N00164.AR.002261
NSA CRANE
5090.3a

FIELD TASK MODIFICATION REQUEST NUMBER 1 SOLID WASTE MANAGEMENT UNIT 25 (SWMU 25) NSA CRANE IN
7/1/2011
TETRA TECH

FIELD TASK MODIFICATION REQUEST NO. 01

SWMU 25
NSA CRANE
CRANE, INDIANA

Groundwater sampling was conducted at NSA Crane SWMU 25 during July 2011. Two of the monitoring wells (25MW04/WES-7-4-81 and 25MW05/WES-7-5-81) were found to be compromised. After an evaluation of the data for these two wells, a determination was made that the data is not representative, and the installation of a new well is recommended. The following presents a discussion of SWMU 25 history and groundwater sampling, including tables and figures from the current SWMU 25 Draft RFI, and specific recommendations for future action.

SITE BACKGROUND

SWMU 25 – Highway 58 Dump Site A was a disposal area that received paper, concrete, pipe, scrap metal, paint thinners, and oil. In 1995 and 1996, an Interim Measure (IM) was conducted at SWMU 25. The objective of the IM was to remove debris and incidental soil excavated with the debris. SWMU 25 Dump Site A consists of two discrete dump areas. A larger area, approximately 150 feet by 39 feet, and a second smaller area, approximately 25 feet by 10 feet. All debris was removed from the smaller dump site area during the IM. However, additional debris discovered during the IM at the larger dump site area was left in place because it appeared to have been used as backfill to support Highway 58. Based on this, it was recommended that SWMU 25 revert back to the RFI process beginning with soil borings along both sides of Highway 58 to determine if there is a need for further remediation.

As part of this RFI, 11 soil and 5 groundwater samples were collected within the SWMU 25 boundary. The samples were collected and analyzed for semi-volatile organic compounds (SVOCs) and metals, as presented in the SAP. All soil samples were able to be collected in accordance with the SAP sampling protocols. However, groundwater samples could only be collected in accordance with the SAP from three of the five wells. Two of the wells (25MW04 and 25MW05) could not be sampled properly due to bent casings, which prohibited a pump from being lowered into the well for low-flow sample collection. Therefore, only grab samples (no purging) were able to be collected with the use of tubing and a foot valve from these two wells, resulting in very turbid samples.

Figure 1 presents the locations of the soil borings and monitoring wells. Figure 2 presents the groundwater flow map.

GROUNDWATER ANALYTICAL RESULTS

The groundwater samples were analyzed for SVOCs and Appendix IX total metals. Wells with turbidity values above 10 NTU were also analyzed for dissolved metals.

Table 1 presents the groundwater analytical data summary for positive hits and exceedances of minimum screening criterion.

Total Metals

Total metals were detected in all five groundwater samples. The regulatory screening values in groundwater total analyses were exceeded for the following metals: aluminum, arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, thallium, and zinc.

The locations of the exceedances of the regulatory screening criteria for total metals in groundwater are shown on Figure 3. The maximum total metal concentrations were predominantly detected in samples collected from monitoring wells 25MW04 and 25MW05.

Dissolved Metals

Dissolved metals were analyzed in 4 of the 5 groundwater samples. The locations of the exceedances of the regulatory screening criteria for dissolved metals in groundwater are shown on Figure 3. Similar to the total metals analyses, the maximum dissolved metal concentrations were predominantly detected in samples collected from in monitoring wells 25MW04 and 25MW05.

SVOCs

SVOCs were detected in only one of the 5 groundwater samples. This sample was collected from monitoring well 25MW04, which is one of the compromised wells. The regulatory screening values in groundwater were only exceeded for the SVOCs n-nitroso-di-n-propylamine (DPN) and pentachlorophenol (PCP).

The location of the exceedances of the regulatory screening criteria for SVOCs in groundwater is shown on Figure 4.

GROUNDWATER DATA

As discussed above, both wells 25MW04 and 25MW05 show apparent damage from land subsidence, and the structural integrity of both wells has been seemingly compromised. The casings are bent in both

wells, and well 25MW04 had 9 feet of sediment at the bottom, indicating the well casing may be broken/cracked as well. Therefore, the groundwater samples collected from these two wells were very turbid, and not comparable to the groundwater samples collected from the other three site wells. The data from these two samples is not believed to be representative of actual aquifer quality conditions. Based on this information, Tetra Tech does not believe the data from these two wells should be used in making risk-based decisions for the site.

RECOMMENDATIONS

Based on the questionable data quality of the two groundwater samples collected from wells 25MW04 and 25MW05, the following are recommended to be implemented:

- Abandon wells 25MW04 and 25MW05.

- Install a new monitoring well (25MWT06) located equidistant between wells 25MW04 and 25MW05, and conduct one additional round of groundwater sampling from the three existing wells (25MW01 to 25MW03) and the one new well. Figure 5 presents the location of the proposed new well. The samples would be analyzed for total and dissolved metals (if turbidity above 10 NTUs), and SVOCs (including PCP and DPN). The new monitoring well will be installed and screened at the same depth as the abandoned wells.

- Develop the newly installed well

- Collect one round of samples from the three existing and one newly installed well.

- Analyze the samples for total and dissolved metals (if turbidity above 10 NTUs), and SVOCs (including PCP and DPN).

Attachment A presents the boring logs and well construction diagrams for the two wells to be abandoned. Attachment B presents the Standard Operating Procedures (SOPs) for well installation, lithologic logging and well abandonment.

TABLE 1

POSITIVE HITS IN GROUNDWATER
SWMU 25 - HIGHWAY 58 DUMP SITE A
NSA CRANE
CRANE, INIDIANA

LOCATION	PSL	PSL REFERENCE	25MW01	25MW02	25MW03		25MW04	25MW05
SAMPLE ID			25GW718101	25GW728101	25GW738101	25GW738101-D	25GW748101	25GW758101
SAMPLE DATE			20110713	20110714	20110713	20110714	20110714	20110714
SAMPLE CODE			NORMAL	NORMAL	NORMAL	DUP	NORMAL	NORMAL
MATRIX			GW	GW	GW	GW	GW	GW
SAMPLE TYPE			NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
DISSOLVED METALS (µg/L)								
ALUMINUM	3700	T-RSL	NA	1.7 J	4.3 J	NA	2.2 J	3.2 J
ARSENIC	0.045	T-RSL	NA	0.41 J	0.85	NA	14	1.3
BARIUM	730	T-RSL	NA	8 J	90	NA	39	34
CHROMIUM	0.043	T-RSL	NA	3.9 J	2.6 J	NA	3.2 J	2.5 J
COBALT	1.1	T-RSL	NA	18	2.4	NA	47	250
COPPER	150	T-RSL	NA	0.91 J	0.61 J	NA	0.42 U	0.34 U
IRON	2600	T-RSL	NA	2400	50 U	NA	4200	100
MANGANESE	88	T-RSL	NA	1200	570	NA	1800	15000
NICKEL	73	T-RSL	NA	42	6	NA	130	63
VANADIUM	18	T-RSL	NA	1 J	0.89 J	NA	0.98 J	0.58 J
ZINC	1100	T-RSL	NA	16 J	2.2 J	NA	20 J	55
TOTAL METALS (µg/L)								
ALUMINUM	3700	T-RSL	61 J	39 J	190 J	76 J	920 J	16000 J
ARSENIC	0.045	T-RSL	1.2 U	1.5 U	2	1 U	32	10
BARIUM	730	T-RSL	120	9.3 J	110	120	200	240
BERYLLIUM	4	G-DCL	0.2 U	0.2 U	0.2 U	0.1 J	0.74	16
CADMIUM	1.8	T-RSL	0.44 U	0.46	0.24 U	0.42 U	0.85	13
CHROMIUM	0.043	T-RSL	0.57 U	0.5 U	1.8 J	0.65 U	2 J	7
COBALT	1.1	T-RSL	7.47	20	3.9	9.2	370	870
COPPER	150	T-RSL	1.8 J	1.4 J	2.3	2.2	11	37
IRON	2600	T-RSL	5500	3300	3900	5200	56000	28000
LEAD	15	T-RSL	0.97	0.32 U	2.4	1.2	8.8	23
MANGANESE	88	T-RSL	6100 J	1400 J	810 J	5600 J	11000 J	30000 J
NICKEL	73	T-RSL	54 J	49 J	9.2 J	53 J	1100 J	150 J
SELENIUM	18	T-RSL	1 U	1 U	1 U	1 U	1.2 U	12
THALLIUM	2	G-DCL	0.29 U	0.2 U	0.2 U	0.2 U	0.2 U	2.4 J
VANADIUM	18	T-RSL	0.2 UJ	0.27 J	2.9 J	0.2 UJ	3.3 J	9.9 J
ZINC	1100	T-RSL	72	17 J	7.4 J	81	1200	980
SEMIVOLATILES (µg/L)								
BIS(2-ETHYLHEXYL)PHTHALATE	4.8	T-RSL	0.5 U	0.5 U	0.5 U	0.76 J	0.35 J	0.73 J
N-NITROSO-DI-N-PROPYLAMINE	0.0096	T-RSL	0.5 U	0.5 U	0.5 U	0.5 U	1.4 J	0.5 U
PENTACHLOROPHENOL	0.17	T-RSL	2.5 UR	2.5 UJ	2.5 UJ	2.5 UR	2.2 J	2.5 UR

Notes:
DUP = duplicate
GW = Groundwater Sample
J = Value is estimated
G-DCL = IDEM Groundwater Default Closure Level (May, 2009).
NA = Not analyzed
PSL = Project Screening Level
T-RSL = USEPA Regions 3, 6, and 9 Regional Screening Level for Soil, Tapwater, adjusted to 1/10 of value for noncarcinogens (November, 2010
U = Analyte not detected at the reporting limit
UJ = Numerical detection limit for the undetected result is estimated
µg/L = Microgram per Liter
Shaded cells and boldface font indicate that the concentration is greater than the minimum screening criterion.

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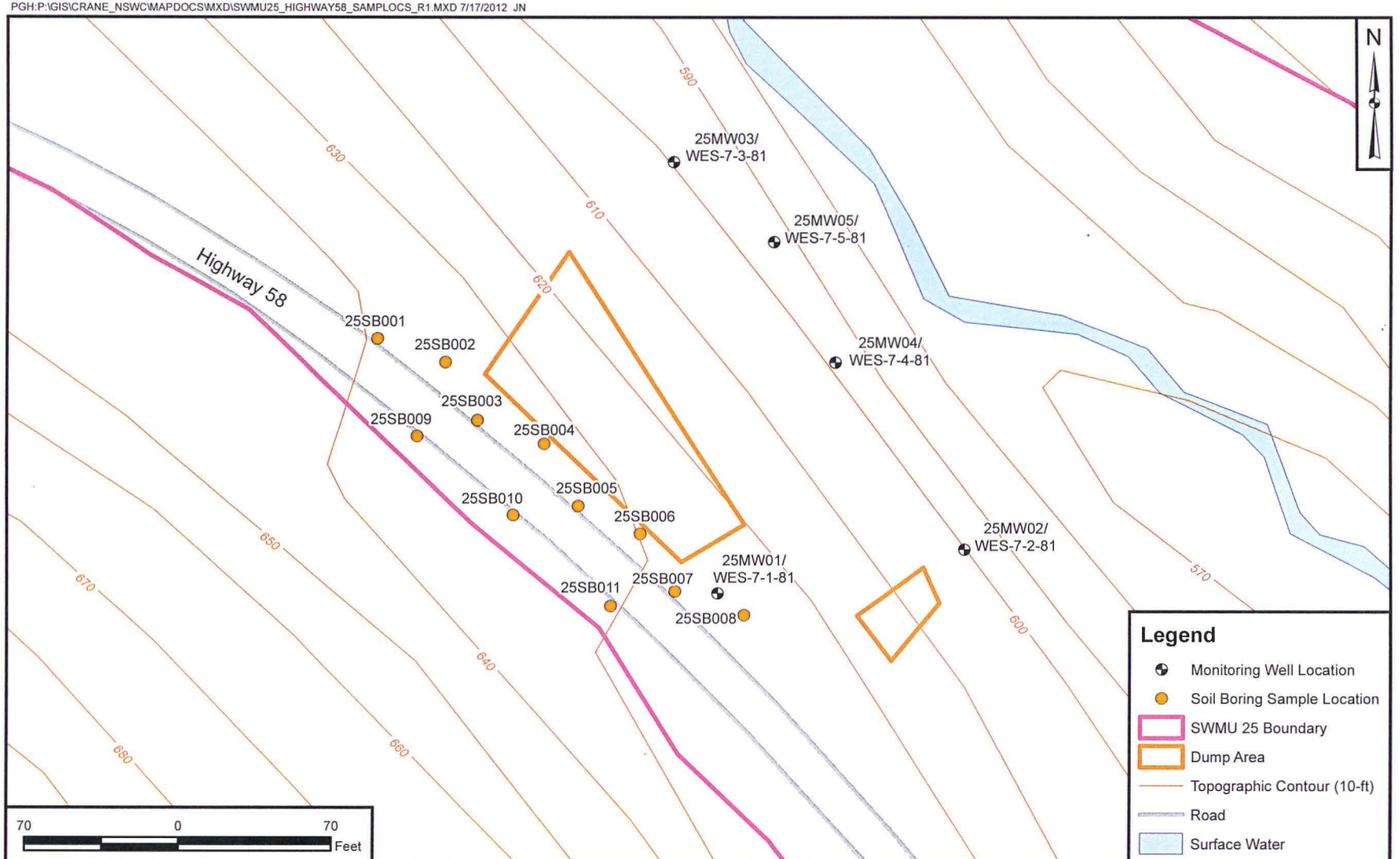

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CHECKED BY J. DUCAR	DATE 7/17/2012	
REVISED BY K. MOORE	DATE 7/17/2012	
SCALE AS NOTED		

NAVFAC

SOIL SAMPLING AND WELL LOCATIONS
SWMU 25 - HIGHWAY 58 DUMP SITE A
NSA CRANE
CRANE, INDIANA

CONTRACT NUMBER CTO F27L	
APPROVED BY ___	DATE ___
APPROVED BY ___	DATE ___
FIGURE NO. FIGURE 1	REV 0

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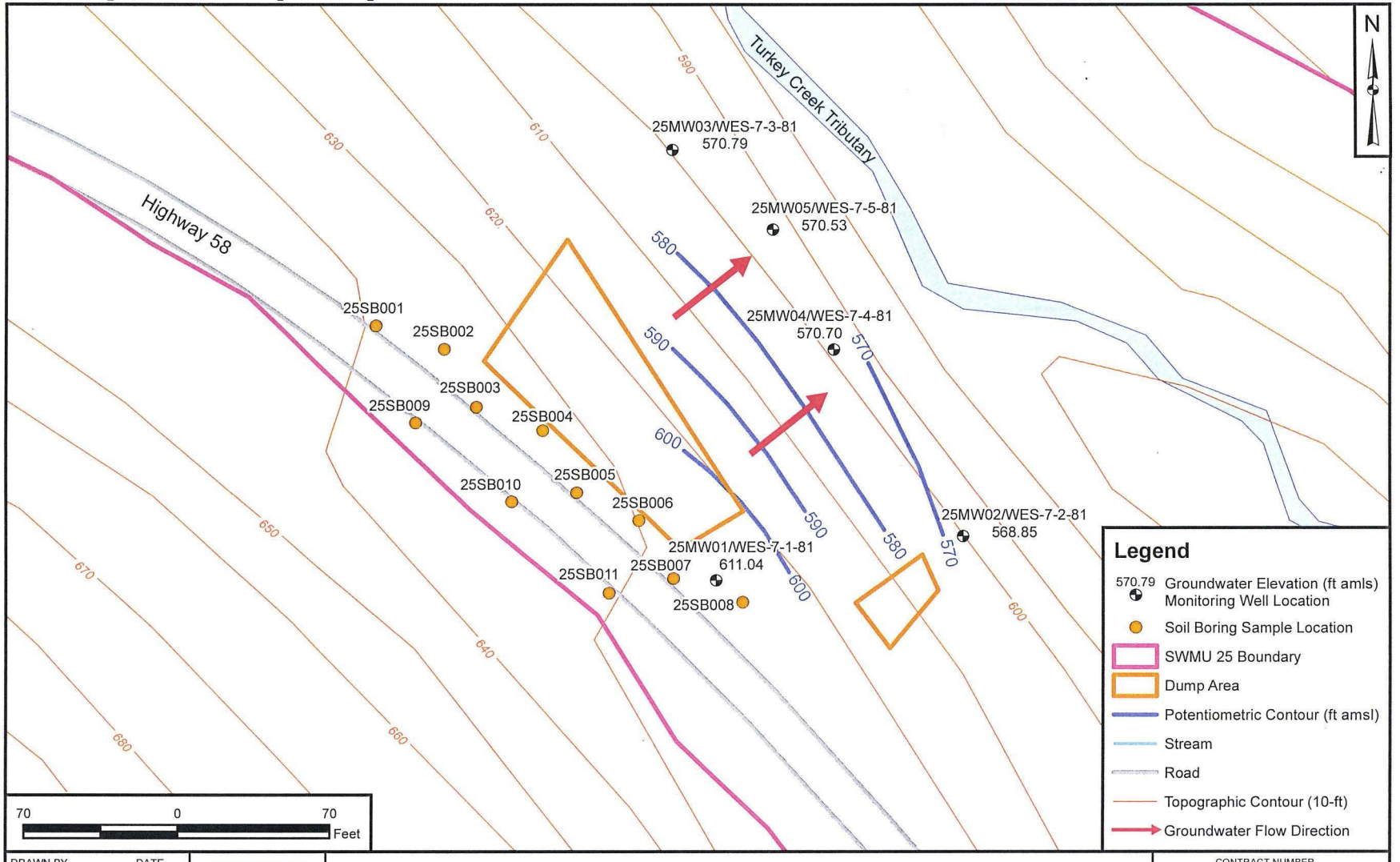

DRAWN BY J. ENGLISH	DATE 12/02/10	
CHECKED BY J. DUCAR	DATE 7/17/2012	
REVISED BY J. NOVAK	DATE 7/17/2012	
SCALE AS NOTED		

NAVFAC

GROUNDWATER ELEVATION MAP
SWMU 25 - HIGHWAY 58 DUMP SITE A
NSA CRANE
CRANE, INDIANA

CONTRACT NUMBER CTO F27L	
APPROVED BY —	DATE —
APPROVED BY —	DATE —
FIGURE NO. FIGURE 2	REV 0

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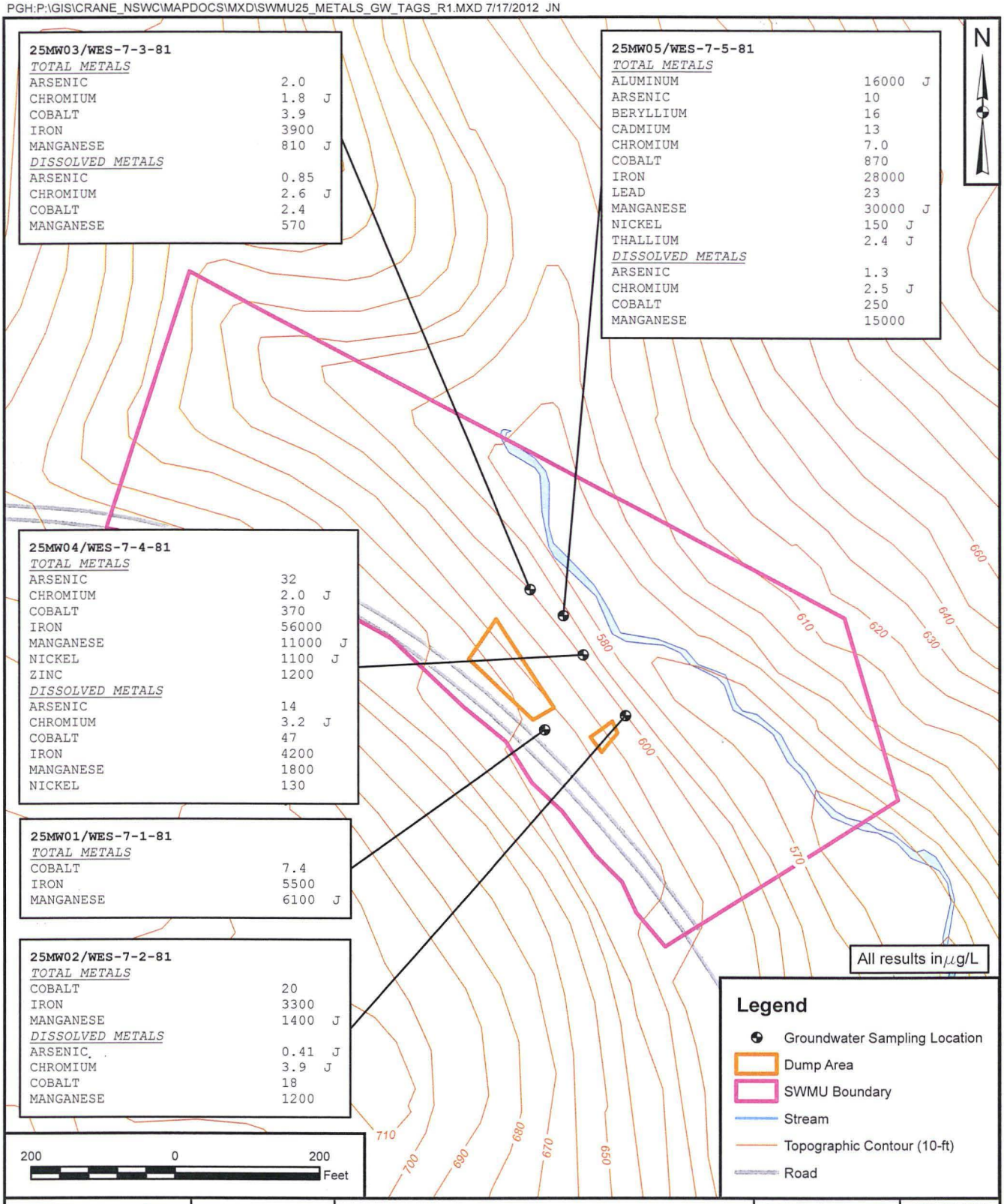

DRAWN BY	DATE			CONTRACT NUMBER	CTO NUMBER
J. NOVAK	03/13/12		METALS EXCEEDING REGULATORY SCREENING VALUES IN GROUNDWATER SWMU 25 - HIGHWAY 58 DUMP SITE A NSA CRANE CRANE, INDIANA	—	F27L
CHECKED BY	DATE			APPROVED BY	DATE
J. DUCAR	7/17/2012			—	—
REVISED BY	DATE			APPROVED BY	DATE
J. NOVAK	7/17/2012			—	—
SCALE AS NOTED		NAVFAC		FIGURE NO. FIGURE 3	REV 0

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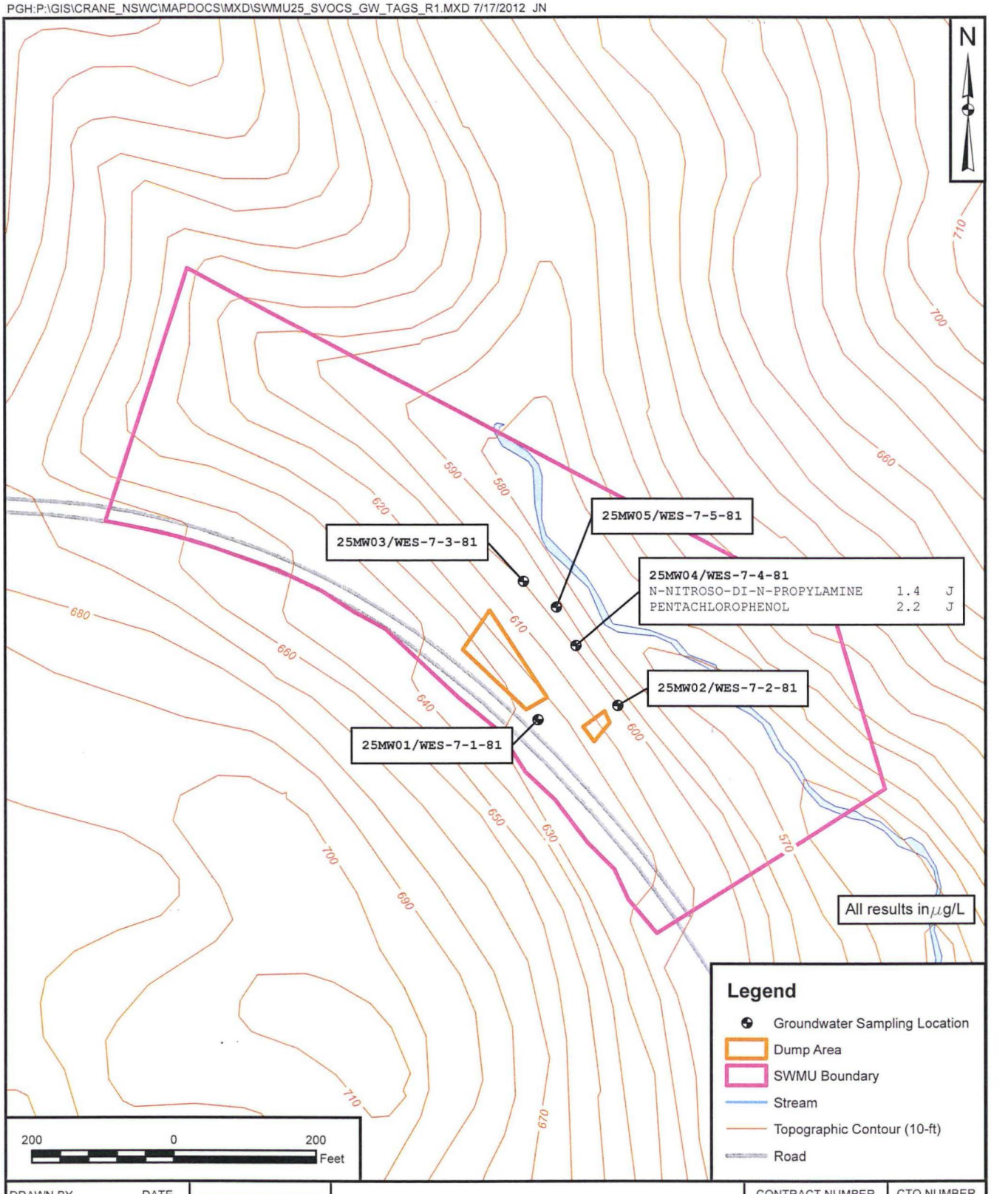

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J. NOVAK	03/13/12
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J. DUCAR	7/17/2012
REVISED BY	DATE
J. NOVAK	7/17/2012
SCALE AS NOTED	

NAVFAC

SVOCs EXCEEDING REGULATORY SCREENING VALUES IN GROUNDWATER
SWMU 25 - HIGHWAY 58 DUMP SITE A
NSA CRANE
CRANE, INDIANA

CONTRACT NUMBER	CTO NUMBER
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APPROVED BY	DATE
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FIGURE NO. FIGURE 4	REV 0

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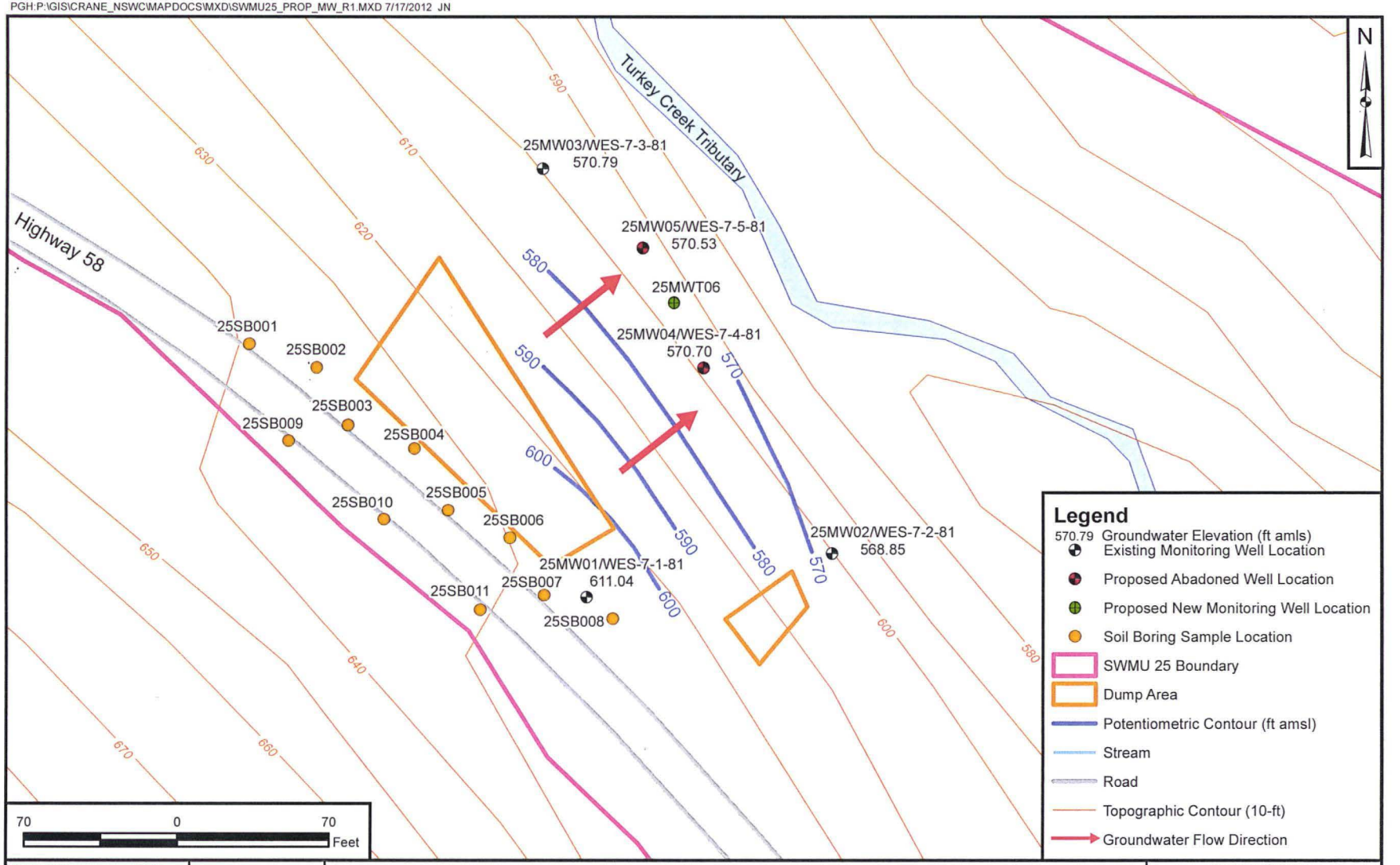

DRAWN BY	DATE
K. MOORE	6/20/12
CHECKED BY	DATE
J. DUCAR	7/17/2012
REVISED BY	DATE
J. NOVAK	7/17/2012
SCALE	
AS NOTED	

NAVFAC

PROPOSED MONITORING WELL INSTALLATION AND ABANDONDMENT LOCATIONS
SWMU 25 - HIGHWAY 58 DUMP SITE A
NSA CRANE
CRANE, INDIANA

CONTRACT NUMBER	
CTO F27L	
APPROVED BY	DATE
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APPROVED BY	DATE
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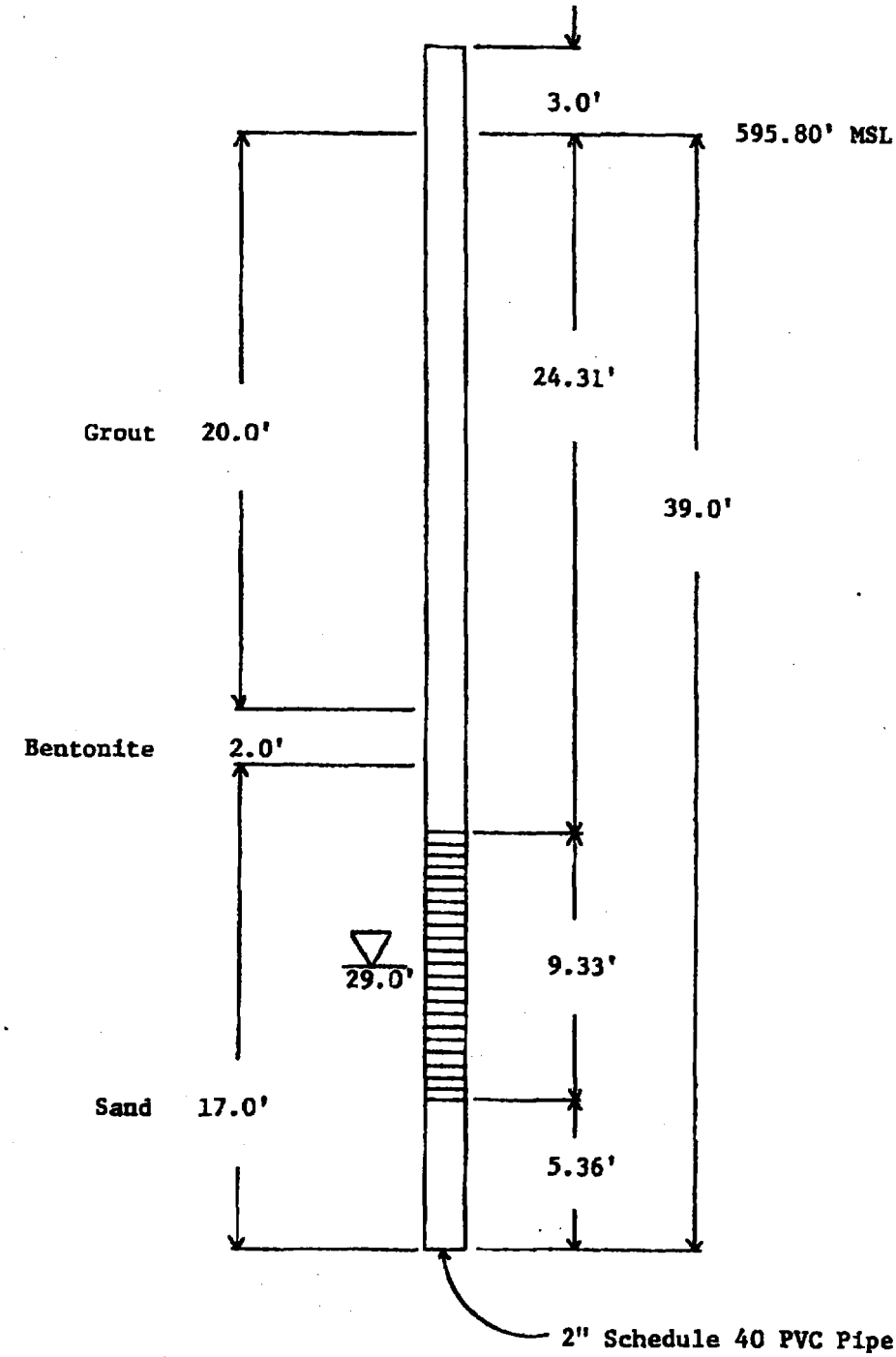
FIGURE NO.	REV
FIGURE 5	0

ATTACHMENT A

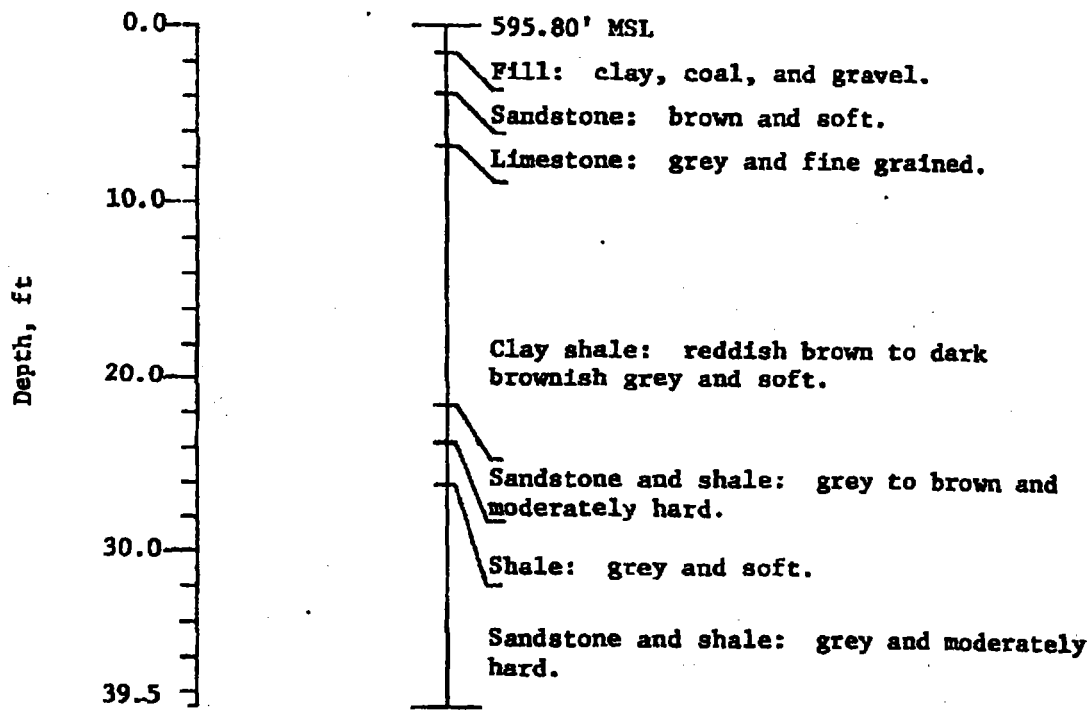
25MW04 AND 25MW05 SOIL BORING LOGS AND WELL CONSTRUCTION DIAGRAMS



Well screen

Water depth at time of drilling

NWSC, Crane, Indiana
Highway 58 Dump Site A
Well Completion
Boring Number: WES-7-4-81

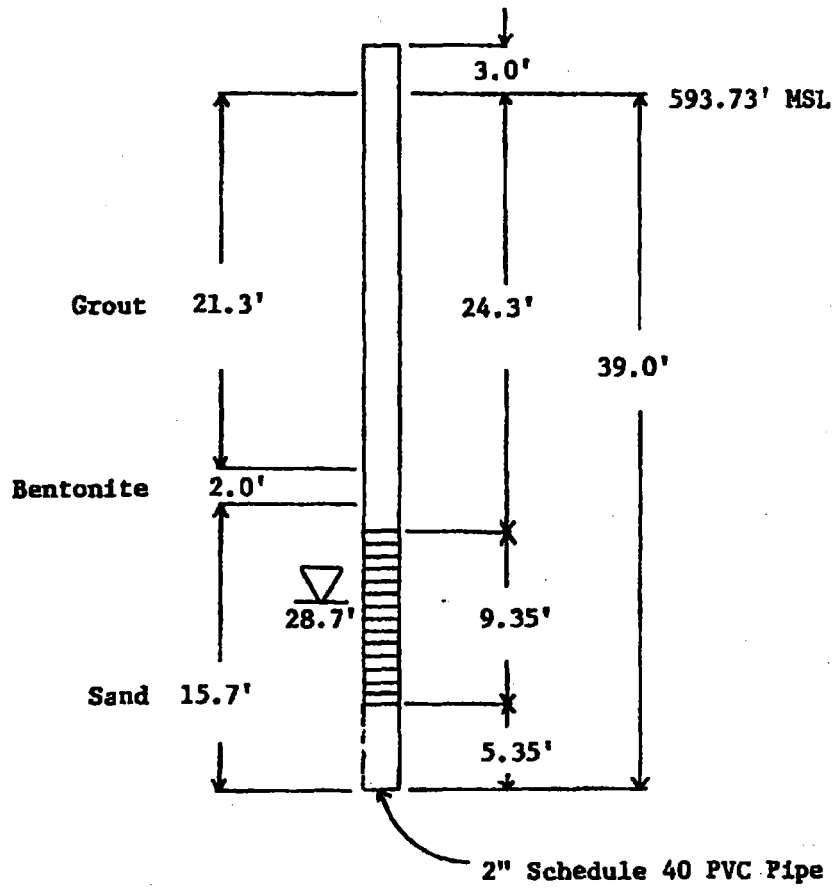


NWSC, Crane, Indiana

Highway 58 Dump Site A

Lithology

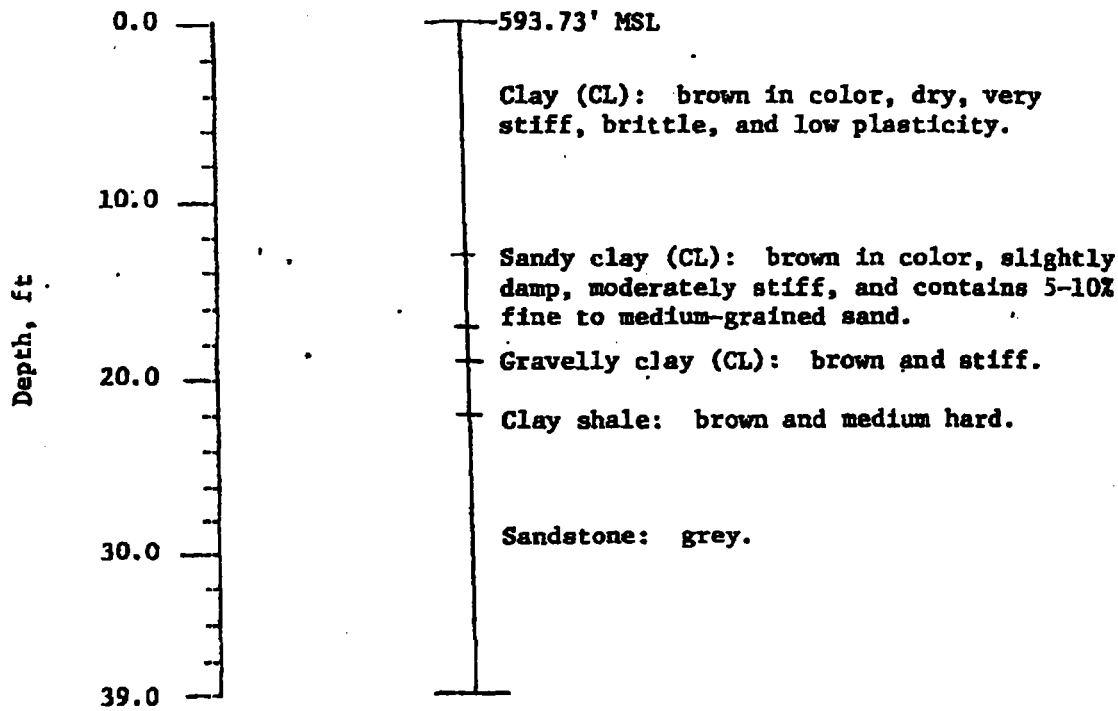
Boring Number: WES-7-4-81



Well screen

Water depth at time of drilling

NWSC, Crane, Indiana
Highway 58 Dump Site A
Well Completion
Boring Number: WES-7-5-81



NWSC, Crane, Indiana

Highway 58 Dump Site A

Lithology

Boring Number: WES-7-5-81

ATTACHMENT B

MONITORING WELL INSTALLATION AND ABANDONMENT SOPs

STANDARD OPERATING PROCEDURE
SOP-16

MONITORING WELL INSTALLATION

1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper design and installation of ground water monitoring wells for the collection of groundwater samples in the upper water-bearing zone. The methods described herein are specific for monitoring well construction at the NSA Crane facility. Guidelines by South Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM, 1997) and the State of Indiana regulatory requirements in Article 16 Water Well Drillers of Chapter 310 of the Indiana Annotated Codes (310 IAC 16) should be consulted.

2.0 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 drilling contractor personnel must have all the health and safety training required to perform the work, as specified in the health and safety plan. The driller is also responsible for obtaining, in advance, any required permits for drilling and monitoring well installation and construction.

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

3.0 REQUIRED EQUIPMENT/ITEMS

The following list includes equipment and items required for monitoring well installation:

Health and safety equipment as required by the HASP and 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 engineer's rule, electronic calculator, clipboard, mirror and flashlight for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, boring logs, soil sample log forms, chain-of-custody records, sample coolers with ice, and a field notebook).

4.0 WELL DESIGN AND CONSTRUCTION

Overburden well borings will be drilled using minimum 4-inch inside diameter hollow-stem augers to the desired depth of each well boring. Rotary drilling with a roller bit and water wash or air rotary drilling can be used to extend the shallow well borings to allow well installation in the upper water-bearing zone. In no cases will the Mississippian Elwren Shale Formation be completely penetrated unless a steel casing is installed and grouted in place at the top of the Elwren Formation.

Bedrock monitoring well borings will be drilled using hollow-stem auger or rotary drilling techniques until the bedrock is reached. For shallow bedrock wells (i.e., those monitoring the upper water-bearing zone in bedrock) where no overburden soil contamination is present, a temporary 6-inch, steel casing will be installed to isolate the overburden while the upper bedrock is drilled. For wells to be installed in the upper water-bearing zone where soil contamination is known to be present, a 6-inch-diameter steel casing will be installed 3- to 5-into to the top of competent bedrock and will be grouted with cement-bentonite slurry in a manner to ensure that the entire annulus between the casing and borehole is sealed. Diamond coring (NX) or air rotary drilling will be initiated after the grout is allowed to cure for a minimum of 24 hours.

For wells using diamond coring, the coring will proceed from the bottom of the casing to the full depth of the boring. Once the coring has been completed and the core has been logged (see SOP-17), then the hole will be reamed out with a minimum 5-inch-diameter air rotary bit.

For wells using air rotary drilling in those cases where coring is not anticipated, the drilling will be performed through the casing after the grout has sufficiently set. These borings will be logged using the rock chips and dust blown up the boring by the return air of the drill bit (see SOP-17). The borehole will then be cleaned out using compressed air from the drill bit. The air rotary equipment must have a filter on the compressed air line going to the borehole to prevent oil and other organics from being introduced.

All monitoring wells will be constructed of Schedule 40, flush-joint-threaded, 2-inch inside diameter polyvinyl chloride (PVC) riser pipe and flush joint threaded, factory slotted well screen with a threaded end cap. The well screens will be factory slotted to 0.010-inch size. Each section of well casing and

screen will be National Sanitation Foundation (NSF) approved. Well screens will be 10 feet long but may be longer or shorter based on the subsurface conditions that are encountered. A PVC cap will be placed on the bottom and will also be flush threaded. Other means of joining casings using glue, gaskets, pop rivets, or screws are not allowed. The screen will pass no more than 10 percent of the pack material or in-situ aquifer material.

Monitoring wells will be installed immediately upon completion of drilling or packer testing, if performed. A well screen section with bottom cap and the proper amount of riser pipe will be assembled and lowered down the borehole. Centralizers will be used as necessary to ensure that the casing and screen are centered and are aligned straight. The sand pack will be extended from 0.5 foot below the well screen to 2.0 feet above the top of the well screen. Clean silica sand of U.S. Standard Sieve Size No. 10 to 20 will be used.

A minimum 3-foot-thick bentonite pellet seal will be installed above the filter pack and allowed to hydrate for a minimum of 3 hours before grout is added above the seal. Only 100 percent, certified pure sodium bentonite will be used for well construction. The depths of backfill materials will be constantly monitored during well installation using a weighted stainless-steel or fiberglass tape measure.

The remaining annulus above the hydrated bentonite seal will be backfilled to the surface using a tremie pipe, with a 20:1 cement/bentonite grout. A maximum of 10 gallons of water per 94-pound bag of Type 1 cement will be used. The grout mixture should be blended in an above-ground rigid container or mixer to produce a thick lump-free mixture. This grout mixture will also be used for placement of steel casings in deep wells.

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 well 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 of the hole upward to prevent bridging and to provide a better seal. However, in shallow boreholes that do not collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

When the well is completed and grouted to the surface, a protective steel surface casing is placed over the top of the riser pipe. The finished well casing will extend at least 2 feet above the ground level. This casing will have a cap that can be locked to prevent vandalism. A vent hole will be provided in the cap to

allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the riser pipe and is set into the wet cement grout over the well upon completion or can be placed between the steel casing and the riser pipe in the case of deep monitoring well borings. 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 that may enter the annulus during well development, purging, or sampling. In traffic areas or high visibility areas, a flush-to-grade protective may be installed over the top of the riser pipe.

5.0 DOCUMENTATION OF FIELD ACTIVITIES

A critical part of monitoring well installation is recording of significant details and events in the site logbook, on field forms, and in a field logbook. Details of borehole logging are contained in SOP-07.

6.0 ATTACHMENTS

1. Bedrock Monitoring Well Sheet
2. Overburden Monitoring Well Sheet

ATTACHMENT 1

BEDROCK MONITORING WELL SHEET

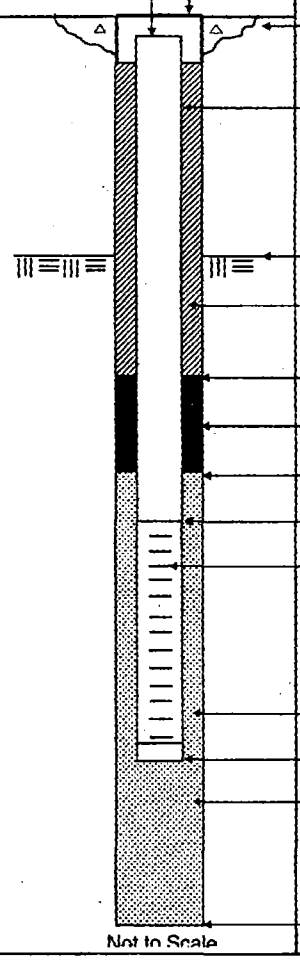
Tetra Tech NUS, Inc.

WELL No.: _____

MONITORING WELL SHEET

PROJECT:		DRILLING Co.:		BORING No.:	
PROJECT No.:		DRILLER:		DATE COMPLETED:	
SITE:		DRILLING METHOD:		NORTHING:	
GEOLOGIST:		DEV. METHOD:		EASTING:	

Ground Elevation =
Datum:



Elevation / Depth of Top of Riser: ____ / ____

Elevation / Height of Top of Surface Casing: ____ / ____

I.D. of Surface Casing: _____

Type of Surface Casing: _____

Type of Surface Seal: _____

I.D. of Riser: _____

Type of Riser: _____

Borehole Diameter: _____

Elevation / Depth Top of Rock: ____ / ____

Type of Backfill: _____

Elevation / Depth of Seal: ____ / ____

Type of Seal: _____

Elevation / Depth of Top of Filter Pack: ____ / ____

Elevation / Depth of Top of Screen: ____ / ____

Type of Screen: _____

Slot Size x Length: _____

I.D. of Screen: _____

Type of Filter Pack: _____

Elevation / Depth of Bottom of Screen: ____ / ____

Elevation / Depth of Bottom of Filter Pack: ____ / ____

Type of Backfill Below Well: _____

Elevation / Total Depth of Borehole: ____ / ____

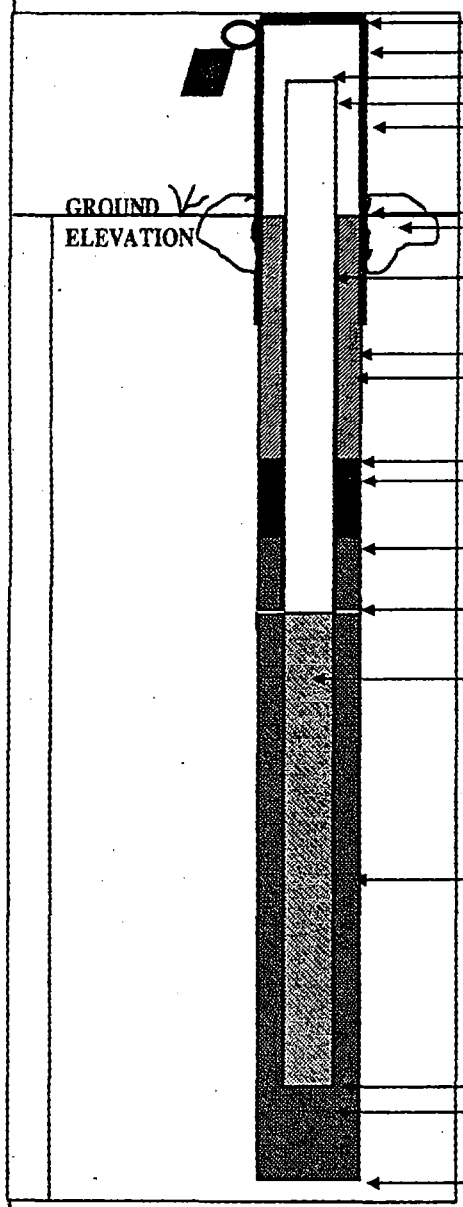
ATTACHMENT 2

OVERBURDEN MONITORING WELL SHEET

BORING NO.: _____

Tetra Tech NUS, Inc. **OVERBURDEN MONITORING WELL SHEET**

PROJECT:	NIROP FRIDLEY	DRILLING Co.:		BORING No.:	
PROJECT No.:	7842 CTO 0057	DRILLER:		DATE COMPLETED:	
SITE:	ANOKA PARK	DRILLING METHOD:		NORTHING:	
GEOLOGIST:		DEV. METHOD:		EASTING:	



ELEVATION OF TOP OF SURFACE CASING: _____
STICK -UP TOP OF SURFACE CASING: _____
ELEVATION OF TOP OF RISER PIPE: _____
RISER STICK-UP ABOVE GROUND SURFACE: _____
I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

GROUND ELEVATION: _____
TYPE OF SURFACE SEAL: _____

RISER PIPE I.D.: 2"
TYPE OF RISER PIPE: CARBON STEEL

BOREHOLE DIAMETER: _____
TYPE OF SEAL: _____

ELEVATION / DEPTH OF SEAL: /
TYPE OF SEAL: BENTONITE CHIPS

ELEVATION / DEPTH TOP OF FILTER PACK: /

ELEVATION / DEPTH TOP OF SCREEN: /

TYPE OF SCREEN: CARBON STEEL

SLOT SIZE X LENGTH: 10 SLOT x

I.D. OF SCREEN: 2"

TYPE OF FILTER PACK: SILICA SAND
(No. 10-20 U.S. STANDARD SEIVE SIZE)

ELEVATION / DEPTH BOTTOM OF SCREEN: /
ELEVATION / DEPTH BOTTOM OF FILTER PACK: /
TYPE OF BACKFILL BELOW WELL: _____
ELEVATION / DEPTH OF BOREHOLE: /

STANDARD OPERATING PROCEDURE
SOP-17

DRILLING AND GEOLOGIC LOGGING OF BOREHOLES IN BEDROCK

1.0 PURPOSE

This procedure describes the methods and equipment necessary to drill bedrock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain rock cores and prepare boring logs during drilling activities. Up to four types of drilling activities and equipment will be used to drill holes and install monitoring wells at the NSA Crane facility:

- Auger drilling with continuous split-spoon sampling will be used to drill through the overburden material.

- Diamond coring equipment will be used to core through the bedrock. NX or similar size diamond core barrels will be used to collect 2- to 3-inch-diameter continuous rock core. These cores will be used to describe the lithologic characteristics and fracture distributions in the bedrock. Diamond coring is relatively slow and more expensive compared to the air rotary method of drilling, so one hole per subarea is proposed to be cored.

- Air-rotary or rotosonic drilling will be used to advance the boreholes not cored. The holes need to be a minimum of 5 inches in diameter in order to install a 2-inch-diameter monitoring well. Air rotary may also be used to deepen well borings in the event bedrock is encountered before the desired well boring depth is reached.

- Rotary drilling with a roller bit and water wash may be used to complete well borings in the event that bedrock is encountered before the desired well boring depth is reached.

2.0 RESPONSIBILITIES

Field Operations Leader (FOL) - The FOL is responsible for coordinating all on-site personnel and for providing technical assistance, when required. The FOL, or designee, will coordinate and lead all activities and will ensure the availability and maintenance of all materials and equipment. The FOL is responsible for the completion of all field activities and field and chain-of-custody documentation. The

FOL will assume custody of all samples and will ensure the proper handling and shipping of samples. The FOL is a highly experienced environmental professional who will report directly to the Tt Task Order Manager (TOM). Specific FOL responsibilities include the following:

- Function as a communications link among field staff members, the site quality assurance/quality control advisor, site safety officer, the site manager, and the TOM.
- Oversee the mobilization and demobilization of all field equipment and subcontractors.
- Coordinate and manage the field technical staff.
- Adhere to the work schedules provided by the TOM.
- Maintain the site logbook and field recordkeeping.
- Initiate field task modification requests, when necessary.
- Identify and resolve problems in the field, resolve difficulties in consultation with the NSA Crane Site Manager, implement and document corrective action procedures, and provide communication between the field team and upper management.

Field Geologist - The field geologist is responsible for ensuring that standard and approved drilling procedures are followed. The field geologist will generate a detailed boring log for each borehole. This log will include a description of geologic materials, samples (if any), method of sampling, and other pertinent information and observations that may be obtained during drilling.

Determination of the exact location for borings is the responsibility of the field geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the QAPP.

Drilling Subcontractor - The subcontractor operates under the supervision of the FOL. He or she is responsible for obtaining all drilling permits and clearances and supplying all services (including labor), equipment, and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical problems encountered in the field to the FOL within 24 hours of determination and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes will be made unless requested and authorized in writing by the FOL (with the concurrence of the project manager). Depending on the subcontract, the project manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

The drilling subcontractor is responsible for following decontamination procedures specified for drilling and coring equipment specified in the project plan documents. The FOL will oversee the in-field equipment decontamination procedures to confirm compliance with the appropriate SOP and specific requirements of the NSA Crane Environmental Department. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

3.0 PROCEDURES

3.1 General

The purpose of drilling boreholes is

- To determine the type, thickness, and certain physical and chemical properties of the soil, water, and rock strata that underlie the site.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP-04. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first and at the most contaminated locations last to reduce the risk of spreading contamination between locations. All borings must be logged by the site geologist as they proceed.

3.2 Rock Coring

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended because the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a

core out of the rock that rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel, and withdrawing the inner barrel. A less efficient variation of this method utilizes a core barrel that cannot be removed without pulling all the drill rods. This variation is practical only if fewer than 50 feet of core is required. When coring rock, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled.

Advantages of core drilling include

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install monitoring wells in coreholes, the hole will be reamed out to the proper size after boring, using air rotary drilling methods. Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less or for specific intervals in the drill hole that require detailed logging and/or analyzing. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and can yield better quality data than air-rotary drilling, although at a substantially reduced drilling rate.

Borehole diameter can be drilled to various sizes, depending on the information needed. NX, or a similar size (2- to 3-inch-diameter core recovery), may be used.

Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10-feet (3-meters), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately.

Since rock structures and the occurrence of bedding planes, porosity type and distribution, and fracture patterns are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: cement the hole, ream and case, or case and advance with the next smaller size core barrel, as conditions warrant.

3.3 Rock Core Management and Labeling

When the core barrel has been recovered, the rock core will be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core will be described, classified, and logged using a uniform system (Sections 4.0 and 5.0 of this SOP).

Rock cores will be placed in the sequence of recovery in well-constructed wooden or cardboard boxes provided by the drilling contractor. Rock cores from two different borings will not be placed in the same core box. The core boxes will be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each. Wood partitions will be placed at the end of each core run. The depth from the surface of the boring to the top and bottom of the drill run and run number will be marked on the wooden partitions with indelible ink. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores will be the same in all core boxes. Rock core will be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box and the bottom of the cored interval is in the lower right corner of the box. The top and bottom of each core obtained and their true depths will be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row will be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid will be marked by indelible ink to show all pertinent data about the box's contents. At a minimum, the following information will be included:

- Project name
- Project number
- Boring number
- Run numbers
- Footage (depths)
- Recovery
- RQD (%)
- Box number and total number of boxes for that boring (Example: Box 5 of 7)
- Contact person's name and telephone number

For easy retrieval when core boxes are stacked, the sides and ends of the box will also be labeled and will include project number, boring number, top and bottom depths of core, and box number.

Before final closing of the core box, a photograph will be taken of the recovered core and the labeling on the inside cover will be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores.)

3.4 Air Rotary Drilling

Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole.

Advantages of this method include

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air-rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large to allow room for proper well installation procedures.

Disadvantages to using this method include

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.

- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.

- In-situ samples cannot be taken, unless the hole is cased.

- Air-rotary drill rigs are large and heavy.

- Large amounts of investigation-derived waste (IDW) may be generated that may require containerization, sampling, and off-site disposal.

3.5 Rotosonic Drilling

The rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construction of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives. The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.

- Continuous sampling, with larger sample volume as compared to split-spoon sampling.

- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.

- Reduction of IDW by an average of 70 to 80 percent.

- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.

- Rotosonic drill rigs are large and need ample room to drill, however, rotosonic units can be placed on the ground or placed on an A TV.

- There are a limited number of rotosonic drilling contractors at the present time.

4.0 GEOLOGIC DESCRIPTION OF BOREHOLES IN ROCK

These procedures provide descriptions of the standard techniques for borehole and sample logging. These logging techniques will be used for each boring to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist or engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

The classification of soil and rocks is one of the most important jobs of the field geologist or engineer. To maintain a consistent flow of information, it is imperative that the field geologist or engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

4.1 Required Field Forms and Equipment

When logging soil and rock samples, the geologist or engineer should be equipped with the following:

Rock hammer
Knife
Camera
10% Dilute hydrochloric acid (HCl)
Ruler (marked in tenths and hundredths of feet)

Hand lens

Writing utensil with indelible ink

Field logbook

Disposable medical-grade gloves (e.g., latex, nitrile)

Soil/rock classification sheets

4.2 Classification of Rocks

Sedimentary rocks are by far the predominant type exposed at the earth's surface and are the only type present at NSA Crane. In classifying a sedimentary rock, the following hierarchy will be noted: Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. The following basic names are applied to the types of rocks found in sedimentary sequences:

Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.

Siltstone - Made up of granular materials between 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.

Claystone - Very fine-grained rock made up of particle less than 1/256 mm in diameter. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.

Shale - A fissile, very fine-grained rock with particles less than 1/256 mm in diameter. Fractures along bedding planes.

Limestone - Rock made up predominantly of calcite ($CaCO_3$, which is mainly fossilized animal and plant debris). Effervesces strongly upon the application of dilute hydrochloric acid.

Coal – A very dark colored rock consisting mainly of organic (mainly fossilized plant debris) remains.

Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record.

The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

4.2.1 Rock Type

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types; therefore, a modifier such as "sandy siltstone" or a "silty sandstone" can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifying descriptions can include carbonaceous, calcareous, siliceous, fossiliferous, etc.

Grain size is the basis for the classification of clastic (sandstones, siltstones, and shales) sedimentary rocks. The Udden-Wentworth classification will be assigned to sedimentary rocks (shown below). The individual boundaries are slightly different than the USGS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse-grained rocks. Alternatively, the division between siltstone and shale may be measurable in the field by the use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a shale.

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm
After Wentworth, 1922	

4.2.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples will be classified while wet, when possible, and air-cored samples will be scraped clean of cuttings prior to color classifications. Soil colors will be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

4.2.3 Bedding Thickness

The bedding thickness designations listed below will also be used for rock classification.

BEDDING THICKNESS CLASSIFICATION

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick bedded
10 cm - 30 cm	4" - 1.0'	Medium bedded
3 cm - 10 cm	1" - 4"	Thin bedded
1 cm - 3 cm	2/5" - 1"	Very thin bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly laminated
< 1 mm	<1/32"	Micro laminated

(Ingram, 1954)

4.2.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock that occupies the zone between the lowest soil horizon and firm bedrock).

Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.

Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.

Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage of the words "scratch" and "gouge." A scratch will be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), and a gouge is much deeper.

4.2.5 Fracturing

Method of Calculating RQD
(After Deere, 1966)

Fractures should also be noted.

$$RQD\ \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured that are greater than 4 inches in length and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

4.2.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

Fresh - The rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

Slight - The rock has some staining that may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration. Oxidation and weathering may affect the degree of fracturing or brokenness of a rock. After eliminating drilling breaks, the average spacing of natural breaks is calculated and the fracturing is described by the following terms:

Very broken (V. BR.) - Less than 2-inch spacing between fractures
Broken (BR.) - 2-inch to 1-foot spacing between fractures
Blocky (BL.) - 1- to 3-foot spacing between fractures

Massive (M.) - 3- to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the rock quality designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run to obtain a percentage.

Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with a hammer.

Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

4.2.7 Other Characteristics

The following items will be included in the rock description:

Description of contact between two rock units. These can be sharp or gradational.

- Stratification (parallel, cross stratified).
- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs will be neat so it can be reproduced on a copy machine for report presentation. The data will be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

4.2.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

Seam - Thin (12 inches or less), probably continuous layer.

Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."

Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."

Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."

Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

4.2.9 Abbreviations

Abbreviations may be used in the description of a rock. However, they will be kept at a minimum. Following are some of the abbreviations that may be used:

C	-	Coarse	Lt	-	Light	Yl	-	Yellow
Med	-	Medium	BR	-	Broken	Or	-	Orange
F	-	Fine	BL	-	Blocky	SS	-	Sandstone
V	-	Very	M	-	Massive	Sh	-	Shale
Sl	-	Slight	Br	-	Brown	LS	-	Limestone
Occ	-	Occasional	Bl	-	Black	Fgr	-	Fine-grained
Tr	-	Trace						

5.0 BORING LOGS AND DOCUMENTATION

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections will be used to complete the logs. A sample boring log is attached at the end of this SOP.

The field geologist or engineer will use this example as a guide in completing each boring log. Each boring log will be fully described by the geologist or engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the

back of the boring log or on a separate sheet, for field use. All data will be written directly on the boring log. Additional notes may be entered in a field notebook if more space is needed.

5.1 Remarks Column

The following information will be entered under the "Remarks" column and will include, but is not limited to, the following:

- Moisture - Estimate moisture content using the following terms: dry, moist, wet, and saturated. These terms are determined by the individual. Whatever method is used to determine moisture should be consistent throughout the log.

- Angularity - Describe angularity of coarse-grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or the Earth Manual for criteria for these terms.

- Particle shape - flat, elongated, or flat and elongated.

- Maximum particle size or dimension.

- Water-level observations.

- Reaction with HCl - none, weak, or strong.

Additional comments:

- Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.

- Indicate odor and photoionization detector (PID) readings.

- Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.

- At the bottom of the page, indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).

- Vertical lines shall be drawn in the Material Description column from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines will be drawn if there is a change in lithology, then vertical lines will be drawn to that point.

- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.2 Rock Classification

Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate core run number, RQD percent, and core recovery under the appropriate columns.

Indicate lithology change by drawing a line at the appropriate depth, as explained above.

Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

Enter color as determined while the core sample is wet; if the sample is cored by air, the core is to be scraped clean before the color is described.

Enter rock type. For sedimentary rocks, use terms as described in Section 4.2. Again, be consistent in classification. Use modifiers and additional terms as needed.

Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M, as explained in Section 4.2.6 and as noted on the back of the boring log.

The following information will be entered under the remarks column. Items will include but are not limited to the following:

- Indicate depths of joints, fractures, and breaks and also approximate to horizontal angle (such as high, low) (i.e., 70° angle from horizontal, high angle).
- Indicate calcareous zones, description of any cavities or vugs.
- Indicate any loss or gain of drill water.

- Indicate drop of drill tools or change in color of drill water.

Remarks at the bottom of boring log will include

- Type and size of core obtained
- Depth casing was set
- Type of rig used

As a final check, the boring log will include the following:

- Vertical lines will be drawn as explained for soil classification to indicate consistency of bedrock material.

- If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that will be followed when logging cuttings are as follows:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or ziplock bag for future reference, and label the jar or bag (i.e., hole number, depth, date, etc.). Cuttings will be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings to estimate changes in lithology.

- Note drop or chattering of drilling tools or a change in the rate of drilling to determine fracture locations or lithologic changes.

- Observe loss or gain of drilling fluids or air (if air rotary methods are used) to identify potential fracture zones.

- Record this and any other useful information onto the boring log.

This logging provides a general description of subsurface lithology, and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less-detailed data generated through borings drilled using air and mud rotary methods.

5.4 Review

Upon completion of the borings logs, copies will be made and reviewed. Items to be reviewed include

- Checking for consistency of all logs
- Checking for conformance to the guideline
- Checking to see that all information is entered in their respective columns and spaces

Originals of the boring logs will be retained in the project files.

7.0 ATTACHMENTS

1. Boring Log

ATTACHMENT 1

BORING LOG

Tetra Tech NUS, Inc.

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING No.: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color*	Material Classification	USCS*	Remarks	FID/PID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**

* When rock coring, enter rock brokeness.
** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

References

Deere, D.U. and Miller, R.P., (1966). Engineering Classification and Index Properties for Intact Rock, Air Force Weapons Lab. Tech. Report AFWL-TR-65-116, Kirtland Base, New Mexico.

Wentworth, C.K., 1922. A Scale of Grade and Class Terms for Caustic Sediments: Jour. Geology, v. 30, p. 377-392.

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STANDARD OPERATING PROCEDURE
SOP-18

MONITORING WELL ABANDONMENT

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the standard procedures and technical guidance on monitoring well abandonment. The application of and adherence to this SOP must comply with Indiana, local, and Federal regulatory requirements.

2.0 FIELD FORMS AND EQUIPMENT

Bentonite and /or Cement
Trash Pump
Gasoline
Tremie-Pipe and Hosing
55-gallon Drum(s)
Slurry Mixing Equipment (e.g., Shovel)
Jackhammer, air compressor, etc. (as needed for pad removal)
Saw
Knife
Weighted Engineer's Tape
Water-level Indicator
Retractable Engineer's Rule
Electronic Calculator
Clipboard
Mirror and Flashlight for Observing Downhole Activities
Boring Logs
Field Notebook
Writing Instrument (preferably black pen with indelible ink)
Well Abandonment Form: An example of this form is attached.

3.0 RESPONSIBILITIES

A field geologist or engineer is responsible for supervising all activities and assuring that each well is properly and completely abandoned.

4.0 WELL ABANDONMENT PROCEDURES

4.1 General

Well abandonment is conducted to eliminate physical hazards, prevent groundwater contamination, prevent intermixing of aquifer waters, and conserve aquifer yield and hydrostatic head. A Licensed/Certified Well Driller in the State of Indiana is required to complete/oversight of this activity.

4.2 Material for Sealing

Acceptable sealing materials include sodium-base bentonite clay. These materials are defined as follows:

- Bentonite slurry (which can include polymers to retard swelling), when applied as a heavy mud-laden fluid under pressure, has most of the advantages of cement grout, but under some conditions may be carried away into the surrounding formation. A bentonite clay mixture shall be composed of not less than 2 pounds of clay per gallon of water. Bentonite clay may not be used where it will come in contact with water of a pH below 5.0 or total dissolved solids (TDS) content greater than 1,000 mg/L, or both.

- Pelletized bentonite or coarse-grade crushed bentonite (312 IAC 13-10-2(e)(6)).

Organic material may not be used and fill material may be required to be disinfected or certified clean prior to use. Spent drilling muds or drill cuttings are not to be used to seal a well.

4.3 Procedures for Sealing Wells

4.3.1 Preliminary Considerations

Several factors should be considered to determine the appropriate well abandonment method. These factors include:

- Conditions of the well.

- Details of well construction, including casing material, diameter of casing, depth of the well, and well plumbness.
- Obstructions within the well that may interfere with filling or sealing.
- Hydrogeologic setting.
- Level of contamination and the zone or zones where it occurs.

4.3.2 Inner Well Casing Removal

The well's inner casing should be attempted to be removed prior to sealing activities. If the borehole is unstable and subject to cave-in, sealing material will be emplaced simultaneously during casing removal. If the well is not grouted, casing may be pulled with hydraulic jacks or a drilling rig.

Degraded wells may not permit casing removal by pulling. Also, the casing material may dictate whether a casing can be removed intact. Stainless steel will have a higher tensile strength than PVC and may hold together while pulling the casing; PVC well casing may break under pulling and may need to be overdrilled to remove it.

Well casings can also be removed by overdrilling. Wells can be overdrilled with larger diameter hollow steam or solid stem augers or direct rotary techniques, using air or mud. Augers used for overdrilling should be at least 2 inches larger in diameter than the diameter of the well casing. If well casing is in poor condition or is grouted in place, the casing may be ripped or perforated and filled and pressure grouted in place.

The depth of the well and well plumbness may limit casing removal depending on whether a casing is pulled or overdrilled. In some cases, inner well casings can be left in-place if they are properly sealed.

In addition, the outer protective steel casing (stick-up or flushmount) and well pad may be removed, and the well pad area restored to pre-well installation conditions (i.e., area backfilled to grade with clean fill material, regraded, reseeded, etc.).

4.3.3 Well Sealing Procedures

Abandoned wells shall be filled with the appropriate sealing material placed from the bottom of the well upward. When cement grout or bentonite slurry is used, it shall be placed in continuous operation using a pump, hosing and tremie pipe. Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent bridging, free fall or dilution.

If the tremie-pipe method cannot be used (e.g., bent casing), the well may be abandoned by slowly pouring bentonite pellets or chips into the well from the bottom to the surface. The depth of the bentonite shall be checked periodically with the use of a weighted engineer's tape to assure the casing is being filled properly.

5.0 DOCUMENTATION OF FIELD ACTIVITIES

A critical part of monitoring well abandonment is recordkeeping of significant details and events in the site logbook, on field forms, and in a field logbook.

In addition, the driller (subcontractor) shall submit a report of well abandonment to NAVFAC Crane for submittal to the Indiana Department of Natural Resources (IDNR) describing in detail the specific methods used to abandon the well not later than thirty (30) days after the completion of well plugging/abandonment operations. The report must:

(1) be on a form provided by IDNR (State Form 35680); and

(2) include an affidavit that:
   (A) certifies that the well was plugged in accordance with Indiana Code 14-37-8 (Chapter 8. Plugging and Abandonment); and
   (B) is signed by the person who performed the well plugging operations and the well owner or operator.

The well abandonment report shall be submitted to:

DNR Division of Water
Water Rights & Use Section
402 W. Washington Street, Room W264
Indianapolis, IN 46204

The Division's phone number is (317) 232-4160 or toll-free (877) 928-3755.

6.0 ATTACHMENTS

1. Tetra Tech Monitoring Well Abandonment Form

7.0 REFERENCES

Indiana Department of Environmental Management, 2009. Drilling Procedures and Monitoring Well Construction Guidelines, Policy Number: WASTE-053-NPD, March 17, 2009.

Indiana Department of Natural Resources. Office of Code Revision Indiana Legislative Services Agency, IC 14-37-8, Chapter 8. Plugging and Abandonment.

Indiana Department of Natural Resources. Office of Code Revision Indiana Legislative Services Agency, IC 312 IAC 13, Rule 10.

U.S. EPA, February 1990. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.

ATTACHMENT 1
MONITORING WELL ABANDONMENT FORM

Project Name: _____ Job Number: _____
Site Location/ _____ Client: _____
Address: _____ Address: _____
_____

WELL INFORMATION

Well Number: _____ Static Water Level: _____
Well Diameter: _____ Well Depth: _____
Casing Material: _____ Screen Length: _____

Reason for Abandonment: _____

METHOD OF ABANDONMENT

In-Situ Grouting: _____ Casing Removal & Grouting: _____ Overdrill & Grouting: _____
Other (Explain): _____

Type and Amount of Plugging Material _____
and Date(s) of Installation: _____
Final Surface Conditions: _____

Additional Notes/Comments:

_____
_____

Inspected by (Contractor): _____ Date: _____
Address: _____
_____

Approved by (Tt Representative): _____ Date: _____
Address: _____
_____