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Table 3. Summary of Dioxin/Furan Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
2,3,7,8-TCDD	ng/L	ND	ND	ND	ND	ND
1,2,3,7,8-PeCDD	ng/L	ND	ND	ND	ND	ND
1,2,3,4,7,8-HxCDD	ng/L	ND	ND	ND	ND	ND
1,2,3,6,7,8-HxCDD	ng/L	ND	ND	ND	ND	ND
1,2,3,7,8,9-HxCDD	ng/L	ND	ND	ND	ND	ND
1,2,3,4,6,7,8-HpCDD	ng/L	ND	ND	ND	ND	ND
OCDD	ng/L	ND	ND	ND	ND	ND
2,3,7,8-TCDF	ng/L	ND	0.00538	ND	ND	ND
1,2,3,7,8-PeCDF	ng/L	ND	0.132	ND	ND	ND
2,3,4,7,8-PeCDF	ng/L	ND	ND	ND	ND	ND
1,2,3,4,7,8-HxCDF	ng/L	ND	0.0151 J	ND	ND	ND
1,2,3,6,7,8-HxCDF	ng/L	ND	ND	ND	ND	ND
2,3,4,6,7,8-HxCDF	ng/L	ND	ND	ND	ND	ND
1,2,3,7,8,9-HxCDF	ng/L	ND	ND	ND	ND	ND
1,2,3,4,6,7,8-HpCDF	ng/L	ND	ND	ND	ND	ND
1,2,3,4,7,8,9-HpCDF	ng/L	ND	ND	ND	ND	ND
OCDF	ng/L	ND	ND	ND	ND	ND

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

ND: Not detected

Table 4. Summary of Chlorinated Herbicide Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
2,4,5-T	µg/L	ND	ND	ND	ND	ND
2,4,5-TP (Silvex)	µg/L	ND	ND	ND	ND	ND
2,4-D	µg/L	ND	ND	ND	ND	ND
2,4-DB	µg/L	ND	ND	ND	ND	ND
Dicamba	µg/L	ND	ND	ND	ND	ND

NOTE:

ND: Not detected

Table 5. Summary of Organochlorine Pesticide Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
4,4'-DDD	µg/L	ND	ND	ND	0.211	ND
4,4'-DDE	µg/L	ND	ND	ND	ND	ND
4,4'-DDT	µg/L	ND	ND	ND	0.244	ND
Aldrin	µg/L	ND	ND	ND	ND	ND
alpha-BHC	µg/L	0.467 N	ND	ND	0.11 J	ND
alpha-Chlordane	µg/L	ND	ND	ND	ND	ND
beta-BHC	µg/L	0.392 N	ND	ND	0.0572 J	ND
Chlordane	µg/L	ND	ND	ND	ND	ND
delta-BHC	µg/L	0.26 N	ND	ND	0.28	ND
Dieldrin	µg/L	0.462 N	ND	ND	0.319	ND
Endosulfan I	µg/L	ND	ND	ND	ND	ND
Endosulfan II	µg/L	ND	ND	ND	ND	ND
Endosulfan sulfate	µg/L	0.0544 J	ND	ND	ND	ND
Endrin	µg/L	ND	ND	ND	ND	ND
Endrin aldehyde	µg/L	ND	ND	ND	ND	ND
Endrin ketone	µg/L	ND	ND	ND	ND	ND
gamma-BHC (Lindane)	µg/L	0.149 N	ND	ND	0.136 J	ND
gamma-Chlordane	µg/L	ND	ND	ND	ND	ND
Heptachlor	µg/L	ND	ND	ND	ND	ND
Heptachlor epoxide	µg/L	ND	ND	ND	ND	ND
Methoxychlor	µg/L	ND	ND	ND	ND	ND
Toxaphene	µg/L	ND	ND	ND	ND	ND

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

N: Tentative detection (qualitatively estimated)

ND: Not detected

Table 6. Summary of Organophosphorus Pesticide Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
Bolstar	µg/L	ND	ND	ND	ND	ND
Chlorpyrifos	µg/L	ND	ND	ND	ND	ND
Coumaphos	µg/L	ND	ND	ND	ND	ND
Demeton	µg/L	ND	ND	ND	ND	ND
Diazinon	µg/L	ND	ND	ND	ND	ND
Dichlorvos	µg/L	ND	ND	ND	ND	ND
Dimethoate	µg/L	ND	ND	ND	ND	ND
Disulfoton	µg/L	ND	ND	ND	ND	ND
EPN	µg/L	ND	ND	ND	ND	ND
Ethoprop	µg/L	ND	ND	ND	ND	ND
Ethyl Parathion	µg/L	ND	ND	ND	ND	ND
Fensulfothion	µg/L	ND	ND	ND	ND	ND
Fenthion	µg/L	ND	ND	ND	ND	ND
Malathion	µg/L	ND	ND	ND	ND	ND
Merphos	µg/L	ND	ND	ND	ND	ND
Methyl Azinphos (Guthion)	µg/L	ND	ND	ND	ND	ND
Methyl Parathion	µg/L	ND	ND	ND	ND	ND
Mevinphos	µg/L	ND	ND	ND	ND	ND
Monocrotophos	µg/L	ND	ND	ND	ND	ND
Naled	µg/L	ND	ND	ND	ND	ND
Phorate	µg/L	ND	ND	ND	ND	ND
Ronnel	µg/L	ND	ND	ND	ND	ND
Stirophos	µg/L	ND	ND	ND	ND	ND
Sulfotep	µg/L	ND	ND	ND	ND	ND
TEPP	µg/L	ND	ND	ND	ND	ND
Tokuthion	µg/L	ND	ND	ND	ND	ND
Trichloronate	µg/L	ND	ND	ND	ND	ND

NOTE:

ND: Not detected

Table 7. Summary of Volatile Organic Compound Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
1,1,1,2-Tetrachloroethane	µg/L	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	µg/L	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	µg/L	ND	ND	ND	113 J	ND
1,1,2-Trichloroethane	µg/L	ND	ND	ND	ND	ND
1,1-Dichloroethane	µg/L	ND	ND	ND	ND	ND
1,1-Dichloroethene	µg/L	ND	ND	ND	ND	ND
1,1-Dichloropropene	µg/L	ND	ND	ND	ND	ND
1,2,3-Trichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,2,3-Trichloropropane	µg/L	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,2,4-Trimethylbenzene	µg/L	150 J	3.75 J	26.8 J	ND	ND
1,2-Dibromo-3-chloropropane	µg/L	ND	ND	ND	ND	ND
1,2-Dibromoethane	µg/L	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,2-Dichloroethane	µg/L	ND	ND	ND	ND	ND
1,2-Dichloropropane	µg/L	ND	ND	ND	ND	ND
1,3,5-Trimethylbenzene	µg/L	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,3-Dichloropropane	µg/L	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
2,2-Dichloropropane	µg/L	ND	ND	ND	ND	ND
2-Butanone	µg/L	ND	ND	ND	ND	ND
2-Chlorotoluene	µg/L	ND	ND	ND	ND	ND
2-Hexanone	µg/L	ND	ND	ND	ND	ND
4-Chlorotoluene	µg/L	ND	ND	ND	ND	ND
4-Isopropyltoluene	µg/L	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	µg/L	ND	ND	ND	ND	ND
Acetone	µg/L	ND	7.7 J	ND	ND	ND
Benzene	µg/L	57.5 J	2.65 J	12.8 J	ND	ND
Bromobenzene	µg/L	ND	ND	ND	ND	ND
Bromochloromethane	µg/L	ND	ND	ND	ND	ND
Bromodichloromethane	µg/L	ND	ND	ND	ND	ND
Bromoform	µg/L	ND	ND	ND	ND	ND
Bromomethane	µg/L	ND	ND	ND	ND	ND
Carbon disulfide	µg/L	ND	ND	ND	ND	ND
Carbon tetrachloride	µg/L	ND	ND	ND	ND	ND
Chlorobenzene	µg/L	ND	ND	ND	ND	ND
Chloroethane	µg/L	ND	ND	ND	ND	ND
Chloroform	µg/L	ND	ND	ND	ND	ND
Chloromethane	µg/L	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	µg/L	82.5 J	3.95 J	ND	ND	1 J
cis-1,3-Dichloropropene	µg/L	ND	ND	ND	ND	ND
Dibromochloromethane	µg/L	ND	ND	ND	ND	ND
Dibromomethane	µg/L	ND	ND	ND	ND	ND
Dichlorodifluoromethane	µg/L	ND	ND	ND	ND	ND
Ethyl Benzene	µg/L	ND	ND	ND	ND	ND
Hexachlorobutadiene	µg/L	ND	ND	ND	ND	ND
Isopropylbenzene (Cumene)	µg/L	ND	ND	ND	ND	ND

3505

Table 7. Continued

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
m,p-Xylene	µg/L	ND	1.15 J	ND	ND	ND
Methyl iodide	µg/L	ND	ND	ND	ND	ND
Methylene chloride	µg/L	ND	1.5 J	ND	ND	1.52 J
Naphthalene	µg/L	ND	ND	ND	ND	ND
n-Butylbenzene	µg/L	ND	ND	ND	ND	ND
n-Propylbenzene	µg/L	ND	ND	ND	ND	ND
o-Xylene	µg/L	ND	0.5 J	ND	ND	ND
sec-Butylbenzene	µg/L	ND	ND	ND	ND	ND
Styrene	µg/L	ND	ND	ND	ND	ND
tert-Butyl methyl ether (MTBE)	µg/L	ND	ND	ND	ND	ND
tert-Butylbenzene	µg/L	ND	ND	ND	ND	ND
Tetrachloroethene	µg/L	8390	149	1250	6960	99.1
Toluene	µg/L	45 J	2.15 J	10 J	ND	ND
trans-1,2-Dichloroethene	µg/L	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	µg/L	ND	ND	ND	ND	ND
trans-1,4-Dichloro-2-butene	µg/L	ND	ND	ND	ND	ND
Trichloroethene	µg/L	145 J	20.9	206	2320	1.36 J
Trichlorofluoromethane	µg/L	ND	ND	ND	ND	ND
Vinyl chloride	µg/L	ND	ND	ND	ND	ND

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

ND: Not detected

Table 8. Summary of Semiolatile Organic Compound Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
1,2,4-Trichlorobenzene	µg/L	3.31 J	ND	ND	ND	ND
1,2-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	µg/L	ND	ND	ND	ND	ND
2,4,5-Trichlorophenol	µg/L	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	µg/L	ND	ND	ND	ND	ND
2,4-Dichlorophenol	µg/L	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	ND	ND	ND	ND	ND
2,4-Dinitrophenol	µg/L	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	µg/L	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	µg/L	ND	ND	ND	ND	ND
2-Chloronaphthalene	µg/L	ND	ND	ND	ND	ND
2-Chlorophenol	µg/L	ND	ND	ND	ND	ND
2-Methylnaphthalene	µg/L	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	ND	ND	ND	ND	ND
2-Nitroaniline	µg/L	ND	ND	ND	ND	ND
2-Nitrophenol	µg/L	ND	ND	ND	ND	ND
3 and/or 4-Methylphenol	µg/L	ND	ND	ND	ND	ND
3,3'-Dichlorobenzidine	µg/L	ND	ND	ND	ND	ND
3-Nitroaniline	µg/L	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	µg/L	ND	ND	ND	ND	ND
4-Bromophenyl phenyl ether	µg/L	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol	µg/L	ND	ND	ND	ND	ND
4-Chloroaniline	µg/L	ND	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	µg/L	ND	ND	ND	ND	ND
4-Nitroaniline	µg/L	ND	ND	ND	ND	ND
4-Nitrophenol	µg/L	ND	ND	ND	ND	ND
Acenaphthene	µg/L	ND	ND	ND	ND	ND
Acenaphthylene	µg/L	ND	ND	ND	ND	ND
Anthracene	µg/L	ND	ND	ND	ND	ND
Benzo(a)anthracene	µg/L	ND	ND	ND	ND	ND
Benzo(a)pyrene	µg/L	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	µg/L	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	µg/L	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	µg/L	ND	ND	ND	ND	ND
Bis(2-Chloroethoxy)methane	µg/L	ND	ND	ND	ND	ND
Bis(2-Chloroethyl)ether	µg/L	ND	ND	ND	ND	ND
Bis(2-Chloroisopropyl)ether	µg/L	ND	ND	ND	ND	ND
Bis(2-Ethylhexyl)phthalate	µg/L	5.62	3.56 J	5.23	2.09 J	6.28
Butyl benzyl phthalate	µg/L	ND	ND	ND	ND	ND
Chrysene	µg/L	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	µg/L	ND	ND	ND	ND	ND
Dibenzofuran	µg/L	ND	ND	ND	ND	ND
Diethyl phthalate	µg/L	ND	ND	ND	ND	ND

Table 8. Continued

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
Dimethyl phthalate	µg/L	ND	ND	ND	ND	ND
Di-n-butyl phthalate	µg/L	ND	ND	ND	ND	ND
Di-n-octyl phthalate	µg/L	ND	ND	ND	ND	ND
Fluoranthene	µg/L	ND	ND	ND	ND	ND
Fluorene	µg/L	ND	ND	ND	ND	ND
Hexachlorobenzene	µg/L	ND	ND	ND	ND	ND
Hexachlorobutadiene	µg/L	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	µg/L	ND	ND	ND	ND	ND
Hexachloroethane	µg/L	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND	ND	ND
Isophorone	µg/L	ND	ND	ND	ND	ND
Naphthalene	µg/L	ND	ND	ND	ND	ND
Nitrobenzene	µg/L	ND	ND	ND	ND	ND
n-Nitrosodi-n-propylamine	µg/L	ND	ND	ND	ND	ND
Pentachlorophenol	µg/L	ND	ND	ND	ND	ND
Phenanthrene	µg/L	ND	ND	ND	ND	ND
Phenol	µg/L	ND	ND	ND	ND	ND
Pyrene	µg/L	ND	ND	ND	ND	ND

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

ND: Not detected

Table 9. Summary of Metal Results for Area 41 Groundwater Samples

Analyte	Unit	B03-470MW	B03-471MW	B03-472MW	B09-181MW	B09-187MW
Arsenic	mg/L	ND	ND	ND	ND	ND
Barium	mg/L	0.177	ND	0.417	0.0269 J	0.0407 J
Cadmium	mg/L	ND	ND	ND	ND	0.0022 J
Chromium	mg/L	0.00236 J	0.00214 J	0.00379 J	0.00214 J	0.00408 J
Lead	mg/L	0.00621 J	ND	ND	ND	0.00795 J
Mercury	mg/L	ND	ND	ND	ND	ND
Selenium	mg/L	ND	ND	ND	ND	ND
Silver	mg/L	0.00315 N	0.0035 N	0.00368 N	0.0032 N	0.0091 N

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

N: Tentative detection (qualitatively estimated)

ND: Not detected

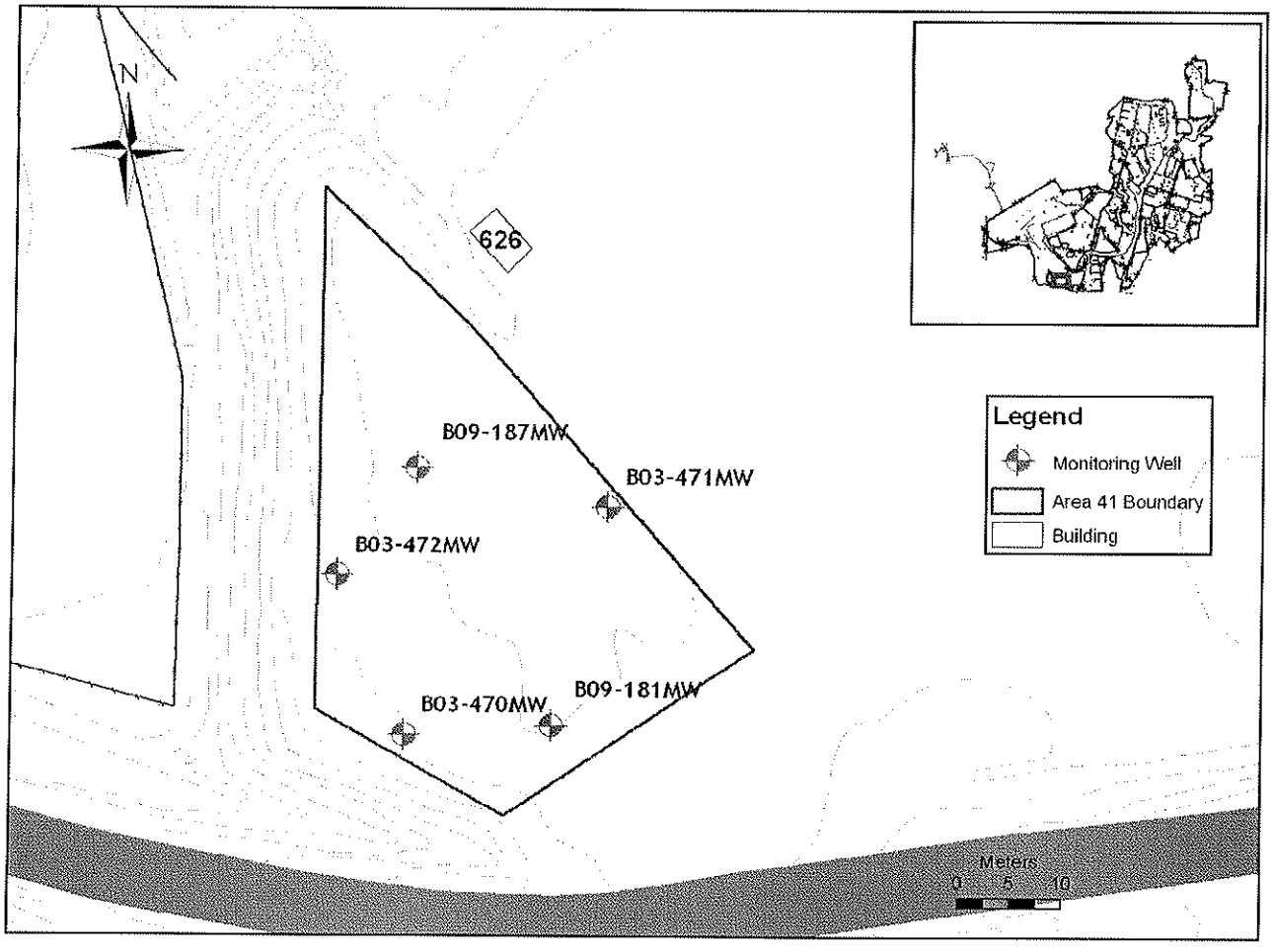

Figure 1. Location of Monitoring Wells at Area 41

APPENDIX A.

Quality Assurance / Quality Control Report

3511

QA/QC Report of Chemical Data

Project ID: **Investigation on Helipad/Drum Burial Site at Cp Carroll**

Phase: **Area 41 Groundwater Sample**

Prepared by: **Geotechnical and Environmental Engineering Branch, US Army Corps of Engineers, Far East District**

Date: **29 August 2011**

1. Background

Groundwater samples were collected from 26 to 28 Jul 2011 from 5 monitoring wells at Area 41, Cp Carroll. Two sample delivery groups were shipped on 28 Jul and 30 Jul to the primary laboratories (SGS Wilmington and subcontracted laboratories - ACCUTEST, ECCS). Both sample delivery groups were received by the laboratories on 1 Aug. A separate sample delivery group was shipped on 28 Jul to the QA laboratory (USA Public Health Commend (PHC) and subcontracted laboratories - CFA, Microbac) and received by the laboratory on 1 Aug. The samples were tested according to US EPA SW-846 methods for dioxins and furans, chlorinated herbicides, organochlorine (OC) pesticides, organophosphorus (OP) pesticides, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and RCRA (Resource Conservation and Recovery Act) metals. Laboratory data packages were reviewed for quality procedures to determine if they conform to the requirements in Engineering Manual (EM) 200-1-6 (Chemical Quality Assurance for Hazardous, Toxic and Radioactive Waste Projects), EM 200-1-10 (Guidance for Evaluating Performance-Based Chemical Data) and DoD Quality System Manual (Version 4.1).

2. Holding time, Storage and Preservation

The validity of sample results was checked based on the recommended holding time, storage, and preservation of the sample from time of collection to time of sample extraction and analysis for the specific analytical method. Sample holding times and preservation methods are identified in Table A-1. One sample delivery group consisting of samples B03-472MW, B09-181MW, and B09-187MW arrived at the SGS Wilmington laboratory with a cooler temperature of 16-20 °C. This temperature range exceeded the temperature criteria for sample preservation (0-6 °C). The incident occurred because delivery of the sample packages was delayed over the weekend. Results of VOC analysis may be affected most by this problem. Analytical data for VOCs may be biased low because of increased temperature during shipping.

Extraction and analyses of samples were completed within holding times except SVOC extraction in QA laboratory. SVOC holding time is 7 days until extraction; however, the QA laboratory took 9 days from the time of sample collection until SVOC extraction.

Table A-1. Holding Times and Preservation of Groundwater Sample

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

3. Quality Control Samples

At the primary laboratories, the testing of five groundwater samples, one blind duplicate, and two trip blanks required one to four batches. The laboratory included quality control (QC) samples with every batch, including method blanks (MB), laboratory control samples (LCS), matrix spikes (MS) and matrix spike duplicate (MSD). If there was insufficient sample quantity to run the MSD, the MSD was replaced with either matrix duplicate (MD) or laboratory control sample duplicate (LCSD). The number of batches and quality control (QC) samples are provided in Table A-2. During the sample testing, the QC samples were run at the desired frequency.

Table A-2. Number of Batches and QC Samples

Parameter	Laboratory	Number of Batches	MB / LCS / MS / MSD
Dioxins and furans	SGS Wilmington	2	2 / 2 / 2 / 2
Chlorinated herbicides	ECCS	1	1 / 1 / 1 / 1
OC pesticides	SGS Wilmington	1	1 / 1 / 2 / 1 plus 1 MD
OP pesticides	ACCUTEST	2	2 / 2 / 2 / 2
VOCs	SGS Wilmington	4	4 / 4 / 2 / 2 plus 4 LCSD
SVOCs	SGS Wilmington	1	1 / 1 / 1 / 0 plus 1 MD

Parameter	Laboratory	Number of Batches	MB / LCS / MS / MSD
Metals	SGS Wilmington	1 1 for mercury	1 / 1 / 1 / 1 1 / 1 / 1 / 1 for mercury

The MB is used to monitor the level of contamination introduced during sample preparation steps. The concentrations of MBs for target analytes in all batches were found less than the detection limits except one analyte, silver. In metal analysis, silver was detected between detection limit and reporting limit in one method blank. Silver was detected in all field samples at a level between the detection limit and reporting limit and the field sample data were flagged as N (tentative detection).

The LCS is used to monitor the accuracy of the analytical process independent of potential matrix effects. It was found that their percent recoveries were within the laboratory defined acceptable limits in all batches except VOC. For the VOC analysis, bromomethane has greater recovery than control limit at 3 of 8 LCS/LCSDs. This indicates that sample may have a high bias, however no bromomethane was detected in any field samples.

The MS and MSD are used to determine sample matrix effect on accuracy of the measurement system. Calculated relative percent differences between MS and MSD is used to represent the precision of the measurement. Some QC samples exceeded laboratory QC criteria either in percent recovery or relative percent difference (RPD). In OP pesticide analysis, one of two batches had relative percent difference (RPD) of MS/MSD greater than laboratory control limits in 10 out of 27 analytes. The other batch had RPD greater than control limit for one analyte. In SVOC analysis, MS recovery was greater than laboratory control limits for 3 analytes.

At the QA laboratories, one sample was analyzed. QC samples such MB, LCS, LCSD, MS, and MSD were appropriately conducted for all analyses except mercury. MS and MSD were not conducted in mercury analysis., failed to meet the MS and MSD criteria. There were a few analytes slightly exceeding laboratory control limits:

- MS and MSD in OC pesticide analysis
- LCSD, MS and MSD in SVOC analysis.

The slight deviation from the limits does not affect the sample results as the analytes were in acceptance limits for other QC data within the same batch.

4. Other Qualifications

4.1 Dioxins and furans

The laboratory's raw data included flag of EMPC (estimated maximum possible concentration due to ion ratio failure) for one 1,2,3,4,6,7,8-HpCDD result and DPE (indicates the presence of a peak in the polychlorinated diphenylether channel that could cause a false positive or an

overestimation of the affected analyte) for one Total PeCDF result. During data validation procedures, these were evaluated as "undetected" due to their uncertainties in presence of analytes and probable overestimate of data.

4.2 Chlorinated herbicides

A modified method from US EPA 8151A was used for analysis of chlorinated herbicides. In the original 8151A method, the samples are extracted with diethyl ether and then esterified with diazomethane. The derivatives are determined by gas chromatography with an electron capture detector (GC/ECD). In the modified method used for this study, the samples were prepared by same extraction and derivatization processes but detected by GC/MS method for instrumental analysis. The laboratory has performed this modification since March 2010 because of the possibility of matrix interference in GC-ECD and the subsequent potential for false positives by GC-ECD. The modified method was approved by EPA's Methods Information Communication Exchange (MICE) through e-mail chain that GC/MS quantitation is a suitable alternative to the typical GC conditions. The laboratory has been accredited by National Environmental Laboratory Accreditation Program with the modified 8151A method.

4.3 OC pesticides

The Sample B03-470MW had P flags in 4 analytes with concentration range of 0.149 ~ 0.467 µg/L by GC-ECD. Though the levels were higher than reporting limits, the presences of the analytes were not able to be confirmed by mass spectrometry due to low concentration of the analytes. As "P" flag is not defined by EM200-1-10, these were replaced with "N" (tentative detection).

The laboratory's raw data indicated a few analytes such as 4,4'-DDD, 4,4'-DDT, aldrin, endrin ketone, lindane, and methoxychlor were detected in several samples (B03-470MW, B03-472MW, and B09-187MW) with both J and P flags. Flag "J" indicates the amount below the reporting limit and "P" indicates RPD is greater than 40% between results of dual columns. As the data with both J and P is considered as small amount with high uncertainty in identification, these were evaluated as "undetected" during data validation procedures and the flag was replaced with "U" (undetected).

4.4 VOC

Due to high concentration of tetrachloroethene (PCE) and trichloroethene (TCE), a dilution facto of 250 was used in the analysis of samples B03-470MW and B09-181MW. The laboratory has been requested to provide results for "undiluted" samples. The only additional runs the laboratory had at the time of this report were screening runs at 40 times dilution at one point calibration. The raw data of 250 times were selected and validated as final results. High dilution factors caused high detection limits for analyses other than PCE and TCE in those two samples.

4.5 SVOC

Bis(2-ethylhexyl)phthalate (DEHP) was detected in all samples in concentration range of 2.09 ~ 6.28 µg/L. DEHP is a common placiticizer used in PVC products, it is a possible contaminant from monitoring well casing.

5. Trip Blank

There were two sample delivery groups and each group had trip blank. Tip blank was prepared in local laboratory and transported with field sample containers to the site in order to evaluate the potential cross-contamination during sample transportation. They were analyzed for VOC and three analytes of acetone, methylene chloride, tetrachloroethene were detected at levels greater than reporting limits. Trip blank test results are provided in Table A-3. These analytes were not detected in any of LBs in VOC analysis. Acetone and methylene chloride were detected in two trip blanks. They were either undetected or detected between detection limit and reporting limit in field samples. Tetrachloroethene was detected in one trip blank with concentration of 2.44 µg/L and detected in field samples with a concentration range of 99 ~ 8390 µg/L. Therefore, the trip blanks were contaminated by three analytes; however, sample results were not likely affected by contamination of these analytes because the amounts detected in the sample were either considerably higher than amount detected in trip blank or negligible.

6. Duplicate Sample and Quality Assurance

One groundwater sample was collected as triplicates and used for QA purposes and performance evaluation. The sample was split between the primary and QA laboratories. In Table A-4, the results of primary, primary duplicate, and QA analyses were provided and compared with each other. The primary duplicate is the sample analyzed in primary laboratory as a blind duplicate.

EM 200-1-6 titled Chemical Quality Assurance for Hazardous, Toxic and Radioactive Waste Projects identifies the criteria for comparing field QC and QA sample data. Based on those criteria, the concentration ratio between primary sample and duplicate sample should be within the limits of 0.50 ~ 2.00 in order to be evaluated as "agreement" with each other. The limits between primary sample and duplicate sample should be 0.33 ~ 3.00 for "agreement", when one result is less than reporting limit. Table A-4 lists the results of triplicate samples for the analytes having at least one quantified result. All data comparisons resulted in "agreement" between Primary and QA as well as Primary and Primary Dup. There were no appropriate results compared for the analytes which were not detected at all.

7. Conclusions/Recommendations

Laboratory data packages were reviewed for quality procedures based on Level 2 Data Validation. From the overall assessment of the data package, quality and usability of the data were verified despite of issues such as sample preservation temperature and VOC detection limits. A request has been sent to the analytical laboratory to provide undiluted or lower diluted VOC data in future samples in order to have sufficient information on analytes with lower concentration as well we higher concentration.

Table A-3. Trip Blank Results

Sample ID		Trip Blank (7/26/2011)		Trip Blank (7/28/2011)	
Analyte	Unit	Result	DL	Result	DL
1,1,1,2-Tetrachloroethane	µg/L	ND	0.104	ND	0.104
1,1,1-Trichloroethane	µg/L	ND	0.123	ND	0.123
1,1,2,2-Tetrachloroethane	µg/L	ND	0.156	ND	0.156
1,1,2-Trichloroethane	µg/L	ND	0.126	ND	0.126
1,1-Dichloroethane	µg/L	ND	0.165	ND	0.165
1,1-Dichloroethene	µg/L	ND	0.212	ND	0.212
1,1-Dichloropropene	µg/L	ND	0.0863	ND	0.0863
1,2,3-Trichlorobenzene	µg/L	ND	0.11	ND	0.11
1,2,3-Trichloropropane	µg/L	ND	0.212	ND	0.212
1,2,4-Trichlorobenzene	µg/L	ND	0.0913	ND	0.0913
1,2,4-Trimethylbenzene	µg/L	ND	0.0961	ND	0.0961
1,2-Dibromo-3-chloropropane	µg/L	ND	0.748	ND	0.748
1,2-Dibromoethane	µg/L	ND	0.12	ND	0.12
1,2-Dichlorobenzene	µg/L	ND	0.137	ND	0.137
1,2-Dichloroethane	µg/L	ND	0.167	ND	0.167
1,2-Dichloropropane	µg/L	ND	0.163	ND	0.163
1,3,5-Trimethylbenzene	µg/L	ND	0.113	ND	0.113
1,3-Dichlorobenzene	µg/L	ND	0.103	ND	0.103
1,3-Dichloropropane	µg/L	ND	0.13	ND	0.13
1,4-Dichlorobenzene	µg/L	ND	0.13	ND	0.13
2,2-Dichloropropane	µg/L	ND	0.393	ND	0.393
2-Butanone	µg/L	ND	0.723	12.3 J	0.723
2-Chlorotoluene	µg/L	ND	0.113	ND	0.113
2-Hexanone	µg/L	ND	0.728	ND	0.728
4-Chlorotoluene	µg/L	ND	0.125	ND	0.125
4-Isopropyltoluene	µg/L	ND	0.0769	ND	0.0769
4-Methyl-2-pentanone	µg/L	ND	0.558	ND	0.558
Acetone	µg/L	26.4	0.864	38.2	0.864
Benzene	µg/L	ND	0.113	ND	0.113
Bromobenzene	µg/L	ND	0.11	ND	0.11
Bromochloromethane	µg/L	ND	0.211	ND	0.211
Bromodichloromethane	µg/L	ND	0.11	ND	0.11
Bromoform	µg/L	ND	0.0974	ND	0.0974
Bromomethane	µg/L	ND	0.237	ND	0.237
Carbon disulfide	µg/L	ND	0.106	ND	0.106
Carbon tetrachloride	µg/L	ND	0.101	ND	0.101

Table A-3. Continued

Sample ID		Trip Blank (7/26/2011)		Trip Blank (7/28/2011)	
Analyte	Unit	Result	DL	Result	DL
Chlorobenzene	µg/L	0.25 J	0.116	ND	0.116
Chloroethane	µg/L	ND	0.311	ND	0.311
Chloroform	µg/L	0.92 J	0.139	0.51 J	0.139
Chloromethane	µg/L	ND	0.448	ND	0.448
cis-1,2-Dichloroethene	µg/L	ND	0.136	ND	0.136
cis-1,3-Dichloropropene	µg/L	ND	0.0767	ND	0.0767
Dibromochloromethane	µg/L	ND	0.134	ND	0.134
Dibromomethane	µg/L	ND	0.168	ND	0.168
Dichlorodifluoromethane	µg/L	ND	0.171	ND	0.171
Ethyl Benzene	µg/L	0.12 J	0.0877	ND	0.0877
Hexachlorobutadiene	µg/L	ND	0.0792	ND	0.0792
Isopropylbenzene (Cumene)	µg/L	ND	0.0869	ND	0.0869
m,p-Xylene	µg/L	ND	0.182	ND	0.182
Methyl iodide	µg/L	ND	0.115	ND	0.115
Methylene chloride	µg/L	76.7	0.152	26.3	0.152
Naphthalene	µg/L	ND	0.0855	ND	0.0855
n-Butylbenzene	µg/L	ND	0.0769	ND	0.0769
n-Propylbenzene	µg/L	ND	0.113	ND	0.113
o-Xylene	µg/L	ND	0.0874	ND	0.0874
sec-Butylbenzene	µg/L	ND	0.112	ND	0.112
Styrene	µg/L	ND	0.102	ND	0.102
tert-Butyl methyl ether (MTBE)	µg/L	ND	0.144	ND	0.144
tert-Butylbenzene	µg/L	ND	0.0855	ND	0.0855
Tetrachloroethene	µg/L	2.44	0.155	ND	0.155
Toluene	µg/L	0.68 J	0.133	0.9 J	0.133
trans-1,2-Dichloroethene	µg/L	ND	0.223	ND	0.223
trans-1,3-Dichloropropene	µg/L	ND	0.0862	ND	0.0862
trans-1,4-Dichloro-2-butene	µg/L	ND	0.414	ND	0.414
Trichloroethene	µg/L	0.21 J	0.125	0.25 J	0.125
Trichlorofluoromethane	µg/L	ND	0.137	ND	0.137
Vinyl chloride	µg/L	ND	0.124	ND	0.124

NOTE:

J: Estimated amount detected between the detection limit and reporting limit
DL: Detection limit
ND: Not detected

Table A-4. Comparison of Triplicate Sample Results from Primary and QA Laboratories

Parameter	Analyte	Unit	Result: B09-187MW			Compare: Primary vs. DUP			Compare: Primary vs. QA		
			Primary	Primary DUP	QA	Ratio	Criteria	Evaluation	Ratio	Criteria	Evaluation
OC Pesticide	4,4'-DDT	µg/L	<0.152	0.0787 J	<0.05	-	-	Agree	-	-	Agree
VOC	Acetone	µg/L	<100	4.92 J	<50	-	-	Agree	-	-	Agree
	cis-1,2-Dichloroethene	µg/L	1 J	1 J	1.2 J	1.00	0.33-3.00	Agree	0.83	0.33-3.00	Agree
	Methylene chloride	µg/L	1.52 J	<20	<10	-	-	Agree	-	-	Agree
	Tetrachloroethene	µg/L	99.1	96	110	1.03	0.50-2.00	Agree	0.90	0.50-2.00	Agree
	Trichloroethene	µg/L	1.36 J	1.4 J	1.6 J	0.97	0.33-3.00	Agree	0.85	0.33-3.00	Agree
SVOC	Bis(2-Ethylhexyl)phthalate	µg/L	6.28	2.64 J	11	2.38	0.33-3.00	Agree	0.57	0.50-2.00	Agree
Metal	Barium	mg/L	0.0407 J	0.0181 J	0.038	2.25	0.33-3.00	Agree	1.07	0.33-3.00	Agree
	Cadmium	mg/L	0.0022 J	<0.005	<0.010	-	-	Agree	-	-	Agree
	Chromium	mg/L	0.00408 J	0.00192 J	<0.020	2.13	0.33-3.00	Agree	-	-	Agree
	Lead	mg/L	0.00795 J	0.00561 J	<0.10	1.42	0.33-3.00	Agree	-	-	Agree
	Silver	mg/L	0.0091 J	0.00345 J	<0.010	2.64	0.33-3.00	Agree	-	-	Agree

NOTES:

1. Non-detects are reported as "less than (<) reporting limit".
2. J: Estimated amount detected between the detection limit and reporting limit
3. N: Tentative detection (quantitatively estimated)
4. Criteria: 0.50 ≤ ratio ≤ 2.00 for detected result, 0.33 ≤ ratio ≤ 3.00 when one result is less than (<) reporting limit

APPENDIX XI. REPORT FOR AREA 41 GROUNDWATER RE-SAMPLE TEST RESULT

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, FAR EAST DISTRICT
Unit #15546
APO AP 96205-5546

OCT 07 2011

REPLY TO
ATTENTION OF:

CEPOF-ED-G

MEMORANDUM FOR USFK Assistant Chief of Staff, Engineers, ATTN: Colonel Joseph F. Birchmeier, UNIT #15237, APO AP 96205-5237

SUBJECT: Test Results of Groundwater Sample from Monitoring Well at B03-470, Cp Carroll, Korea (G&E 11-032E/E2012-5)

1. This memorandum reports the test results for one groundwater sample collected from monitoring well, B03-470 at Area 41, Cp Carroll. Groundwater sampling was conducted on 28 September 2011 by the Geotechnical and Environmental Engineering Branch, US Army Corps of Engineers, Far East District (FED). This well was re-sampled to confirm original sample results. The original sample was collected on 28 July 2011 and reported in FED memorandum E2011-57, dated 31 Aug 2011.

2. The sample was tested by SGS North America for chlorinated herbicides and semivolatile organic compounds (SVOC) according to US EPA Method 8151A and 8270D, respectively.

3. Laboratory Findings

a. Chlorinated Herbicides

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

b. SVOC

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

3521

CEPOF-ED-G
SUBJECT: Test Results of Groundwater Sample from Monitoring Well at B03-470, Cp Carroll, Korea (G&E 11-032E/E2012-5)

4. The POC for this matter is Ms. [redacted] at [redacted]
b6 b6

[redacted] b6

Encl

Chief, Geotechnical and Environmental
Engineering Branch

3582

Table 1. Results of Chlorinated Herbicides of Groundwater at B03-470MW

No	Analyte	Unit	Original Sampling 2011-07-28		Re-Sampling 2011-09-28	
			Result	RL	Result	RL
1	2,4,5-T	µg/L	ND	0.40	ND	0.45
2	2,4,5-TP (Silvex)	µg/L	ND	0.20	ND	0.23
3	2,4-D	µg/L	ND	0.20	ND	0.23
4	2,4-DB	µg/L	ND	0.20	ND	0.23
5	Dicamba	µg/L	ND	0.20	ND	0.23

NOTES:

ND: Not detected

RL: Sample reporting limit

Table 2. Results of Semivolatile Organic Compounds of Groundwater at B03-470MW

No	Analyte	Unit	Original Sampling 2011-07-28		Re-Sampling 2011-09-28	
			Result	RL	Result	RL
1	1,2,4-Trichlorobenzene	μg/L	3.31 J	5.02	ND	5.05
2	1,2-Dichlorobenzene	μg/L	ND	5.02	ND	5.05
3	1,3-Dichlorobenzene	μg/L	ND	5.02	ND	5.05
4	1,4-Dichlorobenzene	μg/L	ND	5.02	ND	5.05
5	2,4,5-Trichlorophenol	μg/L	ND	5.02	ND	5.05
6	2,4,6-Trichlorophenol	μg/L	ND	5.02	ND	5.05
7	2,4-Dichlorophenol	μg/L	ND	5.02	ND	5.05
8	2,4-Dimethylphenol	μg/L	ND	5.02	ND	5.05
9	2,4-Dinitrophenol	μg/L	ND	25.1	ND	25.2
10	2,4-Dinitrotoluene	μg/L	ND	5.02	ND	5.05
11	2,6-Dinitrotoluene	μg/L	ND	5.02	ND	5.05
12	2-Chloronaphthalene	μg/L	ND	5.02	ND	5.05
13	2-Chlorophenol	μg/L	ND	5.02	ND	5.05
14	2-Methylnaphthalene	μg/L	ND	5.02	ND	5.05
15	2-Methylphenol	μg/L	ND	5.02	ND	5.05
16	2-Nitroaniline	μg/L	ND	5.02	ND	5.05
17	2-Nitrophenol	μg/L	ND	5.02	ND	5.05
18	3 and/or 4-Methylphenol	μg/L	ND	5.02	ND	5.05
19	3,3'-Dichlorobenzidine	μg/L	ND	10	ND	10.1
20	3-Nitroaniline	μg/L	ND	25.1	ND	25.2
21	4,6-Dinitro-2-methylphenol	μg/L	ND	25.1	ND	25.2
22	4-Bromophenyl phenyl ether	μg/L	ND	5.02	ND	5.05
23	4-Chloro-3-methylphenol	μg/L	ND	5.02	ND	5.05
24	4-Chloroaniline	μg/L	ND	25.1	ND	25.2
25	4-Chlorophenyl phenyl ether	μg/L	ND	5.02	ND	5.05
26	4-Nitroaniline	μg/L	ND	25.1	ND	25.2
27	4-Nitrophenol	μg/L	ND	25.1	ND	25.2
28	Acenaphthene	μg/L	ND	5.02	ND	5.05
29	Acenaphthylene	μg/L	ND	5.02	ND	5.05
30	Anthracene	μg/L	ND	5.02	ND	5.05
31	Benzo(a)anthracene	μg/L	ND	5.02	ND	5.05
32	Benzo(a)pyrene	μg/L	ND	5.02	ND	5.05
33	Benzo(b)fluoranthene	μg/L	ND	5.02	ND	5.05
34	Benzo(g,h,i)perylene	μg/L	ND	5.02	ND	5.05
35	Benzo(k)fluoranthene	μg/L	ND	5.02	ND	5.05
36	Bis(2-Chloroethoxy)methane	μg/L	ND	5.02	ND	5.05
37	Bis(2-Chloroethyl)ether	μg/L	ND	5.02	ND	5.05
38	Bis(2-Chloroisopropyl)ether	μg/L	ND	5.02	ND	5.05
39	Bis(2-Ethylhexyl)phthalate	μg/L	5.62	5.02	2.02 J	5.05
40	Butyl benzyl phthalate	μg/L	ND	5.02	ND	5.05

Table 2. Continued

No	Analyte	Unit	Original Sampling 2011-07-28		Re-Sampling 2011-09-28	
			Result	RL	Result	RL
41	Chrysene	µg/L	ND	5.02	ND	5.05
42	Dibenz(a,h)anthracene	µg/L	ND	5.02	ND	5.05
43	Dibenzofuran	µg/L	ND	5.02	ND	5.05
44	Diethyl phthalate	µg/L	ND	5.02	ND	5.05
45	Dimethyl phthalate	µg/L	ND	5.02	ND	5.05
46	Di-n-butyl phthalate	µg/L	ND	5.02	ND	5.05
47	Di-n-octyl phthalate	µg/L	ND	5.02	ND	5.05
48	Fluoranthene	µg/L	ND	5.02	ND	5.05
49	Fluorene	µg/L	ND	5.02	ND	5.05
50	Hexachlorobenzene	µg/L	ND	5.02	ND	5.05
51	Hexachlorobutadiene	µg/L	ND	5.02	ND	5.05
52	Hexachlorocyclopentadiene	µg/L	ND	10	ND	10.1
53	Hexachloroethane	µg/L	ND	5.02	ND	5.05
54	Indeno(1,2,3-cd)pyrene	µg/L	ND	5.02	ND	5.05
55	Isophorone	µg/L	ND	5.02	ND	5.05
56	Naphthalene	µg/L	ND	5.02	ND	5.05
57	Nitrobenzene	µg/L	ND	5.02	ND	5.05
58	n-Nitrosodi-n-propylamine	µg/L	ND	5.02	ND	5.05
59	Pentachlorophenol	µg/L	ND	25.1	ND	25.2
60	Phenanthrene	µg/L	ND	5.02	ND	5.05
61	Phenol	µg/L	ND	5.02	ND	5.05
62	Pyrene	µg/L	ND	5.02	ND	5.05

NOTES:

J: Estimated amount detected between the detection limit and reporting limit

ND: Not detected

RL: Sample reporting limit

US Army Corps of Engineers
Far East District

Report for

Environmental Site Investigation at Bachelor's Enlisted Quarters (BEQ) Hill of Camp Carroll, Korea

Submitted to:

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

Prepared by:

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

AUGUST 2011

3526

Executive Summary

This Environmental Site Investigation was conducted in the vicinity of Bachelor's Enlisted Quarter (BEQ) Hill located within Camp Carroll of the United States Army Garrison (USAG) Daegu, Republic of Korea (ROK). Activities occurred during the period of February 2009 to May 2010. The BEQ Hill is located at the northeastern portion of Camp Carroll. The ESI at the site was conducted to better delineate the lateral extent of groundwater contamination in the vicinity of the BEQ Hill. 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.

A total of three groundwater monitoring wells were constructed at the site in order to identify the existence, and extent of, groundwater contamination The wells were placed on the possible migration pathway of groundwater based on the site topography as well as the existing well locations. The existing three monitoring wells were also utilized to identify the groundwater quality of the BEQ Hill. A total of six groundwater samples were collected from monitoring wells including three existing ones, and submitted to the laboratory for volatile organic compounds (VOCs) analysis. The groundwater levels ranged from 17.21 meters to 22.04 meters below groundwater surface during this ESI.

The chemical analysis results for groundwater samples are generally far lower than the laboratory practical quantitation limit (PQL) except chloroform and toluene. The concentration of chloroform has reported from 1μg/Liter (L) to 1.9 mg/L, and toluene was reported at 5.1 μg/L. Except those two chemicals, the reported concentrations are generally below the PQLs.

3527

Table of Contents

3528

List of Table

List of Figure

Appendices

3529

Abbreviations

ABI: Acoustic Borehole Image
ASTM: American Society for Testing and Materials
BEC: Beautiful Environmental Construction (BEC)
BEQ: Bachelor's Enlisted Quarter
BGI: Borehole Geophysical Image
BGS: Below Ground Surface
CD: Compact disk
CSM: Conceptual Site Model
DPW: Directorate of Public Works
EM-Engineering Manual
EPA: Environmental Protection Agency
ESA: Environmental Site Assessment
ESI: Environmental Site Investigation
FED: Far East District
GC/MS: Gas Chromatography/Mass Spectrometer
HTRW: Hazardous, Toxic, and Radioactive Waste
IDIQ: Indefinite Delivery and Indefinite Quantity
IDW: Investigation-derived wastes
LCS: Laboratory Control Sample
LNAPL: Light Non-Aqueous Phase Liquid
MS: Matrix Spike
ND: Not detected
NELAC: National Environmental Laboratory Accreditation Conference
OBI: Observation Borehole Image
OC-pesticides: organo-chlorinated pesticides
PCE: Tetrachloroethene
PID: Photo Ionization
PQL: Practical quantitation limit
PSA: Preliminary Site Assessment
PVC: Polyvinyl Chloride
QA: Quality Assurance
QC: Quality Control
ROK: Republic of Korea
SRL: Sample Reporting Limit
SSHP: Site Safety and Health Plan
SVE: Soil Vapor Extraction

TCE: trichloroethylene
TPH: total petroleum hydrocarbon
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

1. Introduction

This report describes the work conducted and findings obtained from the Environmental Site Investigation/Remediation Evaluation (ESI) conducted in the vicinity of Bachelors' Enlisted Quarters (BEQ) Hill, which is located at the northeastern 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 Indefinite Quantity (IDIQ) contractor Beautiful Environmental Construction (BEC). This report was developed in accordance with industry standards and US Environmental Protection Agency (EPA) guidelines for sampling and analysis. All field and analytical work was according to the Work Plan (WP) and Site Safety and Health Plan (SSHP) developed by FED.

1.1. Project Authority.

FED has been authorized by the US Army Garrison Daegu (USAG-Daegu) Directorate of Public Works (DPW), US Forces Korea (USFK) to perform work on 23 June 2008 and on 20 April 2009 at BEQ Hill through MIPR 8GDBPENV06 and MIPR 9GDATENV05 respectively.

1.2. Project objectives

The overall objective of this ESI was to delineate and identify the current extent and level of contamination that have the potential to affect human health.

In accordance with the scope of work, the project consisted of an expanded site assessment so as to characterize the influence of the existing waste burial cell on the groundwater at the site, determine the concentration levels of chemicals of interest present in the site groundwater, and to identify possible impacts to the supply well system within the installation.

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A scoping meeting was held with DPW Environmental Personnel (Mr. [redacted] Dr. [redacted] Mr. [redacted] on January 2008. At this meeting the constituents of interest were selected based on the potential to impact to the water supply wells within Camp Carroll that are down gradient of the site. From that meeting, the following specific objectives were developed for this ESI of the BEQ Hill site

- Assess the presence of the volatile organic compounds (VOCs) in the groundwater. The site characterization work included the collection of groundwater sample to analyze the concentrations of VOCs.
- Analyze the fracture pattern of the bed rock to evaluate the major discontinuity in the bed rock system and its potential effects on contaminant migration.

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 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.*"

3533

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 (MSC) and functions as a staging ground for U.S. military operations on the Korean Peninsula. The primary mission of the base is to serve as a staging facility and a storage and maintenance depot. Urban areas bound Camp Carroll on the northwest, west and southwest. Hilly, forested areas bound the base on the north and east. Agricultural fields (mostly rice paddies) border the camp on the northeast and the south. The Naktong River flows north-south approximately 0.5 kilometers west of Camp Carroll. The BEQ Hill site is located near the north boundary of Camp Carroll, approximately 30 meters northeast of Building 80 and east of the north water storage tank. Figure 2-2 presents the BEQ Hill location at Camp Carroll.

2.2. BEQ Hill

The BEQ Hill site is located on land acquired in 1959 from the Ministry of Defense of Korea. An aboveground water storage tank is located within the area of concern and an 8 to 10 meter high hill is located on the northwest side of the site. The north and east sides of the site are bounded by steep slopes that drop down approximately 20 meters over a horizontal distance of 60 meters. The Camp Carroll boundary is located approximately 50 meters north and east of the site. During the scoping meeting with DPW it was relayed to FED that according to a former employee, Mr. [redacted] drums, cans, bottles, and other containers of chemicals were buried in the area of the BEQ Hill sometime during the period of 1974 to 1975. According to Mr. [redacted], a bulldozer was used to initially excavate a trench about 15 meters long, 9 meters wide, and about 6 meters deep. Mr. [redacted] recalled that five or six 5-ton trucks transported material for burial in the trench. The containers were dumped directly into the bottom of the trench to a height of about 1.2 meters. A fire ignited when a bulldozer attempted to spread material on the bottom of the trench. After the fire was extinguished, the trench was backfilled with soil.

2.3. Summary of Previous Investigations

The project site has been previously evaluated by FED for its environmental conditions during environmental site investigations as follows:

- Camp Carroll Baseline Groundwater Investigation. Woodward-Clyde Consultants in November 1992
- BEQ Hill, Land Farm, Bldg 326 and Bldg 565: Environmental Site Assessment (ESA) by FED in December 2004
- ESA to support the planned Build to Lease (BTL) Family Housing by FED, 2005.

During a site visit in 1992, Woodward-Clyde personnel observed a slight surface depression in an area. A monitoring well (MW-22) was constructed at the site in 1992 and the groundwater sampled. The analytical result for the groundwater sample indicated the presence

3534

of the volatile organic compounds (VOCs) such as trichloroethylene (TCE), tetrachloroethene (PCE), and 1,2-dichloroethylene (1,2-DCE) in the sample.

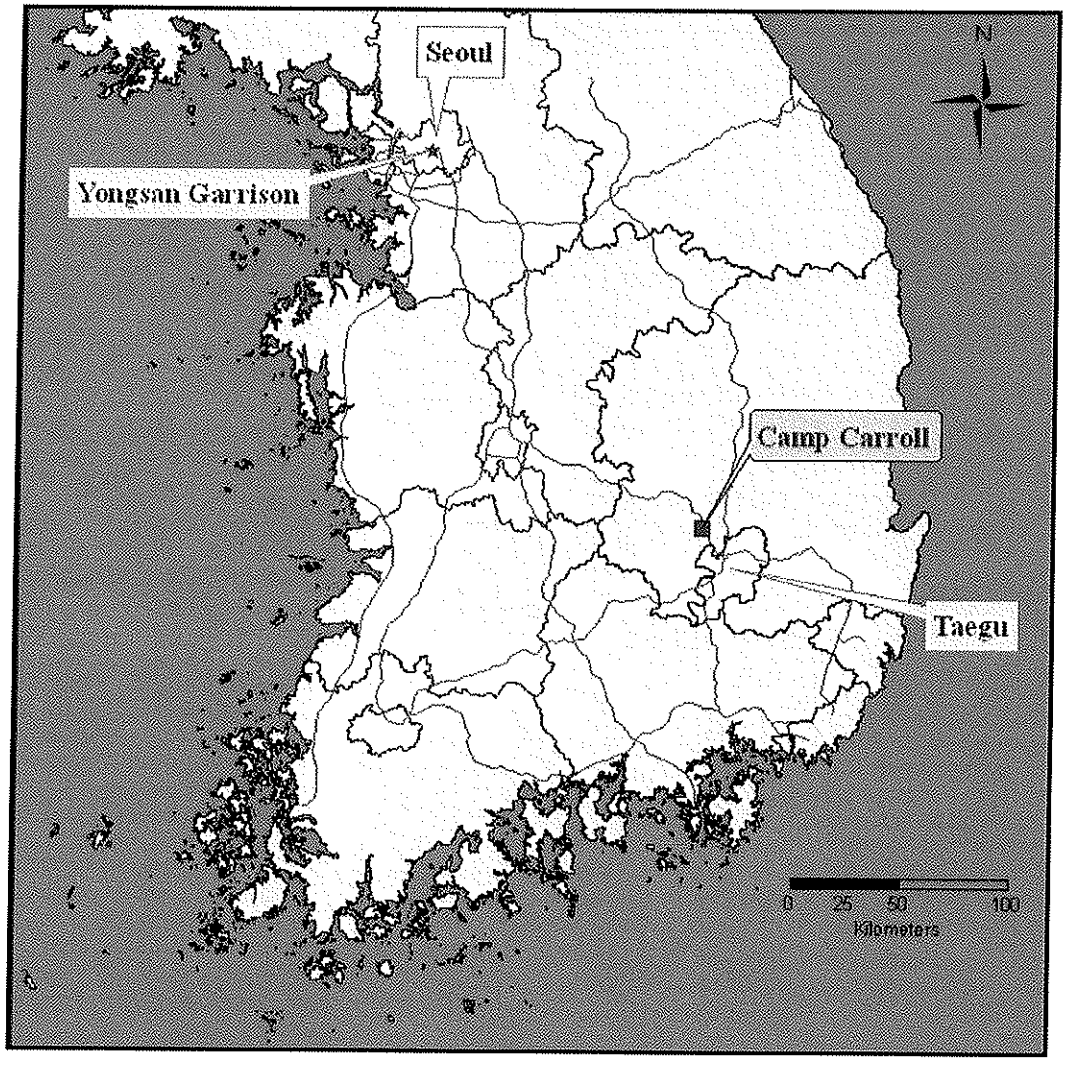
In 2004, the FED assessed the site by geophysical survey and subsurface investigation to identify the waste burial cell and the environmental conditions. The 2004 ESA by FED reported that the size of waste buried cell was approximately 25 meters long, 14 meters wide and 6 meters deep. Laboratory analysis detected several volatile organic compounds (VOCs) in site soils. The predominant VOC detected was PCE, a solvent-related chemical. A few pesticide, metal, and dioxin/furan compounds were also detected in site soils. In addition, the 2004 ESA identified that several of the solvent-related VOCs exceed the EPA guidance values for the threat of soil contamination to groundwater. These solvent-related VOCs were detected in a site groundwater monitoring well. Preliminary findings indicated that contamination from the waste buried cell at the site had been released to the underlying groundwater.

In 2005, the FED conducted the ESA around the BEQ Hill to support the planned Build to Lease (BTL) Family Housing at the site. The purpose of the 2005 ESA was to determine potential impact of contaminated groundwater on the proposed construction at the site. Three groundwater monitoring wells were installed at the proposed BTL site and water samples were collected for chemical analyses. The concentrations of VOCs and organochlorinated (OC)-pesticides were reported above the sample reporting limits. Figure 2-3 summarizes the previous investigation results at the BEQ Hill area.

Recommendations from the ESAs included the following:

- Construct groundwater monitoring wells in the vicinity of the BEQ Hill site,
- Analyze groundwater samples for VOCs and pesticides, and evaluate if the concentrations in the ground water pose a threat to human health. After groundwater assessment determine if corrective actions are required for site soils.

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



3536

Figure 2-2. Location of BEQ Hill Site at Camp Carroll.

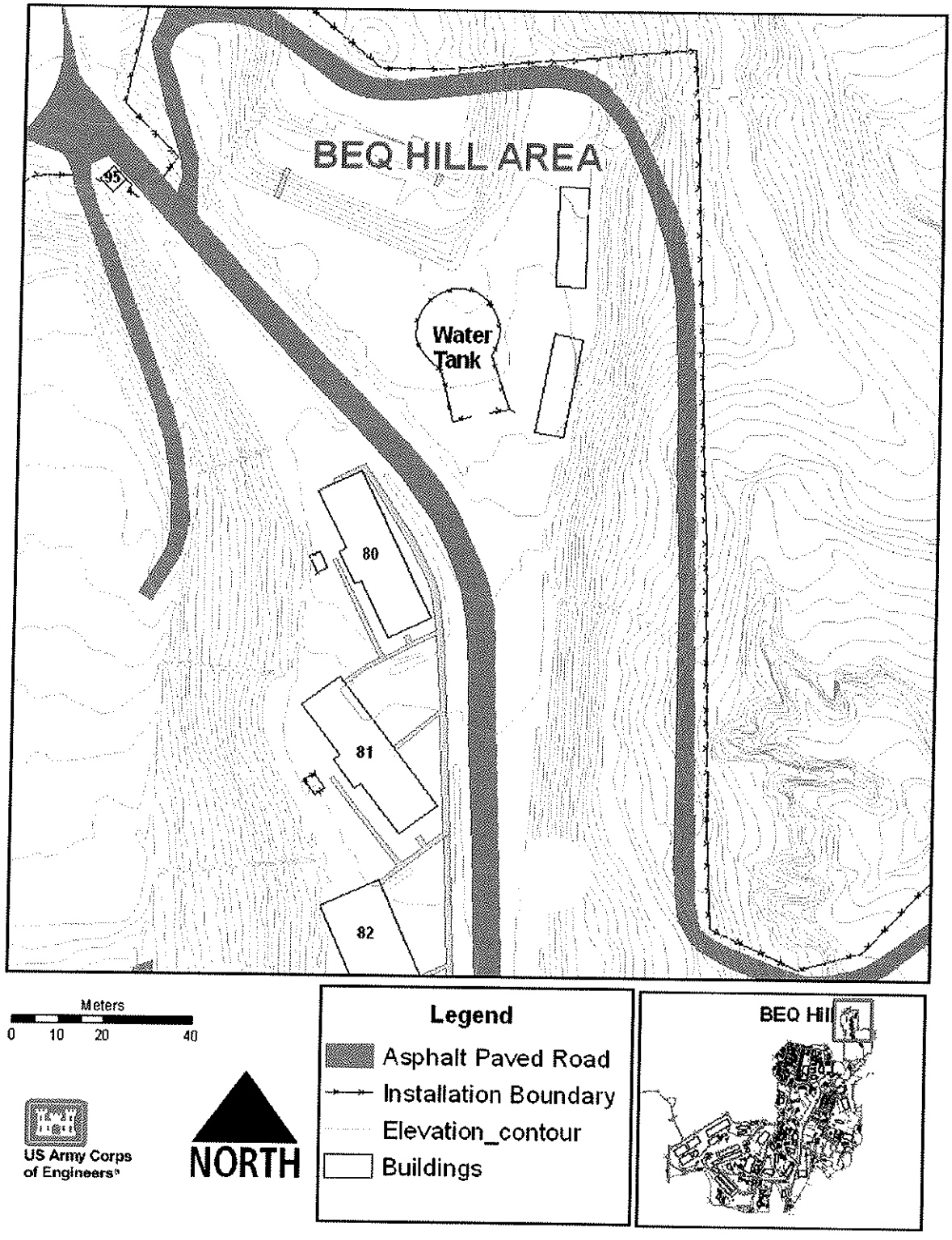


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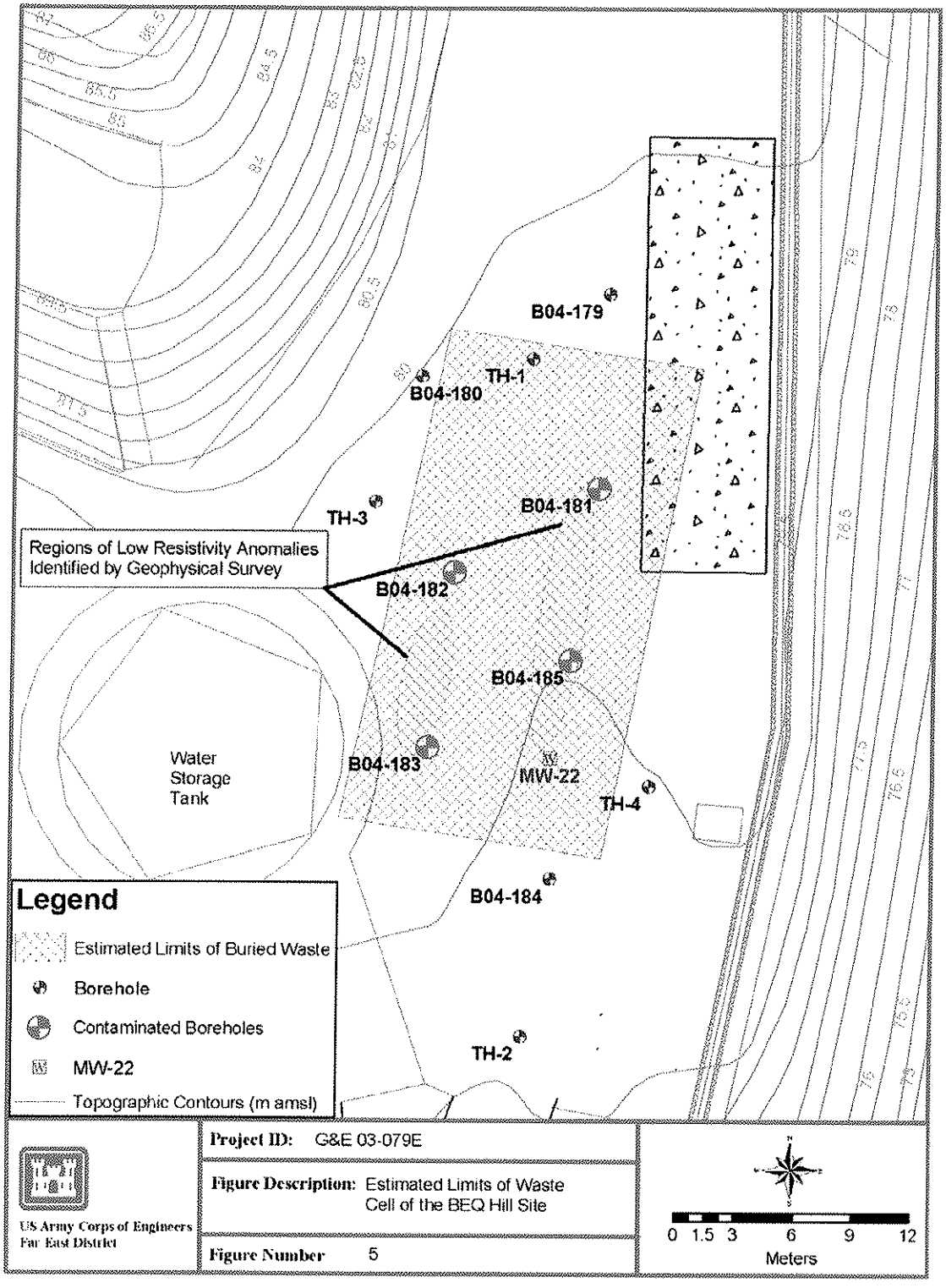
Figure 2-3. Summary of the Previous Investigation Results at BEQ Hill Site.



3538

3. Field Activity

3.1. Field Activities

Field procedures for this ESI followed the description in the project Work Plan. A total of three groundwater monitoring wells were constructed at the site in order to delineate potential groundwater contamination. The wells were placed on the possible migration pathway of groundwater based upon the site topography to identify if any contaminants are transported from the waste burial cell. Groundwater sample collection and analyses were conducted in accordance with industry standard practice and in strict accordance with the requirements of the project specific SSHP. The resultant data was used to help determine the spatial extent of contamination and whether significant subsurface contamination with the chemicals of concern at the site is present in groundwater of the project site. The project chronology is summarized in Table 3-1.

3.2. Groundwater Monitoring Well Construction.

3.2.1. Monitoring well construction

Monitoring wells were constructed after completion of borehole drilling using a FED-owned DRILTECH T40KW – Air Percussion Down-the-Hole Hammer drill rig. The depth of the wells and the length of the screen intervals were determined based on the existing well information. The well locations were chosen to monitor if any contaminants released from the suspected waste burial cell affects to the groundwater quality. A 25 centimeter (cm) diameter air percussion hammer was used to drill a hole while a slightly larger diameter (20 cm) temporary steel casing was pushed and hammered into the subsurface to hold back the overburden and weathered bedrock. After the hammer has reached the target depth, it was removed from the hole. The monitoring well casing material was then placed inside the temporary steel casing.

Groundwater monitoring well construction materials include 5.04 cm inside diameter (ID) threaded Schedule 40 polyvinyl chloride (PVC) solid pipe and slotted screen. Solid 5.04 cm ID schedule 40 PVC pipe with threaded ends was used from approximately 10 cm below ground surface (bgs) to a depth of approximately 5 meter above the level when groundwater encounters first during drilling. A 0.254-mm slotted PVC well screen was threaded onto the bottom of the solid well-pipe to the base of the borehole. A PVC well point was screwed to the bottom of the well screen and a well cap was secured to the top of the well pipe. The annular space around the well from the bottom of the borehole to a minimum of 50 cm above the top of slotted section was filled with clean medium-grained silica sand (0.4-1.2 mm). A 50 cm thick seal of bentonite pellets was placed above the sand pack, and the bentonite pellets are hydrated either by water inside the borehole from cascading perched water or using a known clean water source. The remainder of the hole was filled with a Portland Type I cement grout to just below the frost line. Once the grout cured, concrete was used to fill the rest of the annulus around the well pipe. The wells were then completed with a flush-mount and concrete pad. Groundwater monitoring well location is presented in Figure 3-1. The Appendix I presents the monitoring well construction log.

3.2.2. Monitoring Well Development.

After installation, all wells were fully developed. The objectives of well development were to (1) remove sediment that had settled inside the well during construction; (2) remove all

water that may have been introduced during drilling and well installation; (3) remove very fine grained sediment in the filter pack and nearby formation so that groundwater samples would not be turbid and well silting does not occur; and (4) improve the flow into the well from the adjacent formation, thus yielding a representative groundwater sample and an accurate water level measurement.

Well development consisted of surging by a surge block and pumping out the turbid water using BEC's vacuum truck until a noticeable reduction in sediment occurred in the discharged water. This development continued for a minimum of five well volumes of pumped water and continued until the water was visually clear or the site geologist determined that no further development is practical. Groundwater parameter was measured during well development to see the variation of the parameter, Table 3-2 presents the result of the groundwater parameter. Temperature of groundwater ranges from 14 °C to 15.8 °C and the pH ranges from 6.35 to 7.47.

3.2.3. Groundwater Sampling.

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

A low pressure pump was utilized for micro purging and sampling from the monitoring wells. The groundwater parameters such as pH, temperature, specific conductance and turbidity of the removed water were monitored during the purging and sampling process. Groundwater stabilizing criteria were adopted established in American Society for Testing and Materials (ASTM) D6671-02: pH +/- 0.2, specific conductance +/- 3%, temperature +/- 0.5°C, and turbidity +/- 3%. The groundwater was sampled using a low pressure bladder pump and dedicated tubing for each well sampled. Table 3-2 summarizes the groundwater parameter measured during the sampling activity, which shows a little different value from measurement during well development. Temperature of groundwater ranges from 15.9 °C to 18.0 °C and the pII ranges from 6.3 to 7.8.

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

3.3. Topographic survey

The FED survey section performed a location and topographic survey using a SOKKIA Set 2C Total Station survey instrument. The survey included the ground surface elevation at each monitoring well location, the top of well riser pipe for each monitoring well, and, if necessary the elevations of buildings and any significant utilities. All elevation measurements were expressed in meters above mean sea level (AMSL), and World Geodetic System 84 Universal Transverse Mercator (WGS 84 UTM) Zone-52 grid system was applied for longitude and latitude systems. The accuracy of survey elevation for top of the casing measurements was

to the nearest 3 mm. Ground surface elevations were made to the nearest centimeter. Table 3-3 presents the monitoring well coordinates surveyed.

3.4. Investigation Derived Wastes

Waste materials or investigation-derived wastes (IDW), that required management and disposal during the ESI field work included concrete and asphalt debris, used disposable sampling equipment, well development water, decontamination water and used personal protective equipment (PPE). There are no specific Korean regulations applicable to the small quantities of IDW that were generated during the course of this project. The IDW generated during the course of this investigation was placed in woven synthetic bags while development water was placed in 55-gallon drums. The bags were segregated by their contents and stored on site until transported to BEC's field facility located in Yojoo, Kyeonggi-Do at the end of well construction period for treatment and disposal.

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

3.4.1. Well Development and Decontamination Water

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

3.4.2. Site Restoration

Monitoring wells installed during the project were flush-mounted and pose no impediment to vehicular or foot traffic. All mud and soil cuttings generated in the vicinity of each boring and monitoring well were cleaned up by field personnel immediately following the completion of the task.

3.5. Geohydrology Characterization

Test was performed on the aquifer matrix to determine the saturated and air permeability of the impacted aquifer material present at the site.

3.5.1. Slug Test

The hydraulic characteristics of the aquifer underlying the site were determined by performing slug tests on the monitoring wells. The hydraulic conductivity, K, of the aquifer was calculated using slug tests recovery measurements that were performed on all monitoring wells. After the completion of well purging work, a slug with an approximate volume of 2.5 liter was put in the wells. The drop down water level after 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 the same way. Measurements were collected until the water level within the monitoring well returned to within approximately 3 centimeters of the original water level.

The original water level in the well prior to the tests was measured with a Solinst electronic oil/water interface probe.

3.5.2. Borehole Geophysical Investigation.

Geophysical logging methods used in this investigation included an Observation Borehole Image (OBI), Acoustic Borehole Image (ABI), borehole caliper, fluid resistivity, and fluid temperature. Geophysical surveys were performed after completion of borehole drilling during 18 to 27 February 2009. All depth information on logs is referenced to depth below the top of well casing. The data logs were analyzed as an integrated suit to take an advantage of their synergistic nature. The detail procedure is described in Appendix II.

Caliper logging records borehole diameter by use of a three-arm, spring-loaded tool. Changes in borehole diameter are related to drilling and construction procedures, caving of less competent rocks, and the presence of fractures. The caliper logs were used with the OBI, ABI, fluid resistivity, and fluid temperature logs to characterize flow zones intersected by the boreholes. The fractures with wider openings, fracture zones can provide preferable groundwater pathways in fractured rock aquifer. Therefore, this caliper logging can be used to identify dominant groundwater pathways in the borehole.

OBI televiewer logging records a magnetically oriented, 360° optical image of the borehole wall. An OBI log can be viewed as an unwrapped image similar to the traditional presentation of acoustic-televiewer data or it can be wrapped and viewed as a "virtual core". The OBI can be used in air or below the borehole water level if the water has low turbidity. Fractures and other planar features can be identified and characteristics of the fractures, such as orientation, spacing, aperture, presence of filling material, can be obtained from the OBI. Fractures included bedding-plane separations, joints, shear planes, and other planar breaks in the bedrock. The drilling process commonly causes bedrock adjacent to fractures to break out thereby increasing the apparent widths of fracture openings as viewed on borehole-wall images. Fractures with apparent opening widths of 0.1 inch (2.54 mm) or more were classified as open or partially open.

ABI logging records a magnetically oriented, 360° acoustic image of the borehole wall. The ABI is not affected by the turbidity of the borehole water. Fractures with apparent opening widths greater than 0.1 inch (2.54 mm) can be detected on the ABI images. The ABI logs were used in combination with the OBI logs to determine the character and orientation of fractures.

Fluid-resistivity logging records the electrical resistivity of the water in a borehole. The electrical resistivity of the water is related to its dissolved-solids concentration. Fluid-resistivity logs were collected under ambient conditions. The fluid-resistivity logs were combined with the temperature logs to identify flow zones and to determine the relative dissolved-solids concentration of their contained water.

Temperature logging records the temperature of the water in the borehole. In boreholes with no vertical borehole flow, the temperature of the borehole water generally increases with depth as a function of the geothermal gradient in the surrounding rocks. Temperature gradients less than the geothermal may indicate intervals with vertical or horizontal borehole flow.

Temperature logs were used with the fluid-resistivity logs to identify flow zones under ambient and pumped conditions.

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

Task	Date Performed
Request a site digging permit and get approval	February 6, 2009
Drilling and groundwater monitoring well installation	February 17~23, 2009
Well development	February 23~26, 2009
Geophysical Borehole Investigation	February 18~27, 2009
Groundwater Sampling	June 9~11, 2009
Hydrologic slug test	July 28~29, 2009
Water level measurements	February 23 & May 18, 2010

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

Well ID	Temperature ©		Electric Conductivity (mS/cm)		Dissolved Oxygen (mg/L)		pH		Oxidation Reduction Pontential (mV)		Total Dissolved Solids (NTU$)	
	WD*	Smpl**	WD	Smpl	WD	Smpl	WD	Smpl	WD	Smpl	WD	Smpl
B05-113MW	14.2	15.86	0.833	0.258	9.5	9.4	6.94	7.63	373	312	555	30
B05-114MW	15.8	16.85	0.447	0.132	5.0	8.5	6.35	6.88	388	190	298	94
B05-117MW	15.5	18.01	0.567	0.201	6.9	9.0	7.47	7.70	292	102	378	12
B09-173MW	15.1	16.05	1.255	0.023	6.9	7.6	6.90	6.60	101	157	838	52
B09-174MW	14.0	16.52	0.241	0.102	6.6	9.5	6.47	6.34	306	154	160	17
B09-175MW	15.4	16.65	0.459	0.147	7.8	8.5	7.32	7.45	302	156	307	64

*- measured during well development on 2/23/2009, **- during sampling on 9/1/2009

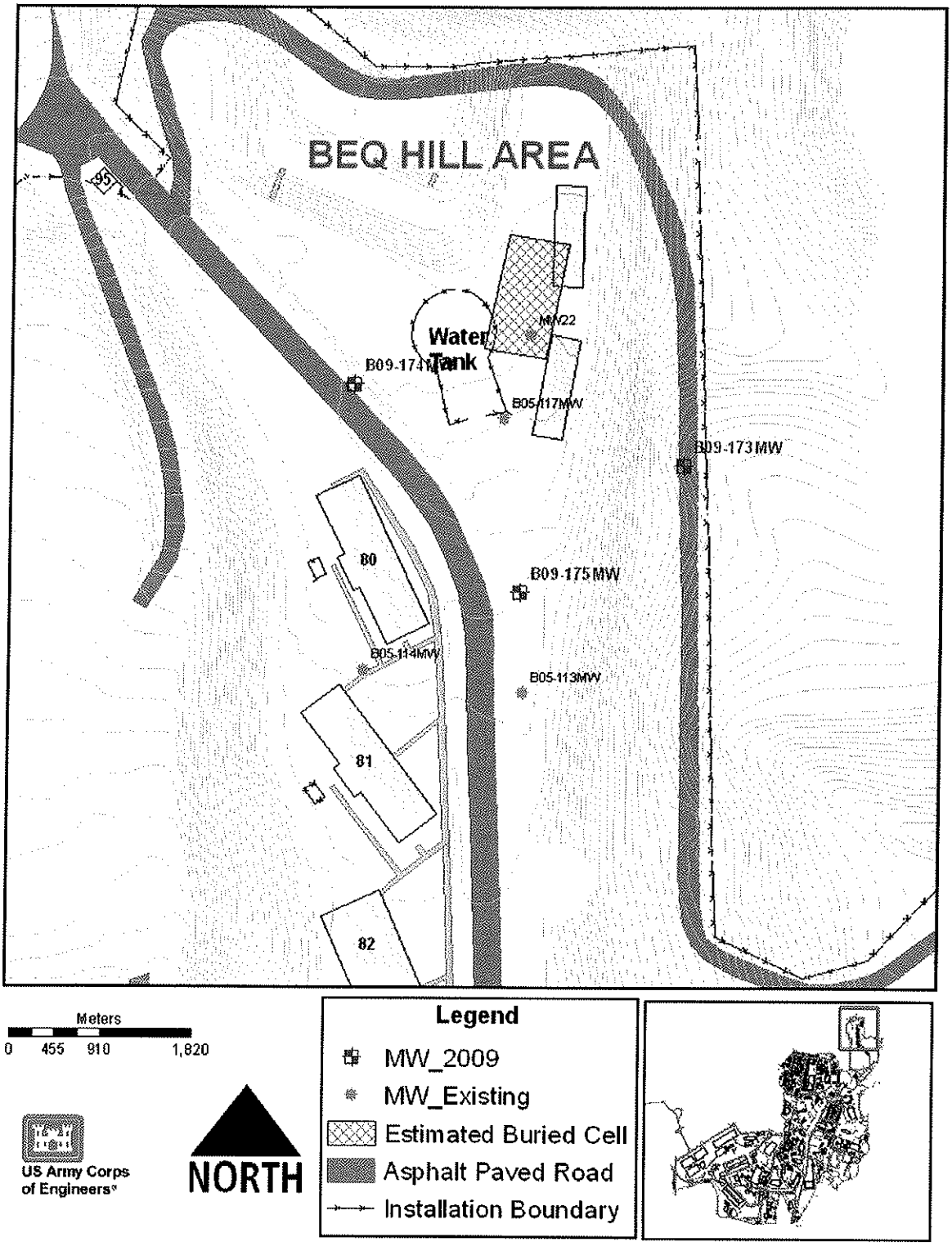
$- Nepthelometric Turbidity Unit

3544

Table 3-3. Coordinate (WGS84 Zone 52N) of Groundwater Monitoring Wells at BEQ Hill of Camp Carroll.

Well ID	Easting	Northing	Ground Elevation (above mean seal level, m)	Top of well Pipe (above mean sea level, m)	Well Depth (from ground surface)
B05*-113MW	447869.82	3984734.23	77.00	76.90	31.00
B05-114MW	447834.52	3984739.19	77.29	77.30	25.00
B05-117MW	447865.07	3984793.60	78.91	78.90	29.55
B09**-173MW	447904.44	3984783.22	66.56	66.48	40.90
B09-174MW	447831.87	3984800.68	77.93	77.87	42.08
B09-175MW	447869.03	3984755.87	77.44	77.38	41.89
*-well constructed in 2005, **- constructed during this project period					

Figure 3-1. Location of Groundwater Monitoring Wells at BEQ Hill.



3546

4. ESI Investigation Results

4.1. Laboratory Analysis.

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.

Groundwater samples collected in this ESI were submitted to the NCA-Korea Laboratory in Anyang, Korea. The contract laboratory shipped the samples for VOCs analysis to the NCA laboratory in the States. Purge & Trap Gas Chromatography (GC)/Mass Spectrometer (MS) methods EPA5030/8260 were used for VOCs analysis of water samples. Table 4-1 presents the analytical result of groundwater.

4.2. Summary of Investigations

A total of three groundwater monitoring wells were constructed during the course of this ESI investigation. Those wells are to measure groundwater level and to monitor groundwater quality during this project period. Figure 3-1 shows the locations of the groundwater monitoring wells installed at the project site during the ESI and those used in this study but installed during the previous investigations. The MW22 installed in 1992 by Woodward-Clyde was not utilized to get groundwater sample due to no water observed during this ESI, probably affected by the driest season during the year.

4.2.1. Groundwater Level Measurements

Groundwater level measurements were performed at six wells from both three existing and three new wells. Table 4-2 summarizes the measurement results of water level. Water levels were measured two times in February and September 2009 from each well with an oil/water interface probe. The measurement of 23 February 2009 is assumed to be a representative water level as a dry winter season, while the result of September 2009 was considered a relatively high water level during this project since it took a measurement about one month after the monsoon. The water level measured during this project ranges from 17.2 m bgs to 22.0 m bgs.

Based on the results of groundwater level measurements and analysis, the groundwater flow direction was determined to be as depicted for the 23 February 2009 case in Figure 4-1a and the 1 September 2009 case in Figure 4-1b, respectively. General groundwater flow pattern is dominantly toward east direction within the area of concern. Southward flow direction is recognized at the relatively flat top of hill. This flow pattern strongly reflects the site topographic features. The flow direction and pattern does not seem to vary during the seasons represented by the two measuring events.

4.2.2. Groundwater Chemical Analytical Result

A total of six groundwater samples were collected from the monitoring wells at BEQ Hill and submitted to the laboratory for VOCs analysis. The analytical results are presented in Table 4-1. A range of quantified VOC concentrations in groundwater samples are generally lower than the laboratory practical quantitation limit (PQL). Some reported values are also below the PQLs but just estimation or associated with method blank contamination. Only the concentrations of

chloroform (1 µg/Liter (L) to 1.9 µg/L) and toluene (5.1 µg/L) were reported above detection limits.

4.3. Data Quality Control/Assurance

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

4.4. Hydrologic Characteristics of the Site

Slug tests were performed for the new groundwater monitoring wells installed during this project at the BEQ Hill site. 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 average K values for the monitoring wells are 8.42E-06 cm/sec at B09-173MW and 3.59E-05 cm/sec at B09-175MW. Table 4-3 presents the hydraulic parameters obtained from the slug test.

4.5. Borehole Geophysical Investigation

Before completion as groundwater monitoring wells of B09-173MW, B09-174MW, B09-175MW at BEQ Hill, a borehole geophysical investigation (BGI) was conducted such as optical borehole image (OBI) log, caliper log, fluid temperature log, and fluid resistivity log. Detail descriptions are presented in Appendix II. The summary is presented in Figure 4-2.

Most fractured rock systems consist of rock blocks bounded by discrete discontinuities comprised of fractures, joints, and shear zones, usually occurring in sets with similar geometries. Fractures may be open, mineral-filled, deformed, or any combination thereof. Open fractures may provide conduits for the movement of ground water and contaminants through an otherwise relatively impermeable rock mass. The nature of the rock matrix plays an important role in the movement of water and contaminants through fractured rock systems. Granite bedrock at the site generally has very low primary porosity and permeability. Fractures may account for most of the permeability in such systems and the movement of water and contaminants into and out of the rock matrix may be minimal. The yield of water from fractured rock is dependent upon the frequency and interconnectivity of flow pathways.

The joint attitude data were collected mostly from 20 m to 40 m deep. A total of about 73 joint set was identified at B09-174MW, but only 36 joint set was identified at B09-175MW with almost identical interval. The dips of joint are relatively steep over 70 degrees. The three joint sets during the BGI were identified from the site bedrock, which are mainly 75/092 (angle/direction of joint from the north), 75/051 and 78/235 from the site. The groundwater flow direction assessed from the dip direction does not closely match with the direction by the actual groundwater level measurement. This indicates that the groundwater flow direction is not obtained solely by the rock fracture system analysis.

Table 4-1. VOC Chemical Test Results for Groundwater Samples from BEQ Hill of Camp Carroll.

Chemical Parameter (EPA Method 8260b)	B05-113MW	B05-114MW	B05-117MW	B09-173MW	B09-174MW	B09-175MW
	µg/L					
Acetone	2.2J	2.2J	-	-	-	2.5J
Benzene	-	-	-	-	-	-
Bromobenzene	-	-	-	-	-	-
Bromochloromethane	-	-	-	-	-	-
Bromodichloromethane	-	-	-	-	-	-
Bromoform	-	-	-	-	-	-
Bromomethane	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-
n-Butylbenzene	-	-	-	-	-	-
sec-Butylbenzene	-	-	-	-	-	-
tert-Butylbenzene	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-
Carbon tetrachloride	-	-	-	-	-	-
Chlorobenzene	-	-	-	-	-	-
Dibromochloromethane	-	-	-	-	-	-
Chloroethane	-	-	-	-	-	-
Chloroform	1.3	0.42J	1.9	1.4	1	1.8
Chloromethane	-	-	-	-	-	-
2-Chlorotoluene	-	-	-	-	-	-
4-Chlorotoluene	-	-	-	-	-	-
1,2-Dibromo-3-chloropropane (DBCP)	-	-	-	-	-	-
1,2-Dibromoethane (EDB)	-	-	-	-	-	-
Dibromomethane	-	-	-	-	-	-
1,2-Dichlorobenzene	-	-	-	-	-	-
1,3-Dichlorobenzene	-	-	-	-	-	-
1,4-Dichlorobenzene	-	-	-	-	-	-
Dichlorodifluoromethane (Freon 12)	-	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-	-
1,2-Dichloroethane	-	-	-	-	-	-
cis-1,2-Dichloroethene	-	-	-	-	-	-
trans-1,2-Dichloroethene	-	-	-	-	-	-
1,1-Dichloroethene	-	-	-	-	-	-
1,2-Dichloropropane	-	-	-	-	-	-

3550

Table 4-1. VOC Chemical Test Results for Groundwater from BEQ Hill (Continued).

Chemical Parameter (EPA Method 8260b)	B05-113MW	B05-114MW	B05-117MW	B09-173MW	B09-174MW	B09-175MW
	µg/L					
1,3-Dichloropropane	-	-	-	-	-	-
2,2-Dichloropropane	-	-	-	-	-	-
cis-1,3-Dichloropropene	-	-	-	-	-	-
trans-1,3-Dichloropropene	-	-	-	-	-	-
1,1-Dichloropropene	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-
Hexachlorobutadiene	-	-	-	-	-	-
2-Hexanone	-	-	-	-	-	-
Isopropylbenzene	-	-	-	-	-	-
p-Isopropyltoluene	-	-	-	-	-	-
Methylene chloride	0.41J	0.46J	0.48J	0.68J	0.54J	0.51J
4-Methyl-2-pentanone (MIBK)	-	-	-	-	-	-
Naphthalene	-	-	-	-	-	-
n-Propylbenzene	-	-	-	-	-	-
Styrene	-	-	-	-	-	-
1,1,1,2-Tetrachloroethane	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	-	-	-	-	-	-
Tetrachloroethene	-	0.14J	0.23J	0.54J	-	-
Toluene	7.9B	5.1	8B	17B	12B	6.3B
1,2,3-Trichlorobenzene	-	-	-	-	-	-
1,2,4-Trichlorobenzene	-	-	-	-	-	-
1,1,1-Trichloroethane	-	-	-	-	-	-
1,1,2-Trichloroethane	-	-	-	-	-	-
Trichloroethene	-	-	-	-	-	-
Trichlorofluoromethane (Freon 11)	-	-	-	-	-	-
1,2,3-Trichloropropane	-	-	-	-	-	-
1,2,4-Trimethylbenzene	-	-	-	-	-	-
1,3,5-Trimethylbenzene	-	-	-	-	-	-
Vinyl chloride	-	-	-	-	-	-
m-Xylene & p-Xylene	-	-	-	-	-	-
o-Xylene	-	-	-	-	-	-
- not detected above the sample reporting limit.						
J- The quantitation is an estimation.						
B- method blank contamination, the associcated method blank contains the target analyte at a reportable level.						

3551

Table 4-2. Groundwater Level Measurement Result at BEQ Hill.

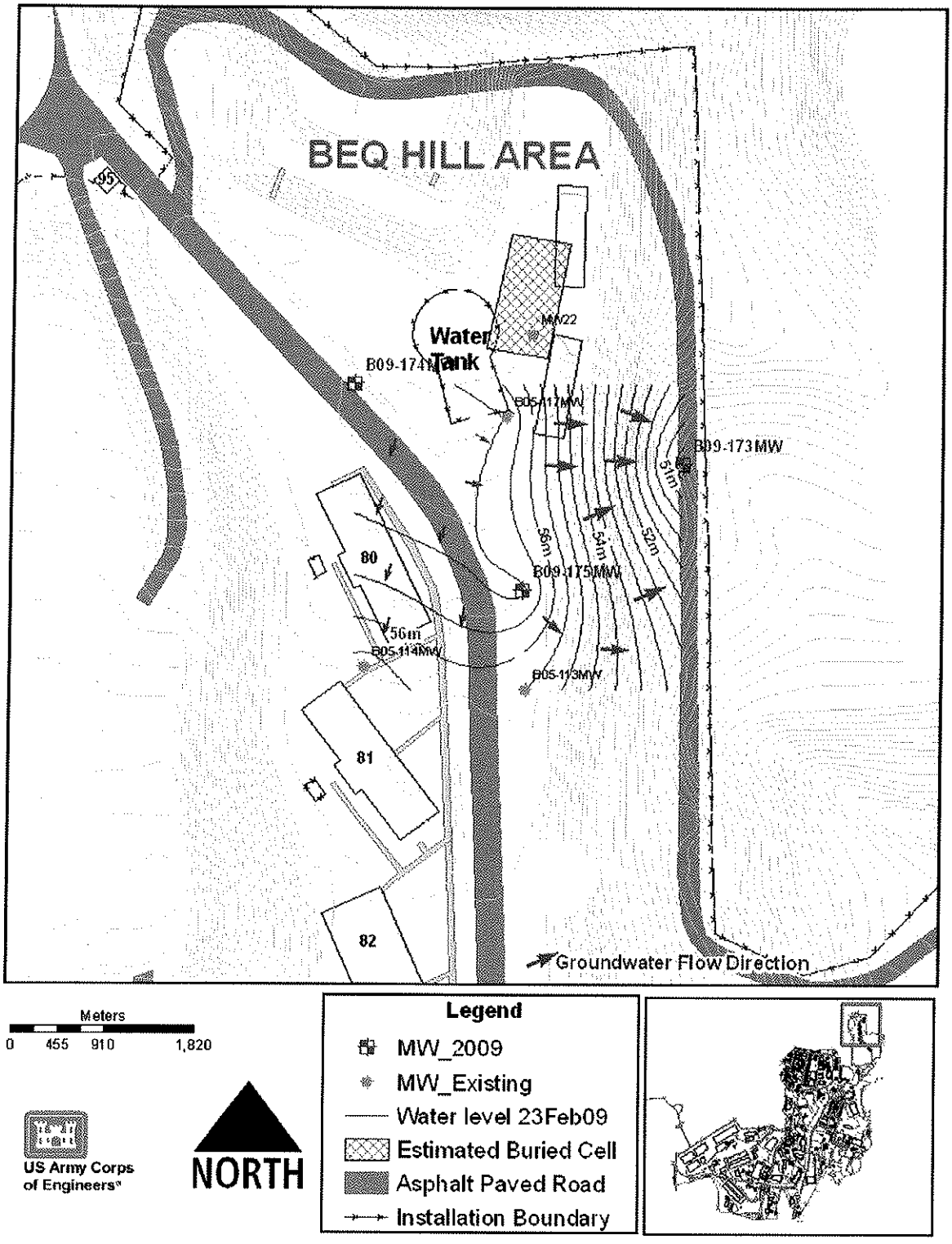
Well ID	Easting	Northing	Top of well pipe	Well Depth	Water level (m, bgs)	Water level (m, bgs)	Water level (above mean sea level, m)	Water level (above mean sea level, m)
					2/23/2009	9/1/2009	2/23/2009	9/1/2009
B05-113MW	447869.82	3984734.23	76.90	31.00	21.41	21.56	55.49	55.34
B05-114MW	447834.52	3984739.19	77.30	25.00	22.04	21.75	55.26	55.55
B05-117MW	447865.07	3984793.60	78.90	29.55	21.93	21.54	56.97	57.36
B09-173MW	447904.438	3984783.218	66.481	40.90	17.39	17.21	49.09	49.27
B09-174MW	447831.872	3984800.680	77.874	42.08	20.59	20.36	57.28	57.51
B09-175MW	447869.033	3984755.871	77.382	41.89	20.28	21.52	57.10	55.86

Table 4-3 Slug Test Result at BEQ Hill.

Well ID	Activities	K (Conductivity)		Average K
		* Bouwer & Rice Method, 1976		
		cm/sec	cm/day	cm/sec
B09-173MW	injection	1.10E-07	0.00941	8.42E-06
	withdrawal	6.00E-08	0.00515	
B09-174MW	injection	4.70E-07	0.0405	5.24E-05
	withdrawal	5.80E-07	0.05002	
B09-175MW	injection	3.30E-07	0.02827	3.59E-05
	withdrawal	3.90E-07	0.03383	

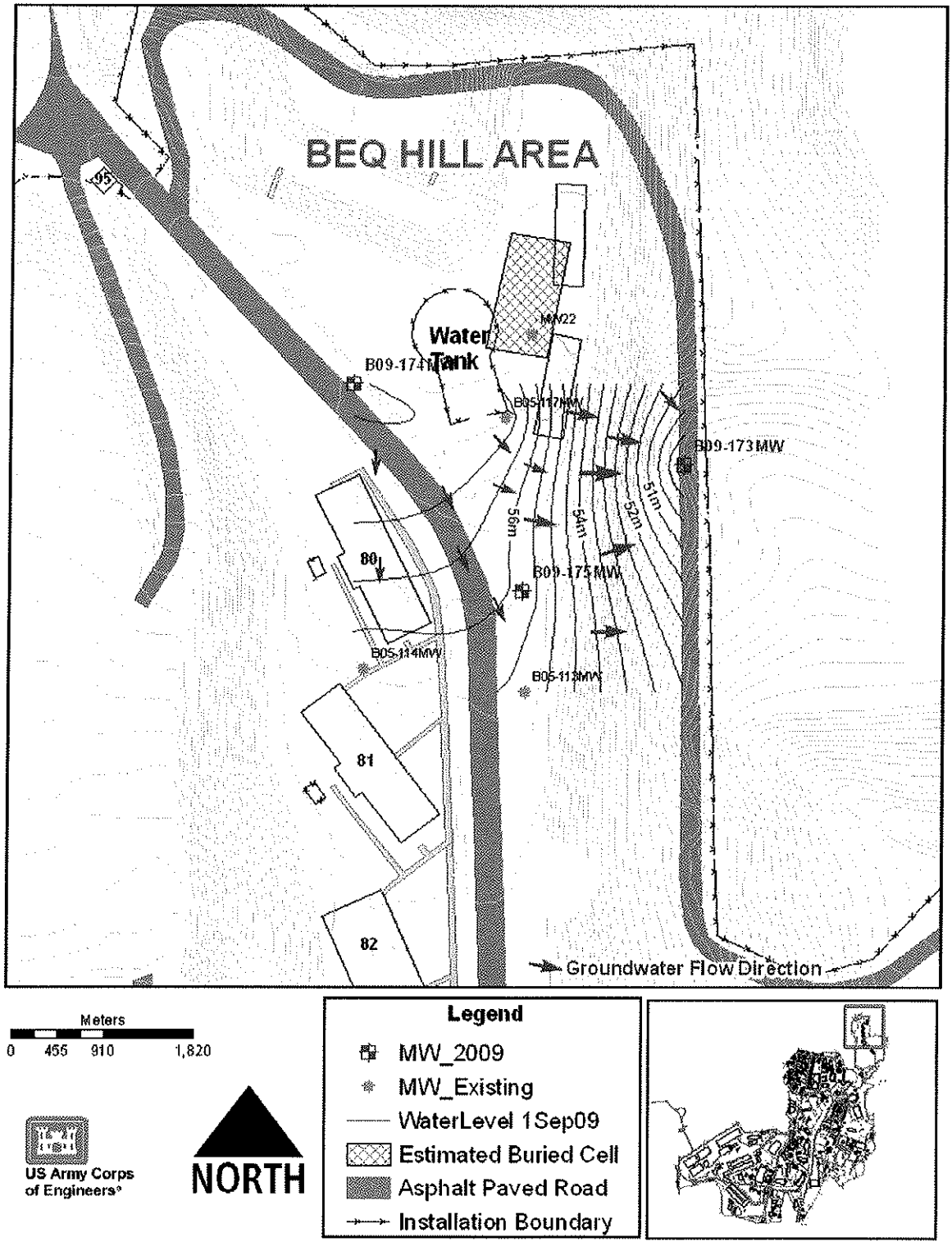
3552

Figure 4-1a. Groundwater Flow Pattern based on the 23 February 2009 Measurement.



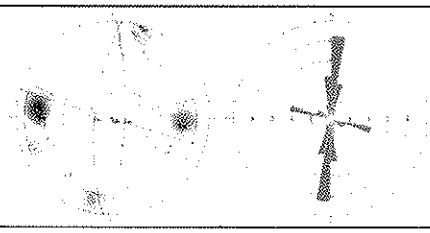
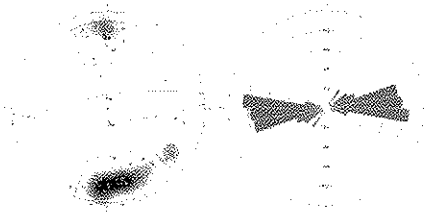
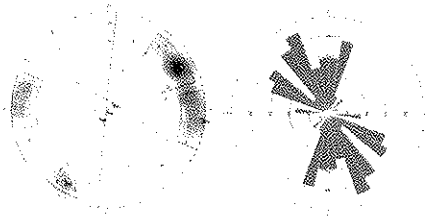
3553

Figure 4-1b. Groundwater Flow Pattern based on the 1 September 2009 Measurement.



3554

Figure 4-2. Orientation and Dip Direction of Joints at BEQ Hill Site.

Location	Joint set	Results	Polar and rose diagram
B09-173	75/092 71/275 89/197	·Main orientation 75/092, Sub orientation 71/275, 89/197 ·Between 19.37~40.53m, measure 48 joints	
B09-174	75/092 71/275 89/197	·Main orientation 75/51, Sub orientation 76/177 ·Between 21.05~41.69m, measure 73 joints	
B09-175	78/235 88/275 80/031	·Main orientation 78/235, Sub orientation 88/275, 80/031 ·Between 19.81~41.40m, measure 36 joints	

3555

5. Reference

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DoD, 2005. Department of Defense Directive 4715.1E. Environment, Safety, and Occupational Health (ESOH), 19 March 2005.

DoD,1998. Department of Defense Instruction 4715.8, Environmental Remediation for DoD Activities Overseas, 2 February 1998.

United States Army Corp of Engineers (USACE), FED: Environmental Site Assessment at Landfarm, BEQ Hill, Building 565 and 326 of Camp Carroll, Korea, 2004

USACE FED. ESA to support the planned Build to Lease (BTL) Family Housing by FED, 2005

United States Forces Korea Regulation 200-1, *United States Forces Korea Remediation Regulation*, 2 October 2007

United States Forces Korea Pamphlet 200-1, *Environmental Governing Standards*, 25 March 2005

Woodward Clyde: Baseline Groundwater Investigation, Camp Carroll, 1992

3556

Appendix I: Monitoring Well Construction Logs

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B05-113MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** G&EE NO.: **08-040E** INSPECTOR: [redacted] b6 b6

DATE STARTED: **16 Feb 05** FINISHED: **16 Feb 05** DRILLER: [redacted]

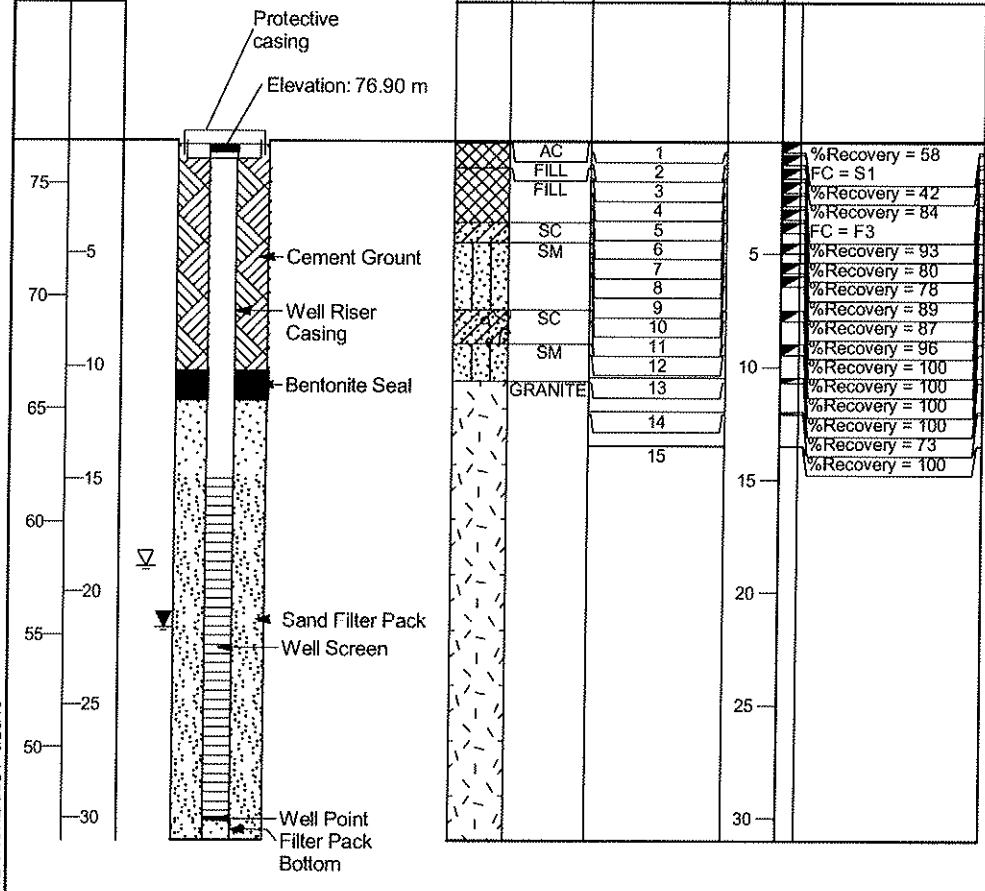
DRILLING METHOD/EQUIPMENT: **Air-Percussion Rotary / TAMROCK T40KW**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **18 cm** TOTAL DEPTH: **31.0 m**

OVERBURDEN THICKNESS: **10.65 m** DEPTH DRILLED: **31.0 m** WATER DEPTH: **21.56 m; AD**

COORDINATES: N: **3,984,731.8** E: **447,870.2** GROUND ELEV.: **76.90 m** DATUM: **MSL**

GROUND COVER: **Asphalt Concrete** TOP of WELL RISER CASING ELEV.: **76.90 m**



PROTECTIVE CASING
Diameter: 20 cm
Type: Manhole
Interval: -0.03 to 0.17m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 0.15 to 15.0m

WELL SCREEN
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 15.0 to 30.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 30.0 to 30.15m

CONCRETE PAD
Diameter: 0.45m
Interval: -0.01 to 0.14m

GROUT
Type: Cement
Interval: 0.14 to 10.2m
Quantity: 8.5 pack (40 Kg/pack)

SEAL
Type: Bentonite
Interval: 10.2 to 11.5m
Quantity: 8 Gal

SAND PACK
Type: Medium sand
Interval: 11.5 to 31.0m
Quantity: 19.5 pack
Grain Size: 0.42 to 2.0 mm

Remarks:
▽ Ground-water level at completion of borehole 02/18/05 18.9m
▼ Ground-water level on 09/01/09 21.56m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B05-114MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** | G&EE NO.: **08-040E** | INSPECTOR: [redacted]

DATE STARTED: **15 Feb 05** | FINISHED: **15 Feb 05** | DRILLER: [redacted]

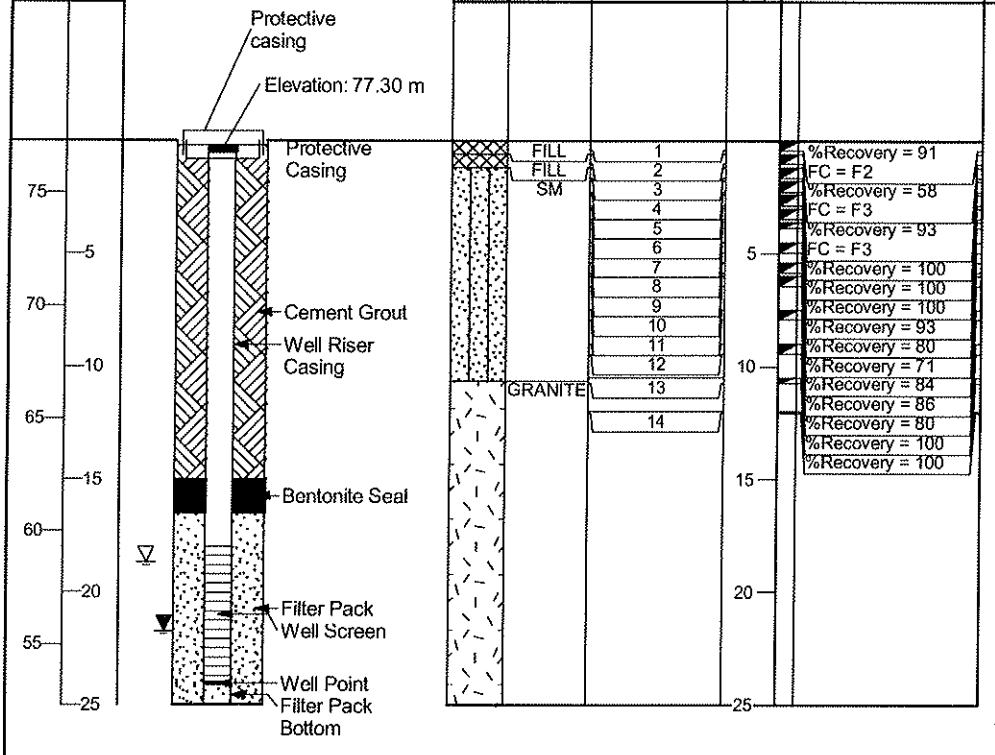
DRILLING METHOD/EQUIPMENT: **Air-Percussion Rotary / TAMROCK T40KW**

DRILLING AGENCY: **Far East District** | HOLE DIAMETER: **18 cm** | TOTAL DEPTH: **25.0 m**

OVERBURDEN THICKNESS: **10.65 m** | DEPTH DRILLED: **25.0 m** | WATER DEPTH: **21.75 m; AD**

COORDINATES: N: **3,984,741.7** E: **447,833.9** | GROUND ELEV.: **77.30 m** | DATUM: **MSL**

GROUND COVER: **Lawn Area** | TOP of WELL RISER CASING ELEV.: **77.30 m**



PROTECTIVE CASING
Diameter: 20 cm
Type: Manhole
Interval: -0.03 to 0.17m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 0.1 to 18.0m

WELL SCREEN
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 18.0 to 24.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 24.0 to 24.15m

CONCRETE PAD
Diameter: 0.45m
Interval: -0.01 to 0.14m

GROUT
Type: Cement
Interval: 0.14 to 15.0m
Quantity: 13 pack (40 Kg/pack)

SEAL
Type: Bentonite Pellet
Interval: 15.0 to 16.5m
Quantity: 8 Gal

SAND PACK
Type: Medium sand
Interval: 16.5 to 25.0m
Quantity: 9.5 pack
Grain Size: 0.42 to 2.0 mm

Remarks:
▽ Ground-water level at completion of borehole 02/18/05 18.67m
▼ Ground-water level on 09/01/09 21.75m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B05-117MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** G&EE NO.: **08-040E** INSPECTOR: [redacted]

DATE STARTED: **17 Feb 05** FINISHED: **17 Feb 05** DRILLER: [redacted]

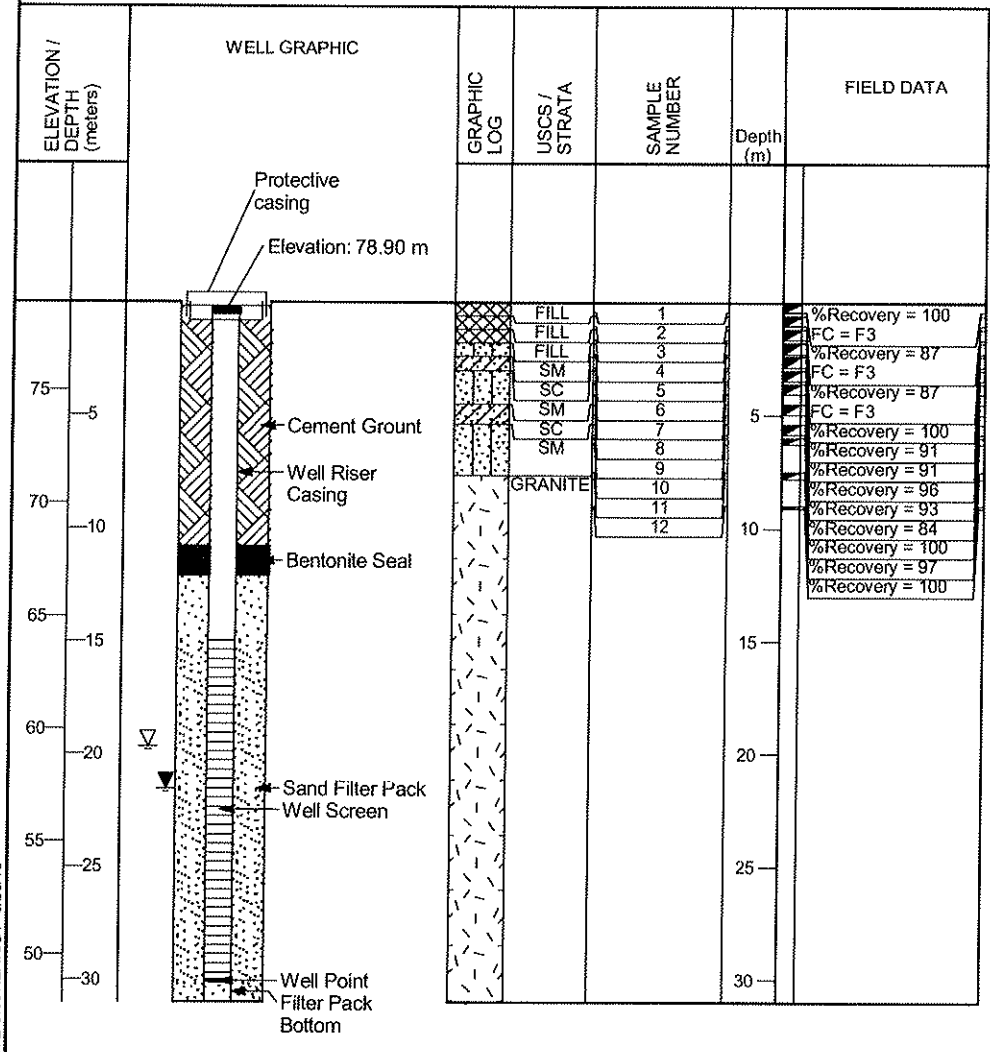
DRILLING METHOD/EQUIPMENT: **Air-Percussion Rotary / TAMROCK T40KW**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **18 cm** TOTAL DEPTH: **31.0 m**

OVERBURDEN THICKNESS: **7.65 m** DEPTH DRILLED: **31.0 m** WATER DEPTH: **21.54 m; AD**

COORDINATES: N: **3,984,798.0** E: **447,867.1** GROUND ELEV.: **78.90 m** DATUM: **MSL**

GROUND COVER: **Lawn Area** TOP of WELL RISER CASING ELEV.: **78.90 m**



PROTECTIVE CASING
Diameter: 20 cm
Type: Manhole
Interval: -0.03 to 0.17m

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 0.1 to 15.0m

WELL SCREEN
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: 15.0 to 30.0m

WELL POINT
Type: Schedule 40 PVC
Interval: 30.0 to 30.15m

CONCRETE PAD
Diameter: 0.45m
Interval: -0.01 to 0.14m

GROUT
Type: Cement
Interval: 0.14 to 10.8m
Quantity: 8.5 pack

SEAL
Type: Bentonite
Interval: 10.8 to 12.1m
Quantity: 8 Gal

SAND PACK
Type: Medium sand
Interval: 12.1 to 31.0m
Quantity: 19.5 pack
Grain Size: 0.42 to 2.0 mm

Remarks:
▽ Ground-water level at completion of borehole 02/18/05 19.7m
▼ Ground-water level on 09/01/09 21.54m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-173MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** G&EE NO.: **08-040E** INSPECTOR: [redacted] 6/6 b6

DATE STARTED: **17 Feb 09** FINISHED: **17 Feb 09** DRILLER: [redacted]

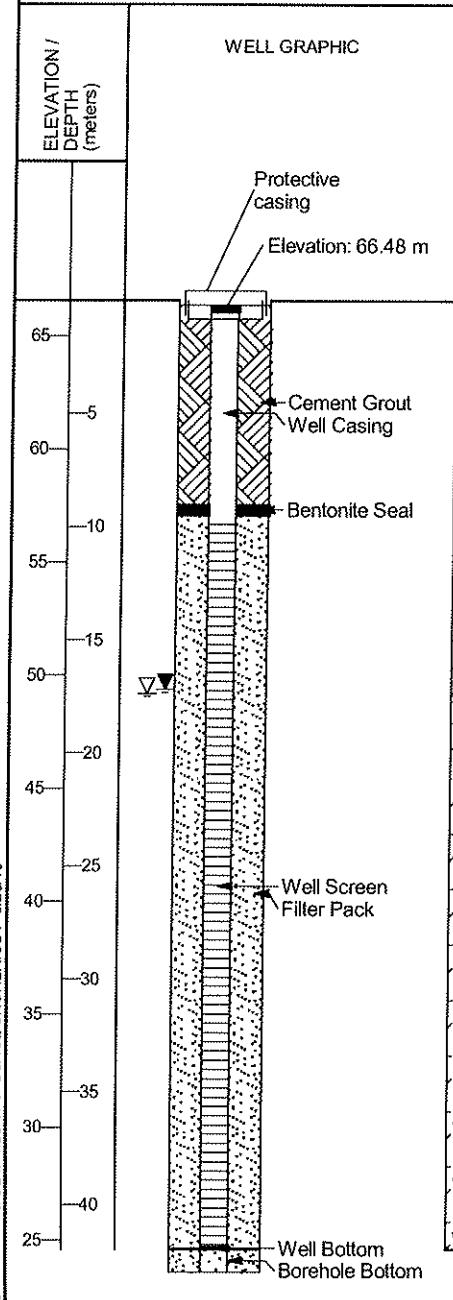
DRILLING METHOD/EQUIPMENT: **DrillTech**

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: **17.21 m; AD**

COORDINATES: N: **3,984,783.2** E: **447,904.4** GROUND ELEV.: **66.56 m** DATUM: **MSL**

GROUND COVER: **Asphalt** TOP of WELL RISER CASING ELEV.: **66.48 m**



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 9.9m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 9.9 to 41.75m

WELL POINT
Type: Schedule 40 PVC
Interval: 41.9 to 42.05m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 9.0m
Quantity: 10 bags of 20 kg

SEAL
Type: Bentonite
Interval: 9.0 to 9.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 9.5 to 43.0m
Quantity: 600kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 02/23/09 17.39m
▼ Ground-water level on 09/01/09 17.21m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-174MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** G&EE NO.: **08-040E** INSPECTOR: [redacted]

DATE STARTED: **18 Feb 09** FINISHED: **18 Feb 09** DRILLER: [redacted]

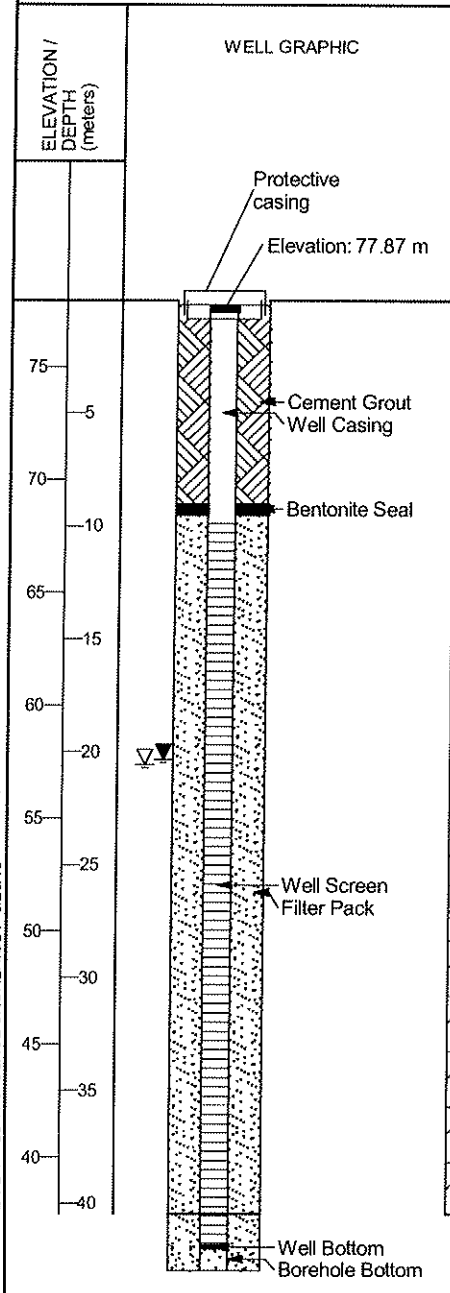
DRILLING METHOD/EQUIPMENT: **DrillTech**

DRILLING AGENCY: **Far East District** HOLE DIAMETER: **18 cm** TOTAL DEPTH: **40.5 m**

OVERBURDEN THICKNESS: **15.0 m** DEPTH DRILLED: **40.5 m** WATER DEPTH: **20.36 m; AD**

COORDINATES: N: **3,984,800.7** E: **447,831.9** GROUND ELEV.: **77.93 m** DATUM: **MSL**

GROUND COVER: **Asphalt** TOP of WELL RISER CASING ELEV.: **77.87 m**



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 9.9m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 9.9 to 41.75m

WELL POINT
Type: Schedule 40 PVC
Interval: 41.9 to 42.05m

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

GROUT
Type: Portland Type II
Interval: 0.0 to 9.0m
Quantity: 8 bags of 20 kg

SEAL
Type: Bentonite
Interval: 9.0 to 9.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 9.5 to 42.0m
Quantity: 600kg
Grain Size: 0.4-1.2 mm

Remarks:
- Ground-water level at completion of borehole 02/23/09 20.59m
- Ground-water level on 09/01/09 20.36m
- Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

US Army Corps Of Engineers

MONITORING WELL LOG

WELL NO. **B09-175MW**

Far East District

PROJECT: **Remedial Investigation/Feasibility Study at BEQ Hill**

LOCATION: **Camp carroll** G&EE NO.: **08-040E** INSPECTOR: [redacted] 66

DATE STARTED: **19 Feb 09** FINISHED: **19 Feb 09** DRILLER: [redacted] 66

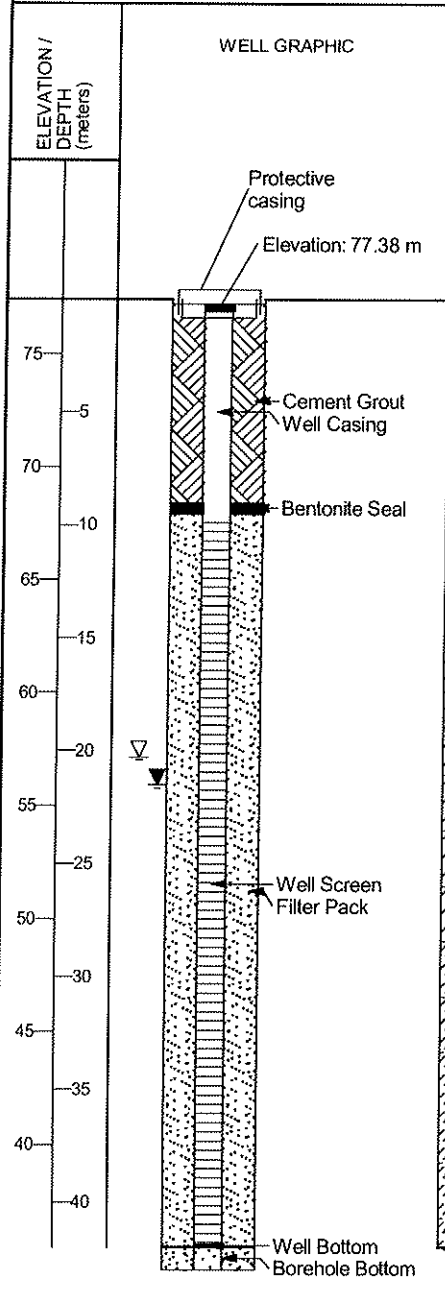
DRILLING METHOD/EQUIPMENT: **DrillTech**

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: **21.52 m; AD**

COORDINATES: N: **3,984,755.9** E: **447,869.0** GROUND ELEV.: **77.44 m** DATUM: **MSL**

GROUND COVER: **Asphalt** TOP of WELL RISER CASING ELEV.: **77.38 m**



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

WELL RISER CASING
Diameter: 2 inch
Type: Schedule 40 PVC
Interval: -0.01 to 10.0m

WELL SCREEN
Diameter: 2 inch
Type: 0.01 Slot Sch 40
Interval: 10.0 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 9.0m
Quantity: 8 bags of 20 kg

SEAL
Type: Bentonite
Interval: 9.0 to 9.5m
Quantity: 2.5 gal

SAND PACK
Type: medium sand
Interval: 9.5 to 43.0m
Quantity: 580kg
Grain Size: 0.4-1.2 mm

Remarks:
▽ Ground-water level at completion of borehole 02/23/09 20.28m
▼ Ground-water level on 09/01/09 21.52m
▲ Product level on

Note:

MONITORING WELL LOG 08-040E BEQ HILL.GPJ USACE SKOREA.GDT 9/28/10

Appendix II: Borehole Geophysical Investigation Result

3564

Borehole Geophysical Investigation Report

Remedial Investigation/Risk Assessment at BEQ Hill, Camp Carroll, Korea

(G&EE 08-040E)

2009. 05

CorEArth Engineering Co., Ltd.

1. Purpose and scope

Recent advances in geophysical logging methods have provided the opportunity to refine our understanding of groundwater flow and contaminant transport in fractured-rock and weathered-rock aquifers. Integration of these new methods with conventional logging techniques can be used to define flow zones, lithology, structure, and their relations in fractured and weathered media.

The purpose of this study in support of remedial investigation/feasibility study (RI/RA) at BEQ Hill of Camp Carroll is primarily to characterize the hydrogeologic properties by analyzing rock fracture patterns of the project site using a borehole camera. Subsidiary, a couple of geophysical modules are employed to reveal groundwater properties and the physical shape of borehole inside by use of optical borehole image (OBI), fluid temperature, fluid resistivity and borehole caliper.

This report includes a description of the geophysical logging methods and presents an integrated analysis of the geophysical logs. The geophysical log methods were employed since the rock core samples were not physically retrieved for this project. Instead, the OBI and other geophysical modules were applied to reveal subsurface geologic conditions and groundwater properties. Site Location at Camp Carroll is presented in Figure 1.

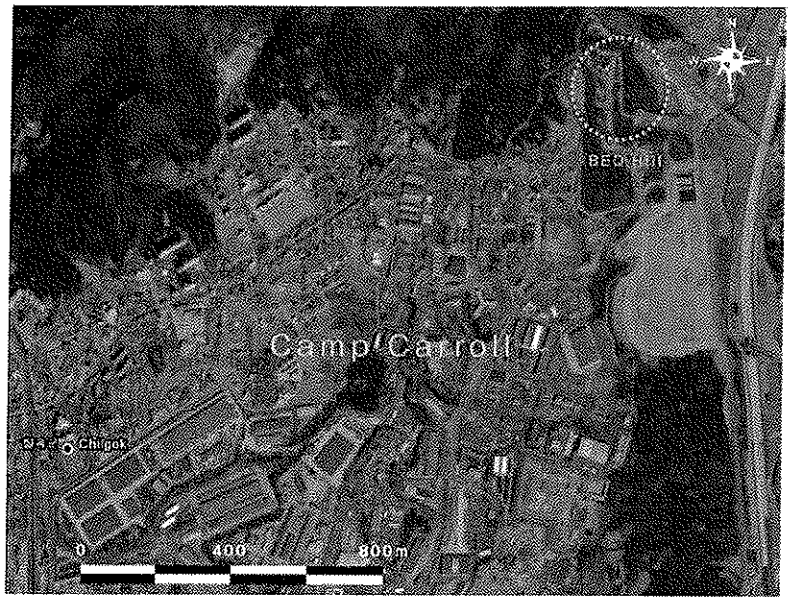


Figure 1. Location of BEQ Hill in Camp Carroll, Wadgwan, Korea

2. GEOPHYSICAL LOGGING METHODS

Geophysical logging methods used in this investigation included OBI, Acoustic Borehole Image (ABI), borehole caliper, fluid resistivity, and fluid temperature. Geophysical surveys were performed during 18 to 27 February 2009. All depth information on logs is referenced to depth below the top of well casing. The data logs were analyzed as an integrated suit to take an advantage of their synergistic nature.

Caliper logging records borehole diameter by use of a three-arm, spring-loaded tool. Changes in borehole diameter are related to drilling and construction procedures, caving of less competent rocks, and the presence of fractures. The caliper logs were used with the OBI, ABI, fluid resistivity, and fluid temperature logs to characterize flow zones intersected by the boreholes. The fractures with wider openings, fracture zones can provide preferable groundwater pathways in fractured rock aquifer. Therefore, this caliper logging can be used to identify dominant groundwater pathways in the borehole.

OBI televiewer logging records a magnetically oriented, 360° optical image of the borehole wall. An OBI log can be viewed as an unwrapped image similar to the traditional presentation of acoustic-televiewer data or it can be wrapped and viewed as a "virtual core". The OBI can be used in air or below the borehole water level if the water has low turbidity. Fractures and other planar features can be identified and characteristics of the fractures, such as orientation, spacing, aperture, presence of filling material, can be obtained from the OBI. Fractures included bedding-plane separations, joints, shear planes, and other planar breaks in the bedrock. The drilling process commonly causes bedrock adjacent to fractures to break out thereby increasing the apparent widths of fracture openings as viewed on borehole-wall images. Fractures with apparent opening widths of 0.1 inch (2.54 mm) or more were classified as open or partially open.

ABI logging records a magnetically oriented, 360° acoustic image of the borehole wall. The ABI is not affected by the turbidity of the borehole water. Fractures with apparent opening widths greater than 0.1 inch (2.54 mm) can be detected on the ABI images. The ABI logs were used in combination with the OBI logs to determine the character and orientation of fractures.

Fluid-resistivity logging records the electrical resistivity of the water in a borehole. The electrical resistivity of the water is related to its dissolved-solids concentration. Fluid-resistivity logs were collected under ambient conditions. The fluid-resistivity logs were combined with the temperature logs to identify flow zones and to determine the relative dissolved-solids concentration of their contained water.

Temperature logging records the temperature of the water in the borehole. In boreholes

with no vertical borehole flow, the temperature of the borehole water generally increases with depth as a function of the geothermal gradient in the surrounding rocks. Temperature gradients less than the geothermal may indicate intervals with vertical or horizontal borehole flow. Temperature logs were used with the fluid-resistivity logs to identify flow zones under ambient and pumped conditions.

3. Results of the borehole-geophysical investigation

Geophysical investigation was conducted for the monitoring wells at Land Farm area of Camp Carroll. Summary of available geophysical log for Land Farm Area is presented in Table 1. Appendix I presents the log results and analysis images of each borehole.

Table 1 Summary of logs at BEQ Hill site

Borehole No	Fluid Temp/ Resistivity	Caliper	Optical Borehole Image (OBI)	Acoustic-Borehole Image(ABI)	Location
B09-173MW	O	O	O		BEQ Hill
B09-174MW	O	O	O	O	BEQ Hill
B09-175MW	O	O	O		BEQ Hill
B05-117MW	O				BEQ Hill

B05 indicates the wells installed in Fiscal Year 05, and B09 is during this investigation. The circle indicates the log is available.

3.1 Fluid temperature and fluid resistivity

Fluid temperature and resistivity results are summarized in Table 2.

Table 2 Range of fluid temperature and resistivity at the BEQ hill site

Borehole No	Fluid Temperature (℃)	Fluid Resistivity (Ohm-m)	Remarks
B09-173MW	16.17~18.41	5.68~23.65	
B09-174MW	17.83~19.17	21.72~51.65	
B09-175MW	18.45~19.1	20.22~35.28	
B05-117MW	13.60~18.86	42.51~48.33	

M05 indicates the wells installed in Fiscal Year 05, and M09 is during this investigation.

3.2 Orientation and dip form the Optical Borehole Image (OBI) Logs

OBI result is summarized in the Table 3.

Table 3 Summary of orientation and dip at the site

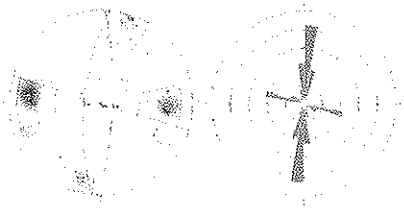
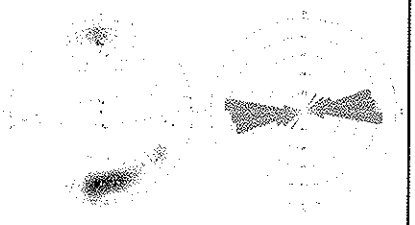
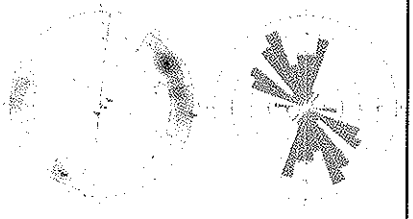
Location	Joint set	Results	Polar and rose diagram
B09-173MW	75/092 71/275 89/197	·Main orientation 75/092, Sub orientation 71/275, 89/197 ·Between 19.37~40.53m, measure 48 joints ·Fracture frequency per depth is 0.446 m	
B09-174MW	75/051 76/177	·Main orientation 75/51, Sub orientation 76/177 ·Between 21.05~41.69m, measure 73 joints ·Fracture frequency per depth is 0.283 m	
B09-175MW	78/235 88/275 80/031	·Main orientation 78/235, Sub orientation 88/275, 80/031 ·Between 19.81~41.40m, measure 36 joints ·Fracture frequency per depth is 0.599 m	

Table 4 Groundwater level at the BEQ Hill site

Monitoring well ID	Groundwater Depth (bgs)	Groundwater Depth (AMSL)	Remarks
B09-173MW	19.15 m	47.41 m	
B09-174MW	20.65 m	57.283 m	
B09-175MW	20.29 m	56.445 m	

Bgs: below ground surface, AMSL: above mean sea level

4. Summary and conclusions

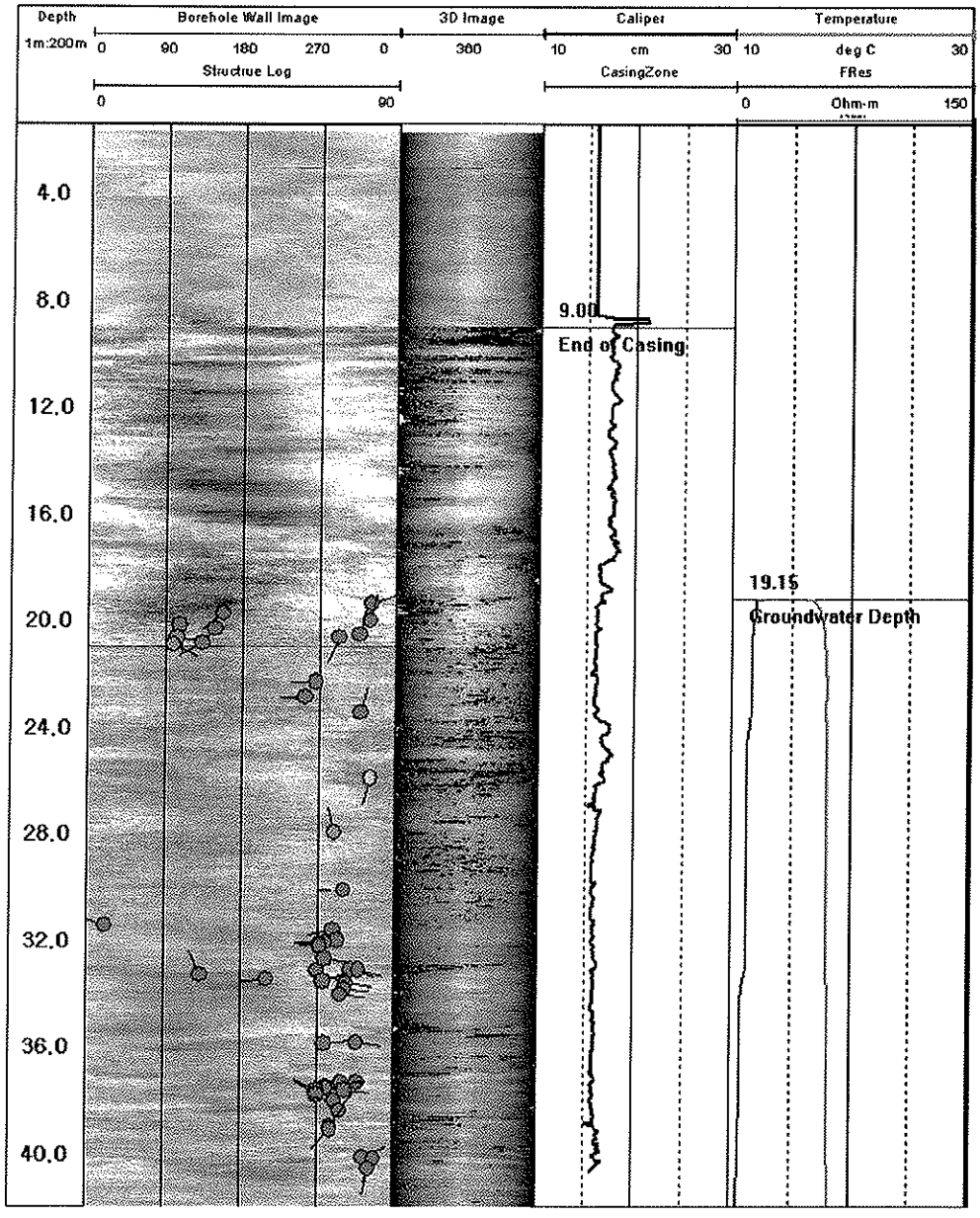
Four geophysical borehole logging systems were applied at Camp Carroll RI/RA sites: OBI, caliper, fluid temperature, and fluid resistivity log.

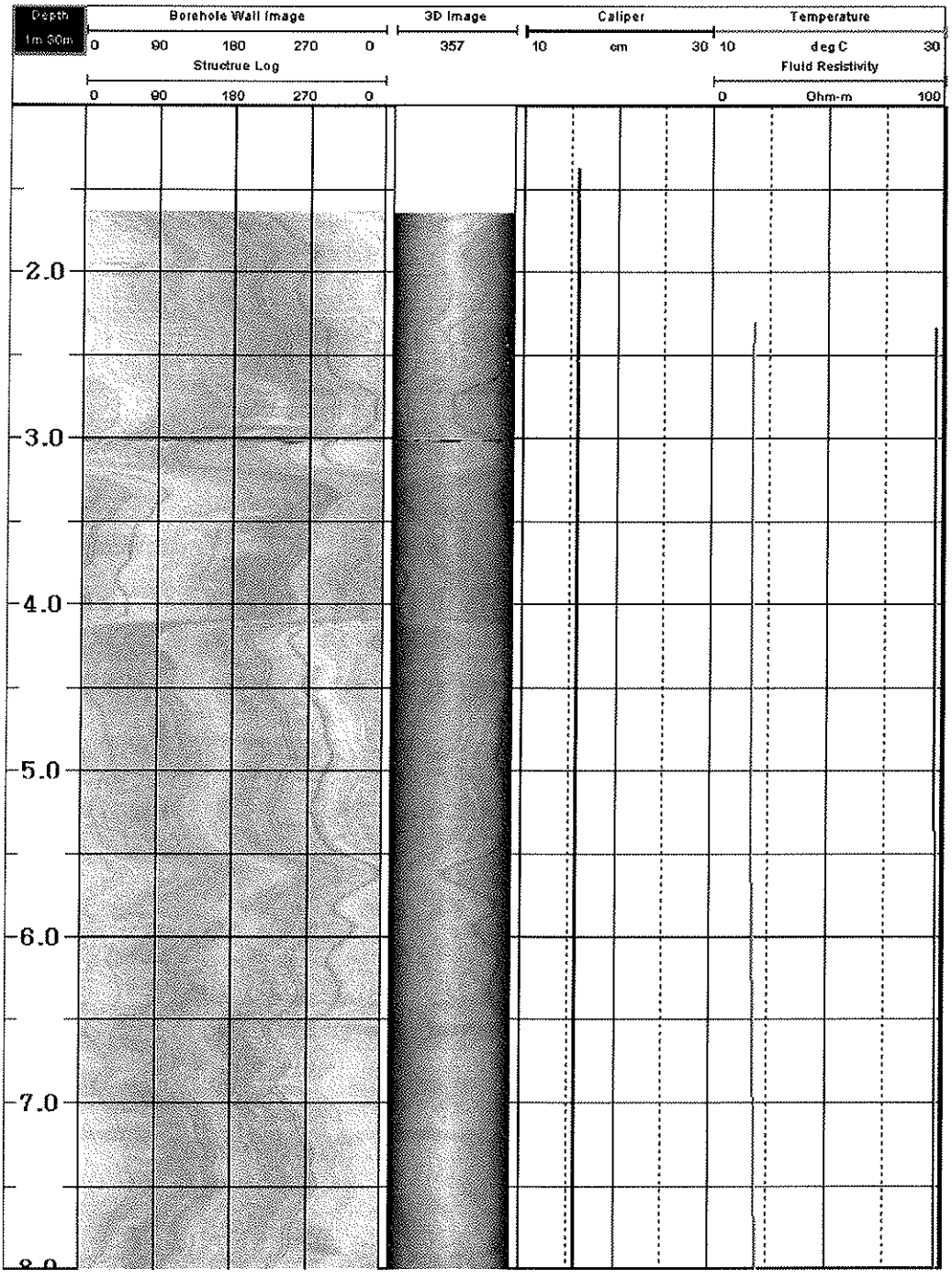
OBI result indicates the main fracture direction in boreholes B09-173MW, B09-174MW, and B09-175MW are 75/092, 75/51 and 78/235 respectively, and fracture frequency distributed from 0.283 m to 0.599 m in this site.

Fluid resistivity result indicates that the resistivity of site groundwater is a little bit lower than generally known uncontaminated water ranging from a few tans to a few hundred Ohm-m.

Appendix I. Geophysical Logging Data BEQ Hill site

- **Borehole B09-173MW**

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Borehole Wall Image
0 90 180 270 0
Structrue Log
0 90 180 270 0
3D Image
357
Caliper
10 cm 30
Temperature
10 deg C 30
Fluid Resistivity
0 Ohm-m 100
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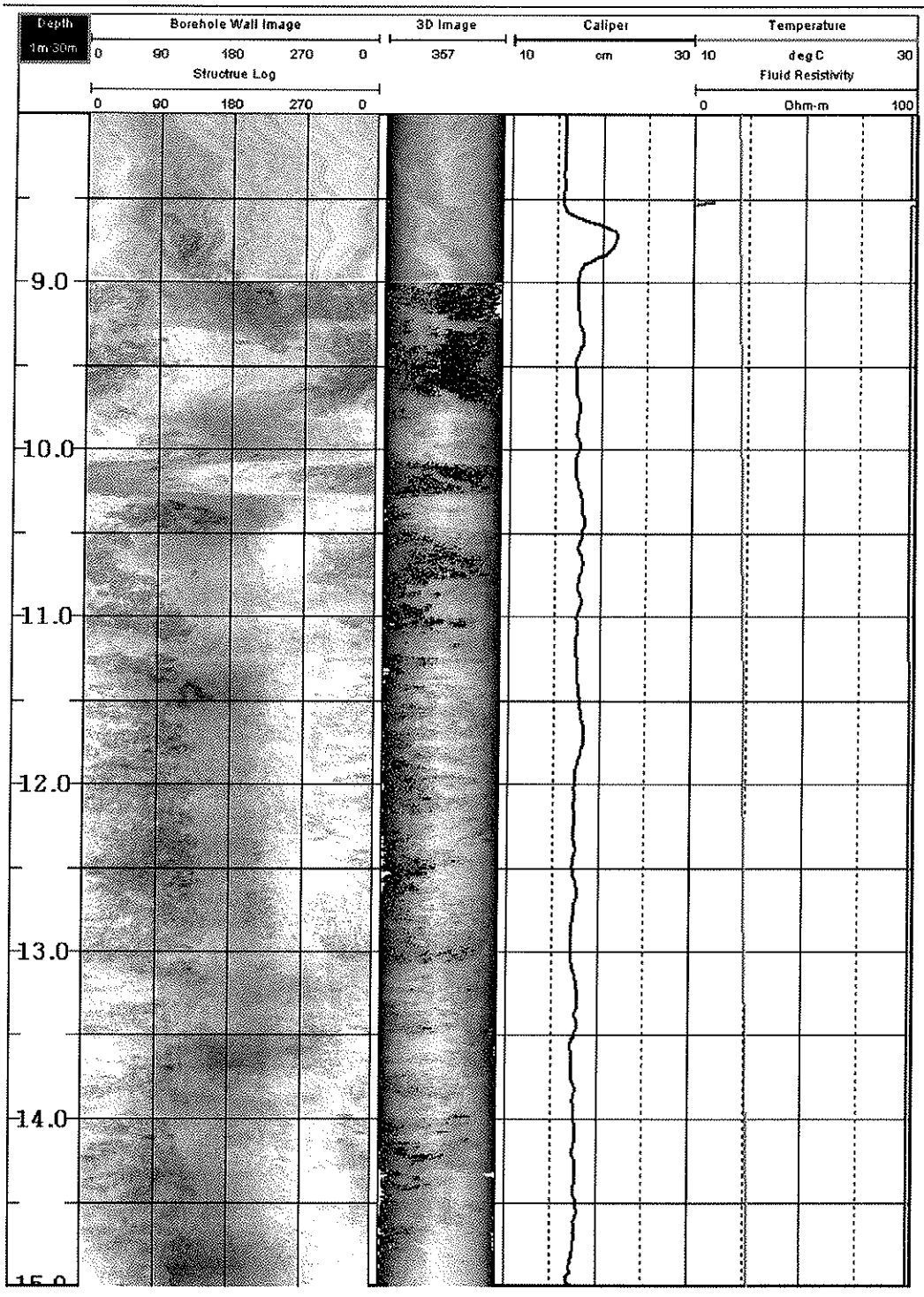
3.0
4.0
5.0
6.0
7.0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270
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Structrue Log
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90
180
270
0
3D Image
357
Caliper
10
cm
30
Temperature
10
deg C
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Fluid Resistivity
0
Ohm-m
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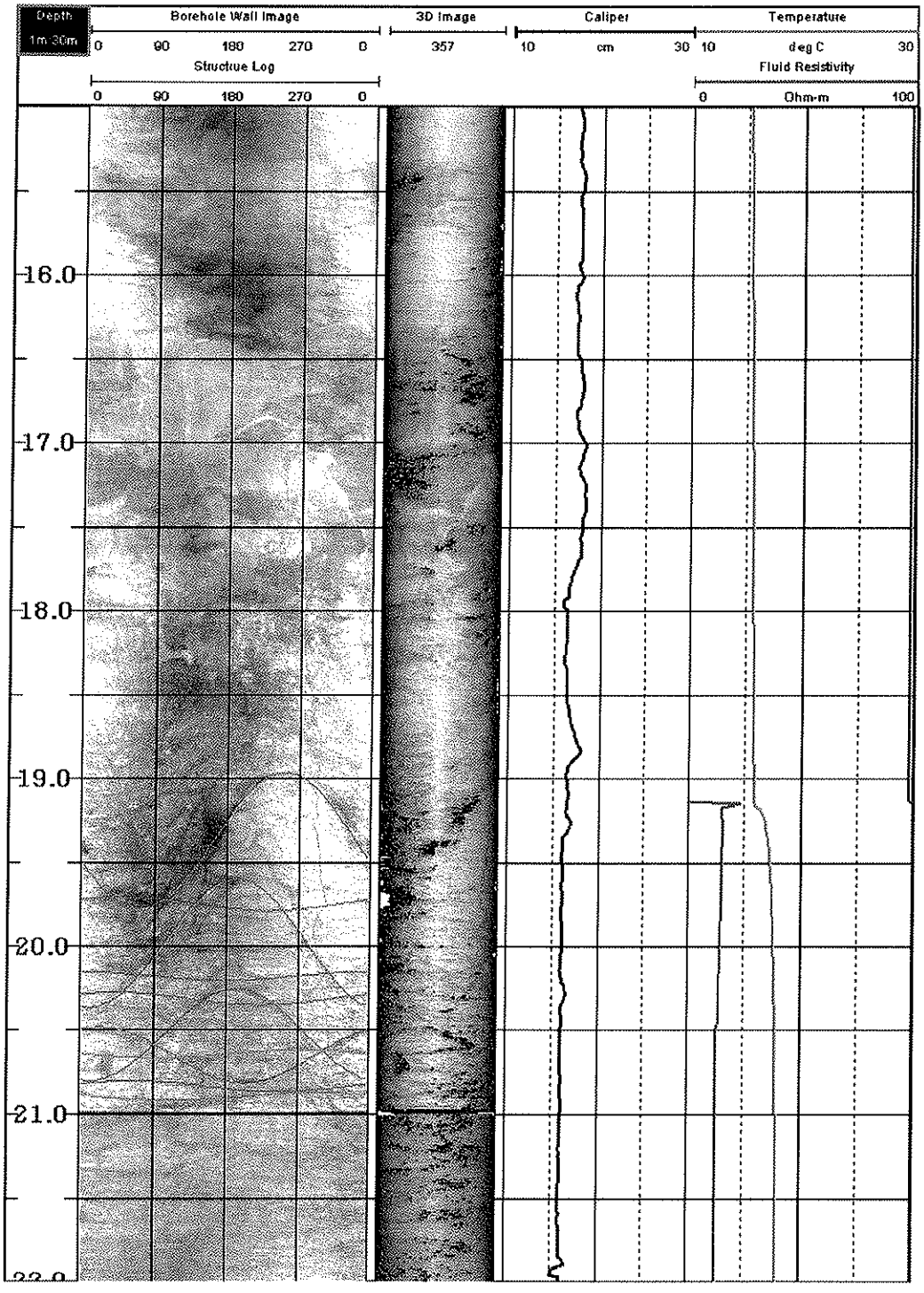
10.0
11.0
12.0
13.0
14.0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270
0
3D Image
357
Caliper
10
cm
30
Temperature
10
deg C
30
Fluid Resistivity
0
Ohm-m
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19.0
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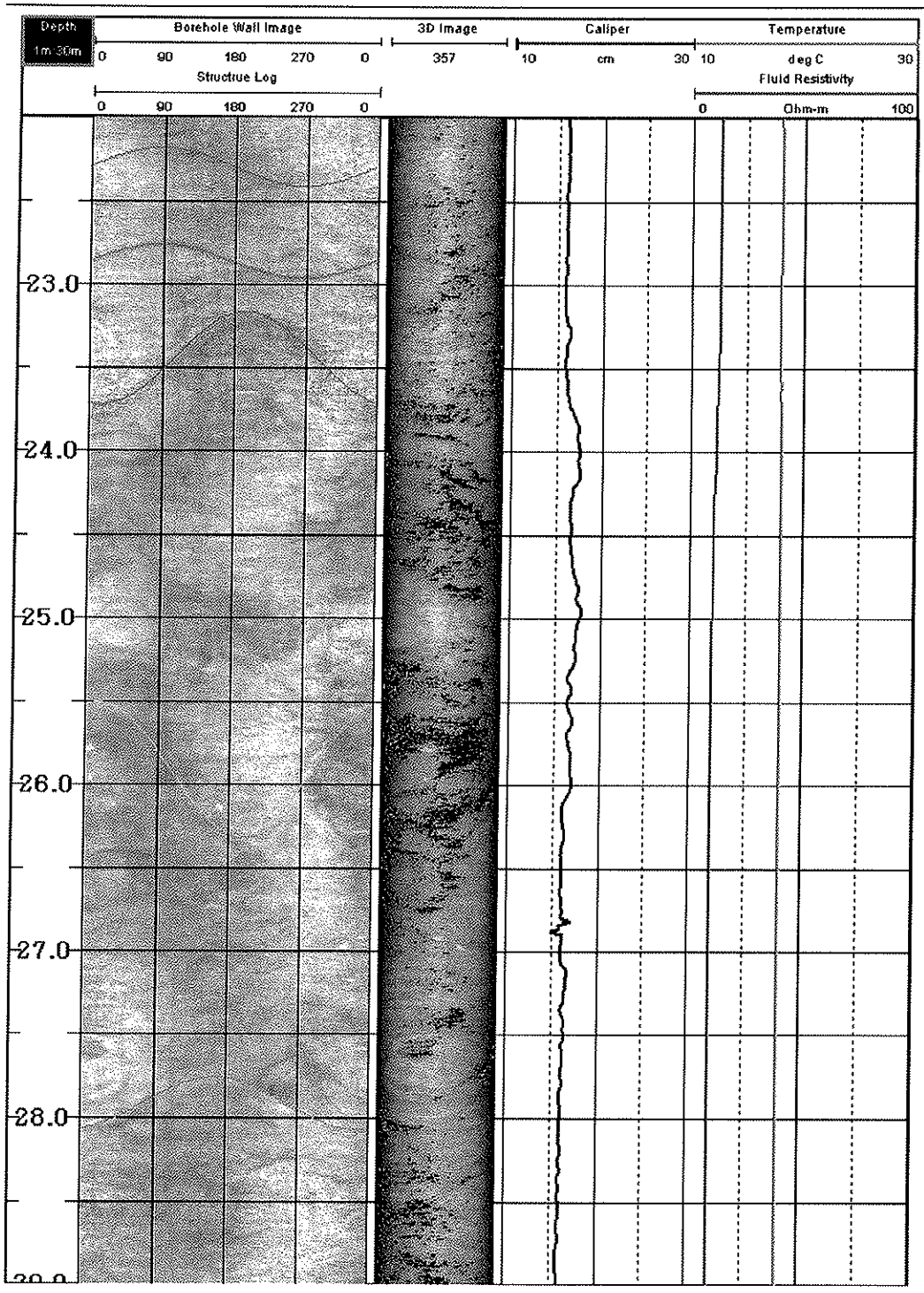
21.0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3D Image
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Caliper
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Temperature
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Fluid Resistivity
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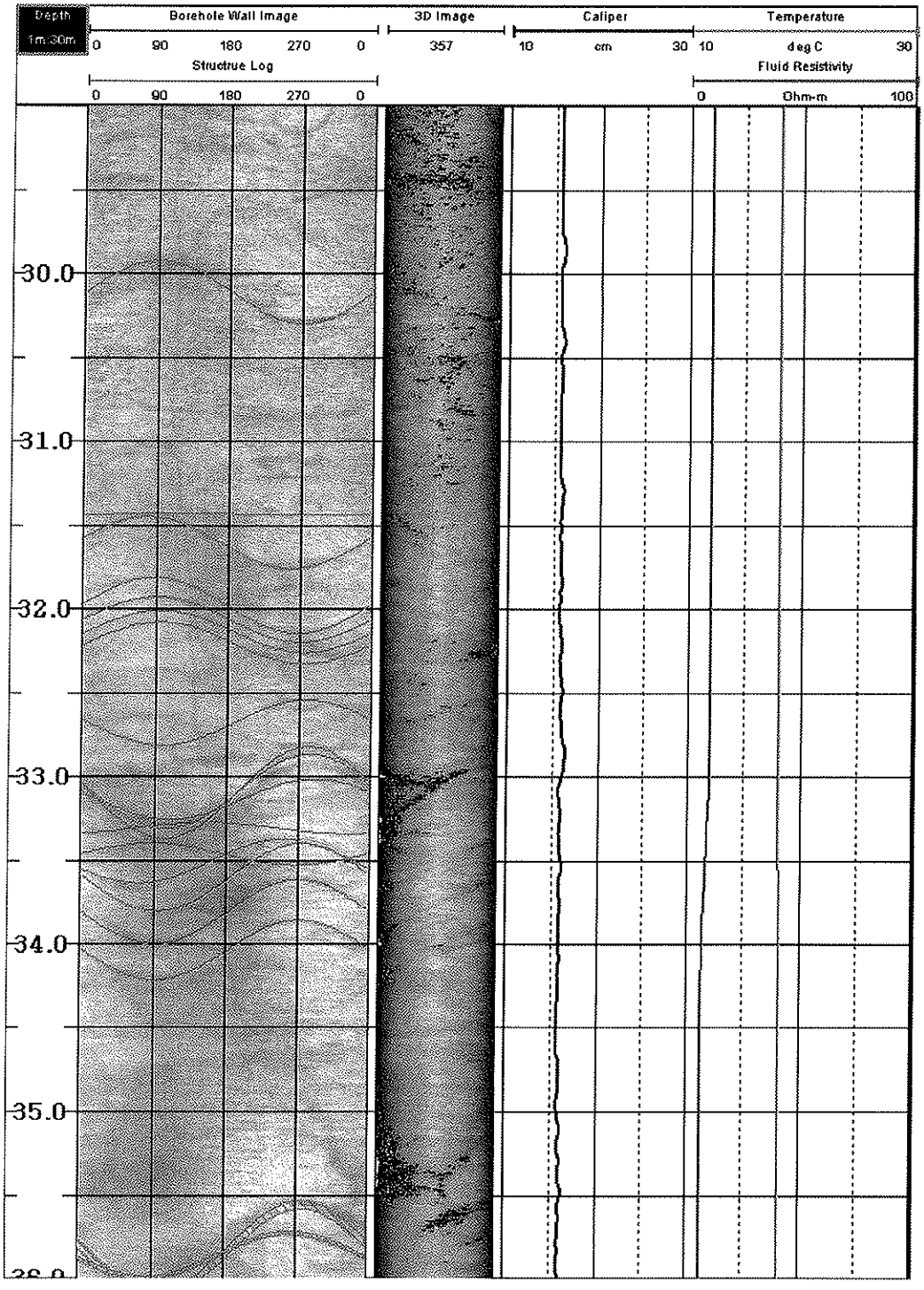
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Caliper
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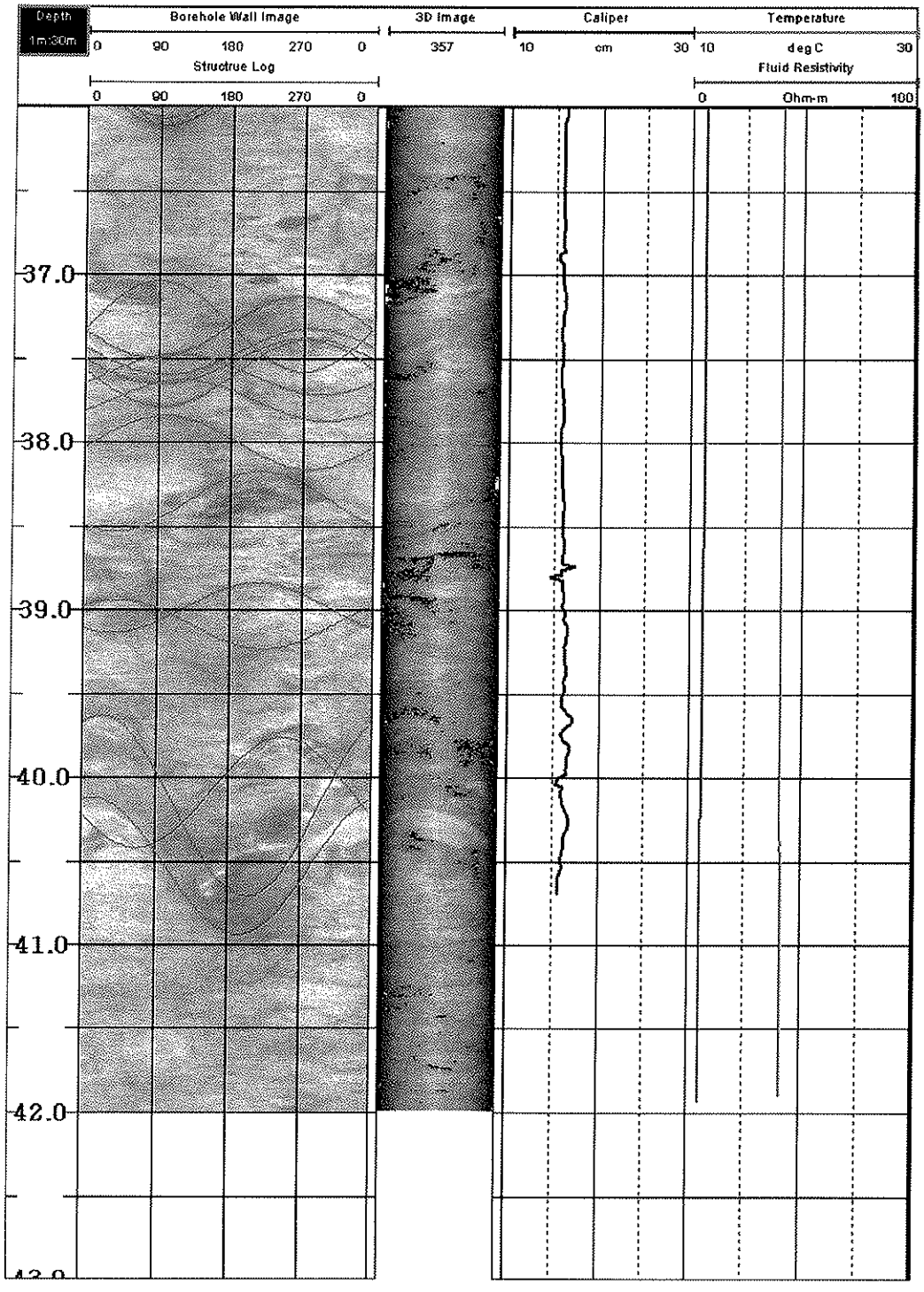
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Caliper
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cm
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Temperature
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deg C
30
Fluid Resistivity
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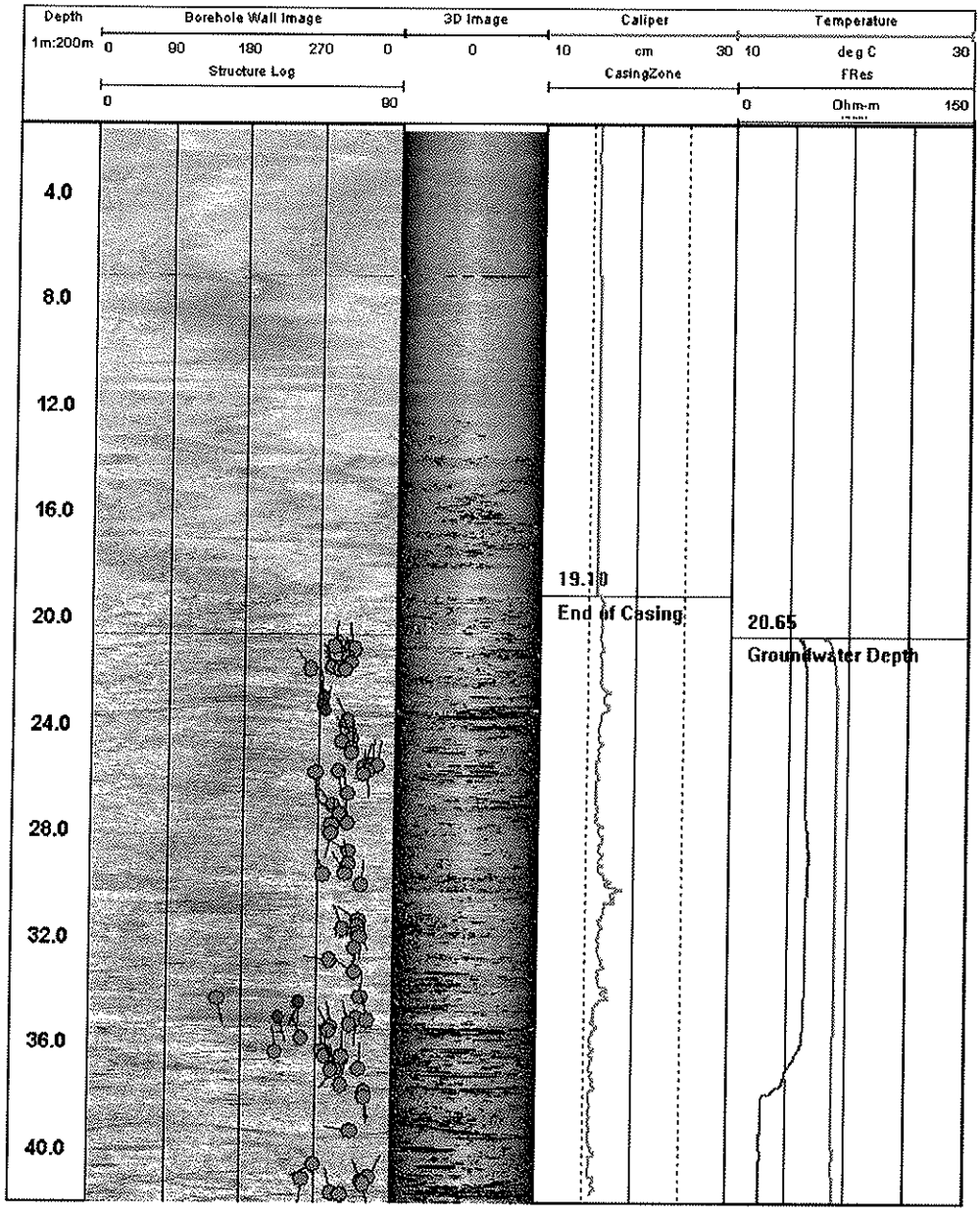
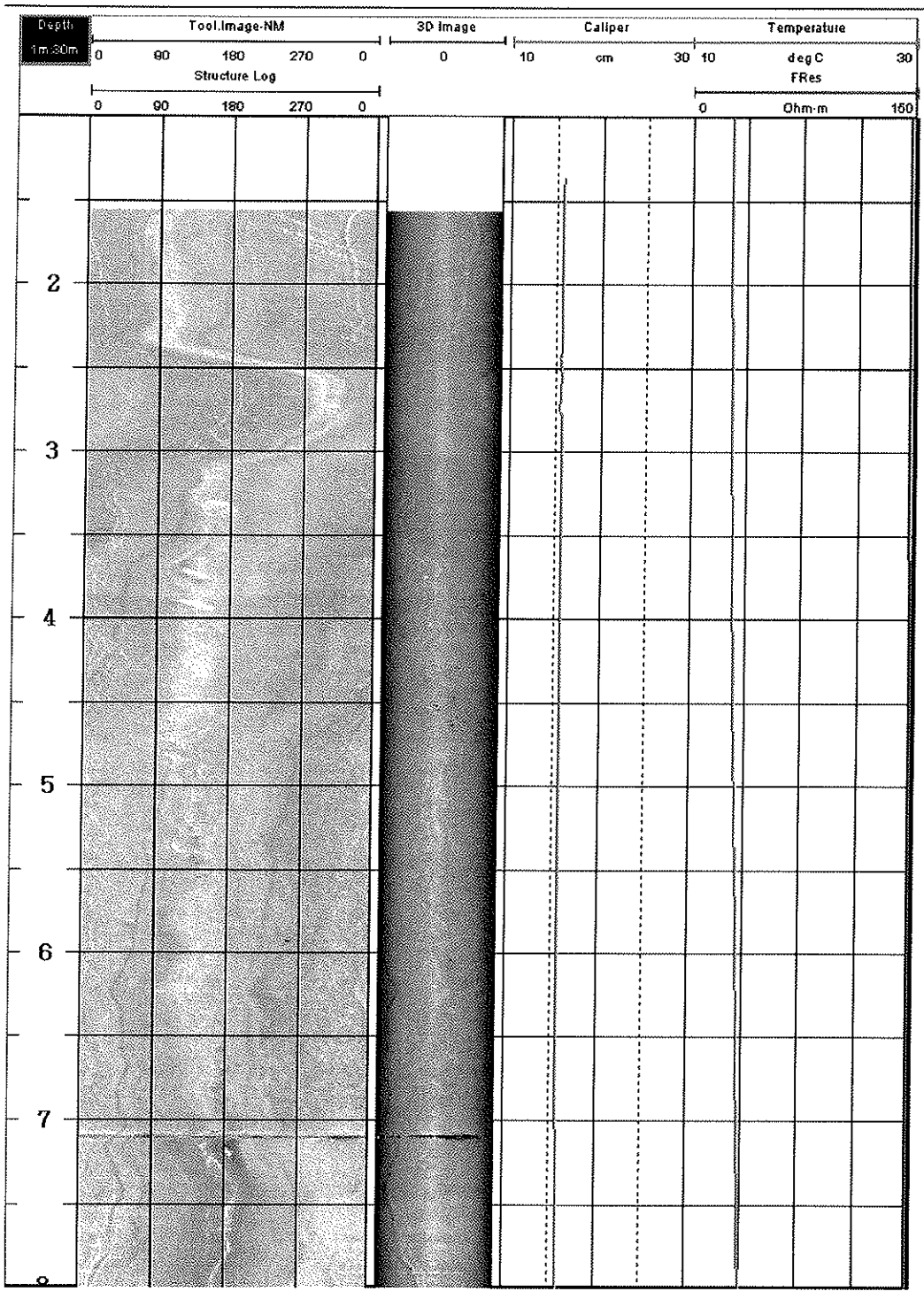
42.0

3579

- **Borehole B09-174MW**

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Temperature
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FRes
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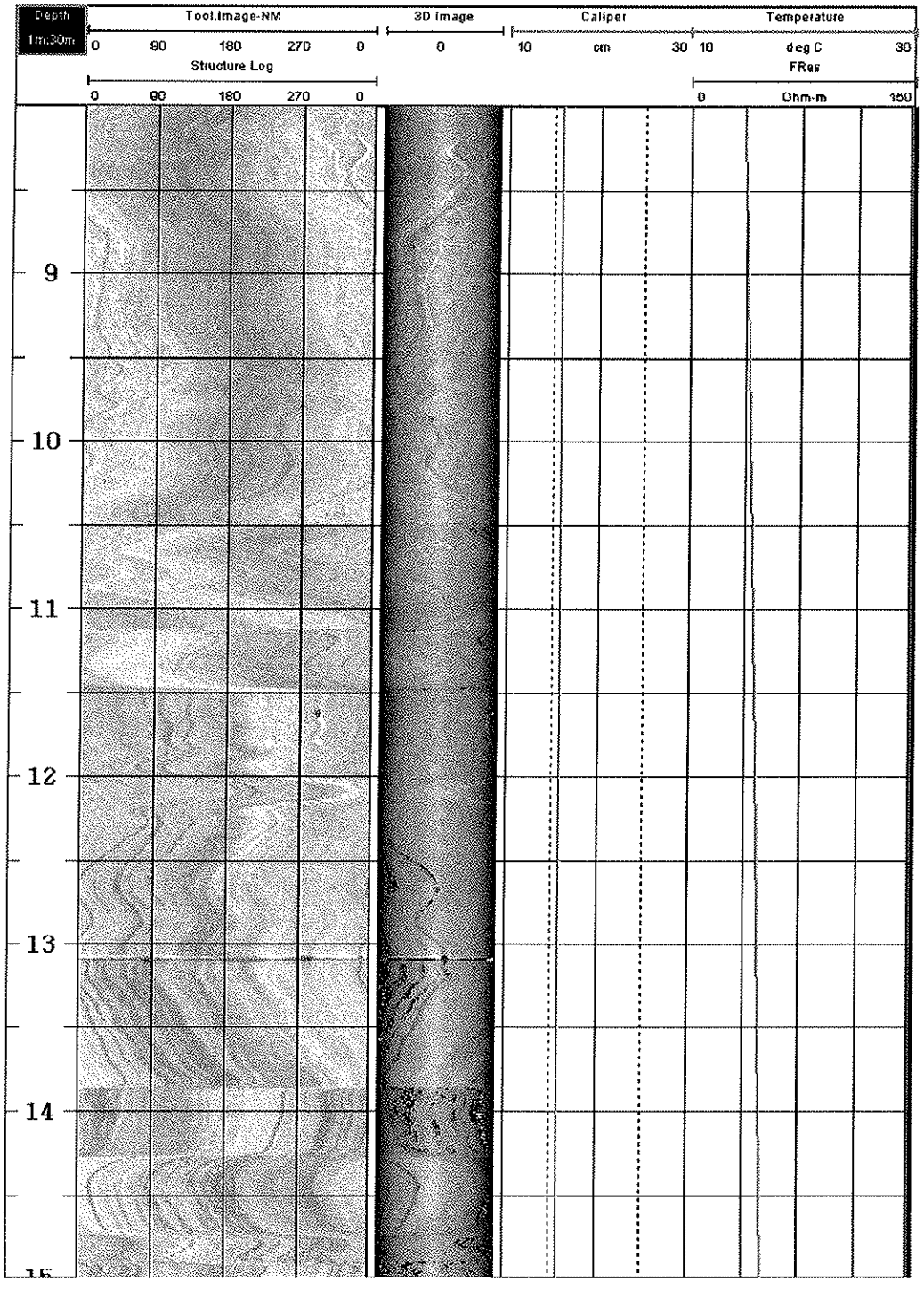
3
4
5
6
7
8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Ohm-m
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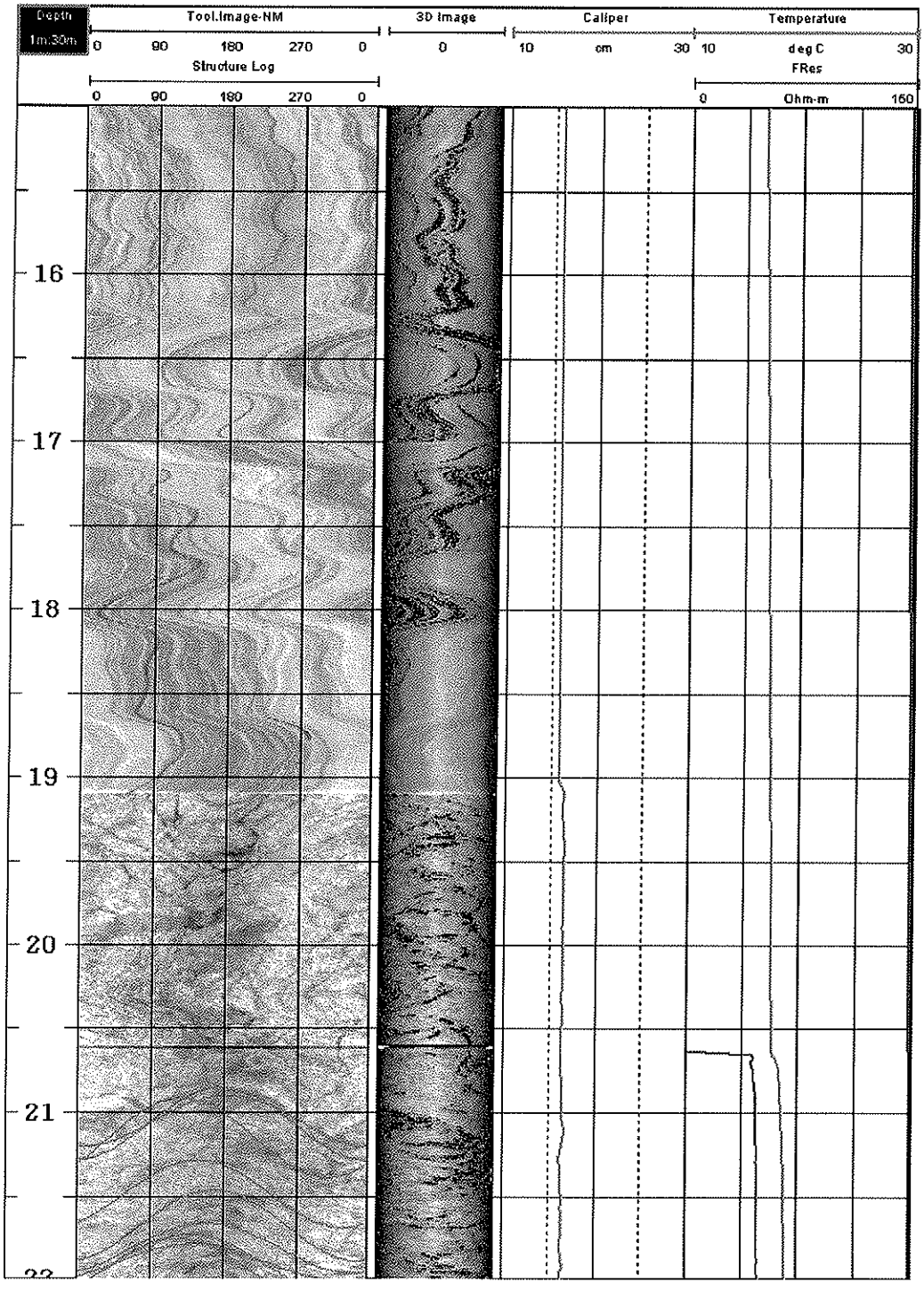
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20
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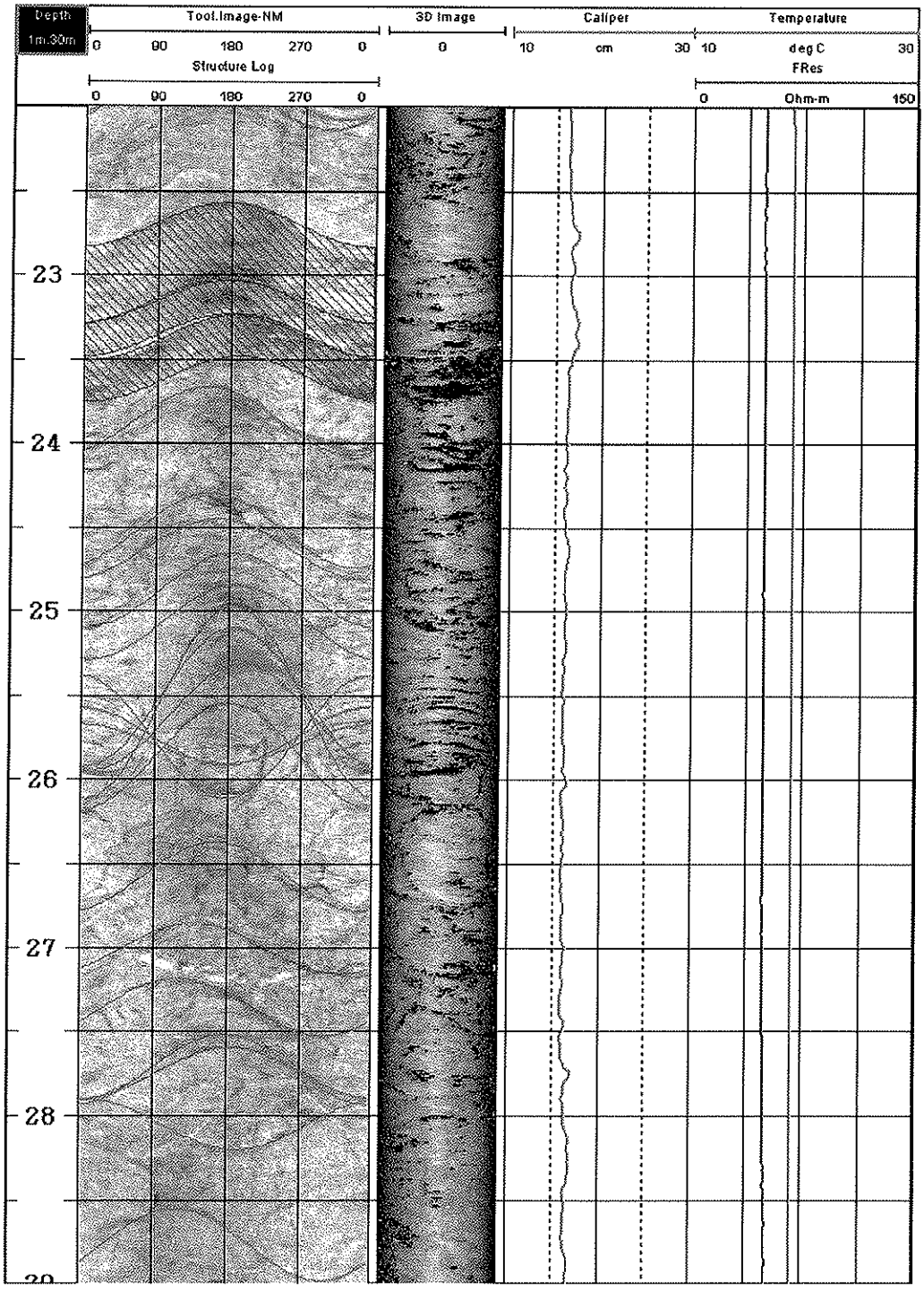
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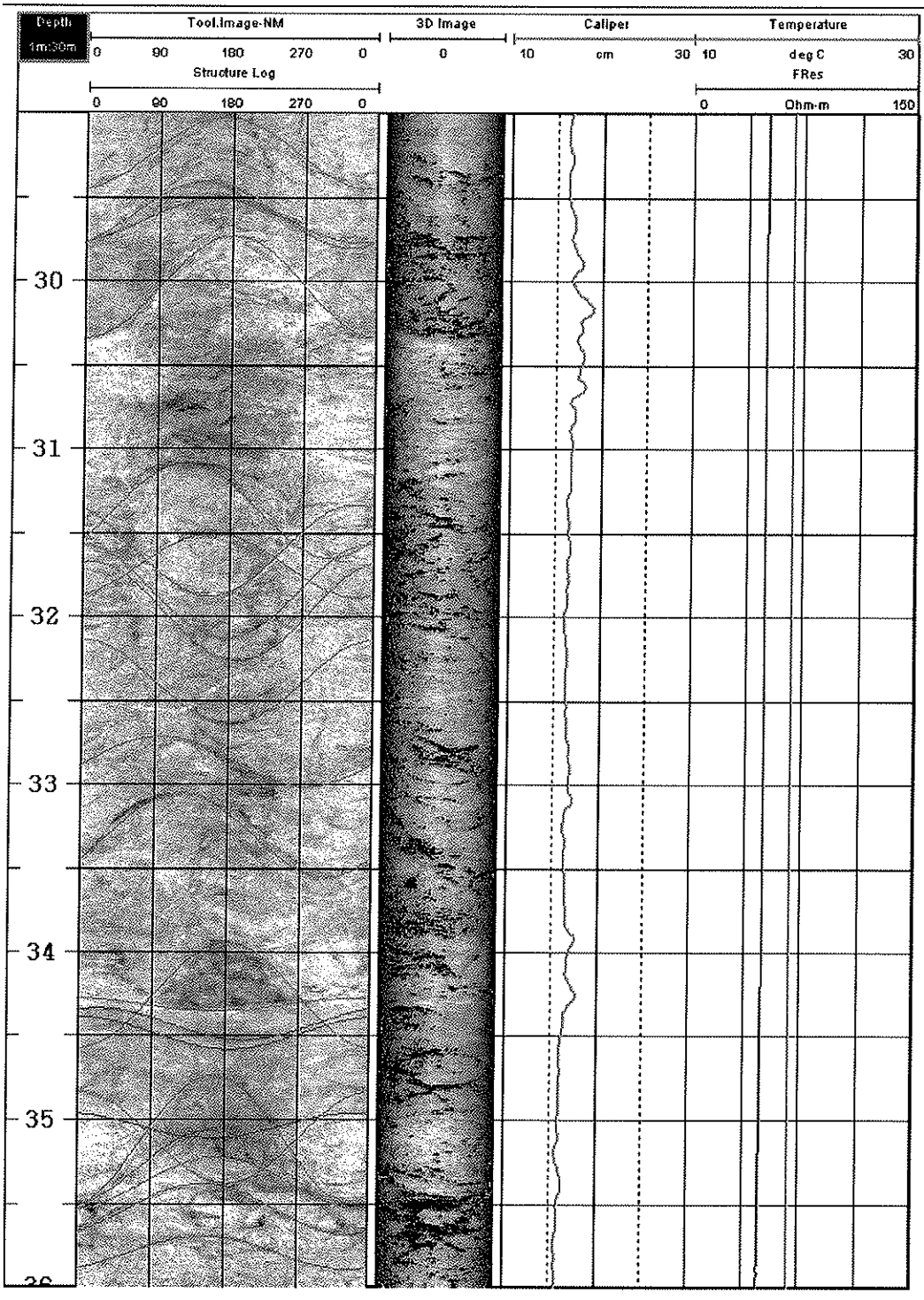
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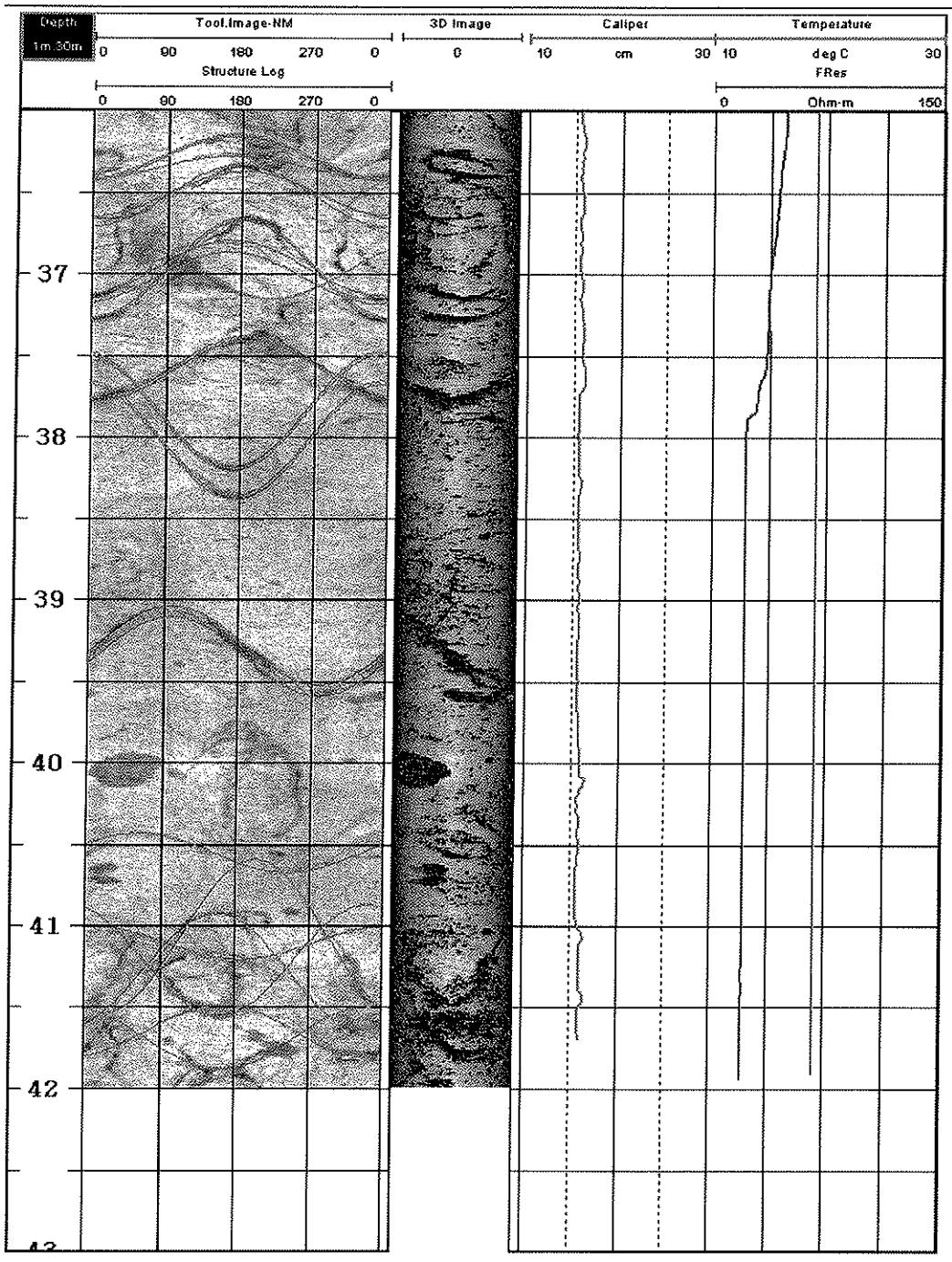
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Caliper
10
cm
30
Temperature
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deg C
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FRes
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Ohm-m
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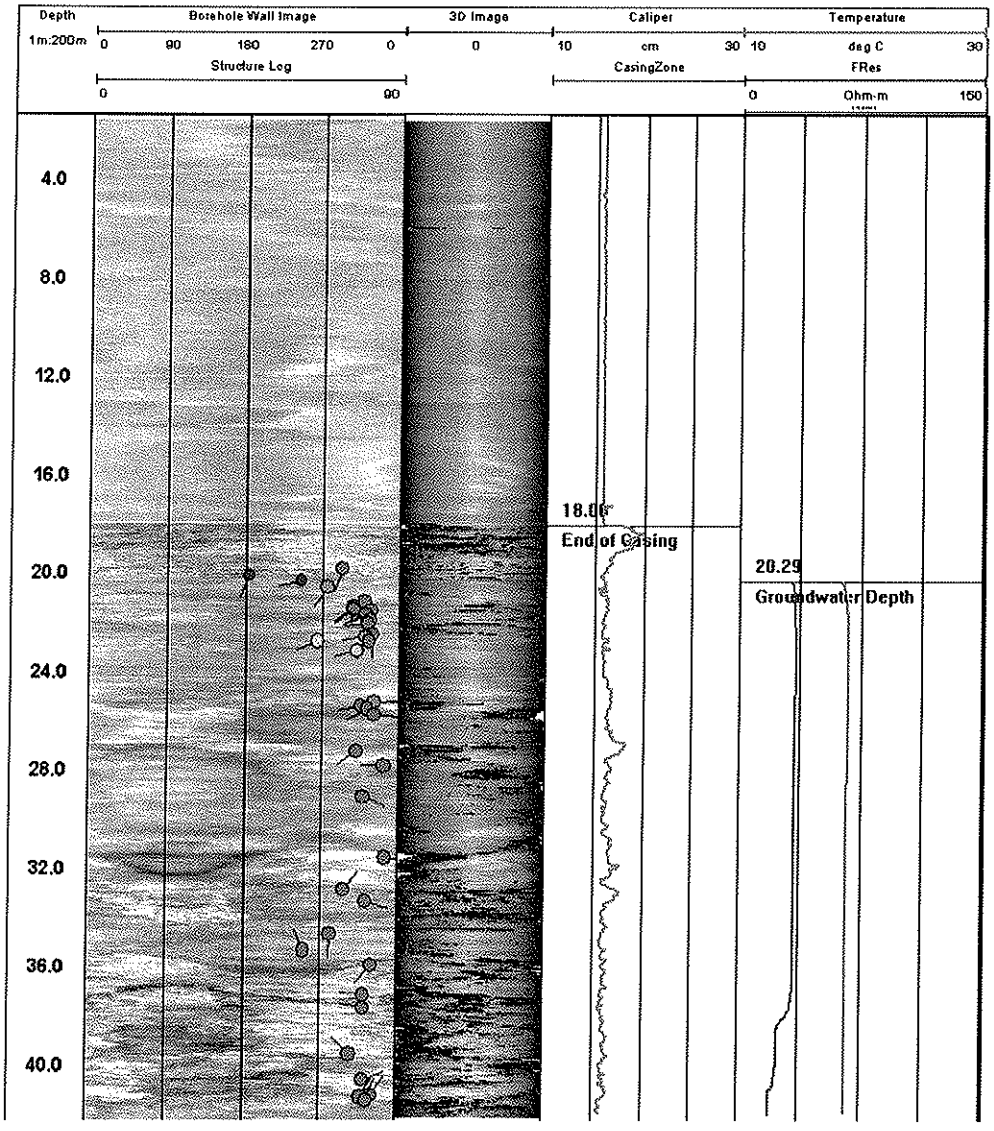
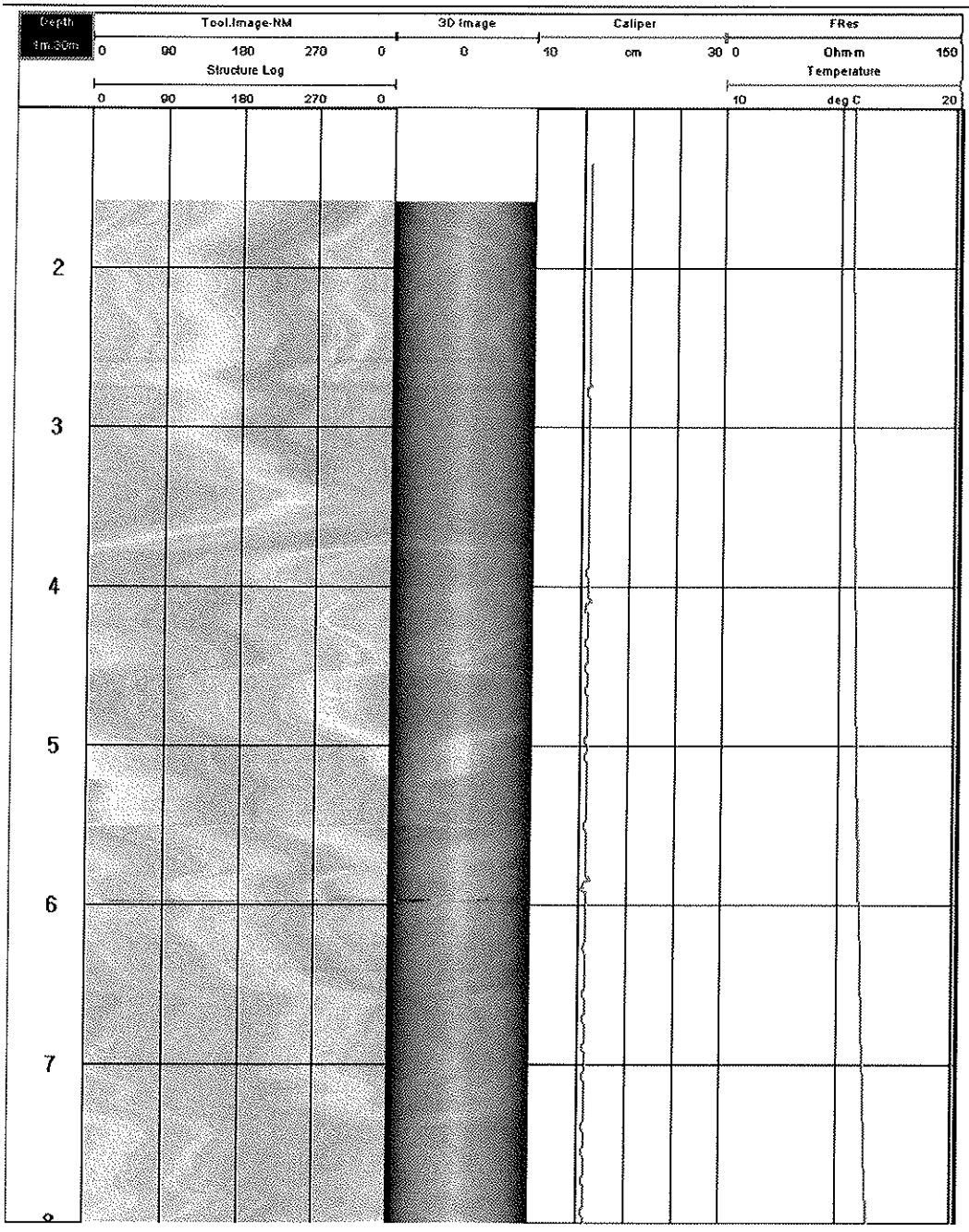
37
38
39
40
41
42

- **Borehole B09-175MW**

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3D Image
Caliper
FRes
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Ohm-m
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Structure Log
Temperature
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deg C
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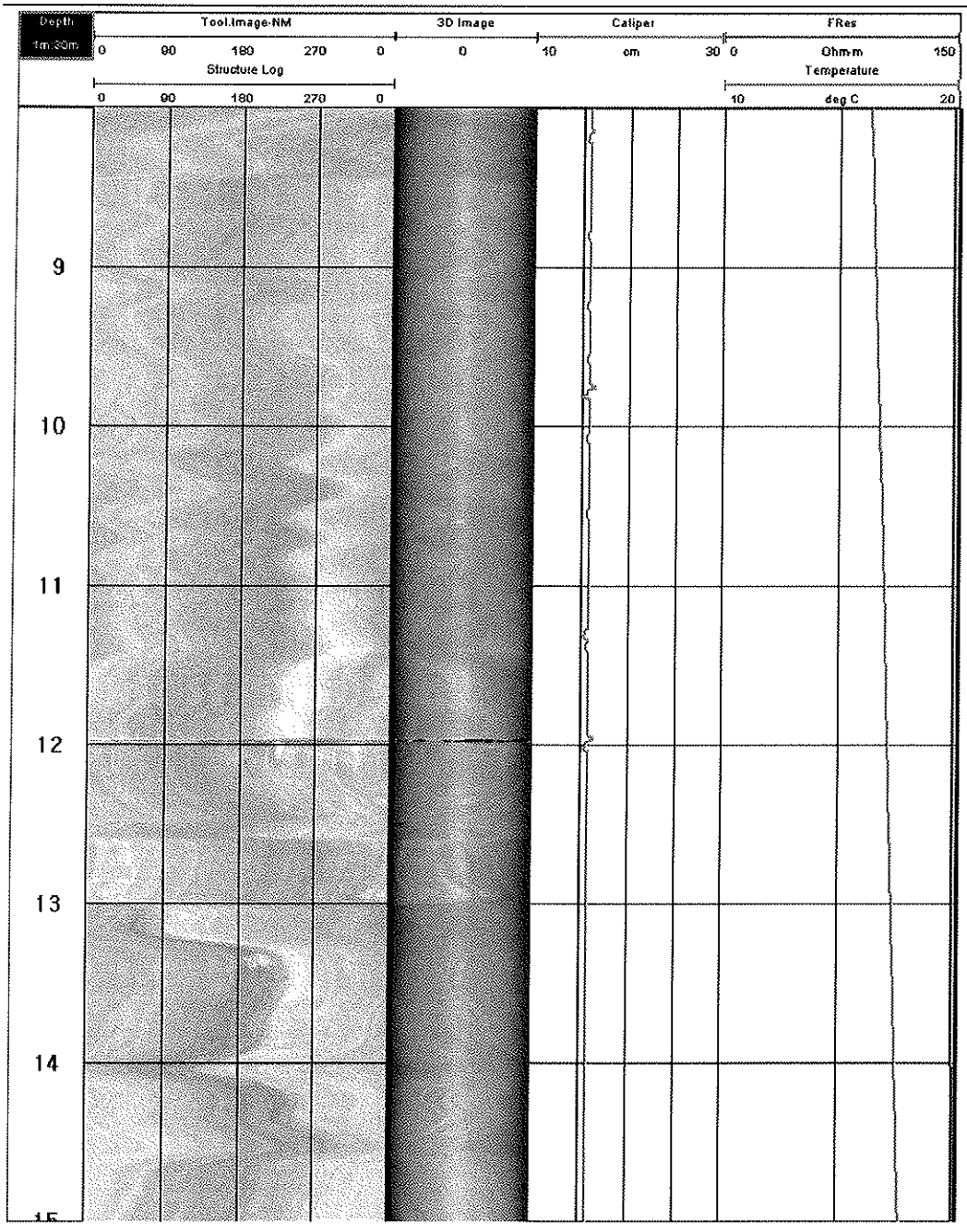
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FRes
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Ohm-m
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deg C
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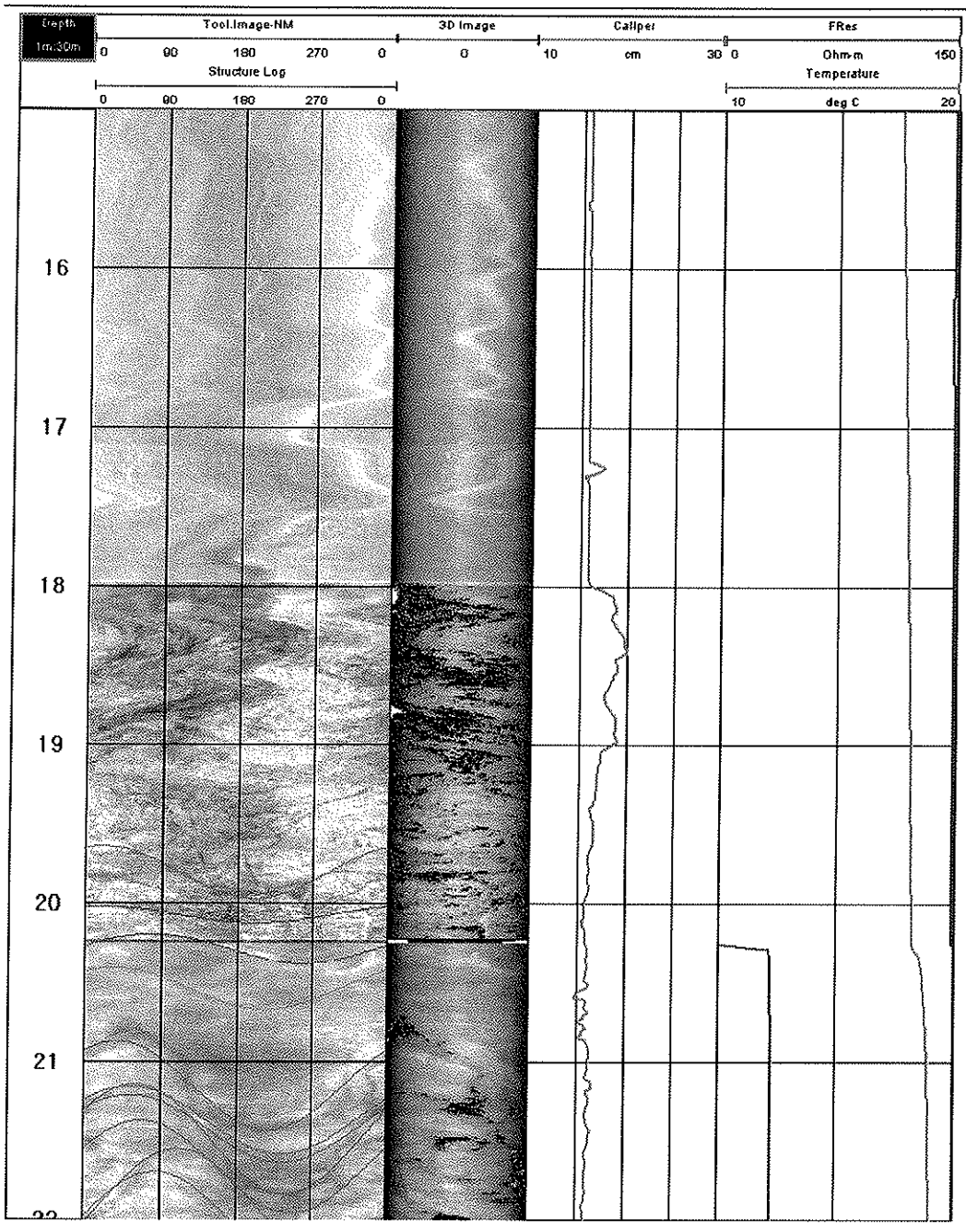
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Temperature
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deg C
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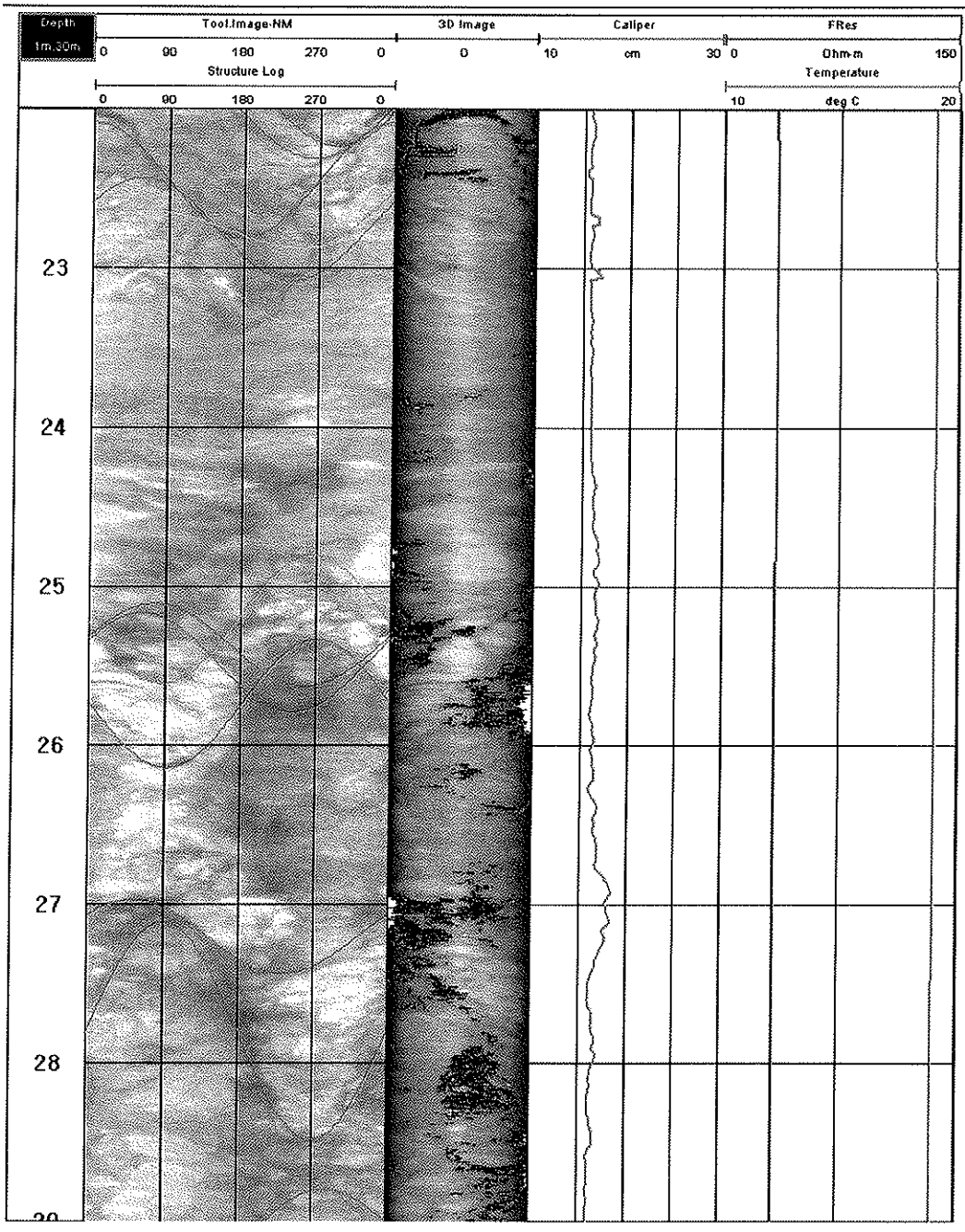
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deg C
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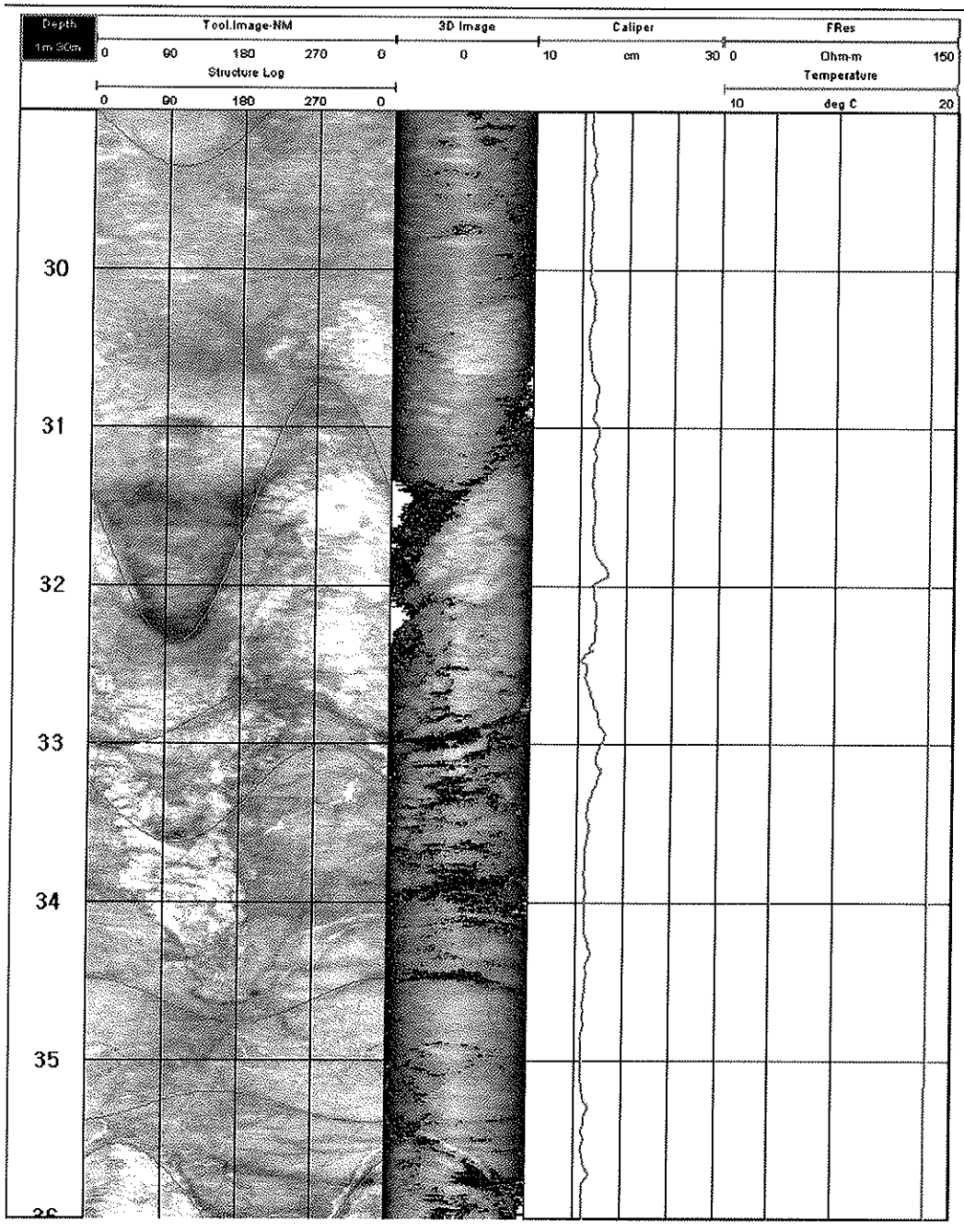
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Temperature
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deg C
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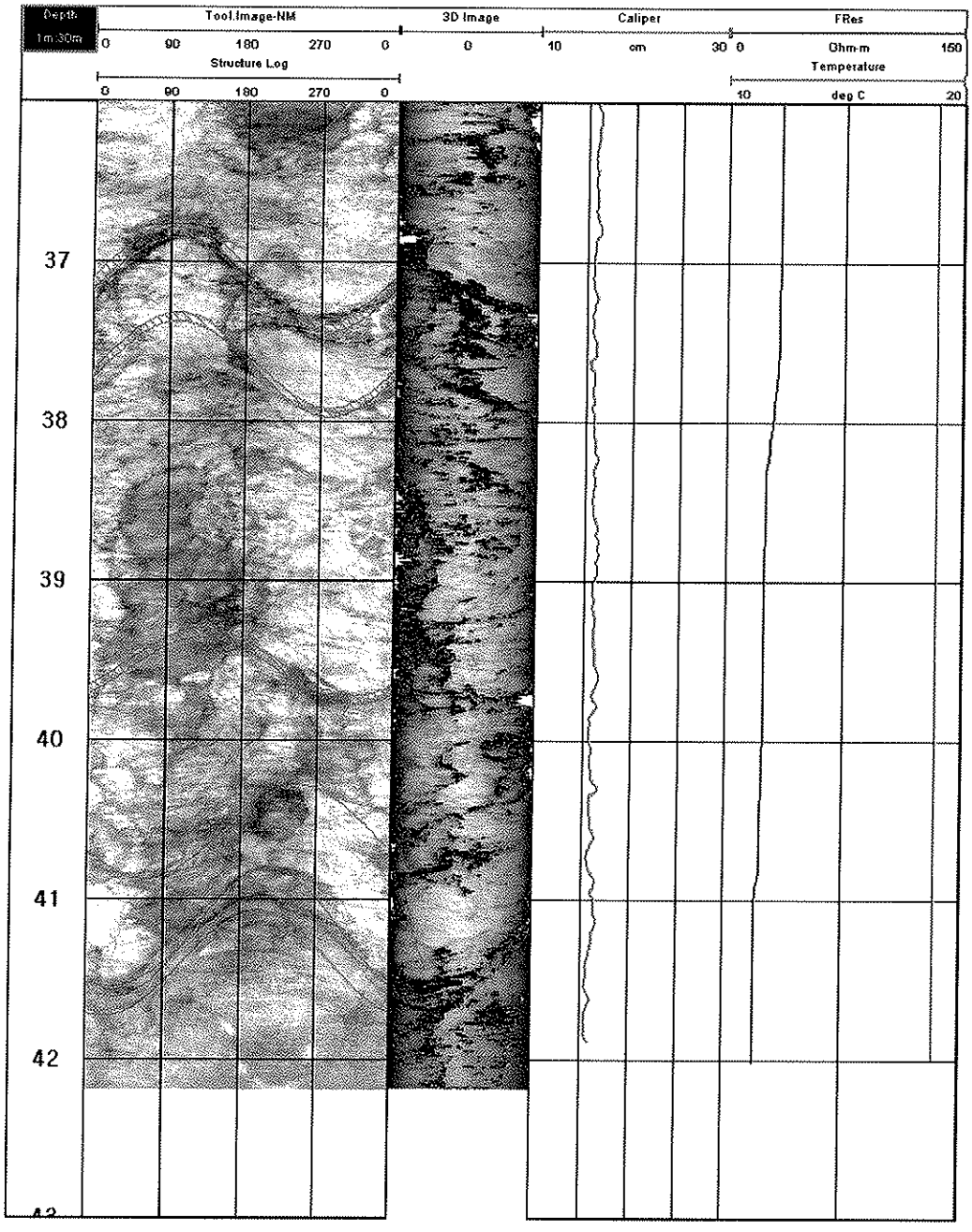
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3D Image
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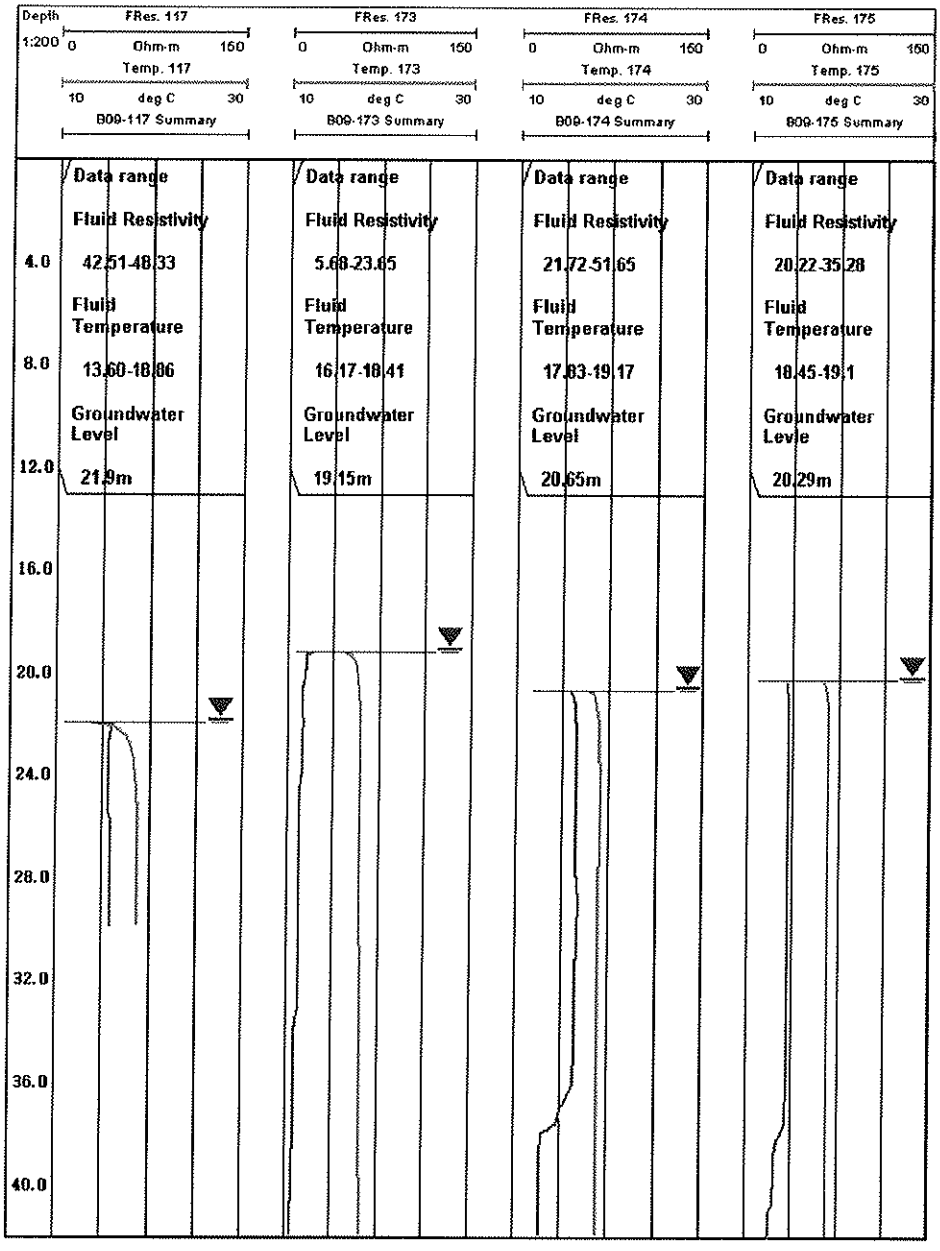
10
Caliper
cm
30
FRes
0
Ohm-m
150
Temperature
10
deg C
20
37
38
39
40
41
42

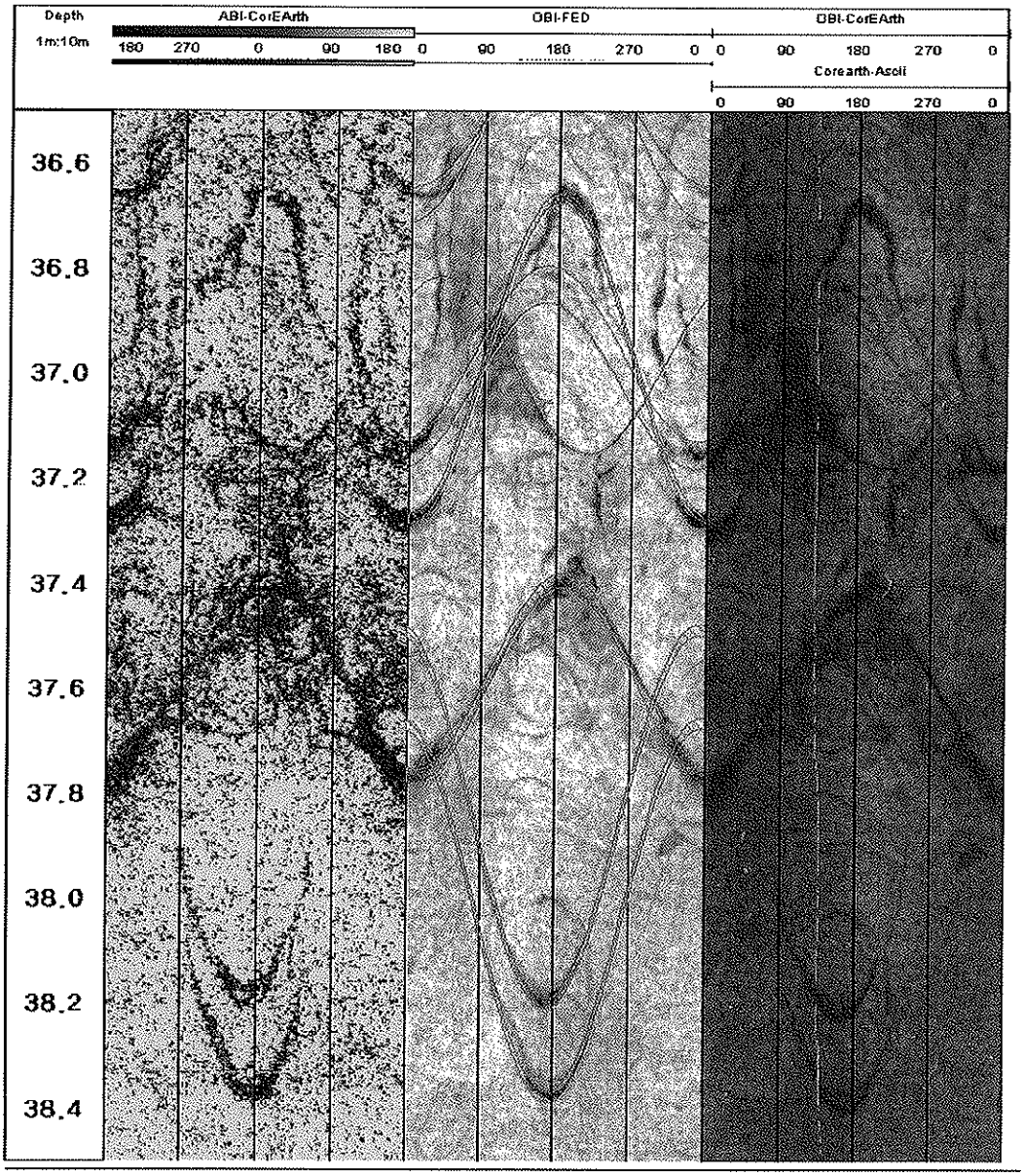
- **Borehole fluid logging at BEQ hill site**



Appendix II. Comparison result of OBI between two equipments what FED and CorEArth have and result of ABI at B09-175MW

Two comparisons take at borehole B09-175MW. One is equipment comparison between what FED and CorEArth have, and the other one is between OBI and ABI. It could be said the result between two different OBI logs are exactly same but the color slightly different because of the different setting. ABI log and OBI log have a good correlation each other.

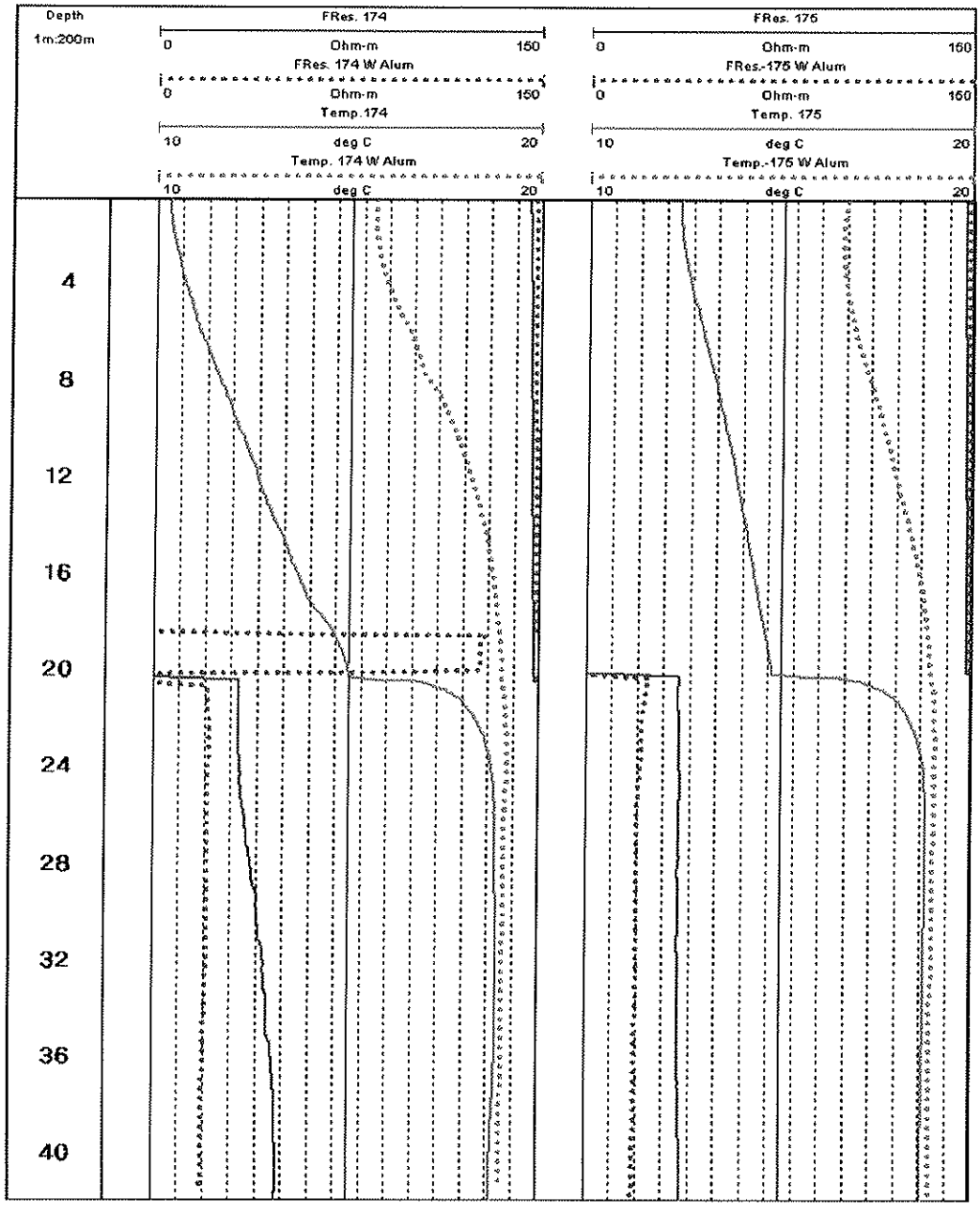
- **Result of comparisons**



Appendix III. Alum effect

The fluid resistivity log conduct more than two times before and after dissolve Alum in the borehole for a comparison. Alum used before OBI log for the clear vision of the borehole below the groundwater table but it influence the fluid resistivity because of its solubility. The fluid resistivities decrease ten to thirty Ohm-m when it use. There are details about Alum in Appendix IV.

- **Alum effect**

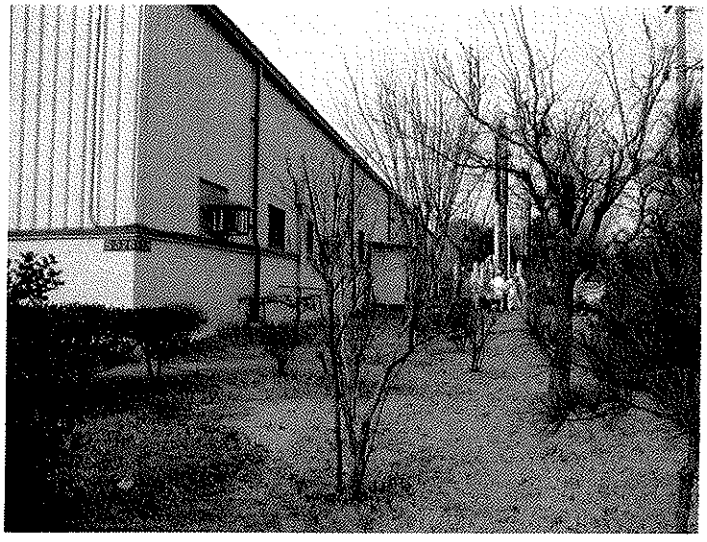


3596

US Army Corps of Engineers
Far East District

Report for

Environmental Site Investigation at Building 326 of Camp Carroll, Republic of Korea



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

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

AUGUST 2011

3597

Executive Summary

This Environmental Site Investigation (ESI) was conducted in the vicinity of Building 326 (also known as S326) located within Camp Carroll of the United States Army Garrison (USAG) Daegu, Republic of Korea (ROK). The presence of petroleum and solvent contamination (primarily residual diesel, gasoline type, as well as volatile organic compounds at the site had been identified during previous environmental sampling conducted in the area (USACE, 2004). The site contamination was the result of leakage from pipes that lead to aboveground storage tanks located to the west of Building S326. 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.

This ESI was conducted to delineate the lateral and vertical extents of soil contamination and the lateral extent of groundwater contamination present at Building 326, which is most likely associated with leakage from an underground fuel line. Thirty-two soil samples from 18 boreholes were collected and analyzed for various fractions of petroleum hydrocarbons. Eighteen of the 32 soil samples were also analyzed for volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). Three monitoring wells were installed and collected groundwater samples were analyzed for VOCs and PAHs.

This ESI identified that soil at the site is contaminated by residual- (RRO), gasoline- (GRO), and diesel- range organics (DRO) petroleum hydrocarbons, VOCs (benzene, toluene, ethylbenzene, total xylenes, 1,2-dichloroethane, hexachlorobutadiene, styrene, 1,1,1,2-tetrachloroethane, 1,2,4-trichlorobenzene, trichloroethene, and vinyl chloride), and PAHs (naphthalene).

The ESI demonstrated that the groundwater is contaminated with VOCs (benzene, toluene, naphthalene, and trichloroethene), and PAHs (2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene). Detections of dibromofluoromethane, 4-bromofluorobenzene, 2-butanone (MEK), carbon disulfide, chloroform and methylene chloride were also reported, but are suspected to be laboratory contaminants due to their detection at similar levels in the associated trip blank.

3598

Acronyms

°C	degrees Celcius
%	percent
µg/L	micrograms per liter
AAFES	Army and Air Force Exchange Service
ASTM	American Society of Test Methods
BEC	Beautiful Environmental Construction
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CEB-NEA	US Army-Combat Equipment Battalion-Northeast Asia
cm	centimeters
COPC	Contaminants of Potential Concern
CSM	conceptual site model
DoD	Department of Defense
DPW	Directorate of Public Works
DRO	Diesel Range Organics
Dup	duplicate
E2	Element Environmental, LLC
EAC	Echelon Above Corps
EDB	ethylene dibromide
EM	engineering manual
ESI	environmental site investigation
EPA	Environmental Protection Agency
FED	Far East District
GRO	gasoline range organics
HTRW	Hazardous, Toxic, and Radioactive Waste
IDW	Investigation-Derived Waste
IMCOM-K	Installation Management Command
K	conductivity
KATUSA	Korean Augmentation to the US Army
KEGS	Korean Environmental Governing Standards
km	kilometer
LCS	laboratory control spike
LCSD	laboratory control spike duplicate
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring
m^2	square meters
m^3/day	square meters
m/day	meters per day
MCLs	maximum contaminant levels
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
MEDLOG	16th Medical Logisitics
MTBE	Methyl tertiary-butyl ether

3599

MS	matrix spike
MSD	matrix spike duplicate
NCA	NCA Laboratory Korea
ND	not detected
N/A	Not Available
PA/SIs	Preliminary Assessments and Site Inspections
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PID	photoionization detector
PKNU	Pukyong National University
PPE	personal protective equipment
ppm	parts per million
PRGs	Preliminary Remediation Goals
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
ROK	Republic of Korea
RPDs	Relative Percent Differences
RRO	Residual Range Organics
SCFH	standard cubic feet per hour
SDGs	sample delivery groups
SI	Site Inspection
SSHO	Site Safety and Health Officer
SSHP	Site Safety and Health Plan
SVE	soil vapor extraction
SVOCs	Semi-Volatile Organic Compounds
TCE	trichloroethene
TPH	Total Petroleum Hydrocarbon
US	United States
USACE	United States Army Corps of Engineers
USACE FED	US Army Corps of Engineers, Far East District
USAG	United States Army Garrison
USAMSC-K	US Army Material Support Center-Korea
USFK	United States Forces Korea
UTM	Universal Transverse Mercator
VOCs	Volatile Organic Compounds
WGS84	World Geodetic System of 1984
WP	Work Plan

3600