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NAS CECIL FIELD
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LETTER TRANSMITTING FIELD TASK MODIFICATION REQUEST FORM FOR SITES 3 AND 5 AND LONG TERM MONITORING AT SITES 3, 5, 16, 17, 21, 57 AND 58 WITH ATTACHMENT NAS CECIL FIELD FL

6/8/2011

TETRA TECH

TETRA TECH

PITT-06-12-024

June 8, 2012

Project Number 112G02267

NAVFAC SE
Attn: Mr. Art Sanford
4130 Faber Place Drive
North Charleston, South Carolina 29405

Reference: CLEAN Contract No. N62470-08-D-1001
Contract Task Order JM09

Subject: Field Task Modification Request Forms: Sites 3 and 5, Modification to Sampling and Analysis Plan (SAP) for Long Term Monitoring at IR Sites 3, 5, 16, 17, 21, 57, and 58
Naval Air Station Cecil Field
Jacksonville, Florida

Dear Mr. Sanford:

Enclosed please find one copy of each subject deliverable. Copies have been sent to the members of the NAS Cecil Field Partnering Team as noted below. These documents are modifications to the SAP for Long Term Monitoring at IR Sites 3, 5, 16, 17, 21, 57, and 58. These FTMRs will be posted to the Cecil Field DWS and incorporated in the annual review submission of this document.

These modifications were discussed and agreed upon at the May 2012 BCT meeting (Decision 846), however, email approvals are required for the project file. Your prompt review and comment/approval is appreciated to enable the modifications to be implemented in the upcoming sampling events.

If you have any questions, please call me at 412-921-8163 or Megan Boerio 412-921-7271.

Sincerely,

Robert F. Simcik, P.E.
Task Order Manager

RFS/clm
Enclosure

cc: D. Vaughn-Wright, U.S. EPA (electronic copy)
D. Grabka, FDEP (1 copy)
M. Davidson, NAVFAC SE (electronic copy)
D. Criswell, NAVFAC SE (electronic copy)
S. Martin, NAVFAC Atlantic (electronic copy)
M. Halil, CH2MHill (electronic copy)
J. Trepanowski, Tetra Tech
S. Currie, Tetra Tech File JM09 (1 copy unbound)

Tetra Tech
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TETRA TECH NUS
FIELD TASK MODIFICATION REQUEST FORM

LTM/NAS Cecil Field Project/Installation Name	**CTO JM09, 112G02267** CTO & Project Number	**06** Task Mod. Number
SAP for Long-Term Monitoring At IR Sites 3,5,16,17,21,57, and 18, March 2011 Modification To (e.g. Work Plan)	**Site 3** Site/Sample Location	**6/08/12** Date

Activity Description: A solar-powered air sparge system is being installed at OU8, Site 3 as part of a Pilot Study. The system was installed in accordance with the approved Pilot Study Work Plan for Solar Powered Low Volume Air Sparging Treatment Curtain at Operable Unit 8, Site 3 (Tetra Tech, April 2012). As part of the pilot study, additional wells and well points were installed to monitor the effectiveness of the system. Wells CEF-003-40S and CEF-003-41S and well points WP#3 and WP#4 were installed the week of May 7, 2012. These wells and well points, along with well CEF-003-031S and well point WP#2 that were already present on site, will be sampled and analyzed for VOCs prior to system start up in accordance with the approved Work Plan and the UFP-SAP approved for Site 3 groundwater and surface water monitoring efforts. These results will be used as a baseline for comparison after system start up. Table 1 shows the wells and well points to be sampled, the analyses required, and the sampling frequency (before system start up, one month after start up, quarterly for four events, and annual). Figure 1 shows these wells and well points in relation to the site features and the solar-powered sparge system components. The current LTM program at Site 3 involves annual monitoring of three shallow wells for 19 VOCs; 6 shallow wells and two intermediate wells for the same 19 VOCs along with 6 SVOCs, and natural attenuation (NA) parameters; and one well point for 19 VOCs, 6 SVOCs, and NA parameters. The resulting groundwater and surface water COC concentrations are then compared against FDEP Groundwater Cleanup Target Levels (GCTLs), FDEP Surface Water Cleanup Target Levels (SWCTLs), and Natural Attenuation Default Criteria (NADCs). The newly-installed monitoring wells and well points are to be added into the regular annual LTM program, but are also to be sampled additionally, according to the approved Work Plan. After one year of monitoring of the wells and well points in the area of the sparge system, the frequency of the sampling will be re-evaluated by the team. All analytical SOPs that are needed for the groundwater and surface water analyses are included in the SAP.

Reason for Change: Additional wells and well points were installed as part of the Pilot Study for Solar-Powered Low-Volume Air Sparging Treatment Curtain at Site 3, NAS Cecil Field, and the new wells and well points must be added to the sampling and analysis plan to ensure that contamination does not enter the creek, and to monitor the effectiveness of the system. Changes to the sampling plan are in accordance with the decision rules established SAP.

Recommended Disposition: Verify acceptance of the revised sampling program via approval of this FTMR by e-mail approval from Tetra Tech PM, NAVFAC SE RPM, and FDEP; and attach these emails to this FTMR and add them to the project file.

T.E. Johnston (signature) — 6-7-12

Quality Assurance Manager (QAPP lead developer) — Date

Approved Disposition:

(signature) — 6/7/12

Project/Task Order Manager (Signature) — Date

Distribution:

Program/Project File – 112G02267
Project/Task Order Manager – Robert Simcik
Field Operations Leader – David Siefkin
NAVFAC SE RPM – Art Sanford

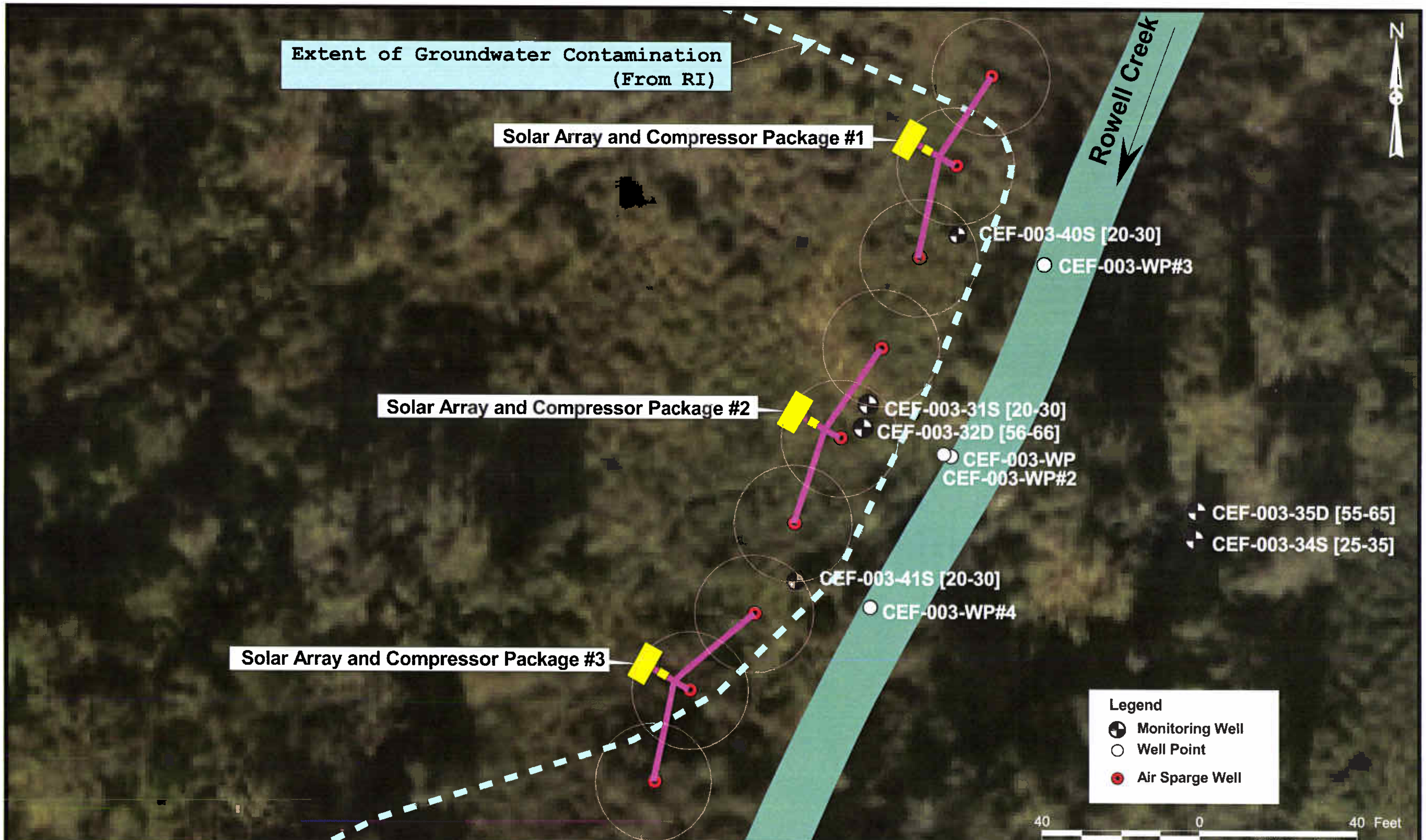
Other: ______

TABLE 1
SITE 3
ANALYTICAL SAMPLING SUMMARY FOR WELLS AND WELL POINTS ADDED TO THE LTM PROGRAM

Field Task Modification Request 06
Naval Air Station Cecil Field
Jacksonville, Florida

COC	# of Samples	Sampling Frequency	Sampling Location IDs	# of QC Samples	Laboratory Method [1]
GROUNDWATER					
VOCs:1,1,1-trichloroethane; 1,1,2-trichloroethane; 1,1-dichloroethane; 1,1-dichloroethene; 1,2-dichloroethane; 1,2-dichloropropane; benzene, carbon tetrachloride; chloroethane; chloroform; cis-1,2-dichloroethene; ethylbenzene; methylene chloride; tetrachloroethene; toluene; trans-1,2-dichloroethene; trichloroethene; vinyl chloride, total xylenes	5	Baseline prior to system start-up, one month after system start-up, Quarterly for one year (3 months after system start-up and then for the next three quarters), Annually as part of the LTM program	CEF-003-31S, CEF-003-40S, CEF-003-41S	1 Duplicate + 1 Trip blank	SW 846 8260B
SURFACE WATER					
VOCs:1,1,1-trichloroethane; 1,1,2-trichloroethane; 1,1-dichloroethane; 1,1-dichloroethene; 1,2-dichloroethane; 1,2-dichloropropane; benzene, carbon tetrachloride; chloroethane; chloroform; cis-1,2-dichloroethene; ethylbenzene; methylene chloride; tetrachloroethene; toluene; trans-1,2-dichloroethene; trichloroethene; vinyl chloride, total xylenes	3	Baseline prior to system start-up, one month after system start-up, Quarterly for one year (3 months after system start-up and then for the next three quarters), Annually as part of the LTM program	CEF-003-WP#2, CEF-003-WP#3, CEF-003-WP#4	1 Duplicate	SW 846 8260B

1 - Laboratory SOPs are included in the UFP-SAP.



DRAWN BY MJJ — DATE 05Jun12 CHECKED BY — DATE COST/SCHEDULE-AREA SCALE AS NOTED	NAVFAC	SOLAR SYSTEM LAYOUT AND SYSTEM MONITORING WELLS AND WELL POINTS OPERABLE UNIT 8, SITE 3 NAVAL AIR STATION CECIL FIELD JACKSONVILLE, FLORIDA	CONTRACT NUMBER 2267 APPROVED BY — DATE APPROVED BY — DATE DRAWING NO. FIGURE 1 — REV 0

\GIS\NAS_Cecil Field\Site-03_20110923 06Jun12 MJJ FTMR

TETRA TECH NUS
FIELD TASK MODIFICATION REQUEST FORM

LTM/NAS Cecil Field	**CTO JM09, 112G02267**	**05**
Project/Installation Name	CTO & Project Number	Task Mod. Number

SAP for Long-Term Monitoring At IR Sites 3,5,16,17,21,57, and 18, March 2011	**Site 5**	**6/06/12**
Modification To (e.g. Work Plan)	Site/Sample Location	Date

Activity Description: A DPT delineation event was conducted at Site 5, in general accordance with the FTMR Task Modification Number 03 to the SAP for Long-Term Monitoring at IR Sites 3,5,16,17,21,57,and 58. The LTM program at Site 5 currently consists of five monitoring wells being sampled on an annual basis to monitor the groundwater COC concentrations by comparing the results against FDEP Groundwater Cleanup Target Levels (GCTLs) and Natural Attenuation Default Criteria (NADCs). COCs include select volatile organic compounds (VOCs), select semi-volatile organic compounds (SVOCs), and vanadium. In addition to COCs, limited NA parameters are being collected. Annual LTM results at Site 5 indicated that a few COC concentrations in wells CEF-005-LTM01, CEF-005-LTM02, CEF-005-LTM04, and CEF-005-LTM05 continue to be greater than FDEP GCTLs as shown in Figure 1, included in Attachment 2 (Solutions-IES). Concentrations in upgradient monitoring well CEF-005-LTM01 have exhibited exceedances of contaminants that are not being detected in other wells at the site during recent sampling events. Because CEF-005-LTM01 has been recognized as the upgradient well, and there are currently several COCs with concentrations exceeding GCTLs, USEPA identified the need for an upgradient monitoring well that has contaminant concentrations less than the FDEP GCTLs. Well CEF-005-07S is upgradient of CEF-005-LTM01, but the well is damaged and cannot be sampled. DPT (Direct Push Technology) sampling was conducted to delineate the extent of the groundwater contamination plume upgradient of the identified source area in accordance with FTMR task modification number 3. The samples were analyzed for select VOCs, select SVOCs, and vanadium. The samples were collected at thirteen locations at a depth of 10 feet bgs, and at four locations at depths of 10 feet bgs and 20 feet bgs. The DPT sample locations are identified on Figure 2. Based on the results of the DPT groundwater samples, three additional monitoring wells were recommended for installation at the May 2012 BCT meeting (Minute 2742). The team agreed to three locations, one upgradient and two downgradient, for new monitoring wells to be installed (Decision 846). Figure 3 shows the agreed upon new well locations. The wells will be installed as one-inch diameter wells with 10-foot screens from 5-15 feet below ground surface. The newly-installed monitoring wells are to be sampled for select VOCs, select SVOCs, and vanadium as upon installation, and then regularly as part of the on-going LTM program. Table 1, included in Attachment 1, shows the parameters and number of samples to be taken for groundwater. Attachment 3 includes the field Standard Operating Procedures (SOPs) necessary in the installation of the new monitoring wells and sampling. All analytical SOPs that are needed for the groundwater analyses are included in the SAP. Changes to the sampling plan are in accordance with the decision rules established in the SAP.

Reason for Change: EPA requested and the BCT agreed that an additional clean upgradient well was required, along with downgradient wells in the new downgradient direction (groundwater flow is to the east, as indicated by the groundwater elevation lines shown on Figure 3). These wells will be installed and added to the LTM program. Samples will be collected and analyzed for the same COCs as included in the LTM plan upon installation and development, and then will be sampled along with all other wells in the plan moving forward.

Recommended Disposition: Verification of acceptance of the revised sampling program via approval of this FTMR by e-mail approval from Tetra Tech PM, NAVFAC SE RPM, EPA and FDEP will be attached to the FTMR and placed in the project file.

T. E. Johnston (signature)

Quality Assurance Manager (QAPP lead developer)

6-7-12

Date

Approved Disposition:

Project/Task Order Manager (Signature)

6/7/12
Date

Distribution:

Program/Project File – 112G02267
Project/Task Order Manager – Robert Simcik
Field Operations Leader – David Siefkin
BRAC PMO RPM – Art Sanford

Other:

ATTACHMENT 1

Table

TABLE 1
SITE 5
ANALYTICAL SAMPLING SUMMARY FOR WELLS
ADDED TO THE LTM PROGRAM

Field Task Modification Request 05
Naval Air Station Cecil Field
Jacksonville, Florida

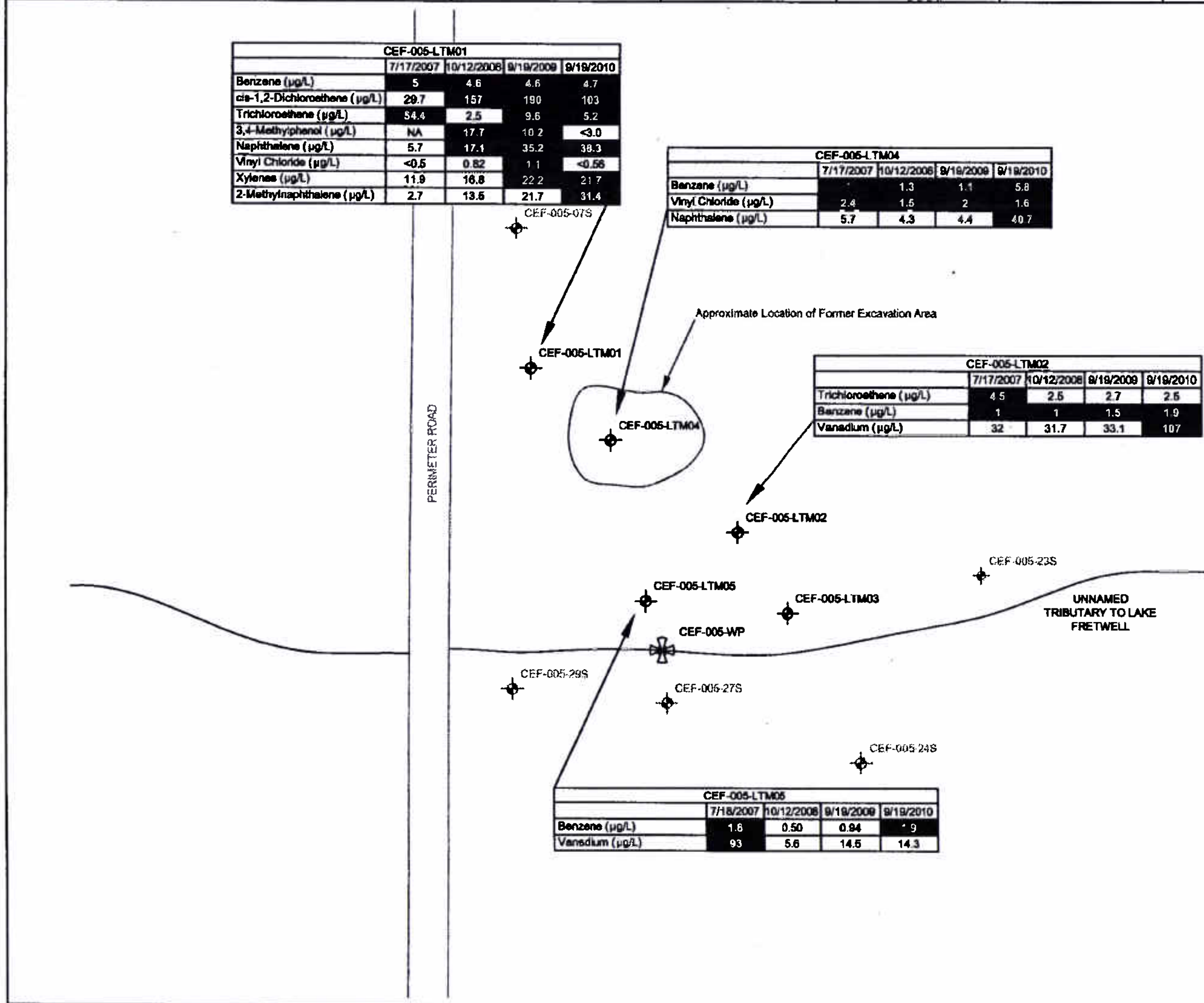
GROUNDWATER				
COC	**# of Samples**	**Sample IDs**	**# of QC Samples**	**Laboratory Method** [1]
VOCs: benzene, 1,1-dichloroethene, cis-1,2-dichloroethene, trichloroethene, vinyl chloride, total xylenes	3	CEF-005-31S, CEF-005-32S, CEF-005-33S	1 Duplicate	SW 846 8260B
PAHs: 1-methylnaphthalene, 2-methylnaphthalene, naphthalene, 4-methylphenol				SW 846 8270 SIM
Vanadium				SW-846 6010B

1 - Laboratory SOPs are included in the UFP-SAP.

ATTACHMENT 2

Figures

FILE	DATE	PROJECT MANAGER	CHECKED BY	DRAFTER	PROJECT NUMBER
Figure 4.pdf	11/29/2010	BMR	XXX	HRG	8030.08A2.NAVF



CEF-005-LTM01	7/17/2007	10/12/2008	9/19/2009	9/19/2010
Benzene (µg/L)	5	4.6	4.6	4.7
cis-1,2-Dichloroethene (µg/L)	29.7	157	190	103
Trichloroethene (µg/L)	54.4	2.5	9.6	5.2
3,4-Methylphenol (µg/L)	NA	17.7	10.2	<3.0
Naphthalene (µg/L)	5.7	17.1	35.2	38.3
Vinyl Chloride (µg/L)	<0.5	0.82	1.1	<0.56
Xylenes (µg/L)	11.9	16.8	22.2	21.7
2-Methylnaphthalene (µg/L)	2.7	13.6	21.7	31.4

CEF-005-LTM04	7/17/2007	10/12/2008	9/19/2009	9/19/2010
Benzene (µg/L)	[illegible]	1.3	1.1	5.8
Vinyl Chloride (µg/L)	2.4	1.5	2	1.6
Naphthalene (µg/L)	5.7	4.3	4.4	40.7

CEF-005-LTM02	7/17/2007	10/12/2008	9/19/2009	9/19/2010
Trichloroethene (µg/L)	4.5	2.5	2.7	2.5
Benzene (µg/L)	1	1	1.5	1.9
Vanadium (µg/L)	32	31.7	33.1	107

CEF-005-LTM05	7/18/2007	10/12/2008	9/19/2009	9/19/2010
Benzene (µg/L)	1.8	0.50	0.94	1.9
Vanadium (µg/L)	93	5.6	14.5	14.3

LEGEND

- MONITORING WELL (WATER LEVEL ONLY)
- MONITORING WELL (SAMPLED)
- WELL POINT SAMPLE LOCATION
- 4.2 EXCEEDANCE OF GCTL[3] OR SWCTL[4]

NOTES:

1) WELL LOCATIONS ARE APPROXIMATE AND BASED ON SURVEY DATA.
2) MAP DRAWN USING GIS DATA FROM Tetra Tech NUS, Inc.
3) GCTL - GROUNDWATER CLEANUP TARGET LEVEL
4) SWCTL - SURFACE WATER CLEANUP TARGET LEVEL

0 100 200

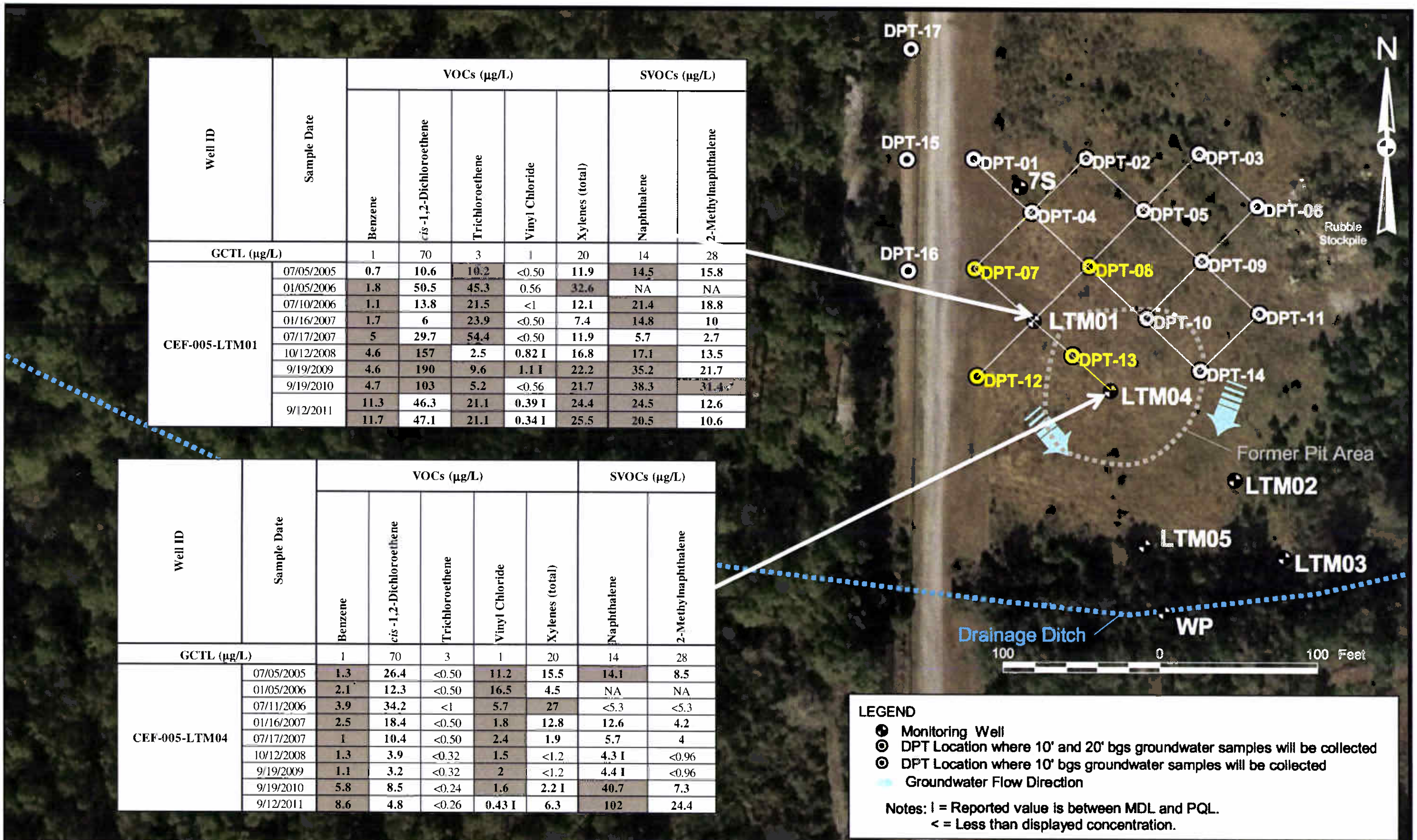
SCALE IN FEET

Solutions-IES
Industrial & Environmental Services
1101 NOWELL ROAD
RALEIGH, NORTH CAROLINA 27607
TEL.: (919) 873-1060 FAX.: (919) 873-1074

CONTAMINANT CONCENTRATION MAP
SITE 5 - NAS CECIL FIELD
JACKSONVILLE, FLORIDA
SEPTEMBER 2010

FIGURE: 1

J:\Project Files\Cecil Field\Cecil Field 2\CAD\Current Drawings\Site 5\8030-SITE5X.dwg, 4, 1:1



Well ID	Sample Date	VOCs (µg/L)					SVOCs (µg/L)	
		Benzene	*cis*-1,2-Dichloroethene	Trichloroethene	Vinyl Chloride	Xylenes (total)	Naphthalene	2-Methylnaphthalene
GCTL (µg/L)		1	70	3	1	20	14	28
CEF-005-LTM01	07/05/2005	0.7	10.6	10.2	<0.50	11.9	14.5	15.8
	01/05/2006	1.8	50.5	45.3	0.56	32.6	NA	NA
	07/10/2006	1.1	13.8	21.5	<1	12.1	21.4	18.8
	01/16/2007	1.7	6	23.9	<0.50	7.4	14.8	10
	07/17/2007	5	29.7	54.4	<0.50	11.9	5.7	2.7
	10/12/2008	4.6	157	2.5	0.82 I	16.8	17.1	13.5
	9/19/2009	4.6	190	9.6	1.1 I	22.2	35.2	21.7
	9/19/2010	4.7	103	5.2	<0.56	21.7	38.3	31.4
	9/12/2011	11.3	46.3	21.1	0.39 I	24.4	24.5	12.6
		11.7	47.1	21.1	0.34 I	25.5	20.5	10.6

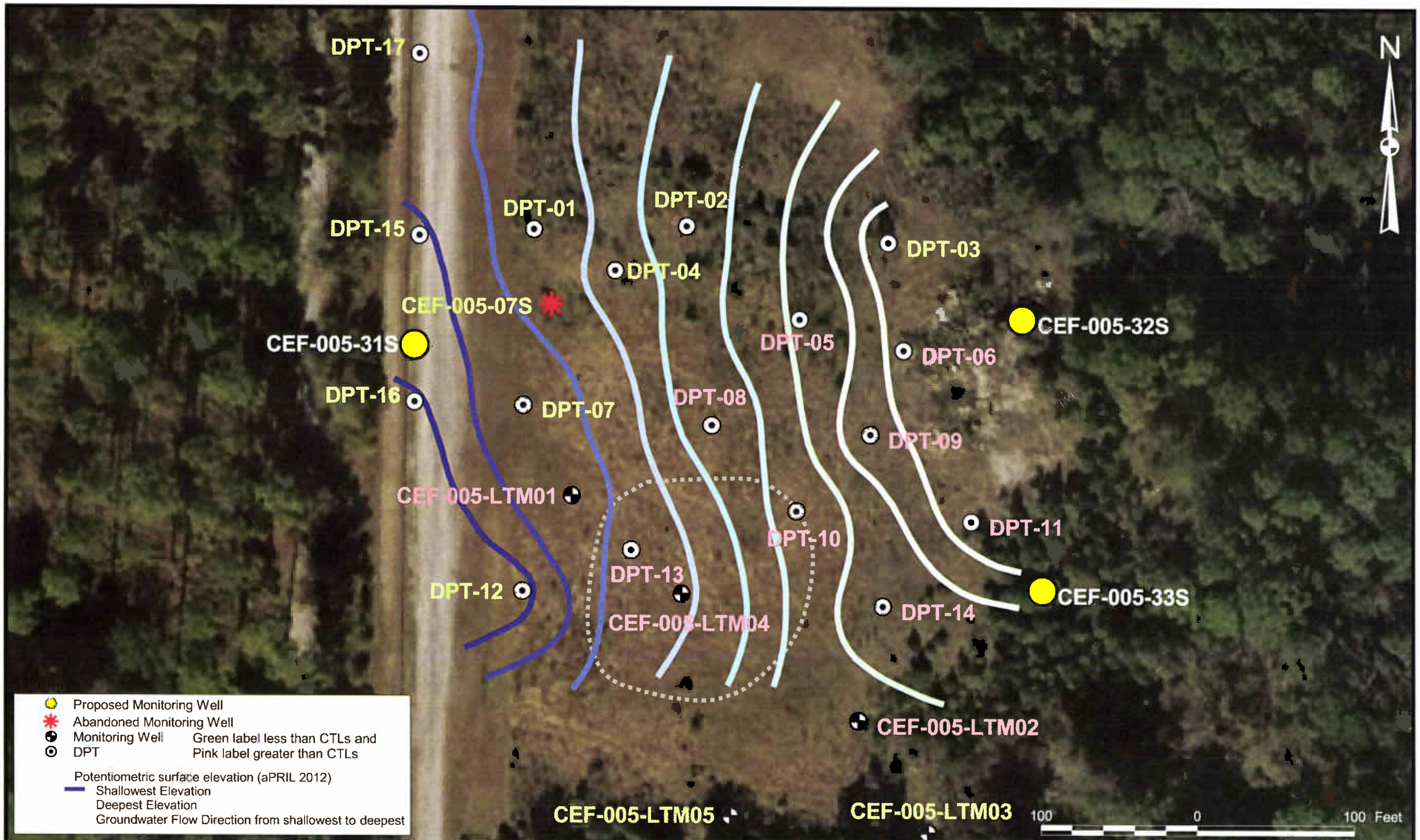
Well ID	Sample Date	VOCs (µg/L)					SVOCs (µg/L)	
		Benzene	*cis*-1,2-Dichloroethene	Trichloroethene	Vinyl Chloride	Xylenes (total)	Naphthalene	2-Methylnaphthalene
GCTL (µg/L)		1	70	3	1	20	14	28
CEF-005-LTM04	07/05/2005	1.3	26.4	<0.50	11.2	15.5	14.1	8.5
	01/05/2006	2.1	12.3	<0.50	16.5	4.5	NA	NA
	07/11/2006	3.9	34.2	<1	5.7	27	<5.3	<5.3
	01/16/2007	2.5	18.4	<0.50	1.8	12.8	12.6	4.2
	07/17/2007	1	10.4	<0.50	2.4	1.9	5.7	4
	10/12/2008	1.3	3.9	<0.32	1.5	<1.2	4.3 I	<0.96
	9/19/2009	1.1	3.2	<0.32	2	<1.2	4.4 I	<0.96
	9/19/2010	5.8	8.5	<0.24	1.6	2.2 I	40.7	7.3
	9/12/2011	8.6	4.8	<0.26	0.43 I	6.3	102	24.4

LEGEND
- Monitoring Well
- DPT Location where 10' and 20' bgs groundwater samples will be collected
- DPT Location where 10' bgs groundwater samples will be collected
- Groundwater Flow Direction

Notes: I = Reported value is between MDL and PQL.
< = Less than displayed concentration.

DRAWN BY	DATE		DPT LOCATION MAP	CONTRACT NUMBER	
MJJ	15Dec11	NAVFAC	OPERABLE UNIT 2, SITE 5	2267	
CHECKED BY	DATE		NAVAL AIR STATION CECIL FIELD	APPROVED BY	DATE
COST/SCHEDULE-AREA			JACKSONVILLE, FLORIDA	APPROVED BY	DATE
SCALE AS NOTED				DRAWING NO. FIGURE 2	REV 0

\GIS\NAS_CecilField\Site-05_20111027.apr 04Jan12 MJJ Layout01-02



DRAWN BY MJJ / DATE 17May12	NAVFAC	PROPOSED WELL LOCATIONS MAP	CONTRACT NUMBER 2267
CHECKED BY / DATE		OPERABLE UNIT 2, SITE 5	APPROVED BY / DATE
COST/SCHEDULE-AREA		NAVAL AIR STATION CECIL FIELD	APPROVED BY / DATE
SCALE AS NOTED		JACKSONVILLE, FLORIDA	DRAWING NO FIGURE 3 / REV 0

site-05_20111027 04Jun12 MJJ Layout4

ATTACHMENT 3

Field SOPs

TABLE OF CONTENTS

SECTION **PAGE**

ATTACHMENTS

1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is screened, cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored. Some monitoring wells may be constructed as open boreholes.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Field Geologist - The field geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well or piezometer:

- Health and safety equipment (hard hats, safety glasses, etc.) as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installation tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 Well Design

The objectives and intended use for each monitoring well must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow directions and potential well locations can be determined by an experienced hydrogeologist through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the depths at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (5 feet or less) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. Drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole bedrock monitoring wells are used. With smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced; however, the sampling devices that can be used are limited.

In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples), particularly if the monitored formation is known to be a low-yielding formation. The unit volume of water contained within a monitoring well is dependent on the well diameter as follows:

Casing Inside Diameter (Inch)	Standing Water Length to Obtain 1 Gallon Water (Feet)
2	6.13
4	1.53
6	0.68

If a well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells (for installation of high capacity pumps); however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "Schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength". Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel. Properties of these two materials are compared in Attachment B. Stainless steel is a good choice where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, ease of manipulation, and widespread acceptance. The crushing strength of PVC may limit the depth of installation, but the use of Schedule 80 materials may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe may corrode and release metal ions or chemically react with organic constituents, but this is considered a minor issue. Galvanized steel is not recommended where samples may be collected for metals analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary, and the annular borehole space around the screened interval is artificially packed with an appropriately sized sand, selected based on formation grain size. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The site geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a medium-to coarse-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed). In this case, the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets, extending to the surface. The grout effectively seals the remaining borehole annulus and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom upward, to prevent bridging, and to provide a better seal. In shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of one or two assemblages of material, (e.g., cement and/or bentonite). A cement-bentonite grout, which is the most common type of grout used in monitoring well completions, normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus 3 to 5 pounds of granular or flake-type bentonite, and 6-7 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6-7 gallons of water. A bentonite slurry (bentonite and water mixed to a thick but pumpable mixture) is sometimes used instead of grout for deep well installations where placement of bentonite pellets is difficult. Bentonite chips are also occasionally used for annular backfill in place of grout.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets/chips or sand. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is typically placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface (flush-mounted) is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter, manhole-type protective collar is set into the wet cement around the well with the top set level with or slightly above the pavement. An appropriately-sized id is placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 Monitoring Well Installation

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is slowly poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur. Centralizers may be used at the geologist's discretion, one above and one below the screen, to assure enough annular space for sand pack placement.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack. Pellets should be added slowly and their fall monitored closely to ensure that bridging does not occur.

The cement-bentonite grout is then mixed and tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between aquifers. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 5 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting a large-diameter casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells. Sufficient time (determined by the field geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 –10 feet into bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued into bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. If a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be removed when the final well installation is completed.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen section is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be manually driven to depths exceeding 10 feet.

Direct push sampling/monitoring point installation methods, using a direct push rig or drilling rig, are described in SOP SA-2.5.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only small-diameter tubes extending to the surface. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. Four manufacturers of these samplers include Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, BARCAD Systems, Inc., of Concord, Massachusetts, Westbay Instruments Ltd. of Vancouver, British Columbia, Canada and the University of Waterloo at Waterloo, Ontario, Canada.. Each manufacturer offers various construction materials.

5.4 <u>Well Development Methods</u>

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity, turbidity, and temperature taken during development may yield information (stabilized values) regarding whether sufficient development has been performed. The selection of the well development method shall be made by the field geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

5.4.1 Overpumping and Backwashing

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

5.4.2 Surging with a Surge Plunger

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is aggressively moved up and down within the well to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus introducing air into the formation and reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 RECORDS

A critical part of monitoring well installation is recording of all significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features, screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed, ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded, depending on whether the well is completed in overburden (single- or double-cased), as a cased well in bedrock, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have an idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in or bridging of the backfill materials. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

7.0 REFERENCES

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ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

1 Teflon[7]
2 Stainless Steel 316
3. Stainless Steel 304
4 PVC 1
5 Lo-Carbon Steel
6 Galvanized Steel
7 Carbon Steel

* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton[7]*	Silicone	Neoprene	Teflon[7]*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

1 Teflon[7]
2 Polypropylene (PP)
3. PVC Flexible/PE Linear
4 Viton[7]
5 PE Conventional
6 Plexiglas/Lucite (PMM)
7 Silicone/Neoprene

* Trademark of DuPont

Source: Barcelona et al., 1983

ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned if organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

* See also Attachment A.