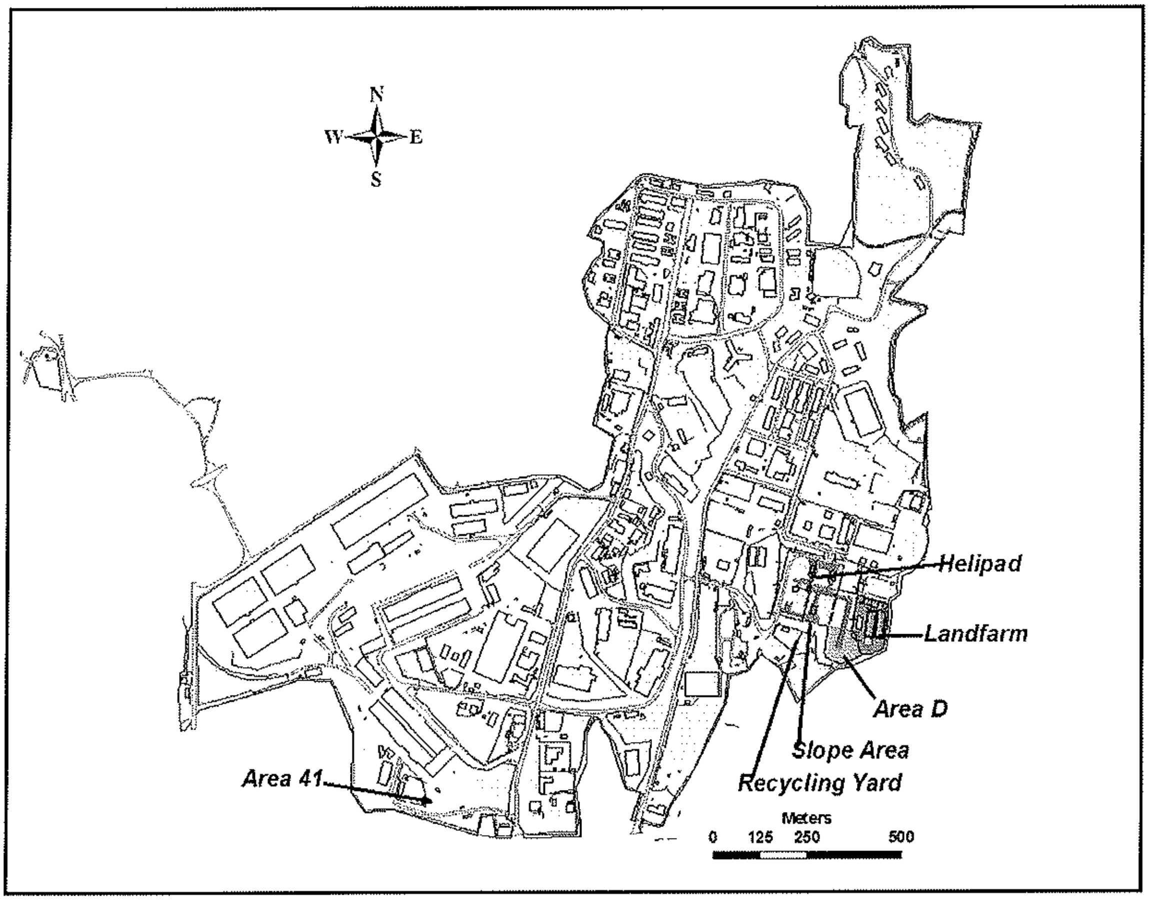
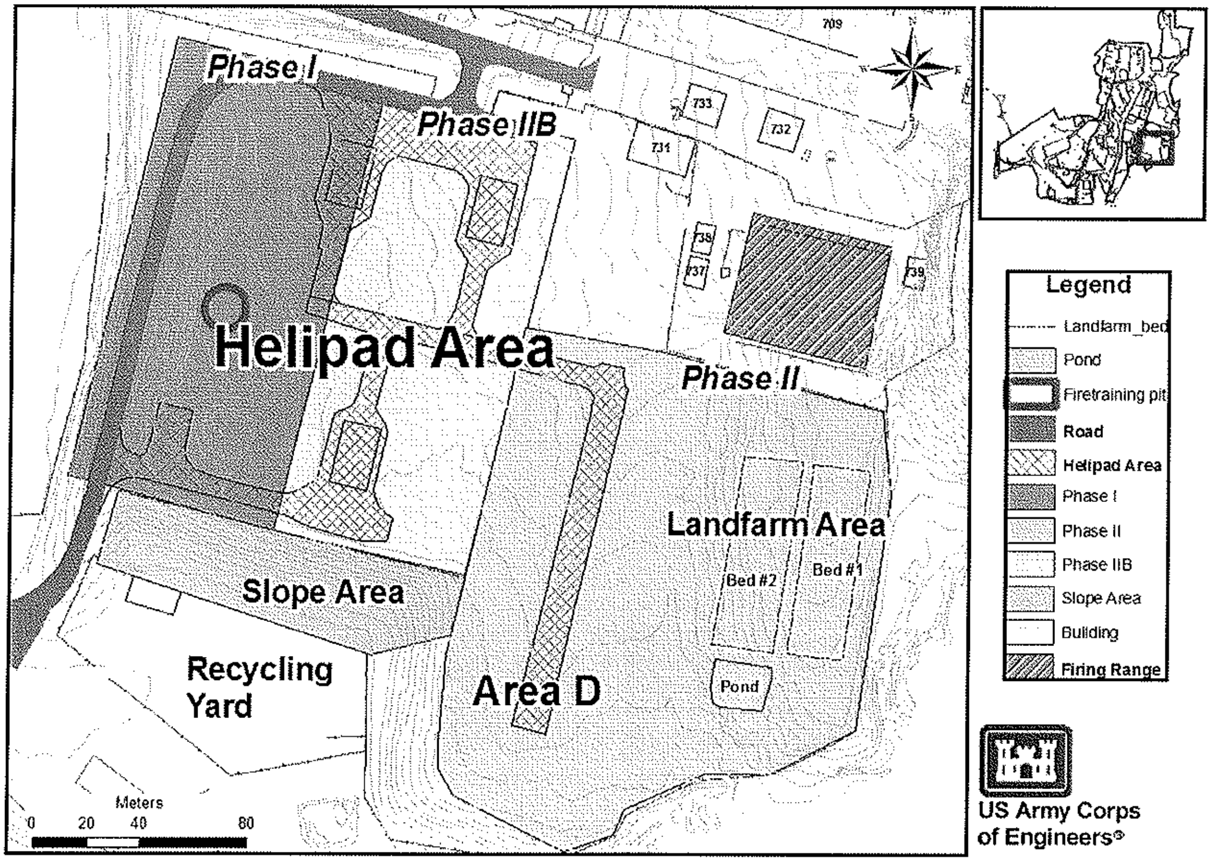
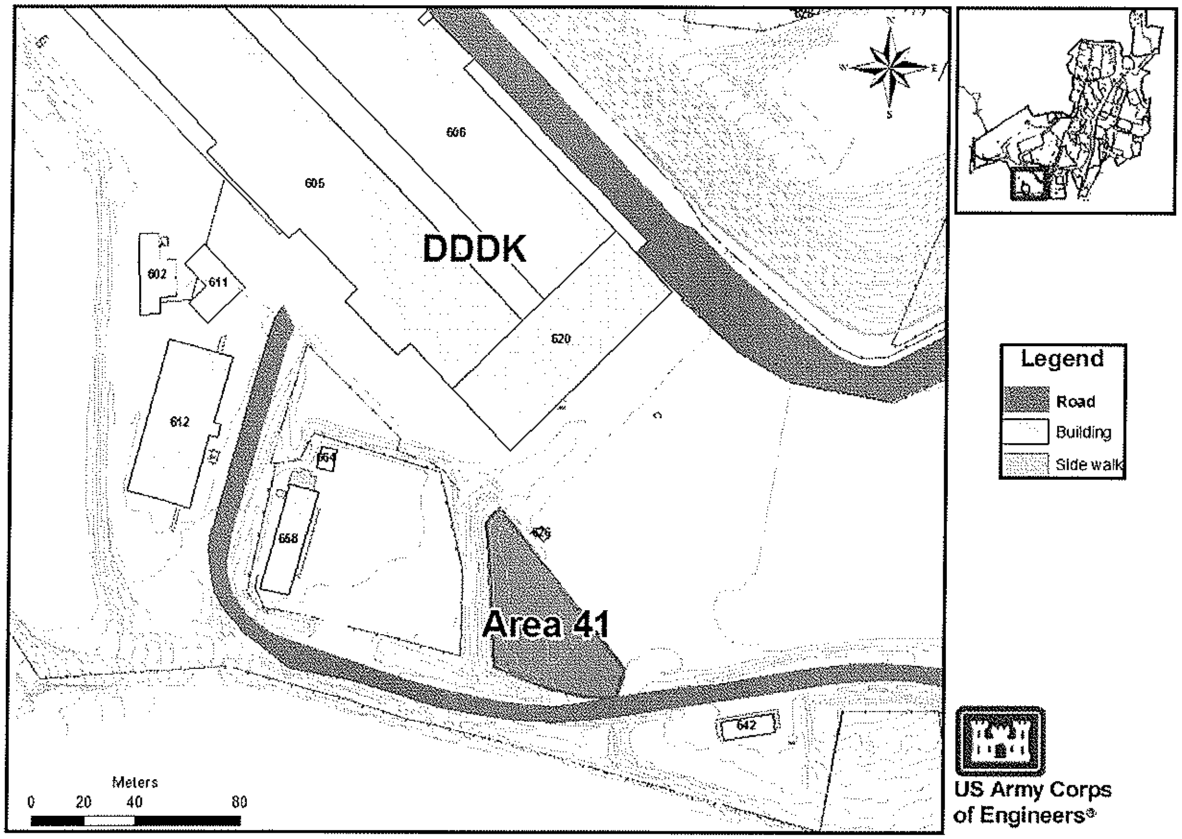


Figure 1-3. Detail Areas of Concern in the Vicinity of Helipad Area at Camp Carroll.



2725

Figure 1-4. Detail Location of Area 41 at Camp Carroll.



2726

This page intentionally left blank

2. PROJECT ACTIVITY OVERVIEW

2.1. KEY PERSONNEL AND ORGANIZATION

Key personnel and their contact information for this project are provided in Table 2-1.

Table 2-1. Key Project Personnel and Contact Information.

Title	Name	Telephone	Email
Project Manager	Mr. [redacted] b6	DSN: [redacted] b6 Commercial: [redacted] b6 Mobile: [redacted]	[redacted]@usace.army.mil b6
Technical Manager	Ms. [redacted] b6	DSN: [redacted] b6 Commercial: [redacted] b6 Mobile: [redacted]	[redacted]@usace.army.mil b6
Project Engineer	Dr. [redacted] b6	DSN: [redacted] b6 Commercial: [redacted] b6 Mobile: [redacted]	[redacted]@usace.army.mil b6
Chemist/QA Manager	Dr. [redacted] b6	DSN: [redacted] b6 Commercial: [redacted] b6 Mobile: [redacted]	[redacted]@usace.army.mil b6
Field Manager	Dr. [redacted] Dr. [redacted] b6	DSN: [redacted] b6 Commercial: [redacted] b6 Mobile: [redacted]	[redacted]@usace.army.mil b6
Public Health Command (PHC) Risk Assessor	Mr. [redacted] b6		[redacted]@us.army.mil b6
Subcontract Drilling Team	BEC Co., Ltd. Mr. [redacted] b6	Commercial: [redacted] Mobile: [redacted] b6	[redacted]@esakorea.com b6
Analytical Laboratory	SGS Korea Mr. [redacted] b6	Commercial: [redacted] Mobile: [redacted] b6	[redacted]@sgs.com b6

2.2. PROJECT CHRONOLOGY

The project was fully recognized as being a very high priority and all aspects of project planning, management, and execution were compressed and expedited. Table 2-2 summarizes the project chronology including not only field activities but also primary meetings and distinct events associated with the project. Field sampling and survey activities are highlighted in the table for convenience.

Table 2-2. Chronological Summary of Camp Carroll Agent Orange Project.

Date	Event	Description
5/20/2011	Initial Discussion about Agent Orange	IMCOM-K consulted FED about alleged Agent Orange burial site at Camp Carroll
5/23/2011	Site Visit by IMCOM-K	IMCOM-K personnel visited Camp Carroll and briefed the site and initial findings to LTG Johnson
5/23/2011	RFP for Geophysical Survey at Phase I (Helipad Area)	FED prepared SOW and issued an RFP for geophysical survey at Phase I (west Helipad Area)
5/25/2011	Summary of Environmental Reports at Cp Carroll	FED prepared a summary of historical and on-going environmental reports relevant to AO investigation
5/26/2011	Draft Site Investigation Plan	FED prepared draft Site Investigation Plan for geophysical survey, groundwater sampling
5/26/2011	Samsung 2003 Site Investigation Report at Phase II (Area D) and Area 41	FED reviewed 2003 Samsung report and checked missing section of the submitted report
5/27/2011	Contract Award	FED awarded contract for Initial Site Investigation (geophysical survey)
5/31/2011	Brief Slide for Geophysical Survey	FED prepared presentation material for Geophysical Survey
6/1/2011	Brief to ROK MOE Minister at CAC	BG Fox and LTG Johnson gave a presentation about alleged AO burial site and investigation plan to MOE
6/1/2011	Site Visit - USFK / ROK MOE / Press	After the briefing, USFK and ROK MOE personnel visited the Helipad site with press
6/2/2011	Phase I Investigation - Geophysical Survey and Groundwater Sampling	Geophysical survey at Phase I area continued until 6/12/2011. Groundwater sampling from 16 existing monitoring wells and 6 water supply wells in the vicinity of the Helipad area continued until 6/17/2011.
6/2/2011	MOE Joint Survey Team	MOE personnel joined FED for Phase I geophysical survey and groundwater sampling. Split samples of groundwater were taken by MOE for separate analysis.
6/13/2011	SOW revision for Mod#2	SOW was revised to include additional task to remove metallic debris in Phase II (Area D). Contract Mod#2 was issued on 6/14.
6/14/2011	Geophysical Survey Plan for Phase II/IIB	Conceptual geophysical survey plan for Phase II and IIB areas was prepared.
6/15/2011	Soil Sampling Plan	Draft Sampling and Analysis Plan (SAP) covering Phases I, II, IIB was prepared
6/15/2011	Phase II Investigation - Geophysical Survey	All storage containers within Phase II removed by Area IV during 6/11 - 6/15. Geophysics initiated at west section of Phase II.
6/20/2011		Geophysical survey was expanded to cover Phase IIB area
6/20/2011	SOW revision for Mod#3	SOW was revised to increase GPR and ER survey frequencies and to include Magnetometer survey per MOE request. RFP was issued on 6/20. The contract was awarded on 6/27

6/23/2011	Phase I (Helipad) Site Geophysical Survey Report	Finalized Geophysical Survey Report for Phase I area was prepared.
6/27/2011	Additional Phase I Geophysical Survey	Per request from MOE, additional Magnetometer survey was conducted at Phase I area
6/28/2011	SOW revision for Mod#4	SOW was revised to remove biopile and chain link fence at Landfarm area. Contract Mod#4 was issued on 7/5.
6/29/2011	Soil Sampling at Landfarm Area	Soil sampling from a being treated soil on Landfarm beds #1 and #2 and untreated stockpile was conducted until 6/30.
6/30/2011	Completion of Geophysical Survey at Phase II/IIB area	Geophysical survey completed in Phases II and IIB excluding structure obstacles in Landfarm due to geophysical interferences (metallic objects and reinforced concrete pad)).
7/1/2011	Technical Meeting with MOE and experts	Technical meeting with MOE expert group was held at FED to discuss geophysical survey data interpretation and results
7/7/2011	Demonstration of Soil Sampling at Phase I	FED with drilling contractor demonstrated soil sampling procedures at site to MOE, press, and public attendees
7/11/2011	Soil Sampling at Phase I	40 borings conducted until 7/19. Split soil samples taken by MOE for separate analysis. Test items include dioxin and furans, chlorinated herbicides, OC-pesticides, OC-pesticides, VOCs, SVOCs, and Metals. A total of 205 chemical compounds were tested for each soil sample.
7/11/2011	Memorandum – Groundwater Test Results	Memorandum for Test Results of Groundwater Samples for Herbicides and Dioxins (Report# E2011-38) was issued.
7/20/2011	Phase II/IIB Geophysical Report	Finalized Geophysical Survey Report for Phases II/IIB was prepared.
7/21/2011	Memorandum – Soil Test Results for Landfarm Area	Report for analytical results for the soil samples collected during 6/29-6/30 from Landfarm area was prepared.
7/22/2011	Re-sampling of Groundwater from Phase I and II	After reviewing FED/MOE analytical results for groundwater samples collected during 6/2 - 6/17, it was determined to re-sample wells suspected to contain 2,4,5-T (OC-Herbicides). Groundwater from 1 water supply well and 4 monitoring wells was re-sampled.
7/26/2011	Groundwater Sampling at Area 41	Groundwater sampling from 5 existing monitoring wells installed at Area 41 was conducted until 7/28.
7/27/2011	Mr. House's Site Visit	Mr. House visited Helipad site to indicate AO burial area, adjusting the location to the Slope Area and/or Recycling Area immediately adjacent to the slope.
8/2/2011	Memorandum – Groundwater Test Results	Memorandum for Test Results of Groundwater Samples for Herbicides (Report# E2011-44) was issued.
8/3/2011	SOW for Geophysical Survey at Slope Area	SOW for geophysical survey at the Slope Area was prepared. The contract was awarded on 8/5.
8/4/2011	Award Direct Push Drilling Contract	Contract for direct push drilling was awarded for soil sampling at Phases II and IIB.
8/5/2011	Soil Sampling at Phase II and IIB Area	Soil sampling from a total of 36 soil borings was conducted until 8/12.

8/5/2011	Plan for Slope Area investigation	After Mr. House's site visit, an additional 7 borings were planned for the Slope Area and adjacent Recycling Yard.
8/6/2011	Geophysical Survey at the Slope Area	Geophysical survey at the Slope Area was until 8/8.
8/10/2011	Geophysical Survey Report for Slope Area	Finalized Geophysical Survey Report for Phases II and IIB, to include Slope Area was submitted.
8/30/2011	Memorandum for Groundwater Samples at Area 41	Finalized report for groundwater samples collected from 5 monitoring wells installed at Area 41 was submitted.
9/9/2011	Memorandum for Phase I Soil Sampling Result	Finalized report for soil samples collected from Phase I was submitted.
9/28/2011	Re-sampling of Groundwater at Area 41	Groundwater re-sampling performed within monitoring well B03-470MW at Area 41.
10/7/2011	Memorandum for Groundwater Re-sampling at Area 41	Finalized report for groundwater samples collected during re-sampling of monitoring wells at Area 41 was submitted.
10/28/2011	Draft Comprehensive Report for Camp Carroll Investigation	Draft Comprehensive Report for Camp Carroll Investigation for Agent Orange submitted.

2731

This page intentionally left blank

3. INVESTIGATION METHODOLOGY

This section addresses the technical approach used to conduct investigation activities at Camp Carroll, Korea. Investigation activities included various geophysical survey technologies, the advancement of soil borings as well as collection of soil samples, and groundwater sampling for Phases I, II, IIB, Slope Area, Recycling Yard, and Area 41. See Figures 1-2 and 1-3 for the location of these investigation Areas of Concern. The investigation for Area 41 only consisted of collecting and testing groundwater samples from existing groundwater monitoring wells.

3.1. GEOPHYSICAL SURVEY

The geophysical survey was conducted using three non-intrusive techniques: magnetic gradiometry, ground penetrating radar (GPR), and electrical resistivity imaging (ERI). The three separate techniques were employed for the survey to ensure optimum coverage and the ability to identify and locate subsurface anomalies prior to intrusive sampling. The following sections provide brief descriptions, along with some of the strengths and limitations associated with each technique. The Geophysical Survey Reports for Phase I and II/IIB are attached as Appendix I and II, respectively, which provide additional explanation of these technologies and results.

3.1.1. Magnetic Gradiometry

Magnetic gradiometry is a more refined technique under the broader category of magnetic geophysical survey. Magnetic surveying in general is a passive method based on the measurement of localized perturbations to the Earth's magnetic field caused by the presence of buried ferrous targets. Magnetic gradiometry determines the vertical gradient of the magnetic field, and is more sensitive to small or weakly magnetic targets than the typical single sensor, total field magnetometer. The limitation with magnetic survey techniques is that they will not identify non-magnetic materials, such as glass, plastics, wood, and non-ferrous metals such as copper and aluminum.

Typically, data is collected in a systematic manner across a field site and then presented as a contoured map in units of nanotesla (nT) or nT per meter (nT/m). The amplitude and shape of an individual anomaly will reflect the dimensions, orientation and magnetic susceptibility of the buried target.

3.1.2. Ground Penetrating Radar

In GPR surveys, electromagnetic waves of frequencies between 50MHz and 2.5GHz (microwave band of the radio spectrum) are transmitted into the ground. This energy is reflected back to the surface when it encounters significant contrasts in dielectric properties. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves. A receiver measures the variation in the strength of the reflected signals with time. The resulting profile is called a "scan." Multiple scans generated by traversing the antenna across the ground surface are used to build 2D vertical cross sections (radargrams) of the subsurface.

The advantage of GPR is that it can be used in a variety of media, including rock, soil, ice, fresh water, pavements and structures. Also, because GPR is sensitive to differences in dielectric properties, it can be used to detect non-ferrous objects, changes in material, and voids and cracks. One limitation with GPR is that signal resolution is dependent on the input signal frequency. Higher frequencies provide higher resolution but provide less penetration depth.

Lower frequencies penetrate deeper into the ground but provide less resolution and hence less accuracy. Another potential limitation with GPR is that the difference between dielectric constants of different materials or layers may be too small to classify, and interpretation of data is less straightforward than magnetic techniques.

3.1.3. Electrical Resistivity Imaging

ERI, also called electrical resistivity tomography (ERT) measures ground resistance by introducing an electric current into the subsurface via two grounded electrodes. The current passing through the ground sets up a distribution of electrical potential in the subsurface. The difference in electrical potential is measured using a second set of electrodes. The transmitting and receiving electrode pairs are referred to as dipoles. Using Ohm's law, this voltage can be converted into a resistance reading in units of ohm-meters (ohm-m) for the ground between the two potential electrodes. By varying the unit length of the dipoles as well as the distance between them, the horizontal and vertical distribution of electrical properties can be recorded.

To build a vertical cross-sectional image of ground resistance, a string of connected electrodes are deployed along a straight line with an inter-electrode spacing of a. Once the resistance measurements have been made, the line is re-surveyed with an inter-electrode spacing of $2a$, $3a$, $4a$, etc. For example, if $a = 1$ m (the initial spacing between the electrodes is 1 m), the next survey along the same line would be conducted for electrodes spaced at 2 m, followed by a survey with electrodes spaced at 3 m, etc. Each increase in the inter-electrode spacing increases the effective depth of the survey. The vertical cross sections are combined to generate a fence diagram output.

3.2. GEOPHYSICAL SURVEY PROCEDURE

This section provides a description of the field procedures and instrumentation used during the geophysical survey. The specifications of the instruments are provided in Appendix I.

The Phase I survey site measures approximately 180 m from north to south and about 80 m from east to west. The Phase II Area D survey site measures approximately 180 m from north to south and about 52 m to 130 m east to west. The Phase II Landfarm site measures approximately 150 m from north to south and 100 m from east to west. The Phase IIB survey area measures approximately 170 m from north to south and 72 m east to west. The Slope Area to the south of Phases I and IIB was also included in the geophysical survey work.

3.2.1. Magnetic Gradiometry Survey

The magnetic gradiometry survey was conducted using a Bartington Instrument Ltd (United Kingdom) model Grad601 gradiometer equipped with a single Grad-01-1000L high stability fluxgate gradient sensor. The data generated was recording using a DL601 Data Logger.

The magnetic gradiometry survey utilized a grid system with north-south and east-west running gridlines at 1 m intervals. The survey sites are shown on Figure 3-1 for Phase I and Phase II/IIB. Including endpoints, this resulted in total of 47,225 intersection points during

Phase I and 2/2B, 14,480 points in Phase I Helipad, 12,718 points in Area D, 7,607 points in the Landfarm site, and 12,420 points in the Phase IIB Helipad site. Magnetic readings were taken at each intersection point.

3.2.2. GPR Survey

The GPR survey was conducted using a MALÅ GeoScience (Sweden) model ProEx™ Professional Explorer GPR. Based on site geology, soil type, subsurface conditions and the alleged depth of buried materials at 5 m to 6 m below ground surface (bgs), an input frequency of 100 megahertz (MHz) was selected to provide the highest resolution. After completion of the survey at 100 MHz, a second survey was conducted using an input frequency of 50 MHz. The lower frequency provides deeper coverage but at a slightly lower resolution.

The initial survey using the 100 MHz antenna was conducted utilizing 2 m interval transects in the east-west direction. The resultant number of transects in the Area D site was 93, 121 transects in the Landfarm site, and 84 transects in the Phase IIB Helipad site. The length of the transects ranged from about 9 m to 90 m. The 50 MHz antenna survey utilized 4 m to 5 m interval transects, also in the east-west direction (see Appendices I and II). For the 50 MHz antenna, there were total 90 transects in the Phase I Helipad, 18 transects in the Area D site, 59 transects in the Landfarm site, and 23 transects in the Phase IIB Helipad site.

3.2.3. ERI Survey

The ERI survey was conducted using an ABEM Instrument AB (Sweden) model Terrameter LS direct current resistivity meter. The survey was conducted along transects , which number 20 for Phase I Helipad, 19 for the Area D, 16 for the Landfarm, and 14 for the Phase IIB Helipad site. Fewer transects were performed for the ERI survey because this technique was used only to provide additional information about anomalies identified by other techniques.

3.3. SOIL BORINGS AND COLLECTION OF SOIL SAMPLES

3.3.1. Sampling Plan

The soil sampling strategy for this project was based on anomalies identified by the geophysical survey results and locations needed to ensure coverage to support the human health risk assessment. This sampling plan was reviewed and agreed by the MOE Joint Investigation Team prior to mobilization.

The criteria below were used as a guidance to collect soil samples and stop drilling at each sampling point if meets one of following conditions;

- If encountered bed rock refusal (drilling speed is slower than 5 cm/ 5min)
- If encountered groundwater
- If drilling to 10 meter depth but encountering residual soil or alluvial soil
- If encountered any evidence of penetrating buried drums.

3.3.2. Soil Boring and Collection of Soil Samples

A total of 83 soil boring locations were selected throughout the areas that encompass the Phase I and Phase II/IIB sites (Figure 1-3): 40 boreholes for Phase I Helipad area; 36 boreholes

Phase II/IIB Helipad, Area D and Landfarm Areas; and 7 boreholes along the Slope Area south of the Helipad.

Soil boring for soil samples was conducted using a direct push technology (DPT) soil probing machine. DPT minimizes cuttings and creates a smaller diameter borehole that is easily grouted/filled after all subsurface soil samples are collected, which was performed for this project. Using DPT, continuous soil cores were retrieved from the surface to the target depth (nominal 10 meters). Subsurface soil sample cores were retrieved by advancing an open barrel sampler with a plastic sample liner (3.7 cm inner diameter) through the sample interval equivalent to the barrel length or less (normally about 0.9 m). After the barrel sampler is pushed through the desired depth interval, the sampler is extracted from the hole and the plastic liner, containing the soil sample, and is removed from the barrel sampler.

Soil sample identification number is the following general sequence:
E11-XXX-SN, where,
E11: Environmental borehole in Fiscal Year 11
XXX: Sequential borehole number
S: Soil sample
N: Sequential sample number in a borehole

3.3.3. Soil Sampling

Composite soil sampling within a given depth interval was used to meet the project requirement. Composite sampling involves collecting samples from certain designated intervals and putting the sample in a ziplock bag to homogenize the sample for chemical analyses. The results would then provide an average contaminant concentration for the depth increment. All soil samples were subsequently placed into a laboratory-provided clean sample jar with appropriate preservative and kept in an ice-cooler for preservation. Additional requirements on sampling activities are provided in Appendix III, Field Sampling Plan (FSP). Analytical parameters and test methods for chemicals of potential concern in soil samples, and information on the sample container labels are also provided in the Appendix III.

Sampling interval was discussed between FED, USFK and MOE prior to collection of sampling. There were four sample intervals discussed as follows:

- Surface to 0. 5 meter below ground surface (bgs)
- 0.5 meter to 2 meter
- 2 meter to 5 meter
- 5 meter to 10 meter or 5 meter to drilling refusal

FED followed the above sampling strategy. MOE collected split samples starting from the 2nd depth interval to the last. All samples were well mixed and homogenized prior to splitting with MOE. A total of 118 soil samples were collected during Phase I and 154 samples during Phase II/IIB drilling activities. MOE collected 70 split samples for Phase I and 154 split samples for Phase II/IIB. Table 3-1 summarizes the CoPC, analytical methods, holding time and preservation for soil samples.

3.4. GROUNDWATER SAMPLING

The depth to groundwater was measured in each monitoring well prior to groundwater sampling. Depth to groundwater measurements was made using an electronic groundwater elevation meter relative to the top of PVC well casing and the distance from ground surface to top of PVC casing. Measurement results were recorded to the nearest 0.001 meter in the field logbook. Well cap was removed at least 30 minutes prior to water level measurement to allow water levels to equilibrate.

Groundwater sample was collected using the low-flow purge sampling method. The low-flow purging and sampling procedure is based on the Ground Water Sampling Guidelines for Superfund and Resource Conservation and Recovery Act (RCRA) Project Managers, EPA 542-S-02-001, May 2002. A well sampling log was used to record water quality parameters and purge rates. The water quality meter was calibrated to the manufacturer's specifications using current (unexpired) standards. Calibration result was documented on a field calibration form. A flow-through cell was used to monitor the water quality parameters. Monitoring well purging and sampling using the low-flow purging and sampling method are described below.

1. Measure the depth to groundwater from the inner PVC casing reference point to the nearest 0.001 meter. Attach the flow-through cell tubing and pressure hose to the sampling cap and begin pumping the well at 0.1 to 0.5 liter per minute (100 to 500 milliliters). Check the water level in the well, and measure the discharge rate of the pump by using a graduated cylinder every minute for the first 5 minutes. Ideally, the pumping rate should equal the well recharge rate with little or no water level drawdown in the well (drawdown may exceed 10 centimeter during purging but should be stabilized for three consecutive readings prior to sample collection).
2. Pumping rates at each well were initiated at the flow rate documented on previous Well Sampling Logs.
3. Measure and record the water level, discharge rate, and water quality indicator parameters in the well on the Well Sampling Log every 5 minutes during purging.
4. During purging, monitor pH, temperature, turbidity, specific conductance, oxidation/reduction potential (ORP), and dissolved oxygen (DO) approximately every other minutes with a calibrated water quality meter.
5. The groundwater should be purged until indicator parameters have stabilized. The well will be considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings, as follows:
    - Consecutive reading within ± 0.005 meter for water level measurements
    - Consecutive readings within ± 0.1 standard units for pH
    - Consecutive readings within ± 1 degree Celsius (°C) for temperature
    - Consecutive readings within ± 10 percent for turbidity (when turbidity is greater than 10 nephelometric turbidity units [NTUs])
    - Consecutive readings within ± 3 percent micromhos per centimeter (µmhos/cm) for specific conductance
    - Consecutive readings within ± 10 millivolts for ORP
    - Consecutive readings within ± 0.3 for DO (mg/L)

6. Once the water quality parameters have stabilized, disconnect the flow-through cell from the pump discharge tubing.
7. Collect samples for analysis of the CoPC.
8. Quality assurance samples were collected such as field duplicate samples, matrix spike/matrix spike duplicate samples, and equipment rinsate blanks.
9. Do not allow containers with preservative to be overfilled to the point where overflow occurs, as overfilling may result in loss of preservative. If a container containing preservative is overfilled and overflow occurs, then discard the sample and resample using a new preserved sample container.
10. Wrap glass bottles in bubble-wrap packaging material, place into resealable bags, and place sample containers into a cooler containing double bagged ice.
11. Record sample number, time and date, and requested analysis on chain-of-custody form.

Groundwater samples in the vicinity of Helipad, Landfarm and Area D were analyzed for Dioxins and OC-Herbicides. Groundwater samples from Area 41 were analyzed for the whole suite of CoPC. Table 3-2 presents the CoPC, analytical methods, holding time and preservation for water samples.

3.5. TOPOGRAPHIC SURVEY

The FED survey section performed a location and topographic survey using a SOKKIA Set 2C Total Station survey instrument. The survey included the ground surface elevation at each borehole location, the top of well riser pipe for each monitoring well, and the location and elevations of buildings, structures, and any significant utilities within the investigation area. All elevation measurements were expressed in meters above mean sea level, and the World Geodetic System 84 Universal Transverse Mercator (WGS 84 UTM) Zone-52 grid system was applied for geographic position. The accuracy of survey elevation for top of the casing measurements was to the nearest 3 mm. Ground surface elevations were made to the nearest centimeter. Tables 3-3 and 3-4 presents the borehole, monitoring and supply wells coordinates surveyed.

3.6. INVESTIGATION DERIVED WASTES

Waste materials or investigation-derived wastes (IDW), that required management and disposal during the field work included soil cuttings, used disposable sampling equipment, well development water, de-contamination water and used personal protective equipment (PPE). There are no specific Korean regulations applicable to the small quantities of IDW that were generated during the course of this project. The IDW generated during the course of this investigation was placed in woven synthetic bags while development water was placed in 55-gallon drums. The bags were segregated by their contents and stored on site until the chemical test results are reported. Water and soil cuttings were properly disposed by Carroll DPW personnel after notifying that no significant chemicals in the segregated water and soil.

3.7. SITE RESTORATION

After retrieving soil samples, the boreholes were backfilled with bentonite pellets and cement. The surfaces sealed with concrete which was backfilled flush to the existing surface grade. All mud and soil cuttings generated in the vicinity of each soil boring were cleaned up by field personnel immediately following the completion of the task.

Table 3-1 Analytical Methods, Holding Time and Preservation of Soil Samples.

Parameter	Test Method (EPA SW-846)	Container/preservative	Holding Time
Dioxins and furans	8290A	250 mL clear wide-mouth glass jar / 4 °C store in dark	30 days until extraction /analyzed within 45 days after extraction
Chlorinated herbicides	8151A	250 mL clear wide-mouth glass jar / 4 °C	14 days until extraction /analyzed within 40 days after extraction
OC pesticides	8081B or 8270D	*Same as 8151A*	*Same as 8151A*
OP pesticides	8141B	*Same as 8151A*	*Same as 8151A*
VOCs	8260B	Add ~5 g soil to 40 mL VOA vial pre-preserved with 10 mL methanol or pre-preserved with $NaHSO_4$ in 5 mL water / 4 °C	14 days
SVOCs	8270D	*Same as 8151A*	*Same as 8151A*
RCRA metals	6010C, 7471B(mercury)	*Same as 8151A*	28 days for mercury, 6 months for other metals

- 8290A: Polychlorinated Dibenzo-p-dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDF) by High-resolution Gas Chromatography/High Resolution Mass Spectrometry (HRGC/HRMS)
- 8151A: Chlorinated Herbicides by GC Using Methylation or Pentafluorobenzylation Derivatization
- 8081B: Organochlorine Pesticides by GC
- 8141B: Organophosphorus Compounds by GC
- 8260B: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
- 8270D: Semivolatile Organic Compounds by GC/MS
- 6010C: Inductively Coupled Plasma-Atomic Emission Spectrometry
- 7471B: Mercury in Solid or Semisolid Waste

Table 3-2 Analytical Methods, Holding Time and Preservation of Groundwater Samples.

Parameter	Test Method (EPA SW-846)	Container/preservative	Holding Time
Dioxins and furans	8290A	1L amber glass bottle / If sample pH > 9, adjust pH 7-9 with H_2SO_4 / 4 °C store in dark	30 days until extraction /analyzed within 45 days after extraction
Chlorinated herbicides	8151A	1 L amber glass bottle / 4 °C	7 days until extraction /analyzed within 40 days after extraction
OC pesticides	8081B	*Same as 8151A*	*Same as 8151A*
OP pesticides	8141B	1L amber glass bottle / Adjust to pH 5-9 with H_2SO_4 or NaOH / 4 °C	*Same as 8151A*
VOCs	8260B	40 mL glass VOA vial, adjust pH to < 2 with H_2SO_4 or HCl / 4 °C	14 days
SVOCs	8270D	*Same as 8151A*	*Same as 8151A*
RCRA metals	6010C, 7470A (mercury)	250 mL HDPE / HNO3 to pH < 2 / 4 °C	28 days for mercury 6 months for other metals

- 8290A: Polychlorinated Dibenzo-p-dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDF) by High-resolution Gas Chromatography/High Resolution Mass Spectrometry (HRGC/HRMS)
- 8151A: Chlorinated Herbicides by GC Using Methylation or Pentafluorobenzylation Derivatization
- 8081B: Organochlorine Pesticides by GC
- 8141B: Organophosphorus Compounds by GC
- 8260B: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
- 8270D: Semivolatile Organic Compounds by GC/MS
- 6010C: Inductively Coupled Plasma-Atomic Emission Spectrometry
- 7470A: Mercury in Liquid Waste

2740

Table 3-3 Coordinates for Borehole in the Vicinity of Helipad of Camp Carroll.

Phase I					Phase II/IIB			
BoreholeID	East	North	Elevation		BoreholeID	East	North	Elevation
E11-114	447604.093	3983549.372	50.44		E11-154	447696.6	3983502	52.293
E11-115	447613.995	3983539.729	50.57		E11-155	447677.1	3983489	51.508
E11-116	447617.644	3983538.926	50.73		E11-156	447679.5	3983460	51.395
E11-117	447621.289	3983542.772	51.05		E11-157	447655.6	3983438	50.755
E11-118	447636.894	3983542.636	51.68		E11-158	447697.4	3983436	51.313
E11-119	447661.049	3983538.692	52.21		E11-159	447689.8	3983424	50.827
E11-120	447586.586	3983527.564	48.89		E11-160	447733.2	3983429	51.93
E11-121	447592.943	3983522.53	49.04		E11-161	447702.2	3983404	50.512
E11-122	447617.287	3983526.387	50.16		E11-162	447742.7	3983412	52.021
E11-123	447622.346	3983525.283	50.38		E11-163	447724	3983373	50.755
E11-124	447648.415	3983521.007	51.7		E11-164	447726.8	3983349	50.631
E11-125	447621.701	3983510.347	50.33		E11-165	447705.6	3983324	49.64
E11-126	447631.546	3983512.932	50.88		E11-166	447813.7	3983422	55.487
E11-127	447623.407	3983502.355	50.45		E11-167	447845.9	3983414	55.978
E11-128	447594.457	3983500.812	48.06		E11-168	447771.8	3983414	52.189
E11-129	447622.895	3983492.211	50.46		E11-169	447789.7	3983405	52.629
E11-130	447633.217	3983489.146	50.91		E11-170	447808.9	3983393	53.729
E11-131	447655.104	3983495.64	51.64		E11-171	447777.2	3983382	52.109
E11-132	447639.655	3983481.399	51.21		E11-172	447767.7	3983357	51.109
E11-133	447626.844	3983467.285	50.93		E11-173	447811.9	3983364	53.53
E11-134	447638.7	3983459.519	50.9		E11-174	447839.1	3983366	54.982
E11-135	447578.232	3983482.426	47.26		E11-175	447784.2	3983347	51.072
E11-136	447608.773	3983472.997	50.12		E11-176	447801.8	3983342	53.358
E11-137	447589.237	3983469.125	47.46		E11-177	447834.7	3983341	54.709
E11-138	447612.039	3983461.821	49.75		E11-178	447752.1	3983357	50.991
E11-139	447608.367	3983454.659	50.06		E11-179	447767.8	3983338	50.599
E11-140	447642.16	3983445.714	50.41		E11-180	447748.9	3983323	50.137
E11-141	447578.584	3983448.072	47.54		E11-181	447762.6	3983318	49.929
E11-142	447600.242	3983442.452	49.13		E11-182	447747.3	3983302	49.726
E11-143	447613.936	3983444.627	49.57		E11-183	447718	3983289	49.379
E11-144	447632.364	3983435.873	50.1		E11-184	447800.2	3983296	50.155
E11-145	447586.65	3983417.931	49.3		E11-185	447806	3983305	50.973
E11-146	447584.591	3983435.904	47.01		E11-186	447822.8	3983297	52.433
E11-147	447609.978	3983432.12	49.45		E11-187	447829.9	3983324	54.905
E11-148	447574.581	3983429.018	47.53		E11-188	447841.8	3983322	55.029
E11-149	447599.314	3983424.678	49.81		E11-189	447835.5	3983311	54.808
E11-150	447628.478	3983413.402	50.06		E11-190	447663.9	3983371	49.607
E11-151	447580.06	3983398.865	47.93		E11-191	447600.8	3983368	43.611
E11-152	447610.117	3983402.754	49.65		E11-192	447699.4	3983360	49.964
E11-153	447621.329	3983391.271	50.17		E11-193	447659.5	3983346	43.315
					E11-194	447607.8	3983354	42.975
					E11-195	447630.8	3983348	42.912
					E11-196	447654.1	3983340	42.901

2741

Table 3-4 Coordinates for Supply and Monitoring Wells Utilized in the Project at Camp Carroll.

Well ID	Easting	Northing
	Supply Well	
12-247	447364.1	3983502.5
13-279	447373.0	3983614.1
14-283	447491.3	3983593.9
15-286	447441.0	3983485.2
16-289	447349.2	3983347.6
20-575	447395.2	3983770.2
	Area D	
B03-463MW	447709.20	3983282.40
B03-464MW	447705.50	3983364.10
B03-465MW	447746.40	3983361.10
B03-466MW	447734.10	3983304.60
B03-467MW	447718.70	3983326.00
B03-468MW	447754.30	3983390.10
B09-193MW	447759.92	3983292.52
B09-221MW	447671.06	3983334.28
	Landfarm	
B07-217MW	447789.23	3983349.44
B07-218MW	447775.80	3983384.33
B07-219MW	447828.37	3983386.25
B07-220MW	447789.89	3983304.56
B07-221MW	447827.00	3983324.75
	Helipad	
B09-176MW	447546.25	3983365.34
B09-177MW	447577.57	3983464.43
B09-178MW	447590.41	3983538.60
	Area 41	
B09-181MW	446674.85	3982894.24
B09-187MW	446661.62	3982919.71
B03-470MW	446660.60	3982893.30
B03-471MW	446680.10	3982915.90
B03-472MW	446653.90	3982909.10

2742

This page intentionally left blank

4. SUMMARY OF INVESTIGATION FINDINGS

Soil and groundwater samples were tested by SGS North America located in Wilmington, NC, according to US EPA SW-846 Methods. Investigation sites (Phases I, II, IIB, Slope Area, Recycling Yard, and Area 41) are delineated in Figure 1-3 and 1-4. Laboratory testing reports will be provided in separate compact disk (CD) or DVD. The following investigation activities were conducted to address the allegations of Agent Orange burial at Camp Carroll.

1) Geophysical Survey – to identify possible drums attributable to Agent Orange burial
   a) Phases I, II, and IIB: GPR, ERI and Magnetic Gradiometry
   b) Slope Area: GPR, ERI and Magnetic Gradiometry
   c) Recycling Yard and Area 41: geophysical surveys not performed
   d) Anomalies identified from geophysical surveys could in general be attributed to soil or bedrock conditions (e.g. high bedrock, high soil moisture contents, and/or differences in material density) or to buried foreign objects such as steel drums. Identified anomalies agreed upon by FED and MOE experts were subject to follow-on intrusive investigation (i.e. borings).
2) Soil Sampling
   a) Phase I: A total of 40 soil boreholes were drilled and a total of 118 soil samples were collected and analyzed for the full suite of CoPCs: VOCs, SVOCs, OC-pesticides, OC-herbicides, OP-pesticides, dioxins, metals. A total of 205 chemical analytes were tested. Figure 4-1 provides the Phase I borehole locations.
   b) Phase II and IIB, Slope Area, and Recycling Yard: A total of 43 soil boreholes were drilled and a total of 154 soil samples were collected and analyzed for the full suite of CoCs: VOCs, SVOCs, OC-pesticides, OC-herbicides, OP-pesticides, dioxins, metals. A total of 205 chemical analytes were tested. Figure 4-2 provides the borehole locations for these sites.
3) Groundwater Sampling
   a) Phases I, II, and IIB: Groundwater from 16 existing monitoring wells and 6 supply wells was tested. The CoPCs were dioxins and OC-herbicides. 5 wells (1 supply well and 4 monitoring wells) were re-sampled to analyze for a component of Agent Orange (OC-Herbicides).
   b) Area 41: Groundwater was tested from 5monitoring wells. One monitoring well (B03-470MW) was re-sampled to analyze for a component of Agent Orange (OC-Herbicides).

4.1. GEOPHYSICAL SURVEY RESULTS

4.1.1. PHASE I

The Phase I geophysical survey report is presented in Appendix I. The Phase I survey area measured approximately 180 m from north to south and 80 m east to west. It is nearly flat and slopes gently down to the southwest. The suit is mostly unpaved and covered with grass. Main physical features at the site include a concrete helipad, a vehicle wash rack, and a firefighting training pit. Additional features at the site include an aboveground fuel storage tank (AST), fuel piping, storm sewer lines, concrete manhole boxes, aboveground and underground water lines and a fire hydrant. There is a possibility that geophysical survey instrument readings taken near these features may have been affected by signal noise.

4.1.1.1.Magnetic Gradiometry Result

The magnetic gradiometry survey result is presented as a single diagram on Figure 4-3. The result is summarized as follows:

- Magnetic field in the area averages in the 400 nT to 500 nT range.
- The red colored areas in the figure may indicate the possible presence of subsurface conductive materials.
- Locations with concrete cover (e.g. wash rack, training pit, and helipad), metallic objects on or above the ground surface (e.g. AST and fire hydrant), and buried metallic objects (water lines, fuel line, sewer) are also shown as red.
- The depth of the anomalies is estimated to be within the first 5 m bgs.

4.1.1.2. GPR Result

The GPR survey was conducted using 50MHz and 100 MHz input signal frequencies. Figure 4-4 presents the subsurface anomalies compiled by each frequency. The strong reflected signals caused by known objects (e.g. helipad and training pit) were excluded. The results are summarized as follows:

- The areas colored indicate strong signal reflection, which could be caused by foreign objects or dense geologic strata.
- Several smaller anomalies shown as irregular red colored points had signals that indicate boulders within the soil stratum.
- The survey results using 50 MHz input signal frequency did not indicate any additional subsurface anomalies.

4.1.1.3. ERI Result

The ERI survey results are presented in Figure 4-5. The results are summarized as follows:

- The ground resistivity in the area ranges from about 90 ohm-m to 300 ohm-m.
- Four low resistivity anomalies have been tentatively identified.
- Conductive objects such as water lines and sewer lines show low resistivity as would be expected.

4.1.1.4. Summary of Phase I Geophysical Survey

Figure 4-6 presents the superimposed results by Magnetometer, GPR and ERI surveys at Phase I. Interpretation made on the anomalies is as follows:

- The Magnetic Gradiometry survey results identified five subsurface anomalies.
- The GPR survey results identified four subsurface anomalies.
- The ERI survey results identified three subsurface anomalies.

2245

- When the results of the three geophysical surveys are combined, they indicate four anomaly zones, identified as Zones A, B, C and D which were marked as areas to be further investigated with soil borings.

4.1.2. Phases II/IIB and Slope area

The geophysical survey report for Phases II and IIB and the Slope Area is presented in Appendix II. The Area D survey area measures approximately 180 m from north to south and from about 52 m to 130 m east to west. The Landfarm survey area measures approximately 150 m from north to south and 100 m east to west. The Phase IIB Helipad survey area measures approximately 170 m from north to south and 72 m east to west. The Slope Area measures approximately 50 m by 150 m.

The Phase II and IIB sites are mostly flat with a slight down slope to the south. The Slope Area slopes to the southwest at roughly a 30 degree. The ground in the area is mostly unpaved and covered with grass. Main physical feature at the sites include the helipad, several concrete pads, asphalt paved taxiways, metal shed, holding pond and the landfarm cells. There are also numerous underground utilities and other features at the site, including water and sewer lines, concrete pad, aboveground and underground drain line. These other features could have interfered with instrument readings during the survey. The location and general layout of these survey areas are shown on Figure 1-2.

4.1.2.1.Magnetic Gradiometry Result

The magnetic gradiometry survey result is presented as a single diagram on Figure 4-7. The results are summarized as follows:

- Magnetic field in the area averages in the 400 nT/m to 500 nT/m range.
- The red and green colored areas in the figure indicate the possible presence of subsurface conductive materials.
- Locations with concrete cover (e.g. helipad and concrete pads), metallic objects on or above the ground surface (e.g. anemometer and utility poles), and buried metallic objects (e.g. water, storm drain, and sanitary sewer lines) also present as red or green.
- There are several additional anomalies not associated with the known objects listed above. The individual anomalies are grouped into zones as shown on Figure 4-7: 4 anomalies for the Area D site, 2 for the Landfarm site, 3 for the Phase IIB Helipad site, and 1 for the Slope area.
- The depth of the anomalies is estimated to be within the first 5 m bgs.

4.1.2.2.GPR Result

The GPR survey was conducted using 50MHz and 100 MHz input signal frequencies. Figure 4-8 presents the subsurface anomalies compiled by each frequency. The strong reflected signals caused by known objects (e.g. helipad, concrete pad, concrete block, anemometer, and asphalt pavement) were excluded. The result is summarized as follows:

- The colored areas indicate a signal reflection, which could be cause by foreign objects or dense geologic strata.

- Several smaller anomalies shown as colored points had signals that indicate boulders within the soil stratum.
- Most of the anomalies that indicate the possible presence of foreign objects occurred at a depth of about 4.0 m bgs.
- The 2D radargrams showed a number of anomalies, which may be attributed to small conductive objects or rocks and boulder. The number of anomalies in each survey site is as follows: three for the Area D site, 3 for the Landfarm site, 2 for the Phase IIB Helipad site, and six for the Slope Area.

4.1.2.3.ERI Result

The ERI survey results are presented in Figure 4-9. The result is summarized as follows:

- The ground resistivity in the area ranges from about 90 ohm-m to 300 ohm-m.
- Conductive materials such as buried water pipes show low resistivity as would be expected.
- Locations with low resistivity anomalies (less than 70 ohm-m) are shown in colored area.
- The Area D site has seven low-resistivity anomalies tentatively identified as follows: Anomalies B and C occur approximately 2 m to 10 m bgs, Anomalies A, D, E, F, and G occur approximately 4 m to 12 m bgs.
- The Landfarm site has five low-resistivity anomalies tentatively identified as follows: Anomalies B, C, and E occur approximately 0.5 m to 10 m bgs, Anomalies A and D occur approximately 4 m to 12 m bgs.
- The Phase IIB Helipad site has six low-resistivity anomalies tentatively identified as follows: Anomalies A, C, and D occur between 1 m to 5 m bgs, Anomalies B, E, and F occur between 4 m to 12 m bgs.

4.1.2.4.Summary of Phases II/IIB and Slope Area Geophysical Survey

The combined results of the magnetic gradiometry and GPR surveys indicate 11 anomaly zones shown on Figure 4-10 which were agreed by FED and MOE experts as worthy of further investigation during the intrusive soil boring phase. There are four such anomalies in the Area D site, three in the Landfarm site, and three in the Phase IIB Helipad site. There were no anomalies of interest detected at the Slope area. The subsurface anomalies identified by the ERI survey were immediately attributed to geologic features and not the presence of buried objects.

4.2. SOIL INVESTIGATION RESULT

4.2.1. Subsurface geology

The subsurface geology of the general investigation area consists mostly of fill materials, alluvial and residual soils overlying weathered bedrock. Fill materials composed of clayey silty sand and clayey sand with gravel were encountered in boreholes with the thicknesses ranging from 3 to 9 m. The fill material layer is generally about 2~3 m thicker at Area D than at the Landfarm. Alluvial soil consists of sandy lean clay, clayey sand, fat clay and poorly graded sand with silt. The alluvial soil layer is generally 0.1 meter to 3 meter in thickness overlying the residual soil. Residual soil, which is decomposed bedrock, consists of fat clay and silty sand. Some boreholes show residual soil from the ground surface, which means there is no fill or

2747

alluvial soils. The bedrock consists of biotite granite. Figures 4-1 and 4-2 present the borehole location for Phases I and II/IIB, respectively. Appendix IV presents the soil boring logs. Appendix V provides the soil descriptive summary and photos that show the bedrock texture within the residual soil.

4.2.2. Chemical Analysis Result for Soil Sample

4.2.2.1.Phase I Soil Analytical Result

During the Phase I investigation, a total of 118 soil samples were collected from total 40 boreholes. Appendix VI provides the Final Test Results of Phase I (Helipad) Soil Samples at Camp Carroll. The soil sample information of Phase I is summarized in Table 4-1. The summary of chemical test results for soil samples are presented in Tables 3~9 of Appendix VI.

4.2.2.1.1. Dioxin and Furan

The chemical compound, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), is one of the Agent Orange indicator compounds found in dioxin and furan congeners. The compound 2,3,7,8-TCDD was detected in 15 samples at the levels between 0.080 and 0.189 pg/g. The results for all 15 samples were less than reporting limit and EMPC-flagged (estimated maximum possible concentration). The EMPC flag means the results were calculated from a signal which did not meet the mass spectrum quality criteria, but was estimated as the maximum possible concentration under the assumption the signal is only originated from the one analyte. None of the samples were detected for 2,3,7,8-TCDD at levels greater than reporting limits. Most of dioxin and furan congeners were found at levels between detection limits and reporting limits and are identified with the flag "J". Octachlorodibenzodioxin (OCDD) was the most common dioxin found during sampling and was detected in 116 out of 118 samples tested. The maximum concentration for OCDD was 524 pg/g at borehole E11-150-S1 (0-0.5m depth). The toxic equivalence factor (TEF) of OCDD for human health risk is relatively lower (TEF=0.0003) than other dioxin congeners. Calculated toxic equivalent (TEQ) values ranged from 0.005 to 1.156 pg/g based on 2005 World Health Organization (WHO) evaluation.

4.2.2.1.2. Chlorinated Herbicide

No chlorinated herbicides were detected in any of the collected samples. Agent Orange-related chemicals in chlorinated herbicides are 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The reporting limits of Agent Orange constituents range from 0.016 to 0.019 mg/kg for both of 2,4-D and 2,4,5-T.

4.2.2.1.3. OC-Pesticide

Analytes such as 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-BHC, delta-BHC, gamma-BHC (Lindane) and gamma-Chlordane were detected in 62 samples. Gamma-BHC has the highest concentration among the analytes and it was found at the concentration of 163,000 μg/kg in borehole E11-118-S2 (0.5-2.0m depth).

4.2.2.1.4. OP-Pesticide

No OP-pesticides were detected in any of the collected samples.

2248

4.2.2.1.5. VOC

A number of VOCs were detected in the collected samples. Tetrachloroethene (PCE) was detected in 25 samples out of a total of 118 samples tested and had the highest VOC concentration of 18,000 μg/kg at borehole E11-119-S2 (0.6-2.0m depth). Trichloroethene (TCE) was detected in 3 samples and had the highest concentration of 186 μg/kg at the same borehole and depth. Benzene had the highest concentration of 117 μg/kg at borehole E11-118-S3 (2.0-5.0m depth). Total xylenes had the highest concentration of 1683 μg/kg at borehole E11-118-S2 (0.5-2.0m depth).

4.2.2.1.6. SVOC

A few SVOC analytes were detected at levels between detection limits and reporting limits.

4.2.2.1.7. Metal

Arsenic and lead were detected in 117 and 118 samples, respectively. Borehole E11-135-S1 (0-0.5m depth) was found to have the highest concentration for both analytes: 39 mg/kg of arsenic, 138 mg/kg of lead. Mercury was detected at levels between detection limits and reporting limits, the maximum concentration was 0.0147 mg/kg at E11-134-S1 (0-0.5m depth).

4.2.2.2.Phase II/IIB Soil Analytical Result

A total of 154 soil samples were collected from a total of 43 boreholes during the Phase II/IIB investigation. Appendix VII provides the Final Test Results of Phase II/IIB Soil Samples at Camp Carroll. The soil sample information of Phase II/IIB is summarized in Table 4-2. The summary of chemical test results for soil samples are presented in Tables 3~9 of Appendix VII.

4.2.2.2.1. Dioxin and Furan

Of particular interest for the dioxins and furans is the dioxin commonly associated with Agent Orange (- 2,3,7,8-TCDD). Three soil samples have concentrations of 2,3,7,8-TCDD at levels greater than reporting limits. The borehole locations, concentrations, and sample depths (meters below ground surface) were as follows:

- E11-171-S3 7.44 pg/g 2.0 to 6.5 m
- E11-181-S1 0.57 pg/g 0.0 to 0.5 m
- E11-184-S1 0.502 pg/g 0.0 to 0.5 m

The result for E11-184-S1 was EMPC-flagged (estimated maximum possible concentration). This means the result was calculated from a signal which did not meet the mass spectrum quality criteria, but was estimated as the maximum possible concentration under the assumption the signal is only originated from the analyte.

An additional 26 samples had detected concentrations of 2,3,7,8-TCDD that were reported at concentration levels between the detection limit and reporting limits. The

2749

concentrations ranged between 0.0683 ~ 0.317 pg/g. These values were flagged "J EMPC" during data validation.

Other dioxin and furan compounds were frequently detected in the collected samples. The most frequently detected dioxins and furans were OCDD (151 of 154 samples); 1,2,3,4,6,7,8-HpCDD (128 of 154 samples); 1,2,3,4,6,7,8-HpCDF (75 of 154 samples); and OCDF (61 of 154 samples). The maximum concentrations, borehole locations, and sample depths (meters below ground surface) of these dioxins and furans were:

- OCDD 1,960 pg/g E11-195-S3 2.0 to 5.0 m
- 1,2,3,4,6,7,8-HpCDD 76.9 pg/g E11-170-S2 0.5 to 2.0 m
- 1,2,3,4,6,7,8-HpCDF 19.7 pg/g E11-178-S1 0.0 to 0.5 m
- OCDF 41.1 pg/g E11-173-S1 0.0 to 0.5 m

Calculated toxic equivalent (TEQ) values for detected dioxins and furans (EMPC included) ranged from 0.00 to 10.09 pg/g based on 2005 World Health Organization (WHO) evaluation. The maximum TEQ was calculated for sample E11-171-S3 (2.0 to 6.5 m bgs).

4.2.2.2.2. Chlorinated Herbicide

No chlorinated herbicides were detected in any of the collected samples. The reporting limits of Agent Orange constituents ranged from 0.0152 to 0.0193 mg/kg for both of 2,4-D and 2,4,5-T.

4.2.2.2.3. OC-Pesticide

Several OC-pesticides were detected in the collected samples. The OC-pesticides most frequently detected were 4,4'-DDD (107 out of 154 samples), 4,4'-DDE (103 out of 154 samples), 4,4'-DDT (117 out of 154 samples), gamma-BHC (Lindane) (45 out of 154 samples), dieldrin (30 out of 154 samples), beta-BHC (29 out of 154 samples), alpha-chlordane (28 out of 154 samples), and gamma-chlordane (27 out of 154 samples). The maximum concentration, borehole location, and depths below ground surface for each of these OC-Pesticides are as follows:

- 4,4'-DDD 13,500 μg/kg E11-179-S1 0.0 to 0.5 m
- 4,4'-DDE 2,830 μg/kg E11-170-S1 0.0 to 0.5 m
- 4,4'-DDT 70,200 μg/kg E11-179-S1 0.0 to 0.5 m
- Lindane 13,900 μg/kg E11-174-S1 0.3 to 0.8 m
- dieldrin 336 μg/kg E11-178-S1 0.0 to 0.5 m
- beta-BHC 112 μg/kg E11-174-S1 0.3 to 0.8 m
- alpha-chlordane 78.7 μg/kg E11-171-S2 0.5 to 2.0 m
- gamma-chlordane 93 μg/kg E11-171-S2 0.5 to 2.0 m

4.2.2.2.4. OP-Pesticide

No OP-pesticides were detected in any of the collected samples.

2750

4.2.2.2.5. VOC

A number of VOCs were detected in the collected samples. The VOCs that were detected most frequently are acetone (76 of 154 samples), tetrachloroethene (63 of 154 samples), 2-butanone (57 of 154 samples), methyl iodide (33 of 154 samples), toluene (32 of 154 samples), methylene chloride (31 of 154 samples), trichloroethene (31 of 154 samples), and cis-1,2-dichloroethene (31 of 154 samples). The maximum concentration, borehole location, and depth below ground surface for each of these VOCs are as follows:

• Acetone	108 µg/kg	E11-193-S1	0.0 to 0.5 m
• tetrachloroethene	32,300 µg/kg	E11-179-S1	0.0 to 0.5 m
• 2-butanone	28 µg/kg	E11-180-S1	0.0 to 0.5 m
• methyl iodide	7.92 µg/kg	E11-180-S1	0.0 to 0.5 m
• toluene	21,300 µg/kg	E11-180-S4	5.0 to 10.0 m
• methylene chloride	38.2 µg/kg	E11-164-S4	5.0 to 11.0 m
• trichloroethene	587 µg/kg	E11-176-S4	5.0 to 10.0 m
• cis-1,2-dichloroethene	558 µg/kg	E11-170-S3	2.0 to 5.0 m

4.2.2.2.6. SVOC

The most common SVOC analyte detected in Phase II and IIB samples was bis(2-ethylhexyl)phthalate. It was detected in 35 of the 154 samples, but 33 of those detected values are estimated and J-flagged because they were less than the reporting limit. Forty-four (44) other SVOCs were detected in the soil samples. Theses detections were often in only one or two samples at levels less than the reporting limit. Indeed, one sample (E11-160 at a depth of 2 to 3.4 meters below ground surface) accounts for 44 of the detected SVOCs found in the soil samples collected during Phase II and IIB.

4.2.2.2.7. Metals

Arsenic, barium, chromium, and lead were detected in all 154 samples. Mercury, selenium, and cadmium were also detected in a significant number of samples collected during Phase II and IIB. Silver was only detected in four of the 154 collected samples. The maximum concentration, borehole location, and depth below ground surface for each of the most frequently detected metals are as follows:

• Arsenic	308 mg/kg	E11-155-S1	0.0 to 0.5 m
• Barium	143 mg/kg	E11-191-S3	2.0 to 5.0 m
• Chromium	19.6 mg/kg	E11-173-S2	0.5 to 2.0 m
• Lead	34.7 mg/kg	E11-190-S3	2.0 to 5.0 m

2757

4.3. GROUNDWATER INVESTIGATION RESULT

4.3.1. Phase I, II, and IIB Groundwater Results

Groundwater samples were collected from total 16 monitoring wells and 6 water supply wells. The monitoring well and supply well locations are presented in Figure 4-11. The samples were tested according to US EPA Method 8151A for OC-Herbicides and 8290A dioxins. Appendix VIII provides the chemical test result for groundwater samples as well as the results of quality control/quality assurance measurements. The groundwater parameters measured during the sampling are presented in Table 4-3. The test results summary for 22 primary field samples is provided in Table 1 of Appendix VIII.

4.3.1.1.OC Herbicides

In chlorinated herbicides, 2,4,5-T was found in 3 samples at concentrations of 1.02 to 2.83 μg/L. The 2,4,5-T was detected in other 2 samples at levels between the detection limit and the reporting limit. Those results were J-flagged (estimated value). No other herbicides were detected in the collected samples.

4.3.1.2.Dioxins

For the dioxin and furan analytical group, 2,3,7,8-TCDD was not detected in any samples. Other dioxin and furan congeners were found in 4 samples at levels between detection limits and reporting limits. These estimated results were identified with the flag "J" or "EMPC" (estimated maximum possible concentration).

4.3.2. Re-Sampling Result

A decision was made to re-collect groundwater samples from one production well and four monitoring wells (15-286, B03-463MW, B03-466MW, B03-467MW and B09-178MW) that were suspected of containing OC-Herbicides based on the initial test results. Five (5) sample extracts obtained from original samples which had detected concentrations of 2,4,5-T were re-analyzed by gas chromatography (GC) equipped with electron capture detector (ECD) and verified with mass spectrometry to confirm presence of 2,4,5-T. Appendix IX presents the report for re-sampling and test result. Subsequent reanalysis showed that there was no 2,4,5-T detected in any of the water samples. The results of re-test are provided in Table 1 of Appendix IX. After further analysis and consultation with the analytical laboratory, the original detection of 2,4,5-T was attributed to interference from the presence of OC-pesticides (such as dieldrin).

4.3.3. Area 41 Groundwater Result

A total of five groundwater samples were collected from Area 41 at Camp Carroll for chemical analysis. The monitoring well locations are presented in Figure 4-12. Groundwater parameters measured prior to sampling are presented in Table 4-4. Appendix X presents the Area 41 groundwater sampling report.

4.3.3.1.Dioxin and Furan, Chlorinated Herbicide

The Agent Orange related compounds of 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-T, and 2,3,7,8-TCDD were not detected in any of the collected samples. One sample from

27572

monitoring well B03-471MW was found to have dioxin and furan congeners. 2,3,7,8-TCDF and 1,2,3,7,8-PeCDF were detected at concentrations of 0.00538 and 0.132 ng/L respectively. 1,2,3,4,7,8-HxCDF was detected at the level between detection limit and reporting limit. No dioxin and furan congeners were detected in other samples. No chlorinated herbicides were detected in any of the collected samples.

4.3.3.2.OC-Pesticide

The analytes such as 4,4'-DDD; 4,4'-DDT; alpha-, beta-, delta-, and gamma-BHCs; dieldrin; and endosulfan sulfate were detected in monitoring wells B03-470MW and B09-181MW with a concentration range of 0.0544 to 0.467 µg/L. The samples were analyzed by GC along with electron capture detector, but the presence of the analytes could not be confirmed by mass spectrometry due to low concentration of analytes.

4.3.3.3.OP-Pesticide

No OP-pesticides were detected in any of the collected samples.

4.3.3.4.VOC

A number of VOCs were detected in the collected samples. Tetrachloroethene (PCE) and Trichloroethene (TCE) were detected in all five monitoring well samples. The highest concentrations were 8390 µg/L of PCE at B03-470MW and 2320 µg/L of TCE at B09-181MW. Benzene and 1,2,4-trimethylbenzene were detected in three samples with highest concentrations of 57.5 µg/L for benzene and 150 µg/L for 1,2,4-trimethylbenzene at B03-470MW. 1,1,2,2-Tetrachloroethane was detected in B09-181MW at a concentration of 113 µg/L.

4.3.3.5.SVOC

Bis(2-ethylhexyl)phthalate (DEHP) was detected in all samples in concentration range of 2.09~6.28 µg/L. DEHP is a common plasticizer used in PVC products and is a possible contaminant from monitoring well casing. No other analytes were detected above the reporting limits.

4.3.3.6.Metal

Barium was detected in four samples with the highest concentration of 0.417 mg/L in monitoring well B03-472MW.

4.3.4. Area 41 Re-Sampling Result

One groundwater sample from B03-470MW at Area 41 was re-collected on 28 September 2011 in order to verify the MOE's finding of OC-Herbicide components in this monitoring well. The sample was tested only for OC-Herbicide by EPA Method 8151A and SVOCs by the Method 8270D (see the table 3-2 for the description of test method). Table 1 of Appendix XI presents the groundwater re-sampling result at Area 41.

4.3.4.1.OC- Herbicides

No chlorinated herbicides were detected in the re-collected sample. The analytical results of chlorinated herbicides are provided in Table 1 of Appendix XI. This result is consistent with results from the original sampling event. For Agent Orange-related chemicals such as 2,4-2,4-D and 2,4,5-T, the reporting limits were 0.23 µg/L for 2,4-D and 0.45 µg/L for 2,4,5-T.

4.3.4.2.SVOC

Bis(2-ethylhexyl)phthalate (DEHP) was detected at a concentration of 2.02 µg/L, which is between the detection limit and reporting limit. The concentration was lower than the original sampling result of 5.62 µg/L. DEHP is considered as a possible contaminant from monitoring well casing. 1,2,4-Trichlorobenzene was not detected in this sampling round, whereas it was detected in concentration of 3.31 µg/L from the previous sampling. The DEHP concentration of 3.31 µg/L was between the detection limit and reporting limit. No other analytes were detected. The results of SVOCs are provided in Table 1 of Appendix XI.

Table 4-1 Soil Sample Information of Phase I at the Helipad of Camp Carroll.

Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)
E11-114	S1	0-0.5	E11-123	S1	0-0.5	E11-137	S1	0-0.5	E11-148	S1	0.3-0.8
	S2	0.5-2.0		S2	0.5-2.0		S2	0.5-2.0		S2	0.8-2.3
	S3	2.0-5.0		S3	2.0-5.0		S3	2.0-5.0		S3	2.3-5.8
	S4	5.0-8.4		S4	5.0-7.7		S4	5.0-6.75	E11-149	S1	0-0.5
E11-115	S1	0-0.5	E11-124	S1	0-0.5	E11-138	S1	0.4-0.9		S2	0.5-2.0
	S2	0.5-2.0		S2	0.5-2.0		S2	0.9-2.22		S3	2.0-3.6
	S3	2.0-5.0		S3	2.0-5.0	E11-139	S1	0-0.5	E11-150	S1	0-0.5
	S4	5.0-9.4	E11-124	S4	5.0-7.35		S2	0.5-2.0		S2	0.5-2.0
E11-116	S1	0-0.5	E11-125	S1	0-0.5		S3	2.0-3.66		S3	2.0-5.0
	S2	0.5-2.0		S2	0.5-1.56	E11-140	S1	0-0.5		S4	5.0-7.0
	S3	2.0-5.0	E11-126	S1	0-0.5		S2	0.5-2.0	E11-151	S1	0-0.5
	S4	5.0-9.7		S2	0.5-1.83		S3	2.0-3.0		S2	0.5-2.0
E11-117	S1	0-0.5	E11-127	S1	0-0.5	E11-141	S1	0.3-0.8		S3	2.0-5.0
	S2	0.5-2.0		S2	0.5-2.32		S2	0.8-2.3		S4	5.0-7.85
	S3	2.0-5.0	E11-128	S1	0-0.5		S3	2.3-5.3	E11-152	S1	0-0.5
	S4	5.0-10.0		S2	0.5-3.2					S2	0.5-2.0
E11-118	S1	0-0.5	E11-129	S1	0-0.76	E11-141	S4	5.3-7.2		S3	2.0-5.0
	S2	0.5-2.0	E11-130	S1	0-1.22	E11-142	S1	0-0.5	E11-153	S1	0.3-0.8
	S3	2.0-5.0	E11-131	S1	0.12-0.5		S2	0.5-2.0		S2	0.8-2.3
	S4	5.0-8.9		S2	0.5-1.7		S3	2.0-4.73		S3	2.3-5.3
E11-119	S1	0.1-0.6	E11-132	S1	0.1-0.6	E11-143	S1	0-0.5		S4	5.3-10.0
	S2	0.6-2.0		S2	0.6-3.0		S2	0.5-2.0			
	S3	2.0-5.0	E11-133	S1	0.15-0.65		S3	2.0-3.55			
	S4	5.0-7.9		S2	0.65-2.46	E11-144	S1	0-0.5			
E11-120	S1	0-0.5	E11-134	S1	0-0.5		S2	0.5-1.52			
	S2	0.5-2.0		S2	0.5-1.51	E11-145	S1	0-0.5			
	S3	2.0-3.3	E11-135	S1	0-0.5		S2	0.5-2.0			
E11-121	S1	0-0.5		S2	0.5-2.0		S3	2.0-5.0			
	S2	0.5-2.7		S3	2.0-5.0	E11-146	S1	0-0.5			
E11-122	S1	0-0.5		S4	5.0-7.65		S2	0.5-2.0			
	S2	0.5-2.0	E11-136	S1	0-0.5		S3	2.0-4.85			
	S3	2.0□5.0		S2	0.5□3.2	E11-147	S1	0□0.5			
	S4	5.0□9.3					S2	0.5□1.97			

Table 4-2 Soil Sample Information of Phase II/IIB at Camp Carroll.

Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)	Borehole	Sample ID	Depth (m)
E11-154	S1	0.0-0.5	E11-164	S1	0.0-0.5	E11-173	S4	5.0-10.0	E11-181	S3	2.0-5.0	E11-189	S3	2.0-5.0
	S2	0.5-2.3		S2	0.5-2.0	E11-174	S1	0.3-0.8	E11-182	S1	0.0-0.5		S4	5.0-10.0
E11-155	S1	0.0-0.5		S3	2.0-5.0		S2	0.8-2.3		S2	0.5-2.0	E11-190	S1	0.0-0.5
	S2	0.5-1.8		S4	5.0-11.0		S3	2.3-5.3		S3	2.0-5.0		S2	0.5-2.0
E11-156	S1	0.0-0.5	E11-165	S1	0.0-0.5		S4	5.3-8.9		S4	5.0-10.0		S3	2.0-5.0
	S2	0.5-2.0		S2	0.5-2.0	E11-175	S1	0.0-0.5	E11-183	S1	0.0-0.5		S4	5.0-10.0
	S3	2.0-6.45		S3	2.0-5.0		S2	0.5-2.0		S2	0.5-2.0	E11-191	S1	0.0-0.5
E11-157	S1	0.0-0.5		S4	5.0-10.0		S3	2.0-5.0		S3	2.0-5.0		S2	0.5-2.0
	S2	0.5-2.0	E11-166	S1	0.3-0.8		S4	5.0-7.25		S4	5.0-10.0		S3	2.0-5.0
	S3	2.0-4.5		S2	0.8-2.7	E11-176	S1	0.0-0.5	E11-184	S1	0.0-0.5		S4	5.0-7.7
E11-158	S1	0.0-0.5	E11-167	S1	0.0-0.5		S2	0.5-2.0		S2	0.5-2.0	E11-192	S1	0.0-0.5
	S2	0.5-2.0		S2	0.5-2.0		S3	2.0-5.0		S3	2.0-5.0		S2	0.5-2.0
	S3	2.0-5.0		S3	2.0-5.5		S4	5.0-10.0		S4	5.0-8.75		S3	2.0-5.0
	S4	5.0-8.5	E11-168	S1	0.0-0.5	E11-177	S1	0.4-0.9	E11-185	S1	0.0-0.5		S4	5.0-10.0
E11-159	S1	0.0-0.5		S2	0.5-3.0		S2	0.9-2.4		S2	0.5-2.0	E11-193	S1	0.0-0.5
	S2	0.5-2.0	E11-169	S1	0.0-0.5		S3	2.4-5.4		S3	2.0-5.0		S2	0.5-2.0
	S3	2.0-5.0		S2	0.5-1.8		S4	5.4-9.0		S4	5.0-8.8		S3	2.0-5.0
	S4	5.0-10.0	E11-170	S1	0.0-0.5	E11-178	S1	0.0-0.5	E11-186	S1	0.0-0.5		S4	5.0-8.6
E11-160	S1	0.0-0.5		S2	0.5-2.0		S2	0.5-2.0		S2	0.5-2.0	E11-194	S1	0.3-0.8
	S2	0.5-2.0		S3	2.0-5.0		S3	2.0-5.0		S3	2.0-5.0		S2	0.8-2.0
	S3	2.0-3.4		S4	5.0-7.5		S4	5.0-10.0		S4	5.0-8.0		S3	2.0-5.0
E11-161	S1	0.0-0.5	E11-171	S1	0.0-0.5	E11-179	S1	0.0-0.5	E11-187	S1	0.0-0.5		S4	5.0-10.0
	S2	0.5-2.0		S2	0.5-2.0		S2	0.5-2.0		S2	0.5-2.0	E11-195	S1	0.3-0.8
	S3	2.0-5.0		S3	2.0-6.5		S3	2.0-5.0		S3	2.0-5.0		S2	0.8-2.0
	S4	5.0-7.9	E11-172	S1	0.0-0.5		S4	5.0-10.0		S4	5.0-10.0		S3	2.0-5.0
E11-162	S1	0.0-0.5		S2	0.5-2.0	E11-180	S1	0.0-0.5	E11-188	S1	0.0-0.5		S4	5.0-10.0
	S2	0.5-1.52		S3	2.0-5.0		S2	0.5-2.0		S2	0.5-2.0	E11-196	S1	0.3-0.8
E11-163	S1	0.0-0.5		S4	5.0-8.7		S3	2.0-5.0		S3	2.0-5.0		S2	0.8-2.3
	S2	0.5-2.0	E11-173	S1	0.0-0.5		S4	5.0-10.0		S4	5.0-9.6		S3	2.3-5.3
	S3	2.0-5.0		S2	0.5-2.0	E11-181	S1	0.0-0.5	E11-189	S1	0.0-0.5		S4	5.3-10.3
	S4	5.0-10.0		S3	2.0-5.0		S2	0.5-2.0		S2	0.5-2.0			

Table 4-3 Groundwater Parameters Measured During Phase I Investigation in the Vicinity of Helipad Area at Camp Carroll.

Well ID	Date measured	Temp	EC (mS/cm)	DO (mg/L)	pH	ORP (mV)	Well Depth (m)	Well Level (m, bgs)
12-247	2011.6.3	17.56	0.302	10.41	7.63	147	72	not measured
13-279	2011.6.3	19.27	0.275	10.12	7.67	139	71	not measured
14-283	2011.6.2	17.45	0.264	11.46	8.13	155	80	not measured
15-286	2011.6.3	20.12	0.376	8.93	7.71	-125	75	not measured
16-289	2011.6.2	17.17	0.306	11.32	7.95	240	75	not measured
20-575	2011.6.2	16.69	0.252	11.24	7.84	166	191	not measured
B03-463MW	2011.6.10	15.37	0.205	1.05	5.48	274	13.7	7.83
B03-464MW	2011.6.15	17.05	0.094	4.19	5.16	309	13.1	8.3
B03-465MW	2011.6.16	17.13	348	1.40	5.76	227	13.1	9.43
B03-467MW	2011.6.15	16.81	0.526	1.93	6.16	-19	12.5	8.45
B03-468MW	2011.6.16	16.66	0.068	5.03	5.98	242		
B06-466MW	2011.6.14	16.57	0.203	1.8	5.21	272	12.5	7.03
B07-217MW	2011.6.12	16.37	0.427	9.43	6.13	284	12.0	3.3
B07-218MW	2011.6.13	16.95	0.340	5.09	5.59	230	12.3	9.34
B07-219MW	2011.6.11	20.69	0.366	4.81	5.81	278	12.0	6.94
B07-220MW	2011.6.12	15.66	0.439	3.47	5.70	333	12.0	2.8
B07-221MW	2011.6.12	16.06	0.349	6.49	5.58	267	12.0	6.53
B09-176MW	2011.6.8	16.32	0.105	8.35	6.25	235	40	7.73
B09-177MW	2011.6.9	16.16	0.116	9.16	6.20	245	40	7.68
B09-178MW	2011.6.9	16.18	0.072	7.86	5.72	329	40	7.68
B09-193MW	2011.6.14	14.78	0.351	6.35	5.57	298	15.5	7.89
B09-221MW	2011.6.10	15.15	0.065	7.32	5.95	312	11.8	4.35
DO- Dissoloved oxygen								
EC- Electric conductivity								
ORP- Oxidation reduction potential								
Temp- Temperature in Celsius								

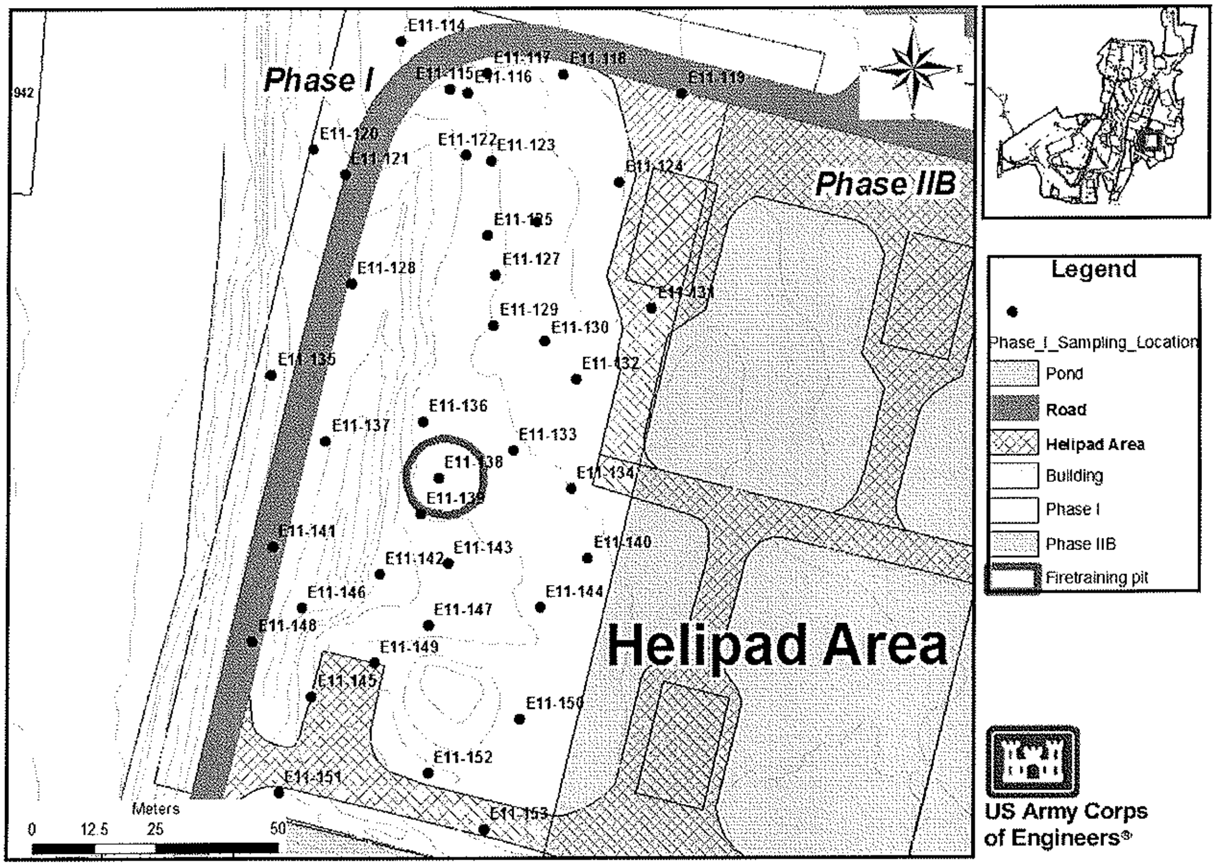
2757

Table 4-4 Groundwater Parameters Measured at Area 41 of Camp Carroll.

Well ID	Date measured	Temp	EC (mS/cm)	DO (mg/L)	pH	ORP (mV)	Well Depth (m)	Well Level (m, bgs)
B03-470MW	**2011.7.28**	18.17	0.503	5.75	5.23	530	13.5	8.5
B03-471MW	**2011.7.27**	17.75	0.871	4.10	5.42	272	12.2	3.8
B03-472MW	**2011.7.27**	18.13	0.051	8.23	5.48	368	15	8.5
B09-181MW	**2011.7.26**	17.08	0.185	4.59	5.63	280	14.5	8.87
B09-187MW	**2011.7.26**	17.39	0.140	7.19	5.58	513	15	3.82
DO- Dissoloved oxygen								
EC- Electric conductivity								
ORP- Oxidation reduction potential								
Temp- Temperature in Celsius								

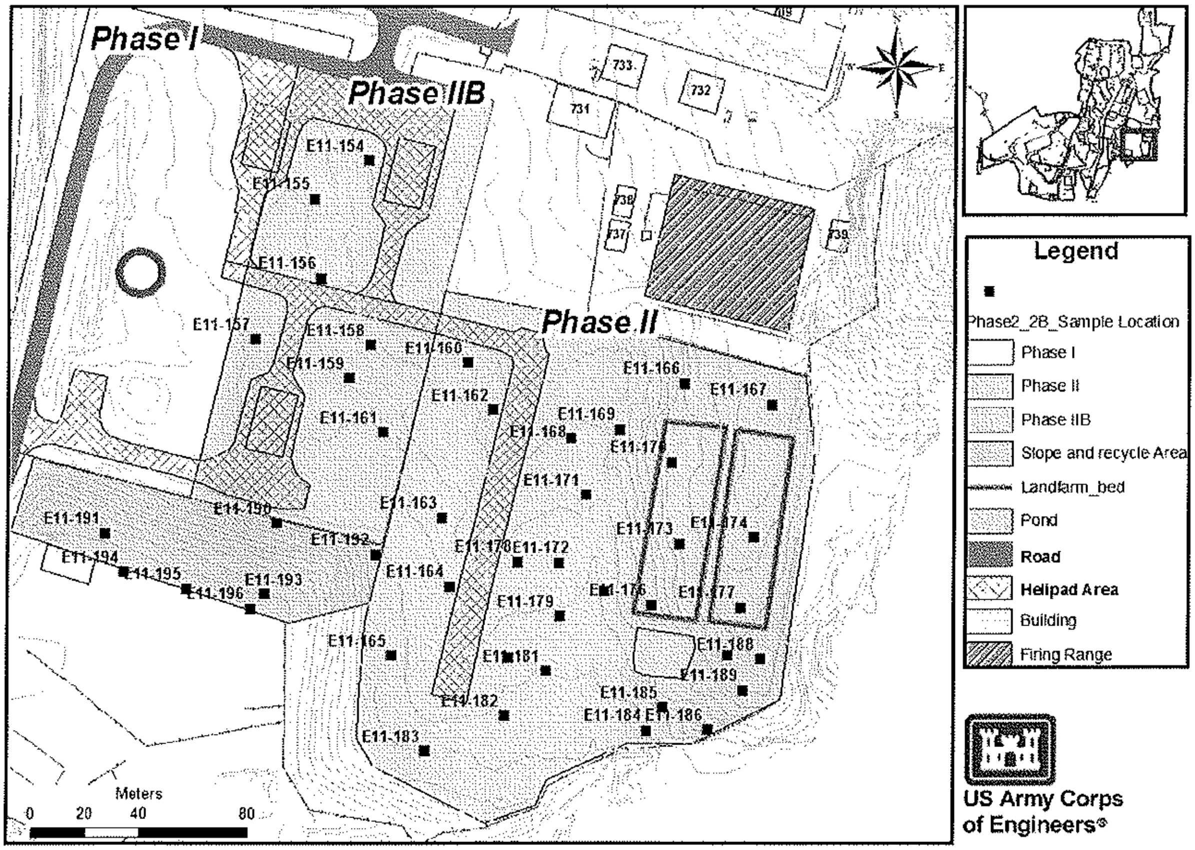
2758

Figure 4-1 Borehole Location of Phase I in Western Helipad Area of Camp Carroll.



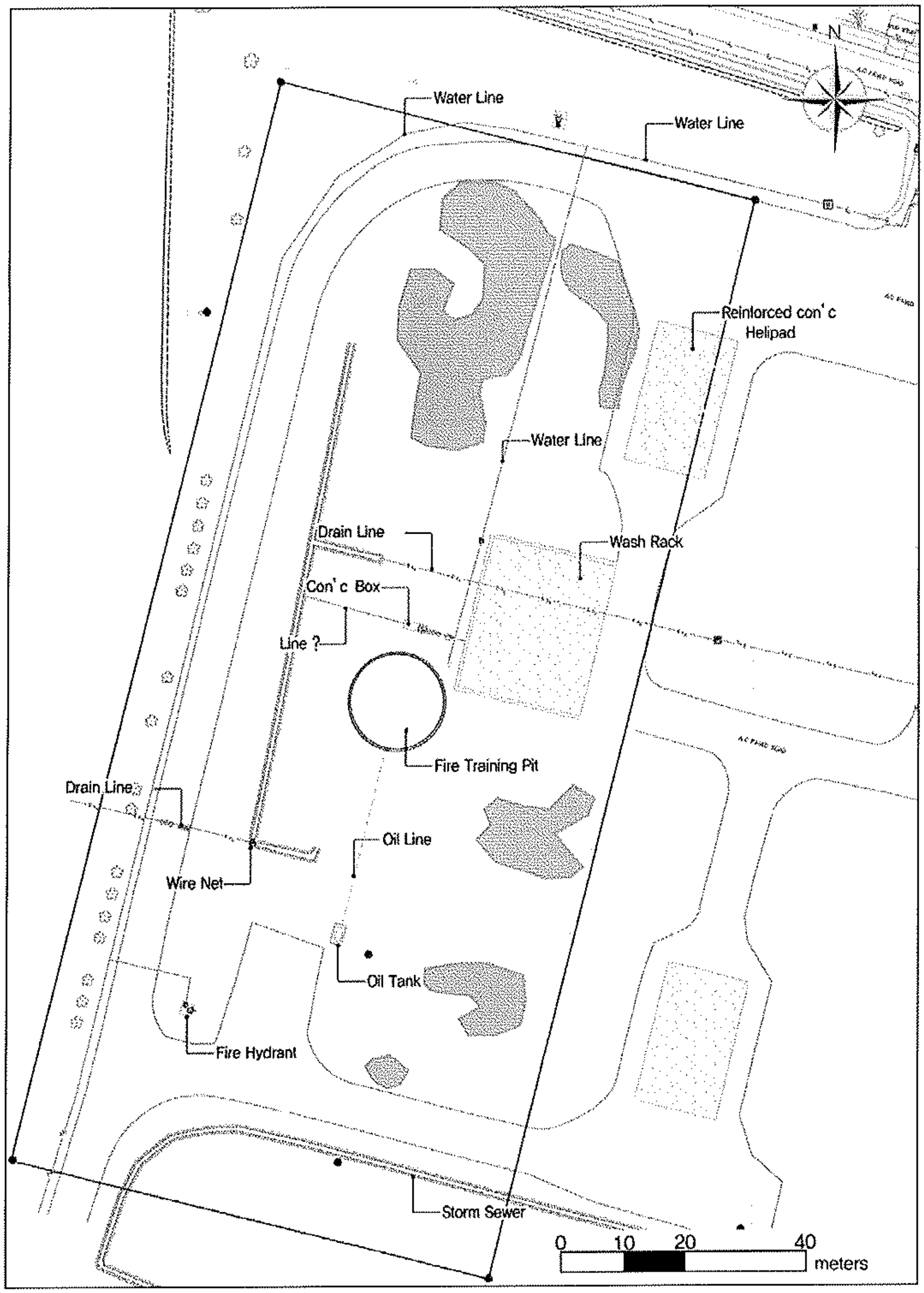
2759

Figure 4-2 Borehole Location of Phase II/IIB at Helipad, Landfarm and Area D of Camp Carroll.



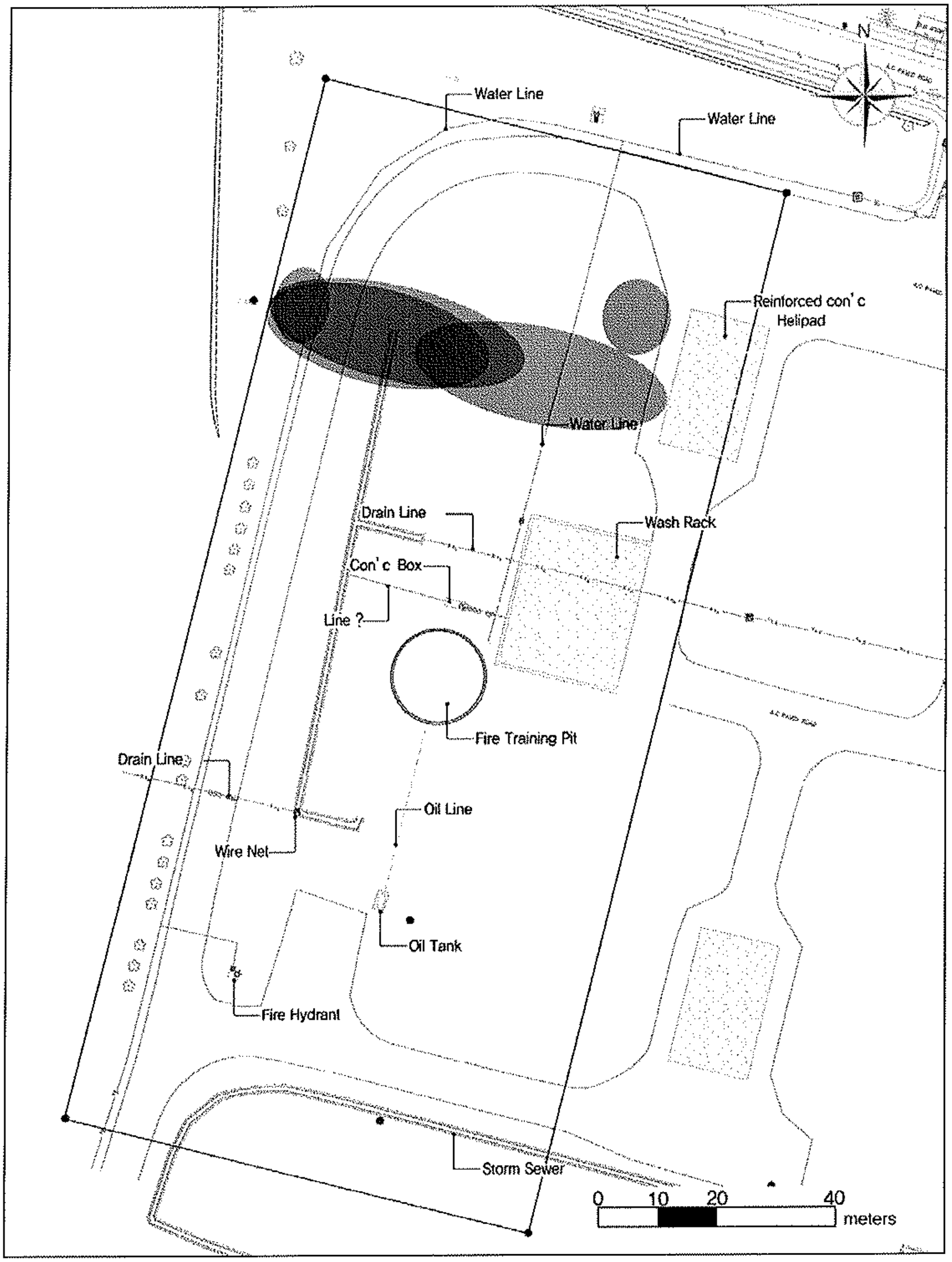
2760

Figure 4-3 Magnetic Gradiometry Survey Result at Phase I of Helipad Area.



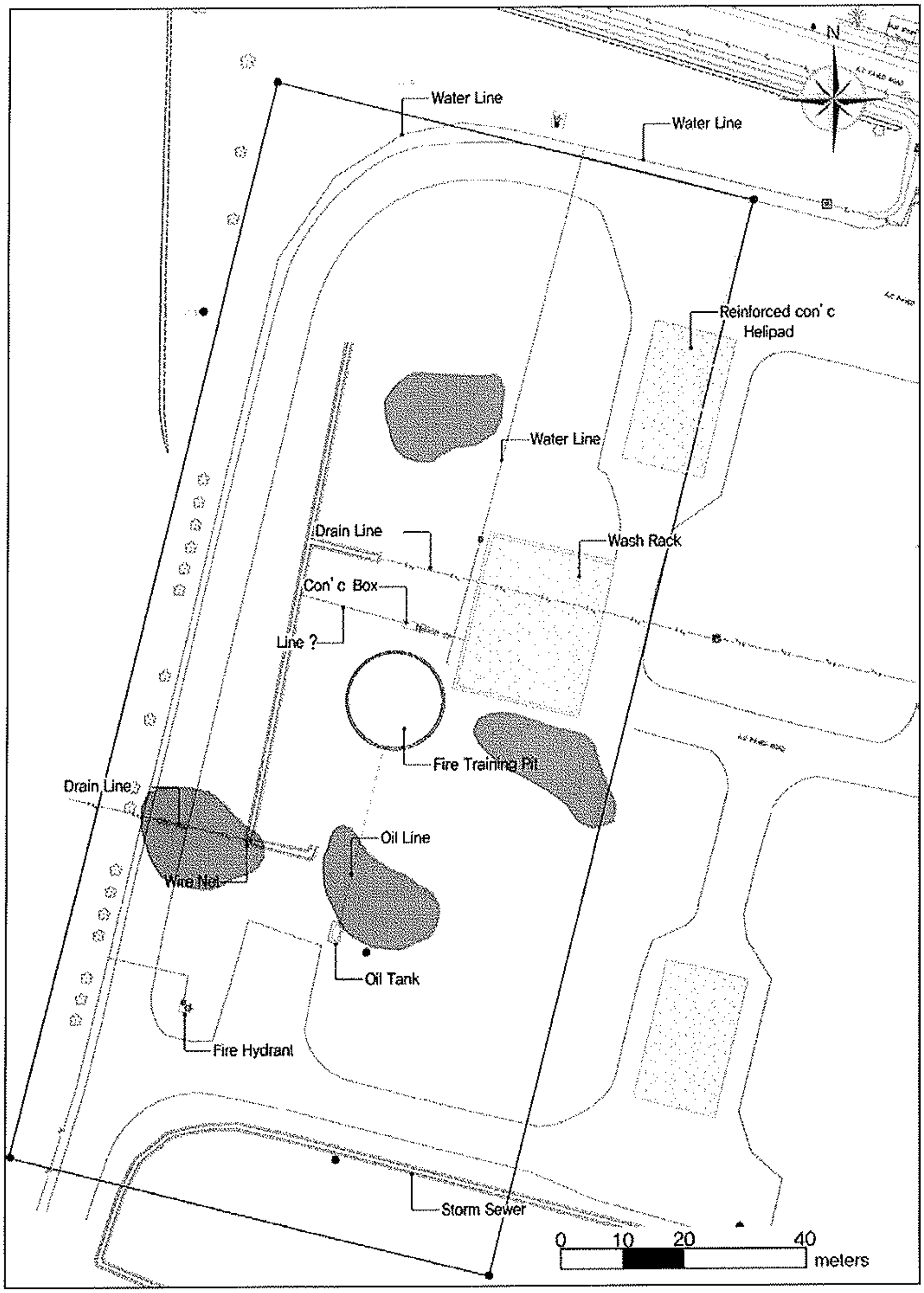
2761

Figure 4-4 GPR Survey Result at Phase I of Helipad Area.



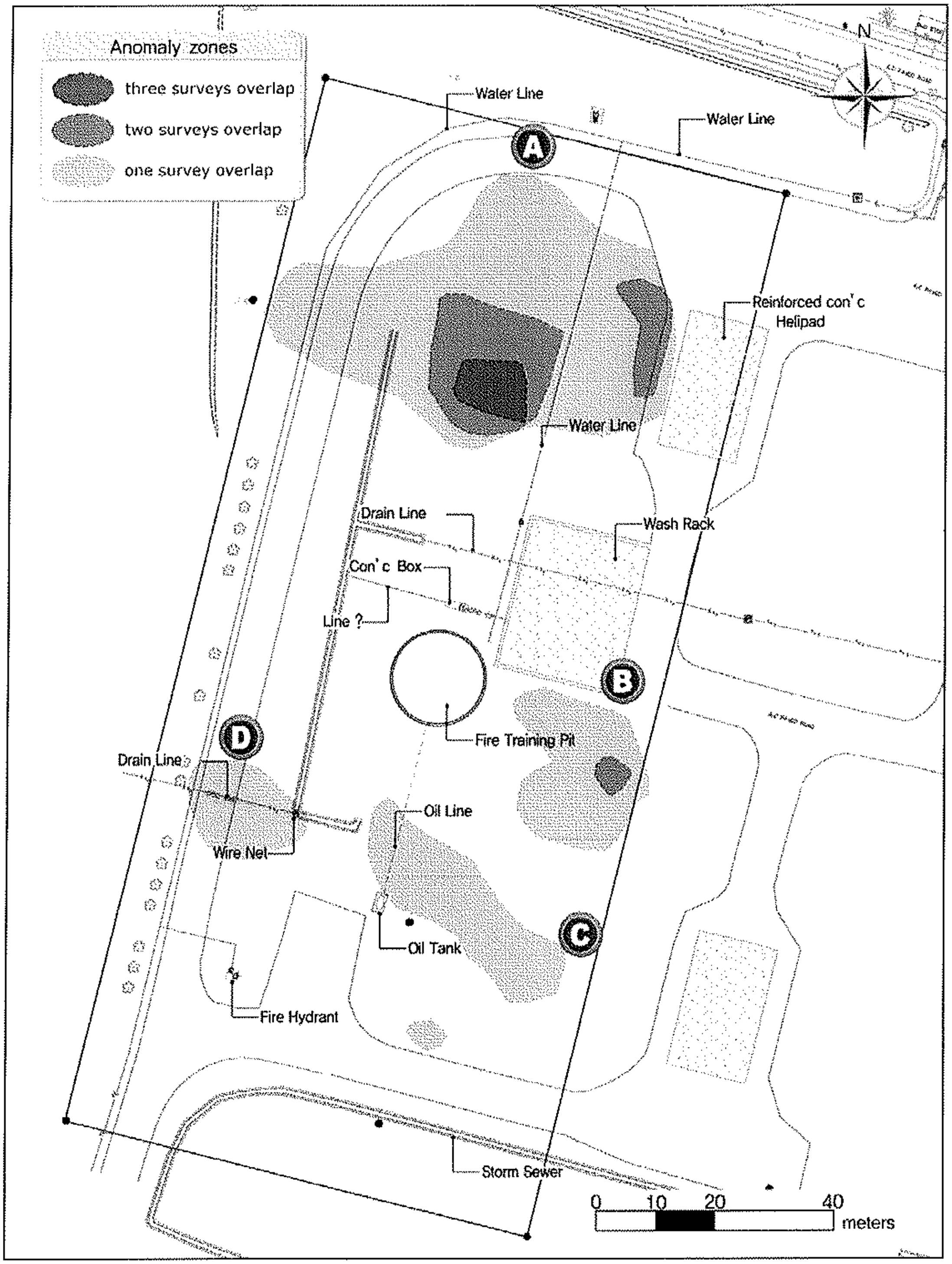
2762

Figure 4-5 ERI Survey Result at Phase I of Helipad Area.



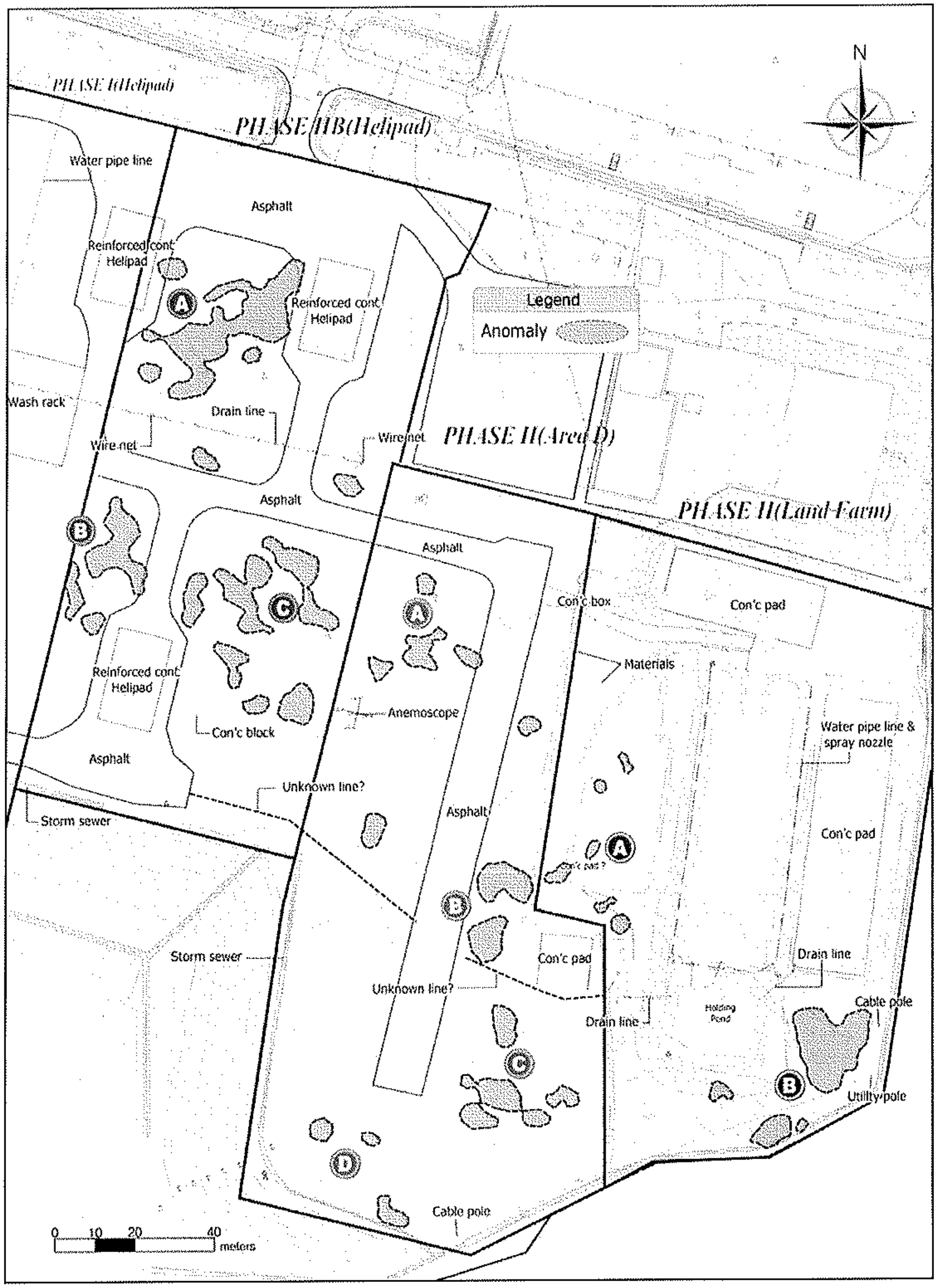
2763

Figure 4-6 Combined Geophysical Survey Results Showing Subsurface Anomaly at Phase I of Helipad Area.



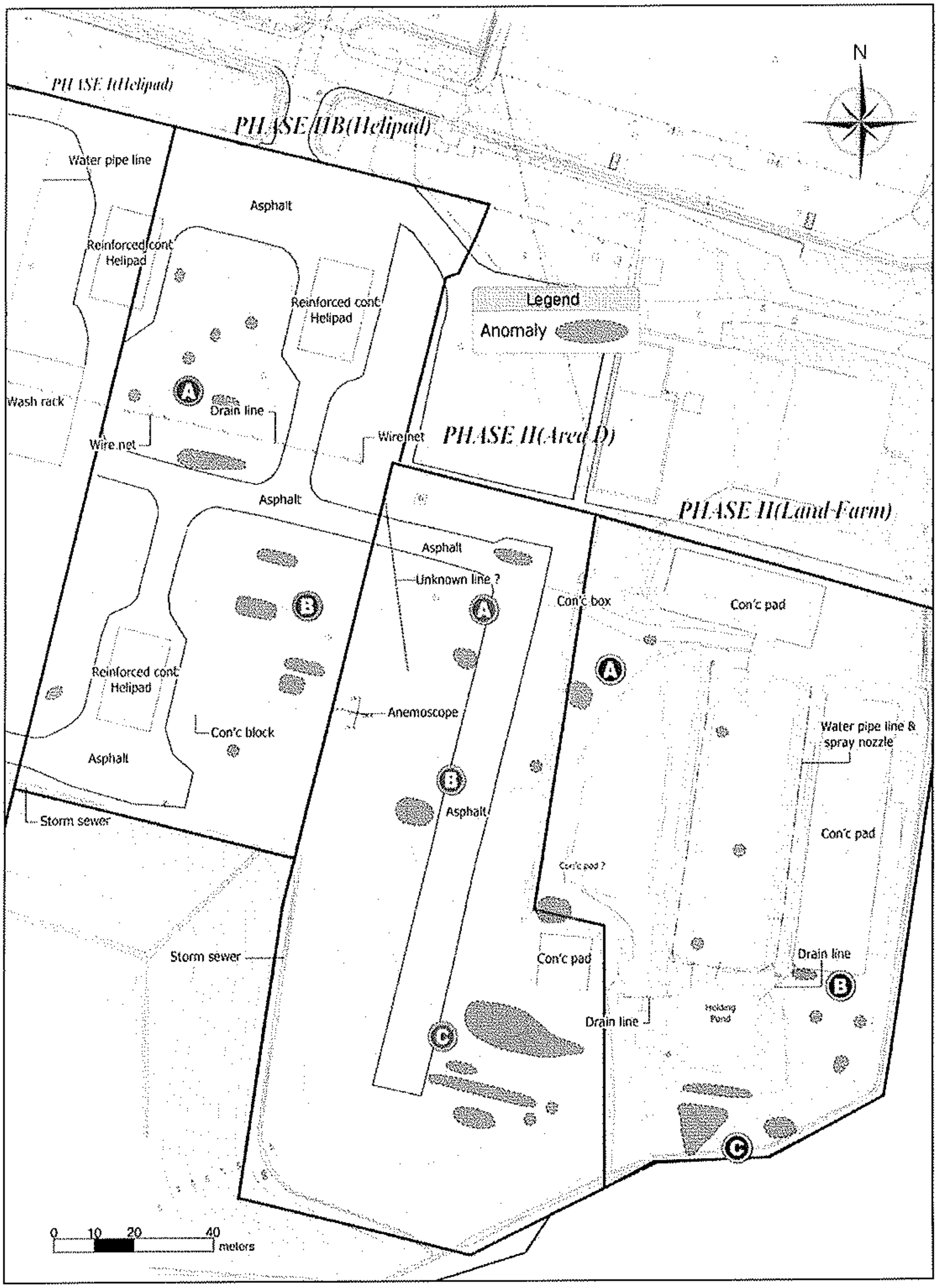
2764

Figure 4-7 Magnetic Gradiometry Survey Result at Phase II/IIB Area.



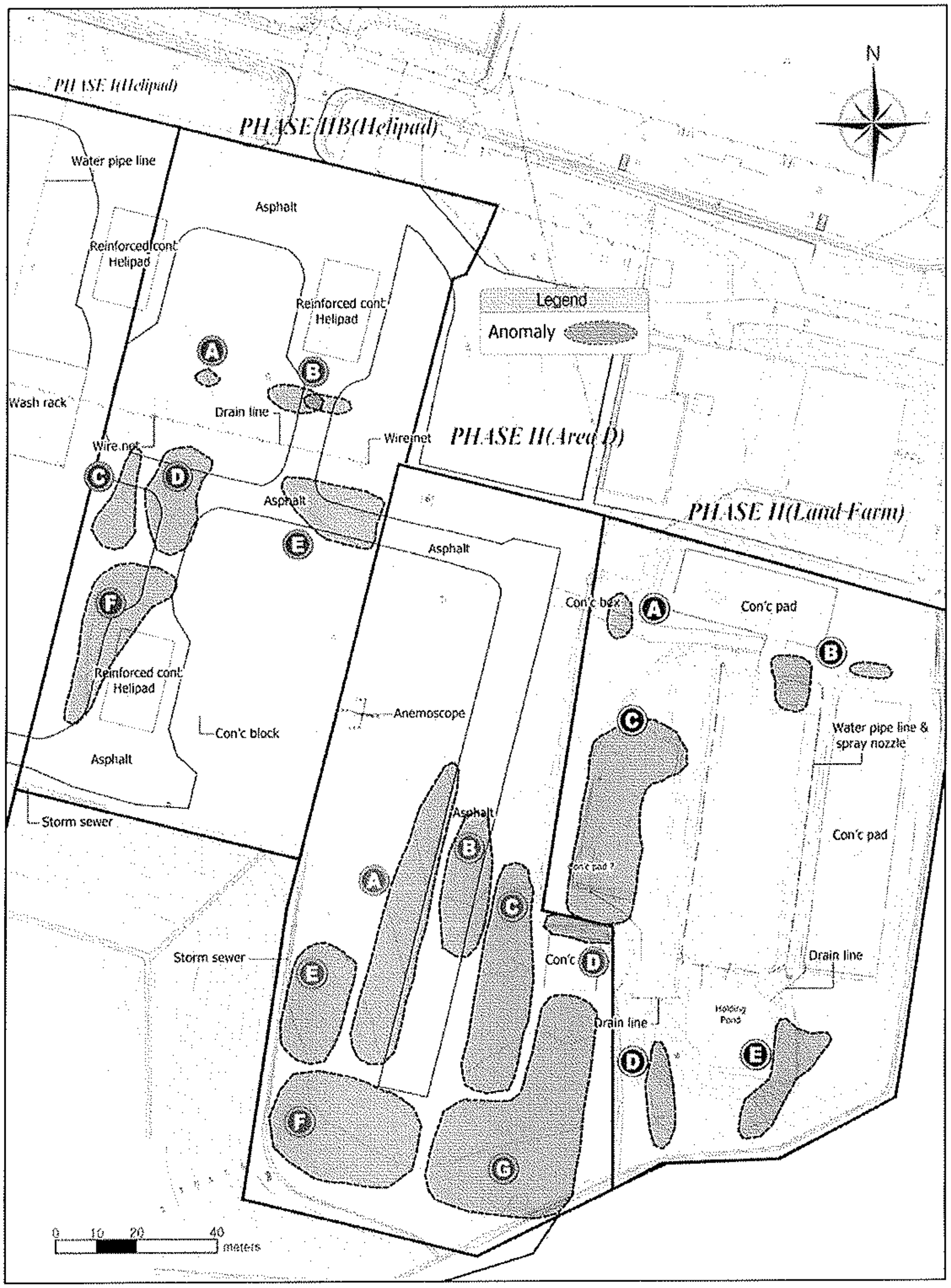
2765

Figure 4-8 GPR Survey Result at Phase II/IIB Area.



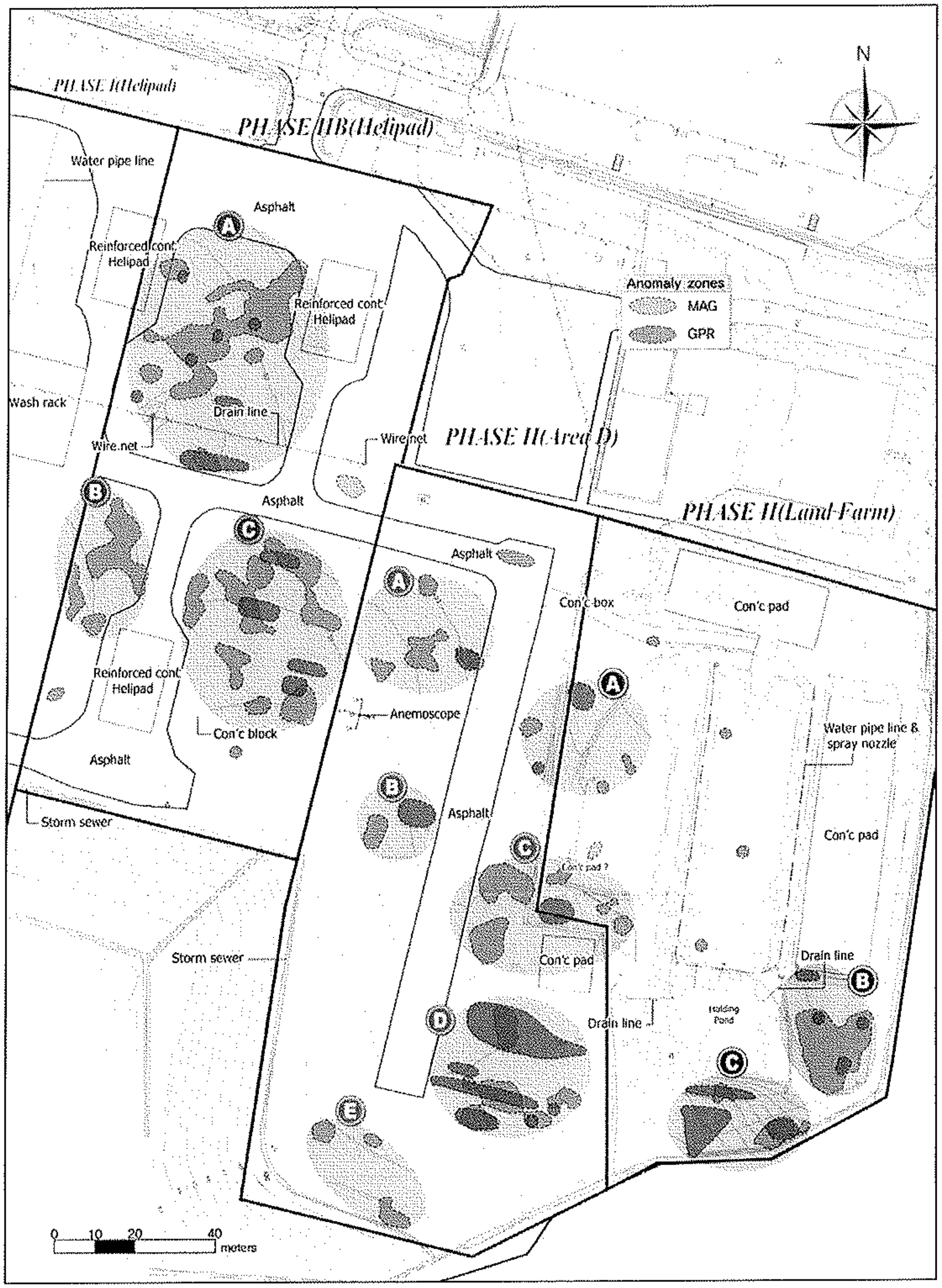
2766

Figure 4-9 ERI Survey Result at Phase II/IIB Area.



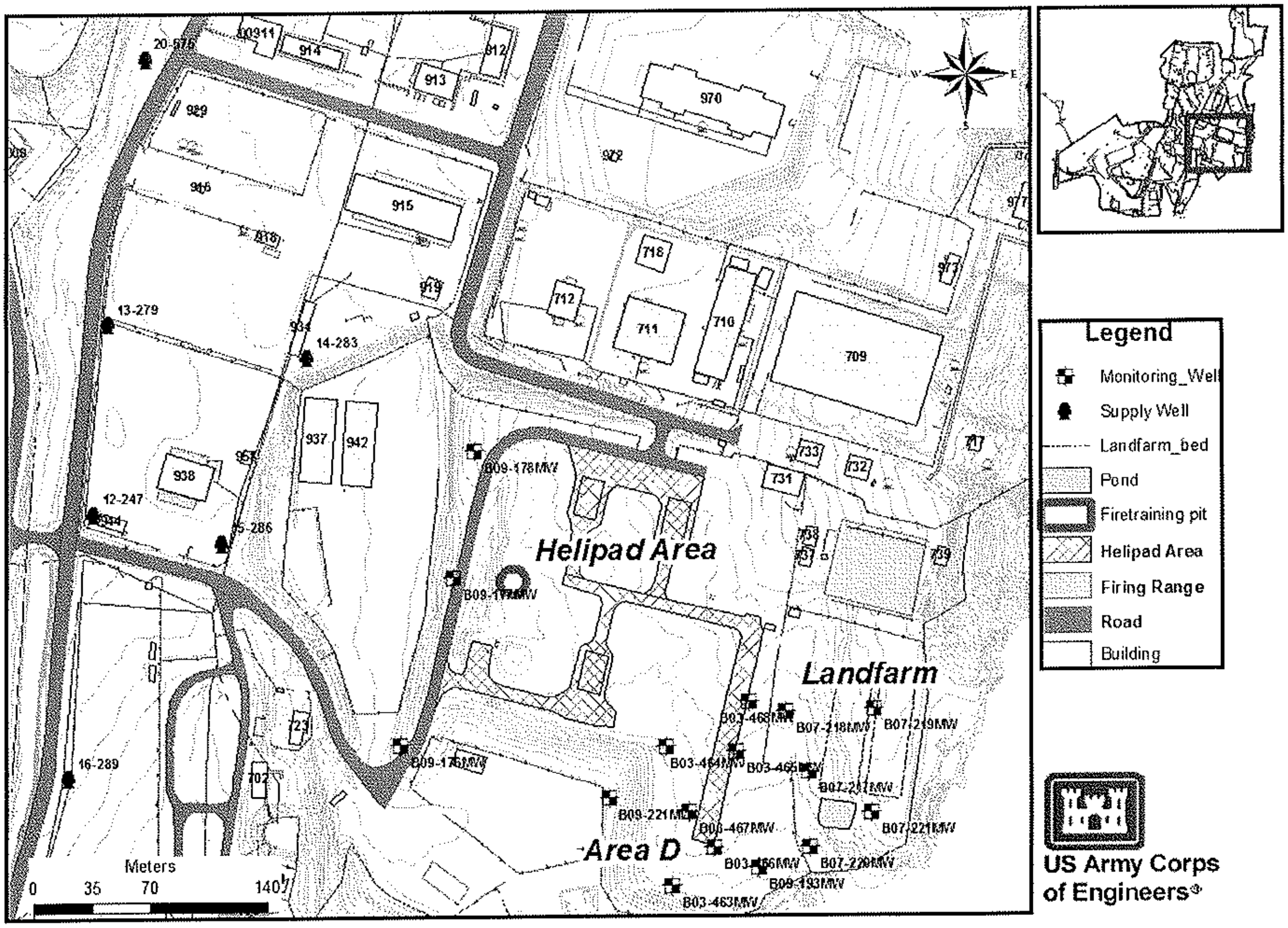
2767

Figure 4-10 Combined Geophysical Survey Results Showing Subsurface Anomaly at Phase II/IIB Area.



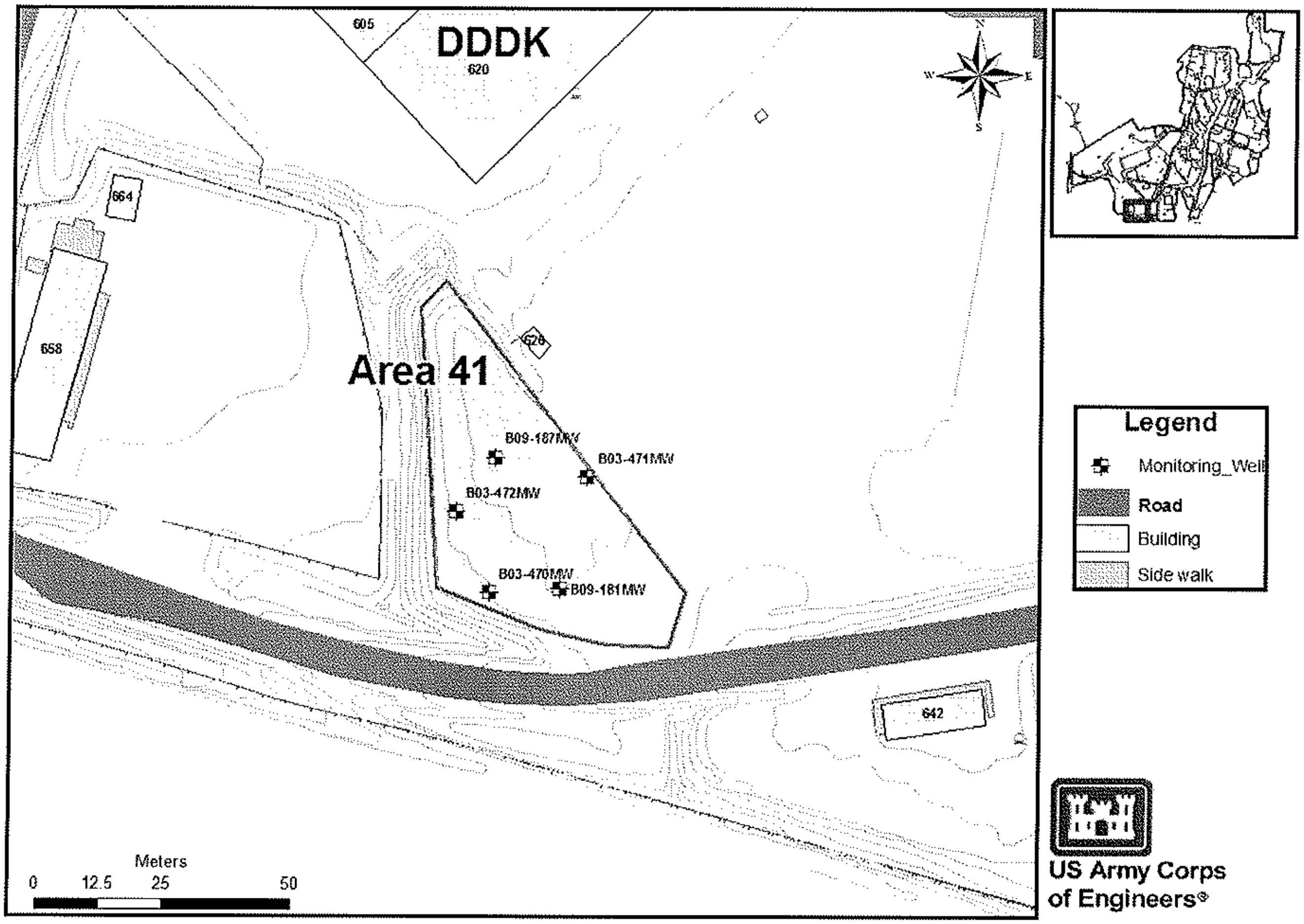
2768

Figure 4-11 Location of Monitoring and Supply Wells in the Vicinity of Helipad Area.



2769

Figure 4-12 Location of Monitoring Well at Area 41.



2770

This page intentionally left blank

2771

5. SUMMARY OF FINDINGS

Efforts by the Far East District to investigate the allegations of Agent Orange burial on Camp Carroll were focused on the following areas: Phase I (west Helipad area), Phase II B (east Helipad area), Phase II (Area D and Landfarm), the Slope Area immediately south of Phases I and IIB, a portion of the Recycling Yard immediately below the Slope Area, and Area 41. Field investigations were initiated on 2 June 2011 and ended on 28 September 2011. Field activities consisted of non-intrusive investigations (geophysical surveys and groundwater sampling from existing monitoring wells and production wells) and intrusive investigations (borings for soil sampling within the areas of interest). Based on the combined physical and chemical evidence produced from these investigations, the following conclusions have been reached:

- There is no evidence of buried drums within the areas investigated by geophysics and soil borings.
- Chemical test results for subsurface soil and groundwater samples do not indicate the presence of Agent Orange (OC-Herbicides together with dioxins).

5.1. GEOPHYSICAL SURVEY

Compiled geophysical survey results are summarized in Figure 5-1. Within the areas surveyed by geophysical means (Phases I, II, IIB, and Slope Area), geophysical anomalies were detected. Certain anomalies could be readily attributed to identifiable structures such as reinforced concrete slabs and underground piping. A smaller number of anomalies were marked by FED and MOE for follow-on evaluation by intrusive means (i.e. borings). After completion of the soil borings, it can be concluded that anomalies which were further evaluated by borings are most likely due to variations in soil and bedrock characteristics (e.g. variations in bedrock depth, soil moisture, material density, and/or soil conductivity) and not due to an alleged drum burial at the site.

5.2. SOIL SAMPLING RESULT

Figure 5-1 presents the soil sample analytical results that indicated soil containing 2,3,7,8-TCDD within the area of concern.

- **<u>Phase I</u>**

A total of 118 soil samples were collected from 40 boreholes within the Phase I area. None of the soil samples were reported to contain OP-pesticides, OC-herbicides and SVOCs. VOCs such as PCE, TCE and xylenes were detected in some samples. The highest concentrations of PCE, TCE and xylenes are 18,000 μg/kg, 117 μg/kg, and 1,683 μg/kg respectively. OC-pesticides such as 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-BHC, delta-BHC, gamma-BHC (Lindane) and gamma-Chlordane were detected in 62 samples. Gamma-BHC shows the highest concentration among the analytes, at a concentration of 163,000 μg/kg. None of the samples were reported to have 2,3,7,8-TCDD at levels greater than reporting limits. Calculated toxic equivalent (TEQ) values ranged from 0.005 pg/g to 1.156 pg/g based on 2005 World Health Organization (WHO) evaluation.

2772

- **Phases II and IIB, Slope Area, and Recycling Yard**

A total of 154 soil samples were collected from 43 boreholes within the Phase II, IIB, Slope Area, and Recycling Yard areas. None of the soil samples were reported to contain OP-pesticides or OC-herbicides. VOCs such as acetone, 2-butanone, methylene iodide, toluene, methylene chloride, PCE, TCE and cis-1,2-dichloroethene were reported in Phase II/IIB samples. PCE and toluene are reported showing relatively high concentrations of 32,300 μg/kg and 21,300 μg/kg, respectively. OC-pesticides such as 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, beta-BHC, gamma-BHC (Lindane), and alpha/gamma-chlordane were detected above the reporting limits in the soil samples. 4,4'-DDD, 4,4'-DDE, 4,4'-DDT and gamma-BHC had relatively high concentrations of 13,500 μg/kg, 2,830 μg/kg, 70,200 μg/kg and 13,900 μg/kg respectively. Results from one sample from each of three boreholes (E11-171, E11-181 and E11-184) reported concentrations of 2,3,7,8-TCDD at levels greater than reporting limits, ranging from 0.502 pg/kg to 7.44 pg/g. Calculated toxic equivalent (TEQ) values ranged from 0.00 pg/g to 10.09 pg/g based on 2005 World Health Organization (WHO) evaluation.

5.3. GROUNDWATER SAMPLING RESULT

- **Phases I, II, and IIB**

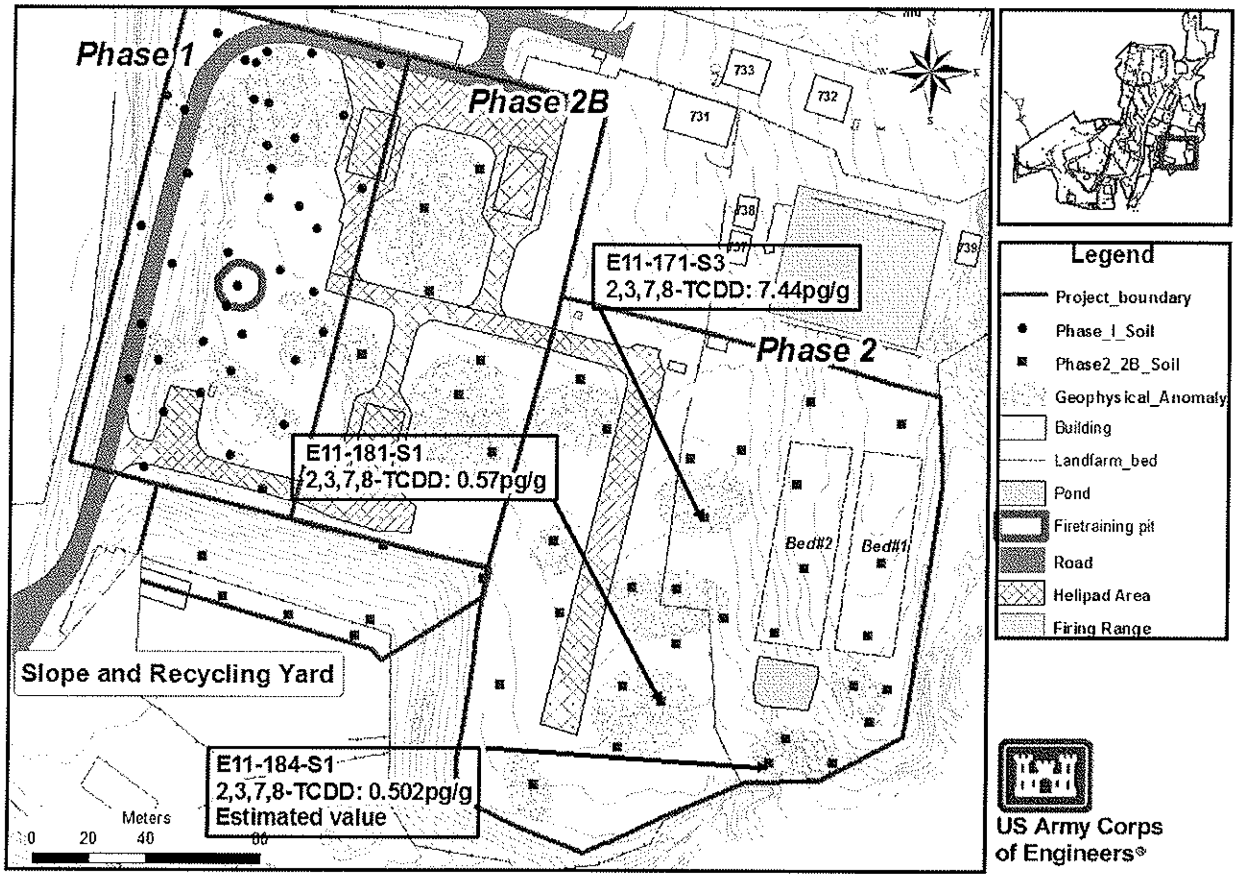
A total of 22 groundwater samples were collected from 16 monitoring wells and 6 supply wells and analyzed for OC-herbicides and dioxins. Three (3) samples out of 22 were reported containing 2,4,5-T at concentrations of 1.02~2.83 μg/L, with two (2) other samples at levels between the detection limit and the reporting limit. These five wells were resampled to verify the initial 2,4,5-T results. The 2,4,5-T was not reported in any of retested well samples. The 2,3,7,8-TCDD was not detected in any of the groundwater samples.

- **Area 41**

A total of five groundwater samples were collected from existing monitoring wells at Area 41 and analyzed for the full suite of chemicals. The Agent Orange related compounds such as 2,4-D, 2,4,5-T, and 2,3,7,8-TCDD were not detected in any of the collected samples. OC-pesticides such as 4,4'-DDD; 4,4'-DDT; alpha-, beta-, delta-, and gamma-BHCs; dieldrin; and endosulfan sulfate were detected in two monitoring wells with a concentration range of 0.0544~0.467 μg/L. VOCs such as PCE, TCE, benzene, 1,2,4-trimethylbenzen, and 1,1,2,2,-tetrachlroethane were detected in the groundwater samples. PCE and TCE were reported to have concentrations as high as 8,390 μg/L and 2,320 μg/L respectively.

2273

Figure 5-1 Summary of Geophysical Survey Results and Location of 2,3,7,8-TCDD Reported within the Investigation Area, Camp Carroll.



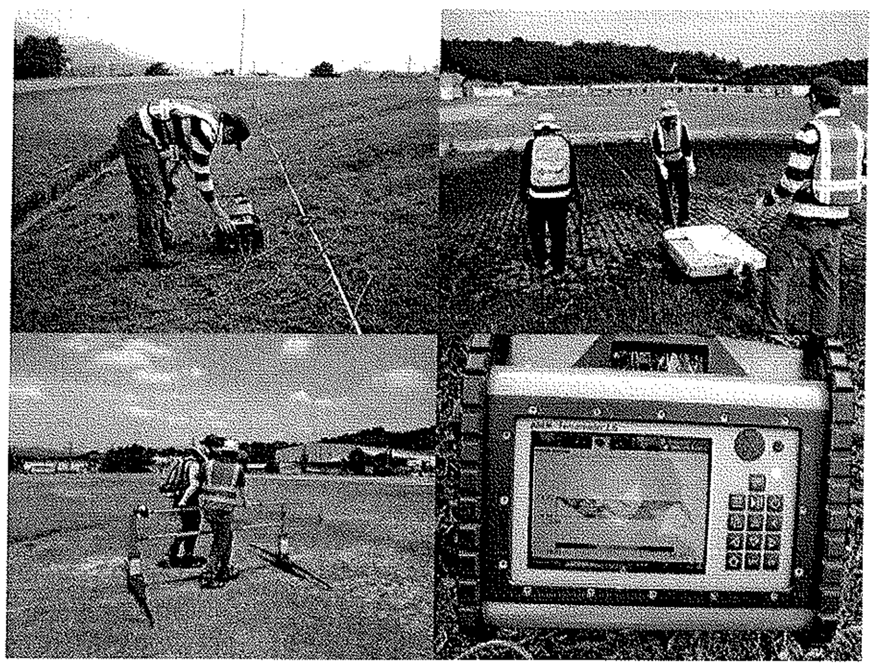
2774

APPENDIX I. GEOPHYSICAL REPORT OF PHASE I IN THE VICINITY OF HELIPAD AREA OF CAMP CARROLL.

US Army Corps of Engineers
Far East District®

PHASE I (HELIPAD) SITE GEOPHYSICAL SURVEY REPORT

Camp Carroll
U.S. Army Garrison Daegu, Republic of Korea



June 23, 2011

Prepared By:

Environmental Section, Geotechnical and Environmental Engineering Branch
Engineering Division, U.S. Army Corps of Engineers, Far East District

In Association With:

SEKOGEO Co., Ltd
Gyeonggi-Do, Anyang-Si, Dongan-Gu, Pyeongchon-Dong, 126-1, Republic of Korea

Beautiful Environmental Construction Co., Ltd
Gyeonggi-Do, Seongnam-Si, Jungwon-Gu, Sangdaewon-Dong, 190-1, Republic of Korea

2776

This page intentionally left blank

EXECUTIVE SUMMARY

This report presents the results of a geophysical survey that was conducted for the Phase I (Helipad) site (Phase I) located on Camp Carroll, Republic of Korea (ROK). The Phase I area is one of three sites located in southeastern portion of Camp Carroll where disposal and burial of hazardous material and waste allegedly occurred between the years 1977 and 1982 (Figure ES-1). The purpose of the survey was to identify and locate foreign objects, especially steel drums and delimit the approximate vertical and horizontal coordinates of the burial.

Geophysical Survey Procedure

The Phase I survey area measures approximately 180 m from north to south and 80 m east to west. The geophysical survey was conducted using three non-intrusive techniques: magnetic gradiometry, ground penetrating radar (GPR), and electrical resistivity imaging (ERI). For the magnetic gradiometry survey, a grid with 1 m intervals was established at survey area. Including endpoints, this resulted in 14,480 intersections points between the north-south and east-west running gridlines. Magnetic readings were taken at each of the intersection points using a Bartington Instrument Ltd (United Kingdom) model Grad601 gradiometer.

The GPR survey was conducted using a MALÅ GeoScience (Sweden) model ProExTM Professional Explorer GPR. The survey utilized a 2 m interval transects in the east-west direction (90 transects). An input frequency of 100 megahertz (MHz) was initially selected. After completion of the survey at 100 MHz, a second survey was conducted at locations where anomalies were detected using an input frequency of 50 MHz. The lower frequency provides deeper coverage but at a slightly lower resolution.

The ERI survey was conducted using an ABEM Instrument AB (Sweden) model Terrameter LS direct current resistivity meter. The survey was conducted along 19 transects.

Geophysical Survey Results and Conclusions

The survey results were combined and a final interpretation of the data and subsurface anomaly zones are shown on Figure ES-2. The conclusions are summarized as follows:

- The Magnetic Gradiometry survey results indicate five subsurface anomalies.
- The GPR survey results indicate four subsurface anomalies.
- The ERI survey results indicate three subsurface anomalies.
- The combined results of the three surveys indicate four anomaly zones, identified as Zones A, B, C and D on Figure 4-5 where foreign objects may be present.
- Subsurface anomalies zones may be attributed to loosely packed soils, high water content, or buried foreign objects such as steel drums.
- Zone A has the highest probability to contain buried foreign objects, with higher probabilities indicated by darker shades of red.

Figure ES-1. Phase I (Helipad) Site Geophysical Survey Location Map

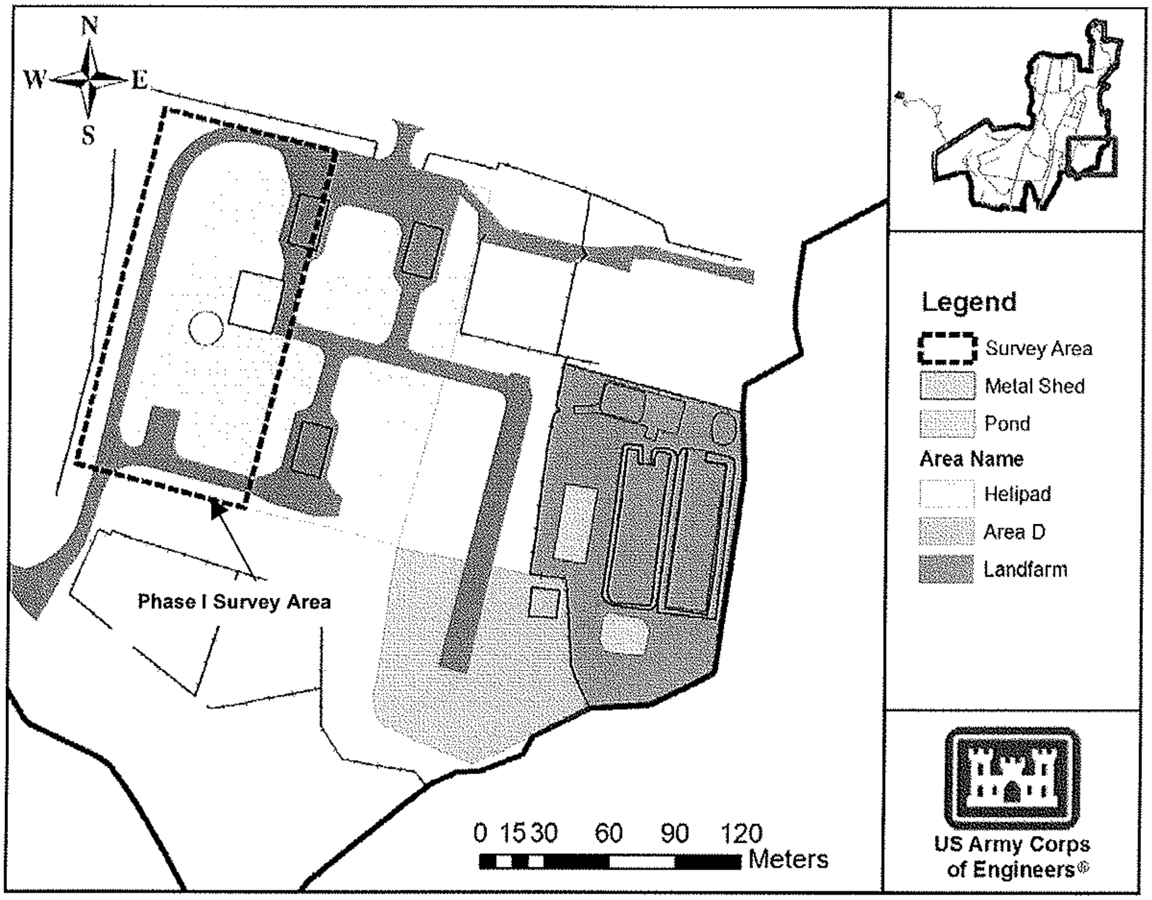
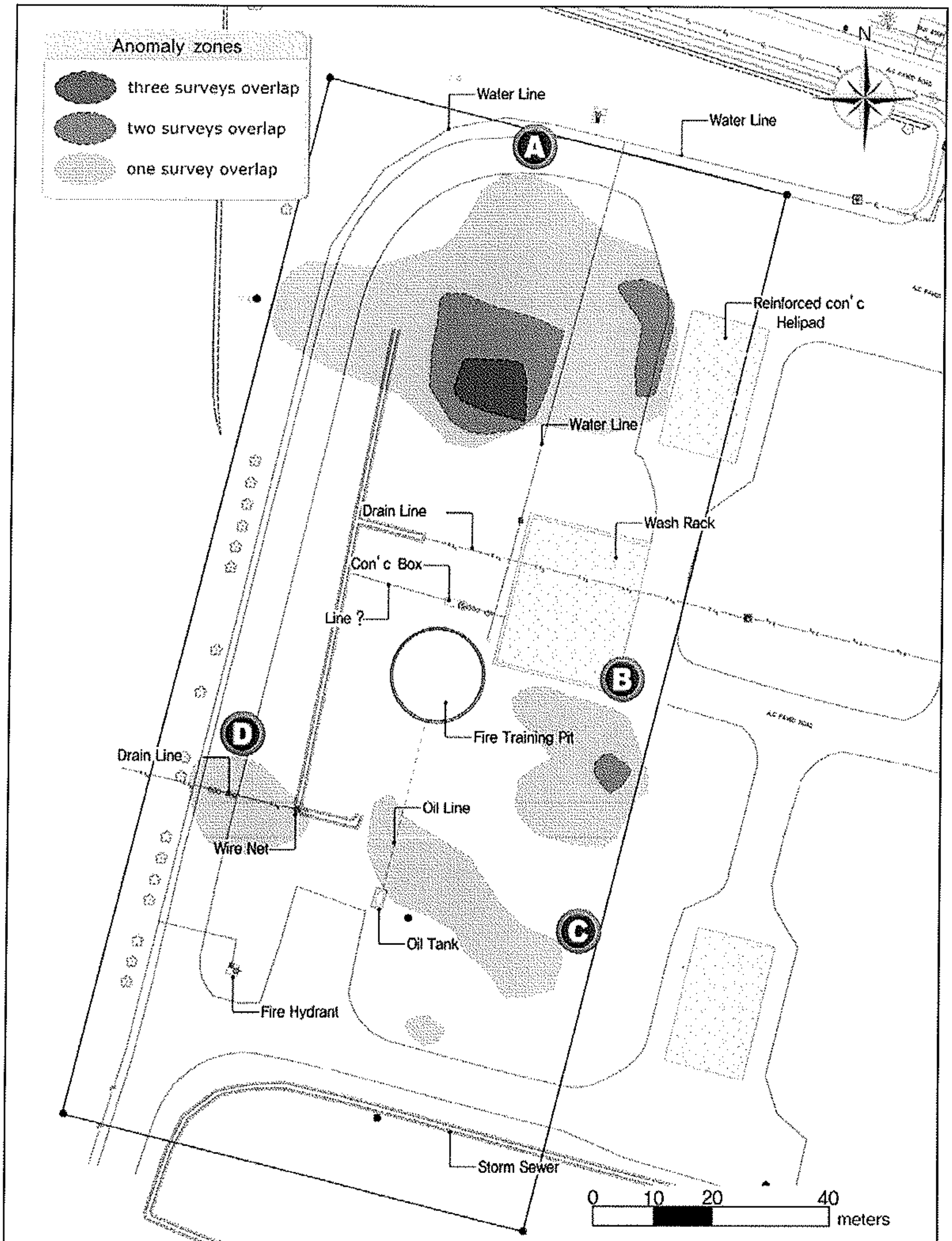


Figure ES-2. Final Interpretation of Subsurface Anomaly Zones



This page intentionally left blank

TABLE OF CONTENT

EXECUTIVE SUMMARY 1
TABLE OF CONTENT i
1. INTRODUCTION 1-1
1.1 Site Description and Background 1-1
1.2 Geophysical Survey Methodologies 1-3
1.2.1 Magnetic Gradiometry 1-3
1.2.2 Ground Penetrating Radar 1-3
1.2.3 Electrical Resistivity Imaging 1-4
2. GEOPHYSICAL SURVEY PROCEDURE 2-1
2.1 Magnetic Gradiometry Survey 2-1
2.2 GPR Survey 2-1
2.3 ERI Survey 2-1
3. GEOPHYSICAL SURVEY RESULTS 3-1
3.1 Magnetic Gradiometry Result 3-1
3.2 GPR Result 3-1
3.3 ERI Results 3-1
4. CONCLUSIONS 4-1

LIST OF FIGURES

Figure 1-1. Camp Carroll Location Map 1-1
Figure 1-2. Phase I (Helipad) Site Geophysical Survey Location Map 1-2
Figure 2-1. Magnetic Gradiometry Survey Area 2-2
Figure 2-2. GRP Survey Transects 2-3
Figure 2-3. ERI Survey Transects 2-4
Figure 3-1. Magnetic Gradiometry Survey Result 3-3
Figure 3-2. GPR 0.83 m to 1.41 m bgs Result 3-4
Figure 3-3. GPR 1.68 m to 2.26 m bgs Result 3-5
Figure 3-4. GPR 2.79 m to 3.37 m bgs Result 3-6
Figure 3-5. GPR 3.64 m to 4.22 m bgs Result 3-7
Figure 3-6. GPR 4.76 m to 5.34 m bgs Result 3-8
Figure 3-7. GPS Results for 50 MHz Input Signal Frequency 3-9
Figure 3-8. ERI Result 3-10
Figure 4-1. Magnetic Gradiometry Confirmed Subsurface Anomalies 4-2
Figure 4-2. GPR Confirmed Subsurface Anomalies 4-3
Figure 4-3. ERI Confirmed Subsurface Anomalies 4-4
Figure 4-4. Combined Magnetic Gradiometry, GPR and ERI Results 4-5
Figure 4-5. Final Interpretation of Subsurface Anomaly Zones 4-6

TABLE OF CONTENT (continued)

LIST OF APPENDIXES

APPENDIX A – GEOPHYSICAL SURVEY INSTRUMENT SPECIFICATIONS
Bartington Instrument Ltd model Grad601 gradiometer
MALÅ GeoScience model ProExTM Professional Explorer GPR
ABEM Instrument AB model Terrameter LS

APPENDIX B – GPR 2-DIMENSIONAL SECTIONS AND ERI VERTICAL CROSS SECTIONS

APPENDIX C – FIELDWORK PHOTOGRAPHS

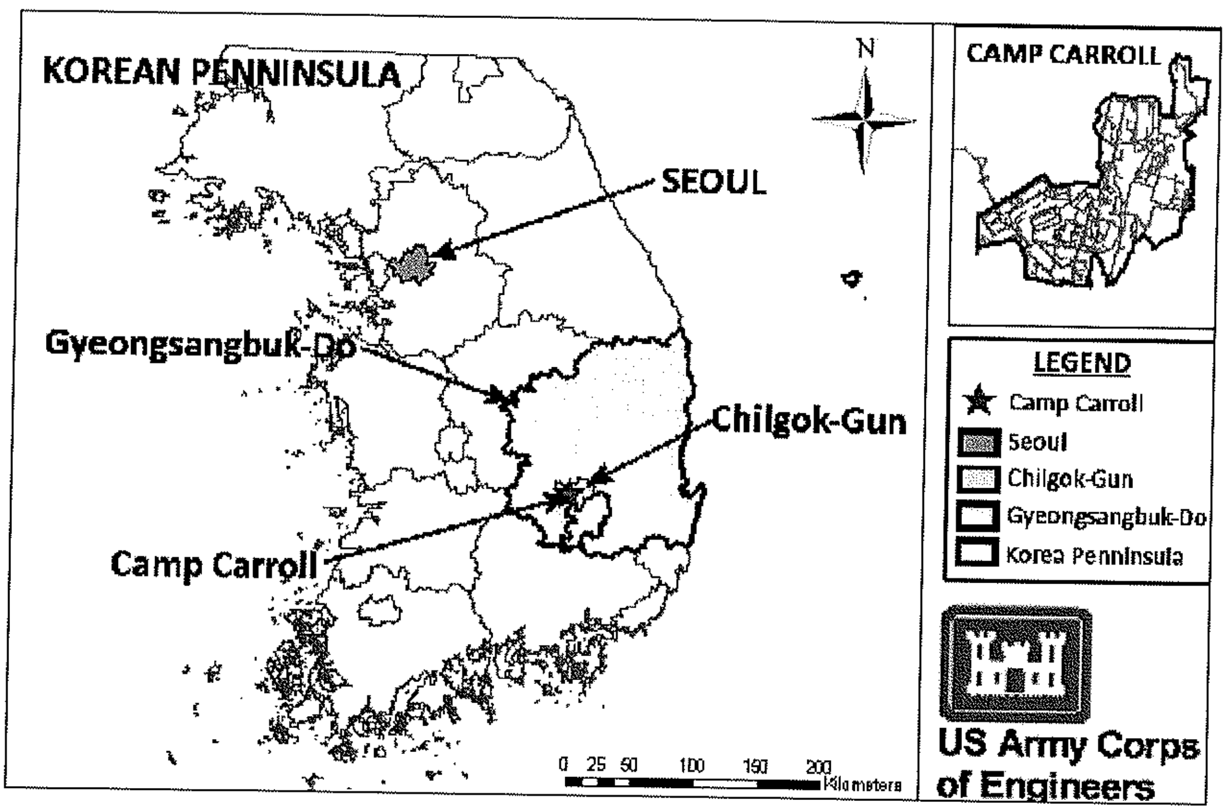
1. INTRODUCTION

This report presents the results of a geophysical survey that was conducted for the Helipad site (Phase I) located on Camp Carroll, Republic of Korea (ROK). The purpose of the geophysical survey was to identify and locate foreign objects, especially steel drums that may have been buried in the area. The survey will also delimit the approximate vertical and horizontal coordinates of subsurface anomalies that potentially indicate the presence of foreign objects.

1.1 Site Description and Background

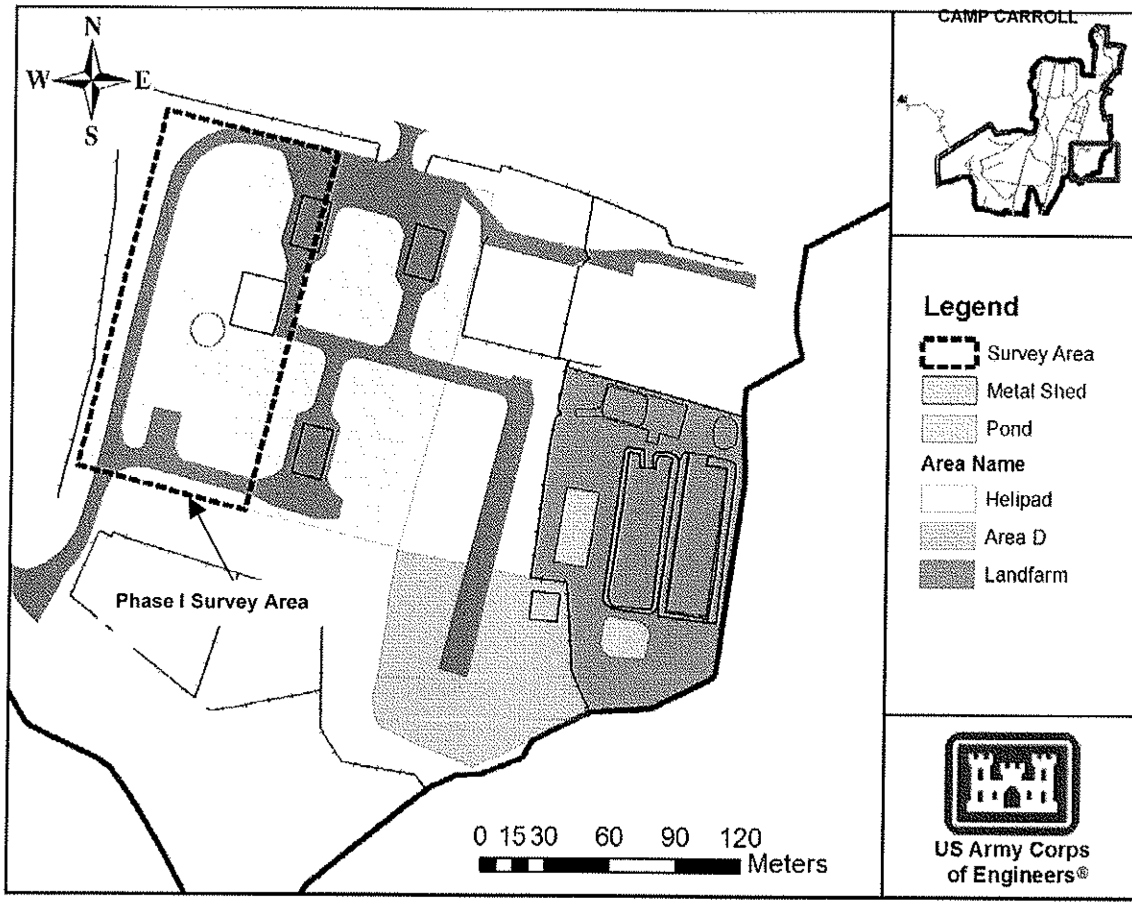
U.S. Army Garrison (USAG) Daegu Camp Carroll (Camp Carroll) is located in Chilgok-Gun, Gyeongsanbuk-Do, adjacent to the village of Waegwan in the south-central portion of the ROK. The general location of the camp is shown on Figure 1-1. Urban areas bound Camp Carroll on the northwest, west and southwest. Hilly, forested areas bound the base on the north and east. Agricultural fields (mostly rice paddies) border the camp on the northeast and the south. The Naktong River flows from north to south approximately 0.5 kilometers west of Camp Carroll.

Figure 1-1. Camp Carroll Location Map



This report specifically applies to geophysical survey conducted within the Phase I area of the Helipad site, as shown on Figure 1-2. This area is one of three sites located in southeastern portion of Camp Carroll near the installation's eastern boundary. Disposal and burial of hazardous material and waste, some in 55-gallon drums, reportedly occurred during the period between the years 1977 and 1982. The other two sites of potential interest as disposal sites are the Land Farm area and Area D. Geophysical investigations will be conducted at these sites in subsequent phases.

Figure 1-2. Phase I (Helipad) Site Geophysical Survey Location Map



The Phase I site is mostly flat and slopes down to the southwest, mostly unpaved and covered with grass. Main physical features at the site include a concrete helipad, a vehicle wash rack, and a firefighting training pit. There are also several features at the site that could causes interference with survey instruments, including an aboveground fuel storage tank (AST), fuel piping, storm sewer lines, concrete manhole boxes, aboveground and underground water lines and a fire hydrant. Survey instrument readings taken near these features were somewhat affected by signal noise.

1.2 Geophysical Survey Methodologies

The geophysical survey for the Phase I area was conducted using three non-intrusive techniques: magnetic gradiometry, ground penetrating radar (GPR), and electrical resistivity imaging (ERI). Three separate techniques were employed for the survey in order to ensure optimum coverage and the ability to identify and locate subsurface anomalies. The following sections provide brief descriptions of each technique, along with some of the strengths and limitations associated with each technique.

1.2.1 Magnetic Gradiometry

Magnetic gradiometry is a more refined technique under the broader category of magnetic geophysical survey. Magnetic surveying in general is a passive method based on the measurement of localized perturbations to the Earth's magnetic field caused by the presence of buried ferrous targets. Magnetic gradiometry determines the vertical gradient of the magnetic field, and are more sensitive to small or weakly magnetic targets than the typical single sensor, total field magnetometer. The limitation with magnetic survey techniques is that they will not identify non-magnetic materials, such as glass, plastics, wood, and non-ferrous metals such as copper and aluminum.

Typically, data is collected in a systematic manner across a field site and then presented as a contoured map in units of nanotesla (nT) or nT per meter (nT/m), which can be interpreted to produce a map of the subsurface. The amplitude and shape of an individual anomaly will reflect the dimensions, orientation and magnetic susceptibility of the buried target.

1.2.2 Ground Penetrating Radar

In GPR surveys, electromagnetic waves of frequencies between 50MHz and 2.5GHz (microwave band of the radio spectrum) are transmitted into the ground. This energy is reflected back to the surface when it encounters significant contrasts in dielectric properties. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves. A receiver measures the variation in the strength of the reflected signals with time. The resulting profile is called a "scan." Multiple scans generated by traversing the antenna across the ground surface are used to build two-dimensional cross sections (radargrams) of the subsurface.

The advantage of GPR is that it can be used in a variety of media, including rock, soil, ice, fresh water, pavements and structures. Also, because GPR is sensitive to differences in dielectric properties, it can be used to detect non-ferrous objects, changes in material, and voids and cracks. The limitation with GPR is that signal resolution is dependent on the input signal frequency. Higher frequencies provide higher resolution, but higher frequencies provide less penetration depth. Lower frequencies penetrate deeper into the ground but provides less resolution and hence less accuracy. Another potential limitation with GPR is that the difference between dielectric constants of different materials or layers may be too small to classify, and interpretation of data is less straightforward than magnetic techniques.

1.2.3 Electrical Resistivity Imaging

ERI, also called electrical resistivity tomography (ERT) measures ground resistance by introducing an electric current into the subsurface via two grounded electrodes. The current passing through the ground sets up a distribution of electrical potential in the subsurface. The difference in electrical potential is measured using a second set of electrodes. The transmitting and receiving electrode pairs are referred to as dipoles. Using Ohm's law, this voltage can be converted into a resistance reading in units of ohm-meters (ohm-m) for the ground between the two potential electrodes. By varying the unit length of the dipoles as well as the distance between them, the horizontal and vertical distribution of electrical properties can be recorded.

To build a vertical cross-sectional image of ground resistance, a string of connected electrodes are deployed along a straight line with an inter-electrode spacing of *a*. Once the resistance measurements have been made, the line is re-surveyed with an inter-electrode spacing of 2*a*, 3*a*, 4*a*, etc. For example, if a = 1 m (the initial spacing between the electrodes is 1 m), the next survey along the same line would be conducted for electrodes spaced at 2 m, followed by a survey with electrodes spaced at 3 m, etc. Each increase in the inter-electrode spacing increases the effective depth of the survey. The vertical cross sections are combined to generate a fence diagram output.

2. GEOPHYSICAL SURVEY PROCEDURE

This section provides a description of the field procedures and instrumentation used in the Phase I area geophysical survey. The specifications of the instruments are provided in Appendix A for reference. The results of the survey are presented in Section 3.

2.1 Magnetic Gradiometry Survey

The magnetic gradiometry survey was conducted using a Bartington Instrument Ltd (United Kingdom) model Grad601 gradiometer equipped with a single Grad-01-1000L high stability fluxgate gradient sensor. The data generated was recording using a DL601 Data Logger.

The survey area at the Phase I site measures approximately 180 m from north to south and 80 m east to west (Figure 2-1). A grid with 1 m intervals was established over the entire survey area. Including endpoints, this resulted in 14,480 intersections points between the north-south and east-west running gridlines. Magnetic readings were taken at each of the intersection points.

2.2 GPR Survey

The GPR survey was conducted using a MALÅ GeoScience (Sweden) model ProEx™ Professional Explorer GPR. The survey utilized a 2 m interval transects in the east-west direction (90 transects), each transect covering a length of 80 m. The GPR survey gridlines are shown on Figure 2-2.

Based on site geology, soil type, subsurface conditions and the anticipated depth of buried materials at 5 m to 6 m below ground surface (bgs), an input frequency of 100 megahertz (MHz) was selected to provide the highest resolution. After completion of the survey at 100 MHz, the data was analyzed and it appeared that there were several subsurface anomalies. A second survey was conducted at these locations using an input frequency of 50 MHz. The lower frequency provides deeper coverage but at a slightly lower resolution.

2.3 ERI Survey

The ERI survey was conducted using an ABEM Instrument AB (Sweden) model Terrameter LS direct current resistivity meter. The survey was conducted along 19 transects as shown on Figure 2-3.

Figure 2-1. Magnetic Gradiometry Survey Area

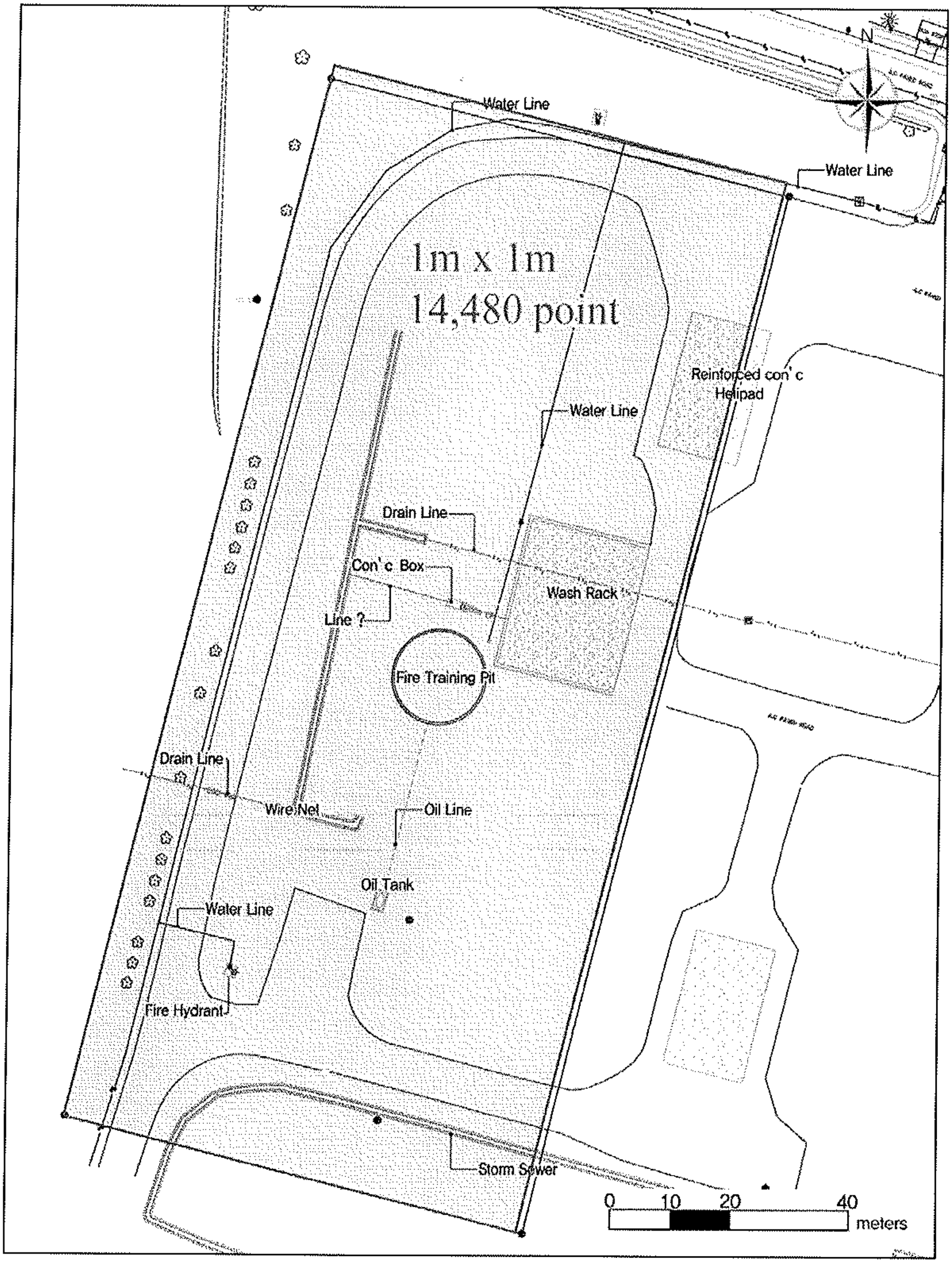


Figure 2-2. GRP Survey Transects

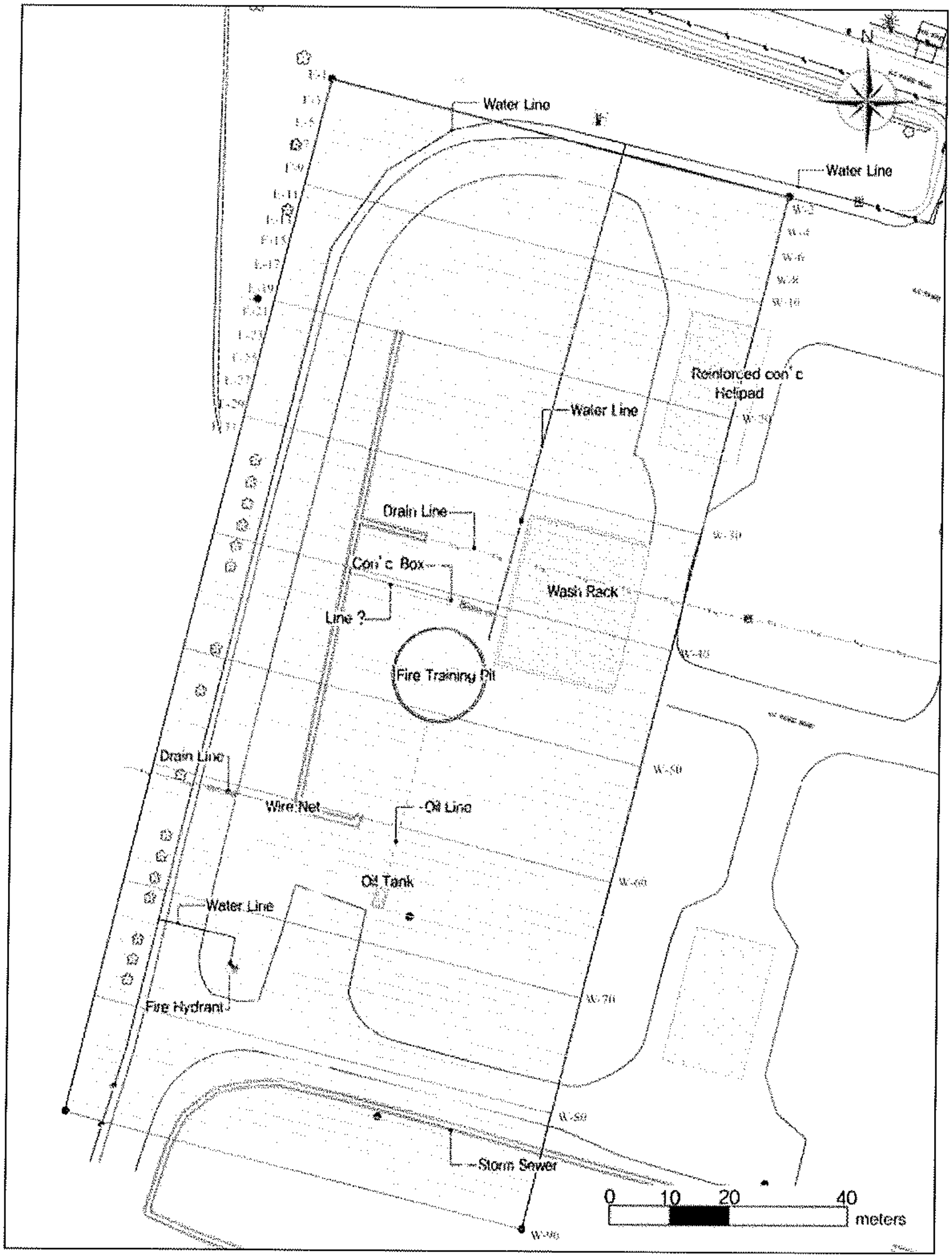
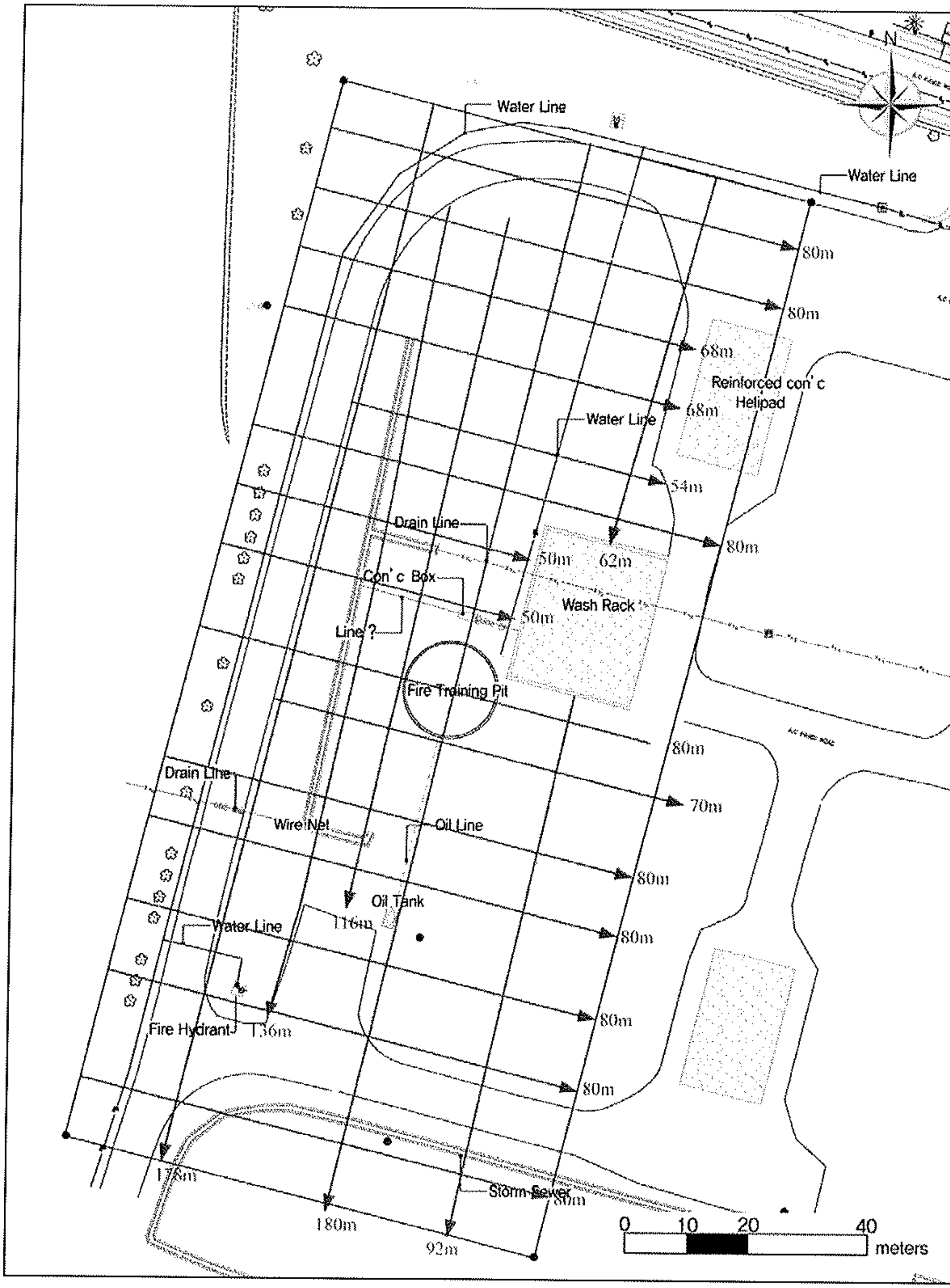


Figure 2-3. ERI Survey Transects



3. GEOPHYSICAL SURVEY RESULTS

This section provides a brief summary of the geophysical survey results and summaries. The 2-dimentional sections from the GPR survey and vertical cross section output from the ERI survey are provided in Appendix B. Photographs documenting field survey activities are provided in Appendix C. Raw data output from the survey instruments will be provided in electronic format. The raw data files are incorporated by reference as part of this report.

3.1 Magnetic Gradiometry Result

The magnetic gradiometry survey result is presented as a single diagram on Figure 3-1. The result is summarized as follows:

- Magnetic field in the area averages in the 400 nT to 500 nT range.
- The red colored areas on Figure 3-1 indicate the possible presence of buried conductive materials.
- Locations with concrete cover (wash rack, training pit, helipad, etc.), metallic objects on or above the ground surface (AST, fire hydrant), and buried metallic objects (water lines, fuel line, sewer) also present as red.
- Five anomalies not associated with the known objects listed above, indicated as locations A, B, C, D and E on Figure 3-1.
- The depth of the anomalies is estimated to be within the first 5 m bgs.

3.2 GPR Result

The GPR survey result using the 100 MHz input signal frequency is presented as a series of horizontal cross section diagrams on Figures 3-2 through 3-6. The result using the 50 MHz input signal frequency is shown on Figure 3-7. Strong reflected signals caused by known objects (helipad, training pit, etc.) were excluded. The result is summarized as follows:

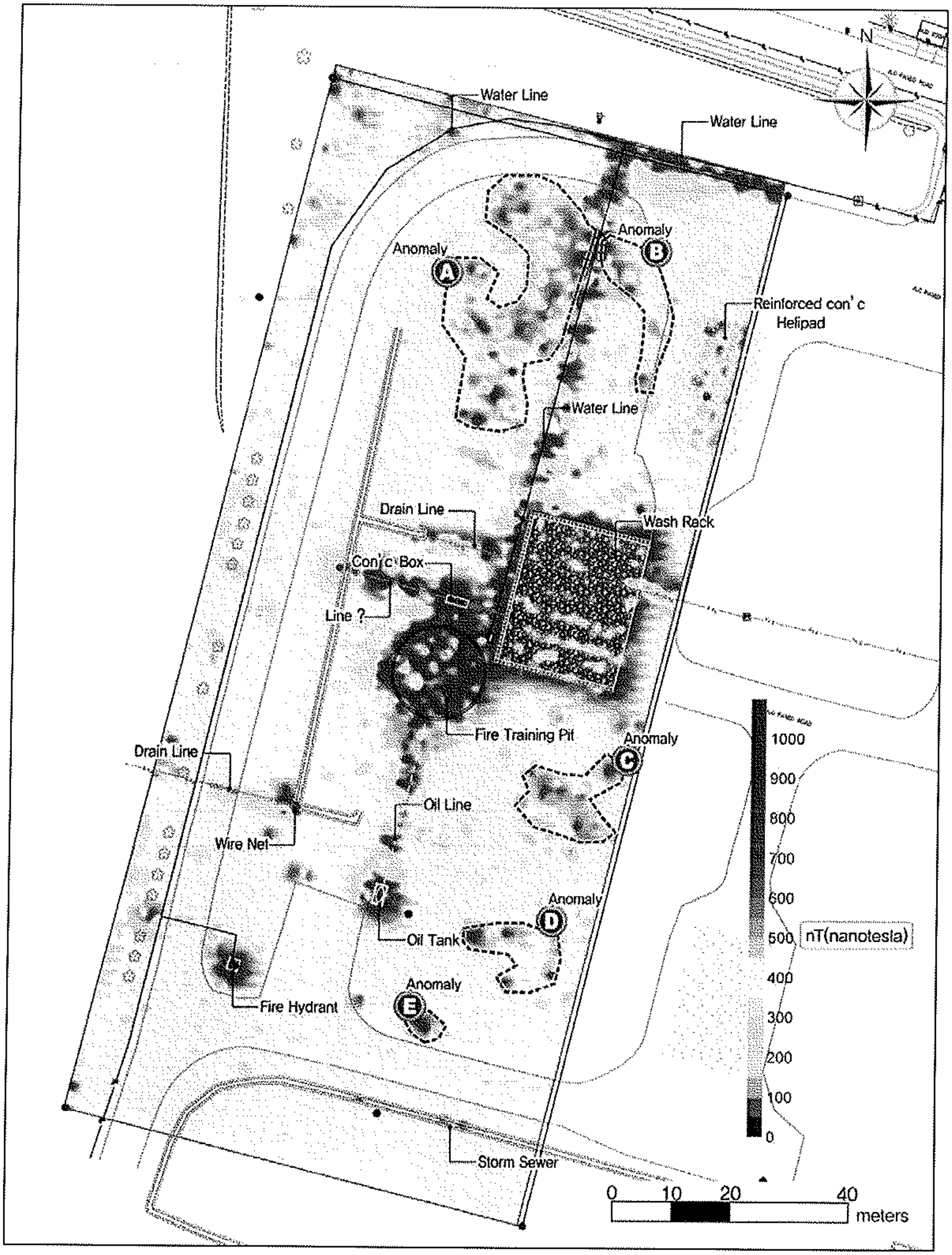
- The areas colored red indicate strong signal reflection, which could be cause by foreign objects or dense geologic strata.
- Several smaller anomalies shown as irregular red colored points had signals that indicate boulders within the soil stratum.
- Anomalies A and B indicate the possible presence of foreign objects at a depth of about 4 m bgs.
- The survey results using 50 MHz input signal frequency did not indicate any additional subsurface anomalies.

3.3 ERI Results

The ERI survey result is presented as a Fence diagram on Figure 3-8. The result is summarized as follows:

- The ground resistivity in the area ranges from about 90 ohm-m to 300 ohm-m.
- Locations with low resistivity anomalies are shown in blue and green.
- Four low resistivity anomalies have been tentatively identified:
  - A, approximately 6 m bgs
  - B, approximately 4 m bgs
  - C, approximately 4 m bgs
  - D, approximately 2 m bgs
- Conductive objects such as water lines, sewer lines show low resistivity as would be expected.

Figure 3-1. Magnetic Gradiometry Survey Result



2794

Figure 3-2. GPR 0.83 m to 1.41 m bgs Result

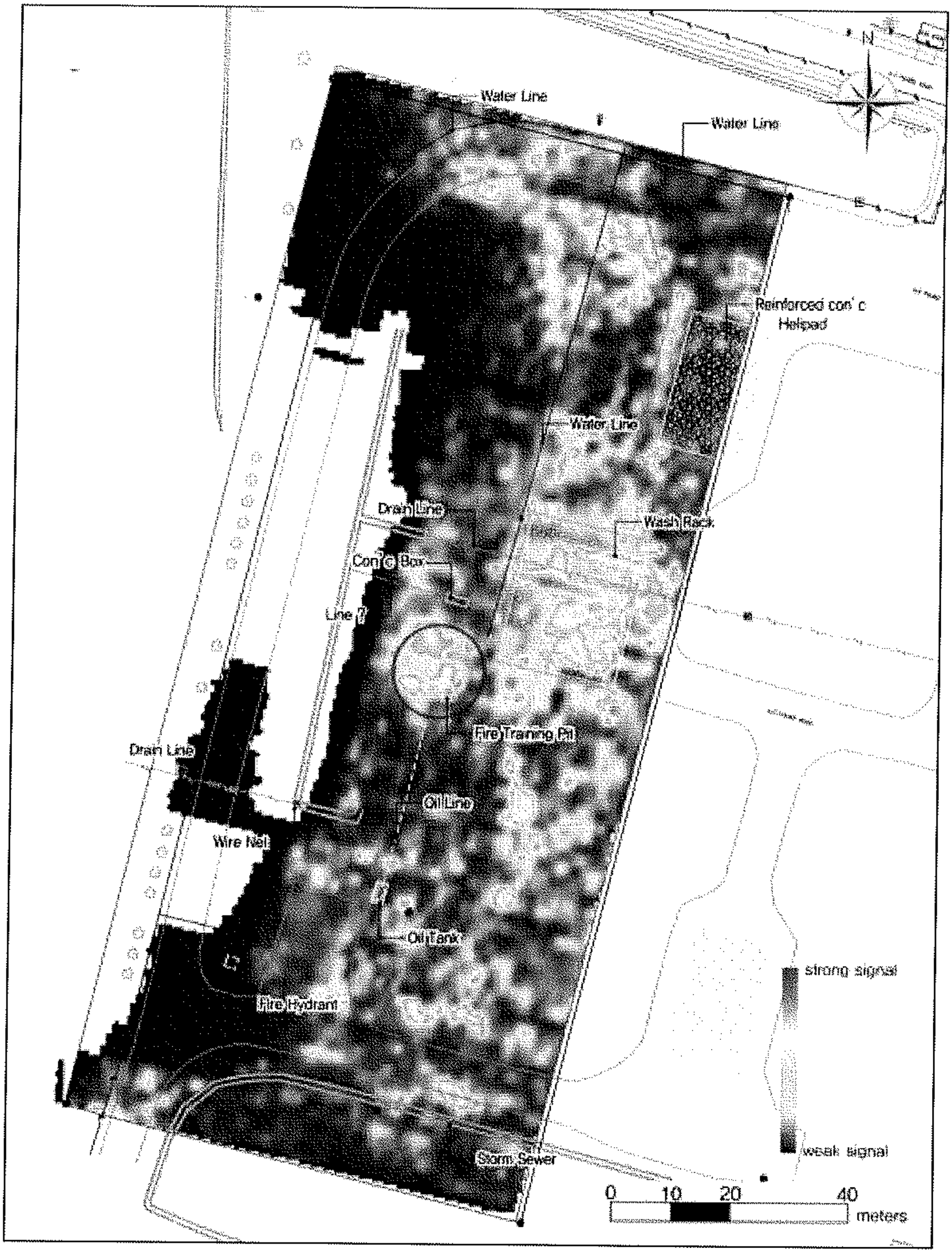


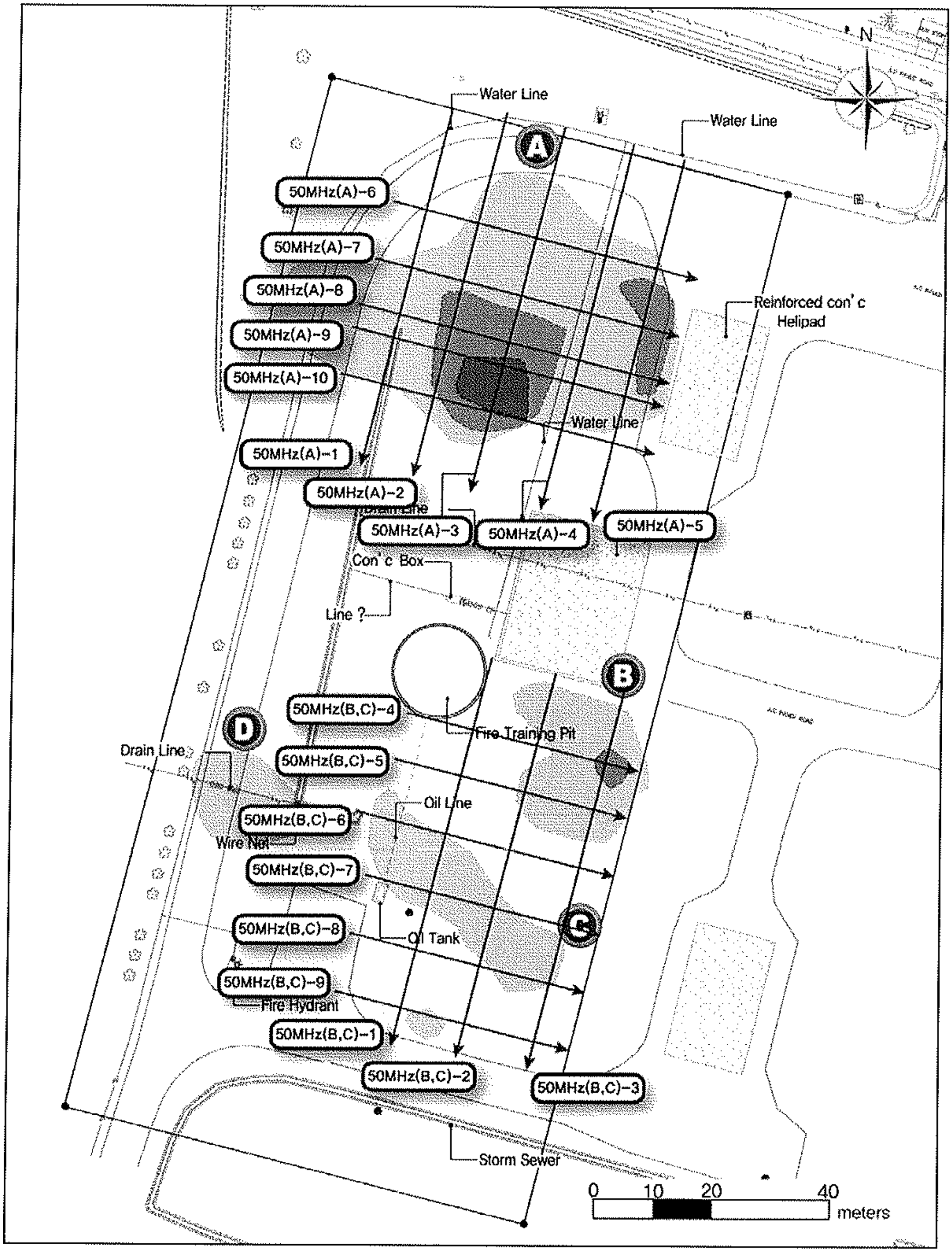
Figure 3-3. GPR 1.68 m to 2.26 m bgs Result

Figure 3-4. GPR 2.79 m to 3.37 m bgs Result

Figure 3-5. GPR 3.64 m to 4.22 m bgs Result

Figure 3-6. GPR 4.76 m to 5.34 m bgs Result

Figure 3-7. GPS Results for 50 MHz Input Signal Frequency



2800