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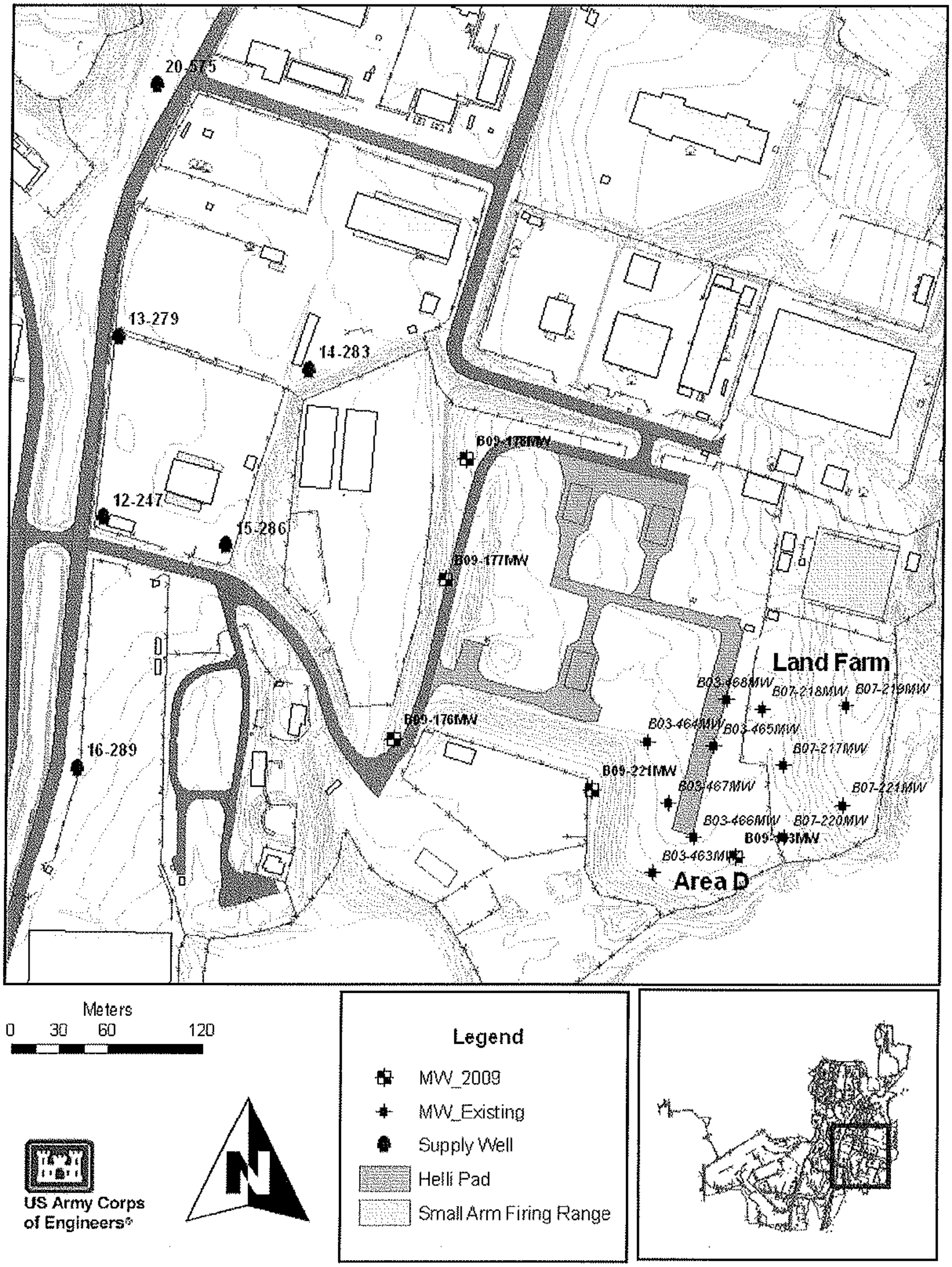
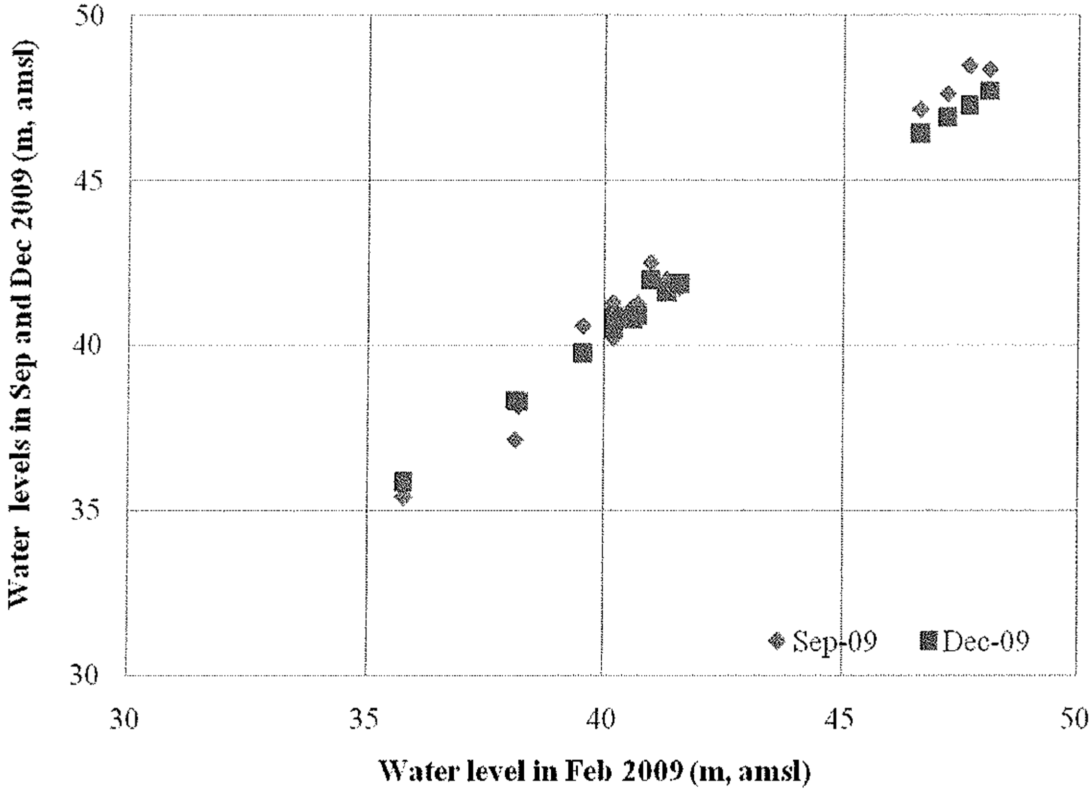
Figure 4-4. Supply Well and Groundwater Monitoring Well Locations in the Vicinity of LF-Area D of Camp Carroll.



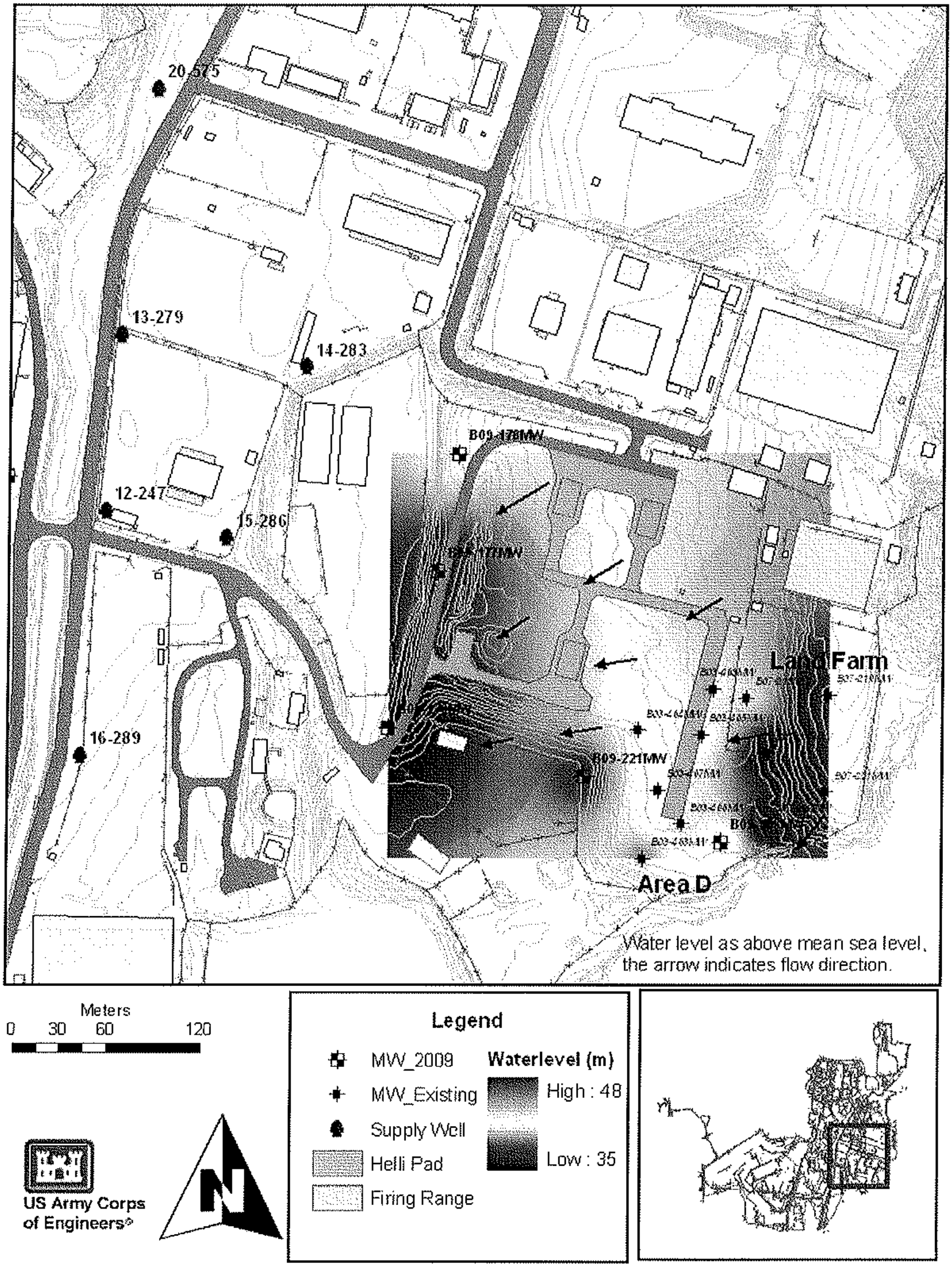
3801

Figure 4-5 Correlation among the Groundwater Level Measurement Results at LF-Area D of Camp Carroll.



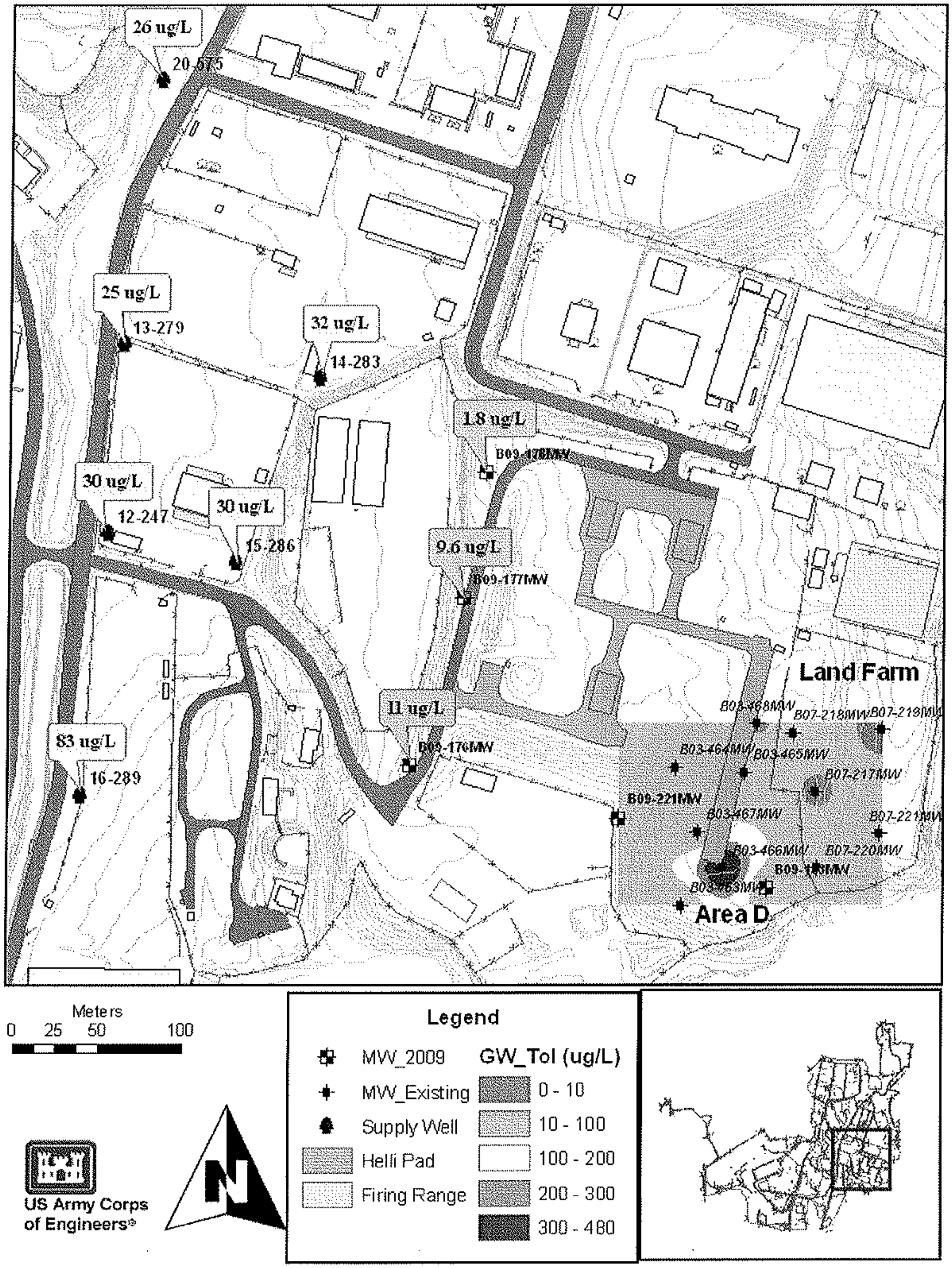
3802

Figure 4-6 Groundwater Flow Direction at LF-Area D of Camp Carroll.



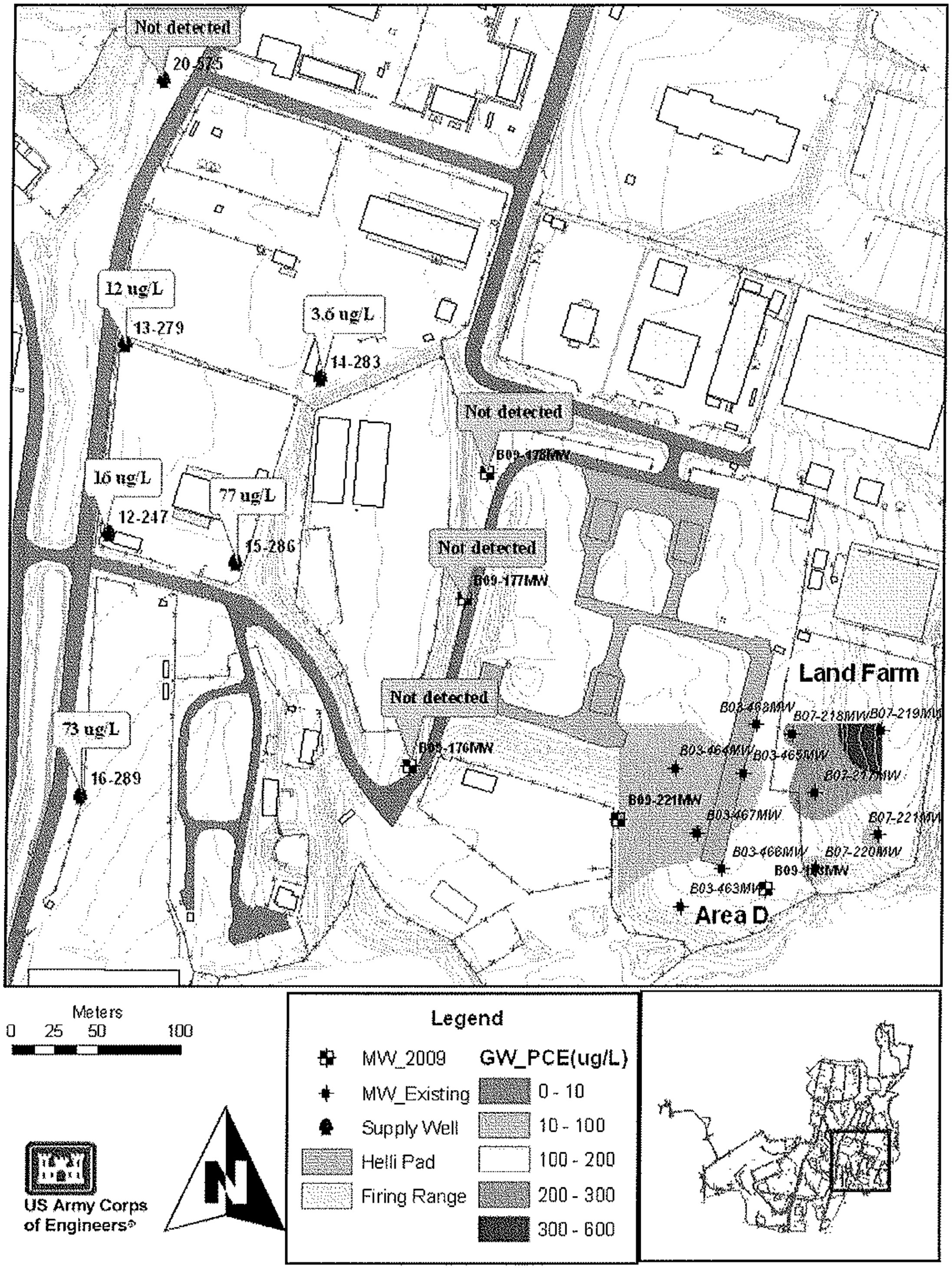
3803

Figure 4-7 Toluene in Groundwater of LF-Area D of Camp Carroll.



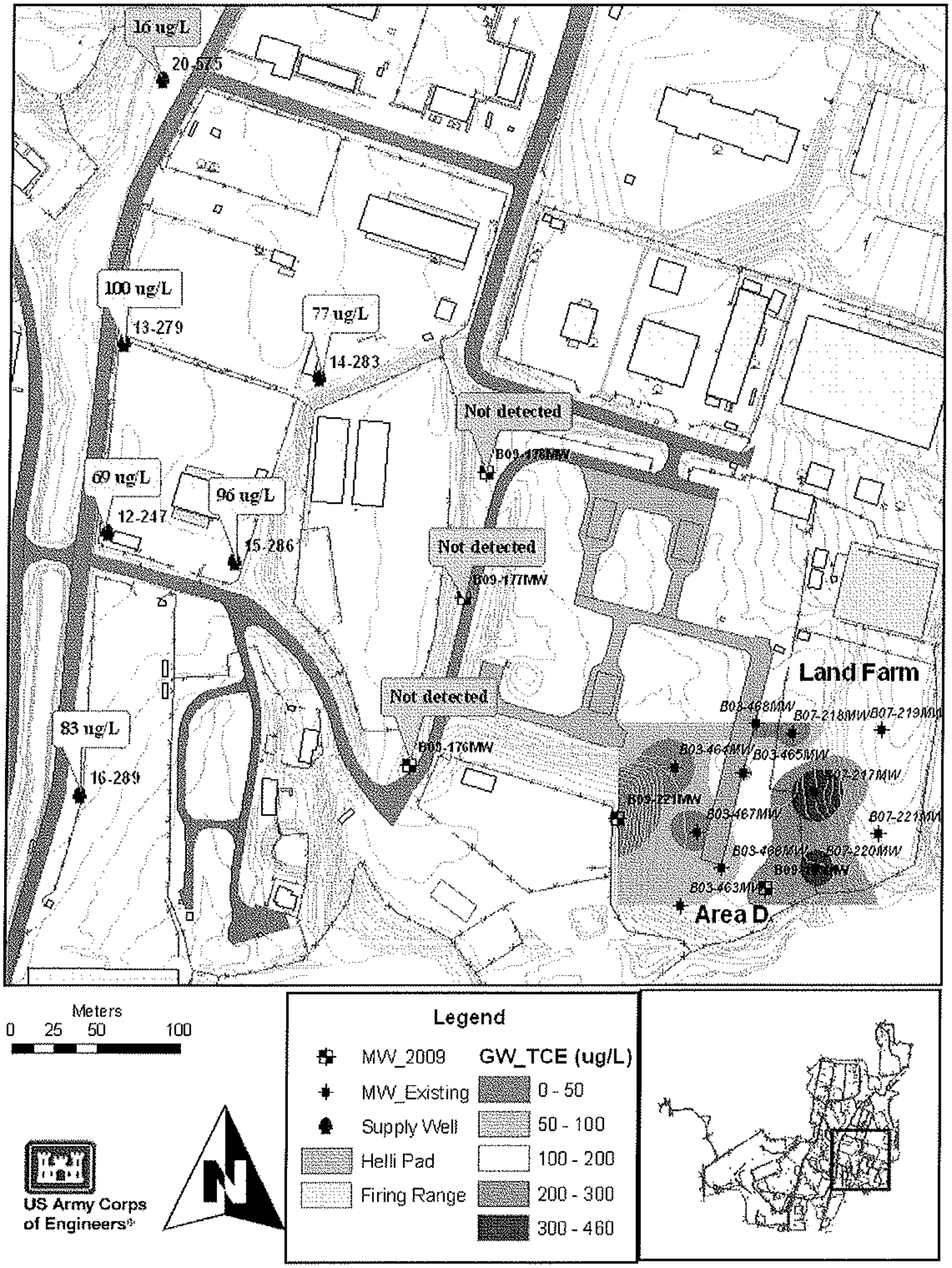
3804

Figure 4-8 PCE in Groundwater of LF-Area D of Camp Carroll.



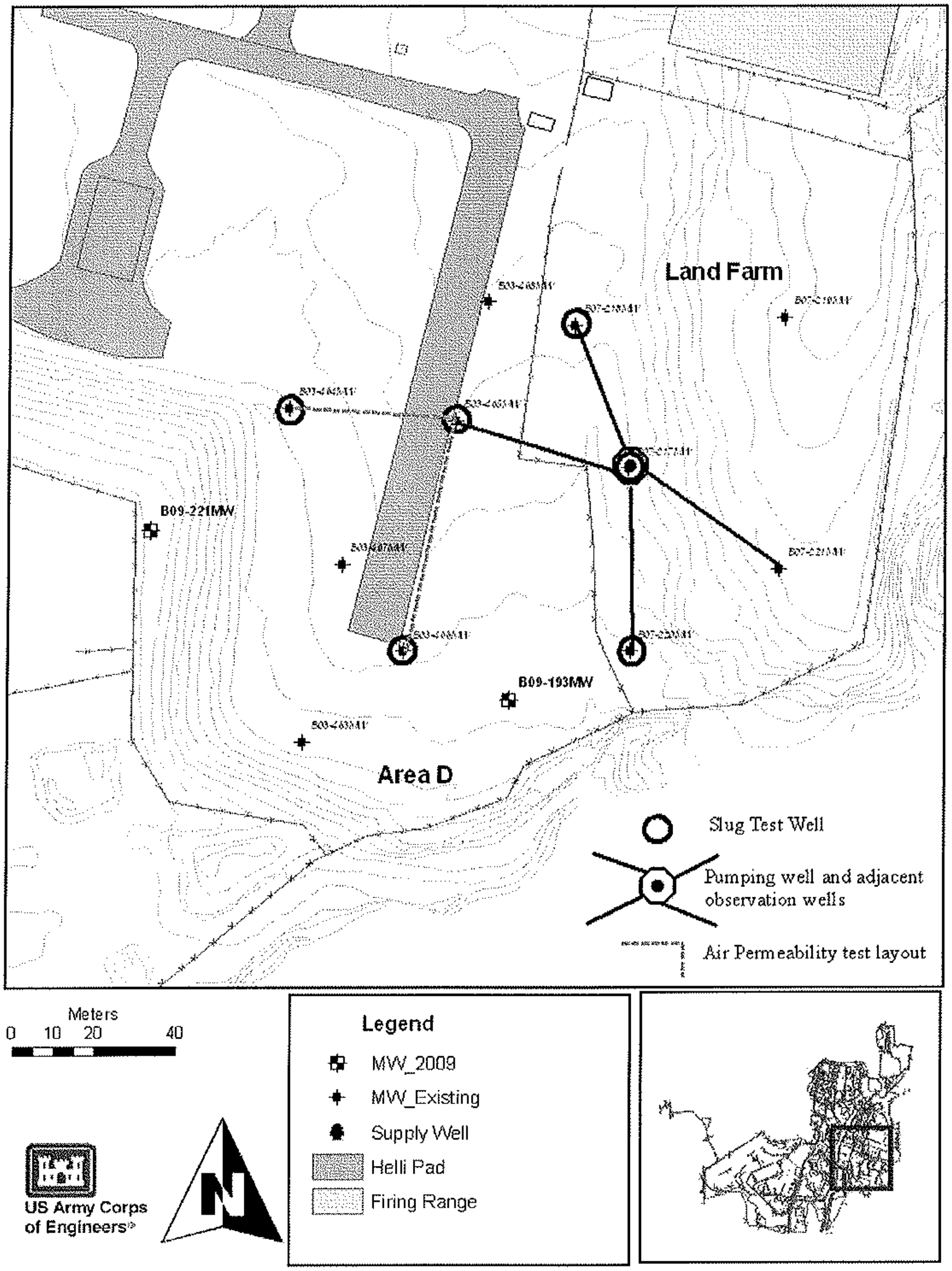
3805

Figure 4-9 TCE in Groundwater of LF-Area D of Camp Carroll.



3806

Figure 4-10 Monitoring Well Layout of Hydrologic Tests at LF-Area D of Camp Carroll.



3807

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Appendix I: Soil Borehole Logs

3809

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-192**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] b6
DATE STARTED: **28 Feb 09** FINISHED: **28 Feb 09** DRILLER: [redacted] b6
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **3.51 m; AD**
COORDINATES: N: **3,983,325.3** E: **447,763.6** GROUND ELEV.: **48.00 m** DATUM: **MSL**
GROUND COVER: **Dirt area** 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
0						FILL	SILTY SAND WITH GRAVEL: brown; moist; about 30% subangular fine to coarse gravel (max.3cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; very loose; fill material (SM); no odor; contain organic.	%Recovery = 48 PID = 6.8ppm FC = F3	
						FILL	SILTY GRAVEL WITH SAND: light brown; moist; about 50% subangular fine to coarse gravel (max.3.5cm); about 30% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; fill material (GM); no odor; contain asphalt concrete pavement.	FC = F3	
47—1	D1					FILL	SILTY SAND: light brown; moist; about 70% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; dense; fill material (SM); no odor.	FC = F3	
						FILL	CLAYEY SAND: light brown; moist; about 70% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; dense; fill material (SC); no odor.	FC = F3	
						FILL	SILT: reddish brown; moist; about 10% subangular fine to medium Sand (max.2mm); about 90% Fines; no plasticity; medium stiff; fill material (ML); no odor.	FC = F4	
46—2						FILL	CLAYEY SAND: brown; moist; about 60% subangular fine to medium Sand (max.2mm); about 40% Fines; low plasticity; loose; fill material (SC); no odor.	%Recovery = 46 PID = 3.4ppm	
						FILL	SILTY SAND: light brown; moist; about 80% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; medium dense; fill material (SM); no odor.		
45—3	D2					FILL	CLAYEY SAND: dark brown to brown; moist; about 10% subangular fine gravel (max.1cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; low plasticity; fill material (SC); no odor.		
44—4								%Recovery = 50 PID = 4.1ppm	
43—5	D3								
						CH	FAT CLAY: dark greenish gray; moist; subangular; about 20% subangular fine to coarse Sand (max.4.8mm); about 80% Fines; medium plasticity; alluvial soil; no odor.		
42—6									

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-193MW**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] ㅎㅎ
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] ㅎㅎ
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **15.5 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **15.5 m** WATER DEPTH: **9.1 m; AD**
COORDINATES: N: **3,983,292.5** E: **447,759.9** GROUND ELEV.: **49.27 m** DATUM: **MSL**
GROUND COVER: **Dirt area** 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
0	D1					FILL	**CLAYEY SAND**: brown; moist; no plasticity; very loose; fill material (SC); no odor; contain organic.	%Recovery = 49 PID = 3.6ppm FC = F3	
48						FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; subangular fine gravel (max.1cm); no plasticity; loose; fill material (SC); no odor.	FC = F3	
2 / 46	D2							%Recovery = 40 PID = 3ppm	
4 / 44	D3					FILL	**CLAYEY SAND**: reddish brown; moist; low plasticity; loose; fill material (SC); no odor.	%Recovery = 43 PID = 4.6ppm	
6						CH	**FAT CLAY**: greenish gray; moist; subangular fine to coarse gravel (max.3.5cm); high plasticity; medium stiff; no odor.		
42 – 34 (8–14)							Drilling from 6 to 15.5 meters to construct monitoring well. No soil samples collected at 6-15.5 m.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

CEPOF-ED-G 38/

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-194**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] b6
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] b6
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **No water; AD**
COORDINATES: N: **3,983,291.3** E: **447,730.6** GROUND ELEV.: **49.40 m** DATUM: **MSL**
GROUND COVER: **Dirt area** 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
0 – 2 (49, 1, 48)	D1					FILL	**CLAYEY SAND**: dark brown; moist; about 80% subangular fine to medium Sand (max.2mm); about 20% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic.	%Recovery = 48 PID = 4.6ppm FC = F3 FC = F3	
						FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine to coarse gravel (max.3cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; loose; fill material (SC); no odor.		
2 – 4 (47, 3, 46)	D2					FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; about 15% subangular fine to coarse gravel (max.3cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; fill material (SC); no odor; gray flat gravel.	%Recovery = 50 PID = 11.7ppm	
						FILL	**CLAYEY SAND**: brown; moist; about 5% subangular fine gravel (max.2cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 45% Fines; no plasticity; fill material (SC); no odor.		
4 – 6 (45, 5, 44)	D3					FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; about 15% subangular fine to coarse gravel (max.5cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 35% Fines; no plasticity; fill material (SC); no odor.	%Recovery = 45 PID = 4.8ppm	
						FILL	**CLAYEY SAND**: brown; moist; about 80% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; low plasticity; medium dense; fill material (SC); no odor. About 60% subangular fine to coarse Sand; about 40% Fines.		
						FILL	**CLAYEY SAND WITH GRAVEL**: greenish gray grades to black; moist; about 20% subangular fine to coarse gravel (max.4cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; low plasticity; fill material (SC); no odor.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

EXPLORATION LOG

US Army Corps Of Engineers — HOLE NO. **B09-195** — Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted]
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted]
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **8.0 m**
OVERBURDEN THICKNESS: **8.0 m** DEPTH DRILLED: **8.0 m** WATER DEPTH: **No water; AD**
COORDINATES: N: **3,983,328.0** E: **447,739.6** GROUND ELEV.: **50.20 m** DATUM: **MSL**
GROUND COVER: **Dirt area** CONTAMINATION: **Yes**
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
50.20 / 0						FILL	**CLAYEY SAND**: dark brown and grayish brown; moist; about 10% subangular fine to coarse gravel (max.3cm); about 70% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic.	%Recovery = 48 PID = 1.4ppm FC = F3	
49.3 / 0.9	D1						Brown; no gravels below 0.9m.		
49 / 1.2						FILL	**CLAYEY SAND**: reddish brown; moist; about 60% subangular fine to medium Sand (max.2mm); about 40% Fines; low plasticity; loose; fill material (SC); no odor.	FC = F3	
48 / 2	D2							%Recovery = 50 PID = 2.3ppm	
47 / 3.2						FILL	**LEAN CLAY WITH SAND**: reddish brown; moist; about 15% subangular fine to medium Sand (max.2mm); about 85% Fines; low plasticity; medium stiff; fill material (CL); no odor.		
46.5 / 3.7						FILL	**CLAYEY SAND**: brown; moist; about 60% subangular fine to coarse Sand (max.4.8mm); about 40% Fines; no plasticity; medium dense; fill material (SC); no odor.		
46 / 4	D3							%Recovery = 45 PID = 1345ppm	
45.6 / 4.6			yes			FILL	**SILTY SAND**: grayish brown; moist; about 70% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; medium dense; fill material (SM); moderate solvent odor 4.6 to 5.7m.		
44.5 / 5.7			yes			FILL	**LEAN CLAY WITH SAND**: reddish brown; moist; about 25% subangular fine to medium Sand (max.2mm); about 75% Fines; medium plasticity; medium stiff; fill material (CL); weak solvent odor 5.7 to 6.0m.		
44.2 / 6	D4		yes			FILL	**SILTY SAND**: dark greenish gray; moist; about 70% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; medium dense; fill material (SM); moderate solvent odor 6.0 to 7.0m.	%Recovery = 25 PID = 4.8ppm	
43.2 / 7						CH	**FAT CLAY**: dark greenish gray; moist; about 15% subangular fine to medium Sand (max.2mm); about 85% Fines; high plasticity; medium stiff; no odor.		
42.2 / 8									

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-196**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted]
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted]
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **5.6 m; AD**
COORDINATES: N: **3,983,357.9** E: **447,745.4** GROUND ELEV.: **50.90 m** DATUM: **MSL**
GROUND COVER: **Dirt area** CONTAMINATION: **Yes**
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
0						FILL	**SILTY GRAVEL WITH SAND**: brown; moist; about 50% subangular fine to coarse gravel (max.3cm); about 35% subangular fine to coarse Sand (max.4.8mm); about 15% Fines; no plasticity; very loose; fill material (GM); no odor.	%Recovery = 40 PID = 3.5ppm FC = F2	
						FILL	**CLAYEY SAND with Gravel**: reddish brown and grayish brown; moist; about 5% subangular fine to coarse gravel (max.3.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; loose; fill material (SC); no odor.	FC = F3	
50 / 1	D1								
						FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine gravel (max.1cm); about 70% subangular fine to medium Sand (max.2mm); about 20% Fines; low plasticity; fill material (SC); no odor.	FC = F3	
49 / 2						FILL	**CLAYEY SAND**: dark greenish gray and brown; moist; about 5% subangular fine gravel (max.1cm); about 65% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; fill material (SC); weak solvent odor 2.0 to 2.4m; contain wood material (3cm, gray, heavy odor).	%Recovery = 40 PID = 391ppm	
48 / 3	D2						Reddish brown; no odor at 2.4 - 4 m.		
47 / 4							Weak solvent odor 4.0 to 5.2m.	%Recovery = 25 PID = 1791ppm	
46 / 5	D3								
						FILL	**CLAYEY SAND**: reddish brown; moist; about 10% subangular fine gravel (max.1cm); about 50% subangular fine to medium Sand (max.2mm); about 40% Fines; no plasticity; fill material (SC); moderate solvent odor 5.2 to 5.6m; contain flat plastic (4cm, black, at 5.2m, heavy odor).		
						FILL	**CLAYEY SAND**: reddish brown; moist; about 5% subangular fine gravel (max.1cm); about 65% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; fill material (SC); weak solvent odor 5.6 to 6.0m.		
45 / 6									

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

3814

EXPLORATION LOG

US Army Corps Of Engineers — HOLE NO. **B09-197** — Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] 66
DATE STARTED: **02 Mar 09** FINISHED: **02 Mar 09** DRILLER: [redacted] 66
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **No water; AD**
COORDINATES: N: **3,983,359.5** E: **447,715.9** GROUND ELEV.: **50.11 m** DATUM: **MSL**
GROUND COVER: **Dirt area** 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
50 / 0						FILL	**CLAYEY GRAVEL WITH SAND**: gray; moist; about 40% subangular fine to coarse gravel (max.4cm); about 30% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; very loose; fill material (GC); no odor; contain organic.	%Recovery = 38 PID = 2.8ppm FC = F3	
						FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; about 15% subangular fine gravel (max.1cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 25% Fines; no plasticity; fill material (SC); no odor.	FC = F3	
49 / 1	D1					FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine gravel (max.1cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 40% Fines; no plasticity; fill material (SC); no odor.	FC = F3	
48 / 2								%Recovery = 50 PID = 1.9ppm	
						FILL	**SANDY CLAY**: reddish brown; moist; about 5% subangular fine gravel (max.1cm); about 20% subangular fine to coarse Sand (max.4.8mm); about 75% Fines; low plasticity; fill material (CL); no odor.		
47 / 3	D2					SC	**CLAYEY SAND**: brown; moist; about 5% subangular fine gravel (max.1cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; no odor.		
46 / 4							Medium dense; no gravels below 4m.	%Recovery = 50 PID = 5.4ppm	
45 / 5	D3								
						CH	**FAT CLAY**: reddish brown; moist; about 10% subangular fine to medium Sand (max.2mm); about 90% Fines; high plasticity; medium stiff; no odor.		
6									

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-198**

Far East District

PROJECT: RIRA at Area D of Camp Carroll

LOCATION: Camp carroll | G&EE NO.: 08-035E | INSPECTOR: [redacted] bb

DATE STARTED: 02 Mar 09 | FINISHED: 02 Mar 09 | DRILLER: [redacted] bb

DRILLING METHOD/EQUIPMENT: Drect-Push

DRILLING AGENCY: Far East District | HOLE DIAMETER: 5 cm | TOTAL DEPTH: 6.0 m

OVERBURDEN THICKNESS: 6.0 m | DEPTH DRILLED: 6.0 m | WATER DEPTH: No water; AD

COORDINATES: N: 3,983,325.6 E: 447,711.6 | GROUND ELEV.: 49.55 m | DATUM: MSL

GROUND COVER: Dirt area | 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
0	D1					FILL	CLAYEY SAND: brown; moist; about 5% subangular fine gravel (max.1cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 35% Fines; no plasticity; fill material (SC); no odor.	%Recovery = 50 PID = 1.8ppm FC = F3	
49						FILL	CLAYEY GRAVEL WITH SAND: light brown; moist; about 60% subangular fine to coarse gravel (max.3.5cm); about 25% subangular fine to medium Sand (max.2mm); about 15% Fines; no plasticity; fill material (GC); no odor.	FC = F2	
						FILL	CLAYEY SAND WITH GRAVEL: brown; moist; about 15% subangular fine gravel (max.1cm); about 55% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; fill material (SC); no odor.	FC = F3	
1						FILL	LEAN CLAY: yellowish brown; moist; about 10% fine Sand (max.0.43mm); about 90% Fines; low plasticity, very stiff; fill material (CL); no odor.	FC = F4	
48						FILL	CLAYEY SAND: brown; moist; about 10% subangular fine gravel (max.2cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; low plasticity; fill material (SC); no odor; contain asphalt concrete pavement (1cm, at 2.2m).		
2 47 3 46	D2							%Recovery = 48 PID = 2.4ppm	
						ML	SILT WITH SAND: greenish brown; moist; about 15% subangular fine Sand (max.0.43mm); about 85% Fines; low plasticity; medium stiff; no odor.		
4 45	D3							%Recovery = 50 PID = 1.9ppm	
						SM	SILTY SAND: yellowish brown; moist; about 5% subangular fine gravel (max.1cm); about 75% subangular fine to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; no odor.		
5						ML	SILT WITH SAND: reddish brown; moist; about 5% subangular fine gravel (max.1cm); about 30% subangular fine to coarse Sand (max.4.8mm); about 65% Fines; no plasticity; no odor.		
44						SC	CLAYEY SAND WITH GRAVEL: brown; moist; about 70% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; dense; no odor.		
						CH	FAT CLAY WITH SAND: greenish gray; moist; about 15% subangular fine to medium Sand (max.2mm); about 85% Fines; high plasticity; stiff; no odor.		
6						SC	CLAYEY SAND: brown; moist; about 70% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; medium dense; no odor.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-199**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**

LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] bb

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

DRILLING METHOD/EQUIPMENT: **Drect-Push**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **8.0 m**

OVERBURDEN THICKNESS: **8.0 m** DEPTH DRILLED: **8.0 m** WATER DEPTH: **No water; AD**

COORDINATES: N: **3,983,296.1** E: **447,707.8** GROUND ELEV.: **49.21 m** DATUM: **MSL**

GROUND COVER: **Dirt area** 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
0–2 (49.21–47.21)	D1					FILL	**CLAYEY GRAVEL WITH SAND**: grayish brown; moist; about 20% subangular fine gravel (max.2cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor; contain organic.	%Recovery = 50 PID = 1.9ppm FC = F3	
						FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine to coarse gravel (max.3cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor.	FC = F3	
						FILL	**SILTY SAND**: brown; moist; about 5% subangular fine gravel (max.0.8cm); about 55% subangular fine to coarse Sand (max.4.8mm); about 40% Fines; no plasticity; fill material (SM); no odor.	FC = F3	
2–4	D2					FILL	**CLAYEY SAND**: light brown; moist; about 5% subangular fine to coarse gravel (max.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor; contain asphalt concrete pavement (2cm, at 3.2m).	%Recovery = 29 PID = 7.9ppm FC = F3	
						CL	**LEAN CLAY**: reddish brown; moist; about 30% subangular fine to medium Sand (max.2mm); about 70% Fines; medium plasticity; medium stiff; no odor.		
4–6	D3					SC	**CLAYEY SAND WITH GRAVEL**: reddish brown; moist; about 20% subangular fine to coarse gravel (max.3cm); about 50% subangular fine to medium Sand (max.2mm); about 30% Fines; low plasticity; no odor.	%Recovery = 43 PID = 2.1ppm	
6–8	D3					SC	**CLAYEY SAND**: brown; moist; about 10% subangular fine gravel (max.2cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; low plasticity; no odor.	%Recovery = 48 PID = 8.6ppm	

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKCREA.GDT 6/7/11

US Army Corps Of Engineers

EXPLORATION LOG

HOLE NO. **B09-200**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**

LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] bb

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

DRILLING METHOD/EQUIPMENT: **Drect-Push**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**

OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **No water; AD**

COORDINATES: N: **3,983,299.2** E: **447,691.4** GROUND ELEV.: **48.61 m** DATUM: **MSL**

GROUND COVER: **Lawn area** 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
0 – 1.7 (48, 1, 47)	D1 (0–2)					FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine gravel (max.1.5cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic at 0-0.1m.	%Recovery = 50 PID = 3.6ppm FC = F3	
1.7 – 2.7 (2, 46)	D2 (2–4)					FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; about 30% subangular fine gravel (max.5cm); about 40% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor.	FC = F3 %Recovery = 50 PID = 1.9ppm	
2.7 – 3.5 (3)						FILL	**CLAYEY SAND**: brown; moist; about 5% subangular fine gravel (max.1cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor.		
3.5 – 3.7 (45)						FILL	**LEAN CLAY**: reddish brown; moist; about 10% subangular fine to medium Sand (max.2mm); about 90% Fines; medium plasticity; medium stiff; fill material (CL); no odor.		
3.7 – 5.8 (4, 44, 5, 43)	D3 (4–6)					FILL	**CLAYEY SAND**: brown; moist; about 10% subangular fine gravel (max.1cm); about 60% subangular fine to medium Sand (max.2mm); about 30% Fines; low plasticity; fill material (SC); no odor.	%Recovery = 50 PID = 2ppm	
5.8 – 6 (6)						FILL	**CLAYEY SAND WITH GRAVEL**: grayish brown; moist; about 30% subangular fine to coarse gravel (max.4cm); about 40% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

EXPLORATION LOG

US Army Corps Of Engineers

HOLE NO. **B09-201**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**

LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] bb

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

DRILLING METHOD/EQUIPMENT: **Drect-Push**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**

OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **No water; AD**

COORDINATES: N: **3,983,326.1** E: **447,695.7** GROUND ELEV.: **48.99 m** DATUM: **MSL**

GROUND COVER: **Lawn area** 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
0						FILL	**CLAYEY SAND**: dark brown; moist; about 5% subangular fine gravel (max.1cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic.	%Recovery = 38 PID = 0.5ppm FC = F3	
						FILL FILL	**WELL GRADED SAND WITH SILT AND GRAVEL**: dark brown; moist; about 30% subangular fine to coarse gravel (max.4cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 10% Fines; no plasticity; loose; fill material (SW-SM); no odor; contain concrete pavement.	FC = F2 FC = F3	
48—1	D1					FILL	**SILTY SAND**: dark brown; moist; about 5% subangular fine gravel (max.1cm); about 70% subangular fine to coarse Sand (max.4.8mm); about 25% Fines; no plasticity; loose; fill material (SM); no odor.	FC = F3	
							SILTY SAND WITH GRAVEL: brown; moist; about 20% subangular fine to coarse gravel (max.5cm); about 60% subangular medium to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; loose; fill material (SM); no odor; contain concrete pavement.		
47—2						FILL	**SILTY SAND WITH GRAVEL**: brown; moist; about 40% subangular fine to coarse gravel (max.4cm); about 40% subangular medium to coarse Sand (max.4.8mm); about 20% Fines; no plasticity; loose; fill material (SM); no odor; contain concrete pavement.	%Recovery = 40 PID = 0.9ppm	
46—3	D2					FILL	**SILTY SAND**: brown; moist; about 5% subangular fine gravel (max.1cm); about 60% subangular medium to coarse Sand (max.4.8mm); about 35% Fines; no plasticity; loose; fill material (SM); no odor.		
45—4						FILL	**CLAYEY SAND**: brown; moist; about 5% subangular fine gravel (max.1cm); about 60% subangular fine to medium Sand (max.2mm); about 35% Fines; medium plasticity; fill material (SC); no odor.	%Recovery = 49 PID = 0.6ppm	
						FILL	**SILTY SAND**: brown; moist; about 5% subangular fine gravel (max.1cm); about 70% subangular fine to coarse Sand (max.4.8mm); about 25% Fines; no plasticity; fill material (SM); no odor.		
44—5	D3					FILL	**CLAYEY SAND**: brown; moist; about 15% subangular fine to coarse gravel (max.5cm); about 55% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; fill material (SC); no odor; contain concrete pavement.		
						FILL	**LEAN CLAY**: reddish brown; moist; about 30% subangular fine to medium Sand (max.2mm); about 70% Fines; medium plasticity; soft; fill material (CL); no odor.		
						FILL	**CLAYEY SAND WITH GRAVEL**: light brown; moist; about 20% subangular fine to coarse gravel (max.4cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; low plasticity; loose; fill material (SC); no odor; contain concrete pavement.		
43—6									

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

EXPLORATION LOG

US Army Corps Of Engineers

HOLE NO. **B09-220**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] b6
DATE STARTED: **03 Mar 09** FINISHED: **03 Mar 09** DRILLER: [redacted] b6
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **No water; AD**
COORDINATES: N: **3,983,362.9** E: **447,700.4** GROUND ELEV.: **49.79 m** DATUM: **MSL**
GROUND COVER: **Lawn area** CONTAMINATION: **Yes**
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
0	D1					FILL FILL	**CLAYEY SAND**: dark brown; moist; about 5% subangular fine gravel (max.1.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic. **SILTY SAND**: brown; moist; about 5% subangular fine gravel (max.1.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; loose; fill material (SM); no odor; contain concrete pavement.	%Recovery = 50 PID = 21.5ppm FC = F3 FC = F3	
49 / 1									
						FILL	**SILTY GRAVEL WITH SAND**: light brown; moist; about 60% subangular fine to coarse gravel (max.5cm); about 25% subangular fine to coarse Sand (max.4.8mm); about 15% Fines; no plasticity; loose; fill material (GM); no odor; contain concrete pavement.	FC = F2	
			■			FILL	**SILTY SAND WITH GRAVEL**: greenish brown and brown; moist; about 20% subangular fine to coarse gravel (max.5cm); about 50% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; loose; fill material (SM); weak fuel odor 1.6 to 1.7m; contain concrete pavement. No odor below 1.7m.	FC = F3	
48 / 2	D2					FILL		%Recovery = 38 PID = 2.5ppm	
							SILTY SAND: brown; moist; about 10% subangular fine to coarse gravel (max.3cm); about 60% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; loose; fill material (SM); no odor.		
47 / 3									
46 / 4	D3							%Recovery = 20 PID = 1.9ppm	
45 / 5									
44 / 6									

EXPLORATION LOG

US Army Corps Of Engineers

HOLE NO. **B09-221MW**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] bb
DATE STARTED: **04 Mar 09** FINISHED: **04 Mar 09** DRILLER: [redacted] bb
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **11.8 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **11.8 m** WATER DEPTH: **5.1 m; AD**
COORDINATES: N: **3,983,334.3** E: **447,671.1** GROUND ELEV.: **42.98 m** DATUM: **MSL**
GROUND COVER: **Lawn area** 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
0	D1					FILL	**CLAYEY SAND**: dark brown; moist; about 5% subangular fine gravel (max.1.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; very loose; fill material (SC); no odor; contain organic.	%Recovery = 38 PID = 1.9ppm FC = F3	
42						FILL	**SILTY SAND**: brown; moist; about 5% subangular fine to coarse gravel (max.3cm); about 70% subangular fine to coarse Sand (max.4.8mm); about 25% Fines; no plasticity; loose; fill material (SM); no odor; no gravels below 0.7m.	FC = F3	
						ML	**SANDY SILT**: reddish brown; moist; about 15% fine Sand (max.0.43mm); about 85% Fines; low plasticity; medium stiff; residual soil; no odor; with mica.	FC = F4	
2 / 40	D2							%Recovery = 50 PID = 2.2ppm	
4 / 38	D3					ML	**SILT**: light brown; moist; about 10% subangular fine to medium Sand (max.2mm); about 90% Fines; low plasticity; medium stiff; residual soil; no odor; with mica.	%Recovery = 43 PID = 3.1ppm	
6 / 36 / 8 / 34 / 10 / 32							Drilling from 6 to 11.8 meters to construct monitoring well. No soil samples collected at 6-11.8 m.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

EXPLORATION LOG

US Army Corps Of Engineers

HOLE NO. **B09-222**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**
LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] bb
DATE STARTED: **04 Mar 09** FINISHED: **04 Mar 09** DRILLER: [redacted] bb
DRILLING METHOD/EQUIPMENT: **Drect-Push**
DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **6.0 m**
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **6.0 m** WATER DEPTH: **1.66 m; AD**
COORDINATES: N: **3,983,308.4** E: **447,670.6** GROUND ELEV.: **43.31 m** DATUM: **MSL**
GROUND COVER: **Lawn area** 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
0 – 1 (43)	D1					FILL	**CLAYEY SAND**: dark brown and brown; moist; about 5% subangular fine gravel (max.1.5cm); about 65% subangular fine to coarse Sand (max.4.8mm); about 30% Fines; no plasticity; very loose to loose; fill material (SC); no odor; contain organic at 0-0.1m.	%Recovery = 43 PID = 2.2ppm FC = F3	
1 (42)						FILL	**FAT CLAY**: brown; moist; about 15% subangular fine to medium Sand (max.2mm); about 85% Fines; high plasticity; medium stiff; fill material (CH); no odor.	FC = F4	
▼						FILL	**CLAYEY SAND**: brown; moist; about 70% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; dense; fill material (SC); no odor.	FC = F3	
2 – 3 (41, 40)	D2							%Recovery = 33 PID = 3.2ppm	
						FILL	**CLAYEY SAND WITH GRAVEL**: brown; moist; about 20% subangular fine to coarse gravel (max.3cm); about 50% subangular fine to medium Sand (max.2mm); about 30% Fines; no plasticity; very dense; fill material (SC); no odor.		
4 (39)						SM	**SILTY SAND**: brown; moist; about 60% subangular fine to medium Sand (max.2mm); about 40% Fines; no plasticity; dense; residual soil; no odor.	%Recovery = 43 PID = 1.7ppm	
						ML	**SANDY SILT**: dark brown; moist; about 30% subangular medium Sand (max.2mm); about 70% Fines; low plasticity; stiff; residual soil; no odor; with mica.		
5 – 6 (38)	D3					ML	**SANDY SILT**: yellowish brown; moist; about 10% fine Sand (max.0.43mm); about 90% Fines; low plasticity; stiff; residual soil; no odor; with mica.		

ENVIRO-EXPLORATION LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 6/7/11

Appendix II: Monitoring Well Construction Logs

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-176MW**

Far East District

PROJECT: Remedial Investigation/Feasibility Study at Land farm

LOCATION: Camp Carroll | G&EE NO.: 08-034E | INSPECTOR: [redacted] bb

DATE STARTED: 20 Feb 09 | FINISHED: 21 Feb 09 | DRILLER: [redacted] bb

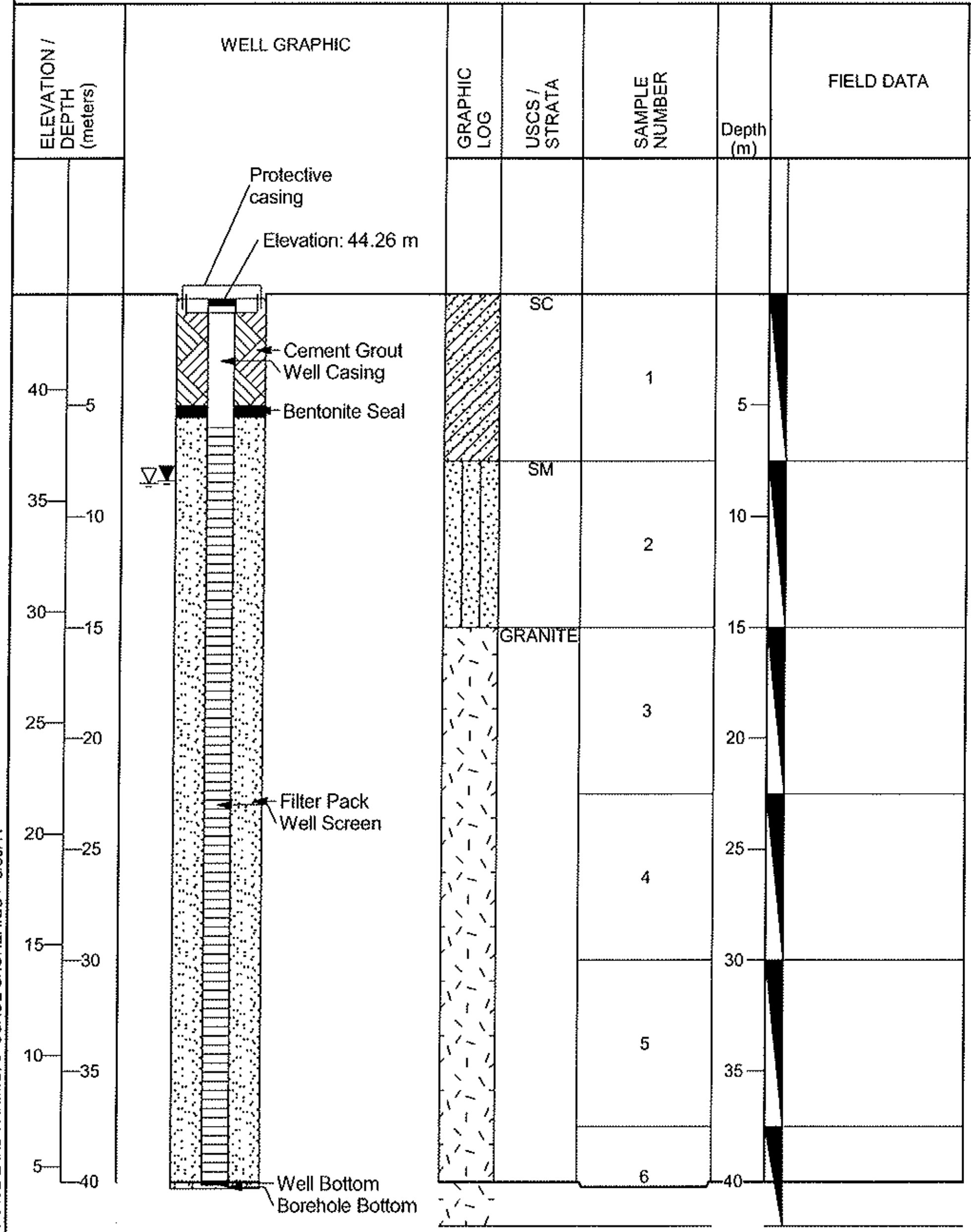
DRILLING METHOD/EQUIPMENT: DrillTech

DRILLING AGENCY: Far East District | HOLE DIAMETER: 18 cm | TOTAL DEPTH: 40.0 m

OVERBURDEN THICKNESS: 15.0 m | DEPTH DRILLED: 40.0 m | WATER DEPTH: 8.4 m

COORDINATES: N: 3,983,365.3 E: 447,546.2 | GROUND ELEV.: 44.29 m | DATUM: MSL

GROUND COVER: Grass | TOP of WELL RISER CASING ELEV.: 44.26 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 6.0m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 6.0 to 40.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 40.0 to 40.15m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 5.0m
Quantity: 4 bags of 20 kg

SEAL
Type: Bentonite
Interval: 5.0 to 5.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 5.5 to 40.15m
Quantity: 95kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 8.5m
▼ Ground-water level on 8.4m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E LAND FARM.GPJ USACE SKOREA.GDT 5/30/11

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-177MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at Land farm**

LOCATION: **Camp Carroll** G&EE NO.: **08-034E** INSPECTOR: [redacted] bb

DATE STARTED: **23 Feb 09** FINISHED: **24 Feb 09** DRILLER: [redacted] bb

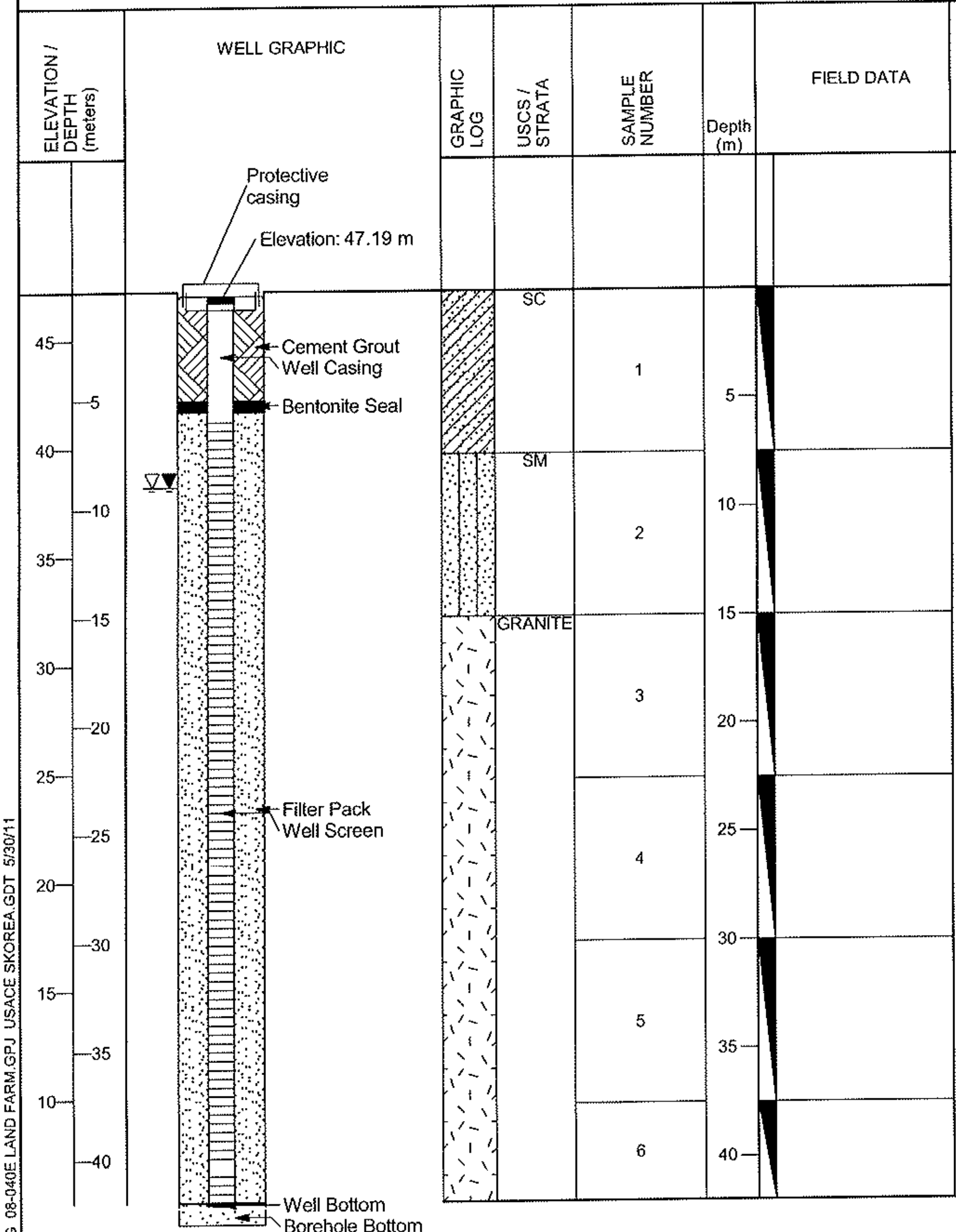
DRILLING METHOD/EQUIPMENT: **DrillTech**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **18 cm** TOTAL DEPTH: **42.0 m**

OVERBURDEN THICKNESS: **15.0 m** DEPTH DRILLED: **42.0 m** WATER DEPTH: **9.0 m**

COORDINATES: N: **3,983,564.4** E: **447,577.6** GROUND ELEV.: **47.20 m** DATUM: **MSL**

GROUND COVER: **Grass** TOP of WELL RISER CASING ELEV.: **47.19 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 6.0m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 6.0 to 42.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 42.0 to 42.15m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 5.0m
Quantity: 4 bags of 20 kg

SEAL
Type: Bentonite
Interval: 5.0 to 5.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 5.5 to 42.15m
Quantity: 100kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 9.0m
▼ Ground-water level on 9.0m
▲ Product level on

Note:

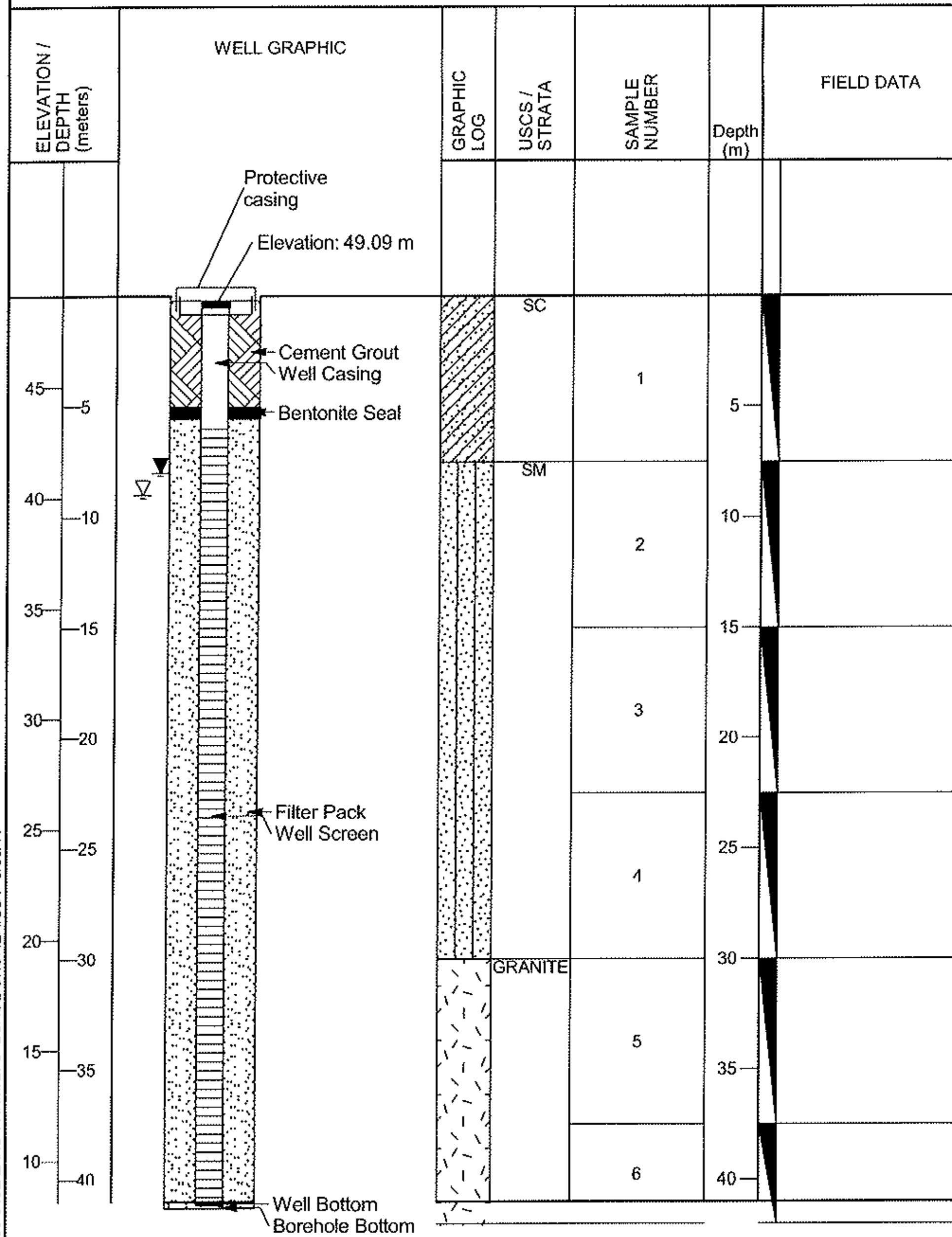
US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-178MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at Land farm**			
LOCATION: **Camp Carroll**	G&EE NO.: **08-034E**	INSPECTOR: [redacted]	
DATE STARTED: **24 Feb 09**	FINISHED: **25 Feb 09**	DRILLER: [redacted]	
DRILLING METHOD/EQUIPMENT: **DrillTech**			
DRILLING AGENCY: **Far East District**	HOLE DIAMETER: **18 cm**	TOTAL DEPTH: **41.0 m**	
OVERBURDEN THICKNESS: **15.0 m**	DEPTH DRILLED: **41.0 m**	WATER DEPTH: **8.0 m**	
COORDINATES: N: **3,983,538.6** E: **447,590.4**	GROUND ELEV.: **49.12 m**	DATUM: **MSL**	
GROUND COVER: **Grass**	TOP of WELL RISER CASING ELEV.: **49.09 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 6.0m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 6.0 to 41.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 41.0 to 41.15m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 5.0m
Quantity: 4 bags of 20 kg

SEAL
Type: Bentonite
Interval: 5.0 to 5.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 5.5 to 41.15m
Quantity: 95kg
Grain Size: 0.4-1.2 mm

Remarks:
∇ Ground-water level at completion of borehole 9.0m
▼ Ground-water level on 8.0m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E LAND FARM.GPJ USACE SKOREA.GDT 5/30/11

CEPOF-ED-G

3826

MONITORING WELL LOG

US Army Corps Of Engineers

WELL NO. **B09-193MW**

Far East District

PROJECT: **RIRA at Area D of Camp Carroll**

LOCATION: **Camp carroll** G&EE NO.: **08-035E** INSPECTOR: [redacted] 66

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

DRILLING METHOD/EQUIPMENT: **Drect-Push**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **5 cm** TOTAL DEPTH: **15.5 m**

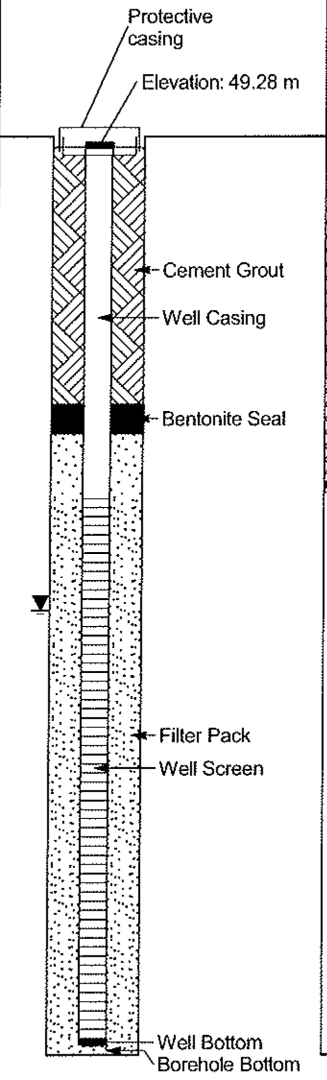
OVERBURDEN THICKNESS: **6.0 m** DEPTH DRILLED: **15.5 m** WATER DEPTH: **8.0 m; AD**

COORDINATES: N: **3,983,292.5** E: **447,759.9** GROUND ELEV.: **49.27 m** DATUM: **MSL**

GROUND COVER: **Dirt area** TOP of WELL RISER CASING ELEV.: **49.28 m**

ELEVATION / DEPTH (meters): 48, 46, 44, 42, 40, 38, 36, 34 / 2, 4, 6, 8, 10, 12, 14

WELL GRAPHIC



GRAPHIC LOG	USCS / STRATA	SAMPLE NUMBER	Depth (m)	FIELD DATA
	FILL	1	0–2	%Recovery = 49 PID = 3.6ppm FC = F3 FC = F3
	FILL	2	2–4	%Recovery = 40 PID = 3ppm
	FILL	3	4–6	%Recovery = 43 PID = 4.6ppm
	CH		6	

Depth (m): 2, 4, 6, 8, 10, 12, 14

WELL CONSTRUCTION DETAILS

PROTECTIVE CASING
Diameter: 30 cm
Type: Manhole
Interval: -0.02 to 0.18m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: -0.01 to 6.1m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 6.1 to 15.2m

WELL POINT
Type: Schedule 40 PVC
Interval: 15.2 to 15.35m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 4.5m
Quantity: 10 bags of 20 kg

SEAL
Type: Bentonite
Interval: 4.5 to 5.0m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 5.0 to 15.2m
Quantity: 80 kg
Grain Size: 0.4-1.2 mm

Remarks:
∇ Ground-water level at completion of borehole 03/03/09 9.1 m
▼ Ground-water level on 09/04/09 8.0m
▲ Product level on

Note:

MONITORING WELL LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 5/31/11

MONITORING WELL LOG

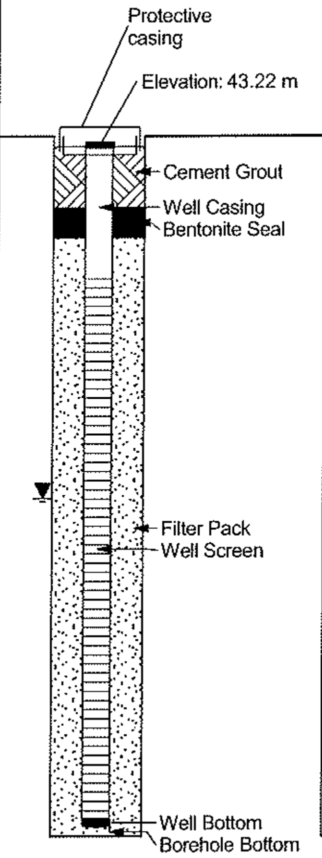
US Army Corps Of Engineers

WELL NO. **B09-221MW**

Far East District

PROJECT: RIRA at Area D of Camp Carroll
LOCATION: Camp carroll G&EE NO.: 08-035E INSPECTOR: [redacted] b6
DATE STARTED: 04 Mar 09 FINISHED: 04 Mar 09 DRILLER: [redacted] b6
DRILLING METHOD/EQUIPMENT: Drect-Push
DRILLING AGENCY: Far East District HOLE DIAMETER: 5 cm TOTAL DEPTH: 11.8 m
OVERBURDEN THICKNESS: 6.0 m DEPTH DRILLED: 11.8 m WATER DEPTH: 6.1 m; AD
COORDINATES: N: 3,983,334.3 E: 447,671.1 GROUND ELEV.: 42.98 m DATUM: MSL
GROUND COVER: LAWN AREA TOP of WELL RISER CASING ELEV.: 43.22 m

ELEVATION / DEPTH (meters)	WELL GRAPHIC	GRAPHIC LOG	USCS / STRATA	SAMPLE NUMBER	Depth (m)	FIELD DATA
42			FILL FILL FILL ML	1		%Recovery = 38 PID = 1.9ppm FC = F3 FC = F3 FC = F3 FC = F4
2 / 40				2	2	%Recovery = 50 PID = 2.2ppm
4 / 38			ML	3	4	%Recovery = 43 PID = 3.1ppm
6 / 36					6	
8 / 34					8	
10 / 32					10	



WELL CONSTRUCTION DETAILS

PROTECTIVE CASING
Diameter: 30 cm
Type: Manhole
Interval: -0.02 to 0.18m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: -0.01 to 2.4m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 2.4 to 11.5m

WELL POINT
Type: Schedule 40 PVC
Interval: 11.5 to 11.65m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 1.2m
Quantity: 10 bags of 20 kg

SEAL
Type: Bentonite
Interval: 1.2 to 1.7m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 1.7 to 11.5m
Quantity: 80 kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 03/04/09 . 5.1 m
▼ Ground-water level on 09/04/09 6.1m
▲ Product level on

Note:

MONITORING WELL LOG 08-035E AREA D CARROLL.GPJ USACE SKOREA.GDT 5/31/11

Appendix III: Hydrologic Field Test (Slug, pumping and air permeability tests)

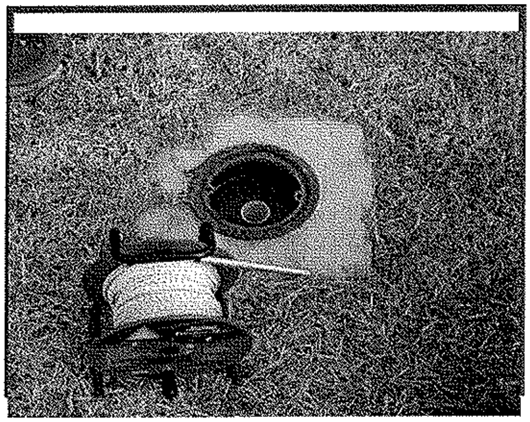
US Army Corps of Engineers

Far East District

Draft Final Report

FOR

TASK ORDER NO.0014
CAMP CARROLL REMEDIAL EVALUATION AT AREA D and LANDFARM



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:

3830

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, pumping 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(2nd). Kinds of field test are slug, pumping, and air permeability tests. The project site were Land farm and Area D in Camp Carroll. Slug test was conducted in the Land farm and Area D. Pumping test and an air permeability test were conducted in the Land farm and Area D respectively (Table 1).

2. ANALYSIS METHOD

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).

3832

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

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

Where:

$\boldsymbol{K}$ = hydraulic conductivity [ft/sec]

$\boldsymbol{R_e}$ = filter pack (borehole) radius [ft]

$\boldsymbol{R}$ = screen radius [ft]

$\boldsymbol{r_c}$ = casing radius [ft]

$\boldsymbol{L_e}$ = length of open screen (or borehole)[ft]

$\boldsymbol{H_0}$ = drawdown at t = 0

$\boldsymbol{H_t}$ = drawdown at t ≥ $\boldsymbol{H_0}$

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:

$\boldsymbol{K}$ = hydraulic conductivity [ft/sec]

$\boldsymbol{r}$ = casing radius [ft]

$\boldsymbol{L}$ = length of open screen (or borehole)[ft]

$\boldsymbol{R}$ = filter pack (borehole) radius [ft]

$\boldsymbol{T_0}$ = 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

$\boldsymbol{H}$ = initial water level prior to removal of slug

3833

H_0 = water level at t = 0

h = recorded water level at t > 0

2.2 Pumping test

The most reliable and commonly used method of determining aquifer characteristics is by controlled aquifer pumping tests. Groundwater flow varies in space and time and depends on the hydraulic properties of the rocks and the boundary conditions imposed on the groundwater system. Pumping tests provide results that are more representative of aquifer characteristics than those predicted by slug or bailer tests. Aquifer characteristics that may be obtained from pumping tests include hydraulic conductivity (K), transmissivity (T), specific yield (Sy) for unconfined aquifers, and storage coefficient (S) for confined aquifers(EPA,1994).

Pumping test is estimated by Cooper-Jacob method. The pumping curves were plotted drawdown as a function of the logarithm of elapsed time since pumping started. Employing the Jacob's Straight-Line method requires fitting a straight line through the straight section of the graph.

Pumping test is recorded the drawdown of well and pumping capacity. The drawdown (after start of pumping) and recovery (after stop of pumping) of the hydraulic head in the pumping well and surrounding monitoring wells are measured. Pumping capacity is constant that is recorded proper interval. Drawdown of well is recoded using DIVER and Interface meter.

Cooper-Jacob's expression for t hydraulic conductivity (K) is:

$$T = \frac{2.3Q}{4\pi \Delta s} \qquad S = \frac{2.25Tt_0}{r^2} \qquad K = \frac{T}{b}$$

Where:

K = hydraulic conductivity [m/day]

T= transmissivity[m^2/day]

Q = pumping capacity [m^3]

Δs= Slope of the straight part of the drawdown on a semi-logarithmic graph (m)

T_0 = Basic Time Lag [sec]; value of t on semi-logarithmic

b = length of aquifer[m]

3834

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 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)	
Area D (9 Nov.)	M07-464	1637	injection	13.00	51	8.685	
		1647	withdrawal				
	M07-465	1550	injection	12.54	51	9.760	
		1603	withdrawal				
	M07-466	1510	injection	12.50	51	8.100	
		1519	withdrawal				
		1035	withdrawal				
Land farm (11 Nov.)	M07-217	1318	injection	12.04	51	3.740	
		1349	Withdrawal				
	M07-218	1405	injection	12.70	51	9.570	
		1603	withdrawal				
	M07-220	1335	injection	9.75	51	2.890	
		1412	withdrawal				
		1027	withdrawal				

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

3.2 Description for the slug test at Sites

Slug tests performed six wells. 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

The diagrams are plots of injection and withdrawal that slug test was performed each in the sites. Each plots of injection and withdrawal is the head (H/H0) against the elapsed time. The Plots 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

3835

analyst is based the hydrogeology. The slop (△s) to need analysis can obtain from fitting line is drew on drawdown of water level.

3.2.1 Area D

Area D is a site identified as a landfill so soil material is estimated heterogeneous. The Slug test conducted B03-464, B03-465 and B03-466 in the Area D. The test well was selected to be evenly located in the study area. The Groundwater level(blg) of MW(monitoring wells) was checked from 8.67m to 9.76m and the depth of MW is from 12.50m to 13.00m. (Fig1).

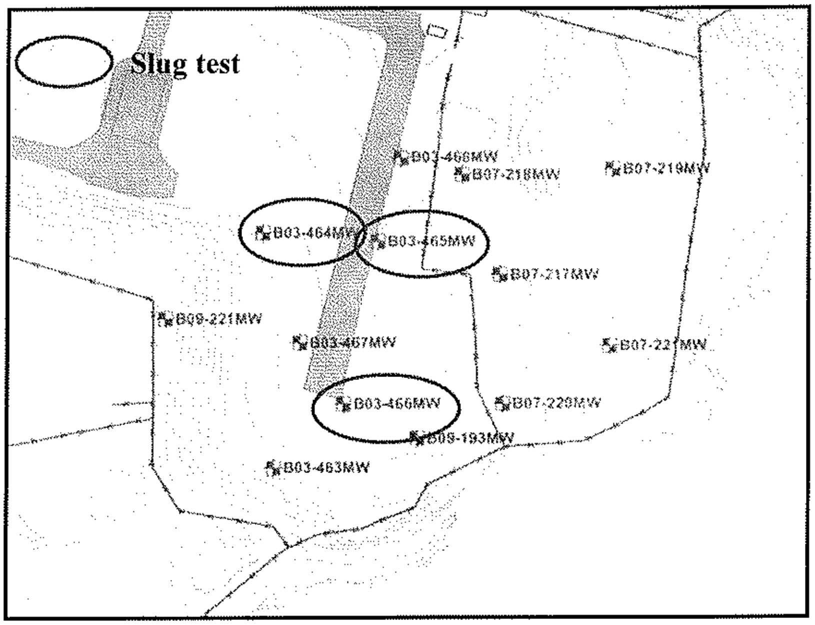
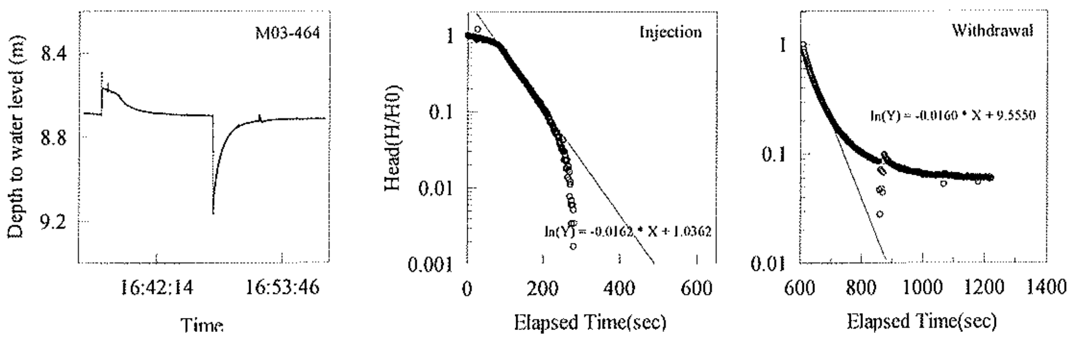


Figure 1 Location of Monitoring well conducted the slug test in the AreaD.



3836

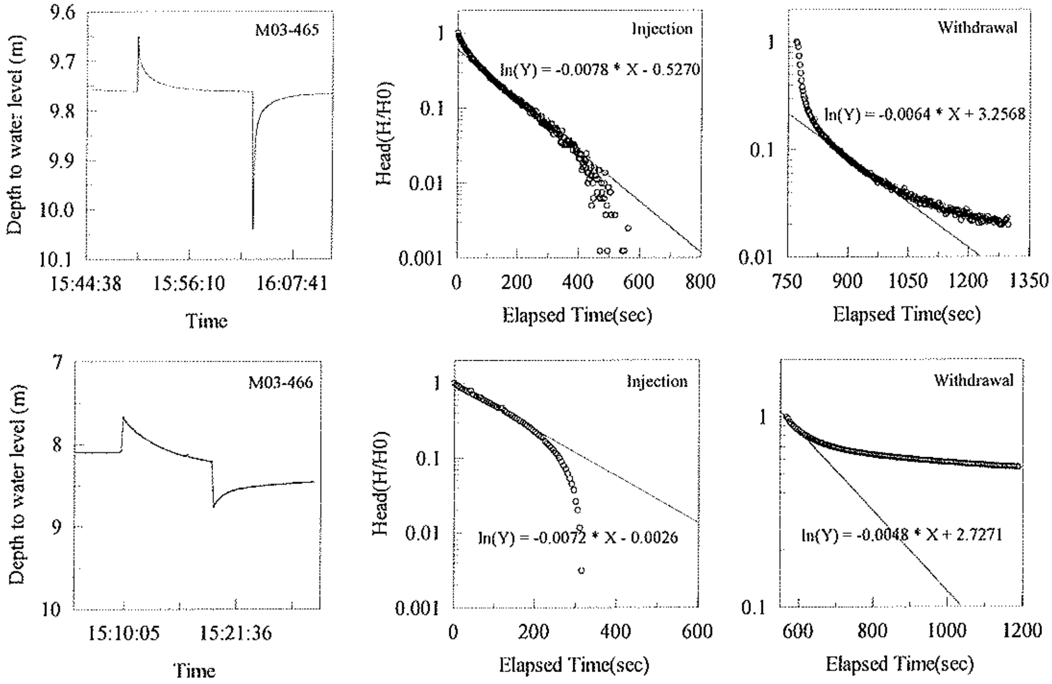


Figure 2 Curve-fitting results against elapsed time at constant slug tests in the AreaD.

The graph of MW464 is different groundwater level fluctuation by the injection and withdrawal of the dummy. When screen section is above the water level to rise by injection of the dummy in the well, groundwater rose quickly flow to screen section around well. Since then, the water level fluctuation becomes slow. The graph of MW465 is general fluctuation by the injection and withdrawal of the dummy. The drawdown of MW 466 is slow recovery of the water level by withdrawal. Sometimes, the injection of dummy disturb particle or precipitate in the well so it fill the pore space of soil.

3.2.2 Landfarm

The Slug test conducted B07-217MW, B07-218MW and B07-220MW in the Landfarm. The Groundwater level (bgs) of MW(monitoring wells) was checked from 2.89m to 9.57m and the depth of MW is from 9.75m to 12.70m.

3837

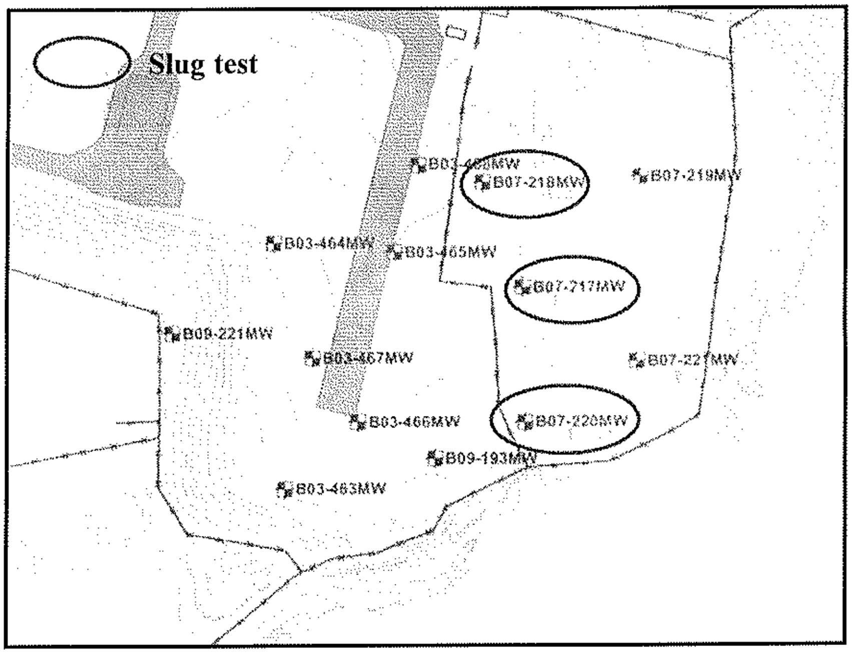
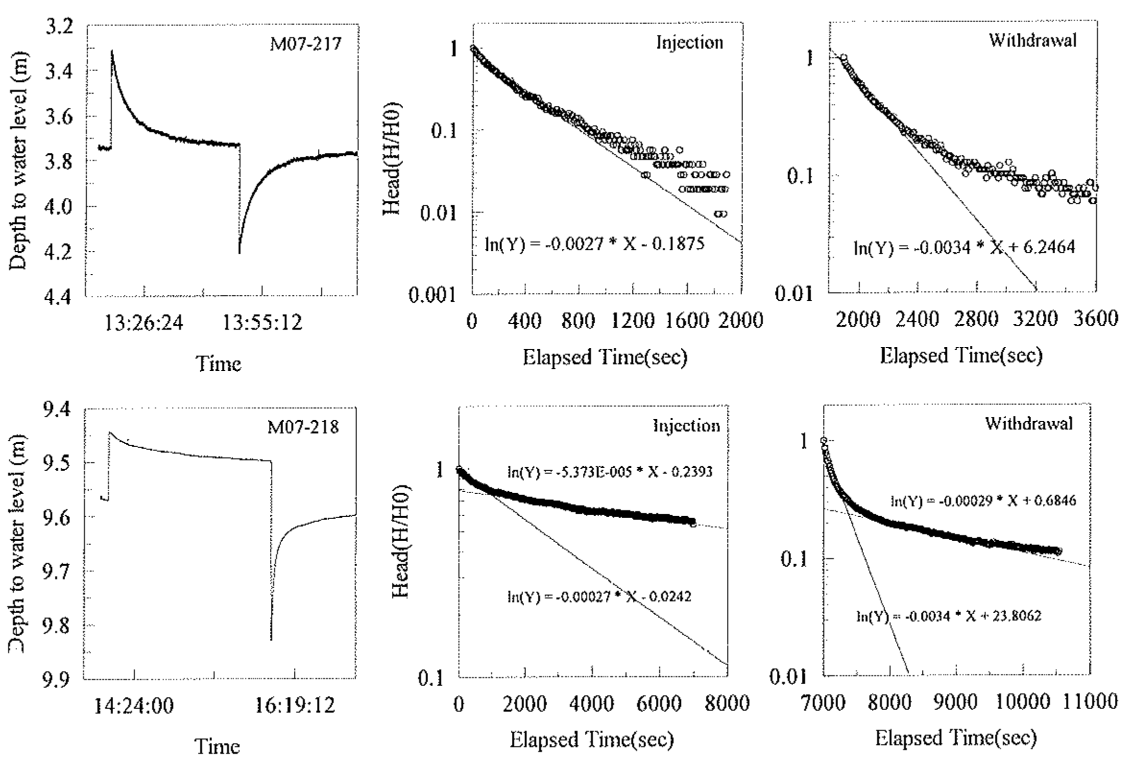


Figure 3 Location of Monitoring well conducted the slug test in the Landfarm.



3838

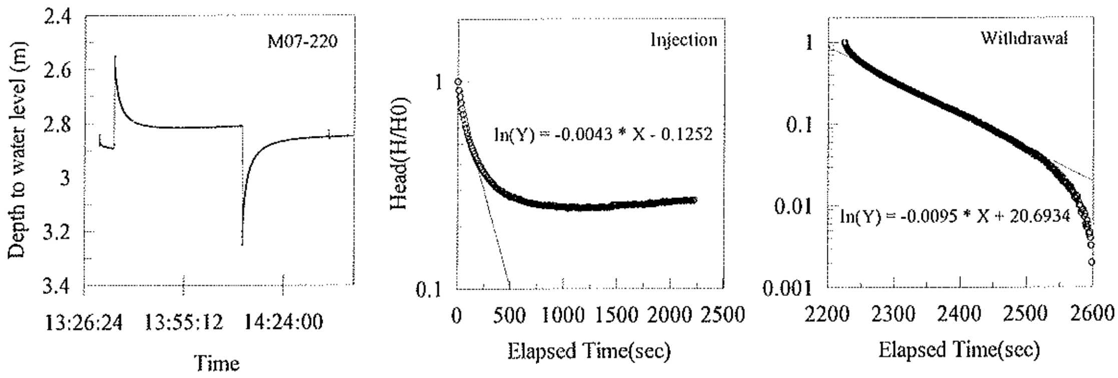


Figure 4 Curve-fitting results against elapsed time at constant slug tests in the Landfarm.

B07-218MW is different the drawdown pattern for the injection and withdrawal of dummy. In such case slope for test analysis can select that is compared the drawdown pattern by injection and withdrawal.

3.3 Description for the Pumping Test at Sites

Pumping test is performed at landfarm area of Camp Carroll(Table 1). First of all, Data of in the Landfarm compiled that test successfully completed.

3.3.1 Landfarm

The pumping test was performed during the period of 24 February, 2010 ~ 25 February, 2010(2nd). The pumping well is B07-217MW, the monitoring well are MW1_B07-218MW, MW2_B03-465MW, MW3_B07-220MW and MW4_B07-221MW. The start time of pumping is on Wednesday, Feb 24, at 16:31, stop time is on Thursday, Feb 25, at 01:02. The elapsed pumping time is about 8hour. The pumping capacity is about 1.183 L/min.

Table 2. Information of pumping test wells performed in the Landfarm.

Well	No.	NG[1](m)	D[2](m)	WD[3] (m)	Note
PW	B07-217	4.43	12	-	
MW1	B07-218	10.25	12	32.2	start time 16:31 Stop time 01:02
MW2	B03-465	10.29	12	12.5	
MW3	B07-220	3.37	12	45	
MW4	B07-221	7.68	12	4.32	

3839

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

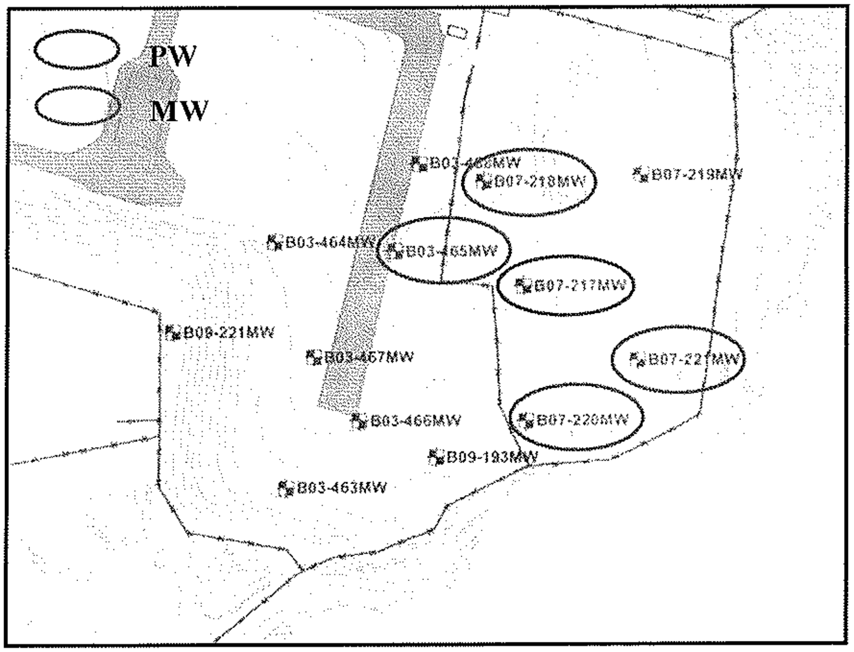
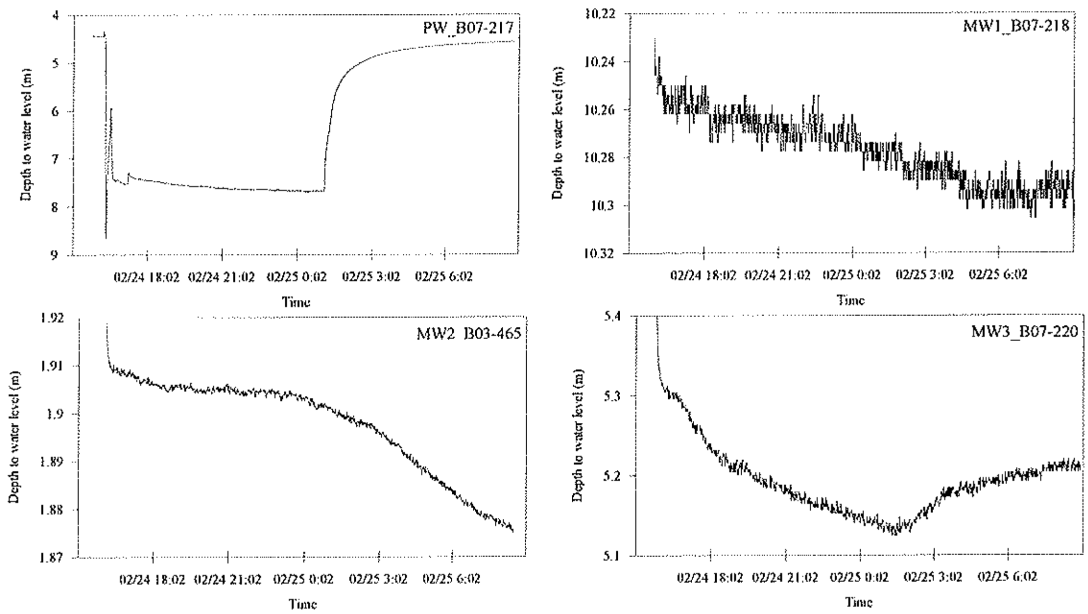


Figure 5 Location of Test wells conducted the Pumping test in the Landfarm.



3840

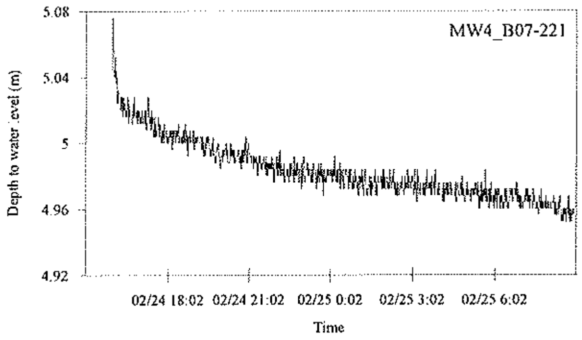


Figure 6 Diagram of elapsed time-depth to water level(blg) during pumping test in the Landfarm

Hydrogeological trend of groundwater level at each wells during pumping test. Groundwater level of B07-217 pumping well showed a fluctuation by pumping and recovery. Groundwater level data of initial pumping is a noise because pump was changed and quickly down.. Data of recovery is quickly fluctuated after pumping stopped.

Analysis of pumping test is calculated using Cooper-Jacob's method. The plots are the drawdown against the elapsed log-time. The slop (Δs) to be analyze is obtained with the fitting line on plots. The fitting line for pumping test has to consider the boundary effect in drawdown .

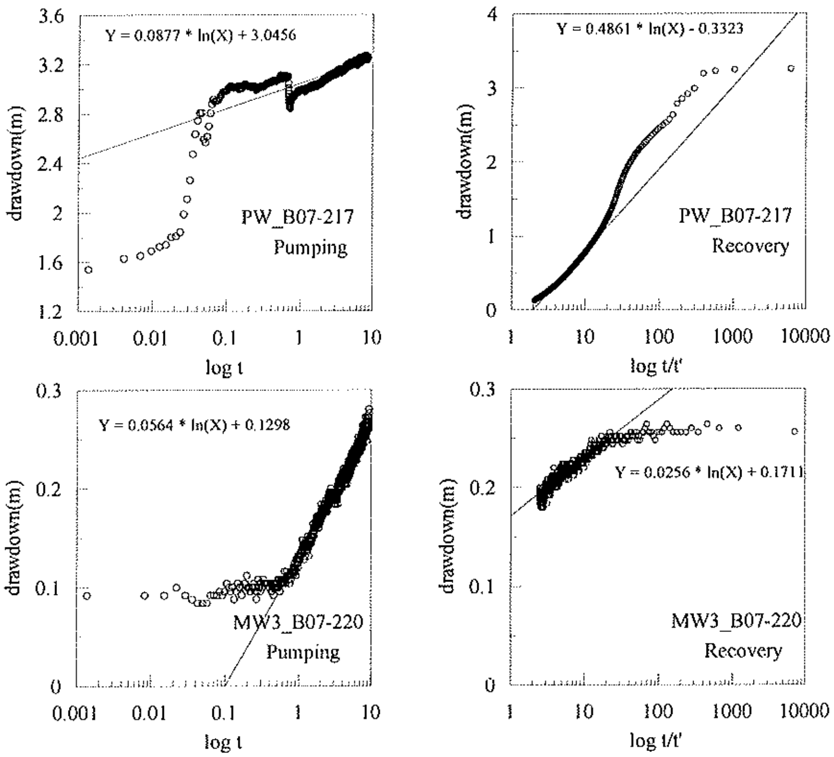


Figure 7 Curve-fitting results against elapsed log-time at constant pumping test in the Landfarm.

3841

3.4 Description for the Air permeability Test at Sites

3.4.1 AreaD

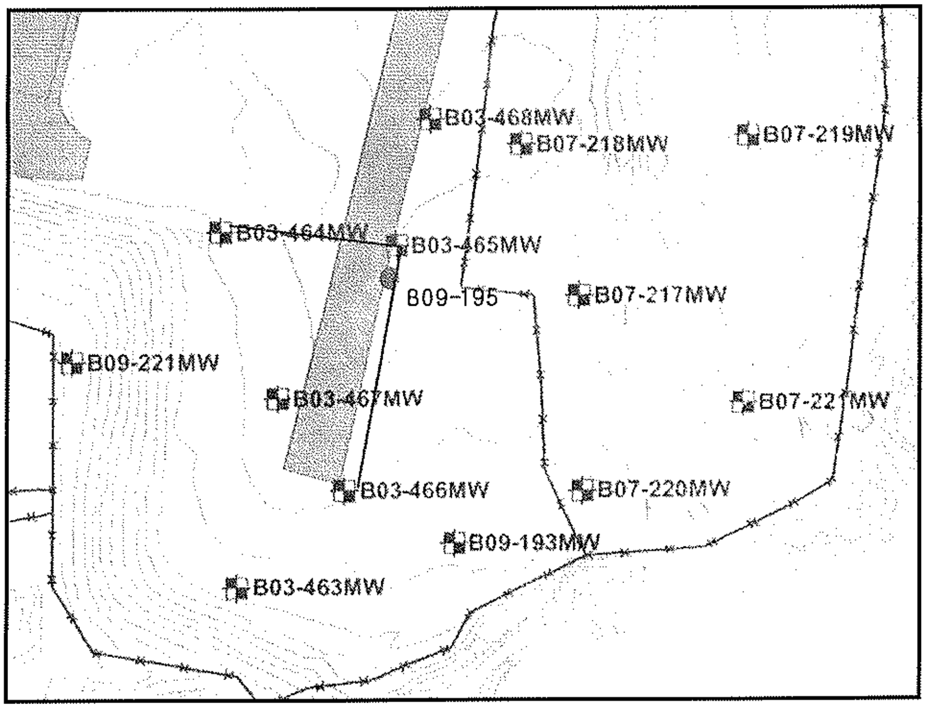


Figure 8 Location of Test wells conducted the air permeability test in the AreaD.

A series of air permeability test were conducted on 17 March 2010, to evaluate subsurface air flow patterns and radius of influence in adjacent to Area D in the Camp Carroll. The layouts of the permeability test were determined based on the location of existing groundwater monitoring wells and the pre-installed air permeability test well. Figure 8 presents the well layout of air permeability tests at the project site at Area D.

Air permeability tests were conducted at four wells (as a set) consisting of one air extraction well(B03-465)and three observation wells(B03-464,B09-195,B03-466). 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.

3842

The test was performed for total about 50 minutes, with air flow rate of each 30 cubic meters per hour. The extraction vacuum used during the test was about 10 ~ 30 kPa. Table 3 shows air permeability test well information in Area D. Figure 9 presents the observation results versus elapsed time. Finally, monitoring well(B09-195,B03-466,B03-464) was no response by reason that monitoring well was very long interval between distance of wells or was no physical connection.

Table 3. Information of air permeability test wells performed in the Area D.

Classify	Well ID	Well Depth(m)	Water level (m)	Water column(m)	Distance (m)
Extraction well	B03-465	13.16	10.33	2.83	(standard)
Monitoring well 1	B09-195	5.28	5.11	0.17	4.33
Monitoring well 2	B03-466	6.28	6.13	0.15	35.35
Monitoring well 3	B03-464	13.175	9.245	9.245	41.05

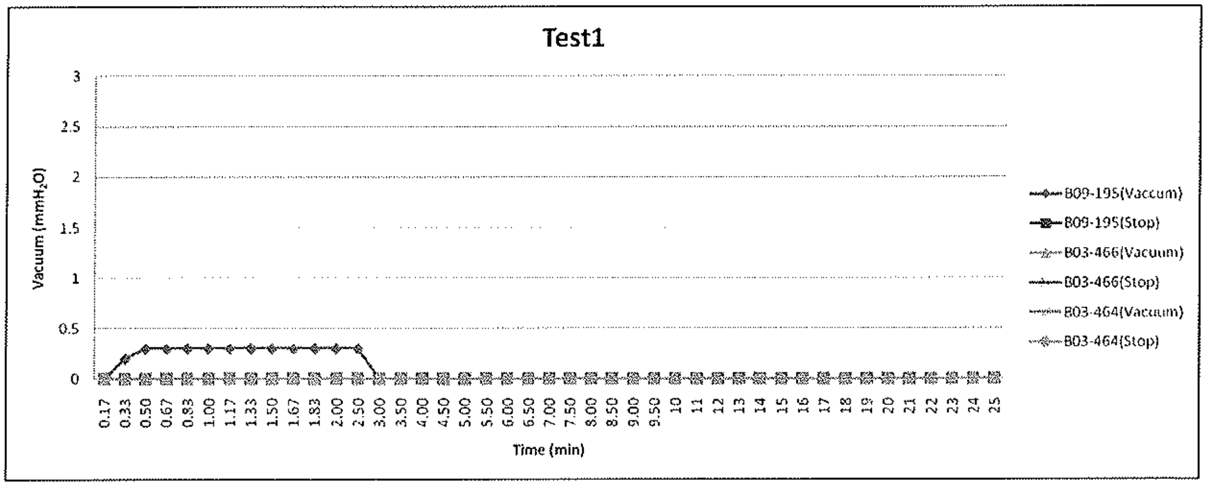


Figure 9 Observation results versus elapsed time at extraction flow rate 30 m^3/hr

3813

3.5 Result

3.5.1 Slug test

The hydraulic conductivity(K) is calculated by the Hvorslev and the Bouwer & Rice methods. Average hydraulic conductivity(K) for slug tests were calculated using the Hvorslev/Bouwer&Rice methods to be;

- 5.53E-04 / 5.18E-04 cm/sec in the Area D
- 1.19E-04 / 9.92E-05 cm/sec in the Land farm

Calculated results of the injection are greater than the withdrawal. In theory, hydraulic conductivity(K) have to be calculated the same value irrespective of injection and withdrawal of the slug. This is estimated a condition of the test apparatus or to be the skin effect around test wells(Lee et al., 1999, Ham et al.,2001). Also, calculated results using Horvslev method is a little differences with the Bouwer&Rice method. A correlation coefficient is 0.99 calculated results using between Horvslev method and the Bouwer&Rice method and it is nearly consistent.

Table 4 Hydraulic conductivity (K) estimated from the slug tests 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
Area D	M07-464	injection	8.4E-06	7.7E-06	0.72557	0.66644	8.34E-04	7.66E-04
		withdrawal	8.3E-06	7.6E-06	0.71637	0.65799		
	M07-465	injection	5.7E-06	5.6E-06	0.49305	0.48227	5.19E-04	5.08E-04
		withdrawal	4.7E-06	4.6E-06	0.40433	0.39549		
	M07-466	injection	3.7E-06	3.3E-06	0.31626	0.28812	3.06E-04	2.79E-04
		withdrawal	2.5E-06	2.2E-06	0.21319	0.19421		
		withdrawal	6.4E-07	5.8E-07	0.05520	0.05002		
	B09-175	injection	3.6E-07	3.3E-07	0.03126	0.02827	3.97E-05	3.59E-05
		withdrawal	4.3E-07	3.9E-07	0.03741	0.03383		
Land farm	M07-217	injection	8.1E-07	6.8E-07	0.06992	0.05834	9.18E-05	7.66E-05
		withdrawal	1.0E-06	8.6E-07	0.08879	0.07409		
	M07-218	injection	1.8E-07	1.7E-07	0.01560	0.01499	1.87E-05	1.79E-05
		withdrawal	1.9E-07	1.9E-07	0.01664	0.01600		
	M07-220	injection	1.5E-06	1.3E-06	0.13224	0.10948	2.45E-04	2.03E-04
		withdrawal	3.4E-06	2.8E-06	0.29148	0.24132		

38/4

3.5.2 Pumping test

The hydraulic conductivity(K) is calculated by the Cooper&Jacob's methods from 3.21E-04 cm/sec to 2.87E-02 cm/sec in the Landfarm. Average hydraulic conductivity(K) for pumping tests were calculated using the Cooper&Jacob's methods to be;

- 1.78E-02 cm/sec in the Landfarm

Calculated results of the pumping test were greater than general hydraulic conductivity(ex: case of silty sand is about 10^{-5} ~10^{-3}). Except pumping well in each study areas, drawdown for most of monitoring well at pumping was within 10cm. It cannot be free from the effect with water level change by the atmospheric pressure.

Table 5 Hydraulic result estimated from the pumping tests using the Cooper&Jacob's method in Landfarm.

site	well	Maximum drawdown of water level(m)	Q (m^3/day)	Slop (Δs)	T (cm2/sec)	K (cm/sec)	Average K (cm/sec)	Storativity
Pumping welll	B07-217 (pumping)	1.956	1.704	0.088	0.41	5.44E-04	3.21E-04	
	B07-217 (recovery)		1.704	0.486	0.07	9.81E-05		
Monitoring well 1	B07-218 (pumping)	0.031	1.704	0.007	5.02	2.87E-02	2.87E-02	3.08E-07
Monitoring well 2	B03-465 (pumping)	0.096	1.704	0.004	9.03	5.28E-02	5.28E-02	
Monitoring well 3	B07-220 (pumping)	0.022	1.704	0.056	0.64	7.42E-04	1.19E-03	7.11E-08
	B07-220 (recovery)		1.704	0.026	1.41	1.63E-03		
Monitoring well 4	B07-221 (pumping)	0.164	1.704	0.014	2.53	5.85E-03	5.85E-03	

3845

Appendix IV: Data Quality Discussion

Laboratory Quality Control (QC).

Laboratory QC consists of those procedures that a laboratory utilizes to verify that the entire analytical system is producing data of known quality. The contact laboratory utilized internal quality control procedures that are specified in the individual EPA test method. Neither laboratory reported difficulty with the sample analysis. The laboratory monitored internal quality through the use of matrix spikes (sample fortification with contaminants) and replicate analysis of selected extracts or digests. Laboratory reports were also reviewed by FED chemist (Dr. [redacted] prior to develop the report.

b6

Field QC Samples.

Field QC samples submitted to the laboratory in this project consists of trip blank and field duplicate samples for monitoring the quality of chemical data during the ESI project sampling and shipments at Camp Carroll. Temperature blanks were also collected and placed into each ice cooler as same as for sample.

1.1. Trip Blank (TB).

Analysis of TB could be able to provide whether a sample bottle was contaminated during shipment from the manufacturer, while in bottle storage, in shipment to the laboratory, or during/after sample collection, or during analysis at lab. A total of eleven blank samples were provided by the contract lab to FED before sampling, and resubmitted to the lab together with soil and groundwater samples for VOCs analysis after sampling. A total of 6 VOC components,2-Butanone, 2-Chlorotoluene, Chloromethane, methylene chloride, n-buthylbenzene and toluene, were reported above the sample reporting limits. The detections in the trip blanks are not certain. Since the blanks have not been opened up in the field, the involvement of such chemicals could come from during blank sample preparation or from blank sample analysis together with samples. However, the level of contamination in the blanks are not significant and do not appear to be significant in the data quality and interpretation. Table 1 shows the analytical results for VOCs of TB.

1.2. Duplicate samples.

A total of 20 field duplicate samples were prepared and submitted to the laboratory to check the reproducibility of sampling and analytical results. The data for the duplicate samples should agree each other within certain permissible range. The duplicate samples reflect an indication of the laboratory precision (precise reproducibility) if the samples were well-mixed and homogenized before sampling. Agreement does not necessarily mean that the reported value is accurate, since the lab might have a systemic error. Data quality check was performed by a comparison of the chemical results from the sample duplicates. The data comparison is expressed as a Relative Percent Difference (RPD) using to compare how close the result is to the true value. When used with duplicate samples, the RPD measures precision: the lower the value is the more precise the results. It can also measure accuracy, when one of your results is the true value, such as the quality control lab results for a split sample, or the actual concentration of a known or unknown sample. Table 2 shows the criteria established by the Corps of Engineers in determining the agreement between samples.

All duplicate chemical data were compared according to the RPD criteria, with an assumption of all the estimated values as actual detections. Table 3~8 presents the data comparison between the duplicate samples. Most of the data comparison fall into "AGREEMENT" category according to Table 2 or are not compared due to very low detection below the quantitation limit. VOCs comparison in soil samples was very varied in the chemicals. The poor reproducibility is likely to be from the sampling method for VOCs. Soil samples for VOCs were collected right after retrieving from subsurface prior to homogenize the samples. This sampling process seems to cause the poor comparison. Toluene and 1,1-dichloroethene in groundwater test results are not agreed in the test results according to the criteria. The disagreement is not certain at this moment.

Table 1. Chemical Test Result for Trip Blank Samples Obtained during Remedial Investigation/Feasibility Study at Camp Carroll.

Components (μg/L)	Landfarm/Area D										
	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8	TB9	TB10	TB11
2-Butanone (MEK)	0.42J*	0.42	-	-	-	-	-	-	-	-	-
2-Chlorotoluene	-	-	0.42J	0.34J	1.00	-	-	0.42J	-	-	-
Chloromethane	-	-	1.90	1.90	0.66J	0.54J	0.66J	1.90	-	-	-
Methylene chloride	1.80	2.40	-	-	-	-	-	-	-	-	12.00
n-Butylbenzene	-	-	-	-	1.2J	1.1J	-	-	0.42J	0.42	-
Toluene	11.00	7.00	12.00	7.20	2.10	1.50	14.00	18.00	11.00	7.00	11.00

* indicates that the value is an estimation and the result is below the reporting limit.

- means not detected above the reporting limit.

Table 2. Criteria for Comparing Field, QC, and QA Sample Data.

Matrix	Parameter	Disagreement	Major Disagreement
All	All	>5x difference when one result is < DL	>10x difference when one result is < DL
All	All	>3x difference when one result is < LRL	>5x difference when one result is < LRL
Water	All except TPH	>2x difference	> 3x difference
Soil	All except metals, VOCs, BTEX, and TPH	>4x difference	>5x difference
Soil	Metals	>2x difference	>3x difference
Water and Soil	TPH	Arbitrary (suggest >3x difference)	Arbitrary (suggest >5x difference)
Soil	VOCs and BTEX	Arbitrary (suggest >5x difference	Arbitrary (suggest >10x difference)

DL: Laboratory Detection Limit

QL: Quantitation Limit, the lowest level of the analyte that can accurately be determined.

2X difference is equivalent to an RPD of 67%; 3X 100%; 5X 133%; 10X 167%

Reference: CRREL Special Report No. 96-9, "Comparison Criteria for Environmental Chemical Analyses of Split Samples Sent to Different Laboratories - Corps of Engineers Archived Data", [redacted] [redacted] USACE Cold Regions & Environmental Research Laboratory, Hanover NH, May 1996. b6
b6

The above criteria shall be applied when comparing field and QC sample pair data, as well as when comparing project and QA sample pair data. With the exceptions of volatile organic compounds (VOCs) in soil; and benzene, toluene, ethylbenzene, and xylenes (BTEX) in soil; and of total petroleum hydrocarbons (TPH) in either water or soil, the above criteria will be used for all data comparisons. There is no definitive data for establishing comparison criteria for TPH (in water or soils) because of the wide variety of method modifications used by laboratories in the SW-846 8015M method ("M" is for "Modified"). The same is true for VOC and BTEX in soils because of the large potential for introducing error during the conventional sample handling process. Result pairs are considered to disagree whether they are in the "Disagreement" or "Major Disagreement" category.

From: Chemical Quality Assurance for HTRW Projects, Engineer Manual EM 200-1-6

Table 3. Field Soil Duplicate Sample Comparison Result for VOCS. According to the Table 2 Guidance. The disagreement in VOCs is likely due to sampling procedure.

Component	Method	Units	B09-195		B09-198		B09-195	B09-198
			S3		S1		RPD	RPD
			Result	Result	Result	Result		
Acetone	8260B	µg/kg	- Q	-	-	-	NA	NA
Benzene	8260B	µg/kg	-	72	-	-	NA	NA
n-Butylbenzene	8260B	µg/kg	-	11J	-	-	NA	NA
sec-Butylbenzene	8260B	µg/kg	-	4.8J	-	-	NA	NA
Chlorobenzene	8260B	µg/kg	-	90	-	-	NA	NA
2-Chlorotoluene	8260B	µg/kg	-	190	-	-	NA	NA
4-Chlorotoluene	8260B	µg/kg	-	160	-	-	NA	NA
1,4-Dichlorobenzene	8260B	µg/kg	-	3.4J	-	-	NA	NA
Ethylbenzene	8260B	µg/kg	-	100	35J	27J	NA	NA
Isopropylbenzene	8260B	µg/kg	-	24J	-	-	NA	NA
p-Isopropyltoluene	8260B	µg/kg	-	8.1J	-	-	NA	NA
Methylene chloride	8260B	µg/kg	41J	30J	61J	52J	NA	NA
Naphthalene	8260B	µg/kg	-	47B	-	-	NA	NA
n-Propylbenzene	8260B	µg/kg	-	73	-	-	NA	NA
Toluene	8260B	µg/kg	6400	1500	9.4J	8.7J	124%	NA
1,2,4-Trimethylbenzene	8260B	µg/kg	-	230	-	-	NA	NA
1,3,5-Trimethylbenzene	8260B	µg/kg	-	130	-	-	NA	NA
m-Xylene & p-Xylene	8260B	µg/kg	67J	350	83J	73J	NA	NA
o-Xylene	8260B	µg/kg	-	98	7.9J	-	NA	NA

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

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

NA- calculation is Not Applicable.

Table 4. Field Soil Duplicate Sample Comparison Result for Dioxin analysis. RPD is According to the Table 2 Guidance.

Component	Method	Units	B09-198-S1		
			Result		RPD
2,3,7,8-TCDD	8290	pg/g	0.03J Q B	ND	NA
1,2,3,7,8-PeCDD	8290	pg/g	ND	ND	NA
1,2,3,4,7,8-HxCDD	8290	pg/g	ND	0.072J	NA
1,2,3,6,7,8-HxCDD	8290	pg/g	0.036J Q	0.076J	NA
1,2,3,7,8,9-HxCDD	8290	pg/g	0.079J Q	0.094J	NA
1,2,3,4,6,7,8-HpCDD	8290	pg/g	0.56J B	1J B	NA
OCDD	8290	pg/g	26B	35B	NA
2,3,7,8-TCDF	8290	pg/g	0.14J B	0.18J B	NA
1,2,3,7,8-PeCDF	8290	pg/g	ND	ND	NA
2,3,4,7,8-PeCDF	8290	pg/g	ND	0.065J Q	NA
1,2,3,4,7,8-HxCDF	8290	pg/g	0.067J Q	0.17J	NA
1,2,3,6,7,8-HxCDF	8290	pg/g	0.048J Q	0.14J Q	NA
2,3,4,6,7,8-HxCDF	8290	pg/g	0.036J Q	0.092J Q	NA
1,2,3,7,8,9-HxCDF	8290	pg/g	0.044J	ND	NA
1,2,3,4,6,7,8-HpCDF	8290	pg/g	0.14J Q	0.3J Q	NA
1,2,3,4,7,8,9-HpCDF	8290	pg/g	ND	0.2J	NA
OCDF	8290	pg/g	0.14J Q B	0.48J B	NA

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

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. ND- not detected.

*RPD- Relative percent difference. **NA- calculation is Not Applicable.

3851

Table 5. Field Soil Duplicate Sample Comparison Result for OC- pesticide analysis. RPD is According to the Table 2 Guidance.

Chemical (μg/kg)	Method	Unit	B09-198-S1		
			Result		*RPD
alpha-BHC	8081A	μg/kg	ND	ND	NA
gamma-BHC (Lindane)	8081A	μg/kg	ND	ND	NA
Heptachlor	8081A	μg/kg	ND	ND	NA
Aldrin	8081A	μg/kg	ND	ND	NA
beta-BHC	8081A	μg/kg	ND	ND	NA
delta-BHC	8081A	μg/kg	ND	ND	NA
Heptachlor epoxide	8081A	μg/kg	ND	ND	NA
Endosulfan I	8081A	μg/kg	ND	ND	NA
gamma-Chlordane	8081A	μg/kg	ND	ND	NA
alpha-Chlordane	8081A	μg/kg	ND	ND	NA
4,4'-DDE	8081A	μg/kg	3.80	2.9J	NA
Dieldrin	8081A	μg/kg	ND	ND	NA
Endrin	8081A	μg/kg	ND	ND	NA
4,4'-DDD	8081A	μg/kg	0.41J	ND	NA
Endosulfan II	8081A	μg/kg	ND	ND	NA
4,4'-DDT	8081A	μg/kg	9.70	7.10	31%
Endrin aldehyde	8081A	μg/kg	ND	ND	NA
Methoxychlor	8081A	μg/kg	ND	ND	NA
Endosulfan sulfate	8081A	μg/kg	ND	ND	NA
Endrin ketone	8081A	μg/kg	ND	ND	NA
Toxaphene	8081A	μg/kg	ND	ND	NA
ND-not detected, NA- calculation is Not Applicable.					
J- the value is an estimation, the concentration is below the detection limit.					
*RPD- Relative percent difference.					

Table 6. Field Soil Duplicate Sample Comparison Result for PCB analysis. RPD is According to the Table 2 Guidance.

Chemical (mg/kg)	Method	unit	B09-198 S1		*RPD
Aroclor 1016	8082A	mg/kg	ND	ND	NA
Aroclor 1221	8082A	mg/kg	ND	ND	NA
Aroclor 1232	8082A	mg/kg	ND	ND	NA
Aroclor 1242	8082A	mg/kg	ND	ND	NA
Aroclor 1248	8082A	mg/kg	ND	ND	NA
Aroclor 1254	8082A	mg/kg	ND	ND	NA
Aroclor 1260	8082A	mg/kg	ND	ND	NA
ND- not detected. NA- calculation is Not Applicable. RPD- Relative percent difference					

3853

Table 7. Field groundwater Duplicate Sample Comparison Result for VOCs analysis. RPD is According to the Table 2 Guidance.

Well_ID	16-289								
Date	5/11/2009		8/30/2009		12/13/2009		5/11/2009	8/30/2009	12/13/2009
Component (µg/L)	Result	Result	Result	Result	Result	Result	RPD *	RPD	RPD
Acetone	2.3J	2.5J	4J	7.1J	ND	ND	NA**	NA	NA
Bromomethane	ND	ND	0.66J	0.89J	ND	ND	NA	NA	NA
Chloroform	0.58J	0.58J	0.57J	0.54J	0.5J	0.51J	NA	NA	NA
Chloromethane	ND	ND	20.00	26.00	ND	ND	NA	26%	NA
1,1-Dichloroethane	9.20	9.30	0.54J	0.52J	0.94J	0.84J	1%	NA	NA
cis-1,2-Dichloroethene	150E	150E	13.00	13.00	20.00	20.00	NA	0%	0%
trans-1,2-Dichloroethene	3.70	2.70	0.18J	0.29J	0.21J	1.10	31%	NA	NA
1,1-Dichloroethene	17.00	18.00	4.50	3.90	5.40	1.10	6%	14%	132%
Methylene chloride	1.50	2.00	ND	ND	1.20	0.9J	29%	NA	NA
Naphthalene	0.29J	0.19J	ND	ND	ND	ND	NA	NA	NA
1,1,2,2-Tetrachloroethane	1.70	1.70	0.26J	0.25J	0.23J	0.35J	0%	NA	NA
Tetrachloroethene	73.00	71.00	11.00	11.00	19.00	20.00	3%	0%	5%
Toluene	30.00	32.00	1.90	2.00	8.40	8.50	NA	NA	NA
1,2,4-Trichlorobenzene	0.15J	0.15J	ND	ND	0.33J B	ND	NA	NA	NA
1,1,1-Trichloroethane	12.00	12.00	1.40	1.30	1.70	1.80	0%	7%	6%
Trichloroethene	83E	82E	19.00	18.00	22.00	23.00	NA	5%	4%
Trichlorofluoromethane	0.3J	0.28J	ND	ND	ND	ND	NA	NA	NA
Vinyl chloride	ND	0.43J	ND	ND	ND	ND	NA	NA	NA
ND- not detected,J- the number is an estimation, detected below the deteciton limit.									
*RPD- Relative percent difference. **- calculation is Not Applicable.									

TABLE 7

3854

CONTINUED.

Well_ID	B07-221MW								
Date	5/11/2009		9/16/2009		12/14/2009		5/11/2009	8/30/3009	12/13/2009
Component (µg/L)	Result	Result	Result	Result	Result	Result	RPD*	RPD	RPD
Acetone	ND q	ND q	ND	ND	ND	ND	NA**	NA	NA
Chloroform	5.20	5.30	ND	0.27J	0.45J	ND	2%	NA	NA
Chloromethane	ND	ND	0.28J	0.26J	ND	ND	NA	NA	NA
cis-1,2-Dichloroethene	52.00	51.00	0.58J	1.20	3.70	4J	2%	NA	NA
trans-1,2-Dichloroethene	0.97J	1.2J	ND	ND	0.14J	ND	NA	NA	NA
1,1-Dichloroethene	ND	0.29J	ND	ND	ND	ND	NA	NA	NA
Methylene chloride	1.2J	1.2J	1.50	1.30	1.40	ND	NA	14%	NA
Tetrachloroethene	74.00	71.00	0.22J	8.60	8.80	9.3J	4%	NA	NA
Toluene	23.00	21.00	2.70	1.00	6.60	6J	9%	92%	NA
Trichloroethene	99.00	96.00	0.37J	5.10	7.10	7.3J	3%	NA	NA
m-Xylene & p-Xylene	0.37J	ND	ND	ND	ND	ND	NA	NA	NA
ND- not detected,J- the number is an estimation, detected below the deteciton limit.									
*RPD- Relative percent difference. **NA- calculation is Not Applicable.									

Table 8. Field Soil Duplicate Sample Comparison Result for OC pesticide analysis. RPD is According to the Table 2 Guidance.

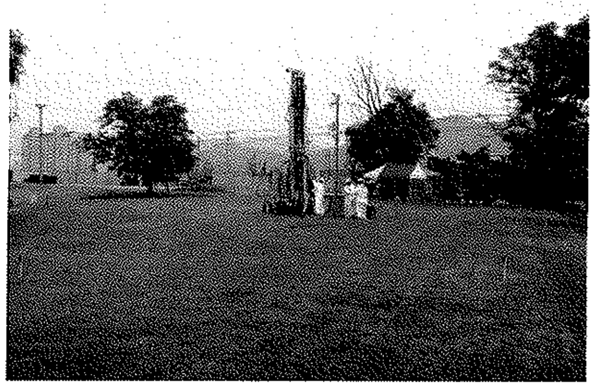
Chemicals (µg/L)	B07-221MW								
	5/11/2009		8/30/2009		12/13/2009		5/11/ 2009	8/30/ 2009	12/13/20 09
	Result	Result	Result	Result	Result	Result	*RPD	RPD	RPD
alpha-BHC	0.018J	0.02J	ND	ND	ND	ND	**NA	NA	NA
gamma-BHC (Lindane)	0.016J	0.018J	0.012J	0.013J	0.014J	0.014J PG	NA	NA	NA
beta-BHC	ND	ND	0.035J PG	0.029J	0.0077 J	ND	NA	NA	NA
delta-BHC	0.016J	0.018J	ND	ND	ND	ND	NA	NA	NA
4,4'-DDD	ND	ND	0.011J	0.014J	0.013J	0.015J	NA	NA	NA
4,4'-DDT	ND	ND	0.017J	0.018J	0.01J	0.012J	NA	NA	NA
PG- the percent difference between the original and confirmation analyses is greater than 40%.									
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.									
ND- not detected.									
*RPD- Relative percent difference. **NA- calculation is Not Applicable.									

3856

US Army Corps of Engineers
Far East District

Report for

Environmental Site Investigation at Area 41 of Camp Carroll, Republic of Korea



Submitted to:
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3857

Executive Summary

This Environmental Site Investigation (ESI) was conducted in the vicinity of Area 41 of located within Camp Carroll of the United States Army Garrison (USAG) Daegu, Republic of Korea (ROK). Field activities occurred during February 2009 to March 2010. Area 41 has been identified as a former drum storage area, and drummed (or otherwise containerized) hazardous materials were stored in Area 41. The drums contained a variety of chemicals including pesticides (including DDT), herbicides, solvents, vehicle fluids (battery acid and antifreeze), POLs, other hydrocarbons, and chemicals. 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 Area 41. 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

All soil samples submitted to the analytical laboratory were analyzed for total petroleum hydrocarbon (TPH), volatile organic compounds (VOCs), semi-VOCs, metals, polychlorinated biphenyl (PCB), organochlorinated pesticides (OC-pesticides), and dioxins-furans. Groundwater samples were collected from groundwater monitoring wells, and analyzed for VOCs and/or OC-pesticides.

A total of 26 soil samples were tested for diesel range (DRO) and residual range (RRO) TPH. Seven samples contained TPH concentration and the sum of TPH fractions ranged from 27 mg/kg to 1,993 mg/kg. A total of thirteen VOC components were detected in subsurface soil samples collected from boreholes drilled at the Area. The detected VOCS (and maximum concentration) in the soil samples of Area 41 include acetone (2,300 µg/kg); n-butylbenzene (120 µg/kg); sec-butylbenzene (96 µg/kg); ethylbenzene (70 µg/kg); methylene chloride (150 µg/kg); n-propylbenzene (74 µg/kg); 1,1,2,2-tetrachloroethane (52 µg/kg); tetrachloroethene (31,000 µg/kg); toluene (97 µg/kg); 1,2,4-trimethylbenzene (680 µg/kg); 1,3,5-trimethylbenzene (160 µg/kg); m-xylene an p-xylene (220 µg/kg), and o-xylene (160 µg/kg). Detected SVOCs in soil are fluorine (490 µg/kg), 2-methylnaphthalene (5,400 µg/kg), naphthalene (1,100 µg/kg) and pyrene (900 µg/kg).

Target metals were detected in all soil samples collected from the boreholes drilled at the Area 41. Selenium and silver were not detected in any soil samples above the PQL. The detected concentration of metals was generally close to the concentrations of the site background samples. Concentrations of barium and lead in soil samples from Area 41 are a little higher than the average background samples.

No PCBs were detected above the PQL in soil samples collected from boreholes drilled at the Area 41.

OC-pesticides were detected in soil samples collected from each of the boreholes drilled at the Area 41. Alpha-BHC (2.3 µg/kg); beta-BHC (25 µg/kg), gamma-BHC (38 µg/kg), delta-BHC (4.5 µg/kg), 4,4'-DDE (3,900 µg/kg), dieldrin (13 µg/kg), 4,4'-DDD (18,000 µg/kg) and

4,4' DDT (43,000 μg/kg) were the chemicals detected above the PQL. A majority of detections were from the shallow soil samples collected at 0 to 2 meter bgs.

Soil samples were submitted for dioxin/furan analysis. The International-Toxic Equivalent (I-TEQ) was calculated for each soil sample with measured concentrations of dioxins and furans detected above the reporting limit. The I-TEQ expresses the toxicity of all detected dioxin-furans 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 detected in only one soil sample reported an estimated value of 0.07 pg/g, the I-TEQ calculated for each of the soil samples collected at the site ranges from 0.001 to 1.332 pg/g.

A total of five groundwater monitoring wells, two new and three existing, were utilized to assess hydrogeologic conditions and groundwater quality of the site. A total of five groundwater samples were collected two times during this project: May and September 2009. Tetrachloroethene (6,500 μg/L), trichloroethene (5,400 μg/L), toluene (8.1 g/L), cis-1,2-dichloroethene (53 μg/L), and 1,1,2,2-dichloroethene (53 μg /L) were most commonly detected in the five monitoring wells. Acetone (360 μg /L), benzene (0.15 μg /L), 2-butanone (64 μg /L), carbon tetrachloride (43 μg /L), and methylene chloride (2.7 μg /L) were detected less frequently, often a single time or a single well.

Acronyms

ASTM: American Society for Testing and Materials
BEC: Beautiful Environmental Construction (BEC)
CD: Compact disk
CSM: Conceptual Site Model
DDD: dichlorodiphenyl dichloroethane
DDDK: Defense Distribution Depot Korea
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
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: Tetrachloroethene
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
TCE: trichloroethylene
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

Table of Contents

List of Table

List of Figure

3863

Appendices

1. Introduction

This report describes the work conducted and findings obtained from the Environmental Site Investigation (ESI) conducted in the vicinity of Area 41, which is 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) Co. 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 was according to the Work Plan (WP) and Site Safety and Health Plan (SSHP) developed by FED.

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 perform work on 30 April 2008 and on 20 April 2009 at Area 41 through MIPR 8GDBPENV06 and MIPR 9GDATENV05, respectively.

1.2. Project objectives

The overall objective of the ESI was to delineate the current extent and level of contamination. The scope of work for the project included collection of samples to characterize the lateral and vertical extent of soil and groundwater contamination at the site, to determine the concentration levels of contamination that could affect human health.

The following specific objectives were addressed during this ESI for Area 41.

- Assess the presence of gasoline, diesel and residual ranges (GRO, DRO and RRO respectively) of TPH, volatile organic compounds (VOCs), semi-VOCs (SVOCs), polychlorinated biphenyl (PCB), metals, dioxins, and organochlorinated pesticide (OC-pesticide) in the subsurface soil.

- Assess the presence of VOCs, SVOCs and OC-pesticides in groundwater samples collected from monitoring 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 determined DoD Instruction 4715.8 titled "*Environmental Remediation for DoD Activities*

3865

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.*"

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. Figure 2-2 presents the landscape around Camp Carroll including Naktong River.

2.2. Area 41

The Area 41 sites are located close to the southern installation boundary of Camp Carroll, next to the Defense Distribution Depot Korea (DDDK) office. Figure 2-3 presents the site location of Area 41 within Camp Carroll. Referring to the content of Samsung 2004 report, Area 41 has been identified as a former drum storage area, and drummed (or otherwise containerized) hazardous materials were stored in Area 41. The drums contained a variety of chemicals including pesticides (including DDT), herbicides, solvents, vehicle fluids (battery acid and antifreeze), POLs, other hydrocarbons, and chemicals. Numerous spill events reportedly occurred in this area between 1976 and 1981. Eye-witness accounts describing soil discoloration and localized ponding of liquids indicated that a significant amount of leakage and spillage of materials occurred in the vicinity of stored containers.

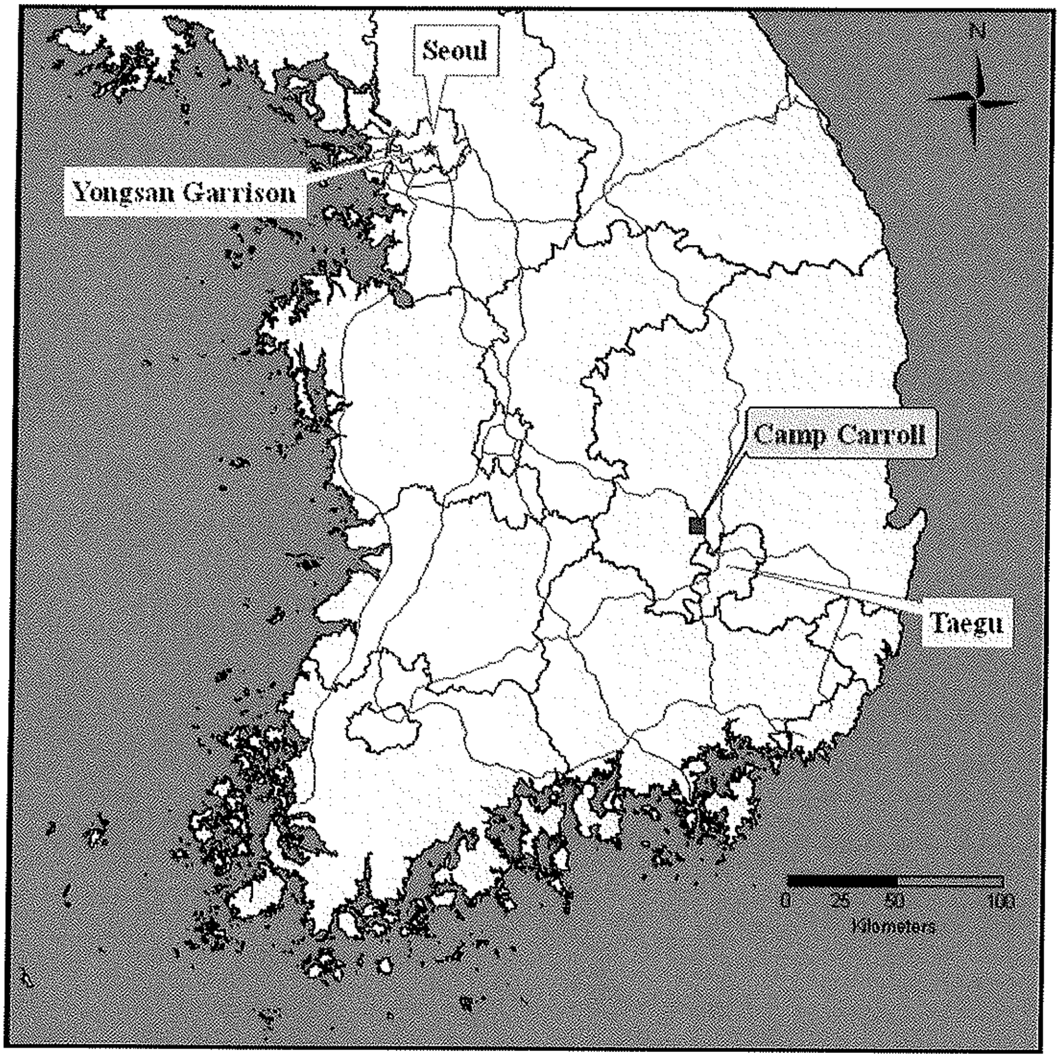
2.3. Summary of Previous Investigations

Area 41 has been previously evaluated for environmental conditions during an environmental site assessment (ESAs) in 2004. Samsung as an FED IDIQ contractor conducted site investigations at Area 41, and reported that the soil contained numerous contaminants including TPH-GRO, TPH-DRO, TPH-RRO, VOCs, SVOCs, pesticides, metals and dioxins. Several soil contaminant concentrations exceeded EPA Region IX preliminary remedial goal (PRG) screening criteria. Groundwater samples obtained from Area 41 monitoring wells contained concentrations of some VOCs including PCE,TCE, and 1,2-DCE. Figures 2- 4 and 2-5 present the VOCs result for soil and groundwater from the previous investigation at Area 41.

2.4. Identification of Data Needs

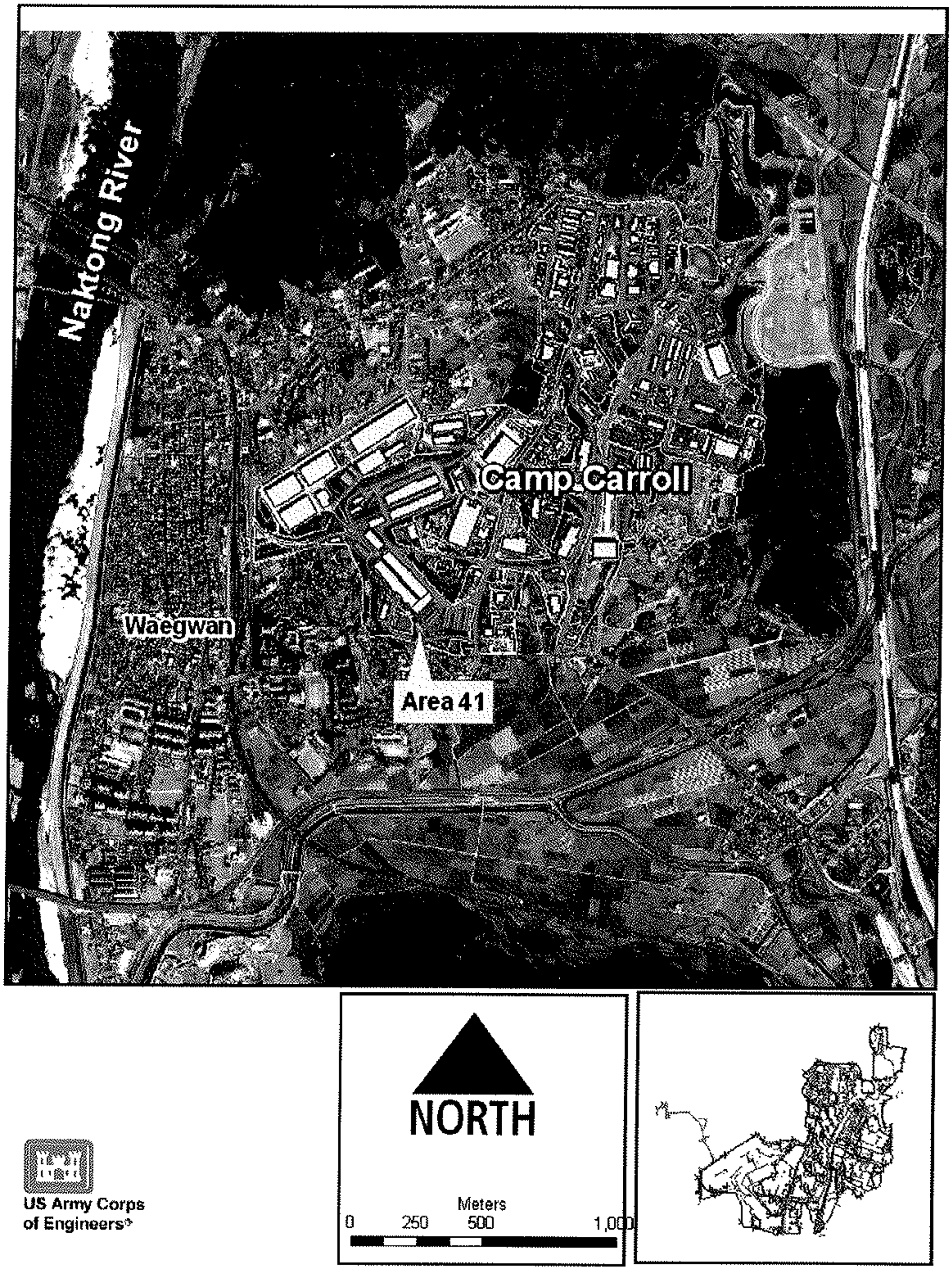
Previous investigations addressed groundwater conditions and surface soil condition using grid soil sampling. The vertical extent of contamination was not defined. This ESI focused on determining the vertical extent of contamination, refining the lateral extent of contaminations in soil, and installation of additional groundwater monitoring wells to determine the groundwater condition. Previous investigations identified contaminants of potential concern for Area 41 as TPH, polycyclic aromatic hydrocarbons (PAH), VOCs, OC-pesticides, metals and dioxins in soil, and VOCs in groundwater. Figures 2-4 and 2-5 present the location of VOCs finding in soil groundwater samples during 2004 investigation as an example.

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



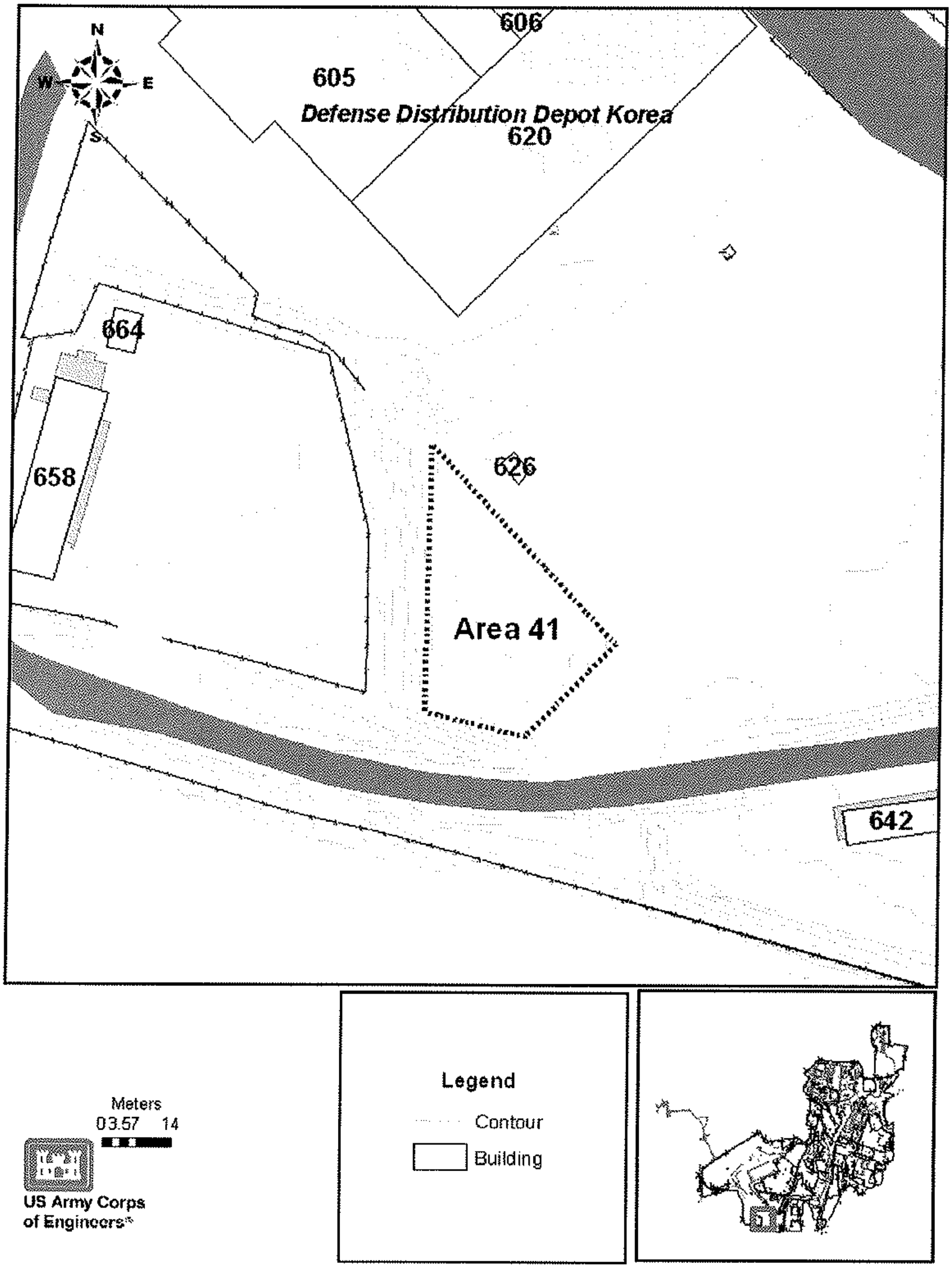
3868

Figure 2-2. Landscape around the Camp Carroll including Area 41.



3869

Figure 2-3. Location of Area 41 at Camp Carroll.



3870

Figure 2-4 Previous Soil VOCs Investigation result at Area 41 in 2004 by Samsung.

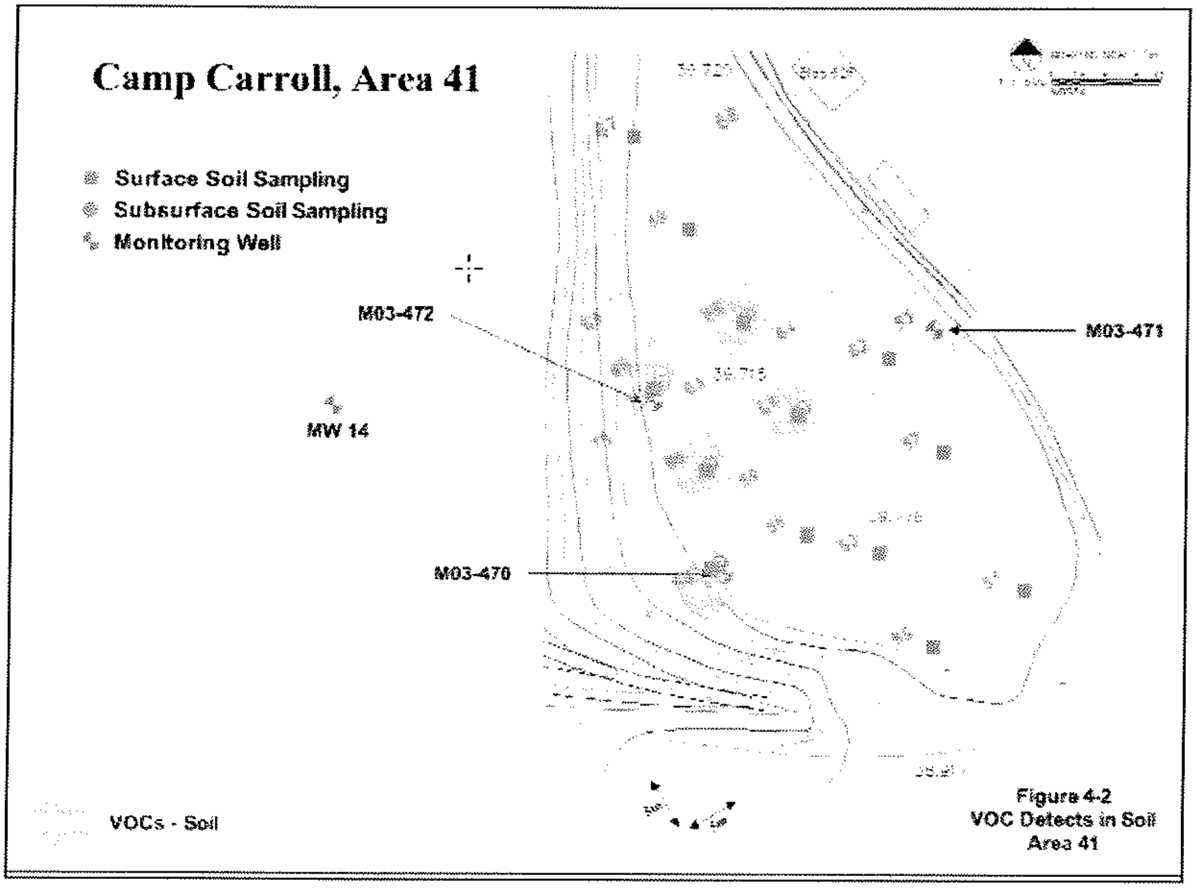
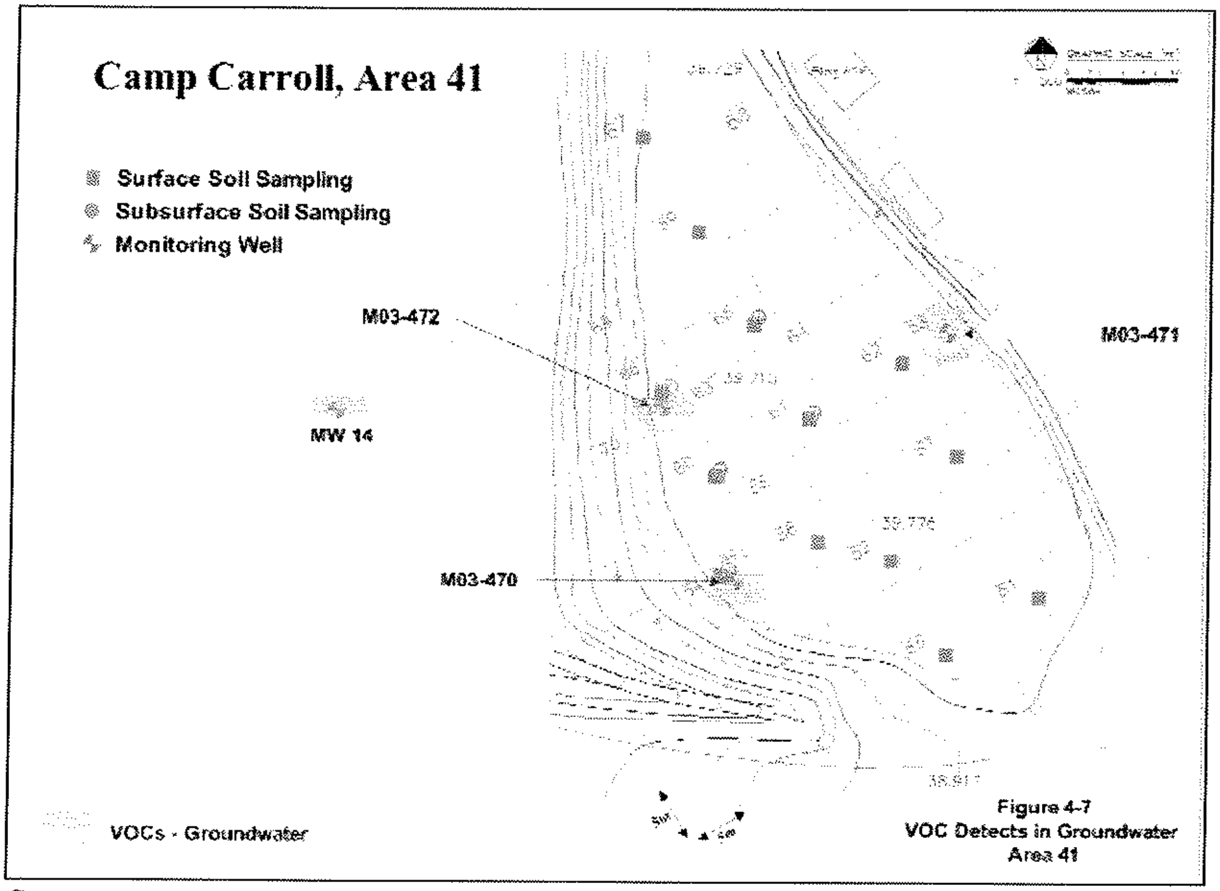


Figure 2-5 Previous Groundwater VOCs Investigation result at Area 41 in 2004 by



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3872

3. Field Activity

3.1. Field Activities

Field procedures for this ESI followed the description in the project Work Plan prepared by FED. A total of thirteen boreholes were drilled for soil sampling at Area 41 and two of those were converted to groundwater monitoring wells during this investigation. 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 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 (B09-181MW and B09-187MW). 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 indicates monitoring well.

3.3. Groundwater Monitoring Well Construction.

3.3.1. Monitoring well construction

A groundwater monitoring well was installed after completion of borehole drilling using DPT. 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 and to provide additional areal coverage in relation to existing monitoring wells. Figure 3-x shows the locations selected for monitoring well installation. The monitoring well construction logs are presented in Appendix II.

3.3.2. Monitoring Well Development.

After installation, all wells were fully developed. The objectives of well development were to remove sediment that had settled inside the well during construction; remove all water that may have been introduced during drilling and well installation; 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 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 using a surge block and pumping out the turbid water using a 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 until the water was visually clear or the site geologist determined that no further development was 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.

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 well development and sampling.

The collected groundwater samples were placed into sample containers that were prepared by the analytical laboratory. Following sample collection , the sample containers were placed immediately into a cooler with ice for preservation below 4 °C during shipment 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 3-2 presents the surveyed coordinates for the boreholes and monitoring wells.

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 to the existing surface grade. Monitoring wells installed during the project were flush-mounted to 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. Additional Site Characterization

Tests were 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 attenuation/degradation of the diesel and gasoline contamination present at the site.

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 10 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 electronic oil/water interface probe. 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 pumping test and recovery period measurement was conducted on 25 ~ 26 February, 2010. The test was comprised of pumping a volume of groundwater from monitoring well B09-187MW at a controlled rate varying between approximately 8.526 Liter/min while monitoring the water levels within the pumping well and four observation wells (B03-470MW, B03-471MW, B03-472MW and B09-181MW). Hydraulic head, temperature, and specific conductance of the groundwater were recorded during the test using pressure sensitive transducers connected to data loggers. 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 applying a vacuum to the central well rather than injection to prevent any spread of contamination from introduction or air into the well.

A constant vacuum 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.

3.6.4. Nutrient and Microbial Sampling

In order to identify biodegradability for TPH contaminated soil, six soil samples were collected, with one sample from each borehole for analysis of biological and chemical properties relevant to potential future remedial measures. Those samples were shipped to the National Instrumentation Center of Environmental Management (NICEM) at Seoul National University.

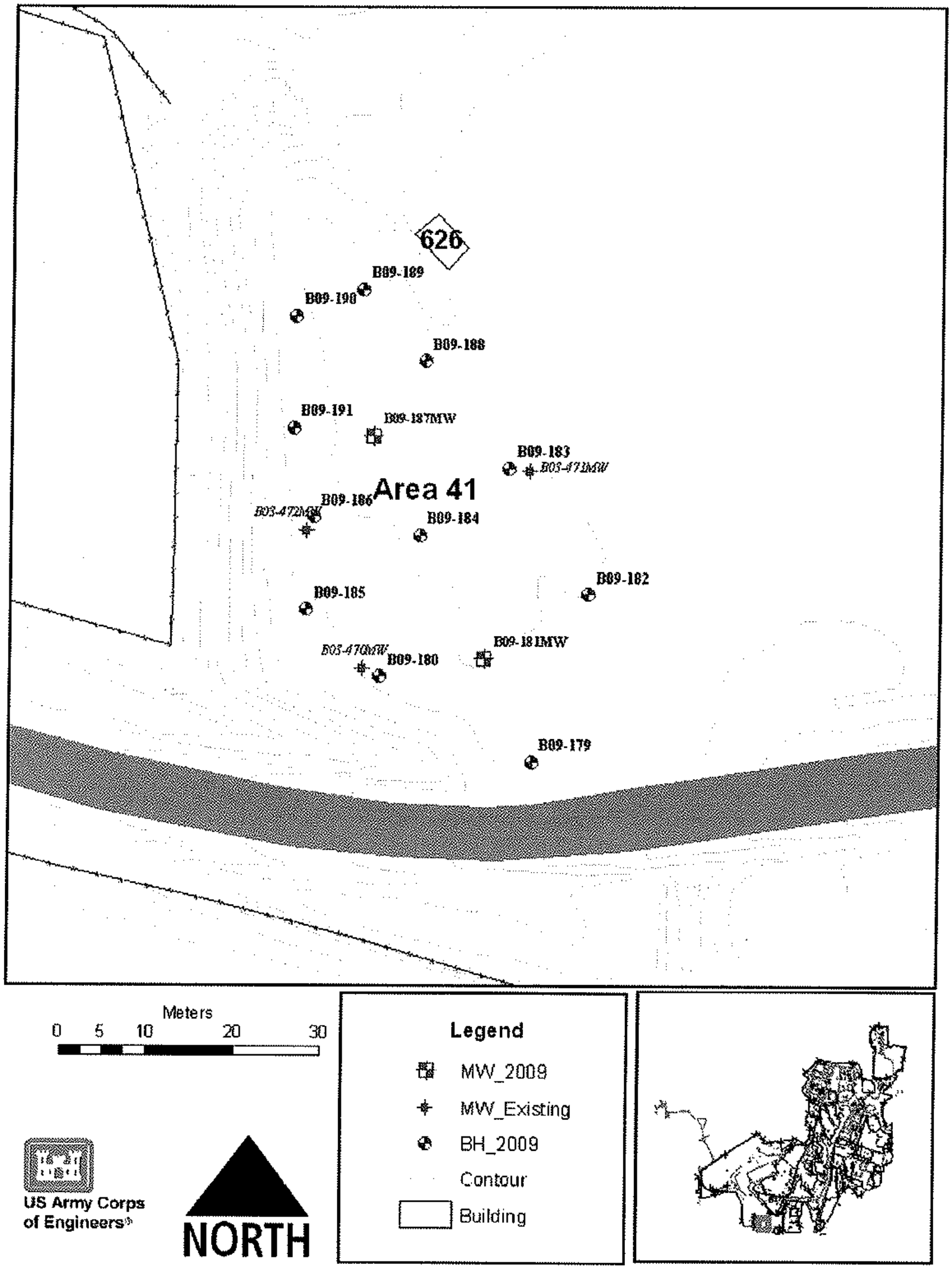
Table 3-1. Project Chronology of ESI at Area 41 of Camp Carroll.

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	May and September4, 2009
Hydrologic slug test	November 10, 2009
Hydrologic pumping test	February 26~26, 2010
Air permeability test	March 19, 2010

Table 3-2. Topographic Survey Result for Borehole and Monitoring Well at Area 41 of Camp Carroll.

BH_ID	Easting	Northing	Elevation (m, amsl*)	Top of well pipes (m, amsl)	Remark
B09-179	446680.60	3982882.56	39.37		borehole
B09-180	446662.72	3982892.31	39.48		borehole
B09-181MW	446674.85	3982894.24	39.78	39.71	monitoring well
B09-182	446686.85	3982901.76	39.74		borehole
B09-183	446677.58	3982916.18	39.82		borehole
B09-184	446667.28	3982908.51	39.79		borehole
B09-185	446654.03	3982900.00	39.38		borehole
B09-186	446654.80	3982910.59	39.57		borehole
B09-187MW	446661.62	3982919.71	39.80	39.75	monitoring well
B09-188	446667.70	3982928.42	39.82		borehole
B09-189	446660.36	3982936.59	39.62		borehole
B09-190	446652.53	3982933.59	39.59		borehole
B09-191	446652.33	3982920.84	39.54		borehole
B03-470MW	446660.60	3982893.30	39.40	39.40	Existing wells
B03-471MW	446680.10	3982915.90	39.74	39.75	
B03-472MW	446653.90	3982909.10	39.47	39.46	
*- above mean sea level					

Figure 3-1. Location of Boreholes and Groundwater Monitoring Wells at Area 41 of Camp Carroll.



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, SVOCs, PAHs, dioxin, OC-pesticides, PCB and metals analyses to the NCA laboratory in the United States because the NCA-Korea lab is only certified for TPH analyses. 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 and metals by 6020A while mercury by 7471B.

The chemical data tables of Table 2 to Table 11 presented in this report is only for those which were detected above the practical quantitation limit (PQL) or at least estimated even though the value was below the PQL. A complete data table with laboratory reports is provided on a separate compact disk (CD).

4.2. Subsurface Soil Investigation Result

Soil sampling strategy at Area 41 is summarized in Table 4-1 based upon information of the previous investigation. The summaries of chemical test results for soil samples are presented. Figure 3-1 shows the locations of the soil boreholes, groundwater monitoring wells installed both this ESI and the previous investigations.

4.2.1. Subsurface Geology

The subsurface geology of Area 41 consists mostly of fill materials and residual soils. Fill materials consist dominantly of clayey sand with gravel and silty sand, were encountered in boreholes with the thicknesses ranging from 1 to 1.5 meters below ground surface (bgs). Residual soil consists of silty sand and lean clay with sand underlying the fill materials.

A noticeable chemical odor was noted during collection of soil samples from four boreholes B09-185, -186, -187 and -190. The collected soil samples were stained and distinctly colored grayish green at these locations.

4.2.2. Chemical Analysis Result for Soil Sample

4.2.2.1. 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. Seven samples were identified containing TPH concentration above the practical quantitation limit (PQL). The sum of TPH fractions ranges from 27 mg/kg to 1,993 mg/kg. The highest concentration of TPH is identified at the borehole B09-186. The detection of TPH in soil samples was limited to the uppermost soil samples between ground surface to 2 meter bgs, with one exception at B09-109. This finding suggests that the TPH detected at the site is probably from a release during military vehicle operations rather than a spill associated an underground fuel storage tank or distribution piping.

4.2.2.2. Volatile Organic Compounds

A total of thirteen VOC components were detected in subsurface soil samples collected from boreholes drilled at the Area 41 (Table 4-3), while the other VOCs were below the PQL or the concentrations were quantitatively estimated by the chemist due to the very low concentrations. The concentration ranges among the VOCS detections in the soil samples of Area 41 are:

Acetone: 1,300 ~ 2,300 μg/kg
n-Butylbenzene: 110 ~ 120 μg/kg
sec-Butylbenzene: 83 ~ 96 μg/kg
Ethylbenzene: 70 μg/kg
Methylene chloride: 98~ 150 μg/kg
n-Propylbenzene: 64 ~ 74 μg/kg
1,1,2,2- Tetrachloroethane: 52 μg/kg
Tetrachloroethene (PCE): 45 ~ 31,000 μg/kg
Toluene: 97 μg/kg
1,2,4- Trimethylbenzene: 640 ~ 680 μg/kg
1,3,5- Trimethylbenzene: 150 ~ 160 μg/kg
m-Xylene & p-Xylene: 180 ~ 220 μg/kg
o-Xylene: 130 ~ 160 μg/kg

The maximum concentration of PCE was identified in the sample collected at the 0~2 meters interval of borehole B09-185. PCE was detected to a depth of 10 meters bgs in borehole B09-186. Figure 4-1presents the distribution of PCE at the site subsurface soil.

4.2.2.3. Semi-Volatile Organic Compounds.

A total of four SVOC components were detected above the PQL in soil samples collected from the boreholes drilled at the Area 41. The detections were identified only from the borehole B09-186 (See the Figure 3-1 for the borehole location). Detected SVOCs are fluorine (490 μg/kg), 2-methylnaphthalene (5,400 μg/kg), naphthalene (1,100 μg/kg) and pyrene (900 μg/kg). Table 4-4 presents the chemical test result for SVOCs.

4.2.2.4. Target Metals.

Target metals were detected in all soil samples collected from the boreholes drilled at the Area 41 (Table 4-5). Selenium and Silver were not detected in any soil samples above the PQL. The detected concentration of metals was generally close to the concentrations of the site background samples. Figure 4-2 presents the comparison diagram of metal concentrations with the average concentration of the site background samples. Barium and Lead are a little higher than the average background samples, while the others are similar to those of the background samples. The concentrations of barium and lead in the sample of B09-185 were detected approximately twice higher than background samples.

4.2.2.5. Polychlorinated Biphenyls.

No PCBs were detected above the PQL in soil samples collected from boreholes drilled at the Area 41.

4.2.2.6. Organochlorinated Pesticides.

OC-pesticides were detected in soil samples collected from each of the borehole drilled at the Area 41 (Table 4-6). Alpha-, beta-, gamma-, delta- BHC, gamma-chlordane, 4,4'-DDE, dieldrin, 4,4'-DDD and 4,4' DDT were the chemicals detected above the PQL. The 4,4'- DDE, DDD and DDT were generally detected above mg/kg levels. A majority of detections were mostly from the shallow soil samples from 0 ~ 2 meter bgs. The highest levels of 4,4'-DDD and DDT were identified in the soil samples of B09-185 with the concentrations of 18,000 µg/kg and 43,000 µg/kg respectively. The concentration ranges of OC-pesticide in the soil samples of Area 41 are:

Alpha-BHC: 2.3 µg/kg
Gamma-BHC (Lindane): 33 ~ 38 µg/kg
Beta-BHC: 19~25 µg/kg
Delta BHC: 1.9 ~ 4.5 µg/kg
4,4'-DDE: 1.7 ~ 3,900 µg/kg
Dieldrin: 13 µg/kg
4,4'-DDD: 0.43 ~ 18,000 µg/kg
4,4'-DDT: 3.7 ~ 43,000 µg/kg

Figure 4-3 presents the distribution of 4,4'-DDT in the site subsurface soil at Area 41. The concentration 4,4'-DDE and 4,4'-DDD in the site subsurface soil is distributed quite similar to the 4,4'-DDT.

4.2.2.7. 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 (TRI) 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. The 2,3,7,8-TCDD was not detected above the PQL in any of the soil samples. One sample from B09-191 had an estimated value of 0.07 pg/g, which is lower than the PQL.

I-TEQs were calculated for all soil samples based the I-TEFs, the measured concentrations of dioxins and furans detected above the reporting limit. The I-TEQ calculated for each of the soil samples collected at the site ranges from 0.001 to 1.332 pg/g.

4.2.3. Groundwater Investigation

4.2.3.1.Groundwater Level Measurement Result

A total of five groundwater monitoring wells, two new and three existing, were utilized to assess hydrogeologic conditions and groundwater quality of the site. Figure 3-1 presents the groundwater monitoring well locations utilized during this project. Table 4-8 summarizes the water level measurements. Water levels were measured a total of three times in each well with an oil/water interface probe. None of the boreholes contained any floating product on the groundwater surface.

The water levels were measured a total three times – during well development and two sampling periods. The two sampling periods were before rainy season (May) and after the monsoon (September). The objective was to determine if any groundwater variation between the seasons occurred. The groundwater level measurements were uniform before and after the monsoon. Based on the result of groundwater level measurements, the groundwater flow direction was analyzed as depicted in Figures 4-4. General groundwater flow pattern is predominantly toward southern direction, which generally follows the site topographic gradient. Since Area 41 is geographic distance to the installation boundary as well as the topographic gradient in this area, a possible groundwater migration could occur to the off-post from Area 41.

4.2.3.2.Groundwater Chemical Test Result

A total of five groundwater samples were collected two times during this project: May and September 2009 to see if any variation in groundwater quality during this period. Tables 4-9, 4-10 and 4-11 presents the groundwater sampling test results for VOCs, SVOCs and OC-pesticides respectively.

4.2.3.2.1. Volatile Organic Compounds

Five VOCs were detected above the PQL from the groundwater samples analyzed: acetone, 2-butanone, 1,1,2,2,-tetrachloroethane, PCE, toluene and TCE. PCE was reported from all the wells with the highest concentration up to 6,500 µg/L at B03-470MW. It is likely to appear at a higher concentration during the dry season. Figure 4-5 presents the distribution of PCE in the monitoring wells, which shows the relatively high concentration at B03-470MW. The concentration ranges of detected VOCs are:

Acetone: 20 ~ 360µg/L
2-Butanone: 11 ~ 64 µg/L
1,1,2,2,-Tetrachloroethane: 1.2 ~ 490µg/L
PCE: 5 ~ 6,500 µg/L
Toluene: 1.4 ~ 8.1 µg/L
TCE: 18 ~ 5,400 µg/L

4.2.3.2.2. Semi Volatile Organic Compounds

Only Naphthalene was detected above the PQL with the concentration of 58 µg/L at B09-181MW.

4.2.3.2.3. Organo Chlorinated Pesticides

A total of seven compounds of OC-pesticides were detected above the PQL from the site groundwater samples.

Alpha BHC: 0.046 ~ 0.16 µg/L

Beta BHC: 0.082 ~ 0.094 μg/L
Gamma BHC (Lindane): 0.072 ~ 0.2 μg/L
Delta BHC: 0.07 ~ 0.075 μg/L
Dieldrin: 0.24 ~ 0.26 μg/L
4,4'-DDD: 0.21 μg/L
4,4'-DDT: 0.16 ~ 0.21 μg/L

4.3. Data Quality Control/Assurance

Field and laboratory QC samples were collected and analyzed in accordance with USACE and industry standard methods and practices. The FED Environmental chemist (Dr. SC Chon) performed data review on soil and groundwater samples collected from the Area 41 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) /quality control (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 discussion.

4.4. Hydrologic Characteristics of the Site

Figure 4-6 presents the groundwater monitoring well locations used for hydrologic field test and air permeability.

4.4.1. Slug Test

Three slug tests were performed to assess the hydrologic properties of Area 41. The monitoring wells selected for slug testing was subject to its relative location within Area 41 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 1.52E-03 cm/sec to 8.72E-04 cm/sec. 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 1.43 cm^2/sec to 86.7 cm^2/sec. The T value is generally higher during water level drawdown than recovery. The K values during pumping test obtained ranging from 1.5E-03 cm/sec to 4.38E-01 cm/sec, with an average of 8.74E-02 cm/sec. The K values obtained during pumping test were quite higher than those during slug test. Table 4-13 presents the result of pumping test.

4.4.3. Air Permeability Test

An air permeability test was conducted to evaluate subsurface air flow patterns and radius of influence (ROI) at Area 41. The layout of the permeability test was determined based on the location of existing groundwater monitoring wells and air monitoring well installed at B09-184. The air permeability test was conducted at four wells (as a set) consisting of one air extraction well (B09-184- air test well) and three observation wells (B09-181MW, B03-471MW, B03-472MW). Figure 4-6 presents the well layout of air permeability test at Area 41.

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 down pressure was monitored at each well to determine any change of pressure. Table 4-14 presents the air permeability test results and the calculated ROI. The air permeability (K) value ranged from 26 cm/sec to 240 cm/sec and the ROI of 14 m when the air volume extraction ratio was 30 m^3/hour.

4.4.4. Nutrient and Microbial Sampling

Six 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 Area 41appears to be 83: 8: 9. Fuel disintegration bacteria were counted up to 47,500 Most Probable Number (MPN)/g in soil. 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 4-15.

Table 4-1. Soil Sample Information vs. the CoPC According to depth from each Borehole.

Borehole ID	Sample ID	Sample Depth	VOCs	OC-pesticide	Dioxins	TPH-D	SVOC	PCB	$Metals
B09-179	S1	0~2m	O	O	O*	O	O	O	O
	S2	2~4m	O	O	O	O	O	X**	X
	S3	4~6m	O	O	O	X	X	X	X
B09-180	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-181MW	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-182	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-183	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-184	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-185	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
	S3	4~6m	O	O	O	X	X	X	X
B09-186	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
	S3	4~6m	O	O	O	X	X	X	X
	S4	6~8m	O	X	X	X	X	X	X
B09-187MW	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-188	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-189	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
B09-190	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X
	S3	4~6m	O	O	O	X	X	X	X
B09-191	S1	0~2m	O	O	O	O	O	O	O
	S2	2~4m	O	O	O	O	O	X	X

*- indicates sample was collected for the analysis, ** not collected, $- two site background samples included.

Table 4-2. TPH Test Results for Soil Samples at Area 41.

BH_ID	Sample ID	Sample Interval	unit	Diesel range ($C_{10\sim24}$)	Residual oil range ($C_{24\sim40}$)	Photo Ionization Detector reading (ppm)
B09-179	S1	0~2 m	mg/kg	-*	-	1.5
	S2	2~4 m	mg/kg	-	-	1
B09-180	S1	0~2 m	mg/kg	27	-	0.3
	S2	2~4 m	mg/kg	-	-	0.6
B09-181MW	S1	0~2 m	mg/kg	127	12	19.2
	S2	2~4 m	mg/kg	-	-	1.5
B09-182	S1	0~2 m	mg/kg	27.9	-	2.7
	S2	2~4 m	mg/kg	-	-	0
B09-183	S1	0~2 m	mg/kg	-	-	0.1
	S2	2~4 m	mg/kg	-	-	1.2
B09-184	S1	0~2 m	mg/kg	-	-	0.7
	S2	2~4 m	mg/kg	-	-	0
B09-185	S1	0~2 m	mg/kg	156	17.7	162
	S2	2~4 m	mg/kg	-	-	143
B09-186	S1	0~2 m	mg/kg	1930	62.5	72.4
	S2	2~4 m	mg/kg	-	-	98.4
B09-187MW	S1	0~2 m	mg/kg	-	-	10.4
	S2	2~4 m	mg/kg	-	-	3.7
B09-188	S1	0~2 m	mg/kg	-	-	2.5
	S2	2~4 m	mg/kg	-	-	3.7
B09-189	S1	0~2 m	mg/kg	-	-	0.8
	S2	2~4 m	mg/kg	-	-	1.7
B09-190	S1	0~2 m	mg/kg	178	-	24.6
	S2	2~4 m	mg/kg	74.2	-	58.6
B09-191	S1	0~2 m	mg/kg	-	-	5.7
	S2	2~4 m	mg/kg	-	-	1.8

*- not detected above the practical quantitation limit.

Table 4-3 VOCs Chemical Test Results for Soil Sample at Area 41.

Component (ug/kg)	B09-179			B09-180		B09-181		B09-182		B09-183		B09-184		B09-185		
	S1	S2	S3	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S3
Acetone	1300	1300	2100	1300	2300	1900	1600	1400 B	1300* B	1200 B	1400 B	1300 B	2100 B	1500 B	1700 B	1700 B
n-Butylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	12J	-	-
sec-Butylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12J
Chloromethane	-	-	-	-	-	-	-	-	9.9**J	-	-	-	-	-	-	-
cis-1,2-Dichloroethene	-	-	-	-	-	-	-	-	-	-	-	29J	-	-	39J	41J
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopropylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	110	120	120	130	130	130	120	110	130	110	120	120	100J	110	120J	150
Naphthalene	13J B	14J B	-	15J B	-	-	-	-	-	-	-	-	-	32J B	-	-
n-Propylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	-	38J	50J	21J	13J	-	-	-	-	-	-	-
Tetrachloroethene	91J	26J	18J	19J	13J	330	49J	29J	-	-	-	300	73J	31000	8800	4800
Toluene	-	-	-	12J	-	-	-	-	-	-	-	-	-	-	-	-
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	21J B	-	-
Trichloroethene	19J B	14J B	-	-	13J B	84J B	60J B	57J	-	-	-	27J	12J	74J	100J	61J
1,2,4-Trimethylbenzene	15J	11J	-	-	-	-	-	-	-	-	-	-	-	39J	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	30J	-	-
m-Xylene & p-Xylene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
o-Xylene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*-The analyte found in a blank associated with the sample. **- Estimated result. Result is less than reporting limit.

3888

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

Component (ug/kg)	B09-186				B09-187		B09-188		B09-189		B09-190			B09-191	
	S1	S2	S3	S4	S1	S2	S1	S2	S1	S2	S1	S2	S3	S1	S2
Acetone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
n-Butylbenzene	-	-	110	-	-	-	-	-	-	-	-	-	-	-	-
sec-Butylbenzene	-	-	83	-	-	-	-	-	-	-	-	-	-	-	-
Chloroform	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloromethane	7.3J	8.8J	-	12J	10J	12J	-	-	-	-	-	-	-	11J	12J
cis-1,2-Dichloroethene	-	15J	24J	-	9.3J	10J	-	-	-	-	-	-	-	-	-
Ethylbenzene	19J	25J	70	26J	22J	18J	20J	22J	18J	22J	18J	25J	21J	25J	21J
Isopropylbenzene	-	-	32J	-	-	-	-	-	-	-	-	-	-	-	-
p-Isopropyltoluene	-	-	44J	-	-	-	-	-	-	-	-	-	-	-	-
Methylene chloride	-	7.6J	-	-	6.5J	-	8J	7.6J	-	7.4J	7.3J	8.1J	6.5J	-	-
Naphthalene	-	-	35J	-	-	-	-	-	-	-	-	-	-	-	-
n-Propylbenzene	-	-	74	-	-	-	-	-	-	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	-	4.2J	-	-	-	-	-	-	-	16J	52
Tetrachloroethene	17J	360	1100	590	43J	45	-	6.3J	-	6.3J	73	24J	27J	-	-
Toluene	6.4J	52J	43J	30J	8J	20J	13J	18J	97	22J	15J	12J	18J	16J	9.7J
1,2,3-Trichlorobenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichloroethene	-	15J	34J	19J	-	-	-	-	-	-	-	-	-	-	6.4J
1,2,4-Trimethylbenzene	-	-	640	-	-	-	-	-	-	-	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	150	-	-	-	-	-	-	-	-	-	-	-	-
m-Xylene & p-Xylene	44J	60J	220	59J	55J	42J	52J	57J	46J	50J	48J	55J	49J	59J	51J
o-Xylene	-	8.8J	160	-	-	-	-	7.5J	-	-	-	-	-	-	-

3889

Table 4-4 SVOCs Chemical Test Results for Soil Samples of Area 41.

Component (μg/kg)	B09-179	B09-180	B09-181	B09-182	B09-183	B09-184	B09-185	B09-186		B09-187	B09-188	B09-189	B09-191
	S1/S2	S1/S2	S1/S2	S1/S2	S1/S2	S1/S2	S1/S2	S1	S2	S1/S2	S1/S2	S1/S2	S1/S2
Fluorene	-*	-	-	-	-	-	-	490	-	-	-	-	-
2-Methylnaphthalene	-	-	-	-	-	-	-	5400	1200	-	-	-	-
Naphthalene	-	-	-	-	-	-	-	1100	240**J	-	-	-	-
Pyrene	-	-	-	-	-	-	-	900	180J	-	-	-	-

*- not detected above the practical quantitation limit, **- J- Estimated result. Result is an estimated value.

Table 4-5. Metal Chemical Test Result for Soil of Area 41.

Component (mg/kg)	Area41_BG*		B09-179	B09-180	B09-181	B09-182	B09-183	B09-184	B09-185	B09-186	B09-187	B09-188	B09-189	B09-190	B09-191
	BG1	BG2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Arsenic	6.1	8	5.3	2.1B	3.5	2.9	1.6B	2.4	4.8	4.2B	2.9B	2.1B	3B	3.8B	3.6B
Barium	71	52.1	84.7	69.9	65.4	73.9	66.2	55	140	71	57.4	43.3	49.3	40	73.2
Cadmium	0.11B**	-***	0.15B	-	-	-	-	-	0.13B	-	-	-	-	-	-
Chromium	15.6	13.5	5.4	6.8	5.5	8.7	3.8	4.8	17.9	11.3	5.2	3.4	4	8.2	8.5
Lead	25.2	20	12.5	8.2	8	10.2	5.9	7.9	54.9	10	7.2	5.9	8.9	9.2	7.3
Selenium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury	0.022B	0.015B	0.035B	0.017B	0.018B	0.018B	-	0.013B	0.022B	-	-	-	0.013B	0.014B	0.013B

*- background sample, **-The analyte found in a blank associated with the sample, ***- not detected above the practical quantitation limit.

3890

Table 4-6. OC-Pesticides Chemical Test Results for Soil of Area 41.

Component (ug/kg)	B09-179			B09-180		B09-181		B09-182		B09-183		B09-184		B09-185		
	S1	S2	S3	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S3
alpha-BHC	- G	-	-	- G	-	-	-	-	-	-	-	-	-	-	0.92J	1J
gamma-BHC (Lindane)	-	-	-	-	-	0.96J	-	-	-	-	-	-	-	-	33	38
Heptachlor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aldrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
beta-BHC	-	0.64J	-	-	-	0.73J	-	-	-	-	-	-	-	-	25	19
delta-BHC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	4
Heptachlor epoxide	-	-	-	-	-	0.8J PG	-	-	-	-	-	-	-	-	-	-
Endosulfan I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	430	-	0.85J	-	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	410PG	-	0.91J PG	-	-	-	-	0.32J	-	-	-	-	-	90J PG	-	-
4,4'-DDE	1400	0.63J	5	33J	0.36J	4	0.29J	27	-	2	-	2	-	3900	-	0.55J
Dieldrin	75J	0.49J	0.51J	9J	0.51J	2.5J	-	13	-	1	-	-	-	210J	-	-
Endrin	-	-	-	-	-	-	-	-	-	- J	-	- J	-	-	-	-
4,4'-DDD	780	0.35J	2.3J	53	0.41J	10	0.69J	20	-	1.3J	-	0	-	18000	1.9J	3.4J
Endosulfan II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDT	22000E	8	66	320	4	29	4	65	-	9.3J	0.56J	0.55J	-	43000	3.7J	6
Endrin aldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	-	-	-	-	-	-	- J	-	-	-	-
Endosulfan sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxaphene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlordane (technical)	2200J	-	-	-	-	-	-	-	-	-	-	-	-	- G	-	-
J- Estimated result. Result is less than reporing limit.																
PG: The percent difference between the original and confirmation analyses is greater than 40%.																

3891

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

Component (ug/kg)	B09-186			B09-187		B09-188		B09-189		B09-190			B09-191	
	S1	S2	S3	S1	S2	S1	S2	S1	S2	S1	S2	S3	S1	S2
alpha-BHC	-	- G	-	- q	2	-	-	-	-	-	-	-	-	-
gamma-BHC (Lindane)	-	22J	-	-	36	-	-	-	-	-	-	-	-	-
Heptachlor	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aldrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
beta-BHC	-	-	-	-	0.79J	-	-	-	-	-	-	-	1J	-
delta-BHC	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Heptachlor epoxide	-	6J	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan I	-	-	-	-	-	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	-	-	-	-	-	-	-	-	-	-	-	-	-
alpha-Chlordane	-	-	0.49J PG	-	-	-	-	1.7J q	-	-	-	-	0.44J	-
4,4'-DDE	220	-	4J	230J	12	3.1J	0.45J	65	2.2J	200 q	-	-	12	0.64J
Dieldrin	49J	-	-	-	1.4J	0.74J	-	15J	0.46J	-	-	-	13	-
Endrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	1400	34J	31	220J	9	0.82J	-	38	1.3J	340	-	-	7	-
Endosulfan II	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4'-DDT	3100	52J	54	2800	150	6	1.1J	410	5	4000	-	-	83	2.5J
Endrin aldehyde	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxaphene	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlordane (technical)	- G	-	-	-	-	-	-	-	-	-	-	-	-	-
J- Estimated result. Result is less than reporing limit.														
PG: The percent difference between the original and confirmation analyses is greater than 40%.														

3892

Table 4-7. Dioxin-Furan Chemical Test Results for Soil samples of Area 41.

Borehole ID	Sample ID	Sample Depth	Analytical Method	International-89 Toxicity Equivalent Quantity* (pg/g)
B09-179	S1	0-2 m	EPA 8290	0.237
	S2	2-4 m	EPA 8290	0.081
	S3	4-6 m	EPA 8290	0.122
B09-180	S1	0-2 m	EPA 8290	0.175
	S2	2-4 m	EPA 8290	0.022
B09-181	S1	0-2 m	EPA 8290	0.081
	S2	2-4 m	EPA 8290	0.131
B09-182	S1	0-2 m	EPA 8290	0.277
	S2	2-4 m	EPA 8290	0.005
B09-183	S1	0-2 m	EPA 8290	0.005
	S2	2-4 m	EPA 8290	0.001
B09-184	S1	0-2 m	EPA 8290	0.064
	S2	2-4 m	EPA 8290	0.042
	S3	4-6 m	EPA 8290	0.077
B09-185	S1	0-2 m	EPA 8290	1.332
	S2	2-4 m	EPA 8290	0.003
	S3	4-6 m	EPA 8290	0.002
B09-186	S1	0-2 m	EPA 8290	0.613
	S2	2-4 m	EPA 8290	0.004
	S3	4-6 m	EPA 8290	0.040
B09-187	S1	0-2 m	EPA 8290	0.017
	S2	2-4 m	EPA 8290	0.005
B09-188	S1	0-2 m	EPA 8290	0.076
	S2	2-4 m	EPA 8290	0.029
B09-189	S1	0-2 m	EPA 8290	0.113
	S2	2-4 m	EPA 8290	0.175
B09-190	S1	0-2 m	EPA 8290	0.215
	S2	2-4 m	EPA 8290	0.024
	S3	4-6 m	EPA 8290	0.017
B09-191	S1	0-2 m	EPA 8290	0.357
	S2	2-4 m	EPA 8290	0.135

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

Table 4-8 Water Level Measurement Result at Area 41

MW_ID	Top of Pipe (m)	Water Level (below ground surface)			Water Level (above mean sea level)		
		3-Mar-09	20-May-09	2-Sep-09	3-Mar-09	20-May-09	2-Sep-09
B03-470MW	39.40	11.12	11.42	10.39	28.28	27.99	29.01
B03-471MW	39.75	5.80	5.44	4.66	33.95	34.31	35.09
B03-472MW	39.46	11.17	11.32	10.43	28.29	28.14	29.03
B09-181MW	39.71	11.20	11.38	10.50	28.51	28.33	29.21
B09-187MW	39.75	5.81	5.42	4.73	33.94	34.33	35.02

* during well development on 3 March 2009, during groundwater sampling both May and September 2009.

3894

Table 4-9 VOCs Chemical Test Result for Groundwater of Area 41.

Component (µg/L)	B03-470MW		B03-471MW		B03-472MW		B09-181MW		B09-187MW	
	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09
Acetone	-*	210q **	-	20	-	360q	-	-	-	44JG** **
Benzene	-	-	-	0.15J* **	-	-	-	-	-	-
2-Butanone (MEK)	-	32	-	11	-	64	-	-	-	9.7J
Carbon tetrachloride	-	-	-	-	-	-	15J	-	-	-
Chloroform	-	4.2J	-	0.4J	-	-	43J	26J	-	-
cis-1,2-Dichloroethene	53J	-	1.2J	0.5J	-	-	21J	-	1.7J	-
Methylene chloride	-	-	-	2.7	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	77J	110	-	1.2	16J	3.4J	490	120	-	0.93J
Tetrachloroethene	6500q	93	150q	5	1300q	2.6J	4400q	2400q	200q	9.6J
Toluene	-	-	8.1	1.4	-	1.8J	-	-	7.6J	-
Trichloroethene	380	6.3J	18	0.75J	350	-	5400	1600	7.7J	-

* not detected above the practical quantitation limit

** quality control parameter out of acceptable range

*** the result is an estimated value.

**** elevated reporting limit. The reporting limit is elevated due to matrix interference.

Table 4-10. SVOCs Chemical Test Result for Groundwater Samples of Area 41.

Component (ng/L)	B03-470MW	B03-470MW	B03-470MW	B09-181MW	B09-187MW
	May-09	May-09	May-09	May-09	May-09
Acenaphthylene	-*	-	-	-	-
Acenaphthene	-	-	-	-	-
Anthracene	5.3J**	-	-	-	-
Benzo(a)anthracene	-	-	-	-	-
Benzo(b)fluoranthene	-	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-	-
Benzo(ghi)perylene	-	-	-	-	-
Benzo(a)pyrene	-	-	-	-	-
Chrysene	-	-	-	-	-
Dibenz(a,h)anthracene	-	-	-	-	-
Fluoranthene	-	-	-	-	-
Fluorene	-	12J	-	-	-
Indeno(1,2,3-cd)pyrene	-	-	-	-	-
Naphthalene	4J	28J	-	58	-
Phenanthrene	-	12J	-	-	-
Pyrene	-	-	-	-	-

* not detected above the practical quantitation limit, ** the result is an estimated value.

Table 4-11. OC-Pesticide Chemical Test Result for Groundwater Sample of Area 41.

Component (μg/L)	B03-470MW		B03-471MW		B03-472MW		B09-181MW		B09-187MW	
	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09	May-09	Sep-09
alpha-BHC	0.16	0.15	-*	-	0.018J PG	0.012J PG	0.033J	0.046	0.011J	-
gamma-BHC (Lindane)	0.12	0.19	-	-	0.072	0.039J PG	0.2	0.12	0.042J	0.013J
Heptachlor	-	0.02J PG	-	-	-	-	-	-	-	-
Aldrin	-	-	-	-	-	0.0068J PG	-	-	-	-
beta-BHC	0.082	0.094	-	-	-	-	0.094	0.045J	0.0067J	-
delta-BHC	0.07	0.039J	-	-	0.004J	-	0.045J	0.075	0.028J	0.0056J PG
Heptachlor epoxide	-	-	-	-	-	0.0025J	0.011J	-	-	-
Endosulfan I	0.025J PG	-	-	-	-	-	-	-	-	-
gamma-Chlordane	-	0.064PG	-	-	-	-	0.011J	-	-	-
alpha-Chlordane	0.03J PG	0.011J PG	-	-	-	-	-	-	-	-
4,4'-DDE	-	-	-	-	-	-	0.027J	-	-	-
Dieldrin	0.26	-	0.016J	-	-	-	0.24	-	-	-
Endrin	0.019J	-	-	-	-	-	-	-	-	-
4,4'-DDD	0.044J	-	-	-	0.0065J PG	-	0.21	-	0.03J	-
Endosulfan II	-	-	-	-	-	-	0.024J	-	-	-
4,4'-DDT	0.053J PG	-	-	-	0.01J PG	-	0.16	-	0.21	-
Endrin aldehyde	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	-	-	-	-	-
Endosulfan sulfate	-	0.014J	-	-	-	-	-	-	-	-
Endrin ketone	-	-	-	-	-	-	-	-	-	-
Toxaphene	-	-	-	-	-	-	-	-	-	-

*- not detected above the practical quantitation limit, J- Estimated result. Result is less than reporing limit.

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

3897

Table 4-12 Slug Test Result at Area 41.

Well ID	Hydraulic Conductivity K(m/sec, B&R*)	K(m/day, B&R)	Average K (cm/sec)	Remark
B03-471MW	3.40E-06	0.29577	3.33E-04	Injection
	3.20E-06	0.27927		Withdrawal
B03-474MW	7.80E-06	0.67675	8.72E-04	Injection
	9.60E-06	0.83086		Withdrawal
B03-475MW	1.60E-05	1.38126	1.52E-03	Injection
	1.40E-05	1.24238		Withdrawal
* Bouwer and Rice (1976)				

Table 4-13 Pumping Test Result at Area 41.

	Monitoring Wells		Drawdown (m)	Q(m3/day)	Slop (Δs)	T (cm2/sec)	K (cm/sec)	Average K(cm/sec)	Storativity
Pumping well	B09-187MW	Pumping	1.956	12.278	0.168	1.55	1.63E-03	1.56E-03	
		Recovery		12.278	0.183	1.43	1.50E-03		
Observation wells	B03-472MW	Pumping	0.031	12.278	0.017	15.4	4.68E-02	5.61E-02	3.78E-05
		Recovery		12.278	0.012	21.51	6.54E-02		
	B03-407MW	Pumping	0.096	12.278	0.012	21.51	1.09E-01	2.73E-01	1.15E-07
		Recovery		12.278	0.003	86.74	4.38E-01		
	B09-181MW	Pumping	0.022	12.278	0.006	44.87	1.42E-01	8.86E-02	2.04E-06
		Recovery		12.278	0.023	11.12	3.52E-02		
	B03-471MW	Pumping	0.164	12.278	0.037	7.13	1.18E-02	1.72E-02	7.22E-07
		Recovery		12.278	0.019	13.7	2.26E-02		

3898

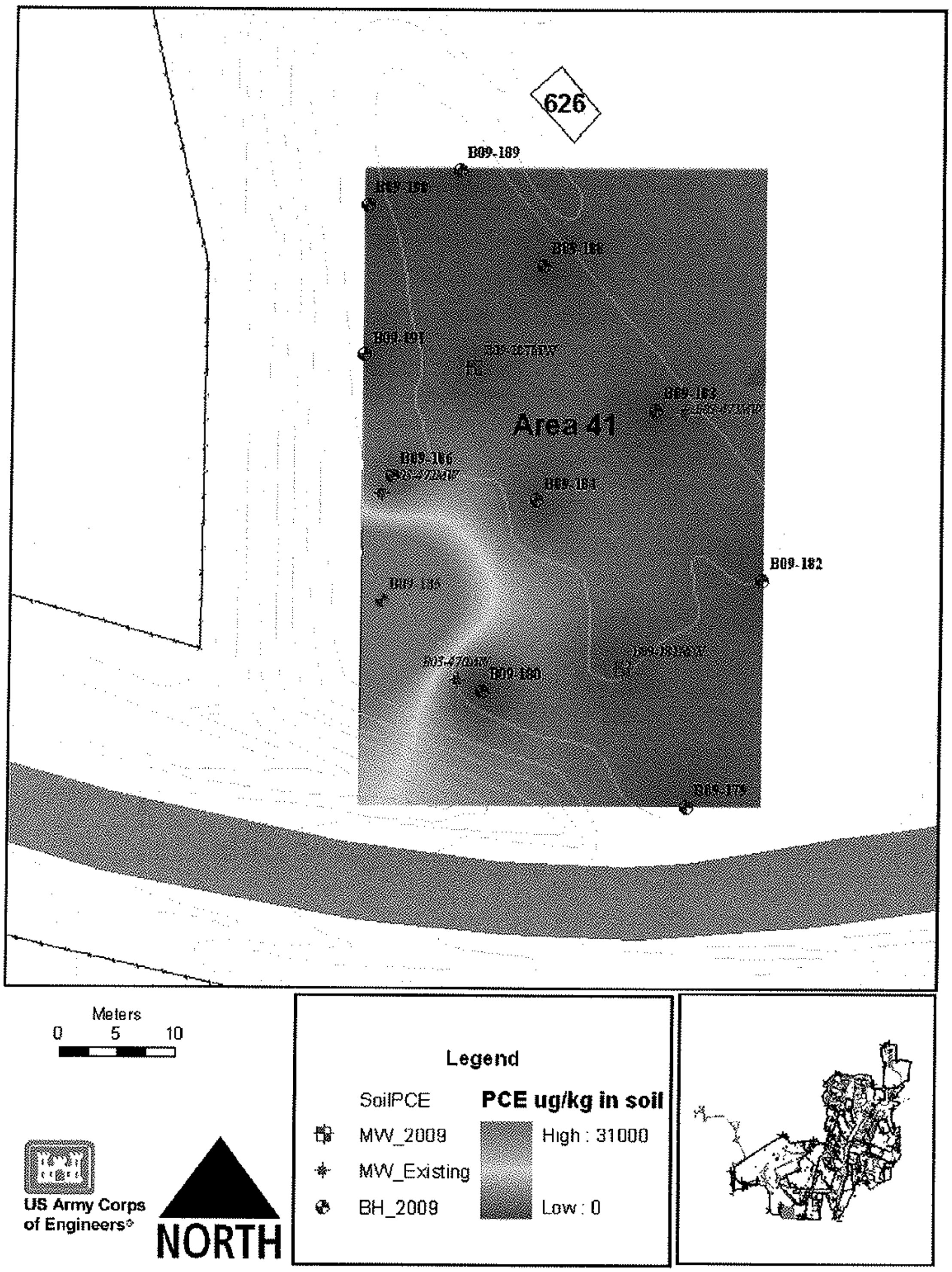
Table 4-14 Air Permeability Test Result at Area 41.

Well ID	Pressure	K(darcy[A])	Radius of Influence (m)	Remark
B09-181	vacuum	26.5	14	Air volume 30 m^3/hour, air extraction well was B09-184
	stop	-36.8		
B03-471	vacuum	240.3		
	stop	-375.1		
B03-472	vacuum	142.8		
	stop	154.4		

Table 4-15 Microbe and Total CNP Analytical Result of Soil at Area 41.

BH_ID	Total Microbe (CFU*/g)	Oil Disintegrated Microbe (MPN**/g)	Total Carbon (%)	Total Nitrogen (%)	Total Phosphorous (mg/kg)
B09-186-S1	8.96×10^6	2.65×10^4	0.51	0.0393	179.21
B09-187-S1	1.06×10^7	6.93×10^3	0.09	0.0144	294.42
B09-188-S1	7.57×10^6	5.56×10^2	0.04	0.071	91.92
B09-189-S1	5.57×10^6	3.92×10^4	0.05	0.0097	103.3
B09-190-S2	9.65×10^5	7.80×10^2	0.22	0.0082	75.1
B09-191-S2	4.60×10^6	4.75×10^4	0.33	0.0264	101.23
* CFU-colony forming unit, ** MPN- most probable number					

Figure 4-1. PCE Distribution in the Subsurface Soil s at Area 41 of Camp Carroll.



3900