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.

3.2.1. Headspace Analysis

Field sampling included the collection of representative headspace samples from each sampling area of concern. Soil samples were collected at periodic depths for headspace analysis to provide a rough indication of the vertical extent of VOC contamination within each soil core. Headspace samples were placed into individual sealable plastic bags. Then, the probe tip of a PID was inserted into the plastic bag to take a reading of the concentration of volatile contaminants present in the sample headspace.

3.2.2. Soil Sampling Strategy and Identification

A continuous soil sample was collected from each borehole for sample description. Sampling interval for laboratory analysis was three: 0~2 m, 2~4m and 10~12m respectively. The first two samples were to see if any chemicals associated with surface activities, and the last was to see if any chemicals might be associated with groundwater which is close to the groundwater table.

Each soil sample has a unique identification number that is consistent with borehole and monitoring well IDs used in previous investigation. The sample identification format provides general information about the boring type, year of investigation, and depth interval. The sample identification number used in this project follows this format: B09-XXX-S#, where

B indicates that the sample came from a soil boring
09 is the year in which the soil boring was drilled (i.e. 2009)
XXX is the sequential soil boring number
S indicates soil sample
is the sequential sample number, from top-down in the boring
MW instead of S# indicates monitoring well converted after completion of XXX boring

3.3. Groundwater Monitoring Well Construction.

3.3.1. Monitoring well construction

Monitoring wells were installed after completion of borehole drilling using a GeoProbe. The depth of the wells and the length of the screen intervals varied depending on the site specific characteristics observed during soil sampling. The well locations were chosen based on their location relative to known groundwater contamination as well as getting additional areal coverage in relation to the existing monitoring wells.

A 12-cm diameter air percussion hammer was used to drill the hole as slightly larger diameter (14-cm) temporary steel casing is pushed and hammered into the subsurface to hold back the overburden. After the hammer has reached the target depth, it was removed from the hole. The monitoring well casing material was then placed inside the temporary steel casing. The steel casing was gradually removed from the hole as the annulus was filled with medium grained sand filter pack, bentonite, and grout.

Groundwater monitoring well construction materials include 5.04 cm inside diameter (ID) threaded Schedule 40 polyvinyl chloride (PVC) solid pipe and slotted screen. Solid 5.04 cm

ID schedule 40 PVC pipe with threaded ends was used from approximately 10 cm below ground surface (bgs) to a depth of approximately 5 meter above the level when groundwater encounters first during drilling. A 0.254-mm slotted PVC well screen was threaded onto the bottom of the solid well-pipe to the base of the borehole. A PVC well point was screwed to the bottom of the well screen and a well cap was secured to the top of the well pipe. The annular space around the well from the bottom of the borehole to a minimum of 50 cm above the top of slotted section was filled with clean medium-grained silica sand (0.4-1.2 mm). A 50 cm thick seal of bentonite pellets was placed above the sand pack, and the bentonite pellets are hydrated either by water inside using a known clean water source. The remainder of the hole was filled with a Portland Type I cement grout to just below the frost line. Once the grout cured, concrete was used to fill the rest of the annulus around the well pipe. The wells were then completed with a flush-mount and concrete pad. Groundwater monitoring well location is presented in Figure 3-1. The Appendix II presents the well construction log.

3.3.2. Monitoring Well Development.

After installation, all wells were fully developed. The objectives of well development were to (1) remove sediment that had settled inside the well during construction; (2) remove all water that may have been introduced during drilling and well installation; (3) remove very fine grained sediment in the filter pack and nearby formation so that groundwater samples would not be turbid and well silting does not occur; and (4) improve the flow into the well from the adjacent formation, thus yielding a representative groundwater sample and an accurate water level measurement.

Well development consisted of surging by a surge block and pumping out the turbid water using BEC's vacuum truck until a noticeable reduction in sediment occurred in the discharged water. This development continued for a minimum of five well volumes of pumped water and continued until the water was visually clear or the site geologist determined that no further development is practical. Groundwater parameters were measured during well development to see the variation of the parameter, Table 3-2 presents the measurement result of the groundwater parameters. Temperature of groundwater ranges from 13.3 °C to 16.7 °C and the pH ranges from 6.0 to 6.4.

3.3.3. Groundwater Sampling.

The groundwater sampling was conducted in accordance with the protocol described in the project Work Plan. Prior to sampling, wells are checked for the presence of any floating product with an electronic oil/water level indicator probe. Then, the well was purged by removing a minimum of three times the standing volume of static water present in the well.

A low pressure pump was utilized for micro purging and sampling from the monitoring wells. The groundwater parameters such as pH, temperature, specific conductance and turbidity of the removed water were monitored during the purging and sampling process. Groundwater stabilizing criteria were adopted established in American Society for Testing and Materials (ASTM) D6671-02: pH +/- 0.2, specific conductance +/- 3%, temperature +/- 0.5°C, and turbidity +/- 3%. The groundwater was sampled using a low pressure bladder pump and dedicated tubing for each well sampled. Table 3-2 summarizes the groundwater parameter

measured during sampling activity. Temperature of groundwater ranges from 16.1 °C to 16.5 °C and the pH ranges from 6.3 to 7.3.

The collected water samples were placed into laboratory-grade, specially cleaned 40 ml sample containers with HCl preservative, and then placed immediately into a cooler with ice for preservation below 4 °C prior to arrival to the analytical laboratory. All samples were transported to the laboratory accompanied by chain-of-custody sheets thru the priority mail service company.

3.4. 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 monitoring well location, the top of well riser pipe for each monitoring well, and, if necessary, the elevations of buildings and any significant utilities. All elevation measurements were expressed in meters above mean sea level (AMSL), and World Geodetic System 84 Universal Transverse Mercator (WGS 84 UTM) Zone-52 grid system was applied for longitude and latitude systems. 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. Table 3-3 presents the monitoring well coordinates surveyed.

3.5. Investigation Derived Wastes

Waste materials or investigation-derived wastes (IDW), that required management and disposal during the ESI field work included concrete and asphalt debris, used disposable sampling equipment, well development water, decontamination 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 transported to BEC's field facility located in Yojoo, Kyeonggi-Do at the end of well construction period for treatment and disposal.

There was very little concrete or asphalt debris generated during the course of the ESI field work. The concrete and asphalt that was generated in order to expose the underlying soil was bagged along with the soil cuttings from the respective borehole. BEC personnel then transported the bags to their field facility for disposal.

3.5.1. Contaminated soil

All soil cuttings retrieved during boring were bagged on-site in tight knit, woven synthetic bags. Apparent petroleum contaminated soils in the cuttings were not segregated from uncontaminated soils. Therefore all soil waste generated during this investigation was considered petroleum impacted and transported for treatment at BEC's off-site remediation facility located in Yojoo, Kyeonggi-Do. A non-hazardous waste manifest was used to document the transport of the contaminated soil to the treatment facility.

3.5.2. Well Development and Decontamination Water

Water from decontamination activities was pumped into a BEC vacuum truck at the end of each day and disposed of at the oil/water separator system at the Land Farm of Camp Carroll. Groundwater generated during well development and pump test activities was pumped into BEC's larger pump truck, and also disposed of at the same system.

3.5.3. Site Restoration

Borings were backfilled with bentonite pellets and the surfaces sealed with concrete which was backfilled flush to the existing surface grade. Monitoring wells installed during the project were flush-mounted and pose no impediment to vehicular or foot traffic. All mud and soil cuttings generated in the vicinity of each boring and monitoring well were cleaned up by field personnel immediately following the completion of the task.

3.6. Additional Site Characterization Sampling

A test was performed on the aquifer matrix to determine the saturated and air permeability of the impacted aquifer material present at the site. In addition, soil samples were collected for chemical and microbial analysis that are useful for determining whether the present physical/chemical/biological condition of the aquifer is conducive for natural degradation of VOCs contamination present at the sites.

3.6.1. Slug Test

The hydraulic characteristics of the aquifer underlying the site were determined by performing slug tests on the monitoring wells both existing and new. The hydraulic conductivity, K, of the aquifer was calculated using slug tests recovery measurements that were performed on all monitoring wells. After the completion of well purging work, a slug with an approximate volume of 2.5 liter was put in the wells. The drop down water level after the slug was put into the wells was recorded using a pressure transducer data logger. Also the rise in water level after removing the slug from the wells was recorded in same way. Measurements were collected until the water level within the monitoring well returned to within approximately 3 centimeters of the original water level. The original water level in the well prior to the tests was measured with a Solinst electronic oil/water interface prove. Appendix III presents the summary of test procedure and slug test result.

3.6.2. Air Permeability Test.

Air Permeability is an integrated measure representing the complex relationship between the geometry of the pore system and hydraulics of the flow of air through that system. Permeability is not measured directly; rather, it is calculated by inverting an assumed model populated with measured state data (i.e. flux and pressure). For this investigation, permeability was determined by applying a pressure gradient across the project site by use of a vacuum truck on 12 November 2009.

In situ air permeability test data were performed at the site by placing a blower on a setup monitoring well and measuring the time varying pressure responses at monitoring wells adjacent to that central well. The decision was made to perform the air permeability test by

blowing out of the well by applying a vacuum rather than injection to prevent the spread of any contaminants due to air introduction into well.

A constant pressure was applied to the injection well for no longer than 25 minutes, and changes in pressure at adjacent wells were recorded at various time intervals on a roughly logarithmic basis. The measured changed in air pressure at the various monitoring wells spaced varying distance from the injection well were evaluated using analytical solutions for aquifer pumping tests that have been modified for vapor flow conditions.

3.6.3. Nutrient and Microbial Sampling

A total of seven soil samples were collected, respectively, from each borehole. The samples were submitted to the National Instrumentation Center of Environmental Management (NICEM) at Seoul National University. The samples were analyzed for biological and chemical properties relevant to potential the potential for natural attenuation.

3705

Table 3-1. Project Chronology of ESI at VCY of Camp Carroll.

Task	Date Performed
Request a site digging permit and get approval	February 6, 2009
Drilling and groundwater monitoring well installation	March 2 ~3, 2009
Well development	March 3~4, 20~23, 2009
Water level measurements	March 20 & May 19~22, 2009
Groundwater Sampling	May 19~20, 2009
Air permeability test	November 12, 2009
Hydrologic slug test	November 9~12, 2009

Table 3-2. Groundwater Parameters Measured During Well Development and Grondwater Sampling.

Well ID	Temperature ©		Electric conductivity (mS/cm)		Dissolved Oxygen (mg/L)		pH		Oxidation Reduction Potential (mV)		Turbidity (NTU^)	
	WD*	GWS$	WD	GWS	WD	GWS	WD	GWS	WD	GWS	WD	GWS
B05-180MW	13.3	16.5	0.024	0.080	7.6	8.9	6.0	7.3	282	219	16	76.7
B09-223MW	14.9	16.1	0.423	0.068	8.5	9.2	6.4	6.3	277	154	287	202
B09-225MW	16.7	16.1	0.110	0.079	8.2	8.9	6.3	6.3	308	287	74	530
* values measured during Well Development on 23 March 2009.												
$ values measured during Groundwater Sampling on 22 May 2009												
^ Nephelometric Turbidity Units												

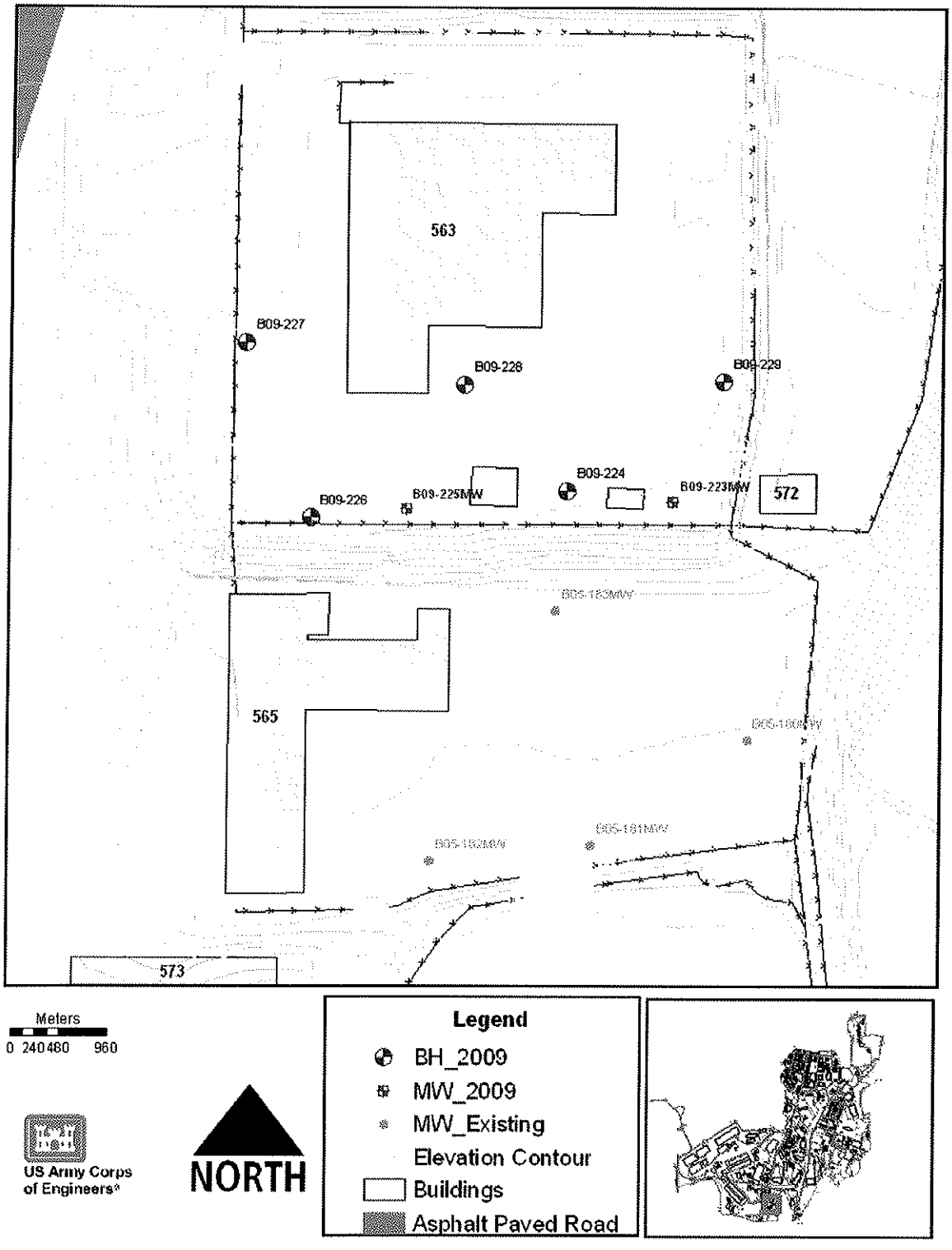
3706

Table 3-3. Coordinate of Borehole and Groundwater Monitoring Wells at VCY of Camp Carroll.

Borehole and Monitoring well	Easting	Northing	Elevation (above mean sea level, m)	Top of Pipe (above mean sea level, m)	Remark
B09-223MW	447006.07	3982991.55	46.51	46.46	monitoring well
B09-224	446989.66	3982993.26	46.53		borehole
B09-225MW	446964.45	3982990.40	46.57	46.63	monitoring well
B09-226	446949.29	3982989.04	46.69		borehole
B09-227	446939.21	3983016.19	46.51		borehole
B09-228	446973.37	3983009.60	46.78		borehole
B09-229	447013.86	3983010.21	46.53		borehole
B05-180MW	447017.90	3982954.80	41.43	41.33	existing well
B05-181MW	446993.60	3982938.40	41.23	41.07	existing well
B05-182MW	446968.40	3982936.10	41.23	41.09	existing well
B05-183MW	446987.80	3982974.70	41.59	41.41	existing well

3707

Figure 3-1. Location of Borehole and Groundwater Monitoring Wells at VCY.



3708

4. ESI Investigation Results

4.1. Laboratory Analysis.

All laboratory analysis was performed using US EPA published methods. The laboratory that performed the analysis is accredited by the National Environmental Laboratory Accreditation Conference (NELAC) for the analytical procedures specified for this project.

Soil and groundwater samples collected in this ESI were submitted to the NCA-Korea Laboratory in Anyang, Korea. The contract laboratory shipped the samples for VOCs and PAHs to the NCA laboratory in the United States since the NCA-Korea lab has only certified TPH and VOCs. Soil samples collected from soil borings were analyzed for gasoline, diesel-range TPH by Ultrasonic extraction GC/FID methods EPA3550/8015. Purge & Trap GC/MS methods EPA5030/8260 were used for VOCs analysis of soil and water samples. PAHs were analyzed by GC/MS SIM (Selective Ion Monitoring: EPA 8270). Table 4-1 to Table 4-3 present the analytical result of soil and Table 4-4 presents those of groundwater.

4.2. Summary of Investigations

A total of 18 soil samples were retrieved from a total of seven boreholes and described and screened for VOCs using a PID. All samples were submitted to the NCA-Korea for TPH, PAH and VOCs analysis. Chemical analytical results for soil are listed in Tables 4-1, 4-2 and 4-3. The summary of laboratory reports is provided in the compact disk (CD) separately.

4.2.1. Subsurface Soil

4.2.1.1.Subsurface geology

FED personnel characterized subsurface soils from each of the seven boreholes at the site. No bedrock was encountered during borehole drilling. The soil types encountered in boreholes were silty gravel with sand (fill), dark red high plasticity fat clay (residual soil), and clay to silty sand (residual soil). Fill material was generally less than 50cm thick. Fat clay was encountered beneath the fill and encountered various depths between 0.5 m and 5 m bgs. The clayey and silty sand of residual soil was encountered beneath the fat clay. Groundwater was not encountered in any of the seven boreholes during soil boring.

4.2.1.2.Total petroleum hydrocarbons

Soil test results produced by the analytical laboratory during this investigation demonstrate subsurface soil contamination by diesel range organics (TPH-DRO) and residual range organics (TPH-RRO). Gasoline range organics (GRO) were not identified in any soil samples. One sample appears consisting of the mixture of TPH DRO and RRO. TPH-DRO concentrations in soil samples range from not detected (ND) to 26.3 mg/kg and RRO from ND to 103 mg/kg. The sum of each TPH range in soil samples varies the concentration from ND to 129.3 mg/kg. Table 4-1 presents the TPH test result. Figure 4-1 depicts the TPH analytical result.

4.2.1.3.Volatile Organic Compounds

A total of eighteen soil samples were submitted to the analytical laboratory for VOCs analysis. Table 4-2 presents the analytical result of VOCs in soil sample.

A total of six chemicals were reported the concentrations above the practical quantification limit (PQL), while the concentrations of the other chemicals appeared below the PQL but the quantitation was estimated. The detection mostly occurred between 0 to 4 m bgs. Benzene and methyl tert-butyl ether (MTBE) considered to be a major component of gasoline were not reported above the PQL. Ethylbenzene and xylenes were reported from one sample (B09-227-S2). The chemicals reported are summarized as below:

1,1- dichloroethylene: 11 µg/kg
Methylene chloride: 51µg/kg to 180µg/kg
Ethylbenzene: 31 µg/kg
Naphthalene: 3.1µg/kg
Toluene: 87µg/kg to 140 µg/kg
Xylenes: 85 µg/kg

4.2.1.4. Polyaromatic Hydrocarbons

A total of eighteen soil samples collected were submitted to the laboratory for PAH analysis. None of the sample concentrations were reported above the PQL. Table 4-4 presents the summary of analytical results of PAHs for soil samples.

4.2.2. Groundwater Contamination

4.2.2.1.Groundwater Level Measurement Result

Only three wells out of total six wells around the site were used to measure the groundwater levels during this project due to the current site activities. Water levels were measured two times in March and September 2009 from each well with an oil/water interface probe. The measurement of 20 March 2009 is assumed to be a representative water level as a dry winter season. There was no water in B05-180MW during the measurement of 1st September 2009. The water level measured during this project ranges from 11.0 m bgs to 16.1 m bgs. Table 4-2 summarizes the water level measurement result.

Based on the result of groundwater level measurements, the groundwater flow direction was analyzed as depicted the result of 20 March 2009 in Figures 4-2. A groundwater flow direction is generally toward southwest and south from the monitoring well B09-223MW within the area of concern.

4.2.2.2.Groundwater Chemical Test Result

A total of three groundwater samples were collected from the monitoring wells at VCY and submitted to the laboratory for VOCs analysis. The analytical results are presented in Table 4-5 and depicted in Figure 4-2. A range of quantified VOC concentrations in groundwater samples are generally lower than the laboratory practical quantitation limit (PQL). Some reported values are also below the PQLs but just estimation or associated with method blank contamination. PCE was identified from all groundwater samples ranging from 5.6 µg/L to 9.5 µg/L. The concentrations above the PQLs are summarized as below:

- B05-180MW
  Chloroform: 1 µg/L

Tetrachloroethylene (PCE): 5.4 µg/L

- B09-223MW
  Cis-1,2-Dichloroethylene (DCE): 5.6 µg/L
  PCE: 9.5 µg/L
  Trichloroethylene (TCE): 1.1 µg/L

- B09-225
  PCE: 7.4 µg/L
  Toluene: 10 µg/L

4.3. Data Quality Control/Assurance

Field and laboratory quality control (QC) samples were collected and analyzed in accordance with USACE and industry standard methods and practices. The FED Environmental chemist (Dr. [redacted] performed a data review on soil and groundwater samples collected from the VCY site. The data review was performed in accordance with the project work plan and Chemical Quality Assurance for Hazardous, Toxic, and Radioactive Waste (HTRW) Projects (USACE, EM 200-1-6, 1997). The accuracy, precision, representativeness, and completeness of the data were evaluated by performing analytical data quality and field quality assurance (QA) /QC data quality review. Accuracy was evaluated using the laboratory sample receipt information, analyses requested, technical holding times, and laboratory QC data (method blank, laboratory control sample (LCS)/LCS duplicate, matrix spike (MS)/MS duplicate, and surrogate recoveries).

4.4. Hydrologic Characteristics of the Site

Two slug tests were performed for the monitoring wells of B09-223MW and B09-225MW at the VCY site. The monitoring wells selected for slug testing was subject to the presence of groundwater and the site accessibility. Measurements of water level versus time, along with other relevant aquifer and well characteristics were then used to determine a value for hydraulic conductivity of the site. The calculations were performed with AQTESOLV aquifer test analysis software. An anisotropy ratio (Kz/Kr) was assumed in the analysis and the analytical solution developed by Bouwer and Rice (1976) for an unconfined aquifer system was used to calculate the hydraulic conductivity. Hydraulic conductivity (K) was obtained by manual fitting using AQTESOLV (Figure 4-3). The calculated K values for the monitoring wells at the VCY area are from 1.2E-04 to 4.2E-04 cm/sec, which belongs to semi-pervious characteristics consisting of very fine sand and clay.

4.5. Air Permeability Test

The layout of the test was determined based on the location of groundwater monitoring wells, which can be focused on the center of the project site. B09-288 was installed as an air monitoring well, use as an air extraction well. The two groundwater monitoring wells of B09-223MW and B09-225MW were used as observation wells. The extraction well was hooked up to the vacuum pump to control the air flow rate. The extraction valves and measurement devices were securely attached and sealed at the top of each well pipe to prevent introducing any ambient air. Table 4-5 presents the well information used for the air permeability test.

Field data were obtained from extraction and observation wells. While the extraction vacuum was maintained at a constant, the observation wells were measured if any pressure change occurs. Field test was lasted for approximately 20 minutes with the air flow rate of 30 cubic meter/hour. The extraction vacuum used during the test was about 10 to 30 kPa. There was no response identified during this test, probably due to the long distance between the wells or due to the very low air permeability by the site subsurface geology.

Table 4-1. TPH Test Results of Soil Samples from the VCY of Camp Carroll.

Borehole ID	Sample ID	Sample Interval	Total Petroleum Hydrocarbons (mg/kg)		
			GRO* (C7-12)	DRO** (C10-24)	RRO*** (C20-40)
B09-223	S1	0~2m	-****	26.3	103
	S2	2~4m	-	-	12.6
	S3	10~12m	-	-	-
B09-224	S1	0~2m	-	-	-
	S2	2~4m	-	-	-
	S3	10~12m	-	-	-
B09-225	S1	0~2m	-	14.1	-
	S2	2~4m	-	17.9	-
	S3	10~12m	-	-	-
B09-226	S1	0~2m	-	-	-
	S2	2~4m	-	-	-
	S3	10~12m	-	-	-
B09-227	S1	0~2m	-	-	-
	S2	2~4m	-	-	-
	S3	10~12m	-	-	-
B09-228	S1	0~2m	-	-	-
	S2	2~4m	-	-	-
	S3	10~12m	-	-	-
B09-229	S1	0~2m	-	-	16.8
	S2	2~4m	-	-	-
	S3	10~12m	-	-	-
*- gasoline range organics, **- diesel range organics, ***- residual range organics					
***- not detected above the practical quantitation limit.					

Table 4-2. VOC Test Results for Soil Samples from the VCY of Camp Carroll

Component (EPA 8260b)	Unit	B09-223			B09-224			B09-225			B09-226			B09-227			B09-228			B09-229		
		S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
		0~2m	2~4m	10~12m	0~2m	2~4m	10~12m	0~2m	2~4m	10~12m	0~2m	2~4m	10~12m	0~2m	2~4m	10~12m	0~2m	2~4m	10~12m	0~2m	2~4m	10~12m
cis-1,2-Dichloroethene	µg/kg	-	-	26J**	-	-	19J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	µg/kg	-	-	-	-	-	8J	-	-	-	-	-	-	-	11	6.4J	8.4J	7.6J	-	-	-	10J
Ethylbenzene	µg/kg	31J	25J	24J	30J	33J	26J	29J	25J	30J	18J	34J	25J	29J	31	25J	33J	39J	26J	26J	28J	26J
Methylene chloride	µg/kg	54J	160	110	120	49J	50J	45J	47J	52J	100	150	110	45J	51	49J	59J	58J	54J	180	50J	56J
Naphthalene	µg/kg	-	2.9JB	-	-	-	-	-	-	-	-	-	-	3.1J	3.1	-	-	-	-	4.7JB	2.6JB	-
Styrene	µg/kg	-	-	-	1.5J	-	-	-	-	-	-	-	-	-	-	1.5J	-	1.7J	-	-	-	-
Tetrachloroethene (PCE)	µg/kg	26J	5.5J	6.8J	-	18J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	µg/kg	24J	27J	24J	35J	36J	60J	92	56J	60J	17J	35J	22J	38J	140	99	64J	88	48J	87	40J	99
1,2,3-Trichlorobenzene	µg/kg	-	18JB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20JB
1,2,4-Trichlorobenzene	µg/kg	-	-	-	-	-	-	-	-	-	-	-	-	13J	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	µg/kg	77J	56J	62J	66J	78J	65J	75J	63J	79J	52J	71J	63J	66J	85	76J	91J	84J	65J	65J	72J	73J
o-Xylene	µg/kg	7.3J	-	-	7.3J	7.4J	-	-	-	7.4J	-	-	-	6.4J	-	-	-	-	6.8J	7.2J	-	-

* B- method blank contamination, the associated method blank contains the target analyte at a reportable level.

** J- the quantitation is an estimation.

3714

Table 4-3. PAH Test Result for Soil Samples from the VCY of Camp Carroll.

Component (EPA 8270C)	Units	B09-223			B09-224			B09-225			B09-226			B09-227			B09-228			B09-229		
		S1[1]	S2[2]	S3[3]	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Acenaphthylene	µg/kg	-	-	-	-	-	-	-	0.61 J	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)anthracene	µg/kg	0.35J *	- **	-	-	-	-	-	0.41 J	-	-	-	-	-	-	-	-	-	-	0.47 J	-	-
Benzo(b)fluoranthene	µg/kg	2J	-	-	-	-	-	-	1.1J	-	0.67 J	-	-	-	-	-	-	-	-	1.4J	-	-
Benzo(ghi)perylene	µg/kg	1.7J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene	µg/kg	0.59J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chrysene	µg/kg	0.89J	-	-	-	-	-	-	1.6J	-	0.54 J	-	-	-	-	-	0.45 J	-	-	1.3J	-	-
Fluoranthene	µg/kg	1J	-	-	-	-	-	0.37 J	2.9J	-	1.1J	-	-	-	-	-	1.7J	-	-	1.4J	0.52 J	-
Indeno(1,2,3-cd)pyrene	µg/kg	0.84J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.64 J	-	-
Phenanthrene	µg/kg	0.61J	-	-	-	-	-	-	2.4J	-	0.46 J	-	-	-	-	-	0.78 J	-	-	0.54 J	-	-
Pyrene	µg/kg	0.72J	-	-	-	-	-	-	2.1J	-	0.8J	-	-	-	-	-	1.2J	-	-	1.5J	-	-

1- sample from 0~2m, 2- depth interval from 2~4 m, 3- depth interval from 10~12 m.

* J- The quantitation is an estimation. **- not detected above the practical quantitation limit.

3715

Table 4-4. VOCs Test Result for Groundwater at the VCY Area.

Chemical Parameter (µg/L)	Unit	B05-180MW	B09-223MW	B09-225MW
Acetone	µg/L	-*	-	2.1J**
Benzene	µg/L	-	-	-
Bromobenzene	µg/L	-	-	-
Bromochloromethane	µg/L	-	-	-
Bromodichloromethane	µg/L	-	-	-
Bromoform	µg/L	-	-	-
Bromomethane	µg/L	-	-	-
2-Butanone (MEK)	µg/L	-	-	-
n-Butylbenzene	µg/L	-	-	-
sec-Butylbenzene	µg/L	-	-	-
tert-Butylbenzene	µg/L	-	-	-
Carbon disulfide	µg/L	-	-	-
Carbon tetrachloride	µg/L	-	-	-
Chlorobenzene	µg/L	-	-	-
Dibromochloromethane	µg/L	-	-	-
Chloroethane	µg/L	-	-	-
Chloroform	µg/L	1	0.5J	0.38 J
Chloromethane	µg/L	-	-	-
2-Chlorotoluene	µg/L	-	-	-
4-Chlorotoluene	µg/L	-	-	-
1,2-Dibromo-3-chloropropane (DBCP)	µg/L	-	-	-
1,2-Dibromoethane (EDB)	µg/L	-	-	-
Dibromomethane	µg/L	-	-	-
1,2-Dichlorobenzene	µg/L	-	-	-
1,3-Dichlorobenzene	µg/L	-	-	-
1,4-Dichlorobenzene	µg/L	-	-	-
Dichlorodifluoromethane (Freon 12)	µg/L	-	-	-
1,1-Dichloroethane	µg/L	-	-	-
1,2-Dichloroethane	µg/L	-	-	-
cis-1,2-Dichloroethylene	µg/L	0.2 J	5.6	-
trans-1,2-Dichloroethylene	µg/L	-	-	-
1,1-Dichloroethylene	µg/L	-	-	-
1,2-Dichloropropane	µg/L	-	-	-
1,3-Dichloropropane	µg/L	-	-	-

Table 4-4. VOCs Test Result (Continued).

Chemical Parameter (µg/L)	Unit	B05-180MW	B09-223MW	B09-225MW
2,2-Dichloropropane	µg/L	-	-	-
cis-1,3-Dichloropropene	µg/L	-	-	-
trans-1,3-Dichloropropene	µg/L	-	-	-
1,1-Dichloropropene	µg/L	-	-	-
Ethylbenzene	µg/L	-	-	-
Hexachlorobutadiene	µg/L	-	-	-
2-Hexanone	µg/L	-	-	-
Isopropylbenzene	µg/L	-	-	-
p-Isopropyltoluene	µg/L	-	-	-
Methylene chloride	µg/L	-	-	-
4-Methyl-2-pentanone (MIBK)	µg/L	-	-	-
Naphthalene	µg/L	-	-	-
n-Propylbenzene	µg/L	-	-	-
Styrene	µg/L	-	-	-
1,1,1,2-Tetrachloroethane	µg/L	-	-	-
1,1,2,2-Tetrachloroethane	µg/L	-	-	-
Tetrachloroethylene (PCE)	µg/L	5.4	9.5	7.4
Toluene	µg/L	16B***	13B	10
1,2,3-Trichlorobenzene	µg/L	-	-	-
1,2,4-Trichlorobenzene	µg/L	-	-	-
1,1,1-Trichloroethane	µg/L	-	-	-
1,1,2-Trichloroethane	µg/L	-	-	-
Trichloroethylene (TCE)	µg/L	0.41 B	1.1	-
Trichlorofluoromethane (Freon 11)	µg/L	-	-	-
1,2,3-Trichloropropane	µg/L	-	-	-
1,2,4-Trimethylbenzene	µg/L	-	-	-
1,3,5-Trimethylbenzene	µg/L	-	-	-
Vinyl chloride	µg/L	-	-	-
m-Xylene & p-Xylene	µg/L	-	-	-
o-Xylene	µg/L	-	-	-
* - not detected above the sample quantitation limit.				
** J- the quantitation is an estimation.				
***B- method blank contamination, the associated method blank contains the target analyte at a reportable level.				

Table 4-5. Monitoring Well Information used for Air Permeability Test at the VCY area.

Purpose	Well ID	Well Depth (m)	Water level	Inter-well Distance
Extraction Well	B09-288	15.2 m	12.4 m bgs*	0
Air Monitoring	B09-223MW	18.5 m	13.5 m bgs	37 m
Air Monitoring	B09-225MW	19.5 m	15.81 m bgs	27 m

*below ground surface

3218

Figure 4-1. TPH Analytical Result (only detection) in Soil Samples from the VCY.

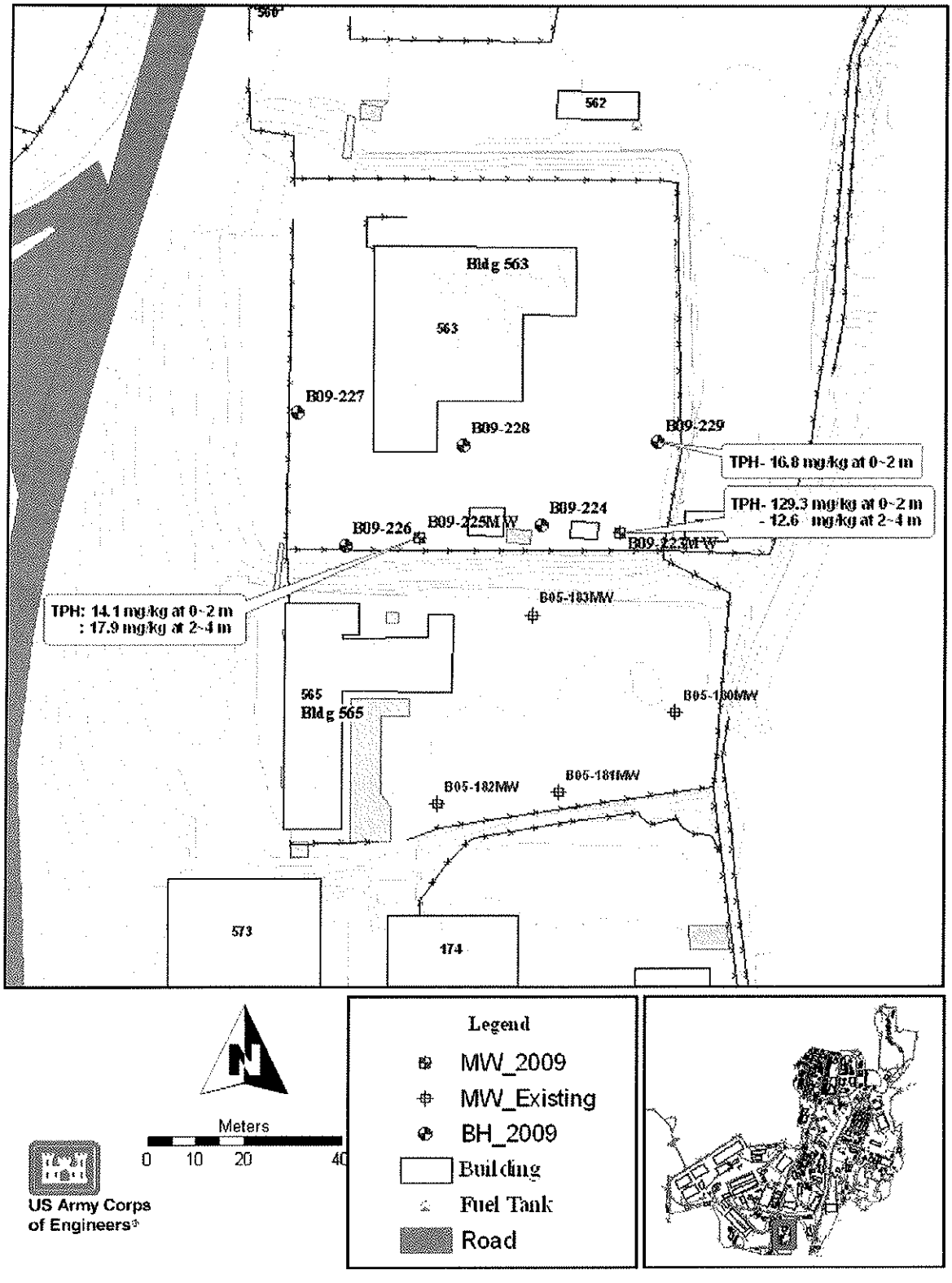
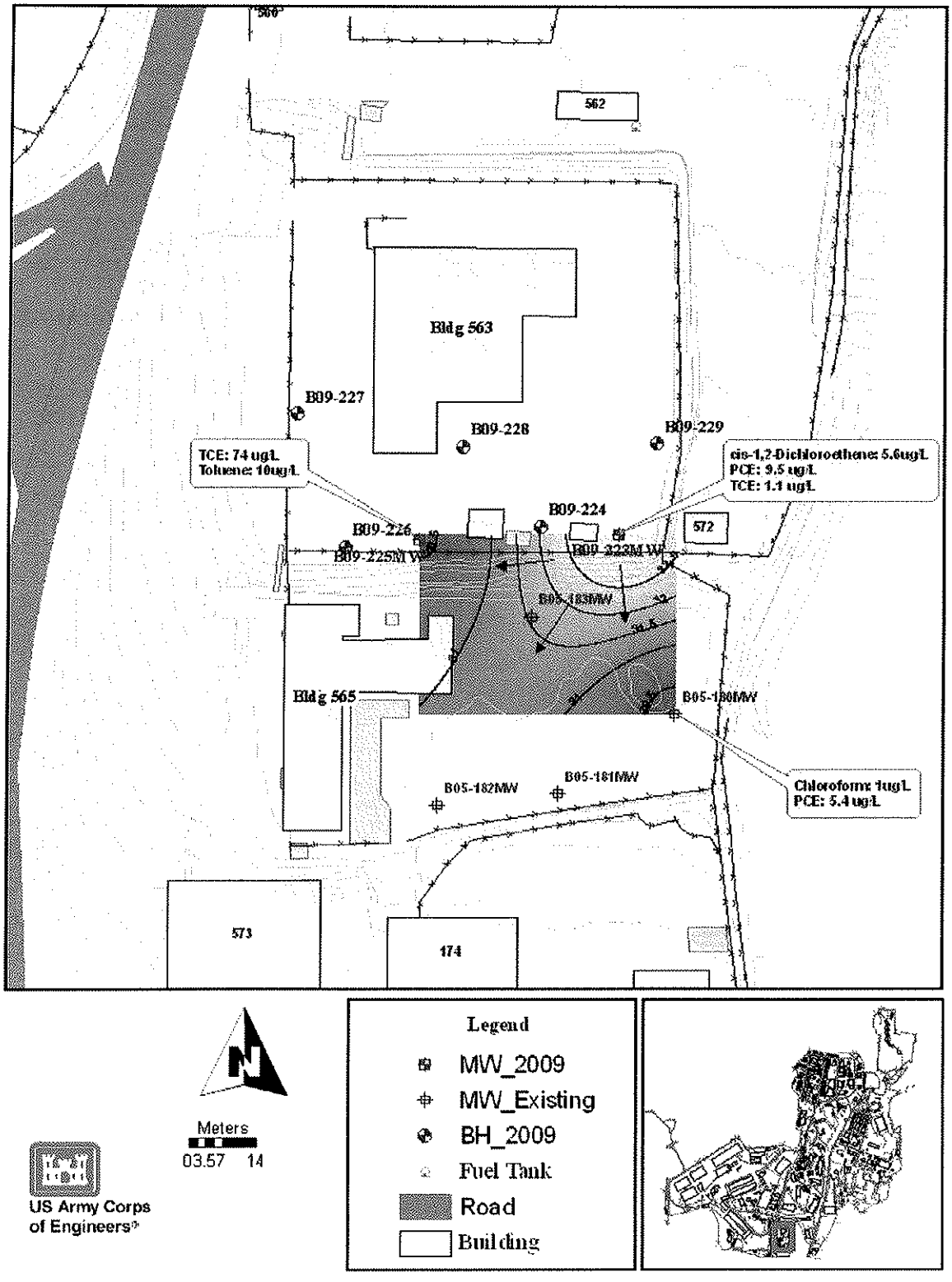
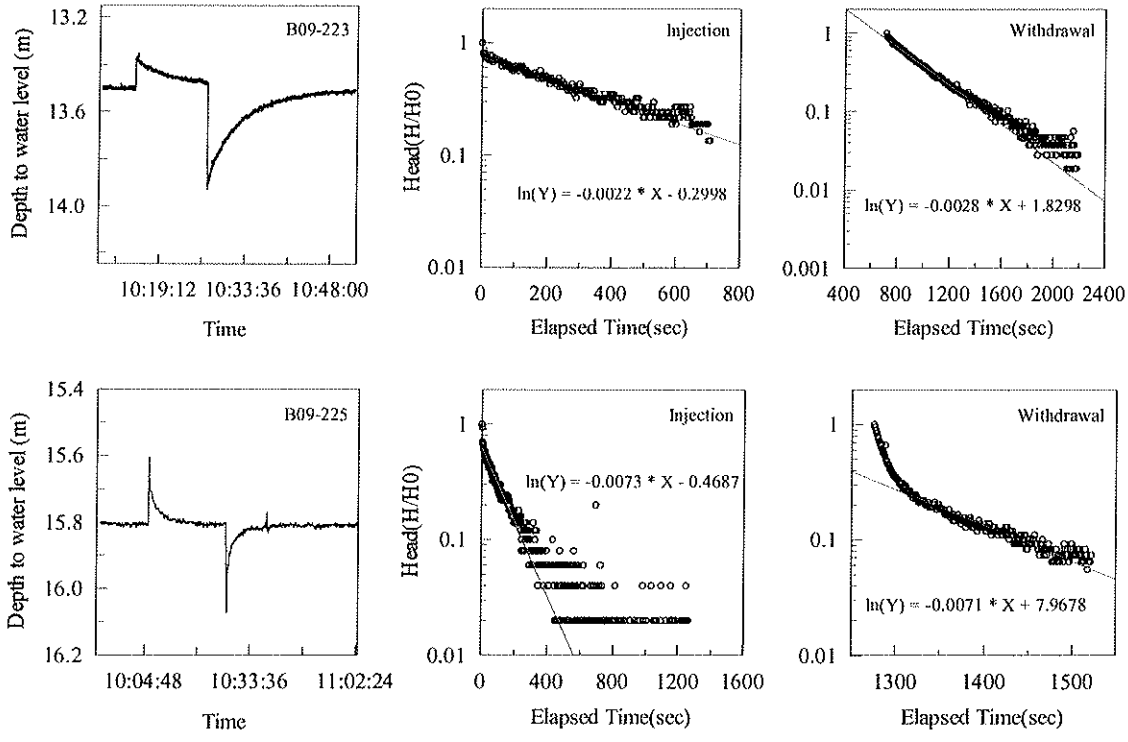


Figure 4-2. Groundwater Flow Direction and Chemical Test Result in Groundwater Sample at the VCY.



3220

Figure 4-3. Curve Fitting Results against Elapsed time during the Slug Test at the VCY Site.



32 21

Appendix I: Soil Borehole Logs

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-223MW**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66

DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] 66

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **19.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **19.0 m** WATER DEPTH:

COORDINATES: N: **3,982,991.5** E: **447,006.1** GROUND ELEV.: **46.51 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION:

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 / 0	S1					CH	**FAT CLAY WITH SAND**: brown; moist; subangular fine to medium Sand (max.2mm); medium plasticity; medium; fill material(CH); no.	%Recovery = 90 FC = F4 FC = S1	
						GP	**POORLY GRADED GRAVEL WITH SAND**: gray; dry; subangular medium to coarse gravel (max.4cm); subangular fine to coarse Sand (max.4.8mm); no plasticity; medium; fill material(GP); no.	FC = F3 %Recovery = 80 PID = 1.3ppm	
44 / 2	S2					CH	**FAT CLAY**: moderate red; moist; subangular medium Sand (max.2mm); high plasticity; stiff; alluvial; no.	%Recovery = 85 PID = 1.6ppm	
	S3							%Recovery = 95 PID = 1.7ppm	
42 / 4	S4							%Recovery = 80 PID = 2.4ppm	
	S5							%Recovery = 80 PID = 2.4ppm	
40 / 6	S6					ML	**SILT**: dark yellowish orange; moist; subangular fine to medium Sand (max.2mm); low plasticity; medium; residual; no; contain MICA.	%Recovery = 90 PID = 1.5ppm	
	S7							%Recovery = 90 PID = 2.8ppm	
38 / 8	S8							%Recovery = 90 PID = 3.7ppm	
	S9							%Recovery = 90 PID = 3.3ppm	
36 / 10	S10							%Recovery = 80 PID = 3.9ppm	
	S11							%Recovery = 100 PID = 4.3ppm	
34 / 12	S12							%Recovery = 0 PID = 0ppm	
	S13							%Recovery = 40 PID = 1.2ppm	
32 / 14	S14							%Recovery = 80 PID = 3ppm	
	S15								
30 / 16	S16					CH	**SANDY FAT CLAY**: yellowish brown; moist; subangular fine to medium Sand (max.2mm); high plasticity; soft; residual; no; contain MICA.	%Recovery = 100 PID = 1.7ppm	
	S17					CH ML	**FAT CLAY**: moderate red; moist; subangular fine to medium Sand (max.2mm); high plasticity; soft; residual; no; contain MICA. **SANDY SILT**: yellowish brown; moist; subangular fine to medium Sand (max.2mm); low plasticity; medium; residual; no; contain MICA.	%Recovery = 100 PID = 1.1ppm	
28 / 18									

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

3783

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-224**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**
LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] 66
DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **12.0 m**
OVERBURDEN THICKNESS: DEPTH DRILLED: **12.0 m** WATER DEPTH:
COORDINATES: N: **3,982,993.3** E: **446,989.7** GROUND ELEV.: **46.53 m** DATUM: **MSL**
GROUND COVER: **Grass** CONTAMINATION:
TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46—0	S1					CH	**SANDY FAT CLAY**: brown; moist; high plasticity; soft; fill material(CH); no.	%Recovery = 70 PID = 3.2ppm FC = F4	
						GP CH ML ML	**POORLY GRADED GRAVEL WITH SNAD**: brown; moist; subangular medium gravel (max.2.5cm); no plasticity; medium; fill material(GP); no.	FC = S1 FC = F3 FC = F4	
	S2					CH	**FAT CLAY**: brown; moist; high plasticity; stiff; fill material(CH); no.	%Recovery = 100 PID = 2.8ppm FC = F4 FC = F3	
44—2	S3						**SILT**: brown; moist; low plasticity; medium; fill material(ML); no.		
	S4						**SILT**: brown; moist; low plasticity; medium; fill material(ML); no.	%Recovery = 80 PID = 2.8ppm	
42—4	S5					ML	**FAT CLAY**: dark yellowish orange; moist; high plasticity; stiff; fill material(CH); no.	%Recovery = 90 PID = 2.3ppm	
	S6						**SILT**: moderate red; moist; low plasticity; stiff; residual; no.	%Recovery = 90 PID = 2.6ppm	
40—6	S7							%Recovery = 80 PID = 2.1ppm %Recovery = 90 PID = 2.1ppm	
	S8							%Recovery = 100 PID = 1.4ppm	
38—8	S9							%Recovery = 0 PID = 0ppm	
	S10					SM	**SILTY SAND**: yellowish brown; moist; medium plasticity; dense; residual; no.	%Recovery = 50 PID = 2.1ppm	
36—10	S11							%Recovery = 80 PID = 0.8ppm	
	S12							%Recovery = 100 PID = 2.8ppm	
—12									

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-225MW**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] b6

DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] b6

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **20.0 m**

OVERBURDEN THICKNESS: _____ DEPTH DRILLED: **20.0 m** WATER DEPTH: _____

COORDINATES: N: **3,982,990.4** E: **446,964.5** GROUND ELEV.: **46.57 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION: _____

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other _____

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 / 0	S1					CH	**SANDY FAT CLAY**; brown; moist; medium plasticity; soft; fill material(CH); no.	%Recovery = 80 PID = 3.3ppm FC = F4	
						GP CH	**POORLY GRADED GRAVEL**; brown; moist; subangular medium gravel (max.3cm); no plasticity; medium; fill material(GP); no.	FC = NFS FC = F3	
44 / 2	S2 S3					ML	**FAT CLAY**; dark yellowish orange; moist; high plasticity; stiff; residual; no.	%Recovery = 90 PID = 2.6ppm	
	S4						**SILT WITH SAND**; moderate red; moist; low plasticity; stiff; residual; no.	%Recovery = 100 PID = 3.3ppm	
42 / 4	S5							%Recovery = 90 PID = 2.3ppm	
	S6							%Recovery = 90 PID = 2.7ppm	
40 / 6	S7							%Recovery = 90 PID = 3.1ppm	
	S8					SM	**SILTY SAND**; yellowish brown; moist; low plasticity; medium; residual; no.	%Recovery = 100 PID = 3ppm	
38 / 8	S9							%Recovery = 100 PID = 2.6ppm	
	S10							%Recovery = 90 PID = 2.9ppm	
36 / 10	S11							%Recovery = 90 PID = 2.3ppm	
34 / 12						SM	**SILTY SAND**; yellowish brown; residual.	%Recovery = 100 PID = 1.3ppm	
32 / 14									
30 / 16									
28 / 18									

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-226**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66

DATE STARTED: **03 Mar 09** FINISHED: **03 Mar 09** DRILLER: [redacted] 66

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **12.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **12.0 m** WATER DEPTH:

COORDINATES: N: **3,982,989.0** E: **446,949.3** GROUND ELEV.: **46.69 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION:

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 / 0	S1					GP-GC	**POORLY GRADED GRAVEL WITH CLAY AND SAND**; dark brown; moist; subangular medium to coarse gravel (max.4cm); low plasticity; loose; fill material(GP-GC); no; contain MICA.	%Recovery = 90 PID = 2.5ppm FC = F2	
	S2					CH	**SANDY FAT CLAY**; dark yellowish orange; moist; medium plasticity; medium; fill material(CH); no.	FC = F4 FC = F3 %Recovery = 100	
44 / 2	S3					CH	**FAT CLAY**; moderate red; moist; high plasticity; medium; alluvial; no.	PID = 2.2ppm %Recovery = 90 PID = 2.4ppm	
	S4					ML	**SILT**; dark yellowish orange; moist; low plasticity; medium; residual; no.	%Recovery = 60 PID = 2.1ppm	
42 / 4	S5							%Recovery = 90 PID = 2.2ppm	
	S6							%Recovery = 90 PID = 1.8ppm	
40 / 6	S7							%Recovery = 90 PID = 3.1ppm	
	S8							%Recovery = 60 PID = 2.5ppm	
38 / 8	S9					SM	**SAND WITH SILT**; yellowish brown; moist; low plasticity; dense; residual; no.	%Recovery = 70 PID = 2ppm	
	S10							%Recovery = 80 PID = 2.1ppm	
36 / 10	S11							%Recovery = 70 PID = 1.7ppm	
	S12							%Recovery = 100 PID = 1.9ppm	
12									

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-227**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66 66

DATE STARTED: **03 Mar 09** FINISHED: **03 Mar 09** DRILLER: [redacted]

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **12.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **12.0 m** WATER DEPTH:

COORDINATES: N: **3,983,016.2** E: **446,939.2** GROUND ELEV.: **46.51 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION:

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 — 0	S1					SC CH SM ML	**CLAYEY SAND WITH GRAVEL**: brown; moist; subangular fine to medium gravel (max.1cm); subangular fine to coarse Sand (max.4.8mm); low plasticity; dense; fill material(SC); no.	%Recovery = 100 PID = 2.3ppm FC = F3	
	S2						**FAT CLAY WITH SAND**: moderate red; moist; subangular fine to medium Sand (max.2mm); medium plasticity; medium; fill material(CH); no.	FC = F4 FC = F3 FC = F4	
44 — 2	S3						**SILTY SAND**: yellowish brown; moist; subangular fine to coarse Sand (max.4.8mm); low plasticity; soft; fill material(SM); no; contain MICA.	%Recovery = 70 PID = 2.6ppm	
	S4						**SANDY SILT**: dark yellowish orange; moist; subangular fine to medium Sand (max.2mm); low plasticity; medium; fill material(ML); no.	%Recovery = 100 PID = 2.6ppm %Recovery = 100 PID = 2.9ppm	
42 — 4	S5							%Recovery = 100 PID = 2.1ppm	
	S6					ML	**SANDY SILT**: dark yellowish orange; moist; subangular fine to medium Sand (max.2mm); low plasticity; medium; residual; no.	%Recovery = 100 PID = 2.6ppm	
40 — 6	S7							%Recovery = 90 PID = 2.2ppm	
	S8							%Recovery = 100 PID = 2.1ppm	
38 — 8	S9							%Recovery = 90 PID = 2.4ppm	
	S10							%Recovery = 100 PID = 2.4ppm	
36 — 10	S11							%Recovery = 100 PID = 1.9ppm	
	S12							%Recovery = 100 PID = 2.3ppm	
— 12									

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE.SKOREA.GDT 7/6/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-228**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] b6 b6

DATE STARTED: **03 Mar 09** FINISHED: **03 Mar 09** DRILLER: [redacted]

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **11.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **11.0 m** WATER DEPTH:

COORDINATES: N: **3,983,009.6** E: **446,973.4** GROUND ELEV.: **46.78 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION:

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 / 0	S1					SC / CH / ML	**CLAYEY SAND WITH GRAVEL**: dark brown; moist; subangular fine gravel (max.1cm); subangular fine to coarse Sand (max.4.8mm); low plasticity; soft; fill material(SC); no.	%Recovery = 100 PID = 0.9ppm FC = F3	
	S2					ML	**FAT CLAY WITH SAND**: moderate red; moist; subangular fine to medium Sand (max.2mm); medium plasticity; medium; fill material(CH); no.	FC = F4 FC = F4	
44 / 2	S3					ML	**SILT WITH SAND**: dark yellowish orange; moist; subangular fine to medium Sand (max.2mm); low plasticity; stiff; residual; no; contain MICA.	%Recovery = 100 PID = 1ppm FC = F4	
	S4						**SILT WITH SAND**: dark yellowish orange; moist; subangular fine to medium Sand (max.2mm); low plasticity; stiff; residual; no; contain MICA.	%Recovery = 100 PID = 1.2ppm	
42 / 4	S5							%Recovery = 100 PID = 1.5ppm	
	S6							%Recovery = 90 PID = 1.7ppm	
40 / 6	S7							%Recovery = 100 PID = 1.7ppm	
	S8					ML	**SNADY SILT**: yellowish brown; moist; subangular fine to medium Sand (max.2mm); low plasticity; medium; residual; no; contain MICA.	%Recovery = 100 PID = 2.1ppm	
38 / 8	S9							%Recovery = 100 PID = 1.6ppm	
	S10							%Recovery = 100 PID = 1.5ppm	
36 / 10	S11							%Recovery = 100 PID = 1.3ppm	
								%Recovery = 90 PID = 1.3ppm	

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-229**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66

DATE STARTED: **03 Mar 09** FINISHED: **03 Mar 09** DRILLER: [redacted] 66

DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **12.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **12.0 m** WATER DEPTH:

COORDINATES: N: **3,983,010.2** E: **447,013.9** GROUND ELEV.: **46.53 m** DATUM: **MSL**

GROUND COVER: **Grass** CONTAMINATION:

TYPE OF HOLE: ☐ Piezometer ☐ Monitoring Well ☐ Test Pit ☐ Auger Hole ☐ other

ELEVATION / DEPTH (meters)	SAMPLE TYPE / NUMBER	GRAPHIC LOG	CONTAMINATED	BLOW COUNT	SPT N-VALUE	USCS / STRATA	DESCRIPTION OF MATERIALS	FIELD DATA	LAB DATA
46 / 0	S1					SC	**CLAYEY SAND WITH GRAVEL**: brown; moist; subangular fine gravel (max.1cm); medium plasticity; medium; fill material(SC); no.	%Recovery = 100 PID = 1ppm FC = F3	
						GP CH	**POORLY GRADED GRAVEL WITH SAND**: dark brown; moist; subangular medium gravel (max.3cm); no plasticity; soft; fill material(GP); no.	FC = NFS FC = F4 %Recovery = 80	
44 / 2	S2						**FAT CLAY WITH SAND**: dark yellowish orange; moist; high plasticity; stiff; fill material(CH); no.	PID = 2.1ppm %Recovery = 100 PID = 2.3ppm	
	S3							%Recovery = 65 PID = 1.6ppm	
42 / 4	S4					ML	**SILT WITH SAND**: moderate red; moist; low plasticity; stiff; residual; no; contain MICA.	%Recovery = 90 PID = 2.4ppm	
	S5							%Recovery = 100 PID = 1.9ppm	
40 / 6	S6							%Recovery = 90 PID = 1.6ppm	
	S7							%Recovery = 90 PID = 2.1ppm	
38 / 8	S8							%Recovery = 90 PID = 2.2ppm	
	S9							%Recovery = 100 PID = 1.8ppm	
36 / 10	S10							%Recovery = 90 PID = 1.6ppm	
	S11							%Recovery = 90 PID = 2ppm	
12	S12								

ENVIRO-EXPLORATION LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

Appendix II: Monitoring Well Construction Logs

US Army Corps Of Engineers

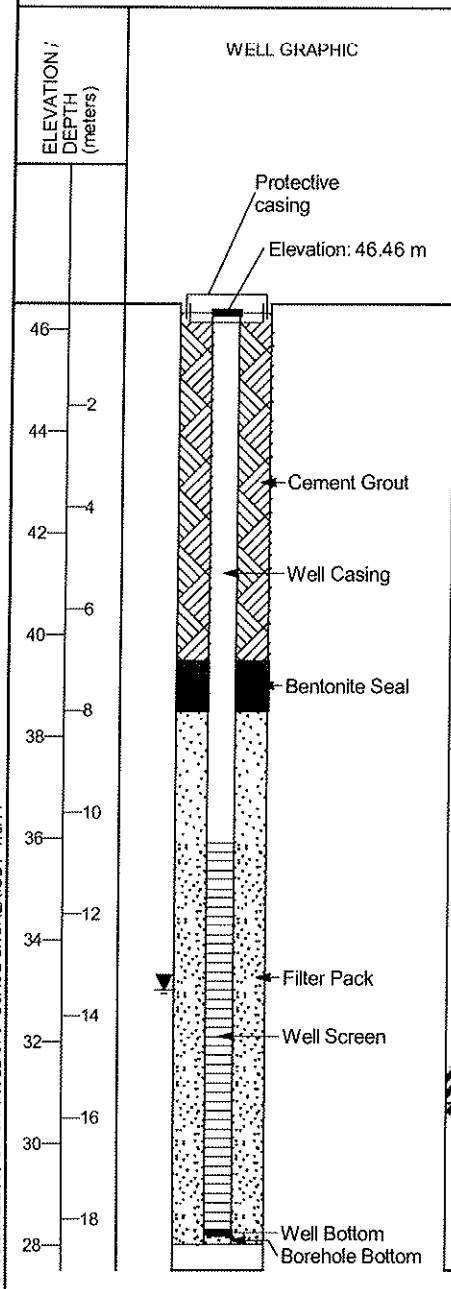
MONITORING WELL LOG

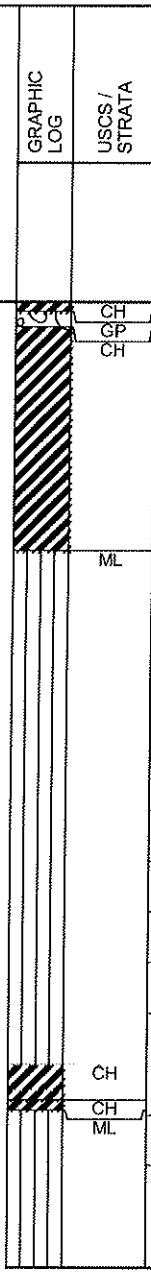
WELL NO. **B09-223MW**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION:	Camp carroll	G&EE NO.:	08-037E	INSPECTOR:	[redacted]
DATE STARTED:	02 Mar 09	FINISHED:	02 Mar 09	DRILLER:	[redacted]
DRILLING METHOD/EQUIPMENT:	GeoProbe 6600				
DRILLING AGENCY:	Far East District	HOLE DIAMETER:	3 cm	TOTAL DEPTH:	19.0 m
OVERBURDEN THICKNESS:		DEPTH DRILLED:	19.0 m	WATER DEPTH:	13.5 m
COORDINATES: N:	3,982,991.5 E: 447,006.1	GROUND ELEV.:	46.51 m	DATUM:	MSL
GROUND COVER:	Grass	TOP of WELL RISER CASING ELEV.:		46.46 m	





SAMPLE NUMBER	Depth (m)	FIELD DATA
1		%Recovery = 90 FC = F4 FC = S1 FC = F3
2	2	%Recovery = 80 PID = 1.3ppm
3		%Recovery = 85 PID = 1.6ppm
4	4	%Recovery = 95 PID = 1.7ppm
5		%Recovery = 80 PID = 2.4ppm
6	6	%Recovery = 80 PID = 2.4ppm
7		%Recovery = 90 PID = 1.5ppm
8	8	%Recovery = 90 PID = 2.8ppm
9		%Recovery = 90 PID = 3.7ppm
10	10	%Recovery = 90 PID = 3.3ppm
11		%Recovery = 80 PID = 3.9ppm
12	12	%Recovery = 100 PID = 4.3ppm
13		%Recovery = 0 PID = 0ppm
14	14	%Recovery = 40 PID = 1.2ppm
15		%Recovery = 80 PID = 3ppm
16	16	%Recovery = 100 PID = 1.7ppm
17		%Recovery = 100 PID = 1.1ppm
	18	

WELL CONSTRUCTION DETAILS

PROTECTIVE CASING
Diameter: 20 cm
Type: Manhole
Interval: -0.02 to 0.18m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: -0.01 to 10.6m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 10.6 to 18.2m

WELL POINT
Type: Schedule 40 PVC
Interval: 18.2 to 18.35m

CONCRETE PAD
Diameter: 0.3m
Interval: -0.05 to 0.15m

GROUT
Type: Portland Type II
Interval: 0.0 to 7.0m
Quantity: 9 bags of 20 kg

SEAL
Type: Bentonite
Interval: 7.0 to 8.0m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 8.0 to 18.5m
Quantity: 135kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 03/03/09 caved
▼ Ground-water level on 13.5m
▲ Product level on

Note:

MONITORING WELL LOG 08-037E B565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-225MW**

Far East District

PROJECT: **Environmental Site Investigation at VCY Area**

LOCATION: **Camp carroll** G&EE NO.: **08-037E** INSPECTOR: [redacted] 66 66

DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted]

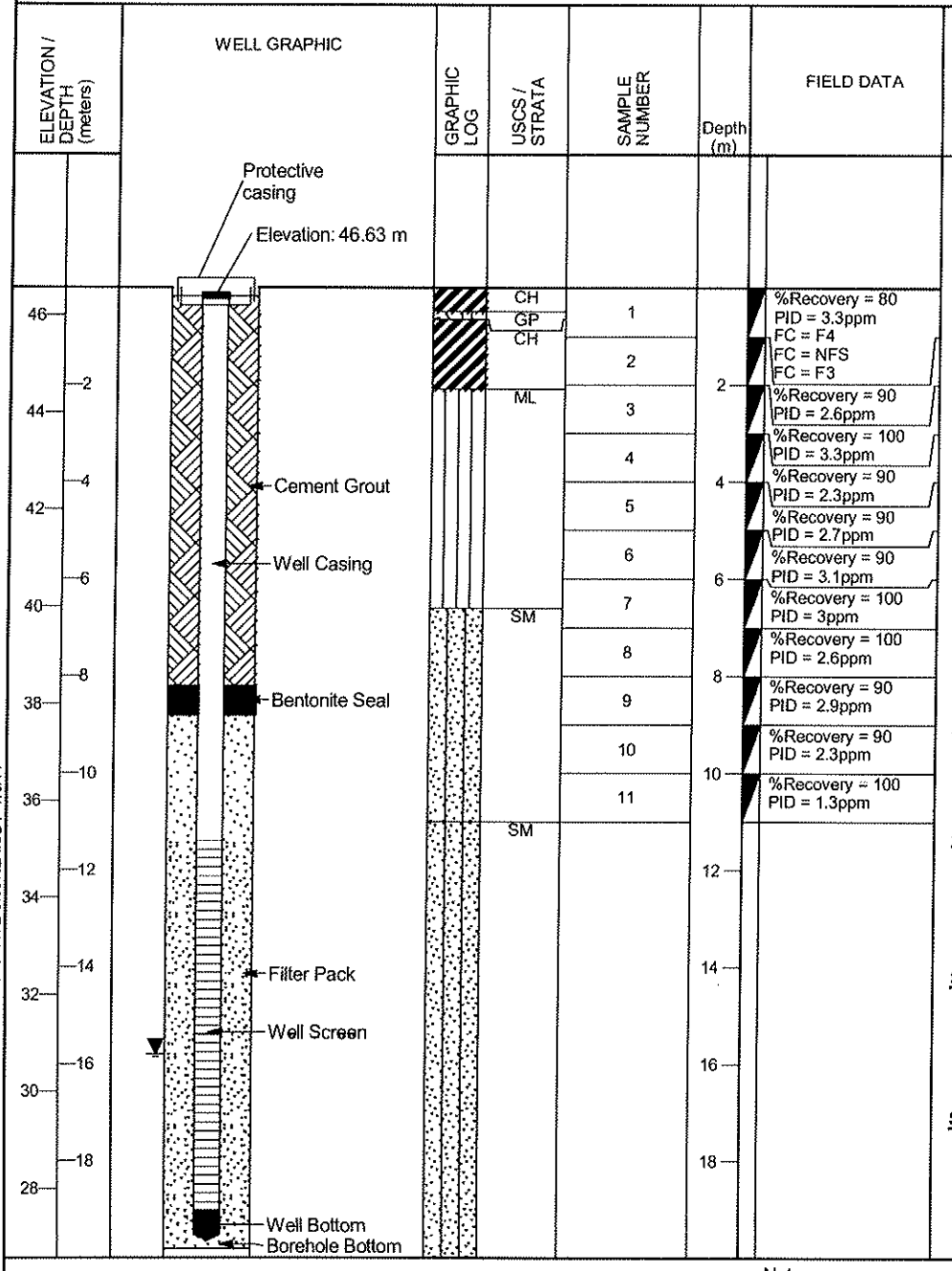
DRILLING METHOD/EQUIPMENT: **GeoProbe 6600**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **3 cm** TOTAL DEPTH: **20.0 m**

OVERBURDEN THICKNESS: DEPTH DRILLED: **20.0 m** WATER DEPTH: **15.8 m**

COORDINATES: N: **3,982,990.4** E: **446,964.5** GROUND ELEV.: **46.57 m** DATUM: **MSL**

GROUND COVER: **Grass** TOP of WELL RISER CASING ELEV.: **46.63 m**



WELL CONSTRUCTION DETAILS

PROTECTIVE CASING
Diameter: 20 cm
Type: Manhole
Interval: -0.02 to 0.18m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: -0.01 to 11.4m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 11.4 to 19.3m

WELL POINT
Type: Schedule 40 PVC
Interval: 19.3 to 19.45m

CONCRETE PAD
Diameter: 0.3m
Interval: -0.05 to 0.15m

GROUT
Type: Portland Type II
Interval: 0.0 to 8.2m
Quantity: 11 bags of 20 kg

SEAL
Type: Bentonite
Interval: 8.2 to 8.8m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 8.8 to 19.5m
Quantity: 180kg
Grain Size: 0.4-1.2 mm

Remarks:
- ▽ Ground-water level at completion of borehole 03/03/09 no water
- ▼ Ground-water level on 15.8m
- ▲ Product level on

Note:

MONITORING WELL LOG 08-037E 3565 CP CARROLL.GPJ USACE SKOREA.GDT 7/6/11

Appendix III: Field Experiment Result- Slug Test

3732.1

US Army Corps of Engineers

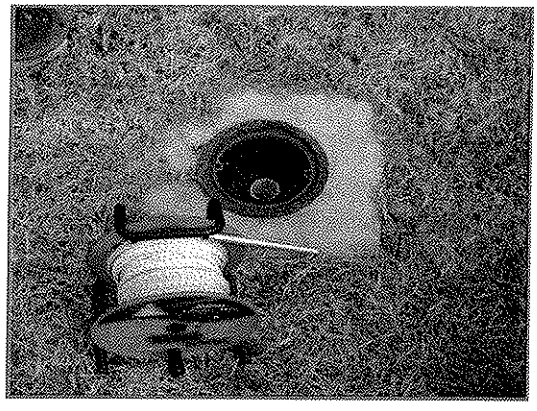
Far East District

Report

FOR

TASK ORDER NO.0014
CAMP CARROLL FIELD SLUG AIR PERMEABILITY TEST

APRIL 2010



Prepared for:

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

Contract # W912UM-07-D-0001
Task Order # 0014

Prepared by:

BEC

3233

Table of Contents

1. INTRODUCTION

1.1 Project Background

BEC has prepared this report for the FED under contract NO. W912UM-07-D-0001, Task Order No.0014. This report summarizes the result to analyze for slug and air permeability test at Camp Carroll.

1.2 Project Progress

Field tests were performed in the camp Carroll during the period of 9 November, 2009 ~ 13 November, 2009(1st) and 22 February, 2010 ~ 25 February, 2010(2^{nd}). Kinds of field test are slug and air permeability tests. The project site is a former vehicle-cutting yard (building 563) in Camp Carroll.

Hydrologic field experiments such as slug and pumping, and air permeability tests were conducted at the project site. Pumping test and air permeability tests were due to not sufficient water level draw down and no response during field experiments.

2. ANALYSIS MATHOD

2.1 Slug test

The slug test method involves the instantaneous injection or withdrawal of a volume or slug of water or solid cylinder of known volume. This is accomplished by displacing a known volume of water from a well and measuring the artificial fluctuation of the groundwater level. The primary advantages of using slug tests to estimate hydraulic conductivities are numerous. First, estimates can be made in-situ, thereby avoiding errors incurred in laboratory testing of disturbed soil samples. Second, tests can be performed quickly at relatively low costs because pumping and observation wells are not required. Lastly, the hydraulic conductivity of small discrete portions of an aquifer can be estimated (e.g., sand layers in a clay)(EPA,1994).

The most commonly used method for determining hydraulic conductivity in groundwater investigation is the Bouwer and Rice slug test shown schematic groundwater level drawdown zone through withdrawal of dummy(Hanmm et al, 2001).

3235

Bouwer and Rice's expression for hydraulic conductivity (K) is:

$$K = \frac{r_c^2 \ln(R_e/R)}{2L_e} \quad \frac{1}{T} \ln \frac{H_t}{H_0}$$

Where:

K = hydraulic conductivity [ft/sec]

R_e = filter pack (borehole) radius [ft]

R = screen radius [ft]

r_c = casing radius [ft]

L_e = length of open screen (or borehole)[ft]

H_0 = drawdown at t = 0

H_t = drawdown at t $\geq$ H_0

The simplest interpretation of piezometer recovery is that of Hvorslev(1951). The analysis assumes a homogenous, isotropic medium in which soil and water are incompressible(EPA,1994).

$$K = \frac{r2 \ln(L/R)}{2L\,T_0} \qquad for\ L/R > 8$$

Where:

K = hydraulic conductivity [ft/sec]

r = casing radius [ft]

L = length of open screen (or borehole)[ft]

R = filter pack (borehole) radius [ft]

T_0 = Basic Time Lag [sec]; value of t on semi-logarithmic plot of H-h/H-H0 vs. t, where H-h/H-H = 0.37 0

H = initial water level prior to removal of slug

3736

H_0 = water level at t = 0

h = recorded water level at t > 0

3. ANALYSIS RESULT

3.1 Information of Monitoring Wells

Next is the information is performed wells each area in camp Carroll. The test is performed by in 9 Nov.~12 Nov and chosen one well that test is possible. The depth, natural groundwater level, radius, order of wells was checked before the test. Water level measured for time after injected the dummy using a diver. If water level has been stable, withdrew the dummy so water level measured. Sometimes, rise up with diver when the dummy is withdrew that get tangled fixed each line of the dummy and diver in well. Also, water level after injected the dummy rose up more than natural groundwater level. It should pay attention to analysis of test results (Table 1).

Table 1. Information of slug test is performed wells

Site	Well No.	Time	Dummy	Well information			Remark
				D[1] (m)	WR[2] (mm)	NG[3] (m)	
VCY (B563)	B09-223	1015	injection	18.50	51	13.502	
		1027	withdrawal				
	B09-225	1006	injection	19.54	51	15.805	
		1027	withdrawal				

1) well depth, 2) well radius, 3) natural groundwater level(blg)

3.2 Description for the slug test at Sites

Generally, groundwater level showed a fluctuation by injection and withdrawal of dummy. Groundwater level data of withdrawal is less than a noise the groundwater level data of injection. Groundwater level had been stable within minutes beyond the stress(dummy). Some data of wells are distinct with other trend of wells. When the slug test analyzed the range of groundwater was assumed in the aquifer

Thc diagrams are plots of injection and withdrawal during the slug test at the site. Each plot of injection and withdrawal is the head (H/H0) against the elapsed time. The plot is drew the fitting line above interval which is consistent on head (H/H0). The analysis for slug test needs the initial drawdown data of water level. Sometimes, the initial drawdown of water level have the noise of data to be different with general trend so the initial drawdown is selected by an analyst is based the hydrogeology. The slope (Δs) to need analysis can obtain from fitting line is drew on drawdown of water level.

3737

3.2.1 Vehicle Cutting Yard

The slug test conducted B09-223 and B09-225 in the VCY site. The groundwater level of MW(monitoring wells) was checked from 13.50m to 15.81m and the depth of MW is from 18.50 m to 19.54m respectively.

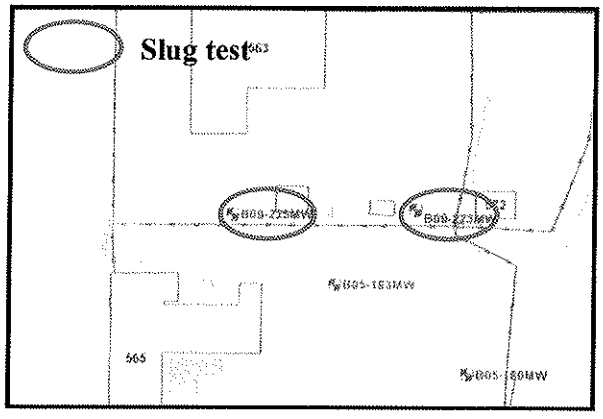


Figure 1 Location of Monitoring well conducted the slug test in the B565.

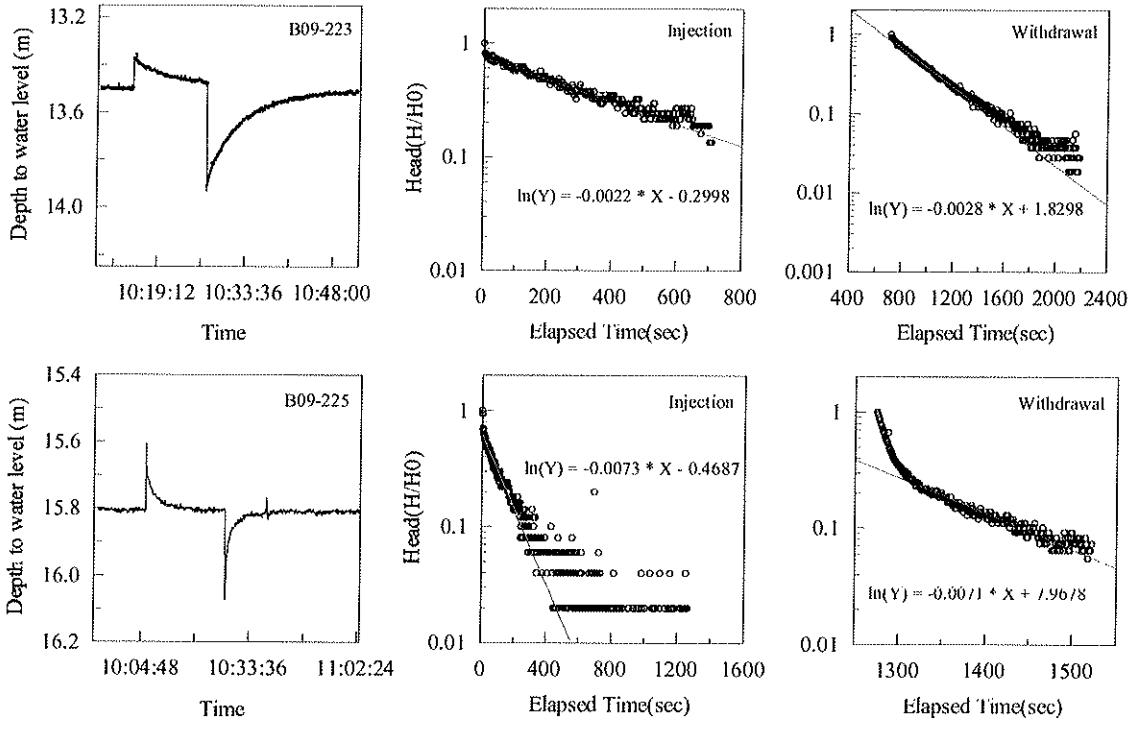


Figure 2 Curve-fitting results against elapsed time at constant slug tests in the B565.

3738

3.3 Result

3.3.1 Slug test

The hydraulic conductivity(K) is calculated by the Hvorslev and the Bouwer & Rice methods:

- 2.68E-04 / 2.62E-04 cm/sec in the VCY

Table 2 Hydraulic conductivity (K) estimated from the slug test using the Horvslev and Bouwer & Rice method

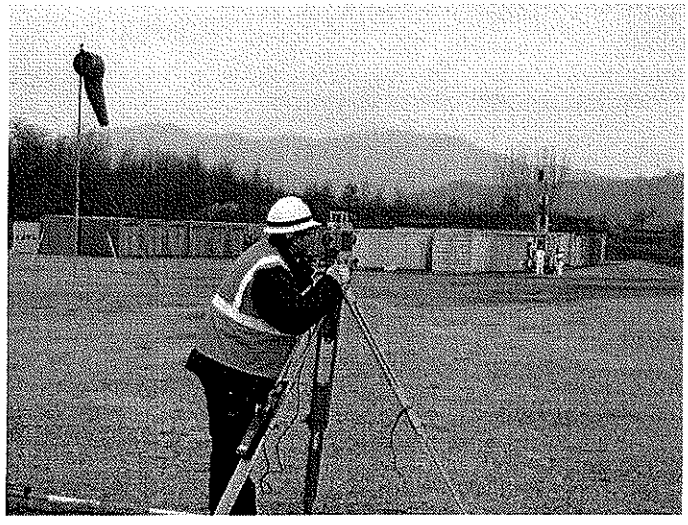
Site	Well	Dummy	K(m/sec) (Horvslev)	K(m/sec) (B& R)	K(m/day) (Horvslev)	K(m/day) (B&R)	Average K (cm/sec) Horvslev	Average K (cm/sec) B&R
VCY	B09-223	injection	1.0E-06	9.7E-07	0.08875	0.08366	1.16E-04	1.09E-04
		withdrawal	1.3E-06	1.2E-06	0.11189	0.10548		
	B09-225	injection	4.2E-06	4.2E-06	0.36696	0.36308	4.19E-04	4.15E-04
		withdrawal	4.1E-06	4.1E-06	0.35765	0.35387		

37 39

US Army Corps of Engineers
Far East District

Report for

Environmental Site Investigation at Land Farm and Area D of Camp Carroll, Republic of Korea



Submitted to:
Environmental Division of Directorate of Public Works
United States Army Garrison Daegu
Unit # 15746, APO AP 96218-5746

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

August 2011

3740

Executive Summary

This Environmental Site Investigation (ESI) was conducted at the Land Farm and Area D (LF-Area D) located within Camp Carroll of the United States Army Garrison (USAG) Daegu, Republic of Korea (ROK) during February 2009 to March 2010. Previous investigations conducted at the area showed the presence of hazardous substances in soil and groundwater from previous burial of drums of hazardous substances. The ESI at the site was conducted to better delineate the lateral extent of subsurface soil and groundwater contamination and the levels of chemicals of potential concern of the LF-Area D. The investigation was completed to allow the installation meet its obligations under DoD Directive 4715.1E to protect DoD personnel and the public from hazardous environmental substances and provide information to support the evaluation process in DoD Instruction 4718.5 for determining the need for remediation of environmental contamination.

Thirteen boreholes were completed during this ESI. A total of 49 soil samples were collected to a depth of 6 meters at 2 meter increments. All 49 samples were submitted to the analytical laboratory for analysis volatile organic compounds (VOCs) and organo-chlorinated pesticides (OC-pesticides). Twenty-six samples (0 to 2 meters and 2 to 4 meters) were submitted for analysis of total petroleum hydrocarbon (TPH), semi-VOCs, and dioxin-furans. Thirteen samples (0 to 2 meters) were submitted for analysis of metals and polychlorinated biphenyls (PCBs). Groundwater samples were collected from 16 groundwater monitoring wells and 6 water supply wells. Those samples were analyzed for VOCs and/or OC-pesticides.

VOCs were detected in some soil samples collected from each of the borehole drilled at the Area D. Toluene; 2,4-chlorotoluene; tetrachloroethene; and trichloroethene were detected in site soil samples. Other VOCs are mostly below the practical quantitation limit (PQL). Toluene was detected in 23 soil samples out of total 49. Tetrachloroethene was detected in 5 soil sample out of total 49. The 2,4-chlorotoluene and trichloroethene were detected in only one sample.

OC-pesticides were detected in soil samples collected from each of the boreholes drilled at the Area D. Lindane, 4,4'-DDE, DDD and DDT were the chemicals detected above the PQL with 4,4-DDD and DDT being the most common pesticides identified in soil samples.

A total of 26 soil samples were tested for diesel range (DRO) and residual range (RRO) petroleum hydrocarbons. Four samples were identified containing petroleum hydrocarbons. The samples with detected petroleum hydrocarbon were the shallow sample depths, indicating incidental releases from vehicle operations rather than a release from a storage tank.

No target SVOCs were detected above the PQL in soil samples collected from boreholes drilled at the Area D. Table 4-4 presents the chemical test result for SVOCs.

Twenty-six soil samples were submitted for dioxin/furan analysis. Various dioxin-furan congeners were detected in soil samples. No 2,3,7,8-TCDD was detected in soil. The International-Toxic Equivalent Factors (I-TEF) for dioxins and furans were used to calculate the International-Toxic Equivalent (I-TEQ) for each soil sample The I-TEQ is expresses the detected concentration of dioxin-furans with respect to the toxicity of 2,3,7,8-TCDD and 1,2,3,7,8-

3741

PeCDD. The I-TEQ calculated for each of the soil samples collected at the site ranges from 0.03 to 1.73.

Target metals were detected in all 13 soil samples collected from the boreholes drilled at the Area D, but the detected concentrations of metals were close to the results from a site background sample. According to the comparison with the site background sample, the metal concentrations of site soil samples have not been affected by historic activities.

No PCBs were detected in soil samples collected from boreholes drilled at the LF-Area D.

3742

Acronyms

ASTM: American Society for Testing and Materials
BEC: Beautiful Environmental Construction (BEC)
CD: Compact disk
COPC: Chemicals of Potential Concern
CSM: Conceptual Site Model
DDD: dichlorodiphenyl dichloroethane
DDT: dichlorodiphenyl trichloroethane
DPW: Directorate of Public Works
EM-Engineering Manual
EPA: Environmental Protection Agency
ESA: Environmental Site Assessment
ESI: Environmental Site Investigation
FED: Far East District
HTRW: Hazardous, Toxic, and Radioactive Waste
IDIQ: Indefinite Delivery and Indefinite Quantity
IDW: Investigation-derived wastes
I-TEF: International-Toxic Equivalent Factors
I-TEQ: International-Toxic Equivalent
LCS: Laboratory Control Sample
LF-Area D: Land Farm and Area D
LNAPL: Light Non-Aqueous Phase Liquid
MS: Matrix Spike
ND: Not detected
NELAC: National Environmental Laboratory Accreditation Conference
O/M: Operation and Maintenance
OC-pesticide: organo-chlorinated pesticides
PCB: polychlorinated biphenyl
PCE: tetrachloroethylene
PID: Photo Ionization
PQL: Practical quantitation limit
PSA: Preliminary Site Assessment
QA: Quality Assurance
QC: Quality Control
ROK: Republic of Korea
SI: Site Investigation
SSHP: Site Safety and Health Plan
SVE: Soil Vapor Extraction
TCE: trichloroethylene

3743

TPH: total petroleum hydrocarbon
TPH-D: diesel range TPH
TPH-G: gasoline range TPH
TPH-O: oil range TPH
USACE: US Army Corps of Engineers
USAG-Daegu: US Army Garrison Daegu
USFK: US Forces Korea
UTM: Universal Transverse Mercator
VOCs: volatile organic compounds
WGS: World Geodetic System
WP: Work Plan
ZVI: Zero Valent Iron

3744

Table of Contents

3745

3746

List of Table

3747

List of Figure

3748

Appendices

I : Soil Borehole Logs
II : Monitoring Well Construction Logs
III : Hydrologic Test Result
IV : Chemical Data Quality Discussions

1. Introduction

This report describes the work results obtained from the Environmental Site Investigation (ESI) conducted for the Land Farm and Area D, which are located at the central eastern portion of Camp Carroll.

This ESI project was conducted by US Army Corps of Engineers, Far East District (FED), with support from FED's Environmental Indefinite Delivery and Indefinite Quantity (IDIQ) contractor Beautiful Environmental Construction (BEC). This report was developed in accordance with industry standards and US Environmental Protection Agency (EPA) guidelines for sampling and analysis. All field and analytical work were conducted according to the Work Plan (WP) and Site Safety and Health Plan (SSHP) developed by FED for this project.

1.1. Project Authority.

FED was authorized by the US Army Garrison Daegu (USAG-Daegu) Directorate of Public Works (DPW), US Forces Korea (USFK) to conduct work on 30 April 2008 at Land Farm and Area D through MIPR 8GDBPENV06.

1.2. Project objectives

The overall objective of this ESI was to delineate the nature and extent of contamination that had a potential to affect human health. The project objectives were developed based upon the previous investigation result by Samsung 2004. The chemicals of interest were selected based on those reported in the 2004 result.

The following specific objectives were addressed during this ESI for Land Farm and Area D:

- Assess the presence of total petroleum hydrocarbons (TPH), volatile organic compounds (VOCs), semi-VOCs, polychlorinated biphenyl (PCB), metals, dioxins, and organochlorinated pesticide (OC-pesticide) in subsurface soil, and VOCs and semi-VOCs for groundwater.

- Assess the potential migration of VOCs from groundwater at the site to nearby operating drinking water supply wells.

1.3 Regulatory Considerations

The release of hazardous substances by DoD activities to the environment has potential implications for health and well-being of DoD personnel (including dependants) on the installation and the public living and working adjacent to the installation. The Department of Defense (DoD) Directive 4715.1E titled "*Environment, Safety, and Occupational Health (ESOH)*" establishes policies for all DOD components world-wide regarding environment, safety, and occupational health (DoD, 2005). DOD 4715.1E states it is DoD policy to protect DoD personnel from accidental death, injury, and occupational illness and to protect the public from risk of death, injury, illness, or property damage because of DoD activities. Consequently, installations have an obligation to identify potential effects to DoD personnel and the public when a release of hazardous substances is discovered. Once the nature of the contamination is

3750

determined DoD Instruction 4715.8 titled "*Environmental Remediation for DoD Activities Overseas*" describes the policy and procedures for remediation of environmental contamination on DoD installations and facilities located outside the US (DoD, 1998). According to this document, remediation of environmental contamination is required when

1. A known imminent and substantial endangerment to human health and safety due to environmental contamination that was caused by DoD operations and that is located on or is emanating from a DoD installation or facility.
2. After consultation with the DoD Environmental Eecutive Agent, the in-thater commander of the DoD Component determines additional remediation of environmental contamination is required to maintain operations or protect human health and safety.
3. International agreements require the United States to fund environmental remediation.

In Korea, DoD Instruction 4715.8 is implemented through US Forces Korea Regulation 200-1 titled "United States Forces Korea Remediation Regulation". Other regulatory guidance for environmental standards in Korea is contained in US Forces Korea Pamphlet 200-1 titled "*Environmental Governing Standards.*"

3751

2. Site Description and History

2.1. Camp Carroll

Camp Carroll is a U.S. Army Installation located adjacent to the village of Waegwan in the south-central portion of Korea (Figure 2-1). 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 base is to serve as a staging facility and a storage and maintenance depot. 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 north-south approximately 0.5 kilometers west of Camp Carroll. The Land Farm and Area D sites are located at the central eastern installation boundary Camp Carroll, next to the H805 helipad. Figure 2-2 presents the location of Land Farm and Area D at Camp Carroll.

2.2. Land Farm

The Camp Carroll Land Farm consists of three engineered units for treatment of contaminated soil. Two of the units are treatment beds, referred to as Bed #1 at east and Bed #2 at west and the third unit is a water retention pond. 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 total Land Farm facility is approximately 9,100 square meters.

Camp Carroll environmental DPW personnel suspect that contaminated soil and material from Area 41 were disposed of in the area now occupied by the Land Farm. Their suspicions are based on the fact that contaminated soil and waste materials, such as one-gallon cans were uncovered during the excavation and construction of Bed #1 in 1995 (northwest corner of Bed #1). The Land Farm is also located near to Area D.

2.3. Area D

Area D is a former hazardous waste disposal area. Numerous hazardous materials were disposed in this disposal 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 disposal area dimensions were approximately 150 meters (m) by 75 m in area; and 6 m to 9 m deep.

Reportedly, much of the disposal area material and surrounding soil was excavated between 1982 and 1983 and placed into 55-gallon drums. The fate of the excavated drums is unknown. 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.

2.4. Summary of Previous Investigations

The two areas to be investigated have been previously evaluated for environmental conditions during an environmental site assessment (ESA) and preliminary site assessment (PSA) as follows:

Land Farm:

ESA by FED in December 2004

Groundwater monitoring well construction in Land Farm in 2007.

Soil sampling to support of construction of treatment bed by FED in February 2008

Excavation of buried construction wastes, drums and cans during excavation for constructing a new treatment bed by the contractor in March 2008

Area D:

Woodward Clyde in 1992

Site Investigation by Samsung in July 2004

2.4.1. Land Farm

In 1992, monitoring well MW-23 was constructed by Woodward-Clyde personnel approximately 140 meters west of the Land Farm facility. Groundwater sample was collected from the well. No VOCs, SVOCs or organophosphorus (OP)-pesticides were detected in the groundwater sample collected from the well in 1992.

In 2004, results of soil sampling during the ESA showed site soils were contaminated with VOCs. Most of the detected VOCs were solvent-related chemicals. VOC contamination was detected as deep as 6 to 8 meters below ground surface. In addition, several 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 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. Groundwater contamination could pose a threat to human health, because ground-water supply wells are used for Camp Carroll's potable water supply.

In 2007, soil and groundwater were sampled and analyzed by FED to determine the level of chemicals potentially from the use of treatment facilities. Results showed there were no chemicals released into the environment from the treatment bed in use. However, results of soil sampling showed that concentrations of VOCs were present, including PCE and TCE. Mixed TPH of JP-8, diesel and oil was identified from one soil boring with the concentration of 10,000 mg/kg. Groundwater sampling result indicate the presence of VOCs, including PCE and TCE. Concentrations of arsenic, lead and OC-pesticide were also detected in groundwater samples.

In 2008, during soil excavation in support of a new treatment bed #2, approximately 2,200 cubic meters of contaminated soils with various chemicals were excavated and stockpiled within the Land Farm facility. In association with the contaminated soil, buried materials were uncovered such as 55gallon drums, 5 gallon cans and construction debris. Most 55 gallon drums were crushed and empty. Despite the removal and excavation activities, residual amounts of contaminated material likely remained. Figure 2-3 to 2-4 summarizes the previous investigation results at Land Farm.

2.4.2. Area D

In 2004, Samsung Co. conducted site investigation (SI) at Area D, and reported that the soil contained numerous contaminants including TPH-G, TPH-D, TPH-O, VOCs, SVOCs, pesticides, metals, and dioxins. The investigation reported that several soil contaminant concentrations exceeded EPA Region IX Preliminary Remedial Goal screening criteria. Groundwater samples obtained from Area D monitoring wells contained concentrations of TPH-G and TPH-D, VOCs, SVOCs, pesticides, metals, and dioxins. Figure 2-5 summarizes the previous investigation results at Area D.

2.5. Identification of Data Needs

2.5.1. Land Farm

Previous environmental investigations at the site found concentrations of VOCs, OC-pesticides, and metals in soils from the site subsurface soil and groundwater. During excavation in support of treatment bed #2 construction, buried drums and cans were uncovered from the bed. Although no chemical data are available, the removal activities of buried drums and cans containing various chemicals are to be believed as a source for soil and groundwater contamination. Groundwater quality is a primary concern for the installation because it is the source of drinking water. Table 2-1 summarizes the groundwater test results available for TCE collected from the supply wells and some buildings following treatment by the aeration tower that was installed in the early 1990. The concentration ranged from not detected (ND) to 1,229 μg/Liter. The highest concentration was found at the Well #15-286 located about 400 meters west of the Land Farm and Area D. Based on the distribution of TCE detected in the supply wells, the TCE contamination in supply wells is not likely to be a single common source. Figure 2-6 shows the location of supply wells with the chemical test data (the highest number) presented in Table 2-1 at Camp Carroll.

This ESI at the Land Farm site will focus on the groundwater quality. To evaluate the groundwater quality of the supply wells in association with the groundwater quality at the Land Farm area, three groundwater monitoring wells (estimated 40 meters deep) were installed between the supply wells and the Land Farm to monitor the gradient of groundwater quality from the Land Farm to the supply wells. The contaminants of intererst in this ESI at Land Farm are VOCs in groundwater.

2.5.2. Area D

The SI for Area D by Samsung in 2004 evaluated groundwater conditions and identified site soil contamination, but did not evaluate the vertical extent of contamination. This ESI at Area D expanded the SI and determined the vertical and the lateral extent of contamination in the

3753

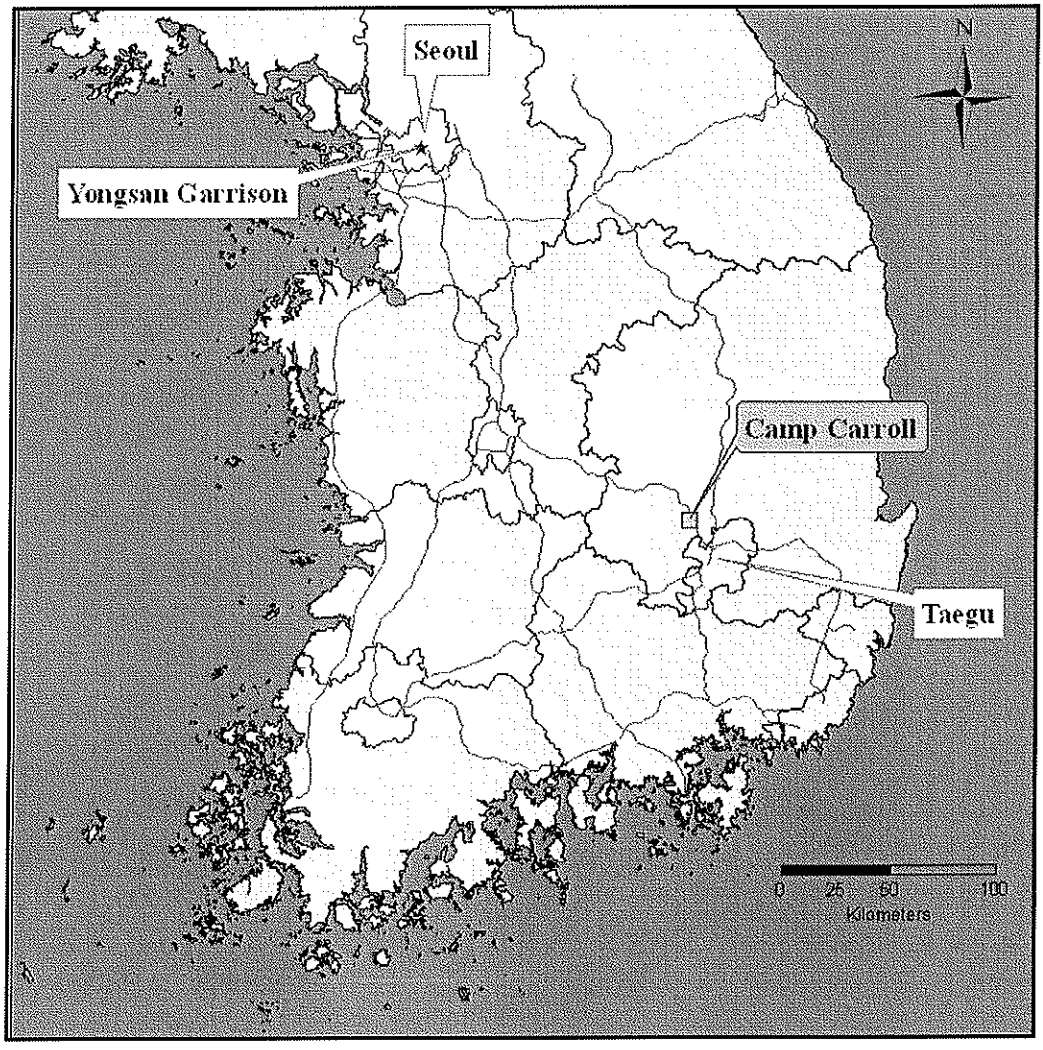
subsurface soil. In addition, groundwater monitoring wells were installed to determine the groundwater condition. The contaminants of interest for this ESI at Area D focuses on TPH, VOCs, semi-VOCs (SVOCs), OC-pesticides, metals, and dioxins in soil; and VOCs and OC-pesticides in groundwater.

Table 2-1 Trichloroethylene (TCE) Concentrations (µg/L) in Groundwater Sample from the Production Wells at Camp Carroll from 1991 to 1996. Drinking water standard of TCE at US Army installations is 5 µg/L (USFK 2004).

Collection Point	28-May-96	23-Apr-96	27-Feb-96	23-Jan-96	4-Dec-95	7-Nov-95	19-Sep-95	8-Aug-95	11-Jul-95	9-May-95	7-Mar-95	2-Nov-94	24-Oct-94	9-Sep-91
Well #1	4.4	-	5.6	5.9	-	-	-	-	-	-	-	-	3.2	5.66
Well #2	21.4	-	13.8	-	-	-	-	-	-	-	-	-	20.4	3.39
Well #3	<0.5	-	<0.5	<0.5	-	-	-	-	-	-	-	-	<0.5	22.22
Well #6	103.1	-	63.9	72.7	-	-	-	-	-	-	-	-	36.8	-
Well #8	<0.5	-	0.5	-	-	-	-	-	-	-	-	-	<0.5	<0.2
Well #10	-	-	-	<0.5	-	-	-	-	-	-	-	-	<0.5	<0.2
12-247	250.7	-	240	368.1	-	-	-	-	-	-	-	-	204.1	116.97
13-279	-	-	-	-	-	-	-	-	-	-	-	-	252.4	125.1
14-283	8.1	-	15.2	8.8	-	-	-	-	-	-	-	-	26.1	-
15-286	1229	-	188.6	217.8	-	-	-	-	-	-	-	-	161.4	-
16-289	22.2	-	28.7	29.5	-	-	-	-	-	-	-	-	44.4	-
Well #17	-	-	-	4.4	-	-	-	-	-	-	-	-	-	-
Well #18	<0.5	-	0.6	<0.5	-	-	-	-	-	-	-	-	-	-
Aeration Tower (all mixed)	79.3	56.6	36.7	92.5	89.4	71.1	64	19	39.4	58.9	34.2	62.2	58	
S-262 Barracks	-	-	-	-	1	1.1	1.6	1.1	4	1.4	0.8	1.7	0.6	-
S-108 BEQs	1.3	0.7	1.3	0.9	0.8	0.9	1.6	1.1	3.3	1.5	1.1	1.7	-	-
S-627 Distribution Room	0.7	1.2	1.2	0.9	0.8	1.1	1.4	1	2.8	1.5	0.7	1.8	0.5	-
S-111 Snack Bar	1.3	-	1.3	1	-	-	-	-	-	-	-	-	-	-
S-117 WCC	1.2	-	1.3	-	-	-	-	-	-	-	-	-	-	-
S-101 BOQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-

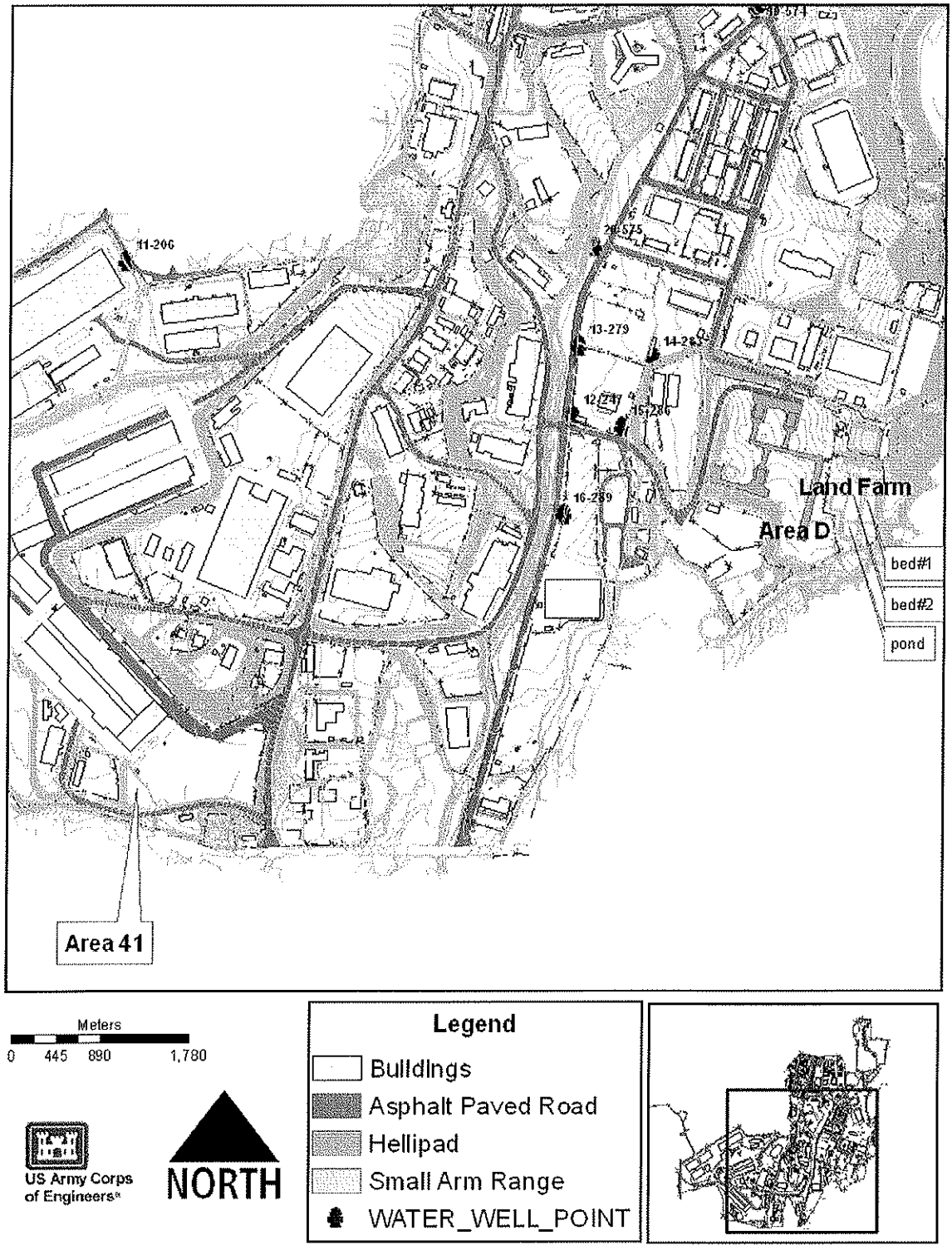
3755

Figure 2-1. Location of Camp Carroll in Republic of Korea.



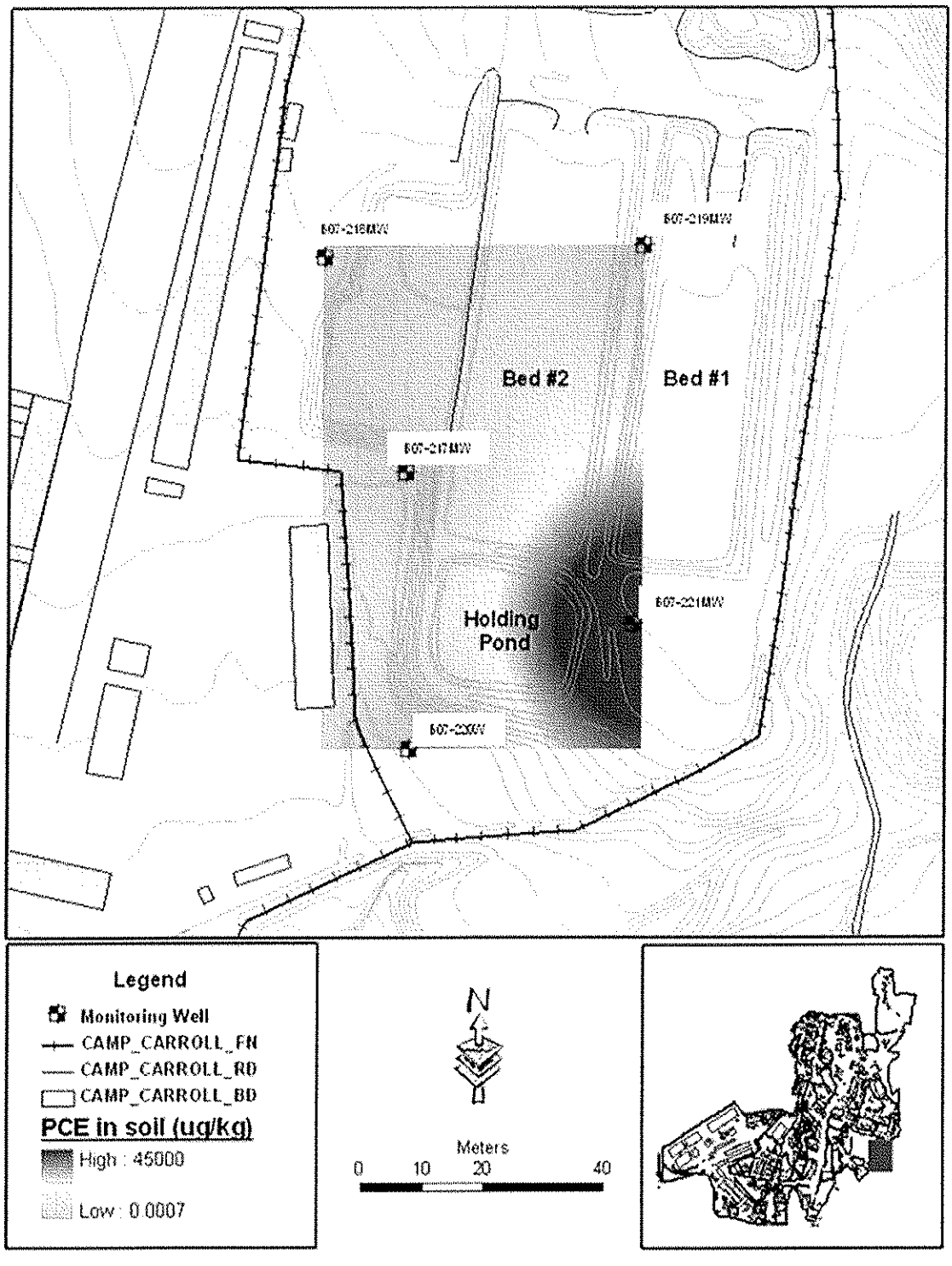
3756

Figure 2-2. Location of Land Farm and Area D at Camp Carroll.



3757

Figure 2-3. Tetrachloroethene (PCE) in the Subsurface Soil at Land Farm by FED in 2007.



3758

Figure 2-4 Groundwater gradient at Land Farm Area by FED in 2007.

WL AMSL- water level above mean sea level

3759

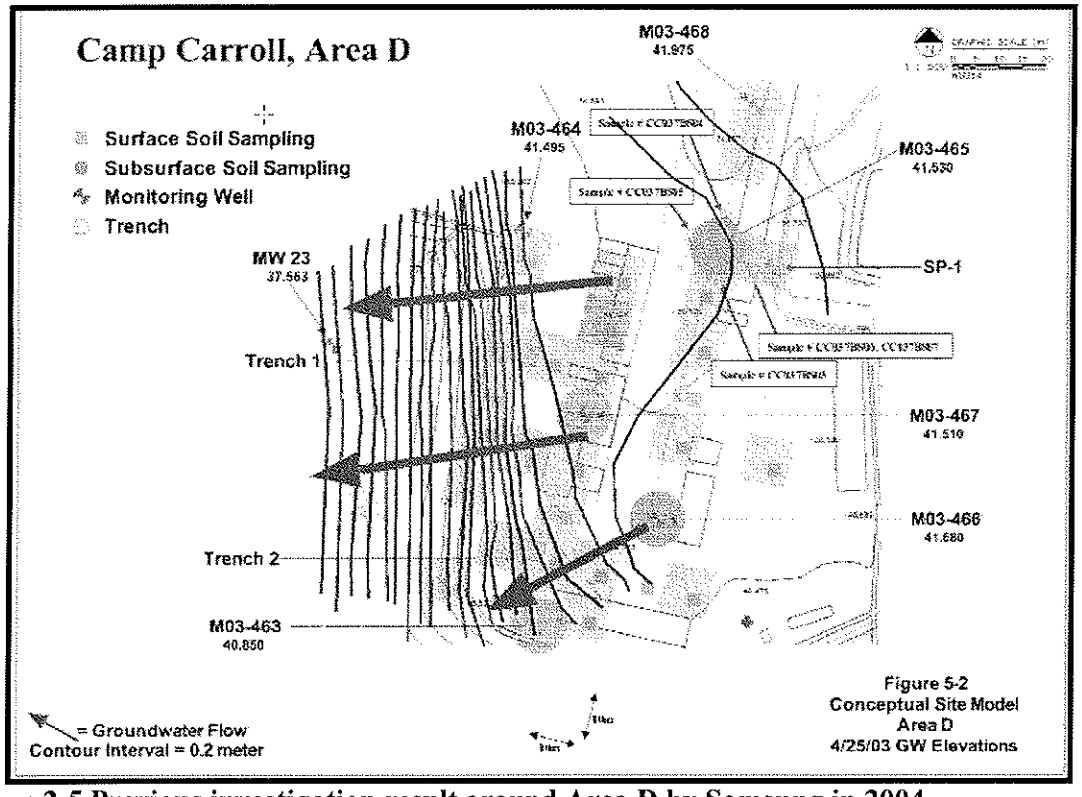
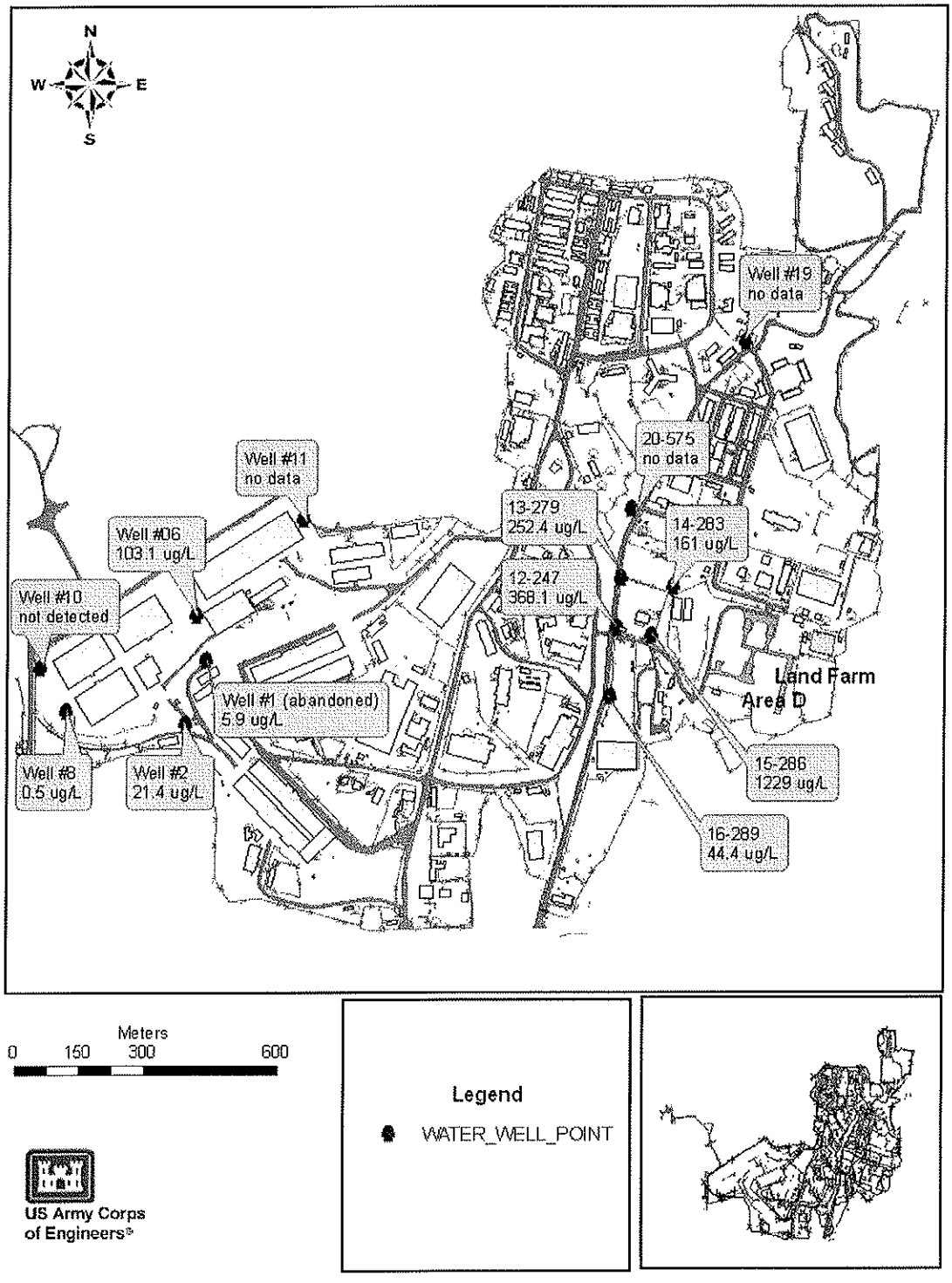


Figure 2-5 Previous investigation result around Area D by Samsung in 2004.

Presenting the groundwater flow direction with the arrows, and color shading indicates the locations that have been affected by chemicals of concern.

3760

Figure 2-6 TCE test results for Groundwater of the Supply Wells at Camp Carroll during 1991~1996.



3761

3. Field Activity

3.1. Field Activities

Field procedures for this ESI followed the description in the project Work Plan. A total of three groundwater monitoring wells were installed in order to assess a groundwater quality for Land Farm. A total of thirteen boreholes were drilled for soil sampling at Area D and two of those were converted to groundwater monitoring wells.

Since the Land Farm and Area D are located physically next to each other, for convenient, hereafter the project site is referred to "**LF-Area D**". All sample collection and analyses were conducted in accordance with industry standard practice and in strict accordance with the requirements of the project specific Site Safety and Health Plan. The resultant data was used to help determine the spatial extent of contamination and whether significant subsurface contamination with the chemicals of concern at the site is present in soil and groundwater of the project site. The analytical results were used to conduct a human health risk assessment with a comparison to the Environmental Action Levels. The project chronology is summarized in Table 3-1.

3.2. Borehole drilling and soil sampling

Borehole locations were chosen prior to actual field work to provide areal coverage based on the existing available data. During performance of the field work, some proposed borehole locations were moved to avoid underground and aboveground utilities and for drill rig accessibility. The number of subsurface soil collection intervals was determined by target depth, apparent contamination, depth to shallow groundwater, and depth to bedrock. Soil samples submitted for laboratory analyses were chosen based on field observations and a Photo Ionization Detector (PID) reading to determine the level of concentrations of the chemicals of concern. Soil samples were collected from every two meters interval to the bottom of each borehole to describe soil visual properties and to submit the samples to the laboratory. Two boreholes were converted into groundwater monitoring wells (B09-193MW and B09-221MW). Those wells are to monitor groundwater quality and to measure the groundwater level.

Borehole drilling for soil samples was conducted using a direct push soil probing machine (GeoProbe). The GeoProbe minimizes cuttings and creates a smaller diameter borehole that is easily grouted/filled after all subsurface soil samples are collected. Using a GeoProbe, continuous soil cores were collected from the ground surface to the target depth. Subsurface soil sample cores were collected 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 was pushed through the desired depth interval, the sampler was extracted from the hole and the plastic liner, containing the soil sample, was removed from the barrel sampler. The discrete soil sample required for chemical analyses (e.g., TPH) was collected from the desired depth by retrieving it from the appropriate interval of the plastic liner. Figure 3-1 presents the soil boring location, Appendix I presents the soil bore logs.

A portion of each recovered soil sample was placed into a sealable plastic bag and the headspace was analyzed for VOCs with a PID. All soil samples were subsequently placed in zip-lock bags and kept in an ice-cooler for preservation until field screening tests were performed

if required except VOCs sample. Soil sample for VOCs a analysis was collected using a Terra Core kit with fixed 5-g volume, and immediately put in methanol preservative 40 ml jar. Information on the sample container labels included project number, installation name, analysis required, sample identification number, depth, name of sample collector, and date and time of collection.

3.2.1. Headspace Analysis

Field sampling included the collection of representative headspace samples from each sampling area of concern. Soil samples were collected at periodic depths for headspace analysis to provide an indication of the vertical extent of VOC contamination within each soil core. Headspace samples were placed into individual sealable plastic bags. Then, the probe tip of a PID was inserted into the plastic bag to take a reading of the concentration of volatile contaminants present in the sample headspace.

After completion of borehole drilling, the top of borehole was plugged to keep the borehole gas inside the hole and take a measure using a PID. The PID readings were recorded by field personnel and ultimately transferred to the electronic boring log.

3.2.2. Soil Sample Identification

Each soil sample has a unique identification number that is consistent with borehole and monitoring well IDs used in previous investigation. The sample identification format provides general information about the boring type, year of investigation, and depth interval. The sample identification number used in this project follows this format: B09-XXX-S#, where

B indicates that the sample came from a soil boring

09 is the year in which the soil boring was drilled (i.e. 2009)

XXX is the sequential soil boring number

S indicates soil sample

is the sequential sample number, from top-down in the boring

MW instead of S# indicates monitoring well after soil boring.

3.3. Groundwater Monitoring Well Construction.

3.3.1. Monitoring well construction

A groundwater monitoring well installation was utilized two different rig types depending upon the well depth. In case of deep well drilling through the bed rock a FED-owned DESILTECHT40KW Air Percussion Down-the-Hole Hammer drill rig was utilized for three monitoring wells (B09-176MW ~ 178MW). Relatively shallow monitoring wells were installed after completion of borehole drilling using a Direct Push GeoProbe. The depth of the wells and the length of the screen intervals varied depending on the site specific characteristics observed during soil boring. The well locations were chosen based on their location relative to known groundwater contamination as well as getting additional areal coverage in relation to the existing monitoring wells.

In case of FED-owned Drill Rig, a 25 centimeter (cm) diameter air percussion hammer was used to drill the hole as slightly larger diameter (20 cm) temporary steel casing is pushed and hammered into the subsurface to hold back the overburden and weathered bedrock. After the hammer has reached the target depth, it was removed from the hole. The monitoring well casing material was then placed inside the temporary steel casing.

In case of GeoProbe a 12-cm diameter air percussion hammer was used to drill the hole as slightly larger diameter (14-cm) temporary steel casing is pushed and hammered into the subsurface to hold back the overburden. After the hammer has reached the target depth, it was removed from the hole. The monitoring well casing material was then placed inside the temporary steel casing. The steel casing was gradually removed from the hole as the annulus was filled with medium grained sand filter pack, bentonite, and grout.

Ground-water monitoring well construction materials include 5.04-cm inside diameter (ID) threaded Schedule 40 polyvinyl chloride (PVC) solid pipe and slotted screen. Solid 5.04-cm ID schedule 40 PVC pipe with threaded ends was used from approximately 10-cm below ground surface (bgs) to a depth of approximately 3-meter above the level when groundwater encounters first during soil boring. A 0.254-mm slotted PVC well screen was threaded onto the bottom of the solid well-pipe to the base of the borehole. A PVC well point was screwed to the bottom of the well screen and a well cap was secured to the top of the well pipe. The annular space around the well from the bottom of the borehole to a minimum of 50-cm above the top of slotted section was filled with clean medium-grained silica sand (0.4-1.2 mm). A 30-cm thick seal of bentonite pellets was placed above the sand pack, and the bentonite pellets are hydrated either by water inside the borehole from cascading perched water or using a known clean water source. The remainder of the hole was filled with a Portland Type I cement grout to just below the frost line. Once the grout cured, concrete was used to fill the rest of the annulus around the well pipe. The wells were then completed with a flush-mount and concrete pad. Groundwater monitoring well location is presented in Figure 3-1 and the construction process was logged and placed in the Appendix II.

3.3.2. Monitoring Well Development.

After installation, all wells were fully developed. The objectives of well development were to (1) remove sediment that had settled inside the well during construction; (2) remove all water that may have been introduced during drilling and well installation; (3) remove very fine grained sediment in the filter pack and nearby formation so that groundwater samples would not be turbid and well silting does not occur; and (4) improve the flow into the well from the adjacent formation, thus yielding a representative groundwater sample and an accurate water level measurement.

Well development consisted of surging by a surge block and pumping out the tubid water using BEC's vacuum truck until a noticeable reduction in sediment occurred in the discharged water. This development continued for a minimum of five well volumes of pumped water and continued until the water was visually clear or the site geologist determined that no further development is practical.

3.3.3. Groundwater Sampling.

The groundwater sampling was conducted in accordance with the protocol described in the project work plan. Prior to sampling, wells are checked for the presence of any floating product with an electronic oil/water level indicator probe. Then, the well was purged by removing a minimum of three times the standing volume of static water present in the well.

Groundwater samples from the six supply wells were also collected and analyzed for VOCs. Sampling from the supply wells were conducted after discharging water for about 10 minutes through the sampling tab. A low pressure pump was utilized for micro purging and sampling from the monitoring wells.

The groundwater parameters such as pH, temperature, specific conductance and turbidity of the removed water were monitored during the purging and sampling process. Groundwater stabilizing criteria were adopted established in American Society for Testing and Materials (ASTM) D6671-02: pH +/- 0.2, specific conductance +/- 3%, temperature +/- 0.5°C, and turbidity +/- 3%. The groundwater was sampled using a low pressure bladder pump and dedicated tubing for each well sampled. Table 3-2 presents the groundwater parameter during sampling and those during well development were also included. Groundwater temperature varies during the year, which is the highest during August to September sampling period. The pH variation shows the relatively high number during August to September, which is likely to be similar to the groundwater temperature variation. A couple of groundwater samples showed negative oxidation-reduction potential values during sampling at B03-466MW, B03-467MW, 14-283 and 15-286.

The collected water samples were placed into laboratory-grade, specially cleaned sample containers, and then placed immediately into a cooler with ice for preservation below 4°C prior to arrival to the analytical laboratory. All samples were transported to the laboratory accompanied by chain-of-custody sheets thru the priority mail service company.

3.4. 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, if necessary the elevations of buildings, any significant utilities and fuel storage tanks. All elevation measurements were expressed in meters above mean sea level, and World Geodetic System 84 Universal Transverse Mercator (WGS 84 UTM) Zone-52 grid system was applied for longitude and latitude systems. 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. Table 3-3 presents the borehole and monitoring well coordinates surveyed.

3.5. Investigation Derived Wastes

Waste materials, or investigation-derived wastes (IDW), that required management and disposal during the ESI field work included concrete and asphalt debris, petroleum contaminated soil, used disposable sampling equipment, well development water, decontamination 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 transported to BEC's field facility located in Yojoo, Kyeonggi-Do at the end of each week for treatment and disposal.

There was very little concrete or asphalt debris generated during the course of the ESI field work. The concrete and asphalt that was generated in order to expose the underlying soil was bagged along with the soil cuttings from the respective borehole. BEC personnel then transported the bags to their field facility for disposal.

3.5.1. Contaminated Soil

All soil cuttings retrieved during boring were bagged on-site in tight knit, woven synthetic bags. Apparent petroleum contaminated soils in the cuttings were not segregated from uncontaminated soils. All soil waste generated during this investigation was transported for treatment at BEC's off-site remediation facility located in Yojoo, Kyeonggi-Do. A non-hazardous waste manifest was used to document the transport of the contaminated soil to the treatment facility.

3.5.2. Well Development and Decontamination Water

Water from decontamination activities was pumped into a BEC vacuum truck at the end of each day and disposed of at the oil/water separator system at the Land Farm facility of Camp Carroll. Groundwater generated during well development and pump test activities was pumped into BEC's larger pump truck, and also disposed of at the same system.

3.5.3. Site Restoration

Borings were backfilled with bentonite pellets and the surfaces sealed with concrete which was backfilled flush to the existing surface grade. Monitoring wells installed during the project were flush-mounted and pose no impediment to vehicular or foot traffic. All mud and soil cuttings generated in the vicinity of each soil boring and monitoring well were cleaned up by field personnel immediately following the completion of the task.

3.6. Supplemental Site Characterization

Test was performed on the aquifer matrix to determine the saturated and air permeability of the impacted aquifer material present at the site. In addition, soil samples were collected for chemical and microbial analysis that are useful for determining whether the present physical/chemical/biological condition of the aquifer is conducive for natural degradation of the diesel and gasoline contamination that is present at the sites.

3.6.1. Slug Test

The hydraulic characteristics of the aquifer underlying the site were determined by performing slug tests on the monitoring wells installed in the previous investigations and during this study. The hydraulic conductivity, K, of the aquifer was calculated using slug tests recovery measurements that were performed on all monitoring wells during 9 ~12 November 2009. After the completion of well purging work, a slug with an approximate volume of 2.5 liter was put in the wells. The drop down water level after slug into the wells was recorded using a pressure

transducer data logger. Also the rise in water level after removing the slug from the wells was recorded in same way. Measurements were collected until the water level within the monitoring well returned to within approximately 3 centimeters of the original water level. The original water level in the well prior to the tests was measured with a Solinst electronic oil/water interface prove. Appendix III presents the summary of test procedure and slug test result.

3.6.2. Aquifer Pumping Test

A pumping test was conducted to obtain information regarding the aquifer characteristics at the site. The aquifer at the site is formed within the open bedrock fractures underneath overlying soil layers. The pumping test and recovery period measurement was conducted on 24 ~ 25 February, 2010. The test was comprised of pumping a volume of groundwater from monitoring well B07-217MW at a controlled rate varying between approximately 1.2 Liter/min while monitoring the water levels within the pumping well and four observation wells (B07-874MW, B09-252MW, B09-256MW, and B01-788MW). Information was collected during the pumping test and subsequent recovery period using pressure sensitive transducers connected to data loggers. Hydraulic head, temperature, and specific conductance of the groundwater were recorded during the test. The pumping test data was interpreted using the Cooper-Jacob's method (1946) method within the computer analysis program AQTESOLV. Appendix III presents the summary of test procedure and aquifer pumping test result.

3.6.3. Air Permeability Test.

Air Permeability is an integrated measure representing the complex relationship between the geometry of the pore system and hydraulics of the flow of air through that system. Permeability is not measured directly; rather, it is calculated by inverting an assumed model populated with measured state data (i.e. flux and pressure). For this investigation, permeability was determined by applying a pressure gradient across the project site by use of a vacuum truck.

In situ air permeability test data were performed at the site by placing a blower on a setup monitoring well and measuring the time varying pressure responses at monitoring wells adjacent to that central well. The decision was made to perform the air permeability test by blowing out of the well by applying a vacuum rather than injection to prevent if any contaminants spread over due to air introduction into well.

A constant pressure was applied to the injection well for no longer than 25 minutes, and changes in pressure at adjacent wells were recorded at various time intervals on a roughly logarithmic basis. The measured changed in air pressure at the various monitoring wells spaced varying distance from the injection well were evaluated using analytical solutions for aquifer pumping tests that have been modified for vapor flow conditions. Appendix III presents the result of air permeability test at the site.

3.6.4. Nutrient and Microbial Sampling

A total of 13 soil samples were collected, with one sample from each borehole. Those samples were shipped to the National Instrumentation Center of Environmental Management (NICEM) at Seoul National University. The samples were analyzed for biological and chemical properties relevant to potential natural degradation of site contamination.

Table 3-1. Project Chronology of ESI at LF-Area D of Camp Carroll.

Task	Date Performed
Request a site digging permit and get approval	February 3 and 16, 2009
Borehole drilling, soil sampling and groundwater monitoring well installation	February 17~ March 13, 2009
Well development	February 23 to March 3, 2009
Groundwater Sampling	August 31 ~ September 4, 2009
Hydrologic slug test	November 9-12, 2009
Hydrologic pumping test	February 24~25, 2010
Air permeability test	March 17, 2010

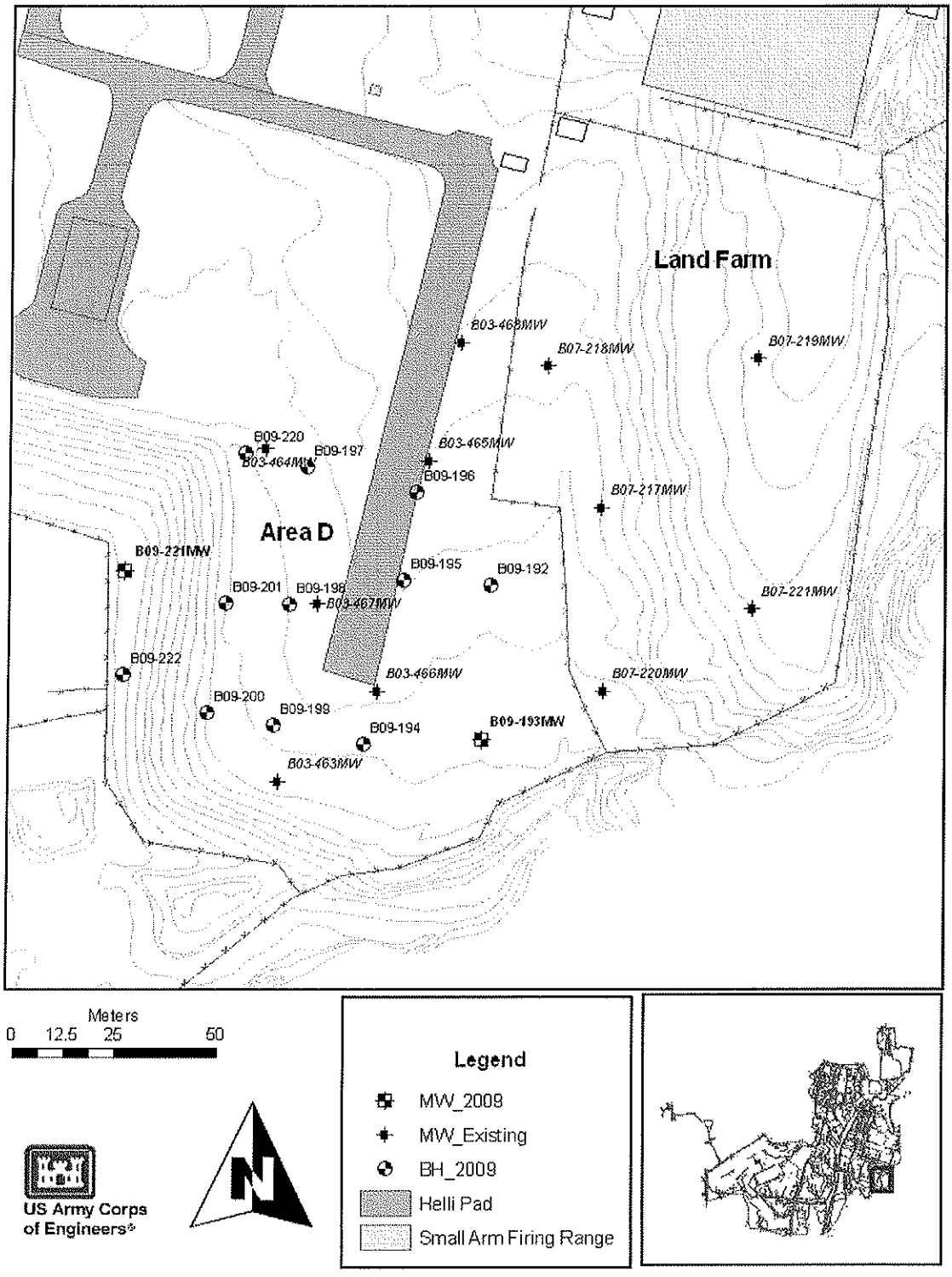
3769

Table 3-2. Topographic Survey Result for Borehole and Monitoring Well at LF-Area D of Camp Carroll.

Site Location	BH_ID	Easting	Northing	Elevation*	Top of Pipe	Year Constructed
Land Farm	B09-176MW**	447546.25	3983365.34	44.29	44.27	2009
	B09-177MW	447577.57	3983464.43	47.20	47.19	2009
	B09-178MW	447590.41	3983538.60	49.12	49.09	2009
	B07-217MW	447789.23	3983349.44	50.99	50.92	2007
	B07-218MW	447775.80	3983384.33	51.83	51.77	2007
	B07-219MW	447828.37	3983386.25	55.43	55.41	2007
	B07-220MW	447789.89	3983304.56	49.74	49.73	2007
	B07-221MW	447827.00	3983324.75	54.61	54.59	2007
Area D	B09-193MW	447759.92	3983292.52	49.27	49.28	2009
	B09-221MW	447671.06	3983334.28	42.98	46.22	2009
	B03-463MW	447709.20	3983282.40	48.74	48.55	2004
	B03-464MW	447705.50	3983364.10	49.92	49.79	2004
	B03-465MW	447746.40	3983361.10	50.99	50.90	2004
	B03-466MW	447734.10	3983304.60	49.72	49.58	2004
	B03-467MW	447718.70	3983326.00	79.93	49.79	2004
	B03-468MW	447754.30	3983390.10	51.55	51.41	2004
	B09-192	447761.76	3983330.29	49.800		2009
	B09-194	447730.65	3983291.25	49.40		2009
	B09-195	447740.11	3983331.66	49.56		2009
	B09-196	44743.40	3983353.04	49.54		2009
	B09-197	447715.86	3983359.47	50.11		2009
	B09-198	447711.56	3983325.59	49.55		2009
	B09-199	447707.79	3983296.07	49.21		2009
	B09-200	447691.37	3983299.22	48.61		2009
	B09-201	447695.66	3983326.08	48.99		2009
	B09-220	447700.44	3983362.88	49.79		2009
	B09-222	447670.59	3983308.41	43.31		2009

* Elevation above the mean sea level. ** MW indicates monitoring well.

Figure 3-1. Location of Boreholes and Groundwater Monitoring Wells at LF-Area D of Camp Carroll.



3271

4. Findings during ESI Investigation

4.1. Laboratory Analysis.

All laboratory analysis was performed using US EPA published methods. The laboratory that performed the analysis is accredited by the National Environmental Laboratory Accreditation Conference (NELAC) for the analytical procedures specified for this project. Soil and groundwater samples collected in this ESI were submitted to the NCA-Korea Laboratory in Anyang, Korea. The contract laboratory shipped the samples for VOCs, semi VOCs (SVOCs), PAHs, dioxin, OC-pesticides, PCB and metals to the NCA laboratory in the States since the NCA-Korea lab has only certified TPH. Soil samples collected from soil borings were analyzed for diesel and residual oil range TPH by EPA 8015D, VOCs by 8260B, SVOCs by 8270D, OC-pesticide by 8081B, PCBs by 8082A, dioxins by 8290A of high resolution mass spectrometry, metals by 6020A, and mercury by 7471B.

The chemical data table presented in this report are only for those which were detected above the practical quantitation limit (PQL) or were qualified as estimated by data validation. The full laboratory reports are provided on the separate compact disk (CD).

4.2. Data Quality Control/Assurance

Field and laboratory quality control (QC) samples were collected and analyzed in accordance with USACE and industry standard methods and practices. The FED Environmental chemist (Dr. SC Chon) performed a data review on soil and groundwater samples collected from the LF-Area D site. The data review was performed in accordance with the project work plan and Chemical Quality Assurance for Hazardous, Toxic, and Radioactive Waste (HTRW) Projects (USACE, EM 200-1-6, 1997). The accuracy, precision, representativeness, and completeness of the data were evaluated by performing analytical data quality and field quality assurance (QA) /QC data quality review. Accuracy was evaluated using the laboratory sample receipt information, analyses requested, technical holding times, and laboratory QC data (method blank, laboratory control sample (LCS) / LCS duplicate, matrix spike (MS) / MS duplicate, and surrogate recoveries). Appendix IV presents the project data quality objectives.

4.3. Subsurface Soil Investigation Result

Soil sampling strategy at LF-Area D is summarized in Table 4-1. The summaries of chemical test results for soil samples are presented. Figure 3-1 presents the locations of the soil boreholes, groundwater monitoring wells installed both this ESI and the previous investigations.

4.3.1. Subsurface Geology

The subsurface geology of LF-Area D consists mostly of fill materials and residual soils. Fill materials of clayey/silty sand/clayey sand with gravel were encountered in boreholes with the thicknesses ranging from 3 to 6 m. The fill material layer is generally about 2~3 m thicker at Area D than at Land Farm. In some location the fill material at Area D appears thicker than 6 m. Residual soil consists of fat clay and silty sand underlying the fill materials.

During drilling, field crews noted a chemical odor emanating from the soil samples collected at 3 meters to 7 meters bgs in boreholes B09-195 and B09-196. The odor was a kind of

mixture of various chemicals. Soil samples were stained and decolorized to grayish green at this horizon. Pieces of metal, wood, and vinyl were also recovered from the depths with soil sample.

4.3.2. Chemical Analysis Result for Soil Sample

4.3.2.1.Total petroleum hydrocarbons

A total of 26 soil samples were tested for diesel range (DRO) and residual range (RRO) TPH. The test result is presented in Table 4-2. Four samples were identified containing TPH. One soil sample contains both DRO and RRO at 55.4 mg/kg and 171 mg/kg respectively. Three other samples contain either DRO or RRO up to 30.7 mg/kg. The samples with detected TPH occur most frequently in shallow sample depths. This finding indicates that the detection of TPH is likely from incidental releases during vehicle operations rather than a spill from a storage tank.

4.3.2.2.Volatile Organic Compounds

VOCs were detected in some soil samples collected from each of the borehole drilled at the Area D (Table 4-3). Toluene; 2-, 4- chlorotoluene; and tetrachloroethene (PCE) were detected in site soil samples. Other VOCs are mostly below the practical quantitation limit (PQL) or the concentrations were quantitatively estimated by the chemist due to the very low concentration. Except the detection of toluene above the PQL, other VOCs normally associated with TPH such as ethylbenzene and xylenes were not reported from site soil samples above the practical quantitation limit (PQL). Figures 4-1 and 4-2 present the distribution of toluene and tetrachloroethene (PCE) in site subsurface soil respectively.

Toluene was detected in 23 soil samples out of total 48. The 2-, 4-chlorotoluene was detected in only one sample. PCE was detected in 5 soil sample out of total 48. Trichloroethene (TCE) was detected in one sample. The highest concentration of VOCs detected was found at the borehole B09-196 (Figure 4-2). The concentration ranges of VOCs in the soil samples of LF-Area D are:

- 2-Chlorotoluene: non-detected (ND) ~ 27,000 µg/kg at B09-196
- 4-Chlorotoluene: ND to 89,000 µg/kg at B09-196
- Toluene: ND to 1,300,000 µg/kg
- PCE: ND to 24,000 µg/kg
- TCE: ND to 70 µg/kg

4.3.2.3. Semi-Volatile Organic Compounds.

No target SVOCs were detected above the PQL in soil samples collected from boreholes drilled at the Area D. Table 4-4 presents the chemical test result for SVOCs.

4.3.2.4. Target Metals.

Target metals were detected in all soil samples collected from the boreholes drilled at the Area D (Table 4-5). Selenium and Silver were not detected in soil samples above the PQL. The concentration of Mercury in soil samples was reported from two samples above the PQL. The detected concentration of metals was close to the result of the site background sample that was

taken from approximately 30 centimeters deep at about 5 meters easterly away from B09-193MW. The concentration ranges of target metals in the soil samples of LF-Area D are:

- Arsenic: 4.6 mg/kg to 11 mg/kg (7.3 mg/kg of background)
- Barium: 61.6 mg/kg to 105 mg/kg (98.2 mg/kg of background)
- Cadmium: 0.33 mg/kg to 0.87 mg/kg (0.51 mg/kg of background)
- Lead: 8.9 mg/kg to 23.7mg/kg (18.7 mg/kg of background)
- Mercury: 0.044 mg/kg to 0.05 mg/kg (0.011B mg/kg of background- this result indicates that the analyte is found in a blank associated with the sample)

According to the comparison with the result of the site background sample, the concentrations of metals in soil samples from the site were not significantly affected by the historic activities.

4.3.2.5. Polychlorinated Biphenyls.

No PCBs were detected in soil samples collected from boreholes drilled at the LF-Area D.

4.3.2.6. Organochlorinated Pesticides.

OC-pesticides were detected in soil samples collected from each of the borehole drilled at the Area D (Table 4-6). Lindane, 4,4'-DDE, DDD and DDT were the chemicals detected above the PQL. The 4,4'- DDD and DDT were the most commonly identified in soil samples. Soil samples from B09-196 contained the highest concentration of OC-pesticide out of the detection. The concentration ranges of OC-pesticide in the soil samples of LF-Area D are:

- Lindane: ND to 4,300 µg/kg
- 4,4'-DDE: ND to 42 µg/kg
- 4,4'-DDD: ND to 24,000 µg/kg
- 4,4'-DDT: ND to 54,000 µg/kg

4,4'-DDT was identified in soil samples collected from most of the boreholes. Maximum detected concentrations of DDT were reported from the samples collected in boreholes B09-196 and B09-201. Figure 4-3 presents the distribution of 4,4'-DDT in the site subsurface soil at LF-Area D due to detected in most site soil samples.

4.3.2.7. Dioxins/Furans.

Soil samples were submitted for dioxin/furan analysis (Table 4-7). The International-Toxic Equivalent Factors (I-TEF) for dioxins and furans were used to calculate the International-Toxic Equivalent (I-TEQ) for each soil sample according to the Toxics Release Inventory Program updated April 23, 2009 (http://www.epa.gov/tri/lawsandregs/teq/teqpfinalrule.html). The I-TEQ is expressed with respect to the toxicity of 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD. Although 2,3,7,8-TCDD was not detected any of the soil samples above the PQL, I-TEQs were calculated for all soil samples based the I-TEFs. The I-TEQ calculated for each of the soil samples collected at the site ranges from 0.03 to 1.73.

4.3.3. Groundwater Contamination

4.3.3.1.Groundwater Level Measurement Result

Five groundwater monitoring wells were newly installed in the vicinity of LF-Area D. The five wells in association with the six supply wells and the eleven monitoring wells installed during the previous investigations were used to assess the site hydrogeologic conditions and the groundwater quality. Figure 4-4 presents the supply and groundwater monitoring well locations utilized during this project. Table 4-8 summarizes the measurement results of water level in both below ground surface (bgs) and above mean sea level (amsl). Water levels were measured a total of three times in each well with an oil/water interface probe. Floating product was not detected in any borehole.

The water levels were measured total three times before rainy season (May), after monsoon (August) and dry season (December) to determine if any groundwater level variation occurs during the year. The groundwater level variation among the measurements is quite systematic with a linear correlation as shown in Figure 4-5. Based on the result of groundwater level measurements, the groundwater flow direction was analyzed as depicted in Figures 4-6. General groundwater flow pattern is dominantly toward western and southwestern direction, which is similar to the site topographic gradient. The flow direction could be a function of the volume of water pumped at the supply wells at west, so the groundwater migration further to the off-post remains to be resolved with more data.

4.3.3.2.Groundwater Chemical Test Result

Groundwater samples were collected three times during this ESI projects: May, September and December 2010 to see if any variation in groundwater quality during one year. Table 4-9 presents the groundwater sampling strategy during this project.

4.3.3.2.1. Organochlorinated Pesticides

A total of sixteen groundwater samples were collected from groundwater monitoring wells installed the LF-Area D area for OC-pesticide analysis. Table 4-10 summarizes the OC-pesticide chemical test result. An OC-pesticide was detected above the reporting limit in eleven groundwater monitoring wells during the sampling events. A total of seven OC-pesticides were detected above the reporting limit as:

Alpha-BHC: 0.046 to 0.37 µg/L
Gamma-BHC: 0.054 to 4.9 µg/L
Beta-BHC: 0.072 to0.73 µg/L
Dclta-BHC: 0.047 to 1.1 µg/L
Dieldrin: 0.12to 0.44 µg/L
4,4'-DDD: 0.1µg/L at B07-218MW
4, 4'-DDT: 0.1 µg/L at B07-220MW

4.3.3.2.2. Volatile Organic Compounds

A total of twenty-two groundwater samples were collected including the six supply wells for VOCs analysis. Table 4-11 summarizes the VOCs chemical test result. VOCs were detected above the reporting limit from all the groundwater samples analyzed. A total of twenty-six chemical components of VOCs were reported from the samples. Groundwater samples from the six supply wells contained thirteen chemical components of VOCs. A majority of groundwater samples including those of the supply wells contains cis-1,2-DCE, methylene chloride, PCE, toluene and TCE. A couple of more VOC components appear during the 2nd or 3rd sampling event in the cases of B03-465MW and B03-466MW. Figures 4-7, 4-8 and 4-9 present the distributions of Toluene, PCE, and TCE in groundwater.

4.4. Hydrologic Characteristics of the Site

Figure 4-10 presents the groundwater monitoring well locations used for air permeability and hydrologic field test.

4.4.1. Slug Test

Six slug tests were performed at the LF-Area D. The monitoring wells selected for slug testing was subject to its relative location within the LF-Area D area. Measurements of water level versus time, along with other relevant aquifer and well characteristics were then used to determine a value for hydraulic conductivity of the site. The calculations were performed with AQTESOLV aquifer test analysis software. An anisotropy ratio (Kz/Kr) was assumed in the analysis and the analytical solution developed by Bouwer and Rice (1976) for an unconfined aquifer system was used to calculate the hydraulic conductivity. Hydraulic conductivity (K) was obtained by manual fitting using AQTESOLV.

The calculated K values for the monitoring wells were similar between injection and withdrawal. The K values ranged from 1.7E-05 to 7.70E-04 cm/sec for inserting the slug and from 1.90E-05 to 7.60E-04 cm/sec for withdrawal the slug from the monitoring wells. Table 4-12 presents the hydraulic parameters obtained from the slug test.

4.4.2. Pumping Test

A review of the pumping test results indicates that the calculated transmissivity (T) values ranged from 0.07 cm^2/sec to 9.03 cm^2/sec. The T value is generally higher during water level drawdown than recovery. The K values during pumping test obtained ranging from 9.81E-05 cm/sec to 5.28E-02 cm/sec, with an average of 1.29E-02 cm/sec. The K values obtained during pumping test were quite higher than those during slug test. This high K value during pumping test might reflect the existence of high K interval within the well screened interval during pumping test. Table 4-13 presents the result of pumping test.

4.4.3. Air Permeability Test

An air permeability test was conducted on 17 March 2010, to evaluate subsurface air flow patterns and radius of influence at LF-Area D of the Camp Carroll. The layout of the permeability test was determined based on the location of existing groundwater monitoring wells and the pre-installed air permeability test well. Air permeability test was conducted at four wells (as a set) consisting of one air extraction well (B03-465MW) and three observation wells (B03-

464MW, B09-195, B03-466MW). Figure 4-10 presents the well layout of air permeability test at LF-Area D.

The extraction well was attached to a vacuum pump to control the air extraction rate. The extraction valves and measurement devices were securely attached and sealed at the top of each well pipe to prevent introducing any ambient air. Upon starting the vacuum pump for subsurface air extraction, field measurement data was collected from both extraction and observation wells. During the entire air permeability test, the extraction vacuum was maintained at a constant rate and the monitoring wells' down pressure was monitored indications in change of pressure. Conclusively, the observation wells (B09-195, B03-466MW and B03-464MW) did not respond during the permeability test probably due to the well locations are beyond the radius of influence.

4.4.4. Nutrient and Microbial Sampling

All soil samples were analyzed for their heterotrophic bacteria content. The following chemical parameters were also measured on these soils: Total Carbon, Total Nitrogen and Total Phosphorous (Total C/N/P). The average ratio of Total C/N/P at LF-Area D project site of Camp Carroll appears to be 83: 8: 9. Fuel disintegration bacteria were counted up to 517,000 Most Probable Number (MPN)/g in soil. However, the bacteria were not identified in some samples. The presence of fuel disintegration bacteria and the C/N/P ratio suggest a certain degree of biodegradation could positively occur within the contaminated soil formation. The biological and chemical parameters measured on these soil samples are summarized in Table 4-14.

Table 4-1. Soil Sample Information versus the Chemical of Concern from each Borehole.

Borehole ID	Sample ID	Sample Depth	VOCs	OC-pest	Dioxins	TPH-D	SVOC	PCB	Metals
B09-192	S1	0~2m	O	O	O*	O	O	O	O
	S2	2~4m	O	O	O	O	O	-**	-
	S3	4~6m	O	O	-	-	-	-	-
B09-193	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-194	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-195	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-196	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-197	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-198	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-199	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-200	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-201	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-220	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-221	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-
B09-222	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	-	-
	S3	4~6m	O	O	-	-	-	-	-

*- indicates sample was collected for the analysis, ** not collected.

3238

Table 4-2. TPH Chemical Test Results for Soil Samples at LF-Area D.

BH_ID	Sample ID	Sample Interval	unit	Diesel range ($C_{10\sim24}$)	Residual oil range ($C_{24\sim40}$)	TPH (mg/kg)	PID
B09-192	S1	0~2 m	mg/kg	ND	ND	ND	6.8
	S2	2~4 m	mg/kg	ND	ND	ND	3.4
B09-193	S1	0~2 m	mg/kg	55.4	171	236	3.6
	S2	2~4 m	mg/kg	ND	ND	ND	3
B09-194	S1	0~2 m	mg/kg	ND	ND	ND	4.6
	S2	2~4 m	mg/kg	ND	ND	ND	11.7
B09-195	S1	0~2 m	mg/kg	ND	ND	ND	1.4
	S2	2~4 m	mg/kg	ND	ND	ND	2.3
B09-196	S1	0~2 m	mg/kg	12.1	ND	12.1	3.5
	S2	2~4 m	mg/kg	ND	19	19	391
B09-197	S1	0~2 m	mg/kg	ND	ND	ND	2.8
	S2	2~4 m	mg/kg	ND	ND	ND	1.9
B09-198	S1	0~2 m	mg/kg	ND	ND	ND	1.8
	S2	2~4 m	mg/kg	ND	ND	ND	2.4
B09-199	S1	0~2 m	mg/kg	ND	ND	ND	1.9
	S2	2~4 m	mg/kg	ND	ND	ND	7.9
B09-200	S1	0~2 m	mg/kg	ND	ND	ND	3.6
	S2	2~4 m	mg/kg	ND	ND	ND	1.9
B09-201	S1	0~2 m	mg/kg	ND	ND	ND	0.5
	S2	2~4 m	mg/kg	ND	ND	ND	0.9
B09-202	S1	0~2 m	mg/kg	ND	ND	ND	21.5
	S2	2~4 m	mg/kg	ND	ND	ND	2.5
B09-221	S1	0~2 m	mg/kg	ND	30.7	30.7	1.9
	S2	2~4 m	mg/kg	ND	ND	ND	2.2
B09-222	S1	0~2 m	mg/kg	ND	ND	ND	2.2
	S2	2~4 m	mg/kg	ND	ND	ND	3.2
ND- not detected							

3779

Table 4-3 VOCs Chemical Test Results for Soil Sample at LF-Area D.

Chemicals (µg/kg)	B09-192			B09-193			B09-194			B09-195			B09-196			B09-197		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
2-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	160J	27000	-	-	-
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	440	89000	-	-	-
cis-1,2-Dichloroethene	-	-	18J	-	14J	21J	-	-	-	-	-	-	-	150J	-	-	-	-
1,1-Dichloroethene	-	-	-	-	7.7J	12J	-	9.9J	-	-	-	-	-	-	-	9.5J	-	5.8J
Ethylbenzene	32J	21J	24J	33J	27J	20J	25J	20J	25J	19J	21J	-	28J	-	-	29J	24J	20J
Methylene chloride	61J	33J	44J	52J	38J	33J	37J	34J	36J	30J	42J	41J	47J	52J	-	48J	41J	41J
Naphthalene	-	2.8J B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Styrene	-	-	-	-	-	-	-	-	-	-	1.6J	-	-	-	-	-	-	-
Tetrachloroethene	6.4J	12J	57	-	20J	36J	110	41J	45J	-	-	-	58	350	24000	-	9J	19J
Toluene	87	14J	34J	70	100	110	23J	89	51	83	27J	6400	48J	16000	1300000	170	76	60
1,2,4-Trichlorobenzene	-	10J B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	9.9J	-	26J	70	27J	14J	-	-	-	-	-	76J	-	-	-	-
m-Xylene & p-Xylene	94J	51J	63J	80J	60J	51J	55J	59J	58J	47J	52J	67J	74J	68J	-	68J	63J	60J
o-Xylene	7.8J	-	7.1J	7.9J	6.3J	-	5.7J	-	-	-	-	-	7.5J	-	-	7.1J	-	6.6J
B-The analyte was found in a blank associated with the sample. "-" not detected above the detection limit.																		
J- Estimated result. Result is less than reporting limit.																		
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.																		
G- Elevated reporting limit. The reporting limit is elevated due to matrix interference.																		

3780

Table 4-3 VOCs Chemical Test Results (Continued).

Chemicals (µg/kg)	B09-198			B09-199			B09-200			B09-201			B09-220			B09-221			B09-222		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
2-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	9.5J	-	-	-	-	8.3J	-	-	-	5.2J	-	-	-	-	-	-	6.2J
Ethylbenzene	35J	27J	31J	26J	27J	32J	28J	27J	25J	22J	24J	33J	21J	26J	21J	24J	28J	24J	18J	20J	28J
Methylene chloride	61J	43J	45J	47J	48J	51J	49J	39J	42J	40J	42J	54J	31J	41J	46J	41J	36J	47J	32J	35J	43J
Naphthalene	-	-	-	-	-	4.9J B	-	-	-	-	-	-	-	-	-	6.5J B	-	-	-	-	-
Styrene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5J	-	-	-	-	-	-
Tetrachloroethene	-	5.5J	8J	-	6.1J	-	-	-	-	-	-	-	-	-	7.7J	-	-	-	-	-	-
Toluene	9.4J	54	45J	42J	250	110	42J	64	43J	63	68	39J	49J	42J	72	39J	39J	71	20J	69	99
1,2,4-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	83J	70J	77J	68J	73J	75J	81J	68J	62J	63J	61J	82J	51J	66J	66J	75J	70J	70J	46J	54J	68J
o-Xylene	7.9J	7.3J	-	7.8J	6.1J	8J	9.6J	7.1J	-	5.8J	6.1J	7.9J	-	6.6J	6.7J	9.1J	-	8J	-	7.2J	-

J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
"-" not detected above the detection limit.

Table 4-4 SVOCs Chemical Test Results for Soil Samples of LF-Area D.

Chemicals (µg/kg)	B09-192		B09-193		B09-194		B09-195		B09-196		B09-197		B09-198		B09-199		B09-200		B09-201		B09-220		B09-221		B09-222	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
bis(2-Ethylhexyl) phthalate	-	-	-	-	-	-	-	-	-	-	-	-	120J	-	-	-	300J	-	-	-	-	-	230J	-	-	-
J- Estimated result. Result is less than reporting limit. "-" not detected above the detection limit.																										

3781

Table 4-5. Metal Chemical Test Result for Soil of LF- Area D.

Chemical (mg/kg)	AreaD-BG[&]	B09-192	B09-193	B09-194	B09-195	B09-196	B09-197	B09-198	B09-199	B09-200	B09-201	B09-202	B09-220	B09-221	B09-222
		S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Arsenic	7.3	8.7	3.2B*	5.5	8.3	8	6.9	7.2	3.7B	6.7	7.5	11	5.8	4.6	3.3B
Barium	98.2	105	65	71.4	102	71.9	86.6	88.5	61.6	98.7	85.3	99.7	103	76.5	63.5
Cadmium	0.51	0.86	0.28B	0.48	0.33	0.17B	0.43	0.39	0.46	0.63	0.54	0.87	0.42	0.31B	0.24B
Chromium	3.8	4.4	5.1	3.4	3.2	4.5	3.3	4.9	5.2	3.5	2.3	3.2	3.2	5.4	3.7
Lead	18.7	22	14.6	23.7	12.6	8.9	15.4	14.6	18.3	20.5	20.4	19.6	12.5	18.2	13.2
Selenium	-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver	-	-	-	-	-	-	-	-	-	0.14B	-	-	0.15B	0.13B	-
Mercury	0.011B	-	0.05	-	-	-	0.044	-	-	-	-	-	-	-	-

&- Background data of Area D, *- the analyte is found in a blank associated with the sample, **- not detected.

3782

Table 4-6. OC-Pesticides Chemical Test Results for Soil of LF-Area D.

Chemical (µg/kg)	B09-192			B09-193			B09-194			B09-195				B09-196			B09-197		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3		S1	S2	S3	S1	S2	S3
alpha-BHC	-	-	-	0.71J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
gamma-BHC (Lindane)	-	1.5J	-	**11**	-	0.7J	**6.4**	3.4J	0.29J	-	-	-	-	**4300**	5.8J	250J	26J	2J	-
beta-BHC	-	0.74J	-	-	-	0.86J	-	-	0.59J	-	-	-	-	-	-	-	-	-	-
delta-BHC	-	1J	-	1.6J	-	0.29J	-	-	0.35J	-	-	-	2.2J	-	-	-	-	-	-
Heptachlor epoxide	-	1.1J PG	2.9J PG	-	-	-	-	-	-	-	-	-	-	260J PG	-	-	-	-	-
gamma-Chlordane	6.2J PG	1.9J	10PG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	2.9PG	8.5J PG	2.3J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDE	37J	7.5	**37**	11	-	0.35J	**3.9**	**27**	-	2.9J	12J	-	15J	730J	**25**	290J	20J	11J	-
Dieldrin	4.5J	1.6J	7J	0.39J	-	0.42J	-	-	-	-	1.8J	-	1.3J	-	-	-	-	-	-
4,4'-DDD	15J	6.4	18J	**40**	1.1J	1.2J	0.64J	**37**	-	0.49J	7.2J	-	**22**	**24000**	17J PG	**12000**	47J	9.7J	-
4,4'-DDT	**740**	**47**	**280**	**130**	1.9J	2.6J	**28**	**120**	-	**15**	**240**	-	**260**	**54000**	**500**	**26000**	**750**	**200**	0.69J

B-The analyte found in a blank associated with the sample. "-" not detected above the detection limit.

J- Estimated result. Result is less than reporting limit.

Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.

G- Elevated reporting limit. The reporting limit is elevated due to matrix interference.

PG: The percent difference between the original and confirmation analyses is greater than 40%.

3783

Table 4-6. OC-Pesticides Chemical Test Results (Continued).

Chemical (µg/kg)	B09-198			B09-199				B09-200			B09-201			B09-220			B09-221			B09-222		
	S1	S2	S3	S1	S2	S3	S4	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
alpha-BHC	-	-	0.47J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
gamma-BHC (Lindane)	-	-	**8.6**	-	2.8J	**7.1**	1.3J	-	-	-	-	4.5 J	-	-	-	-	-	-	-	-	-	-
beta-BHC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
delta-BHC	-	-	0.67J	-	-	0.46J	0.46J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptachlor epoxide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDE	**3.8**	28J	0.53J	4.1J	**12**	**8.1**	-	0.33J	**9.6**	240J	**4**	35J	80J	-	**13**	**44**	**29**	0.52J	-	1.6 J	-	-
Dieldrin	-	2J	-	-	-	1.1J	-	-	-	-	-	-	-	-	0.24J	-	-	-	-	-	-	-
4,4'-DDD	0.41J	**300**	**4.1**	-	**24**	**48**	-	-	1.4J	**670**	-	17J	**250**	-	**3.7**	19J	13J	0.44J	-	3.5 J	-	-
4,4'-DDT	**9.7**	**360**	**12**	**8.9**	**72**	**220**	0.68J	0.53J	**30**	**7300**	**4**	**300**	**4400**	0.63J	**85**	**460**	**190**	2J	0.65 J	1.8 J	-	-

J- Estimated result. Result is less than reporting limit.
"-" not detected above the detection limit.

3784

Table 4-7. Dioxin-Furan Chemical Test Results for Soil of LF-Area D.

Borehole ID	Sample ID	Sample interval (m)	Method	International-89 Toxicity Equivalent Quantity*
B09-192	S1	0~2	SW8290	0.14
	S2	2~4	SW8290	0.20
B09-193	S1	0~2	SW8290	0.26
	S2	2~4	SW8290	0.11
B09-194	S1	0~2	SW8290	0.16
	S2	2~4	SW8290	1.73
B09-195	S1	0~2	SW8290	0.06
	S2	2~4	SW8290	0.06
B09-196	S1	0~2	SW8290	0.24
	S2	2~4	SW8290	0.04
B09-197	S1	0~2	SW8290	0.06
	S2	2~4	SW8290	0.07
B09-198	S1	0~2	SW8290	0.11
	S2	2~4	SW8290	0.05
B09-199	S1	0~2	SW8290	0.03
	S2	2~4	SW8290	0.06
B09-200	S1	0~2	SW8290	0.06
	S2	2~4	SW8290	0.33
B09-201	S1	0~2	SW8290	0.64
	S2	2~4	SW8290	0.51
B09-220	S1	0~2	SW8290	0.73
	S2	2~4	SW8290	0.14
B09-221	S1	0~2	SW8290	0.86
	S2	2~4	SW8290	0.74
B09-222	S1	0~2	SW8290	0.77
	S2	2~4	SW8290	0.48

* I-TEQ value calculated using International-89 Toxicity Equivalent Factors based on 2,3,7,8-TCDD.

3785

Table 4-8 Water Level Measurement Result at LF-Area D

Proj_ID	Sites	MW_ID	Well Depth (m)	Top of Pipe (m)	Water Level					
					28-Feb-09		4-Sep-09		16-Dec-09	
					bgs*	amsl^	bgs	amsl	bgs	amsl
08-035E	Area D	B03-463MW	11.8	48.55	9.0	39.6	7.97	40.6	8.8	39.8
		B03-464MW	13.0	49.79	9.1	40.7	8.59	41.2	8.9	40.9
		B03-465MW	13.0	50.90	10.2	40.7	9.65	41.3	10.0	40.9
		B03-466MW	12.3	49.58	8.0	41.6	7.85	41.7	7.7	41.9
		B03-467MW	12.3	49.79	9.2	40.6	8.64	41.2	9.0	40.8
		B03-468MW	13.4	51.41	10.1	41.3	9.42	42.0	9.8	41.6
		B09-193MW	15.5	49.28	9.1	40.2	8.00	41.3	8.8	40.5
		B09-221MW	11.8	43.22	5.1	38.1	6.10	37.1	4.9	38.3
08-034E	Land Farm	B07-217MW	11.4	50.92	3.7	47.2	3.28	47.6	4.0	46.9
		B07-218MW	12.3	51.77	10.8	41.0	9.27	42.5	9.8	42.0
		B07-219MW	11.7	55.41	7.3	48.1	7.04	48.4	7.7	47.7
		B07-220MW	9.2	49.73	3.1	46.6	2.57	47.2	3.3	46.4
		B07-221MW	11.7	54.59	6.9	47.7	6.1	48.5	7.3	47.3
		B09-176MW	40.0	44.27	8.5	35.8	8.87	35.4	8.4	35.9
		B09-177MW	42	47.19	9	38.2	9.04	38.2	9	38.3
		B09-178MW	41	49.09	9	40.2	8.87	40.2	8	40.9
Supply Wells		12-247	70		Not measured !					
		13-279	73							
		14-283	80							
		15-286	77							
		16-289	85							
		20-575	184							

*- below ground surface; ^- above mean sea level.

Table 4-9 Groundwater Sampling Strategy at LF-Area D.

Proj_ID	Sites	BH_ID	Well Depth (m)	Water level	VOCs	OC Pest
08-035E	Area D	B03-463MW	12.4	7.97	O	O
		B03-464MW	13.1	8.59	O	O
		B03-465MW	13.1	9.65	O	O
		B03-466MW	17.9	7.85	O	O
		B03-467MW	12.4	8.64	O	O
		B03-468MW	13.5	9.42	O	O
		B09-193MW	15.0	8.00	O	O
		B09-221MW	12.4	6.10	O	O
08-034E	Land Farm	B07-217MW	12.0	3.28	O	O
		B07-218MW	12.7	9.27	O	O
		B07-219MW	12.3	7.04	O	O
		B07-220MW	9.7	2.57	O	O
		B07-221MW			O	O
		B09-176MW	40.0	8.87	O	
		B09-177MW	40	9.04	O	
		B09-178MW	40	8.87	O	
Supply Wells		12-247	70		O	
		13-279	73		O	
		14-283	80		O	
		15-286	77		O	
		16-289	85		O	
		20-575	184		O	

3787

Table 4-10 OC-Pesticides Chemical Test Result of Groundwater at LF-Area D.

Chemicals (µg/L)	B03-463MW			B03-464MW			B03-465MW			B03-466MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
alpha-BHC	0.34	0.53J G	0.37	-	-	-	0.14PG	- G	0.057 PG	0.07PG	0.067J G	0.097 PG
gamma-BHC	3.5q	4.9	3.3	0.01J	-	-	0.069	0.022J	0.039 J	0.17	0.21J PG	0.26
Heptachlor	-	-	-	-	-	-	0.031J	-	-	-	-	-
beta-BHC	0.73	0.76J PG	0.52	0.0047J	-	-	0.53PG	0.27PG	0.26 PG	0.66	0.75PG	0.71
delta-BHC	1	1.1	0.98	0.0073J	-	-	-	-	0.024J PG	0.57	0.51	0.51
Heptachlor epoxide	-	-	-	-	-	-	-	-	0.019J PG	-	-	0.015J PG
Endosulfan I	-	-	-	-	-	-	-	-	-	0.017J PG	-	-
gamma-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDE	-	-	-	-	-	-	-	-	-	-	-	-
Dieldrin	0.007J	-	-	-	-	-	0.048J PG	-	0.037J PG	0.028J PG	0.078J	0.074J
Endrin	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDT	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan sulfate	-	-	-	-	-	-	-	-	-	-	-	-
Endrin ketone	-	-	-	-	-	-	-	-	-	-	-	-
Sampling at 1st: May 11~15, 2009: at 2nd August 31~Sep 2, Sep14~16, 2009: at 3rd: Dec 12~15, 2009												
PG- the percent difference between the original and confirmation analyses is greater than 40%. "-" indicates not detected above the detection limit.												
J- Estimated result. Result is less than reporting limit.												
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.												
G- Elevated reporting limit. The reporting limit is elevated due to matrix interference.												

3788

Table 4-10 OC-Pesticides Chemical Test Result (Continued).

Chemicals (µg/L)	B03-467MW			B03-468MW			B07-217MW			B07-218MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
alpha-BHC	0.033J PG	- G	0.038J PG	-	-	-	0.028J	-	0.024J	-	0.019J	-
gamma-BHC	0.05PG	0.6	0.24 PG	0.043J	-	-	0.06	0.018J	0.033J	0.016J	0.09J	0.026J
Heptachlor	-	-	-	-	-	-	-	-	0.0076J PG	-	-	0.0075J
beta-BHC	0.14PG	0.19J PG	0.072	-	-	-	-	-	-	0.025J PG	0.027J PG	0.013J PG
delta-BHC	0.3	0.11J	0.22	-	-	-	-	-	-	-	0.028J PG	0.012J PG
Heptachlor epoxide	-	-	-	-	-	-	-	-	-	0.01J	0.011J	0.0057J
Endosulfan I	-	-	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	-	-	-	-	-	-	-	-	0.015J PG	0.0097J	0.011J PG
alpha-Chlordane	-	-	-	-	-	-	-	-	-	0.022J PG	0.0096J PG	0.0089J PG
4,4'-DDE	-	-	-	-	-	-	-	-	-	0.0095J	0.0084J	-
Dieldrin	-	-	-	-	-	-	0.0096J	-	0.019J	0.04J	0.025J	0.016J
Endrin	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	-	-	-	-	-	-	-	-	-	0.1	0.084J	0.031J
4,4'-DDT	-	-	-	-	-	-	-	-	-	0.017J	0.048J	0.019J
Endosulfan sulfate	-	-	-	-	-	-	-	-	-	-	0.01J PG	-
Endrin ketone	-	-	-	-	-	-	-	-	-	-	-	-

PG- the percent difference between the original and confirmation analyses is greater than 40%.
J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.
G- Elevated reporting limit. The reporting limit is elevated due to matrix interference.
"-" not detected above the detection limit.

3789

Table 4-10 OC-Pesticides Chemical Test Result (Continued).

Chemicals (µg/L)	B07-219MW			B07-220MW			B07-221MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
alpha-BHC	0.041J PG	0.043J	0.046	-	0.025J	0.032J	0.018J	-	-
gamma-BHC	0.054	0.15	0.098	0.021J	0.15	0.2	0.016J	0.012J	0.014J
Heptachlor	-	-	-	-	-	-	-	-	-
beta-BHC	0.16	0.35	0.27	0.017J	0.19	0.26	-	0.035J PG	0.0077J
delta-BHC	0.065	0.047	0.059	-	0.012J	0.024J	0.016J	-	-
Heptachlor epoxide	-	-	0.0054J	-	-	0.012J	-	-	-
Endosulfan I	-	0.0061J PG	0.049 PG	-	-	0.02J	-	-	-
gamma-Chlordane	-	-	-	-	-	0.018J PG	-	-	-
alpha-Chlordane	-	-	0.011J PG	-	-	-	-	-	-
4,4'-DDE	-	-	-	-	-	-	-	-	-
Dieldrin	0.12	0.28	0.44	-	-	0.062J	-	-	-
Endrin	-	0.0054J	0.013J PG	-	-	-	-	-	-
4,4'-DDD	-	-	-	-	-	0.006J	-	0.011J	0.013J
4,4'-DDT	-	-	-	0.0079J	-	0.1	-	0.017J	0.01J
Endosulfan sulfate	-	-	-	-	-	0.0067J PG	-	-	-
Endrin ketone	-	0.038J	0.055J	-	-	-	-	-	-

PG- the percent difference between the original and confirmation analyses is greater than 40%.
J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.
G Elevated reporting limit. The reporting limit is elevated due to matrix interference.
"-" not detected above the detection limit.

3790

Table 4-11 VOCs Chemical Test Result for Groundwater of LF-Area D.

Component (μg/L)	B03-463MW			B03-464MW			B03-465MW			B03-466MW			B03-467MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Acetone	-	-	- q	3.4J	-	-	-	-	-	4.4J	-	- q	15	11	-
Benzene	0.97J	-	1.1J	0.45J	-	-	9.8J	11	9.3	0.98J	4.2	1.7J	4.3	8	7.2
2-Butanone (MEK)	-	-	-	0.6J	-	-	-	-	-	-	-	-	0.77J	0.38J	-
Carbon disulfide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24J
Chlorobenzene	4.9J	3.5J	7.9	-	-	-	-	5.4	5.3	2.8	15	5.9J	6.1	3	11
Chloroethane	-	-	-	-	-	-	-	4.4	3.4	-	-	-	7.6	7.9	7.1
Chloroform	1.9J	1.4J	1.4J	0.39J	0.22J	0.48J	-	0.42J	0.47J	0.68J	1.2	1.6J	0.62J	0.23J	0.29J
Chloromethane	-	-	-	-	-	-	-	-	-	-	0.28J	-	-	0.3J	-
2-Chlorotoluene	-	-	0.39J	-	-	-	9.2J	19	14	0.099J	1.9	-	0.73J	0.085J	0.46J
4-Chlorotoluene	-	-	-	-	-	-	-	0.7J	0.54J	-	0.89J	-	0.53J	-	0.14J
1,2-Dichlorobenzene	-	-	0.72J	-	-	-	-	-	-	-	0.28J	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	0.28J	-	-	-	0.13J
1,4-Dichlorobenzene	-	1J	0.95J	-	-	-	-	0.26J	0.29J	0.2J	0.73J	-	0.34J	0.4J	0.59J
Dichlorodifluoromethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	2J	2.5J	1.7J	-	-	-	11J	11	12	0.3J	0.42J	-	7.4	5.6	18
1,2-Dichloroethane	-	-	-	-	-	-	-	-	0.98J	-	-	-	-	-	0.31J
cis-1,2-Dichloroethene	95q	98	160E	0.21J	0.5J	0.63J	1100q	1100E	1100E	15	54	26	7.7	7.7	29
trans-1,2-Dichloroethene	-	-	0.65J	-	-	-	18J	28	24	-	0.52J	-	0.24J	0.49J	0.92J
1,1-Dichloroethene	-	-	0.3J	-	0.16J	0.37J	-	4.7	3.3	-	-	-	-	-	0.21J
1,2-Dichloropropane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19J
Ethylbenzene	-	-	-	0.32J	-	-	-	-	-	0.27J	1.9	-	0.71J	0.12J	0.26J
Isopropylbenzene	-	-	-	-	-	-	-	-	-	0.47J	0.57J	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	0.73J	-	-	-	-
Methylene chloride	-	-	1.5J	1.2	1	1.3	-	3.4	3	0.61J	1.6	-	0.92J	1.7	1.7
Naphthalene	-	-	-	0.35J	-	-	-	-	-	-	5.3	-	-	-	-
Tetrachloroethene	110G	120	160E	23	40	30	23J	27	21	13	200E	180	2.2	0.94J	0.21J
Toluene	33	1.5J	8.1	21	0.7J	6.9	49J	9.2	22	14	480E	8.8J	34B	1.4	7.3
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	0.41J B	-	-	-	-
1,2,4-Trichlorobenzene	-	-	0.4J	-	-	-	-	-	-	-	0.53J B	-	-	-	0.19J
1,1,1-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	62G	58	89	1.2	12	15	100	210E	150E	20	50	29	2.3	16	1.3
Trichlorofluoromethane	-	-	0.62J	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	0.32J	-	-	-	-	-	-	7.1	1.4J	0.14J	-	0.44J
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	1.8	-	-	-	-
Vinyl chloride	-	-	2.6	-	-	-	18J	57	32	-	5.2	-	2.8	2.6	6.7
m-Xylene & p-Xylene	-	-	-	0.9J	-	-	-	-	-	0.2J	1.6	-	0.22J	-	0.28J
o-Xylene	-	-	-	0.37J	-	-	-	-	-	0.18J	0.87J	-	0.13J	0.11J	0.33J
Sampling at 1st: May 11~15, 2009: at 2nd August 31~Sep 2, Sep14~16, 2009: at 3rd: Dec 12~15, 2009															
PG- the percent difference between the original and confirmation analyses is greater than 40%. "-" not detected above the detection limit.															
J- Estimated result. Result is less than reporting limit.															
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.															
G- Elevated reporting limit. The reporting limit is elevated due to matrix interference. E Estimated result. Result concentration exceeds the calibration range.															

Table 4-11 VOCs Chemical Test Result (Continued).

Component (µg/L)	B03-468MW			B07-217MW			B07-218MW			B07-219MW			B07-220MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Acetone	-	-	-	2.6J	-	- q	2.3J	-	- q	-	-	- q	- q	-	- q
Benzene	-	-	-	0.34J	-	-	0.23J	-	-	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzene	-	-	-	0.35J	-	-	-	-	-	-	0.52J	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	0.86 J	0.23 J	0.6J	3.7	2.7J	3.7J	0.48J	-	-	-	0.49J	-	4.3	1.8J	1.2J
Chloromethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	0.23J	-	-	-	-
Dichlorodifluoromethane	-	-	-	0.53J	-	-	-	-	-	-	-	-	0.65 J	-	-
1,1-Dichloroethane	-	-	-	0.15J	0.14J	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	-	0.11 J	0.57 J	84E	110E	120	32	42q	71	84	75	96	35	190	120
trans-1,2-Dichloroethene	-	-	-	1.3	2.9	3.7J	0.19J	0.38J	-	-	6.1	6.3J	0.53 J	1.1J	1.9J
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloropropane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	0.2J	-	-	0.21J	-	-	-	-	-	-	-	-
Isopropylbenzene	-	-	-	-	-	-	0.47J	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	-	1.9	1.7	1.5	-	-	1.6	2.3	-	-	1.9	-	1.7J	-	-
Naphthalene	-	-	-	0.27J	-	-	0.4J	-	-	-	-	-	-	-	-
Tetrachloroethene	140q	70	160E	130E	180	280	32	78	210	590q	270E	410	86	41	32
Toluene	11	0.95 J	5.8	17	-	7.7J	17	0.62J	7.7J	11J	2.2	6.3J	19	-	5.3J
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1J B
1,1,1-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	6.1	1.7	11	210E	350	460	3.4	2.5	5.3J	150	80	120	110	230	340
Trichlorofluoromethane	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	0.17J	-	-	0.26J	-	-	-	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	-	-	-	0.52J	-	-	0.61J	-	-	-	-	-	0.4J	-	-
o-Xylene	-	-	-	0.24J	-	-	0.23J	-	-	-	-	-	-	-	-

PG- the percent difference between the original and confirmation analyses is greater than 40%.
J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
Q- Elevated reporting limit. The reporting limit is elevated due to high analyte levels.
G- Elevated reporting limit. The reporting limit is elevated due to matrix interference.
E- Estimated result. Result concentration exceeds the calibration range.
"-" not detected above the detection limit.

3232

Table 4-11 VOCs Chemical Test Result (Continued).

Component (µg/L)	B07-221MW			B09-176MW			B09-177MW			B09-178MW		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Acetone	- q	-	-	2.1J	-	-	-	-	-	2.6J	-	- q
Benzene	-	-	-	-	-	-	0.23 J	-	-	0.27 J	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-	-	0.52 J	-	-
Carbon disulfide	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	5.2	-	0.45 J	0.21 J	0.18 J	0.37J	0.4J	0.17 J	0.37J	0.19 J	-	-
Chloromethane	-	0.28 J	-	-	-	-	-	-	-	-	-	-
2-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
Dichlorodifluoromethane	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	52	0.58 J	3.7	0.17 J	0.15 J	0.12J	-	-	-	0.13 J	-	-
trans-1,2-Dichloroethene	0.97 J	-	0.14 J	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichloropropane	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	0.22 J	-	-	0.47 J	-	-
Isopropylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	1.2J	1.5	1.4	1.5	1.3	1.1	1.2	0.79 J	1.1	0.54 J	0.8J	-
Naphthalene	-	-	-	-	-	-	0.29 J	-	-	-	-	-
Tetrachloroethene	74	0.22 J	8.8	0.74 J	1.2	1.7	1.1	-	-	1.8	2.1	17 0
Toluene	23	2.7	6.6	11	1	5.6	9.6	0.64 J	6.6	19B	1.8	6.3 J
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-	-	0.31J B	-	-	0.32J B	-	0.22J B	-
1,1,1-Trichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	99	0.37 J	7.1	0.68 J	0.96 J	0.99J	0.6J	-	-	0.51 J	-	-
Trichlorofluoromethane	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-	0.27 J	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	0.37 J	-	-	-	-	-	0.59 J	-	-	0.23 J	-	-
o-Xylene	-	-	-	-	-	-	0 24 J	-	-	-	-	-

J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
"-" not detected above the detection limit.

3293

Table 4-11 VOCs Chemical Test Result (Continued).

Component (µg/L)	B09-193MW			B09-221MW			12-247			13-279		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Acetone	-	-	- q	-	-	-	-	5.1J	-	-	4.5J	-
Benzene	-	-	-	0.25J	-	-	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzene	-	0.22J	-	-	-	-	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	3.3J	2.3	2.4J	0.57J	0.32J	0.24J	1.1	0.65J	0.35J	1.8	1.2	1.1
Chloromethane	-	-	-	-	-	-	-	3.9	-	-	9.6	-
2-Chlorotoluene	-	-	-	0.38J	-	-	-	-	-	-	-	-
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	-
1,2-Dichlorobenzene	-	0.33J	-	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	-	0.12J	-	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
Dichlorodifluoromethane	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	-	0.17J	-	-	-	-	0.5J	1	0.17J	0.3J	-	0.15J
1,2-Dichloroethane	-	-	-	-	-	-	0.37J	-	-	1.1	0.93J	0.79J
cis-1,2-Dichloroethene	130	130E	140	8.3	1.3	0.58J	8	19	8.7	29	9.1	16
trans-1,2-Dichloroethene	1.3J	0.91J	1.3J	0.22J	-	-	0.75J	0.34J	-	1.2	0.53J	0.5J
1,1-Dichloroethene	-	0.27J	-	-	-	-	1.8	4.4	2.5	2.3	0.29J	1.5
1,2-Dichloropropane	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	0.11J	-	-	-	-	-	-	-	-
Isopropylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	-	2.2	-	0.41J	1.4	1.5	1.8	-	0.97J	1.4	-	1.2
Naphthalene	-	-	-	-	-	-	-	-	-	-	-	0.29J B
Tetrachloroethene	29	110E	98	1.7	8.7	0.21J	5.8	16	2.6	12	4.5	9.6
Toluene	28	2	6.1J	12	1.6	6	30	1.6	9.5	25	1.3	8.2
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	0.26J B	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-	-	-	-	-	0.34J B	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-	0.36J	1.6	0.5J	0.65J	-	0.27J
Trichloroethene	170	260E	240	2.7	4.8	-	69	21	59	100E	23	39
Trichlorofluoromethane	-	-	-	-	-	-	0.26J	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	-	-	-	0.27J	-	-	-	-	-	-	-	-
o-Xylene	-	-	-	-	-	-	-	-	-	-	-	-

J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
E- Estimated result. Result concentration exceeds the calibration range.
"-" not detected above the detection limit.

Table 4-11 VOCs Chemical Test Result (Continued).

Component (µg/L)	14-283			15-286			16-289			20-575		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Acetone	2.2J	-	-	-	-	- q	2.3J	4J	-	-	-	-
Benzene	-	-	-	-	-	-	0.14 J	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzene	-	-	-	0.12 J	-	-	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	0.37 J	0.73 J	0.46J	0.83 J	0.76 J	0.5J	0.58 J	0.57 J	0.5J	0.56 J	0.77 J	0.7J
Chloromethane	-	61	-	-	15	-	-	20	-	-	-	-
2-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	0.24 J
4-Chlorotoluene	-	-	-	-	-	-	-	-	-	-	-	0.15 J
1,2-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
Dichlorodifluoromethane	-	-	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethane	0.24 J	0.18 J	0.22J	9.5	5.7	7.4	9.2	0.54 J	0.94J	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	12	9.3	9.4	160 E	110 q	150	150 E	13	20	1.7	1.7	1.7
trans-1,2-Dichloroethene	0.22 J	0.12 J	-	1.1	1.3J	1J	3.7	0.18 J	0.21J	0.19 J	0.12 J	0.27 J
1,1-Dichloroethene	3.4	3.2	2.5	17	7.7	18	17	4.5	5.4	-	-	-
1,2-Dichloropropane	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
Isopropylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	1.3	-	1.1	1.9	-	1J	1.5	-	1.2	1.4	3.1	1.2
Naphthalene	-	-	0.29J B	-	-	-	0.29 J	-	-	-	-	-
Tetrachloroethene	3.6	2.4	2.2	67	39	77	73	11	19	-	-	0.1J
Toluene	32	2.6	9.1	30	2.9J	7.5	30	1.9	8.4	26	1.3	1.3
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-	-	0.7J B	0.15 J	-	0.33J B	-	-	-
1,1,1-Trichloroethane	0.72 J	0.58 J	0.58J	13	6.3	11	12	1.4	1.7	-	-	-
Trichloroethene	77	66	63	80E	53	96	83E	19	22	16	16	15
Trichlorofluoromethane	-	-	-	0.25 J	-	-	0.3J	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-
Vinyl chloride	-	-	-	0.36 J	-	0.49J	-	-	-	-	-	-
m-Xylene & p-Xylene	-	-	-	-	-	-	-	-	-	-	-	-
o-Xylene	-	-	-	-	-	-	-	-	-	-	-	-

J- Estimated result. Result is less than reporting limit.
B-The analyte was found in a blank associated with the sample.
E- Estimated result. Result concentration exceeds the calibration range.
"-" not detected above the detection limit.

3295

Table 4-12 Slug Test Result at LF-Area D.

Well_ID	Activity	Bouwer and Rice (1976)	
		K(m/sec)	Average K (cm/sec)
B03-464	Injection	7.70E-04	7.65E-04
	Withdrawal	7.60E-04	
B03-465	Injection	5.60E-04	5.10E-04
	Withdrawal	4.60E-04	
B03-466	Injection	3.30E-04	2.75E-04
	Withdrawal	2.20E-04	
B07-217	Injection	6.80E-05	7.70E-05
	Withdrawal	8.60E-05	
B07-218	Injection	1.70E-05	1.80E-05
	Withdrawal	1.90E-05	
B07-219	Injection	1.30E-04	2.05E-04
	Withdrawal	2.80E-04	

Table 4-13 Pumping Test Result at LF-Area D.

Monitoring Well		Status	Level of Displacement (m)	Q (m^3/day)	Slop (Δs)	T (cm2/sec)	K (cm/sec)	Average K (cm/sec)
Pumping welll	B07-217	Drawdown	1.956	1.704	0.088	0.41	5.44E-04	3.21E-04
		Recovery		1.704	0.486	0.07	9.81E-05	
Observation Well 1	B07-218	Drawdown	0.031	1.704	0.007	5.02	2.87E-02	2.87E-02
Observation Well 2	B03-465	Drawdown	0.096	1.704	0.004	9.03	5.28E-02	5.28E-02
Observation Well 3	B07-220	Drawdown	0.022	1.704	0.056	0.64	7.42E-04	1.19E-03
		Recovery		1.704	0.026	1.41	1.63E-03	
Observation Well 4	B07-221	Drawdown	0.164	1.704	0.014	2.53	5.85E-03	5.85E-03
K = hydraulic conductivity [m/day], T= transmissivity[m2/day],Q = pumping capacity [m3]								
Δs = Slope of the straight part of the drawdown on a semi-logarithmic graph (m)								

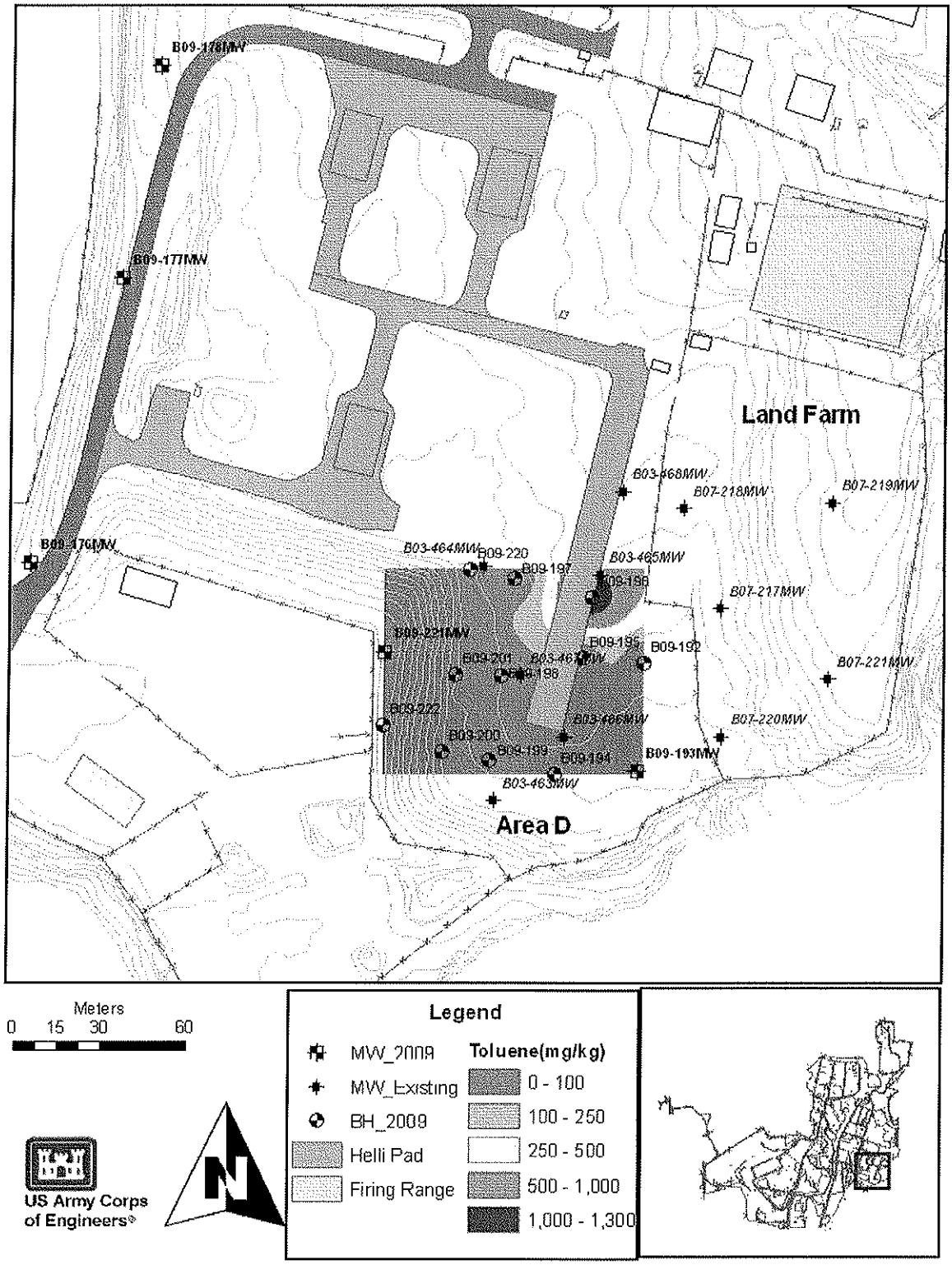
3296

Table 4-14 Microbe and Total CNP Analytical Result of Soil at LF-Area D.

BH_ID	Total Microbe (CFU*/g)	Oil Disintegrated Microbe (MPN**/g)	Total Carbon (%)	Total Nitrogen (%)	Total Phosphorous (mg/kg)
B09-192-S3	$1.99x10^6$	$2.58x10^2$	0.25	0.0323	222.3
B09-193-S2	$3.12x10^5$	$3.12x10^4$	0.08	0.0106	263.24
B09-194-S1	$5.35x10^5$	$5.91x10^4$	0.01	0.0062	332.36
B09-195-S3	$4.50x10^5$	not detected (ND)	0.03	0.0081	197.7
B09-196-S3	$1.18x10^6$	$2.84x10^2$	0.1	0.0106	173.32
B09-197-S1	$5.22x10^5$	ND	0.07	0.0065	265.24
B09-198-S3	$8.00x10^4$	$3.30x10^4$	0.18	0.0115	81.72
B09-199-S1	$8.28x10^5$	$4.49x10^5$	0.17	0.0151	276.08
B09-200-S1	$1.67x10^6$	$5.22x10^3$	0.34	0.0221	353.89
B09-201-S1	$3.39x10^6$	$5.17x10^5$	0.64	0.0507	322.35
B09-220-S3	$2.13x10^5$	$4.40x10^2$	0.23	0.0221	136
B09-221-S2	$1.49x10^6$	$4.75x10^3$	0.18	0.0133	59.16
B09-222-S2	$3.27x10^6$	$2.88x10^4$	0.2	0.0294	100.37
* CFU-colony forming unit, ** MPN- most probable number					

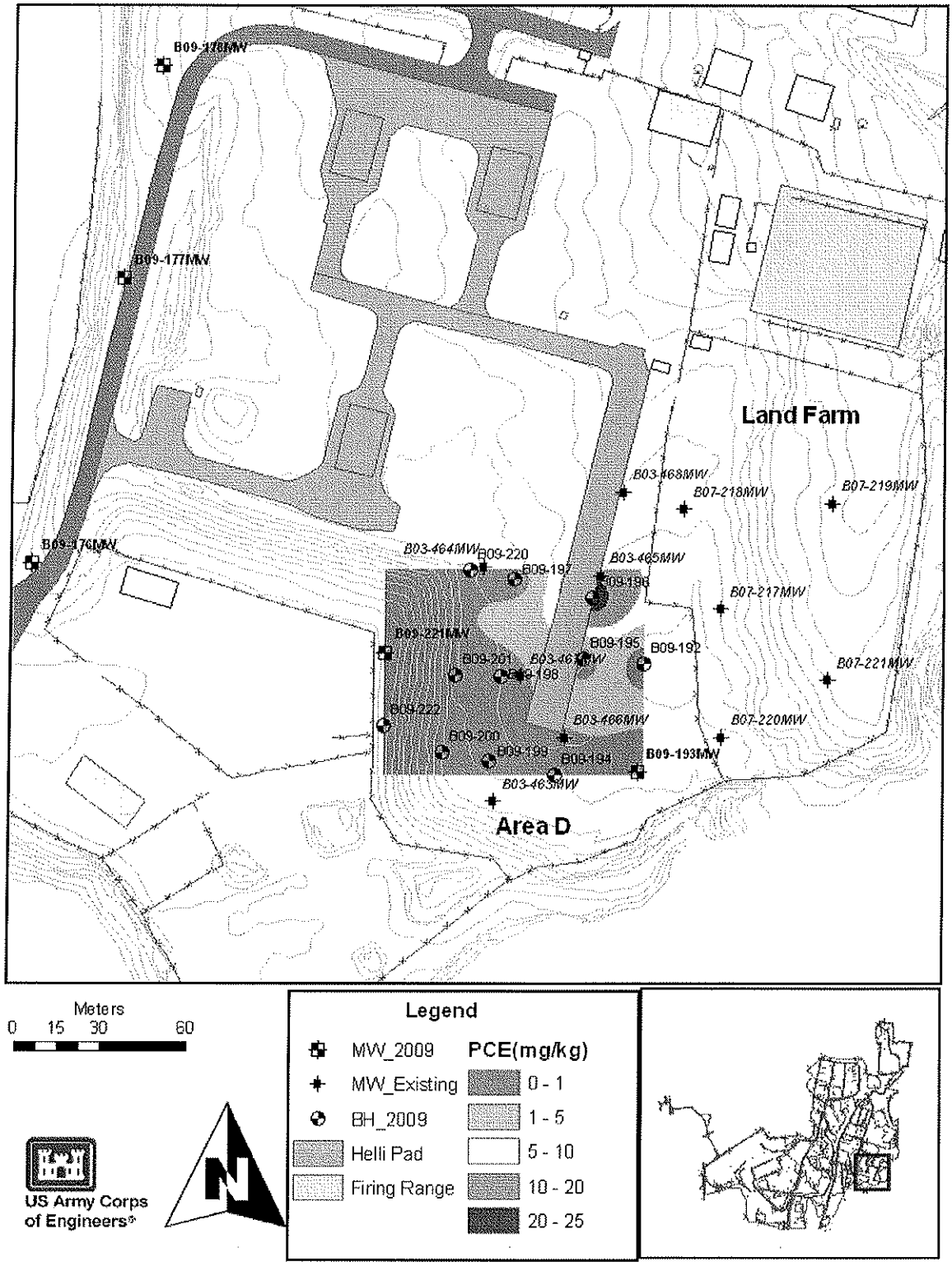
3253

Figure 4-1. Toluene Concentration in Soil at LF-Area D of Camp Carroll.



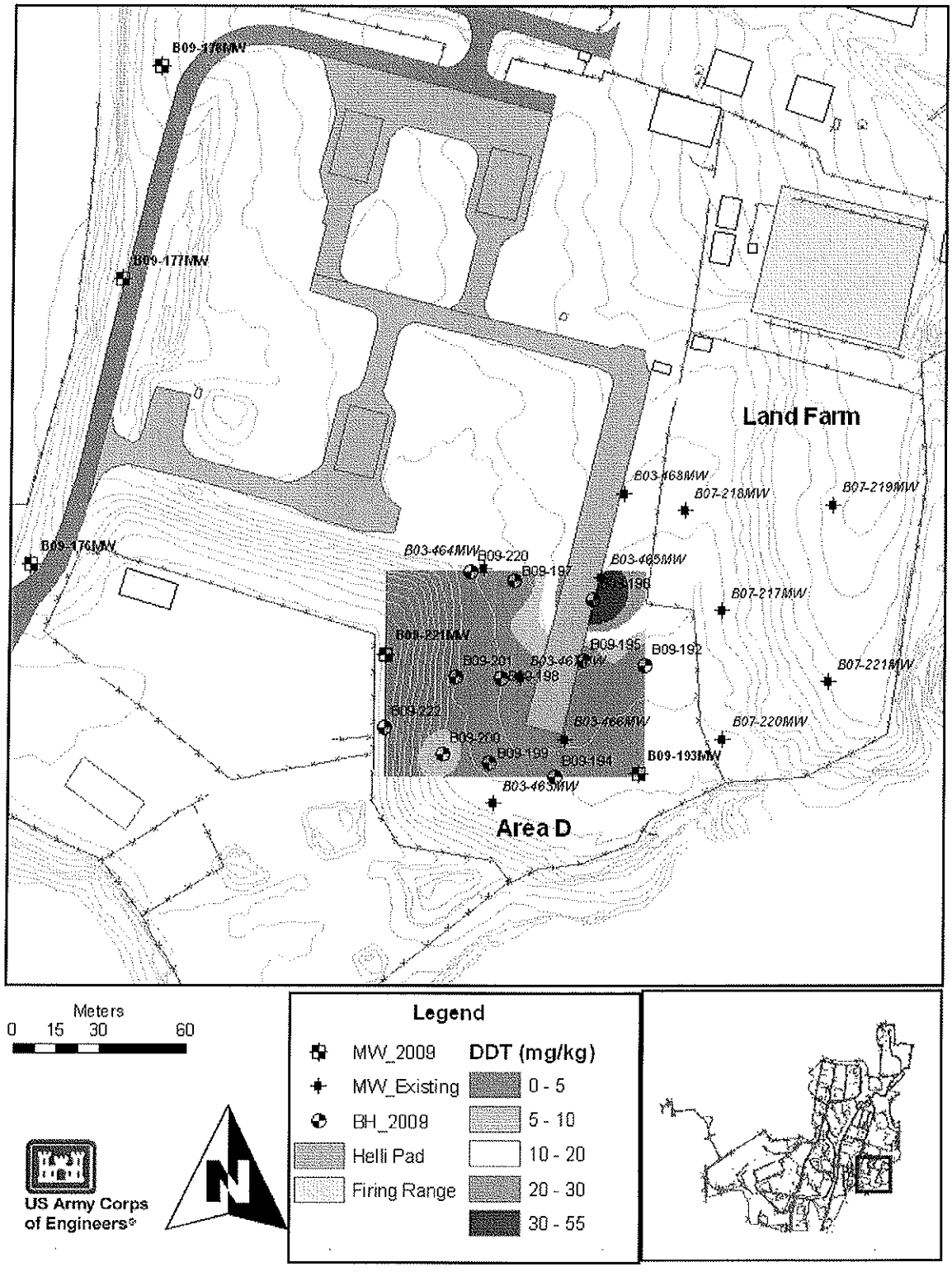
3798

Figure 4-2. PCE Concentration in Soil at LF-Area D of Camp Carroll.



3799

Figure 4-3 4',-4 DDT in Soil at LF-Area D of Camp Carroll.



3800