

Appendix A

US EPA Region IV Quality Assurance Project Plan Checklist

Superfund Division QAPP Final Checklist - 2007

**USEPA
REGION 4 QUALITY ASSURANCE SECTION
QAPP SUPERFUND DIVISON FINAL CHECKLIST 2007**

QAPP Title:
Project Location:
Originating Organization:
QAPP Date:
Receipt Date:
Review Date:
Reviewer:
EPA Regional Project Manager:
EPA Project Officer:

Topic covered in accordance with requirements: 9 Yes 9 No

9 Yes - Indicates that the topic/element was covered in sufficient detail to meet EPA=s requirements as specified in this checklist.

9 No - Indicates that the topic/element covered in the QAPP does not provide sufficient detail to meet EPA=s requirements or the topic is entirely missing from the document.

Element	Meets Requirements 9 Yes 9 No
A-1. Title and Approval Page	9 Yes 9 No
Title of QAPP	9 Yes 9 No
Organization=s Name: Both the name of the organization preparing the QAPP and the organization conducting the project or the grantee=s name.	9 Yes 9 No
Dated Signature of Project Manager: Both the originating organization=s PM and EPA=s corresponding PM and/or PO.	9 Yes 9 No
Date and Signature of Quality Assurance	9 Yes 9 No

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Manager=s approval for the originating entity and for EPA.	
Other Signatures as Needed:	9 Yes 9 No
A-2. Table of Contents: Including Tables, Figures and Appendices	9 Yes 9 No
A-3. Distribution List: Including Addresses of all entities or agencies requiring copies of the QAPP	9 Yes 9 No
A-4. Project - Task Organization	
Identifies key project personnel, specifies technical disciplines, details their roles/responsibilities and details the chain of command	9 Yes 9 No
Organization chart provided: Depicts lines of authority, independence (of QA manager), and reporting responsibilities. Org- chart also contains entries for all agencies, contractors and individuals responsible for performing QAPP preparation, sample collection, laboratory analysis, data verification, review and validation, data quality assessment; and project oversight responsibilities.	9 Yes 9 No
A-5. Problem Definition/Background.	
Clearly states the particular environmental problem to be solved, decision to be made, or outcome to be achieved. Include sufficient background information to provide a historical, scientific, and regulatory perspective for this particular project.	9 Yes 9 No
Provides historical and background information concerning prior environmental investigations or assessments performed at the site. Discusses the data collected from these prior investigations and identifies any additional information that may be contained in computer databases (secondary data), etc.	9 Yes 9 No

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A-6 Project/Task Description	
Provides a summary of all work to be performed, products to be produced, and the schedule for implementation. Lists the actual measurements to be made: Including in-situ field measurements, fixed laboratory measurements, or any other type of information collected as part of the project.	9 Yes 9 No
Cites applicable regulatory standards or criteria such as action limits, ARARs, PRGs, MCLs, risk assessment screening levels, etc. Must provide the actual numerical criteria for the above items.	9 Yes 9 No
Identifies all instruments/equipment needed to conduct project and identifies all key study personnel (field technicians, chemists, risk assessors, engineers, project managers, quality assurance managers, etc.)	9 Yes 9 No
Provides work schedule for all tasks including report preparation, response to comments, etc.	9 Yes 9 No
Identifies all all required reports, records, data reports, quality assurance reports/documents	9 Yes 9 No
A-7. Data and Field Quality Objectives and Criteria for All On-Site and Off-Site Measurement Data	
Provides the Data Quality Objectives in accordance and compliance with EPA=s Data Quality Objective Process (EPA-QA/G-4) document. Lists the seven steps of the DQO process and provides the project-specific information pertaining to each of these steps.	9 Yes 9 No
Applies the DQO process to the project study undertaken. Provides the qualitative and quantitative data quality objectives for all aspects of the project. Must provide clearly	9 Yes 9 No

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delineated project objectives such as determining the presence/absence of potential contaminants, nature and extent of contamination, determining whether human health is affected. Must provide a list of decisions and alternative actions (remediation, removal, further assessments, no further action, etc.).	
Provides all regulatory standards/criteria as part of DQO process (action limits, ARARs, PRGs, MCLs, etc.) on an analyte by analyte basis.	9 Yes 9 No
Provides a list of all the critical contaminants/analytes along with their respective detection limit requirements (for chemical parameters) and QA/QC requirements.	9 Yes 9 No
A-8. Special Training Requirements and Special Certifications	
Identifies how training needs are determined and lists all training requirements for the project. Specifies whether certain professionals require a license or certification to perform duties as required by federal or state laws.	9 Yes 9 No
Identifies where training records will be maintained	9 Yes 9 No
Identifies how any new training requirements are communicated to program/upper management	9 Yes 9 No
Discusses the importance of QA training and discusses how this training is provided.	9 Yes 9 No

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A-9. Documentation and Records	9 Yes 9 No
Provides a comprehensive list of the documents and records required for this project (including raw data, field logs, audit reports, QA reports, progress or status reports, analytical data reports, data validation reports/data quality assessments reports.)	9 Yes 9 No
Specifies the turnaround time for laboratory data deliverables (both hardcopy and electronic formats). Provides hardcopy data package content requirements and electronic data requirements	9 Yes 9 No
Provides the retention time and location of study records, reports and formal documents.	9 Yes 9 No
B-1. Sampling Process Design	
Provides a table with type and number of samples required for collection such as surface, subsurface, or groundwater.	9 Yes 9 No
Provides design of the sampling/collection network	9 Yes 9 No
Provides maps or diagrams with sample locations/collection locations and provides table with frequency of sampling events	9 Yes 9 No
Provides the sample matrices slated for collection in the sample table (surface soil, subsurface soil, sediment, surface water, groundwater samples, etc).	9 Yes 9 No
Provides an extensive discussion regarding the rationale for the sampling design. (This also includes a discussion regarding the rationale and relevance of the analytical program).	9 Yes 9 No
Provides a table identifying the chemical parameters/analytes of interest for each	9 Yes 9 No

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collected sample along with the required detection limits, regulatory standards/criteria, QA/QC criteria, analytical method number, sample container requirements, sample preservation requirements, sample volume requirements and holding time criteria.	
B-2. Sampling Method Requirements	
Provides the required field sample collection procedures, protocols and methods	9 Yes 9 No
Provides a list of sampling/collection equipment (including make and model of equipment).	9 Yes 9 No
Identifies on-site support facilities that are available to field staff.	9 Yes 9 No
Identifies key study personnel in charge of or overseeing sampling/collection activities	9 Yes 9 No
Describes equipment decontamination procedures and requirements. Discusses whether sampling equipment is dedicated or non-dedicated.	9 Yes 9 No
Provides table listing sample container requirements and preparation requirements for these containers (if provided by laboratory, clearly states such).	9 Yes 9 No
Provides table listing sample preservation requirements (for chemical parameters) and holding time criteria (where applicable).	9 Yes 9 No
B-3. Sample Handling and Custody Requirements	
Provides a detail description of the procedures for post sample handling (once the sample has been collected).	9 Yes 9 No
Provides a detailed description of the chain-of-custody procedures.	9 Yes 9 No

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B-4. Analytical Method Requirements	
Clearly identifies the extraction, digestion, analytical methodologies (provides the actual method numbers) to be followed (includes all relevant options or modifications required), identifies the required instrumentation. Provides laboratory SOPs or QAM.	9 Yes 9 No
Provides validation criteria for non-standard or unpublished methodologies proposed for use for a given study.	9 Yes 9 No
Identifies individual(s) responsible for overseeing the success of the analysis and for implementing corrective actions if deemed necessary.	9 Yes 9 No
Specifies the turnaround time for hardcopy and electronic laboratory data deliverables.	9 Yes 9 No
B-5. Quality Control Requirements	
Identifies the type, number and frequency of procedures and frequency of QA/QC sample collection along with the required QC statistically derived limits for each analyte (for spike samples, internal standards, surrogate spikes).	9 Yes 9 No
Provides the statistical equations for accuracy, precision, and comparability. Specifies the acceptance criteria for these measurements.	9 Yes 9 No
B-6. Instrument or Equipment Testing and Inspection Requirements	9 Yes 9 No
Provides a list of all in-situ testing instruments and field equipment.	9 Yes 9 No
Provides the technical criteria by which the field instruments or sampling equipment is checked for acceptable performance.	9 Yes 9 No

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Provides a comprehensive list of the supplies required for the project	9 Yes 9 No
Identifies the individual(s) responsible for checking and inspecting consumables and supplies	9 Yes 9 No
Provides the acceptance criteria consumable item, instrument and equipment	9 Yes 9 No
Describes equipment and corrective maintenance practices to ensure that on-site equipment or instruments are performing within the required specifications	9 Yes 9 No
Identifies the availability and location of spare parts	9 Yes 9 No
B-7. Instrument Calibration and Frequency	
Identifies all equipment requiring calibration and discusses the frequency of calibration	9 Yes 9 No
Identifies the calibration requirements for each instrument requiring calibration. (For fixed laboratory this may be in the SOPs or QA manual).	9 Yes 9 No
Provides the calibration requirements and calibration acceptance criteria for each type of equipment or instrument. (Again for the off-site laboratory this information will reside in the method-specific SOPs and the QA manual).	9 Yes 9 No
Identifies the type of documentation required for calibrations and instrument checks and discusses how calibrations are traced back to specific instruments for each analytical parameter. (Once again for the off-site laboratory this information will reside in the method-specific SOPs and the QA manual).	9 Yes 9 No

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B-8 Inspection/Acceptance Criteria and Requirements for Supplies and Consumables	9 Yes 9 No
Provides a comprehensive list of the consumables such as, solvents, reagents, buffer solutions and other consumables or supplies required for the project.	9 Yes 9 No
Provides the acceptance criteria for each of these items.	9 Yes 9 No
Identifies those individual(s) responsible for checking/inspecting supplies and consumables.	9 Yes 9 No
B-9. Data Acquisition Requirements for Non-Direct Measurements	
Identifies the type and frequency of non-direct measurement techniques for the project (for computer databases, literature searches, etc.)	9 Yes 9 No
Clearly identified and describes the limitations of such data	9 Yes 9 No
Discusses the rationale for using this data and explains its relevance to the project	9 Yes 9 No
Specifies how limitations in this data will be communicated to all end data users and stakeholders.	9 Yes 9 No
B-10. Data Management	
Describes the record-keeping, archival and retrieval requirements for hard-copy and electronic information produced during the course of the project.	9 Yes 9 No
Provides audit checklists or other standardized forms in an appendix to the QAPP.	9 Yes 9 No

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Describes data handling equipment and procedures used to process, compile and analyze data (provides a complete list of computer hardware and software needs) - Specifies whether computer databases will have restricted access or will be password protected Discusses how the accuracy of computer databases is assured.	9 Yes 9 No
Describes process for assuring that applicable Office of Information Resource Management requirements are satisfied (mainly this is required if the data will be entered into an EPA or other Federal Database)	9 Yes 9 No
C-1. Assessments, Audits and Corrective Actions	
Lists the required number, frequency and type of assessments with approximate dates and names of individual(s) responsible for performing these assessments	9 Yes 9 No
Discusses one or more of the following types of assessments: peer reviews, technical audits, surveillance, management system reviews, readiness reviews, quality system audits, performance evaluations, data quality assessments.	9 Yes 9 No
Identifies the individual(s) performing these assessments and discusses the authority and independence of these individual(s) in relation to those being assessed	9 Yes 9 No
Provides a description of the types of corrective actions that may be instituted to resolve any issues raised during the audit	9 Yes 9 No
Discusses where audit findings will be documented and how the audit findings will be communicated to all key project staff, state and EPA personnel responsible for the study	9 Yes 9 No

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oversight	
C-2. Reports to Management: Identifies the frequency and distribution of the following types of reports:	
Project Status Reports	9 Yes 9 No
Results of Assessments or Audits	9 Yes 9 No
Results of periodic Data Quality Assessments	9 Yes 9 No
QA Audit Reports	9 Yes 9 No
Identifies the individual(s) responsible for preparing, reviewing and receiving these reports - discusses the retention time for maintaining such reports	9 Yes 9 No
D-1 & D-2. Data Review, Verification and Validation	
Identifies the guidance documents or SOPs governing the data review, verification and validation processes	9 Yes 9 No
Clearly discusses the criteria by which data will be accepted or rejected and provides a comprehensive list of the data flags or qualifiers that will be assigned to non-compliant data points (including the definitions for each of these flags)	9 Yes 9 No
Describes the process, and provides the criteria by which the data will be assessed for its overall usability and intended purpose.	9 Yes 9 No
Identifies the individual(s) responsible for validating the data and identifies the company or consultant for whom they work (Note: EPA recommends using an independent second or third party validator or at least a person that is unaffiliated with the laboratory performing the analyses on site samples).	9 Yes 9 No

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Identifies how problems associated with the laboratory will be documented and communicated to all end data users and stakeholders (where will the results of the data validation process be documented)	9 Yes 9 No
D-3. Reconciliation of the Data to the Project-Specific DQOs	
Describes the process by which the on-site and off-site analytical data will be reconciled to the project-specific DQOs (especially if the data is non-compliant)	9 Yes 9 No
Discusses how limitations in the final data set will be documented and communicated to all end data users and stakeholders.	9 Yes 9 No
Describes the circumstances under which data would be rejected and removed from the final data set	9 Yes 9 No
Identifies the individual(s) responsible for reconciling the data to the project-specific DQOs	9 Yes 9 No
Identifies the SOP or guidance document outlining the DQO reconciliation process	9 Yes 9 No

Note: EPA's guidance and requirements documents for the DQO process, QAPP preparation, Data Validation and Data Quality Assessments, are located at www.epa.gov/quality. These documents include:

Final QAPP Disposition:

____ *Approved, no comments*

Signature of Designated Approval Official (DAO) _____

Signature of Section Chief of the DAO _____

____ *Not Approved, Address Comments, Submit Revised QAPP to the EPA Designated*

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Approval Official

References

1. EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5, EPA/240/B-01/002 (March 2001).
2. EPA Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, EPA/240/B-06/001 (February 2006).

Both documents can be accessed at the following website: www.epa.gov/quality - Select guidance from the menu options to the left of the screen.

Appendix B

Target Analyte Lists and Reporting Limits

Appendix B Method Analyte Lists and Reporting Limits

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Water Samples																		
Volatile Organic Compounds (GC/MS)																		
	8260B																	
Acetone	67-64-1	10.00	µg/L	5.00	µg/L	39	162	%	50	%	39	162	%	50	%	NA	NA	%
Benzene	71-43-2	1.00	µg/L	0.25	µg/L	74	123	%	30	%	74	123	%	30	%	NA	NA	%
Bromodichloromethane	75-27-4	1.00	µg/L	0.25	µg/L	72	129	%	30	%	72	129	%	30	%	NA	NA	%
4-Bromofluorobenzene (Surr)	460-00-4	NA	µg/L	NA	µg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
Bromoform	75-25-2	1.00	µg/L	0.50	µg/L	60	134	%	30	%	60	134	%	30	%	NA	NA	%
Bromomethane	74-83-9	5.00	µg/L	2.00	µg/L	10	171	%	50	%	10	171	%	50	%	NA	NA	%
2-Butanone (MEK)	78-93-3	10.00	µg/L	1.00	µg/L	55	142	%	30	%	55	142	%	30	%	NA	NA	%
Carbon disulfide	75-15-0	2.00	µg/L	0.60	µg/L	63	142	%	30	%	63	142	%	30	%	NA	NA	%
Carbon tetrachloride	56-23-5	1.00	µg/L	0.50	µg/L	70	131	%	30	%	70	131	%	30	%	NA	NA	%
Chlorobenzene	108-90-7	1.00	µg/L	0.25	µg/L	79	120	%	30	%	79	120	%	30	%	NA	NA	%
Chloroethane	75-00-3	5.00	µg/L	2.00	µg/L	47	148	%	40	%	47	148	%	40	%	NA	NA	%
Chloroform	67-66-3	1.00	µg/L	0.14	µg/L	76	128	%	30	%	76	128	%	30	%	NA	NA	%
Chloromethane	74-87-3	1.00	µg/L	0.33	µg/L	47	151	%	30	%	47	151	%	30	%	NA	NA	%
cis-1,2-Dichloroethene	156-59-2	1.00	µg/L	0.15	µg/L	78	127	%	30	%	78	127	%	30	%	NA	NA	%
cis-1,3-Dichloropropene	10061-01-5	1.00	µg/L	0.11	µg/L	73	128	%	30	%	73	128	%	30	%	NA	NA	%
Cyclohexane	110-82-7	1.00	µg/L	0.25	µg/L	68	137	%	30	%	68	137	%	30	%	NA	NA	%
Dibromochloromethane	124-48-1	1.00	µg/L	0.10	µg/L	63	134	%	50	%	63	134	%	50	%	NA	NA	%
1,2-Dibromo-3-Chloropropane	96-12-8	5.00	µg/L	0.44	µg/L	57	126	%	50	%	57	126	%	50	%	NA	NA	%
1,2-Dibromoethane	106-93-4	1.00	µg/L	0.25	µg/L	75	127	%	30	%	75	127	%	30	%	NA	NA	%
Dibromofluoromethane (Surr)	1868-53-7	NA	µg/L	NA	µg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
1,2-Dichlorobenzene	95-50-1	1.00	µg/L	0.21	µg/L	77	124	%	30	%	77	124	%	30	%	NA	NA	%
1,3-Dichlorobenzene	541-73-1	1.00	µg/L	0.25	µg/L	79	123	%	30	%	79	123	%	30	%	NA	NA	%
1,4-Dichlorobenzene	106-46-7	1.00	µg/L	0.28	µg/L	76	124	%	30	%	76	124	%	30	%	NA	NA	%
1,1-Dichloroethane	75-34-3	1.00	µg/L	0.25	µg/L	69	132	%	30	%	69	132	%	30	%	NA	NA	%
1,2-Dichloroethane	107-06-2	1.00	µg/L	0.10	µg/L	75	120	%	30	%	75	120	%	30	%	NA	NA	%
1,2-Dichloroethane-d4 (Surr)	17060-07-0	NA	µg/L	NA	µg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
1,1-Dichloroethene	75-35-4	1.00	µg/L	0.11	µg/L	73	134	%	30	%	73	134	%	30	%	NA	NA	%
1,2-Dichloropropane	78-87-5	1.00	µg/L	0.13	µg/L	71	126	%	30	%	71	126	%	30	%	NA	NA	%
Ethylbenzene	100-41-4	1.00	µg/L	0.11	µg/L	78	125	%	30	%	78	125	%	30	%	NA	NA	%
2-Hexanone	591-78-6	10.00	µg/L	1.00	µg/L	52	149	%	30	%	52	149	%	30	%	NA	NA	%
Isopropylbenzene	98-82-8	1.00	µg/L	0.10	µg/L	72	129	%	30	%	72	129	%	30	%	NA	NA	%
Methyl acetate	79-20-9	5.00	µg/L	0.19	µg/L	26	182	%	30	%	26	182	%	30	%	NA	NA	%
Methylcyclohexane	108-87-2	1.00	µg/L	0.10	µg/L	72	133	%	30	%	72	133	%	30	%	NA	NA	%
Methylene Chloride	75-09-2	5.00	µg/L	1.00	µg/L	79	124	%	30	%	79	124	%	30	%	NA	NA	%
4-Methyl-2-pentanone (MIBK)	108-10-1	10.00	µg/L	1.00	µg/L	51	143	%	30	%	51	143	%	30	%	NA	NA	%
Methyl tert-butyl ether	1634-04-4	10.00	µg/L	0.20	µg/L	76	126	%	30	%	76	126	%	30	%	NA	NA	%
m-Xylene & p-Xylene	179601-23-1	1.00	µg/L	0.20	µg/L	79	126	%	30	%	79	126	%	30	%	NA	NA	%
o-Xylene	95-47-6	1.00	µg/L	0.25	µg/L	78	126	%	30	%	78	126	%	30	%	NA	NA	%
Styrene	100-42-5	1.00	µg/L	0.11	µg/L	75	129	%	30	%	75	129	%	30	%	NA	NA	%
1,1,2,2-Tetrachloroethane	79-34-5	1.00	µg/L	0.18	µg/L	71	127	%	30	%	71	127	%	30	%	NA	NA	%
Tetrachloroethene	127-18-4	1.00	µg/L	0.15	µg/L	77	128	%	30	%	77	128	%	30	%	NA	NA	%
Toluene	108-88-3	1.00	µg/L	0.33	µg/L	77	125	%	30	%	77	125	%	30	%	NA	NA	%
Toluene-d8 (Surr)	2037-26-5	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	70	130	%
trans-1,2-Dichloroethene	156-60-5	1.00	µg/L	0.20	µg/L	78	130	%	30	%	78	130	%	30	%	NA	NA	%
trans-1,3-Dichloropropene	10061-02-6	1.00	µg/L	0.21	µg/L	72	127	%	50	%	72	127	%	50	%	NA	NA	%
1,2,4-Trichlorobenzene	120-82-1	5.00	µg/L	0.25	µg/L	67	134	%	30	%	67	134	%	30	%	NA	NA	%
1,1,1-Trichloroethane	71-55-6	1.00	µg/L	0.50	µg/L	76	126	%	30	%	76	126	%	30	%	NA	NA	%
1,1,2-Trichloroethane	79-00-5	1.00	µg/L	0.13	µg/L	69	127	%	30	%	69	127	%	30	%	NA	NA	%
Trichloroethene	79-01-6	1.00	µg/L	0.13	µg/L	80	120	%	30	%	80	120	%	30	%	NA	NA	%
Trichlorofluoromethane	75-69-4	1.00	µg/L	0.25	µg/L	66	144	%	30	%	66	144	%	30	%	NA	NA	%
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1.00	µg/L	0.50	µg/L	72	139	%	30	%	72	139	%	30	%	NA	NA	%
1,2,4-Trimethylbenzene	95-63-6	1.00	µg/L	0.47	µg/L	80	124	%	20	%	80	124	%	20	%	NA	NA	%
1,3,5-Trimethylbenzene	108-67-8	1.00	µg/L	0.31	µg/L	80	120	%	20	%	80	120	%	20	%	NA	NA	%
Vinyl chloride	75-01-4	1.00	µg/L	0.18	µg/L	58	141	%	30	%	58	141	%	30	%	NA	NA	%
Xylenes, Total	1330-20-7	1.00	µg/L	0.20	µg/L	80	124	%	30	%	80	124	%	30	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatile Organic Compounds (GC/MS) - Standard	8270D/3520																	
Acenaphthene	83-32-9	10.00	µg/L	1.50	µg/L	32	107	%	50	%	32	107	%	20	%	NA	NA	%
Acenaphthylene	208-96-8	10.00	µg/L	1.60	µg/L	10	119	%	50	%	10	119	%	20	%	NA	NA	%
Acetophenone	98-86-2	10.00	µg/L	1.80	µg/L	40	104	%	50	%	40	104	%	30	%	NA	NA	%
Anthracene	120-12-7	10.00	µg/L	1.70	µg/L	38	112	%	50	%	38	112	%	20	%	NA	NA	%
Benzo[a]anthracene	56-55-3	10.00	µg/L	1.90	µg/L	36	115	%	50	%	36	115	%	40	%	NA	NA	%
Benzo[a]pyrene	50-32-8	10.00	µg/L	2.40	µg/L	13	120	%	50	%	13	120	%	40	%	NA	NA	%
Benzo[b]fluoranthene	205-99-2	10.00	µg/L	2.10	µg/L	32	117	%	50	%	32	117	%	50	%	NA	NA	%
Benzo[g,h,i]perylene	191-24-2	10.00	µg/L	2.00	µg/L	21	118	%	50	%	21	118	%	50	%	NA	NA	%
Benzo[k]fluoranthene	207-08-9	10.00	µg/L	2.50	µg/L	28	125	%	50	%	28	125	%	40	%	NA	NA	%
1,1'-Biphenyl	92-52-4	10.00	µg/L	1.50	µg/L	29	100	%	50	%	29	100	%	50	%	NA	NA	%
Bis(2-chloroethoxy)methane	111-91-1	10.00	µg/L	1.70	µg/L	28	122	%	50	%	28	122	%	50	%	NA	NA	%
Bis(2-chloroethyl)ether	111-44-4	10.00	µg/L	1.40	µg/L	32	97	%	50	%	32	97	%	50	%	NA	NA	%
Bis(2-ethylhexyl) phthalate	117-81-7	10.00	µg/L	2.40	µg/L	35	123	%	50	%	35	123	%	50	%	NA	NA	%
4-Bromophenyl phenyl ether	101-55-3	10.00	µg/L	1.80	µg/L	39	115	%	50	%	39	115	%	50	%	NA	NA	%
Butyl benzyl phthalate	85-68-7	10.00	µg/L	2.30	µg/L	23	125	%	50	%	23	125	%	50	%	NA	NA	%
Carbazole	86-74-8	10.00	µg/L	2.10	µg/L	10	146	%	50	%	10	146	%	50	%	NA	NA	%
4-Chloroaniline	106-47-8	20.00	µg/L	1.30	µg/L	10	112	%	50	%	10	112	%	50	%	NA	NA	%
4-Chloro-3-methylphenol	59-50-7	10.00	µg/L	1.70	µg/L	43	110	%	50	%	43	110	%	50	%	NA	NA	%
2-Chloronaphthalene	91-58-7	10.00	µg/L	1.40	µg/L	29	97	%	50	%	29	97	%	50	%	NA	NA	%
2-Chlorophenol	95-57-8	10.00	µg/L	1.50	µg/L	38	98	%	50	%	38	98	%	50	%	NA	NA	%
4-Chlorophenyl phenyl ether	7005-72-3	10.00	µg/L	1.80	µg/L	36	111	%	50	%	36	111	%	50	%	NA	NA	%
Chrysene	218-01-9	10.00	µg/L	1.90	µg/L	36	113	%	50	%	36	113	%	50	%	NA	NA	%
Dibenz(a,h)anthracene	53-70-3	10.00	µg/L	1.70	µg/L	32	115	%	50	%	32	115	%	40	%	NA	NA	%
Dibenzofuran	132-64-9	10.00	µg/L	1.70	µg/L	38	106	%	50	%	38	106	%	50	%	NA	NA	%
3,3'-Dichlorobenzidine	91-94-1	60.00	µg/L	40.00	µg/L	10	131	%	50	%	10	131	%	50	%	NA	NA	%
2,4-Dichlorophenol	120-83-2	10.00	µg/L	1.70	µg/L	41	107	%	50	%	41	107	%	50	%	NA	NA	%
Diethyl phthalate	84-66-2	10.00	µg/L	2.00	µg/L	45	112	%	50	%	45	112	%	50	%	NA	NA	%
2,4-Dimethylphenol	105-67-9	10.00	µg/L	1.30	µg/L	32	97	%	50	%	32	97	%	50	%	NA	NA	%
Dimethyl phthalate	131-11-3	10.00	µg/L	2.00	µg/L	44	112	%	50	%	44	112	%	50	%	NA	NA	%
Di-n-butyl phthalate	84-74-2	10.00	µg/L	1.90	µg/L	42	117	%	50	%	42	117	%	50	%	NA	NA	%
4,6-Dinitro-2-methylphenol	534-52-1	50.00	µg/L	17.00	µg/L	33	126	%	50	%	33	126	%	50	%	NA	NA	%
2,4-Dinitrophenol	51-28-5	50.00	µg/L	25.00	µg/L	16	132	%	50	%	16	132	%	50	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	10.00	µg/L	0.84	µg/L	44	116	%	50	%	44	116	%	50	%	NA	NA	%
2,6-Dinitrotoluene	606-20-2	10.00	µg/L	1.20	µg/L	43	115	%	50	%	43	115	%	50	%	NA	NA	%
Di-n-octyl phthalate	117-84-0	10.00	µg/L	2.50	µg/L	37	109	%	50	%	37	109	%	50	%	NA	NA	%
Fluoranthene	206-44-0	10.00	µg/L	1.90	µg/L	41	113	%	50	%	41	113	%	40	%	NA	NA	%
Fluorene	86-73-7	10.00	µg/L	1.80	µg/L	39	115	%	50	%	39	115	%	20	%	NA	NA	%
2-Fluorobiphenyl	321-60-8	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	32	114	%
2-Fluorophenol (Surr)	367-12-4	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	26	107	%
Hexachlorobenzene	118-74-1	10.00	µg/L	1.70	µg/L	38	114	%	50	%	38	114	%	50	%	NA	NA	%
Hexachlorobutadiene	87-68-3	10.00	µg/L	0.83	µg/L	13	75	%	50	%	13	75	%	50	%	NA	NA	%
Hexachlorocyclopentadiene	77-47-4	10.00	µg/L	0.75	µg/L	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Hexachloroethane	67-72-1	10.00	µg/L	0.83	µg/L	10	67	%	50	%	10	67	%	50	%	NA	NA	%
Indeno[1,2,3-cd]pyrene	193-39-5	10.00	µg/L	1.80	µg/L	16	119	%	50	%	16	119	%	40	%	NA	NA	%
Isophorone	78-59-1	10.00	µg/L	1.30	µg/L	38	103	%	50	%	38	103	%	50	%	NA	NA	%
2-Methylnaphthalene	91-57-6	10.00	µg/L	1.30	µg/L	24	92	%	50	%	24	92	%	30	%	NA	NA	%
2-Methylphenol	95-48-7	10.00	µg/L	1.40	µg/L	39	100	%	50	%	39	100	%	30	%	NA	NA	%
3 & 4 Methylphenol	15831-10-4	10.00	µg/L	1.30	µg/L	40	97	%	50	%	40	97	%	50	%	NA	NA	%
Naphthalene	91-20-3	10.00	µg/L	1.20	µg/L	24	85	%	50	%	24	85	%	40	%	NA	NA	%
2-Nitroaniline	88-74-4	50.00	µg/L	10.00	µg/L	22	119	%	50	%	22	119	%	50	%	NA	NA	%
3-Nitroaniline	99-09-2	50.00	µg/L	10.00	µg/L	10	150	%	50	%	10	150	%	50	%	NA	NA	%
4-Nitroaniline	100-01-6	50.00	µg/L	10.00	µg/L	10	142	%	50	%	10	142	%	50	%	NA	NA	%
Nitrobenzene	98-95-3	10.00	µg/L	1.30	µg/L	35	100	%	50	%	35	100	%	50	%	NA	NA	%
Nitrobenzene-d5 (Surr)	4165-60-0	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	30	117	%
2-Nitrophenol	88-75-5	10.00	µg/L	2.00	µg/L	34	112	%	50	%	34	112	%	50	%	NA	NA	%
4-Nitrophenol	100-02-7	50.00	µg/L	10.00	µg/L	34	111	%	50	%	34	111	%	50	%	NA	NA	%
N-Nitrosodi-n-propylamine	621-64-7	10.00	µg/L	1.50	µg/L	39	101	%	50	%	39	101	%	50	%	NA	NA	%
N-Nitrosodiphenylamine	86-30-6	10.00	µg/L	1.80	µg/L	9	126	%	50	%	9	126	%	50	%	NA	NA	%
2,2'-oxybis[1-chloropropane]	108-60-1	10.00	µg/L	1.20	µg/L	26	117	%	50	%	26	117	%	50	%	NA	NA	%
Pentachlorophenol	87-86-5	50.00	µg/L	10.00	µg/L	40	119	%	50	%	40	119	%	50	%	NA	NA	%
Phenanthrene	85-01-8	10.00	µg/L	1.90	µg/L	40	114	%	50	%	40	114	%	40	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Phenol	108-95-2	10.00	µg/L	1.50	µg/L	30	93	%	50	%	30	93	%	50	%	NA	NA	%
Phenol-d5 (Surr)	4165-62-2	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	25	109	%
Pyrene	129-00-0	10.00	µg/L	1.90	µg/L	29	118	%	50	%	29	118	%	50	%	NA	NA	%
Terphenyl-d14 (Surr)	1718-51-0	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	10	132	%
2,4,6-Tribromophenol (Surr)	118-79-6	NA	µg/L	NA	µg/L	NA	NA	%	50	%	NA	NA	%	50	%	34	140	%
2,4,5-Trichlorophenol	95-95-4	10.00	µg/L	1.80	µg/L	42	114	%	50	%	42	114	%	50	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	10.00	µg/L	1.50	µg/L	42	112	%	50	%	42	112	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatile Organic Compounds (GC/MS) - Low Level	8270D_LL																	
Acenaphthene	83-32-9	0.2	ug/L	0.10	ug/L	42	130	%	50	%	42	130	%	50	%	NA	NA	%
Acenaphthylene	208-96-8	0.2	ug/L	0.10	ug/L	45	130	%	50	%	45	130	%	50	%	NA	NA	%
Acetophenone	98-86-2	1	ug/L	0.30	ug/L	45	130	%	50	%	45	130	%	50	%	NA	NA	%
Anthracene	120-12-7	0.2	ug/L	0.10	ug/L	58	130	%	50	%	58	130	%	50	%	NA	NA	%
Benzo[a]anthracene	56-55-3	0.2	ug/L	0.10	ug/L	42	143	%	50	%	42	143	%	50	%	NA	NA	%
Benzo[a]pyrene	50-32-8	0.2	ug/L	0.10	ug/L	45	151	%	50	%	45	151	%	50	%	NA	NA	%
Benzo[b]fluoranthene	205-99-2	0.2	ug/L	0.10	ug/L	41	140	%	50	%	41	140	%	50	%	NA	NA	%
Benzo[g,h,i]perylene	191-24-2	0.2	ug/L	0.10	ug/L	27	134	%	50	%	27	134	%	50	%	NA	NA	%
Benzo[k]fluoranthene	207-08-9	0.2	ug/L	0.10	ug/L	45	140	%	50	%	45	140	%	50	%	NA	NA	%
1,1'-Biphenyl	92-52-4	1	ug/L	0.10	ug/L	50	130	%	50	%	50	130	%	50	%	NA	NA	%
Bis(2-chloroethoxy)methane	111-91-1	1	ug/L	0.10	ug/L	47	130	%	50	%	47	130	%	50	%	NA	NA	%
Bis(2-chloroethyl)ether	111-44-4	1	ug/L	0.10	ug/L	36	130	%	50	%	36	130	%	50	%	NA	NA	%
Bis(2-ethylhexyl) phthalate	117-81-7	5	ug/L	2.00	ug/L	10	158	%	50	%	10	158	%	50	%	NA	NA	%
4-Bromophenyl phenyl ether	101-55-3	1	ug/L	0.12	ug/L	44	130	%	50	%	44	130	%	50	%	NA	NA	%
Butyl benzyl phthalate	85-68-7	1	ug/L	0.12	ug/L	60	130	%	50	%	60	130	%	50	%	NA	NA	%
Carbazole	86-74-8	2	ug/L	0.10	ug/L	19	191	%	50	%	19	191	%	50	%	NA	NA	%
4-Chloroaniline	106-47-8	4	ug/L	2.00	ug/L	17	130	%	50	%	17	130	%	50	%	NA	NA	%
4-Chloro-3-methylphenol	59-50-7	1	ug/L	0.12	ug/L	54	130	%	50	%	54	130	%	50	%	NA	NA	%
2-Chloronaphthalene	91-58-7	1	ug/L	0.10	ug/L	48	130	%	50	%	48	130	%	50	%	NA	NA	%
2-Chlorophenol	95-57-8	1	ug/L	0.12	ug/L	45	130	%	50	%	45	130	%	50	%	NA	NA	%
4-Chlorophenyl phenyl ether	7005-72-3	1	ug/L	0.10	ug/L	52	130	%	50	%	52	130	%	50	%	NA	NA	%
Chrysene	218-01-9	0.2	ug/L	0.05	ug/L	40	142	%	50	%	40	142	%	50	%	NA	NA	%
Dibenz(a,h)anthracene	53-70-3	0.2	ug/L	0.10	ug/L	38	130	%	50	%	38	130	%	50	%	NA	NA	%
Dibenzofuran	132-64-9	1	ug/L	0.10	ug/L	56	130	%	50	%	56	130	%	50	%	NA	NA	%
3,3'-Dichlorobenzidine	91-94-1	20	ug/L	2.00	ug/L	10	158	%	50	%	10	158	%	50	%	NA	NA	%
2,4-Dichlorophenol	120-83-2	1	ug/L	0.10	ug/L	58	130	%	50	%	58	130	%	50	%	NA	NA	%
Diethyl phthalate	84-66-2	1	ug/L	0.11	ug/L	60	130	%	50	%	60	130	%	50	%	NA	NA	%
2,4-Dimethylphenol	105-67-9	2	ug/L	0.69	ug/L	41	130	%	50	%	41	130	%	50	%	NA	NA	%
Dimethyl phthalate	131-11-3	1	ug/L	0.10	ug/L	58	130	%	50	%	58	130	%	50	%	NA	NA	%
Di-n-butyl phthalate	84-74-2	1	ug/L	0.39	ug/L	59	130	%	50	%	59	130	%	50	%	NA	NA	%
4,6-Dinitro-2-methylphenol	534-52-1	5	ug/L	1.00	ug/L	10	182	%	50	%	10	182	%	50	%	NA	NA	%
2,4-Dinitrophenol	51-28-5	10	ug/L	1.10	ug/L	10	200	%	50	%	10	200	%	50	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	1	ug/L	0.12	ug/L	57	130	%	50	%	57	130	%	50	%	NA	NA	%
2,6-Dinitrotoluene	606-20-2	1	ug/L	0.13	ug/L	53	130	%	50	%	53	130	%	50	%	NA	NA	%
Di-n-octyl phthalate	117-84-0	1	ug/L	0.17	ug/L	19	130	%	50	%	19	130	%	50	%	NA	NA	%
Fluoranthene	206-44-0	0.2	ug/L	0.10	ug/L	46	136	%	50	%	46	136	%	50	%	NA	NA	%
Fluorene	86-73-7	0.2	ug/L	0.10	ug/L	48	130	%	50	%	48	130	%	50	%	NA	NA	%
2-Fluorobiphenyl	321-60-8	NA	ug/L	NA	ug/L	10	130	%	50	%	10	130	%	50	%	34	130	%
2-Fluorophenol (Surr)	367-12-4	NA	ug/L	NA	ug/L	10	130	%	50	%	10	130	%	50	%	25	130	%
Hexachlorobenzene	118-74-1	1	ug/L	0.10	ug/L	49	130	%	50	%	49	130	%	50	%	NA	NA	%
Hexachlorobutadiene	87-68-3	1	ug/L	0.10	ug/L	36	130	%	50	%	36	130	%	50	%	NA	NA	%
Hexachlorocyclopentadiene	77-47-4	2	ug/L	0.50	ug/L	16	130	%	50	%	16	130	%	50	%	NA	NA	%
Hexachloroethane	67-72-1	1	ug/L	0.50	ug/L	32	130	%	50	%	32	130	%	50	%	NA	NA	%
Indeno[1,2,3-cd]pyrene	193-39-5	0.2	ug/L	0.10	ug/L	12	130	%	50	%	12	130	%	50	%	NA	NA	%
Isophorone	78-59-1	1	ug/L	0.10	ug/L	45	130	%	50	%	45	130	%	50	%	NA	NA	%
2-Methylnaphthalene	91-57-6	0.2	ug/L	0.10	ug/L	51	130	%	50	%	51	130	%	50	%	NA	NA	%
2-Methylphenol	95-48-7	2	ug/L	0.74	ug/L	49	130	%	50	%	49	130	%	50	%	NA	NA	%
3 & 4 Methylphenol	15831-10-4	2	ug/L	0.66	ug/L	55	130	%	50	%	55	130	%	50	%	NA	NA	%
Naphthalene	91-20-3	0.2	ug/L	0.10	ug/L	35	130	%	50	%	35	130	%	50	%	NA	NA	%
2-Nitroaniline	88-74-4	1	ug/L	0.16	ug/L	48	130	%	50	%	48	130	%	50	%	NA	NA	%
3-Nitroaniline	99-09-2	5	ug/L	0.16	ug/L	18	147	%	50	%	18	147	%	50	%	NA	NA	%
4-Nitroaniline	100-01-6	5	ug/L	0.50	ug/L	31	147	%	50	%	31	147	%	50	%	NA	NA	%
Nitrobenzene	98-95-3	1	ug/L	0.10	ug/L	45	130	%	50	%	45	130	%	50	%	NA	NA	%
Nitrobenzene-d5 (Surr)	4165-60-0	NA	ug/L	NA	ug/L	NA	NA	%	50	%	NA	NA	%	50	%	32	130	%
2-Nitrophenol	88-75-5	1	ug/L	0.10	ug/L	49	130	%	50	%	49	130	%	50	%	NA	NA	%
4-Nitrophenol	100-02-7	8	ug/L	4.00	ug/L	36	132	%	50	%	36	132	%	50	%	NA	NA	%
N-Nitrosodi-n-propylamine	621-64-7	1	ug/L	0.13	ug/L	42	130	%	50	%	42	130	%	50	%	NA	NA	%
N-Nitrosodiphenylamine	86-30-6	1	ug/L	0.37	ug/L	38	130	%	50	%	38	130	%	50	%	NA	NA	%
2,2'-oxybis[1-chloropropane]	108-60-1	1	ug/L	0.10	ug/L	39	130	%	50	%	39	130	%	50	%	NA	NA	%
Pentachlorophenol	87-86-5	5	ug/L	0.40	ug/L	12	156	%	50	%	12	156	%	50	%	NA	NA	%
Phenanthrene	85-01-8	0.2	ug/L	0.10	ug/L	45	134	%	50	%	45	134	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Phenol	108-95-2	1	ug/L	0.13	ug/L	44	130	%	50	%	44	130	%	50	%	NA	NA	%
Phenol-d5 (Surr)	4165-62-2	NA	ug/L	NA	ug/L	NA	NA	%	50	%	NA	NA	%	50	%	27	130	%
Pyrene	129-00-0	0.2	ug/L	0.10	ug/L	47	143	%	50	%	47	143	%	50	%	NA	NA	%
Terphenyl-d14 (Surr)	1718-51-0	NA	ug/L	NA	ug/L	NA	NA	%	50	%	NA	NA	%	50	%	36	130	%
2,4,6-Tribromophenol (Surr)	118-79-6	NA	ug/L	NA	ug/L	10	130	%	50	%	10	130	%	50	%	30	130	%
2,4,5-Trichlorophenol	95-95-4	1	ug/L	0.12	ug/L	61	130	%	50	%	61	130	%	50	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	1	ug/L	0.17	ug/L	61	130	%	50	%	61	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Metals (ICP)	6010C																	
Aluminum	7429-90-5	200	µg/L	100	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Antimony	7440-36-0	20.00	µg/L	5.30	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Arsenic	7440-38-2	20.00	µg/L	4.60	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Barium	7440-39-3	10.00	µg/L	2.30	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Beryllium	7440-41-7	4.00	µg/L	0.20	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Cadmium	7440-43-9	5.00	µg/L	2.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Calcium	7440-70-2	500	µg/L	96.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Chromium	7440-47-3	10.00	µg/L	1.20	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Cobalt	7440-48-4	10.00	µg/L	0.95	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Copper	7440-50-8	20.00	µg/L	1.90	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Iron	7439-89-6	100	µg/L	50.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Lead	7439-92-1	10.00	µg/L	4.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Magnesium	7439-95-4	500	µg/L	9.90	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Manganese	7439-96-5	10.00	µg/L	2.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Nickel	7440-02-0	40.00	µg/L	2.30	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Potassium	9/7/7440	1000	µg/L	22.00	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Selenium	7782-49-2	20.00	µg/L	6.40	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Silver	7440-22-4	10.00	µg/L	0.89	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Sodium	7440-23-5	1000	µg/L	500	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Thallium	7440-28-0	25.00	µg/L	8.80	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Vanadium	7440-62-2	10.00	µg/L	2.40	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Zinc	7440-66-6	20.00	µg/L	8.70	µg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Terpenes	8270																	
Borneol	507-70-0	2	µg/L	0.45	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Camphene	79-92-5	2	µg/L	0.47	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Camphor	76-22-2	2	µg/L	0.47	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Cineole	470-82-6	2	µg/L	0.57	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Dipentene	5989-27-5	2	µg/L	0.47	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Isoborneol	124-76-5	2	µg/L	0.53	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
Limonene	138-86-3	2	µg/L	0.89	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
alpha-Pinene	80-56-8	2	µg/L	0.81	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
beta-Pinene	127-91-3	2	µg/L	0.48	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%
alpha-Terpineol	98-5-5	2	µg/L	0.47	µg/L	NA	NA	%	NA	%	50	150	%	30	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Groundwater GeoChemistry																		
Dissolved Gases (GC)		RSK_175																
Methane	74-82-8	2.00	µg/L	NA	µg/L	70	130	%	30	%	70	130	%	30	%	NA	NA	%
Ethane	74-84-0	4.00	µg/L	NA	µg/L	70	130	%	30	%	70	130	%	30	%	NA	NA	%
Ethylene	74-85-1	3.00	µg/L	NA	µg/L	70	130	%	30	%	70	130	%	30	%	NA	NA	%
Dissolved Gases (GC)		RSK_175_CO2																
Carbon dioxide	124-38-9	1000	µg/L	NA	µg/L	70	130	%	30	%	70	130	%	30	%	NA	NA	%
Anions, Ion Chromatography		9056A_ORGFM_28D																
Bromide	24959-67-9	0.50	mg/L	0.20	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Chloride	16887-00-6	0.50	mg/L	0.20	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Sulfate	14808-79-8	1.00	mg/L	0.40	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Anions, Ion Chromatography		9056A_ORGFM_48H																
Nitrate as N	14797-55-8	0.05	mg/L	0.023	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Nitrite as N	14797-65-0	0.05	mg/L	0.023	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Nitrate Nitrite as N	STL00217	0.05	mg/L	0.023	mg/L	90	110	%	30	%	80	120	%	30	%	NA	NA	%
Alkalinity		2320B																
Total Alkalinity	STL00171	5.00	mg/L	NA	mg/L	80	120	%	30	%	NA	NA	%	NA	%	NA	NA	%
Bicarbonate Alkalinity as CaCO3	STL00138	5.00	mg/L	NA	mg/L	80	120	%	30	%	NA	NA	%	NA	%	NA	NA	%
Carbonate Alkalinity as CaCO3	STL00154	5.00	mg/L	NA	mg/L	80	120	%	30	%	NA	NA	%	NA	%	NA	NA	%
Carbon Dioxide, Free	STL00334	5.00	mg/L	NA	mg/L	80	120	%	30	%	NA	NA	%	NA	%	NA	NA	%
Disinfection By-Products, (IC)		300.1B_28D																
Bromide	24959-67-9	0.02	mg/L	0.0047	mg/L	85	115	%	10	%	75	125	%	10	%	NA	NA	%
COD		410.4																
Chemical Oxygen Demand	STL00070	10.00	mg/L	5.00	mg/L	90	110	%	30	%	90	110	%	30	%	NA	NA	%
Sulfide, Total		SM4500_S2_F																
Sulfide	18496-25-8	1.00	mg/L	NA	mg/L	75	125	%	30	%	75	125	%	30	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Soil Samples																		
Volatile Organic Compounds (GC/MS)		8260B																
Acetone	67-64-1	50.00	µg/kg	11.00	µg/kg	54	139	%	50	%	54	139	%	50	%	NA	NA	%
Benzene	71-43-2	5.00	µg/kg	0.73	µg/kg	76	120	%	30	%	76	120	%	50	%	NA	NA	%
Bromodichloromethane	75-27-4	5.00	µg/kg	0.97	µg/kg	72	131	%	30	%	72	131	%	50	%	NA	NA	%
4-Bromofluorobenzene (Surr)	460-00-4	NA	µg/kg	NA	µg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	65	130	%
Bromoform	75-25-2	5.00	µg/kg	1.50	µg/kg	64	150	%	30	%	64	150	%	50	%	NA	NA	%
Bromomethane	74-83-9	5.00	µg/kg	1.50	µg/kg	10	174	%	30	%	10	174	%	50	%	NA	NA	%
2-Butanone (MEK)	78-93-3	25.00	µg/kg	2.40	µg/kg	66	123	%	30	%	66	123	%	50	%	NA	NA	%
Carbon disulfide	75-15-0	5.00	µg/kg	1.10	µg/kg	74	125	%	30	%	74	125	%	50	%	NA	NA	%
Carbon tetrachloride	56-23-5	5.00	µg/kg	0.83	µg/kg	67	140	%	30	%	67	140	%	50	%	NA	NA	%
Chlorobenzene	108-90-7	5.00	µg/kg	0.96	µg/kg	80	120	%	30	%	80	120	%	50	%	NA	NA	%
Chloroethane	75-00-3	5.00	µg/kg	2.70	µg/kg	10	176	%	30	%	10	176	%	50	%	NA	NA	%
Chloroform	67-66-3	5.00	µg/kg	1.10	µg/kg	80	121	%	30	%	80	121	%	50	%	NA	NA	%
Chloromethane	74-87-3	5.00	µg/kg	1.00	µg/kg	48	146	%	30	%	48	146	%	50	%	NA	NA	%
cis-1,2-Dichloroethene	156-59-2	5.00	µg/kg	1.40	µg/kg	80	120	%	30	%	80	120	%	50	%	NA	NA	%
cis-1,3-Dichloropropene	10061-01-5	5.00	µg/kg	0.83	µg/kg	74	125	%	30	%	74	125	%	50	%	NA	NA	%
Cyclohexane	110-82-7	5.00	µg/kg	1.30	µg/kg	70	130	%	30	%	70	130	%	50	%	NA	NA	%
Dibromochloromethane	124-48-1	5.00	µg/kg	1.70	µg/kg	77	132	%	30	%	77	132	%	50	%	NA	NA	%
1,2-Dibromo-3-Chloropropane	96-12-8	10.00	µg/kg	4.40	µg/kg	49	152	%	30	%	49	152	%	50	%	NA	NA	%
1,2-Dibromoethane	106-93-4	5.00	µg/kg	1.50	µg/kg	72	129	%	30	%	72	129	%	50	%	NA	NA	%
Dibromofluoromethane (Surr)	1868-53-7	NA	µg/kg	NA	µg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	65	130	%
1,2-Dichlorobenzene	95-50-1	5.00	µg/kg	1.30	µg/kg	75	128	%	30	%	75	128	%	50	%	NA	NA	%
1,3-Dichlorobenzene	541-73-1	5.00	µg/kg	1.60	µg/kg	76	128	%	30	%	76	128	%	50	%	NA	NA	%
1,4-Dichlorobenzene	106-46-7	5.00	µg/kg	0.74	µg/kg	76	128	%	30	%	76	128	%	50	%	NA	NA	%
1,1-Dichloroethane	75-34-3	5.00	µg/kg	1.10	µg/kg	80	120	%	30	%	80	120	%	50	%	NA	NA	%
1,2-Dichloroethane	107-06-2	5.00	µg/kg	1.10	µg/kg	61	140	%	30	%	61	140	%	50	%	NA	NA	%
1,2-Dichloroethane-d4 (Surr)	17060-07-0	NA	µg/kg	NA	µg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	65	130	%
1,1-Dichloroethene	75-35-4	5.00	µg/kg	1.50	µg/kg	64	138	%	50	%	64	138	%	50	%	NA	NA	%
1,2-Dichloropropane	78-87-5	5.00	µg/kg	0.86	µg/kg	73	121	%	30	%	73	121	%	50	%	NA	NA	%
Ethylbenzene	100-41-4	5.00	µg/kg	1.30	µg/kg	78	121	%	30	%	78	121	%	50	%	NA	NA	%
2-Hexanone	591-78-6	25.00	µg/kg	3.30	µg/kg	60	126	%	30	%	60	126	%	50	%	NA	NA	%
Isopropylbenzene	98-82-8	5.00	µg/kg	1.90	µg/kg	79	124	%	30	%	79	124	%	50	%	NA	NA	%
Methyl acetate	79-20-9	25.00	µg/kg	5.00	µg/kg	43	135	%	30	%	43	135	%	50	%	NA	NA	%
Methylcyclohexane	108-87-2	5.00	µg/kg	0.86	µg/kg	77	118	%	30	%	77	118	%	50	%	NA	NA	%
Methylene Chloride	75-09-2	5.00	µg/kg	0.98	µg/kg	80	120	%	30	%	80	120	%	50	%	NA	NA	%
4-Methyl-2-pentanone (MIBK)	108-10-1	25.00	µg/kg	4.20	µg/kg	59	127	%	30	%	59	127	%	50	%	NA	NA	%
Methyl tert-butyl ether	1634-04-4	5.00	µg/kg	1.00	µg/kg	80	121	%	30	%	80	121	%	50	%	NA	NA	%
m-Xylene & p-Xylene	179601-23-1	5.00	µg/kg	2.60	µg/kg	78	122	%	30	%	78	122	%	50	%	NA	NA	%
o-Xylene	95-47-6	5.00	µg/kg	1.10	µg/kg	80	121	%	30	%	80	121	%	50	%	NA	NA	%
Styrene	100-42-5	5.00	µg/kg	0.93	µg/kg	78	123	%	30	%	78	123	%	50	%	NA	NA	%
1,1,2,2-Tetrachloroethane	79-34-5	5.00	µg/kg	1.60	µg/kg	70	123	%	30	%	70	123	%	50	%	NA	NA	%
Tetrachloroethene	127-18-4	5.00	µg/kg	1.90	µg/kg	77	130	%	30	%	77	130	%	50	%	NA	NA	%
Toluene	108-88-3	5.00	µg/kg	0.84	µg/kg	73	122	%	30	%	73	122	%	50	%	NA	NA	%
Toluene-d8 (Surr)	2037-26-5	NA	µg/kg	NA	µg/kg	NA	NA	%	30	%	NA	NA	%	50	%	65	130	%
trans-1,2-Dichloroethene	156-60-5	5.00	µg/kg	0.63	µg/kg	79	120	%	30	%	79	120	%	50	%	NA	NA	%
trans-1,3-Dichloropropene	10061-02-6	5.00	µg/kg	0.87	µg/kg	69	133	%	30	%	69	133	%	50	%	NA	NA	%
1,2,4-Trichlorobenzene	120-82-1	5.00	µg/kg	0.89	µg/kg	77	142	%	30	%	77	142	%	50	%	NA	NA	%
1,1,1-Trichloroethane	71-55-6	5.00	µg/kg	0.59	µg/kg	73	132	%	30	%	73	132	%	50	%	NA	NA	%
1,1,2-Trichloroethane	79-00-5	5.00	µg/kg	1.30	µg/kg	72	124	%	30	%	72	124	%	50	%	NA	NA	%
Trichloroethene	79-01-6	5.00	µg/kg	1.30	µg/kg	78	125	%	30	%	78	125	%	50	%	NA	NA	%
Trichlorofluoromethane	75-69-4	5.00	µg/kg	1.20	µg/kg	60	148	%	30	%	60	148	%	50	%	NA	NA	%
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	5.00	µg/kg	1.30	µg/kg	62	141	%	40	%	62	141	%	50	%	NA	NA	%
1,2,4-Trimethylbenzene	95-63-6	5.00	µg/kg	1.40	µg/kg	77	126	%	30	%	77	126	%	50	%	NA	NA	%
1,3,5-Trimethylbenzene	108-67-8	5.00	µg/kg	1.70	µg/kg	77	126	%	30	%	77	126	%	50	%	NA	NA	%
Vinyl chloride	75-01-4	5.00	µg/kg	1.50	µg/kg	65	133	%	30	%	65	133	%	50	%	NA	NA	%
Xylenes, Total	1330-20-7	10.00	µg/kg	1.10	µg/kg	79	121	%	30	%	79	121	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatile Organic Compounds (GC/MS) - Standard	8270D																	
Acenaphthene	83-32-9	330	µg/kg	41.0	µg/kg	47	130	%	50	%	58	130	%	50	%	NA	NA	%
Acenaphthylene	208-96-8	330	µg/kg	36.0	µg/kg	45	130	%	50	%	58	130	%	50	%	NA	NA	%
Acetophenone	98-86-2	330	µg/kg	28.0	µg/kg	44	130	%	50	%	42	130	%	50	%	NA	NA	%
Anthracene	120-12-7	330	µg/kg	25.0	µg/kg	50	130	%	50	%	60	130	%	50	%	NA	NA	%
Benzo[a]anthracene	56-55-3	330	µg/kg	27.0	µg/kg	50	130	%	50	%	62	130	%	50	%	NA	NA	%
Benzo[a]pyrene	50-32-8	330	µg/kg	52.0	µg/kg	47	131	%	50	%	68	131	%	50	%	NA	NA	%
Benzo[b]fluoranthene	205-99-2	330	µg/kg	38.0	µg/kg	48	130	%	50	%	53	130	%	50	%	NA	NA	%
Benzo[g,h,i]perylene	191-24-2	330	µg/kg	22.0	µg/kg	42	130	%	50	%	54	130	%	50	%	NA	NA	%
Benzo[k]fluoranthene	207-08-9	330	µg/kg	65.0	µg/kg	48	108	%	50	%	57	130	%	50	%	NA	NA	%
1,1'-Biphenyl	92-52-4	1700	µg/kg	1700	µg/kg	48	130	%	50	%	57	130	%	50	%	NA	NA	%
Bis(2-chloroethoxy)methane	111-91-1	330	µg/kg	39.0	µg/kg	47	130	%	50	%	56	130	%	50	%	NA	NA	%
Bis(2-chloroethyl)ether	111-44-4	330	µg/kg	45.0	µg/kg	37	130	%	50	%	42	130	%	50	%	NA	NA	%
Bis(2-ethylhexyl) phthalate	117-81-7	330	µg/kg	29.0	µg/kg	48	130	%	50	%	62	132	%	50	%	NA	NA	%
4-Bromophenyl phenyl ether	101-55-3	330	µg/kg	36.0	µg/kg	53	130	%	50	%	65	130	%	50	%	NA	NA	%
Butyl benzyl phthalate	85-68-7	330	µg/kg	26.0	µg/kg	53	134	%	50	%	65	134	%	50	%	NA	NA	%
Carbazole	86-74-8	330	µg/kg	30.0	µg/kg	51	130	%	50	%	60	130	%	50	%	NA	NA	%
4-Chloroaniline	106-47-8	660	µg/kg	52.0	µg/kg	10	130	%	50	%	36	130	%	50	%	NA	NA	%
4-Chloro-3-methylphenol	59-50-7	330	µg/kg	35.0	µg/kg	51	130	%	50	%	52	130	%	50	%	NA	NA	%
2-Chloronaphthalene	91-58-7	330	µg/kg	35.0	µg/kg	48	130	%	50	%	55	130	%	50	%	NA	NA	%
2-Chlorophenol	95-57-8	330	µg/kg	40.0	µg/kg	47	130	%	50	%	51	130	%	50	%	NA	NA	%
4-Chlorophenyl phenyl ether	7005-72-3	330	µg/kg	44.0	µg/kg	49	130	%	50	%	61	130	%	50	%	NA	NA	%
Chrysene	218-01-9	330	µg/kg	21.0	µg/kg	47	130	%	50	%	62	130	%	50	%	NA	NA	%
Dibenz(a,h)anthracene	53-70-3	330	µg/kg	39.0	µg/kg	44	130	%	50	%	56	130	%	50	%	NA	NA	%
Dibenzofuran	132-64-9	330	µg/kg	33.0	µg/kg	49	130	%	50	%	56	130	%	50	%	NA	NA	%
3,3'-Dichlorobenzidine	91-94-1	660	µg/kg	28.0	µg/kg	16	130	%	50	%	45	130	%	50	%	NA	NA	%
2,4-Dichlorophenol	120-83-2	330	µg/kg	35.0	µg/kg	48	130	%	50	%	53	130	%	50	%	NA	NA	%
Diethyl phthalate	84-66-2	330	µg/kg	37.0	µg/kg	49	130	%	50	%	62	130	%	50	%	NA	NA	%
2,4-Dimethylphenol	105-67-9	330	µg/kg	44.0	µg/kg	43	130	%	50	%	47	130	%	50	%	NA	NA	%
Dimethyl phthalate	131-11-3	330	µg/kg	34.0	µg/kg	50	130	%	50	%	63	130	%	50	%	NA	NA	%
Di-n-butyl phthalate	84-74-2	330	µg/kg	30.0	µg/kg	52	130	%	50	%	65	130	%	50	%	NA	NA	%
4,6-Dinitro-2-methylphenol	534-52-1	1700	µg/kg	170.0	µg/kg	23	130	%	50	%	14	137	%	50	%	NA	NA	%
2,4-Dinitrophenol	51-28-5	1700	µg/kg	830.0	µg/kg	10	130	%	50	%	10	154	%	50	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	330	µg/kg	49.0	µg/kg	49	111	%	50	%	55	130	%	50	%	NA	NA	%
2,6-Dinitrotoluene	606-20-2	330	µg/kg	42.0	µg/kg	49	130	%	50	%	57	130	%	50	%	NA	NA	%
Di-n-octyl phthalate	117-84-0	330	µg/kg	29.0	µg/kg	46	130	%	50	%	59	146	%	50	%	NA	NA	%
Fluoranthene	206-44-0	330	µg/kg	32.0	µg/kg	51	130	%	50	%	62	130	%	50	%	NA	NA	%
Fluorene	86-73-7	330	µg/kg	36.0	µg/kg	52	130	%	50	%	58	130	%	50	%	NA	NA	%
2-Fluorobiphenyl (Surr)	321-60-8	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	41	116	%
2-Fluorophenol (Surr)	367-12-4	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	39	114	%
Hexachlorobenzene	118-74-1	330	µg/kg	39.0	µg/kg	53	130	%	50	%	59	130	%	50	%	NA	NA	%
Hexachlorobutadiene	87-68-3	330	µg/kg	36.0	µg/kg	48	130	%	50	%	47	130	%	50	%	NA	NA	%
Hexachlorocyclopentadiene	77-47-4	330	µg/kg	41.0	µg/kg	28	130	%	50	%	35	130	%	50	%	NA	NA	%
Hexachloroethane	67-72-1	330	µg/kg	28.0	µg/kg	42	130	%	50	%	44	130	%	50	%	NA	NA	%
Indeno[1,2,3-cd]pyrene	193-39-5	330	µg/kg	28.0	µg/kg	41	130	%	50	%	52	130	%	50	%	NA	NA	%
Isophorone	78-59-1	330	µg/kg	33.0	µg/kg	48	130	%	50	%	48	130	%	50	%	NA	NA	%
2-Methylnaphthalene	91-57-6	330	µg/kg	38.0	µg/kg	48	130	%	50	%	55	130	%	50	%	NA	NA	%
2-Methylphenol	95-48-7	330	µg/kg	27.0	µg/kg	46	130	%	50	%	49	130	%	50	%	NA	NA	%
3 & 4 Methylphenol	15831-10-4	330	µg/kg	43.0	µg/kg	46	130	%	50	%	50	130	%	50	%	NA	NA	%
Naphthalene	91-20-3	330	µg/kg	30.0	µg/kg	47	130	%	50	%	54	130	%	50	%	NA	NA	%
2-Nitroaniline	88-74-4	1700	µg/kg	45.0	µg/kg	44	130	%	50	%	52	130	%	50	%	NA	NA	%
3-Nitroaniline	99-09-2	1700	µg/kg	46.0	µg/kg	21	130	%	50	%	42	130	%	50	%	NA	NA	%
4-Nitroaniline	100-01-6	1700	µg/kg	49.0	µg/kg	41	130	%	50	%	49	130	%	50	%	NA	NA	%
Nitrobenzene	98-95-3	330	µg/kg	26.0	µg/kg	45	130	%	50	%	43	130	%	50	%	NA	NA	%
Nitrobenzene-d5 (Surr)	4165-60-0	NA	µg/kg	NA	µg/kg	NA	NA	%	50	%	NA	NA	%	50	%	37	115	%
2-Nitrophenol	88-75-5	330	µg/kg	41.0	µg/kg	43	130	%	50	%	45	130	%	50	%	NA	NA	%
4-Nitrophenol	100-02-7	1700	µg/kg	330.0	µg/kg	40	130	%	50	%	30	130	%	50	%	NA	NA	%
N-Nitrosodi-n-propylamine	621-64-7	330	µg/kg	32.0	µg/kg	38	130	%	50	%	48	130	%	50	%	NA	NA	%
N-Nitrosodiphenylamine	86-30-6	330	µg/kg	33.0	µg/kg	50	130	%	50	%	62	130	%	50	%	NA	NA	%
2,2'-oxybis[1-chloropropane]	108-60-1	330	µg/kg	30.0	µg/kg	38	130	%	50	%	44	130	%	50	%	NA	NA	%
Pentachlorophenol	87-86-5	1700	µg/kg	330.0	µg/kg	41	130	%	50	%	38	131	%	50	%	NA	NA	%
Phenanthrene	85-01-8	330	µg/kg	27.0	µg/kg	52	130	%	50	%	61	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Phenol	108-95-2	330	µg/kg	34.0	µg/kg	47	130	%	50	%	46	130	%	50	%	NA	NA	%
Phenol-d5 (Surr)	4165-62-2	NA	µg/kg	NA	µg/kg	NA	NA	%	50	%	NA	NA	%	50	%	38	122	%
Pyrene	129-00-0	330	µg/kg	27.0	µg/kg	50	130	%	50	%	59	130	%	50	%	NA	NA	%
Terphenyl-d14 (Surr)	1718-51-0	NA	µg/kg	NA	µg/kg	NA	NA	%	50	%	NA	NA	%	50	%	46	126	%
2,4,6-Tribromophenol (Surr)	118-79-6	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	45	129	%
2,4,5-Trichlorophenol	95-95-4	330	µg/kg	35.0	µg/kg	51	130	%	50	%	60	130	%	50	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	330	µg/kg	29.0	µg/kg	50	130	%	50	%	53	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatile Organic Compounds (GC/MS) - Low Level	8270D_LL																	
Acenaphthene	83-32-9	6.70	µg/kg	3.30	µg/kg	13	130	%	50	%	13	130	%	50	%	NA	NA	%
Acenaphthylene	208-96-8	6.70	µg/kg	3.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Acetophenone	98-86-2	33.00	µg/kg	6.80	µg/kg	14	130	%	50	%	14	130	%	50	%	NA	NA	%
Anthracene	120-12-7	6.70	µg/kg	3.30	µg/kg	18	130	%	50	%	18	130	%	50	%	NA	NA	%
Benzo[a]anthracene	56-55-3	6.70	µg/kg	3.30	µg/kg	16	130	%	50	%	16	130	%	50	%	NA	NA	%
Benzo[a]pyrene	50-32-8	6.70	µg/kg	1.20	µg/kg	18	139	%	50	%	18	139	%	50	%	NA	NA	%
Benzo[b]fluoranthene	205-99-2	6.70	µg/kg	3.30	µg/kg	18	130	%	50	%	18	130	%	50	%	NA	NA	%
Benzo[g,h,i]perylene	191-24-2	6.70	µg/kg	3.30	µg/kg	21	130	%	50	%	21	130	%	50	%	NA	NA	%
Benzo[k]fluoranthene	207-08-9	6.70	µg/kg	2.00	µg/kg	22	130	%	50	%	22	130	%	50	%	NA	NA	%
1,1'-Biphenyl	92-52-4	33.00	µg/kg	7.20	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Bis(2-chloroethoxy)methane	111-91-1	33.00	µg/kg	6.50	µg/kg	15	130	%	50	%	15	130	%	50	%	NA	NA	%
Bis(2-chloroethyl)ether	111-44-4	33.00	µg/kg	6.50	µg/kg	11	130	%	50	%	11	130	%	50	%	NA	NA	%
Bis(2-ethylhexyl) phthalate	117-81-7	66.00	µg/kg	6.00	µg/kg	29	130	%	50	%	29	130	%	50	%	NA	NA	%
4-Bromophenyl phenyl ether	101-55-3	33.00	µg/kg	6.90	µg/kg	13	130	%	50	%	13	130	%	50	%	NA	NA	%
Butyl benzyl phthalate	85-68-7	33.00	µg/kg	5.50	µg/kg	30	130	%	50	%	30	130	%	50	%	NA	NA	%
Carbazole	86-74-8	33.00	µg/kg	6.70	µg/kg	23	171	%	50	%	23	171	%	50	%	NA	NA	%
4-Chloroaniline	106-47-8	66.00	µg/kg	5.20	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
4-Chloro-3-methylphenol	59-50-7	33.00	µg/kg	7.00	µg/kg	18	130	%	50	%	18	130	%	50	%	NA	NA	%
2-Chloronaphthalene	91-58-7	33.00	µg/kg	6.00	µg/kg	14	130	%	50	%	14	130	%	50	%	NA	NA	%
2-Chlorophenol	95-57-8	33.00	µg/kg	5.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
4-Chlorophenyl phenyl ether	7005-72-3	33.00	µg/kg	6.40	µg/kg	15	130	%	50	%	15	130	%	50	%	NA	NA	%
Chrysene	218-01-9	6.70	µg/kg	3.30	µg/kg	12	130	%	50	%	12	130	%	50	%	NA	NA	%
Dibenz(a,h)anthracene	53-70-3	6.70	µg/kg	3.30	µg/kg	17	130	%	50	%	17	130	%	50	%	NA	NA	%
Dibenzofuran	132-64-9	33.00	µg/kg	6.70	µg/kg	20	130	%	50	%	20	130	%	50	%	NA	NA	%
3,3'-Dichlorobenzidine	91-94-1	66.00	µg/kg	17.00	µg/kg	10	200	%	50	%	10	200	%	50	%	NA	NA	%
2,4-Dichlorophenol	120-83-2	33.00	µg/kg	7.20	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Diethyl phthalate	84-66-2	33.00	µg/kg	7.40	µg/kg	24	130	%	50	%	24	130	%	50	%	NA	NA	%
2,4-Dimethylphenol	105-67-9	66.00	µg/kg	7.60	µg/kg	10	134	%	50	%	10	134	%	50	%	NA	NA	%
Dimethyl phthalate	131-11-3	33.00	µg/kg	7.50	µg/kg	20	130	%	50	%	20	130	%	50	%	NA	NA	%
Di-n-butyl phthalate	84-74-2	170	µg/kg	17.00	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
4,6-Dinitro-2-methylphenol	534-52-1	170	µg/kg	17.00	µg/kg	14	130	%	50	%	14	130	%	50	%	NA	NA	%
2,4-Dinitrophenol	51-28-5	330	µg/kg	130	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	33.00	µg/kg	7.50	µg/kg	19	130	%	50	%	19	130	%	50	%	NA	NA	%
2,6-Dinitrotoluene	606-20-2	33.00	µg/kg	7.90	µg/kg	18	130	%	50	%	18	130	%	50	%	NA	NA	%
Di-n-octyl phthalate	117-84-0	33.00	µg/kg	3.60	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Fluoranthene	206-44-0	6.70	µg/kg	3.30	µg/kg	14	130	%	50	%	14	130	%	50	%	NA	NA	%
Fluorene	86-73-7	6.70	µg/kg	3.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
2-Fluorobiphenyl (Surr)	321-60-8	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	11	130	%
2-Fluorophenol (Surr)	367-12-4	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	10	130	%
Hexachlorobenzene	118-74-1	33.00	µg/kg	7.60	µg/kg	12	130	%	50	%	12	130	%	50	%	NA	NA	%
Hexachlorobutadiene	87-68-3	33.00	µg/kg	6.80	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Hexachlorocyclopentadiene	77-47-4	66.00	µg/kg	3.70	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Hexachloroethane	67-72-1	33.00	µg/kg	5.80	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Indeno[1,2,3-cd]pyrene	193-39-5	6.70	µg/kg	3.30	µg/kg	11	130	%	50	%	11	130	%	50	%	NA	NA	%
Isophorone	78-59-1	33.00	µg/kg	7.00	µg/kg	14	130	%	50	%	14	130	%	50	%	NA	NA	%
2-Methylnaphthalene	91-57-6	6.70	µg/kg	3.30	µg/kg	20	130	%	50	%	20	130	%	50	%	NA	NA	%
2-Methylphenol	95-48-7	33.00	µg/kg	6.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
3 & 4 Methylphenol	15831-10-4	33.00	µg/kg	7.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Naphthalene	91-20-3	6.70	µg/kg	3.30	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
2-Nitroaniline	88-74-4	170	µg/kg	7.00	µg/kg	21	130	%	50	%	21	130	%	50	%	NA	NA	%
3-Nitroaniline	99-09-2	170	µg/kg	6.70	µg/kg	10	134	%	50	%	10	134	%	50	%	NA	NA	%
4-Nitroaniline	100-01-6	170	µg/kg	8.30	µg/kg	14	143	%	50	%	14	143	%	50	%	NA	NA	%
Nitrobenzene	98-95-3	33.00	µg/kg	6.60	µg/kg	11	130	%	50	%	11	130	%	50	%	NA	NA	%
Nitrobenzene-d5 (Surr)	4165-60-0	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	18	130	%
2-Nitrophenol	88-75-5	33.00	µg/kg	5.80	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
4-Nitrophenol	100-02-7	170	µg/kg	73.00	µg/kg	11	130	%	50	%	11	130	%	50	%	NA	NA	%
N-Nitrosodi-n-propylamine	621-64-7	33.00	µg/kg	7.50	µg/kg	16	130	%	50	%	16	130	%	50	%	NA	NA	%
N-Nitrosodiphenylamine	86-30-6	33.00	µg/kg	6.10	µg/kg	22	130	%	50	%	22	130	%	50	%	NA	NA	%
2,2'-oxybis[1-chloropropane]	108-60-1	33.00	µg/kg	7.20	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Pentachlorophenol	87-86-5	170	µg/kg	67.00	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Phenanthrene	85-01-8	6.70	µg/kg	2.40	µg/kg	18	130	%	50	%	18	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Phenol	108-95-2	33.00	µg/kg	6.50	µg/kg	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Phenol-d5 (Surr)	4165-62-2	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	10	130	%
Pyrene	129-00-0	6.70	µg/kg	3.30	µg/kg	11	136	%	50	%	11	136	%	50	%	NA	NA	%
Terphenyl-d14 (Surr)	1718-51-0	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	27	130	%
2,4,6-Tribromophenol (Surr)	118-79-6	NA	µg/kg	NA	µg/kg	10	130	%	50	%	10	130	%	50	%	24	130	%
2,4,5-Trichlorophenol	95-95-4	33.00	µg/kg	7.60	µg/kg	16	130	%	50	%	16	130	%	50	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	33.00	µg/kg	7.90	µg/kg	15	130	%	50	%	15	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Metals (ICP)	6010C																	
Aluminum	7429-90-5	20.00	mg/Kg	10	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Antimony	7440-36-0	2.00	mg/Kg	0.530	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Arsenic	7440-38-2	2.00	mg/Kg	0.590	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Barium	7440-39-3	1.00	mg/Kg	0.300	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Beryllium	7440-41-7	0.40	mg/Kg	0.020	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Cadmium	7440-43-9	0.50	mg/Kg	0.100	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Calcium	7440-70-2	50.00	mg/Kg	20	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Chromium	7440-47-3	1.00	mg/Kg	0.500	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Cobalt	7440-48-4	1.00	mg/Kg	0.120	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Copper	7440-50-8	2.50	mg/Kg	1.100	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Iron	7439-89-6	20.00	mg/Kg	7.000	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Lead	7439-92-1	1.00	mg/Kg	0.530	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Magnesium	7439-95-4	50.00	mg/Kg	2.400	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Manganese	7439-96-5	1.00	mg/Kg	0.300	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Nickel	7440-02-0	4.00	mg/Kg	0.310	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Potassium	9/7/7440	100	mg/Kg	8.00	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Selenium	7782-49-2	2.50	mg/Kg	1.00	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Silver	7440-22-4	1.00	mg/Kg	0.096	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Sodium	7440-23-5	200	mg/Kg	82.00	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Thallium	7440-28-0	2.50	mg/Kg	0.990	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Vanadium	7440-62-2	1.00	mg/Kg	0.240	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Zinc	7440-66-6	2.00	mg/Kg	1.200	mg/Kg	80	120	%	20	%	75	125	%	20	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
TPH and Fingerprinting	8015																	
TPH - Light Naptha	---	50.00	mg/kg	20.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Aviation Gas	---	50.00	mg/kg	20.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Stoddard Solvent	---	20.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Heavy Naptha	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Gasoline	---	20.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Jet Fuel (JP4)	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Jet Fuel (JP5)	---	10.00	mg/kg	4.60	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Jet Fuel (JP6)	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Jet Fuel (JP8)	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Kerosene	---	10.00	mg/kg	1.40	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Diesel (FFP)	---	10.00	mg/kg	1.20	mg/kg	52	131	%	30	%	52	131	%	30	%	NA	NA	%
TPH - Fuel Oil	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Fuel Oil #6	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Crude Oil	---	20.00	mg/kg	2.80	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Hydraulic Oil/Motor Oil	---	20.00	mg/kg	6.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Waste Oil	---	20.00	mg/kg	10.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - WD-40	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Mineral Oil	---	50.00	mg/kg	20.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Mineral Spirit	---	20.00	mg/kg	10.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Motor Oil	---	20.00	mg/kg	6.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Lube Oil	---	20.00	mg/kg	10.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Olive Oil	---	20.00	mg/kg	10.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Diluent	---	10.00	mg/kg	5.00	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Tetracosane (Surr)	646-31-1	NA	mg/kg	NA	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Carbon Chain																		
TPH - C8 - C9	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C10 - C11	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C12 - C14	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C15 - C16	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C17 - C18	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C19 - C20	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C21 - C22	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C23 - C28	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C29 - C32	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C33 - C36	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C37 - C40	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C41 - C43	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - C44 plus	---	1.00	mg/kg	0.50	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH (Total)	---	10.00	mg/kg	2.30	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
TPH - Diesel (FFP)	---	10.00	mg/kg	1.20	mg/kg	52	131	%	30	%	52	131	%	30	%	NA	NA	%
Tetracosane (Surr)	646-31-1	NA	mg/kg	NA	mg/kg	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Terpenes	8270																	
Borneol	507-70-0	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Camphene	79-92-5	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Camphor	76-22-2	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Cineole	470-82-6	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Dipentene	5989-27-5	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Isoborneol	124-76-5	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
Limonene	138-86-3	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
alpha-Pinene	80-56-8	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
beta-Pinene	127-91-3	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%
alpha-Terpineol	98-5-5	0.10	mg/kg	0.05	mg/kg	50	150	%	30	%	50	150	%	30	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Organic Carbon, Total (TOC)	WALKLEY BLACK																	
Total Organic Carbon	7440-44-0	250	mg/Kg	67.00	mg/Kg	80	120	%	20	%	NA	NA	%	NA	%	NA	NA	%
Grain Size	D422																	
Sieve Size 3 inch	STL00567	NA	NA	NA	NA		NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size 2 inch	STL00568	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size 1.5 inch	STL00569	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size 1 inch	STL00570	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size 0.75 inch	STL00571	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size 0.375 inch	STL00572	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #4	STL00573	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #10	STL00574	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #20	STL00575	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #40	STL00576	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #60	STL00577	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #80	STL01176	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #100	STL01175	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sieve Size #200	STL00579	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 1	STL01158	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 2	STL01159	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 3	STL01160	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 4	STL01161	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 5	STL01162	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 6	STL01163	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 7	STL01164	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Gravel	STL00581	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Sand	STL00582	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Coarse Sand	STL00583	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Medium Sand	STL00584	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Fine Sand	STL00585	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Silt	STL00586	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Clay	STL00587	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 1 - Particle Size	STL01494	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 2 - Particle Size	STL01495	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 3 - Particle Size	STL01496	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 4 - Particle Size	STL01497	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 5 - Particle Size	STL01498	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 6 - Particle Size	STL01499	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Hydrometer Reading 7 - Particle Size	STL01500	NA	NA	NA	NA	NA	NA	%	NA	%	NA	NA	%	NA	%	NA	NA	%
Percent Moisture	Moisture																	
Percent Moisture	STL00177	0.01	%	NA	NA	NA	NA	%	NA	%	NA	NA	%	20	%	NA	NA	%
Percent Solids	STL00234	0.01	%	NA	NA	NA	NA	%	NA	%	NA	NA	%	20	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Wastewater																		
Volatile Organic Compounds (GC/MS) 624 5ml UP 3day																		
Acrolein	107-02-8	0.02	mg/L	0.0074	mg/L	54	145	%	50	%	54	145	%	50	%	NA	NA	%
Acrylonitrile	107-13-1	0.02	mg/L	0.0072	mg/L	10	183	%	50	%	10	183	%	50	%	NA	NA	%
Benzene	71-43-2	0.001	mg/L	0.0002	mg/L	37	151	%	30	%	37	151	%	30	%	NA	NA	%
4-Bromofluorobenzene (Surr)	460-00-4	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	71	121	%
Bromoform	75-25-2	0.001	mg/L	0.0005	mg/L	45	169	%	30	%	45	169	%	30	%	NA	NA	%
Bromomethane	74-83-9	0.005	mg/L	0.002	mg/L	1	242	%	100	%	1	242	%	100	%	NA	NA	%
Carbon tetrachloride	56-23-5	0.001	mg/L	0.0005	mg/L	70	140	%	30	%	70	140	%	30	%	NA	NA	%
Chlorobenzene	108-90-7	0.001	mg/L	0.0001	mg/L	37	160	%	30	%	37	160	%	30	%	NA	NA	%
Chlorodibromomethane	124-48-1	0.001	mg/L	0.0005	mg/L	53	149	%	30	%	53	149	%	30	%	NA	NA	%
Chloroethane	75-00-3	0.005	mg/L	0.002	mg/L	14	230	%	50	%	14	230	%	50	%	NA	NA	%
2-Chloroethyl vinyl ether	110-75-8	0.01	mg/L	0.00026	mg/L	1	305	%	100	%	1	305	%	100	%	NA	NA	%
Chloroform	67-66-3	0.001	mg/L	0.00014	mg/L	51	138	%	30	%	51	138	%	30	%	NA	NA	%
Chloromethane	74-87-3	0.001	mg/L	0.00015	mg/L	1	273	%	50	%	1	273	%	50	%	NA	NA	%
cis-1,3-Dichloropropene	10061-01-5	0.001	mg/L	0.00011	mg/L	1	227	%	30	%	1	227	%	30	%	NA	NA	%
Dibromofluoromethane (Surr)	1868-53-7	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	77	129	%
1,2-Dichlorobenzene	95-50-1	0.001	mg/L	0.00021	mg/L	18	190	%	30	%	18	190	%	30	%	NA	NA	%
1,3-Dichlorobenzene	541-73-1	0.001	mg/L	0.00025	mg/L	59	156	%	30	%	59	156	%	30	%	NA	NA	%
1,4-Dichlorobenzene	106-46-7	0.001	mg/L	0.00028	mg/L	18	190	%	30	%	18	190	%	30	%	NA	NA	%
Dichlorobromomethane	75-27-4	0.001	mg/L	0.0005	mg/L	35	155	%	30	%	35	155	%	30	%	NA	NA	%
1,1-Dichloroethane	75-34-3	0.001	mg/L	0.0005	mg/L	59	155	%	30	%	59	155	%	30	%	NA	NA	%
1,2-Dichloroethane	107-06-2	0.001	mg/L	0.0001	mg/L	49	155	%	30	%	49	155	%	30	%	NA	NA	%
1,2-Dichloroethane-d4 (Surr)	17060-07-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
1,1-Dichloroethene	75-35-4	0.001	mg/L	0.0005	mg/L	1	234	%	30	%	1	234	%	30	%	NA	NA	%
Ethylbenzene	100-41-4	0.001	mg/L	0.00011	mg/L	37	162	%	30	%	37	162	%	30	%	NA	NA	%
Methylene Chloride	75-09-2	0.005	mg/L	0.001	mg/L	1	221	%	30	%	1	221	%	30	%	NA	NA	%
1,1,2,2-Tetrachloroethane	79-34-5	0.001	mg/L	0.00018	mg/L	46	157	%	30	%	46	157	%	30	%	NA	NA	%
Tetrachloroethene	127-18-4	0.001	mg/L	0.0005	mg/L	64	148	%	30	%	64	148	%	30	%	NA	NA	%
Toluene	108-88-3	0.001	mg/L	0.0001	mg/L	47	150	%	30	%	47	150	%	30	%	NA	NA	%
Toluene-d8 (Surr)	2037-26-5	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	79	119	%
trans-1,2-Dichloroethene	156-60-5	0.001	mg/L	0.0002	mg/L	54	156	%	30	%	54	156	%	30	%	NA	NA	%
trans-1,3-Dichloropropene	10061-02-6	0.001	mg/L	0.00021	mg/L	17	183	%	30	%	17	183	%	30	%	NA	NA	%
1,1,1-Trichloroethane	71-55-6	0.001	mg/L	0.00012	mg/L	52	162	%	30	%	52	162	%	30	%	NA	NA	%
1,1,2-Trichloroethane	79-00-5	0.001	mg/L	0.0005	mg/L	52	150	%	30	%	52	150	%	30	%	NA	NA	%
Trichloroethene	79-01-6	0.001	mg/L	0.0005	mg/L	71	157	%	30	%	71	157	%	30	%	NA	NA	%
Vinyl chloride	75-01-4	0.001	mg/L	0.00018	mg/L	1	251	%	50	%	1	251	%	50	%	NA	NA	%
Xylenes, Total	1330-20-7	0.002	mg/L	0.0001	mg/L	78	119	%	30	%	78	119	%	30	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatile Organic Compounds (GC/MS)		625																
Acenaphthene	83-32-9	0.01	mg/L	0.00075	mg/L	47	145	%	40	%	47	145	%	40	%	NA	NA	%
Acenaphthylene	208-96-8	0.01	mg/L	0.0008	mg/L	33	145	%	40	%	33	145	%	40	%	NA	NA	%
Anthracene	120-12-7	0.01	mg/L	0.00073	mg/L	27	133	%	40	%	27	133	%	40	%	NA	NA	%
Benzidine	92-87-5	0.08	mg/L	0.042	mg/L	1	200	%	40	%	1	200	%	40	%	NA	NA	%
Benzo[a]anthracene	56-55-3	0.01	mg/L	0.00094	mg/L	33	143	%	40	%	33	143	%	40	%	NA	NA	%
Benzo[a]pyrene	50-32-8	0.01	mg/L	0.00074	mg/L	17	163	%	40	%	17	163	%	40	%	NA	NA	%
Benzo[b]fluoranthene	205-99-2	0.01	mg/L	0.0025	mg/L	24	159	%	40	%	24	159	%	40	%	NA	NA	%
Benzo[g,h,i]perylene	191-24-2	0.01	mg/L	0.00089	mg/L	1	219	%	40	%	1	219	%	40	%	NA	NA	%
Benzo[k]fluoranthene	207-08-9	0.01	mg/L	0.0009	mg/L	11	162	%	40	%	11	162	%	40	%	NA	NA	%
Bis(2-chloroethoxy)methane	111-91-1	0.01	mg/L	0.0011	mg/L	33	184	%	40	%	33	184	%	40	%	NA	NA	%
Bis(2-chloroethyl)ether	111-44-4	0.01	mg/L	0.0011	mg/L	12	158	%	40	%	12	158	%	40	%	NA	NA	%
bis (2-chloroisopropyl) ether	108-60-1	0.01	mg/L	0.00085	mg/L	36	166	%	40	%	36	166	%	40	%	NA	NA	%
Bis(2-ethylhexyl) phthalate	117-81-7	0.01	mg/L	0.0016	mg/L	8	158	%	40	%	8	158	%	40	%	NA	NA	%
4-Bromophenyl phenyl ether	101-55-3	0.01	mg/L	0.0008	mg/L	53	127	%	40	%	53	127	%	40	%	NA	NA	%
Butyl benzyl phthalate	85-68-7	0.01	mg/L	0.0012	mg/L	1	152	%	40	%	1	152	%	40	%	NA	NA	%
4-Chloro-3-methylphenol	59-50-7	0.01	mg/L	0.0011	mg/L	22	147	%	40	%	22	147	%	40	%	NA	NA	%
2-Chloronaphthalene	91-58-7	0.01	mg/L	0.00078	mg/L	60	118	%	40	%	60	118	%	40	%	NA	NA	%
2-Chlorophenol	95-57-8	0.01	mg/L	0.0009	mg/L	23	134	%	40	%	23	134	%	40	%	NA	NA	%
4-Chlorophenyl phenyl ether	7005-72-3	0.01	mg/L	0.00081	mg/L	25	158	%	40	%	25	158	%	40	%	NA	NA	%
Chrysene	218-01-9	0.01	mg/L	0.00052	mg/L	17	168	%	40	%	17	168	%	40	%	NA	NA	%
Dibenz(a,h)anthracene	53-70-3	0.01	mg/L	0.00076	mg/L	1	227	%	40	%	1	227	%	40	%	NA	NA	%
1,2-Dichlorobenzene	95-50-1	0.01	mg/L	0.00056	mg/L	32	129	%	40	%	32	129	%	40	%	NA	NA	%
1,3-Dichlorobenzene	541-73-1	0.01	mg/L	0.00066	mg/L	1	172	%	40	%	1	172	%	40	%	NA	NA	%
1,4-Dichlorobenzene	106-46-7	0.01	mg/L	0.00058	mg/L	20	124	%	40	%	20	124	%	40	%	NA	NA	%
3,3'-Dichlorobenzidine	91-94-1	0.06	mg/L	0.03	mg/L	1	262	%	40	%	1	262	%	40	%	NA	NA	%
2,4-Dichlorophenol	120-83-2	0.01	mg/L	0.0011	mg/L	39	135	%	40	%	39	135	%	40	%	NA	NA	%
Diethyl phthalate	84-66-2	0.01	mg/L	0.00086	mg/L	1	114	%	40	%	1	114	%	40	%	NA	NA	%
2,4-Dimethylphenol	105-67-9	0.01	mg/L	0.0039	mg/L	32	119	%	40	%	32	119	%	40	%	NA	NA	%
Dimethyl phthalate	131-11-3	0.01	mg/L	0.00097	mg/L	1	112	%	40	%	1	112	%	40	%	NA	NA	%
Di-n-butyl phthalate	84-74-2	0.01	mg/L	0.00088	mg/L	1	118	%	40	%	1	118	%	40	%	NA	NA	%
4,6-Dinitro-2-methylphenol	534-52-1	0.05	mg/L	0.005	mg/L	1	181	%	40	%	1	181	%	40	%	NA	NA	%
2,4-Dinitrophenol	51-28-5	0.05	mg/L	0.01	mg/L	1	191	%	40	%	1	191	%	40	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	0.01	mg/L	0.0012	mg/L	39	139	%	40	%	39	139	%	40	%	NA	NA	%
2,6-Dinitrotoluene	606-20-2	0.01	mg/L	0.0011	mg/L	50	158	%	40	%	50	158	%	40	%	NA	NA	%
Di-n-octyl phthalate	117-84-0	0.01	mg/L	0.0013	mg/L	4	146	%	40	%	4	146	%	40	%	NA	NA	%
1,2-Diphenylhydrazine	122-66-7	0.01	mg/L	0.00086	mg/L	30	130	%	40	%	30	130	%	40	%	NA	NA	%
Fluoranthene	206-44-0	0.01	mg/L	0.00071	mg/L	26	137	%	40	%	26	137	%	40	%	NA	NA	%
Fluorene	86-73-7	0.01	mg/L	0.00093	mg/L	59	121	%	40	%	59	121	%	40	%	NA	NA	%
2-Fluorobiphenyl	321-60-8	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	38	121	%
2-Fluorophenol	367-12-4	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	35	110	%
Hexachlorobenzene	118-74-1	0.01	mg/L	0.00081	mg/L	1	152	%	40	%	1	152	%	40	%	NA	NA	%
Hexachlorobutadiene	87-68-3	0.01	mg/L	0.00062	mg/L	24	116	%	40	%	24	116	%	40	%	NA	NA	%
Hexachlorocyclopentadiene	77-47-4	0.02	mg/L	0.01	mg/L	1	200	%	40	%	1	200	%	40	%	NA	NA	%
Hexachloroethane	67-72-1	0.01	mg/L	0.00081	mg/L	40	113	%	40	%	40	113	%	40	%	NA	NA	%
Indeno[1,2,3-cd]pyrene	193-39-5	0.01	mg/L	0.0011	mg/L	1	171	%	40	%	1	171	%	40	%	NA	NA	%
Isophorone	78-59-1	0.01	mg/L	0.0009	mg/L	21	196	%	40	%	21	196	%	40	%	NA	NA	%
Naphthalene	91-20-3	0.01	mg/L	0.0007	mg/L	21	133	%	40	%	21	133	%	40	%	NA	NA	%
Nitrobenzene	98-95-3	0.01	mg/L	0.00058	mg/L	35	180	%	40	%	35	180	%	40	%	NA	NA	%
Nitrobenzene-d5	4165-60-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	44	119	%
2-Nitrophenol	88-75-5	0.01	mg/L	0.00074	mg/L	29	182	%	40	%	29	182	%	40	%	NA	NA	%
4-Nitrophenol	100-02-7	0.05	mg/L	0.01	mg/L	1	132	%	40	%	1	132	%	40	%	NA	NA	%
N-Nitrosodimethylamine	62-75-9	0.02	mg/L	0.01	mg/L	10	150	%	40	%	10	150	%	40	%	NA	NA	%
N-Nitrosodi-n-propylamine	621-64-7	0.01	mg/L	0.00074	mg/L	1	230	%	40	%	1	230	%	40	%	NA	NA	%
N-Nitrosodiphenylamine	86-30-6	0.01	mg/L	0.00091	mg/L	10	150	%	40	%	10	150	%	40	%	NA	NA	%
Pentachlorophenol	87-86-5	0.05	mg/L	0.0018	mg/L	14	176	%	40	%	14	176	%	40	%	NA	NA	%
Phenanthrene	85-01-8	0.01	mg/L	0.00081	mg/L	54	120	%	40	%	54	120	%	40	%	NA	NA	%
Phenol	108-95-2	0.01	mg/L	0.0011	mg/L	5	112	%	40	%	5	112	%	40	%	NA	NA	%
Phenol-d5	4165-62-2	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	27	119	%
Pyrene	129-00-0	0.01	mg/L	0.00064	mg/L	52	115	%	40	%	52	115	%	40	%	NA	NA	%
Terphenyl-d14	1718-51-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	10	165	%
2,4,6-Tribromophenol	118-79-6	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	34	132	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
1,2,4-Trichlorobenzene	120-82-1	0.01	mg/L	0.00056	mg/L	44	142	%	40	%	44	142	%	40	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	0.01	mg/L	0.00082	mg/L	37	144	%	40	%	37	144	%	40	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Metals (ICP)	200.7_CWA																	
Aluminum	7429-90-5	0.20	mg/L	0.10	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Antimony	7440-36-0	0.02	mg/L	0.0053	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Arsenic	7440-38-2	0.02	mg/L	0.0046	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Barium	7440-39-3	0.01	mg/L	0.0023	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Beryllium	7440-41-7	0.004	mg/L	0.0002	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Cadmium	7440-43-9	0.005	mg/L	0.002	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Calcium	7440-70-2	0.50	mg/L	0.096	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Chromium	7440-47-3	0.01	mg/L	0.0012	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Cobalt	7440-48-4	0.01	mg/L	0.00095	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Copper	7440-50-8	0.02	mg/L	0.0019	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Iron	7439-89-6	0.10	mg/L	0.05	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Lead	7439-92-1	0.01	mg/L	0.004	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Magnesium	7439-95-4	0.50	mg/L	0.0099	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Manganese	7439-96-5	0.01	mg/L	0.002	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Nickel	7440-02-0	0.04	mg/L	0.0023	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Potassium	9/7/7440	1.00	mg/L	0.022	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Selenium	7782-49-2	0.02	mg/L	0.0064	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Silver	7440-22-4	0.01	mg/L	0.00089	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Sodium	7440-23-5	1.00	mg/L	0.50	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Thallium	7440-28-0	0.025	mg/L	0.0088	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Vanadium	7440-62-2	0.01	mg/L	0.0024	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%
Zinc	7440-66-6	0.02	mg/L	0.0087	mg/L	85	115	%	20	%	75	125	%	20	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Waste Characterization																		
Volatile Organic Compounds (GC/MS)		8260B/1311/5030																
1,2-Dichloroethane	107-06-2	0.02	mg/L	0.02	mg/L	75	120	%	30	%	75	120	%	30	%	NA	NA	%
Chlorobenzene	108-90-7	0.02	mg/L	0.02	mg/L	79	120	%	30	%	79	120	%	30	%	NA	NA	%
Tetrachloroethene	127-18-4	0.02	mg/L	0.02	mg/L	77	128	%	30	%	77	128	%	30	%	NA	NA	%
Carbon tetrachloride	56-23-5	0.02	mg/L	0.02	mg/L	70	131	%	30	%	70	131	%	30	%	NA	NA	%
Chloroform	67-66-3	0.02	mg/L	0.02	mg/L	76	128	%	30	%	76	128	%	30	%	NA	NA	%
Benzene	71-43-2	0.02	mg/L	0.02	mg/L	74	123	%	30	%	74	123	%	30	%	NA	NA	%
Vinyl chloride	75-01-4	0.02	mg/L	0.02	mg/L	58	141	%	30	%	58	141	%	30	%	NA	NA	%
1,1-Dichloroethene	75-35-4	0.02	mg/L	0.02	mg/L	73	134	%	30	%	73	134	%	30	%	NA	NA	%
2-Butanone	78-93-3	0.20	mg/L	0.20	mg/L	55	142	%	30	%	55	142	%	30	%	NA	NA	%
Trichloroethene	79-01-6	0.02	mg/L	0.02	mg/L	80	120	%	30	%	80	120	%	30	%	NA	NA	%
Toluene-d8 (Surr)	2037-26-5	NA	mg/L	NA	mg/L	NA	NA	%	50	%	NA	NA	%	50	%	70	130	%
1,2-Dichloroethane-d4 (Surr)	17060-07-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
Dibromofluoromethane (Surr)	1868-53-7	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%
4-Bromofluorobenzene (Surr)	460-00-4	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	70	130	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Semivolatle Organic Compounds (GC/MS)	8270D/1311/3520																	
1,4-Dichlorobenzene	106-46-7	0.05	mg/L	0.05	mg/L	43	130	%	50	%	43	130	%	50	%	NA	NA	%
2,4-Dinitrotoluene	121-14-2	0.05	mg/L	0.05	mg/L	63	130	%	50	%	63	130	%	50	%	NA	NA	%
2-Fluorobiphenyl	321-60-8	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	38	130	%
2-Fluorophenol (Surr)	367-12-4	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	25	130	%
Hexachlorobenzene	118-74-1	0.05	mg/L	0.05	mg/L	52	130	%	50	%	52	130	%	50	%	NA	NA	%
Hexachlorobutadiene	87-68-3	0.05	mg/L	0.05	mg/L	36	130	%	50	%	36	130	%	50	%	NA	NA	%
Hexachloroethane	67-72-1	0.05	mg/L	0.05	mg/L	39	130	%	50	%	39	130	%	50	%	NA	NA	%
2-Methylphenol	95-48-7	0.05	mg/L	0.05	mg/L	55	130	%	50	%	55	130	%	50	%	NA	NA	%
3 & 4 Methylphenol	15831-10-4	0.05	mg/L	0.05	mg/L	35	130	%	50	%	35	130	%	50	%	NA	NA	%
Nitrobenzene	98-95-3	0.05	mg/L	0.05	mg/L	56	130	%	50	%	56	130	%	50	%	NA	NA	%
Nitrobenzene-d5 (Surr)	4165-60-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	39	130	%
Pentachlorophenol	87-86-5	0.25	mg/L	0.25	mg/L	42	138	%	50	%	42	138	%	50	%	NA	NA	%
Phenol-d5 (Surr)	4165-62-2	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	25	130	%
Pyridine	110-86-1	0.25	mg/L	0.25	mg/L	10	130	%	50	%	10	130	%	50	%	NA	NA	%
Terphenyl-d14 (Surr)	1718-51-0	NA	mg/L	NA	mg/L	NA	NA	%	NA	%	NA	NA	%	NA	%	10	143	%
2,4,6-Tribromophenol (Surr)	118-79-6	NA	mg/L	NA	mg/L	10	130	%	NA	%	10	130	%	NA	%	31	141	%
2,4,5-Trichlorophenol	95-95-4	0.05	mg/L	0.05	mg/L	61	130	%	50	%	61	130	%	50	%	NA	NA	%
2,4,6-Trichlorophenol	88-06-2	0.05	mg/L	0.05	mg/L	57	130	%	50	%	57	130	%	50	%	NA	NA	%

Analyte Description	CAS Number	Reference RL		Reference MDL		Reference LCSREC			Reference		Reference MSREC			Reference MSRPD		Reference SUREC		
		Limit	Units	Limit	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units	Precision	Units	Recovery Low	Recovery High	Units
Metals (ICP)	6010C/1311/3010																	
Arsenic	7440-38-2	0.20	mg/L	0.20	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Barium	7440-39-3	1.00	mg/L	1.00	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Cadmium	7440-43-9	0.10	mg/L	0.10	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Chromium	7440-47-3	0.20	mg/L	0.20	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Lead	7439-92-1	0.20	mg/L	0.20	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Selenium	7782-49-2	0.50	mg/L	0.50	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%
Silver	7440-22-4	0.10	mg/L	0.10	mg/L	80	120	%	20	%	75	125	%	20	%	NA	NA	%

Notes:

Analyte list is subject to change with time.

The values in this table are updated periodically by the laboratory and may vary.

The list of metals for sample analyses is the US EPA Contract Laboratory Program (CLP) metals list.

The Waste Characterization lists are determined by the waste disposal facility.

COD = Chemical Oxygen Demand

FFP = Fuel Fingerprint

GC/MS = Gas Chromatography/Mass Spectrometry

IC = Ion Chromatography

ICP = Inductively Coupled Plasma

LCSREC = Laboratory Control Sample Recovery

LCSRPD = Laboratory Control Sample Relative Percent Difference

MDL = Minimum Detection Limit

MEK = Methyl Ethyl Ketone

MIBK = Methyl Isobutyl Ketone

MSREC = Matrix Spike Recovery

MSRPD = Matrix Spike Relative Percent Difference

NA = Not Applicable

RL = Reporting Limit

SUREC = Surrogate Recovery

Surr = Surrogate

TPH = Total Petroleum Hydrocarbon

Appendix D

Field Standard Operating Procedures

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

GUIDANCE

Title: Design and Installation of Monitoring Wells

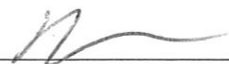
Effective Date: January 29, 2013

Number: SESDGUID-101-R1

Authors

Name: Brian Striggow

Title: Environmental Engineer

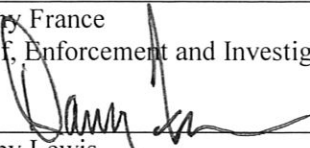
Signature: 

Date: 1-22-13

Approvals

Name: Danny France

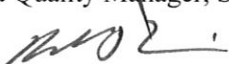
Title: Chief, Enforcement and Investigations Branch

Signature: 

Date: 1-22-13

Name: Bobby Lewis

Title: Field Quality Manager, Science and Ecosystem Support Division

Signature: 

Date: 1/22/13

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

History	Effective Date
<p>SESDGUID-101-R1, <i>Design and Installation of Monitoring Wells</i>, replaces SESDPROC-101-R0.</p> <p>General: Corrected any typographical, grammatical and/or editorial errors.</p> <p>Cover Page: The Enforcement and Investigations Branch Chief was changed from Antonio Quinones to Danny France. The FQM was changed from Laura Ackerman to Bobby Lewis.</p> <p>Section 1.2: Added the following statement: Mention of trade names or commercial products does not constitute endorsement or recommendation for use.</p> <p>Section 1.3: Omitted the reference to the H: drive of the LAN.</p> <p>Section 1.4: Replaced the “SESD Operating Procedure for Field Records and Documentation, SESDPROC-204-Most Recent Version” with its updated version, the “SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version.</p> <p>Section 1.5.1: Updated the SEMP Manual reference to reflect that the most recent version of the Manual will be used.</p> <p>Section 1.5.2: On the second bullet, replaced the reference with the “SESD Operating Procedure for Logbooks (SESDPROC-010).”</p>	January 29, 2013
SESDGUID-101-R0, <i>Design and Installation of Monitoring Wells</i> , Original Issue	February 18, 2008

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1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when designing and installing permanent and temporary groundwater monitoring wells to be used for collection of groundwater samples.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when designing, constructing and installing groundwater monitoring wells. On the occasion that SESD field personnel determine that any of the procedures described in this section are either inappropriate, inadequate or impractical and that another procedure must be used for any aspect of the design, construction and/or installation of a groundwater monitoring well, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring its use. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD local area network (LAN). The Document Control Coordinator is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 References

USEPA Region 4 Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), November 2001

USEPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Science and Ecosystem Support Division, Region 4, Athens, GA, Most Recent Version

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Groundwater Sampling, SESDPROC-301, Most Recent Version

SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202, Most Recent Version

EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation*

ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in Aquifers*

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when constructing and installing groundwater monitoring wells. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy (SHEMP) Manual (Most Recent Version) and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear and gloves. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate. Section 2.6, Safety Procedures for Drilling Activities, contains detailed and specific safety guidelines that must be followed by Branch personnel when conducting activities related to monitoring well construction and installation.

1.5.2 Procedural Precautions

The following precautions should be considered when constructing and installing groundwater monitoring wells.

- Special care must be taken to minimize or prevent inadvertent cross-contamination between borehole locations. Equipment, tools and well materials must be cleaned and/or decontaminated according to procedures found in SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205).
- All field activities are documented in a bound logbook according to the procedures found in SESD Operating Procedure for Logbooks (SESDPROC-010).

2 Permanent Monitoring Well Design Considerations

2.1 General

The design and installation of permanent monitoring wells involves drilling into various types of geologic formations that exhibit varying subsurface conditions. Designing and installing permanent monitoring wells in these geologic environments may require several different drilling methods and installation procedures. The selection of drilling methods and installation procedures should be based on field data collected during a hydrogeologic site investigation and/or a search of existing data. Each permanent monitoring well should be designed and installed to function properly throughout the duration of the monitoring program. When designing monitoring wells, the following should be considered:

- Short-and long-term objectives;
- Purpose of the well(s);
- Probable duration of the monitoring program;
- Contaminants likely to be monitored;
- Surface and subsurface geologic conditions;
- Properties of the aquifer(s) to be monitored;
- Well screen placement;
- General site conditions; and
- Potential site health and safety hazards.

In designing permanent monitoring wells, the most reliable, obtainable data should be utilized. Once the data have been assembled and the well design(s) completed, a drilling method(s) must be selected. The preferred drilling methods for installing monitoring wells are those that temporarily case the borehole during drilling and the construction of the well, e.g. hollow-stem augers and sonic methods. However, site conditions or project criteria may not allow using these methods. When this occurs, alternate methods should be selected that will achieve the project objectives. The following discussion of methods and procedures for designing and installing monitoring wells will cover the different aspects of selecting materials and methods, drilling boreholes, and installing monitoring devices.

2.2 Drilling Methods

The following drilling methods may be used to install environmental monitoring wells or collect samples under various subsurface conditions. In all cases the preferred methods are those that case the hole during drilling, i.e. Hollow Stem Augers (HSA) and sonic methods using an override system. Other methods may be used where specific subsurface or project criteria dictate.

2.2.1 Hollow Stem Auger (HSA)

This type of auger consists of a hollow, steel stem or shaft with a continuous, spiraled steel flight, welded onto the exterior. A hollow auger bit, generally with carbide teeth, disturbs soil material when rotated, whereupon the spiral flights transport the cuttings to the surface. This method is best suited in soils that have a tendency to collapse when disturbed. A monitoring well can be installed inside of hollow-stem augers with little or no concern for the caving potential of the soils. If caving sands exist during monitoring well installations, a drilling rig must be used that has enough power to extract the augers from the borehole without having to rotate them. A bottom plug, trap door, or pilot bit assembly can be used at the bottom of the augers to keep out most of the soils and/or water that have a tendency to enter the bottom of the augers during drilling. Potable water (analyzed for contaminants of concern) may be poured into the augers during drilling to equalize pressure so that the inflow of formation materials will be held to a minimum. Water-tight center bits are not acceptable because they create suction when extracted from the augers. This suction forces or pulls cuttings and formation materials into the augers, defeating the purpose of the center plug. Augering without a center plug or pilot bit assembly is permitted, provided that the soil plug, formed in the bottom of the augers, is removed before sampling or installing well casings. Removing the soil plug from the augers can be accomplished by drilling and washing out the plug using a rotary bit, or augering out the plug with a solid-stem auger bit sized to fit inside the hollow-stem auger. Bottom plugs can be used where no soil sampling is conducted during the drilling process. The bottom plug is wedged into the bottom of the auger bit and is knocked out at depth with drill pipe or the weight of the casing and screen assembly. The plug material should be compatible with the screen and casing materials. The use of wood bottom plugs is not acceptable. The type of bottom plug, trap door, or pilot bit assembly proposed for the drilling activity should be approved by a senior field geologist prior to drilling operations. Boreholes can be augered to depths of 150 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

2.2.2 Solid Stem Auger

This type of auger consists of a sealed hollow or solid stem or shaft with a continuous spiraled steel flight welded on the outside of the stem. An auger bit connected to the bottom disturbs soil material when rotated and the helical flights transport cuttings to the surface. At the desired depth the entire auger string is removed to gain access to the bottom of the borehole. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augered to depths of 200 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

Both of the previously discussed auger methods can be used in unconsolidated soils and semi-consolidated (weathered rock) soils, but not in competent rock.

Each method can be employed without introducing foreign materials into the borehole such as water and drilling fluids, minimizing the potential for cross contamination. Minimizing the risk of cross contamination is one of the most important factors to consider when selecting the appropriate drilling method(s) for a project.

2.2.3 *Sonic Methods*

These methods generally alternately advance concentric hollow drill stems using rotation in conjunction with axial vibration of the drill stem. After each stage of drill stem advancement, the inner string is removed with a core of drill cuttings while the outer ‘override’ string remains to hold the borehole open. The cuttings can be removed nearly intact from the inner casing for examination of the stratigraphy prior to sampling or disposal. Because there are no auger flights to increase the borehole diameter, the quantity of cuttings removed from the hole is minimized as compared to hollow stem augering. With moderate rotation, smearing of the formation materials on the borehole walls is reduced as well. This drilling method is useful in a variety of materials, from flowing sands to heavily consolidated or indurated formations.

In flowing sands, the drill casings can be filled and/or pressurized with potable water to prevent excess entry of formation materials into the drill string. The same QA/QC requirements for sampling of material introduced to the borehole apply as in other drilling methods. Because the amount of water introduced into the borehole can be significant, an approximation of the water used in the drilling process should be logged for use in estimating appropriate well development withdrawal.

Sonic drilling allows a larger diameter temporary casing to be set into a confining layer while drilling proceeds into deeper aquifers. This temporary casing is then removed during the grouting operation. In many cases this will be acceptable technique. However, the level of contamination in the upper aquifer, the importance of the lower aquifers for drinking water uses, the permeability and continuity of the confining layer, and state regulations should be taken into account when specifying this practice as opposed to permanent outer casing placed into the confining unit. Note that when using the temporary casing practice, it is critical that grout be mixed and placed properly as specified elsewhere in this section.

Because the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, particular care should be taken that the well casing is placed in the center of the drill stem while placing the filter pack. Centralizers should be used in most cases to facilitate centering, particularly in the case of deep wells with PVC casing.

2.2.4 Rotary Methods

These methods consist of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through the soils. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids which generally consist of water, drilling mud, or air. The water, drilling mud, or air are forced down through the drill pipe, and out through the bottom of the drilling bit. The cuttings are then lifted to the surface between the borehole wall and the drill pipe, (or within a concentric drill stem in reverse rotary). Except in the case of air rotary, the drilling fluid provides a hydrostatic pressure that reduces or prevents borehole collapse. When considering this method, it is important to evaluate the potential for contamination when fluids and/or air are introduced into the borehole.

Due to the introduction of the various circulating fluids, the use of rotary methods requires that the potential for contamination by these fluids be evaluated. Water and mud rotary methods present the possibility of trace contamination of halogenated compounds when municipal water supplies are used as a potable water source. Air rotary drilling can introduce contamination through the use of lubricants or entrained material in the air stream. Unless contaminated formations are cased off, the circulation of drilling fluids presents a danger of cross contamination between formations. In any of the rotary (or sonic) methods, care must be exercised in the selection and use of compounds to prevent galling of drill stem threads.

2.2.4.1 Water Rotary

When using water rotary, potable water (that has been analyzed for contaminants of concern) should be used. If potable water (or a higher-quality water) is not available on-site, then potable water will have to be transported to the site or an alternative drilling method will have to be selected. Water does not clog the formation materials, but the suspended drilling fines can be carried into the formation, resulting in a very difficult to develop well. This method is most appropriate for setting isolation casing.

2.2.4.2 Air Rotary

Air rotary drilling uses air as a drilling fluid to entrain cuttings and carry them to the surface. High air velocities, and consequently large air volumes and compressor horsepower are required. "Down-the-hole" (DTH) percussion hammers driven by the air stream can be used with this method to rapidly penetrate bedrock materials. Where a casing through unconsolidated material is required to prevent borehole collapse, it can be driven in conjunction with advancement of the drill stem.

When using air rotary drilling in any zone of potential contamination, the cuttings exiting the borehole must be controlled. This can be done using

the dual-tube reverse circulation method where cuttings are carried to the surface inside dual-wall drill pipe and separated with a cyclone separator. An air diverter with hose or pipe carrying cuttings to a waste container is also an acceptable alternative. Allowing cuttings to blow uncontrolled from the borehole is not acceptable.

When using air rotary, the issue of contaminants being introduced into the borehole by the air stream must be addressed. Screw compressor systems should have a coalescing filter system in good working order to capture excess entrained compressor oils. The lubricant to be used with DTH hammers as well as thread lubricants to be used on drill stem should be evaluated for their potential impact on analytical samples.

2.2.4.3 Mud Rotary

Mud rotary is an undesirable drilling method because contamination can be introduced into the borehole from the constituents in the drilling mud, cross contamination can occur along the borehole column, and it is difficult to remove the drilling mud from the borehole after drilling and during well development. The drilling mud can also carry contaminants from a contaminated zone to an uncontaminated zone thereby cross-contaminating the borehole. If mud rotary is selected, only potable water and pure (no additives) bentonite drilling muds should be used. All materials used should have adequate documentation as to manufacturer's recommendations and product constituents. QA/QC samples of drilling muds and potable water should be sampled at a point of discharge from the circulation system to assure that pumps and piping systems are not contributing cross-contamination from previous use.

2.2.5 Other Methods

Other methods such as the cable-tool method, jetting method, and boring (bucket auger) method are available. If these and/or other methods are selected for monitoring well installations, they should be approved by a senior field geologist before field work is initiated.

2.3 Borehole Construction

2.3.1 Annular Space

The borehole or hollow stem auger should be of sufficient diameter so that well construction can proceed without major difficulties. For open boreholes, the annular space should be approximately 2" to allow the uniform deposition of well materials around the screen and riser, and to allow the passage of tremie pipes and well materials without unduly disturbing the borehole wall. For example, a 2" nominal diameter (nom.) casing would require a 6" inside diameter (ID) borehole.

In hollow stem augers and sonic method drill casing, the ID should be of sufficient size to allow the passage of the tremie pipe to be used for well grout placement, as well as free passage of filter sands or bentonite pellets dropped through the auger or casing. In general, 4-1/4" ID should be the minimum size used for placement of 2" nom. casing and 8-1/4" ID for 4" nom. casing. Larger augers should be used where installation difficulties due to geologic conditions or greater depths are anticipated, e.g. larger augers might be required to place a bentonite pellet seal through a long water column.

2.3.2 Over-drilling the Borehole

Sometimes it is necessary to over-drill the borehole in anticipation of material entering the augers during center bit removal or knocking out of the bottom plug. Normally, 3 to 5 feet is sufficient for over-drilling. The borehole can also be over-drilled to allow for an extra space or a "sump" area below the well screen. This "sump" area provides a space to attach a 5 or 10 foot section of well casing to the bottom of the well screen. The extra space or "sump" below the well screen serves as a catch basin or storage area for sediment that flows into the well and drops out of suspension. These "sumps" are added to the well screens when the wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the "sump" preventing the well screen from clogging or "silting up". If the borehole is inadvertently drilled deeper than desired, it can be backfilled to the design depth with bentonite pellets, chips, or the filter sand that is to be used for the filter pack.

2.3.3 Filter Pack Placement

When placing the filter pack into the borehole, a minimum of 6-inches of the filter pack material should be placed under the bottom of the well screen to provide a firm base. Also, the filter pack should extend a minimum of 2-feet above the top of the well screen to allow for settling and to isolate the screened interval from the grouting material. In open boreholes, the filter pack should be placed by the tremie or positive displacement method. Placing the filter pack by pouring the sand into an open drill stem is acceptable with the use hollow stem augers, and other methods where the borehole is temporarily cased down to the filter pack.

2.3.4 Filter Pack Seal – Bentonite Pellet Seal (Plug)

Bentonite pellets consist of ground, dried bentonite compacted into pellets available in several sizes. Bentonite pellets are compressed to a bulk density of 70-80 lbs/ft³ and hydrate to a 30% min. solids material. Where neat cement grouts are to be used, the placement of a bentonite pellet seal above the filter pack is mandatory to prevent the possibility of grout infiltration into the screened interval prior to setting. Bentonite chips or other sealing products should not be

substituted in this application. Where bentonite grouts are to be used, the placement of a bentonite pellet seal is optional, but desirable.

Since bentonite pellets begin hydrating rapidly, they can be very difficult to place properly. They are generally placed by pouring slowly into open boreholes, hollow stem augers or sonic drill pipe. In some cases, pellets are placed by tremie pipe and flushed into place with potable water. A tamper can be used to ensure that the material is being placed properly and to rapidly break up any pellet bridging that occurs.

Pellet seals should be designed for a two-foot thickness of dry pellets above the filter pack. Hydration may extend the height of the seal. Where neat cement grouts are to be used, the pellets should be hydrated for eight hours, or the manufacturer's recommended hydration time, whichever is greater. Where the water table is temporarily below the pellet seal, potable (or higher quality) water should be added repeatedly to hydrate the pellets prior to grouting.

2.3.5 Grouting the Annular Space

The annular space between the casing and the borehole wall should be filled with either a 30% solids bentonite grout, a neat cement grout, or a cement/bentonite grout. Each type of grout selected should be evaluated as to its intended use and integrity. Bentonite grouts are preferred unless the application dictates the use of another material.

Bentonite grout shall be a 30% solids pure bentonite grout. Drilling muds are not acceptable for grouting. The grout should be placed into the borehole, by the tremie method, from the top of the bentonite seal to within 2-feet of the ground surface or below the frost line, whichever is the greater depth. The bentonite pellet seal or filter pack should not be disturbed during grout placement, either by the use of a side discharge port on the tremie tube, or by maintaining clearance between the bottom of the tremie tube and the bentonite seal or filter pack. The grout should be allowed to cure for a minimum of 24 hours before the concrete surface pad is installed. The preferred method of achieving proper solids content is by measurement of ingredients per the manufacturer's specifications during mixing with a final check by grout balance after mixing. Bentonite grouts should have a minimum density of 10 lbs/gal to ensure proper gelling and low permeability. The density of the first batch of grout should be measured while mixing to verify proper measurement of ingredients. In addition, the grouting operation should not cease until the bentonite grout flowing out of the borehole has a minimum density of 10 lbs/gal. Estimating the grout density is not acceptable.

Cement grouts are generally dictated where a high level of dissolved solids or a particular dissolved constituent would prevent proper gelling of a bentonite grout. Neat cement grouts (cement without additives) should be mixed using 6 gallons of

water per 94-lb bag of Type 1 Portland cement to a density of 15lbs/gal. The addition of bentonite (5 to 10 percent) to the cement grout can be used to delay the "setting" time and may not be needed in all applications. The specific mixtures and other types of cement and/or grout proposed should be evaluated on a case by case basis by a senior field geologist.

2.3.6 Above Ground Riser Pipe and Outer Casing

The well casing, when installed and grouted, should extend above the ground surface a minimum of 2.5 feet. A vent hole should be drilled into the top of the well casing cap to permit pressure equalization, if applicable. An outer protective casing should be installed into the borehole after the annular grout has cured for at least 24 hours. The outer protective casing should be of steel construction with a hinged, locking cap. Generally, outer protective casings used over 2-inch well casings are 4 inches square by 5 feet long. Similarly, protective casings used over 4-inch well casings are 6 inches square and 5 feet long. Other types of protective casing including those constructed of pipe are also acceptable. All protective casings should have sufficient clearance around the inner well casings, so that the outer protective casings will not come into contact with the inner well casings after installation. The protective casings should have a weep hole to allow drainage of accumulated rain or spilled purge water. The weep hole should be approximately 1/4-inch in diameter and drilled into the protective casings just above the top of the concrete surface pad to prevent water from standing inside of the protective casings. Protective casings made of aluminum or other soft metals are normally not acceptable because they are not strong enough to resist tampering. Aluminum protective casing may be used in very corrosive environments such as coastal areas.

Prior to installing the protective casing, the bentonite grout in the borehole annulus is excavated to a depth of approximately two feet. The protective casing is installed by pouring concrete into the borehole on top of the grout. The protective casing is then pushed into the wet concrete and borehole a minimum of 2 feet. Extra concrete may be needed to fill the inside of the protective casing so that the level of the concrete inside of the protective casing is at or above the level of the surface pad. In areas where frost heave of the surface pad is possible, the protective casing should first be pressed into the top surface of the bentonite grout seal and concrete poured around the protective casing. A granular material such as sand or gravel can then be used to fill the space between the riser and protective casing. The use of granular material instead of concrete between the protective casing and riser will also facilitate the future conversion of the well to a flush-mount finish, if required. The protective casing should extend above the ground surface to a height so that the top of the inner well casing is exposed when the protective casing is opened. At each site, all locks on the outer protective casings should be keyed alike.

2.3.7 Concrete Surface Pad

A concrete surface pad should be installed around each well at the same time as the outer protective casing is being installed. The surface pad should be formed around the well casing. Concrete should be placed into the pad forms and into the borehole (on top of the grout) in one operation making a contiguous unit. The size of the concrete surface pad is dependent on the well casing size. If the well casing is 2 inches in diameter, the pad should be 3 feet x 3 feet x 4 inches. If the well casing is 4 inches in diameter, the pad should be 4 feet x 4 feet x 6 inches. Round concrete surface pads are also acceptable. The finished pad should be slightly sloped so that drainage will flow away from the protective casing and off of the pad. A minimum of one inch of the finished pad should be below grade to prevent washing and undermining by soil erosion.

2.3.8 Surface Protection – Bumper Guards

If the monitoring wells are located in a high traffic area, a minimum of three bumper guards consisting of steel pipes 3 to 4 inches in diameter and a minimum 5-foot length should be installed. These bumper guards should be installed to a minimum depth of 2 feet below the ground surface in a concrete footing and extend a minimum of 3 feet above ground surface. Concrete should also be placed into the steel pipe to provide additional strength. Substantial steel rails and/or other steel materials can be used in place of steel pipe. Welding bars between the bumper posts can provide additional strength and protection in high traffic areas, but the protective bumpers should not be connected to the protective casing.

2.4 Construction Techniques

2.4.1 Well Installation

The borehole should be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob or level. Deviation from plumb should be within 1° per 50ft of depth. Slanted boreholes are undesirable and should be noted in the boring logs and final construction logs. The depth and volume of the borehole, including the over-drilling if applicable, should have been calculated and the appropriate materials procured prior to drilling activities.

The well casings should be secured to the well screen by flush-jointed threads and placed into the borehole and plumbed by the use of centralizers and/or a plumb bob and level. Another method of placing the well screen and casings into the borehole and plumbing them at the same time is to suspend the string of well screen and casings in the borehole by means of a hoist on the drill rig. This wireline method is especially useful if the borehole is deep and a long string of well screen and casings have to be set and plumbed.

No lubricating oils or grease should be used on casing threads. No glue of any type should be used to secure casing joints. Teflon "O" rings can also be used to insure a tight fit and minimize leakage; however, "O" rings made of other materials are not acceptable if the well is going to be sampled for organic compound analyses.

Before the well screen and casings are placed on the bottom of the borehole, at least 6 inches of filter material should be placed at the bottom of the borehole to serve as a firm footing. The string of well screen and casings should then be placed into the borehole and plumbed. Centralizers can be used to plumb a well, but centralizers should be placed so that the placement of the filter pack, bentonite pellet seal, and annular grout will not be hindered. Centralizers placed in the wrong locations can cause bridging during material placement. Monitoring wells less than 50 feet deep generally do not need centralizers. If centralizers are used they should be placed below the well screen and above the bentonite pellet seal. The specific placement intervals should be decided based on site conditions.

When installing the well screen and casings through hollow-stem augers, the augers should be slowly extracted as the filter pack, bentonite pellet seal, and grout are tremied and/or poured into place. The gradual extraction of the augers will allow the materials being placed in the augers to flow out of the bottom of the augers into the borehole. If the augers are not gradually extracted, the materials (sand, pellets, etc.) will accumulate at the bottom of the augers causing potential bridging problems.

After the string of well screen and casing is plumb, the filter pack material should then be placed around the well screen to the designated depth. With cased drilling methods, the sand should be poured into the casing or augers until the lower portion is filled. The casing or augers are then withdrawn, allowing the sand to flow into the evacuated space. With hollow stem augers, sand should always fill the augers 6-12 inches, maintained by pouring the sand while checking the level with a weighted tag line. The filter pack sand in open boreholes should be installed by tremie methods, using water to wash the sand through the pipe to the point of placement.

After the filter pack has been installed, the bentonite pellet seal (if used) should be placed directly on top of the filter pack to an unhydrated thickness of two feet. When installing the seal for use with cement grouts, the bentonite pellet seal should be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer.

After the pellet seal has hydrated for the specified time, the grout should then be pumped by the tremie method into the annular space around the casings. The grout should be allowed to set for a minimum of 24 hours before the surface pad and protective casing are installed.

After the surface pad and protective casing are installed, bumper guards should be installed (if needed). The bumper guards should be placed around the concrete surface pad in a configuration that provides maximum protection to the well. Each piece of steel pipe or approved material should be installed into an 8-to 10-inch diameter hole, to a minimum depth of 2 feet below ground surface, and filled with concrete. As previously stated, the bumper guard should extend above the ground surface a minimum of 3 feet. The total length of each bumper guard should be a minimum of 5 feet.

After the wells have been installed, the outer protective casing should be painted with a highly visible paint. The wells should be permanently marked with the well number, date installed, site name, elevation, etc., either on the cover or an appropriate place that will not be easily damaged and/or vandalized.

If the monitoring wells are installed in a high traffic area such as a parking lot, in a residential yard, or along the side of a road it may be desirable to finish the wells to the ground surface and install water-tight flush mounted traffic and/or man-hole covers. Flush mounted traffic and man-hole covers are designed to extend from the ground surface down into the concrete plug around the well casing. Although flush mounted covers may vary in design, they should have seals that make the unit water-tight when closed and secured. The flush mounted covers should be installed slightly above grade to minimize standing water and promote runoff. Permanent identification markings should be placed on the covers or in the concrete plug around the cover. Expansive sealing plugs should be used to cap the well riser to prevent infiltration of any water that might enter the flush cover.

2.4.2 Double-Cased Wells

Double-cased wells should be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross-contamination or when flowing sands make it impossible to install a monitoring well using conventional methods. A highly contaminated surface soil zone may also be cased off so that drilling may continue below the casing with reduced danger of cross contamination. A pilot borehole should be bored through the overburden and/or the contaminated zone into the clay confining layer or bedrock. An outer casing (sometimes called surface or pilot casings) should then be placed into the borehole and sealed with grout. The borehole and outer casing should extend into tight clay a minimum of two feet and into competent bedrock a minimum of 1 foot. The total depths into the clay or bedrock will vary, depending on the plasticity of the clay and the extent of weathering and/or fracturing of the bedrock. The final depths should be approved by a senior field geologist. The size of the outer casing should be of sufficient inside diameter to contain the inner casing, and the 2-inch minimum annular space. In addition, the borehole should be of sufficient size to contain the outer casing and the 2-inch minimum outer annular space, if applicable.

The outer casing should be grouted by the tremie, displacement, grout shoe, or Halliburton method from the bottom to the ground surface. The grout should be pumped into the annular space between the outer casing and the borehole wall. A minimum of 24 hours should be allowed for the grout plug (seal) to cure before attempting to drill through it. The grout mixture used to seal the outer annular space should be either a neat cement, cement/bentonite, cement/sand, or a 30% solids bentonite grout. However, the seal or plug at the bottom of the borehole and outer casing should consist of a Type I portland cement/bentonite or cement/sand mixture. The use of a pure bentonite grout for a bottom plug or seal is not acceptable, because the bentonite grout cures to a gel-like material, and is not rigid enough to withstand the stresses of drilling. When drilling through the seal, care should be taken to avoid cracking, shattering, or washing out the seal. If caving conditions exist so that the outer casing cannot be sufficiently sealed by grouting, the outer casing should be driven into place and a grout seal placed in the bottom of the casing.

2.4.2.1 Bedrock Wells

The installation of monitoring wells into bedrock can be accomplished in two ways:

1. The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock. An outer casing is then installed into the borehole by setting it into the bedrock, and grouting it into place as described in the previous section. After the grout has set, the borehole can then be advanced through the grout seal into the bedrock. The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are used in soft bedrock, but extreme caution should be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and "down" pressure can cause cracking, eroding (washing), and/or shattering of the seal. Low volume air hammers may be used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. If the structural integrity of the grout seal is in question, a pressure test can be utilized to check for leaks. A visual test can also be made by examining the cement/concrete core that is collected when the seal is cored with a diamond coring bit. If the seal leaks (detected by pressure testing) and/ or the core is cracked or shattered, or if no core is recovered because of washing, excessive down pressure, etc., the seal is not acceptable. The concern over the structural integrity of the grout seal applies to all double cased wells. Any proposed method of double casing and/or seal testing will be evaluated on its own merits, and will have to be approved by a senior field geologist before and during drilling activities, if

applicable. When the drilling is complete, the finished well will consist of an open borehole from the ground surface to the bottom of the well. There is no inner casing, and the outer surface casing, installed down into bedrock, extends above the ground surface, and also serves as the outer protective casing. If the protective casing becomes cracked or is sheared off at the ground surface, the well is open to direct contamination from the ground surface and will have to be repaired immediately or abandoned. Another limitation to the open rock well is that the entire bedrock interval serves as the monitoring zone. In this situation, it is very difficult or even impossible to monitor a specific zone, because the contaminants being monitored could be diluted to the extent of being non-detectable. The installation of open bedrock wells is generally not acceptable in the Superfund and RCRA programs, because of the uncontrolled monitoring intervals. However, some site conditions might exist, especially in cavernous limestone areas (karst topography) or in areas of highly fractured bedrock, where the installation of the filter pack and its structural integrity are questionable. Under these conditions the design of an open bedrock well may be warranted.

2. The second method of installing a monitoring well into bedrock is to install the outer surface casing and drill the borehole (by an approved method) into bedrock, and then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. The well is completed with a surface protective casing and concrete pad. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. In addition, it gives structural integrity to the well, especially in unstable areas (steeply dipping shales, etc.) where the bedrock has a tendency to shift or move when disturbed. Omitting the filter pack around the well screen is a general practice in some open rock borehole installations, especially in drinking water and irrigation wells. However, without the filter pack to protect the screened interval, sediment particles from the well installation and/or from the monitoring zone could clog the well screen and/or fill the screened portion of the well rendering it inoperable. Also, the filter pack serves as a barrier between the bentonite seal and the screened interval. Rubber inflatable packers have been used to place the bentonite seal when the filter pack is omitted, but the packers have to remain in the well permanently and, over a period of time, will decompose and possibly contribute contaminants to the monitoring zone.

2.5 Well Construction Materials

2.5.1 Introduction

Well construction materials are chosen based on the goals and objectives of the proposed monitoring program and the geologic conditions at the site(s). In this section, the different types of available materials will be discussed.

2.5.2 Well Screen and Casing Materials

When selecting the materials for well construction, the prime concern should be to select materials that will not contribute foreign constituents, or remove contaminants of concern from the ground water. If the monitoring program is designed to analyze for organic compounds, stainless steel materials are the preferred choice. If the monitoring program calls for the analyses of only inorganic compounds or the contaminants or formation are highly corrosive, then rigid PVC materials meeting National Sanitary Foundation (NSF) Standard 14 type WC (Well Casing) are acceptable. PVC materials may be acceptable for monitoring identified organic compounds in a soluble aqueous phase where incompatibilities are known to not exist. EPA document EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation* (<http://www.epa.gov/ada/-download/issue/napl.pdf>) should be used for guidance in this area and in the use of PVC with non-aqueous phase liquids (NAPLs). Another concern is to select materials that will be rugged enough to endure the entire monitoring period. Site conditions will generally dictate the type of materials that can be used. A preliminary field investigation should be conducted to determine the geologic conditions, so that the most suitable materials can be selected. The best grade or highest quality material for that particular application should be selected. Each manufacturer can supply the qualitative data for each grade of material that is being considered. All materials selected for monitoring well installation should be evaluated and approved by a senior field geologist prior to field activities.

Well screen and casing materials generally used in monitoring well construction on RCRA and Superfund sites are listed in order of preference:

1. Stainless Steel (304 or 316)
2. Rigid PVC meeting NSF Standard 14 (type WC)
3. Other (where applicable)

There are other materials used for well screens and casings such as black iron, carbon steel, galvanized steel, and fiberglass, but these materials are not recommended for use in long term monitoring programs at hazardous waste sites, because of their low resistance to chemical attack and potential constituent contribution to the ground water. In cases where a driven casing is used, or a high strength outer casing is needed, carbon steel may be acceptable in non-corrosive aquifers. This outer casing should have threaded connections. Welding casing is

not an acceptable practice unless all relevant safety issues have been adequately addressed.

The minimum nominal casing size for most permanent monitoring wells will be 2". Where a complete program of installation, monitoring, and abandonment is being designed, smaller wells may be installed if suitable purging and sampling equipment for the smaller diameter wells can be specified and obtained. The length of well screens in permanent monitoring wells should be long enough to effectively monitor the interval or zone of interest. However, well screens designed for long term monitoring purposes should normally not be less than 5 feet in length. Well screens less than 5 feet long are generally only used in temporary monitoring wells where ground water samples are collected for screening purposes.

2.5.3 Filter Pack Materials

The filter pack materials should consist of clean, rounded to well-rounded, hard, insoluble particles of siliceous composition. The required grain-size distribution or particle sizes of the filter pack materials should be selected based upon a sieve analysis conducted on the soil samples collected from the aquifer materials and/or the formation(s) to be monitored. Filter pack materials should not be accepted unless proper documentation can be furnished as to the composition, grain-size distribution, cleaning procedure, and chemical analysis. If a data search reveals that there is enough existing data to adequately design the well screen and filter pack, then it may not be necessary to conduct a sieve analysis on the formation materials to be monitored. However, all data and design proposals will be evaluated and approved by a senior staff geologist before field activities begin.

2.5.4 Filter Pack and Well Screen Design

The majority of monitoring wells are installed in shallow ground water aquifers that consist of silts, clays, and sands in various combinations. These shallow aquifers are not generally characteristic of aquifers used for drinking water. Therefore, modifications to the procedures used for the design of water well filter packs may be required. In cases where insufficient experience exists with local or similar materials, the filter pack and well screen design should be based on the results of a sieve analysis conducted on soil samples collected from the aquifer or the formation(s) that will be monitored.

In formations consisting primarily of fines (silts and clays), the procedures for water well screen design may result in requirements for filter packs and screen slot sizes that are not available. In those cases the selection of 0.010" screen slots with a 20-40 sand filter pack, or 0.005" screen slots with 100 sand filter pack for very fine formations, will be acceptable practice. Table 6.6.1 provides size specifications for the selection of sand packs for fine formation materials. ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in*

Aquifers, may be consulted for further guidance on specifications for sand appropriate for these applications.

Table 6.6.1
Sand Pack Specifications

Screen Opening (in)	Sand Pack Mesh Name	1% Passing Size (d-1) (in)	10% Passing Size (d-10) (in)	30% Passing Size (d-30) (in)	Derived 60% Passing Size (d-60) (in)	Range for Uniformity Coefficient
0.005-0.006	100	.0035 - .0047	.0055 - .0067	.0067 - .0083	.0085 - .0134	1.3 - 2.0
0.010"	20-40	.0098 - .0138	.0157 - .0197	.0197 - .0236	.020 - .0315	1.1 - 1.6

The following procedure should be used in coarser grained formations:

The data from the sieve analysis are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. From this grain-size distribution curve, the uniformity coefficient (Cu) of the aquifer material is determined. The Cu is the ratio of the 60 percent finer material (d60) to the 10 percent finer material (d10)

$$Cu = (d60/d10)$$

The Cu ratio is a way of grading or rating the uniformity of grain size. For example, a Cu of unity means that the individual grain sizes of the material are nearly all the same, while a Cu with a large number indicates a large range of particle sizes. As a general rule, a Cu of 2.5 or less should be used in designing the filter pack and well screen.

Before designing the filter pack and well screen, the following factors should be considered:

1. Select the well screen slot openings that will retain 90 percent of the filter pack material.
2. The filter pack material should be of the size that minimizes head losses through the pack and also prevents excessive sediment (sand, silt, clay) movement into the well.

3. A filter material of varying grain sizes is not acceptable because the smaller particles fill the spaces between the larger particles thereby reducing the void spaces and increasing resistance to flow. Therefore, filter material of the same grain size and well rounded is preferred.
4. The filter pack design is based on the gradation of the finest aquifer materials being analyzed.

Steps to design a filter pack in aquifers:

1. Construct a grain-size distribution curve, on a grain-size distribution graph, from the sieve analysis of the aquifer materials. The filter pack design (as stated above) is based on the gradation of the finest aquifer materials.
2. Multiply the d30 size from the grain-size distribution graph by a factor of four to nine (Pack-Aquifer ratio). A factor of four is used if the formation is fine-grained and uniform (Cu is less than 3), six if it is coarse-grained and non-uniform, and up to nine if it is highly non-uniform and contains silt. Head losses through filter packs increase as the Pack-Aquifer (P-A) ratios decrease. In order to design a fairly stable filter pack with a minimum head loss, the d30 size should be multiplied by a factor of four.
3. Plot the point from step 2 on the d30 abscissa of a grain-size distribution graph and draw a smooth curve with a uniformity coefficient of approximately 2.5.
4. A curve for the permissible limits of the filter pack is drawn plus or minus 8 per cent of the desired curve with the Cu of 2.5.
5. Select the slot openings for the well screen that will retain 90 per cent or more of the filter pack material.

The specific steps and procedures for sieve analysis and filter pack design can be found in soil mechanics, ground water, and water well design books. The staff geologists and/or engineers should be responsible for the correct design of the monitoring wells and should be able to perform the design procedures.

2.6 Safety Procedures for Drilling Activities

A site health and safety plan should be developed and approved by the Branch Safety Officer or designee prior to any drilling activities, and should be followed during all drilling activities. The driller or designated safety person should be responsible for the safety of the drilling team performing the drilling activities. All personnel conducting drilling activities should be qualified in proper drilling and safety procedures. Before any drilling activity is initiated, utilities should be marked or cleared by the appropriate state or municipal utility protection organization. In developed areas, additional measures

should be taken to locate utilities not covered by the utility protection program. Before operating the drill rig, a pilot hole should be dug (with hand equipment) to a depth of three feet to check for undetected utilities or buried objects. Proceed with caution until a safe depth is reached where utilities normally would not be buried. The following safety requirements should be adhered to while performing drilling activities:

1. All drilling personnel should wear safety hats, safety glasses, and steel toed boots. Ear plugs are required and will be provided by the safety officer or driller.
2. Work gloves (cotton, leather, etc.) should be worn when working around or while handling drilling equipment.
3. All personnel directly involved with the drilling rig(s) should know where the kill switch(s) is located in case of emergencies.
4. All personnel should stay clear of the drill rods or augers while in motion, and should not grab or attempt to attach a tool to the drill rods or augers until they have completely stopped rotating. Rod wipers, rather than gloves or bare hands should be used to remove mud, or other material, from drill stem as it is withdrawn from the borehole.
5. Do not hold drill rods or any part of the safety hammer assembly while taking standard penetration tests or while the hammer is being operated.
6. Do not lean against the drill rig or place hands on or near moving parts at the rear of the rig while it is operating.
7. Keep the drilling area clear of any excess debris, tools, or drilling equipment.
8. The driller will direct all drilling activities. No work on the rig or work on the drill site will be conducted outside of the driller's direction. Overall drill site activities will be in consultation with the site geologist or engineer, if present.
9. Each drill rig will have a first-aid kit and a fire extinguisher located on the rig in a location quickly accessible for emergencies. All drilling personnel will be familiarized with their location.
10. Work clothes will be firm fitting, but comfortable and free of straps, loose ends, strings etc., that might catch on some moving part of the drill rig.
11. Rings, watches, or other jewelry will not be worn while working around the drill rig.
12. The drill rig should not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig should not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

2.7 Well Development

A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before development procedures are initiated. The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction, around the immediate vicinity of each well. A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In most cases the above requirements can be satisfied; however, in some cases the pH, temperature, and specific conductivity may stabilize but the water remains turbid. In this case the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete the well development. If the well is pumped to dryness or near dryness, the water table should be allowed to sufficiently recover (to the static water level) before the next development period is initiated. Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The onsite geologist should make the decision as to the development completion of each well. All field decisions should be documented in the field log book.

The following development procedures, listed in approximate increasing order of the energy applied to the formation materials, are generally used to develop wells:

1. Bailing
2. Pumping/overpumping
3. Surging
4. Backwashing ("rawhiding")
5. Jetting
6. Compressed air (with appropriate filtering): airlift pumping and air surging

These development procedures can be used, individually or in combination, in order to achieve the most effective well development. In most cases, over-pumping and surging will adequately develop the well without imparting undue forces on the formation or well materials. Except when compressed air is being used for well development, sampling can be initiated as soon as the ground water has re-equilibrated, is free of visible sediment, and the water quality parameters have stabilized. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a new monitoring well. Wells developed with stressful measures may require as long as a 7-day interval before sampling. In particular, air surge developed wells require 48 hours or longer after development so that the formation can dispel the compressed air and re-stabilize to pre-well construction conditions. Because of the danger of introducing

contaminants with the airstream, the possibility of entraining air in the aquifer, and the violent forces imparted to the formation, air surging is the least desired method of development and should only be used where there is a specific need for the procedure. Air-lift pumping is permissible where an eductor pipe is used and several well volumes of water are removed from the well by other by pumping means after air-lift pumping. The selected development method(s) should be approved by a senior field geologist before any well installation activities are initiated.

2.8 Well Decommissioning (Abandonment)

When a decision is made to decommission (abandon) a monitoring well, the borehole should be sealed in such a manner that the well cannot act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly decommission a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete. In order to comply with state well decommissioning requirements, the appropriate state agency should be notified (if applicable) of monitoring well decommissioning. However, some state requirements are not explicit, so a technically sound well abandonment method should be designed based on the site geology, well casing materials, and general condition of the well(s).

2.8.1 Decommissioning Procedures

As previously stated the preferred method should be to completely remove the well casing and screen from the borehole. This may be accomplished by augering with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing should then be removed from the hole with the drill rig. The clean borehole can then be backfilled with the appropriate grout material. The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method). This abandonment method can be accomplished on small diameter (1-inch to 4-inch) wells without too much difficulty. With wells having 6-inch or larger diameters, the use of hollow-stem augers for casing removal is very difficult or almost impossible. Instead of trying to ream the borehole with a hollow-stem auger, it is more practical to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole. Wells with little or no grouted annular space and/or sound well casings can be removed in this manner. However, old wells with badly corroded casings and/or thickly grouted annular space have a tendency to twist and/or break-off in the borehole. When this occurs, the well will have to be grouted with the remaining casing left in the borehole. The preferred method in this case should be to pressure grout the borehole by placing the tremie tube to the bottom of the well casing, which will be the well screen or the bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter material and up the inside of the well casing sealing holes and breaks that are present.

A PVC well casing may be more difficult to remove from the borehole than a metal casing, because of its brittleness. If the PVC well casing breaks during removal, the borehole should be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by water or drilling mud. Another method is to use a solid-stem auger with a carbide tooth pilot bit to grind the PVC casing into small cuttings that will be brought to the surface on the rotating flights. After the casing materials have been removed from the borehole, the borehole should be cleaned out and pressure grouted with the approved grouting materials.

Where state regulations and conditions permit, it may be permissible to grout the casing in place. This decision should be based on confidence in the original well construction practice, protection of drinking water aquifers, and anticipated future property uses. The pad should be demolished and the area around the casing excavated. The casing should be sawn off at a depth of three feet below ground surface. The screen and riser should be tremie grouted with a 30% solids bentonite grout in the saturated zone. The remaining riser may be grouted with a cement grout for long term resistance to desiccation.

3 Temporary Monitoring Well Installation

3.1 Introduction

Five types of temporary monitoring well installation techniques have been demonstrated as acceptable. The type selected for a particular site is dependent upon site conditions. The project leader and site geologist should be prepared to test temporary well installations on site and select the best solution. Temporary wells are cost effective, may be installed quickly, and provide a synoptic picture of ground water quality.

Temporary monitoring well locations are not permanently marked, nor are their elevations normally determined. Sand pack materials may or may not be used, but typically there is no bentonite seal, grout, surface completion, or extensive development (as it normally applies to permanent monitoring wells). Temporary wells are generally installed, purged, sampled, removed, and backfilled in a matter of hours.

Due to the nature of construction, turbidity levels may initially be high. However, these levels may be reduced by low flow purging and sampling techniques as described in Section 7.2.4.

Temporary wells may be left overnight, for sampling the following day, but the well must be secured, both against tampering and against the fall hazard of the open annulus. If the well is not sampled immediately after construction, the well should be purged prior to sampling as specified in SESD Operating Procedure for Groundwater Sampling, SESDPROC-301.

3.2 Data Limitation

Temporary wells described in this section are best used for delineation of contaminant plumes at a point in time, and for some site screening purposes. They are not intended to replace permanent monitoring wells. Temporary wells can be used in conjunction with a mobile laboratory, where quick analytical results can be used to delineate contaminant plumes.

3.3 Temporary Well Materials

Materials used in construction of temporary monitoring wells are the same standard materials used in the construction of permanent monitoring wells. Sand used for the filter pack (if any) should be as specified in Section 2.5.3, Filter Pack Materials. The well screen and casing should be stainless steel for ruggedness and suitability for steam cleaning and solvent rinsing. Other materials may be acceptable, on a case by case basis. Some commercially available temporary well materials, pre-packed riser, screen and filter pack assemblies are available commercially; however, these pre-assembled materials cannot be cleaned. Appropriate QA/QC must be performed to assure there will be no introduction of contamination.

3.4 Temporary Monitoring Well Borehole Construction

Borehole construction for temporary wells is as specified in Section 2.3, using a drill rig. Alternatively, boreholes may be constructed using hand augers or portable powered augers (generally limited to depths of ten feet or less). If a drill rig is used to advance the borehole, the augers must be pulled back the length of the well screen (or removed completely) prior to sampling. When hand augers are used, the borehole is advanced to the desired depth (or to the point where borehole collapse occurs). In situations where borehole collapse occurs, the auger bucket is typically left in the hole at the point of collapse while the temporary well is assembled. When the well is completely assembled, a final auger bucket of material is quickly removed and the well is immediately inserted into the borehole, pushing, as needed, to achieve maximum penetration into the saturated materials.

3.5 Temporary Monitoring Well Types

Five types of monitoring wells which have been shown to be acceptable are presented in the order of increasing difficulty to install and increasing cost:

3.5.1 No Filter Pack

This is the most common temporary well and is very effective in many situations. After the borehole is completed, the casing and screen are simply inserted. This is the least expensive and fastest well to install. This type of well is extremely sensitive to turbidity fluctuations because there is no filter pack. Care should be taken to not disturb the casing during purging and sampling.

3.5.2 Inner Filter Pack

This type differs from the "No Filter Pack" well in that a filter pack is placed inside the screen to a level approximately 6 inches above the well screen. This ensures that all water within the casing has passed through the filter pack. For this type well to function properly, the static water level must be at least 6-12 inches above the filter pack. The screen slots may plug in some clayey environments with this construction method and others that use sand only inside the well screen.

3.5.3 Traditional Filter Pack

For this type of well, the screen and casing are inserted into the borehole, and the sand is poured into the annular space surrounding the screen and casing. Occasionally, it may be difficult to effectively place a filter pack around shallow open boreholes, due to collapse. This method requires more sand than the "inner filter pack" well, increasing material costs. As the filter pack is placed, it mixes with the muddy water in the borehole, which may increase the amount of time needed to purge the well to an acceptable level of turbidity.

3.5.4 Double Filter Pack

The borehole is advanced to the desired depth. As with the "inner filter pack" the well screen is filled with filter pack material and the well screen and casing inserted until the top of the filter pack is at least 6 inches below the water table. Filter pack material is poured into the annular space around the well screen. This type temporary well construction can be effective in aquifers where fine silts or clays predominate. This construction technique takes longer to implement and uses more filter pack material than others previously discussed.

3.5.5 Well-in-a-Well

The borehole is advanced to the desired depth. At this point, a 1-inch well screen and sufficient riser is inserted into a 2-inch well screen with sufficient riser, and centered. Filter pack material is then placed into the annular space surrounding the 1-inch well screen, to approximately 6 inches above the screen. The well is then inserted into the borehole.

This system requires twice as much well screen and riser, with attendant increases in assembly and installation time. The increased amount of well construction materials results in a corresponding increase in decontamination time and costs. The use of pre-packed well screens in this application will require rinse blanks of each batch of screens. Pre-pack Screen assemblies cannot be decontaminated for reuse.

3.6 Decommissioning

Temporary well boreholes must be decommissioned after sampling and removal of the screen and riser. Backfilling the holes with cuttings may be acceptable practice for shallow holes in uniform materials with expected low contamination levels. Use of cuttings would not be an acceptable practice if waste materials were encountered or a confining layer was breached. Likewise, where the borehole is adjacent to, or downgradient of contaminated areas, the loose backfilled material could create a highly permeable conduit for contaminant migration. If the borehole will not be backfilled with the soil cuttings for this or other reasons, then SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202, should be referenced regarding disposal of the cuttings as IDW.

4 Temporary Monitoring Well Installation Using the Geoprobe® Screen Point 15/16 Groundwater Sampler

4.1 Introduction

The Geoprobe® Screen Point 15/16 Groundwater Sampler is a discrete interval ground water sampling device that can be pushed to pre-selected sampling depths in saturated, unconsolidated materials. Once the target depth has been reached, the screen is opened and groundwater can be sampled as a temporary monitoring well, which yields a representative, uncompromised sample from that depth. Using knock-out plugs, this method also allows for grouting of the push hole during sample tool retrieval.

The Screen Point® 15 sampler consist of four parts (drive point, screen, sampler sheath and drive head), with an assembled length of 52 inches (1321 mm) and a maximum OD of 1.5 inches (38 mm). When opened, it has an exposed screen length of 41 inches (1041 mm). It is typically pushed using 1.25-inch probe rod. The Screen Point® 16 consists of the same parts and works in the same fashion, the only differences being larger diameter and its use with 1.5” rods.

4.1.1 Assembly of Screen Point® 15/16 Groundwater Sampler

1. Install O-ring on expendable point and firmly seat in the angled end of the sampler sheath.
2. Place a grout plug in the lower end of the screen section. Grout plug material should be chosen with consideration for site specific Data Quality Objectives (DQOs).
3. When using stainless steel screen, place another O-ring* in the groove on the upper end of the screen and slide it into the sampler sheath.
4. Place an O-ring* on the bottom of the drive head and thread into the top of the sampler sheath.
5. The Screen Point® 15/16 Groundwater Sampler is now assembled and ready to push for sample collection.

* It should be noted that O-ring use in steps 3 and 4 are optional.

4.1.2 Installation of Screen Point® 15/16 Groundwater Sampler

1. Attach drive cap to top of sampler and slowly drive it into the ground. Raise the hammer assembly, remove the drive cap and place an O-ring* in the top groove of the drive head. Add a probe rod and continue to push the rod string.

2. Continue to add probe rods until the desired sampling depth is reached.
3. When the desired sampling depth is reached, re-position the probe derrick and position either the casing puller assembly or the rod grip puller over the top of the top probe rod.
4. Thread a screen push adapter on an extension rod and attach sufficient additional extension rods to reach the top of the Screen Point® 15/16 sampler. Add an extension handle to the top of the string of extension rods and run this into the probe rod, resting the screen push adapter on top of the sampler.
5. To expose the screened portion of the sampler, exert downward pressure on the sampler, using the extension rod and push adapter, while pulling the probe rod upward. To expose the entire open portion of the screen, pull the probe rod upward approximately 41 inches.
6. At this point, the Screen Point® 15/16 Groundwater Sampler has been installed as a temporary well and may be sampled using appropriate ground water sampling methodology. If water levels are less than approximately 25 feet, EIB personnel typically use a peristaltic pump, utilizing low-flow methods, to collect ground water samples from these installations. If water levels are greater than 25 feet, a manual bladder pump, a micro bailer, or other method may have to be utilized to collect the sample (SESD Operating Procedure for Groundwater Sampling, SESDPROC-301-R0) provides detailed descriptions of these techniques and methods).

4.1.3 Special Considerations for Screen Point® 15/16 Installations

Decommissioning (Abandonment)

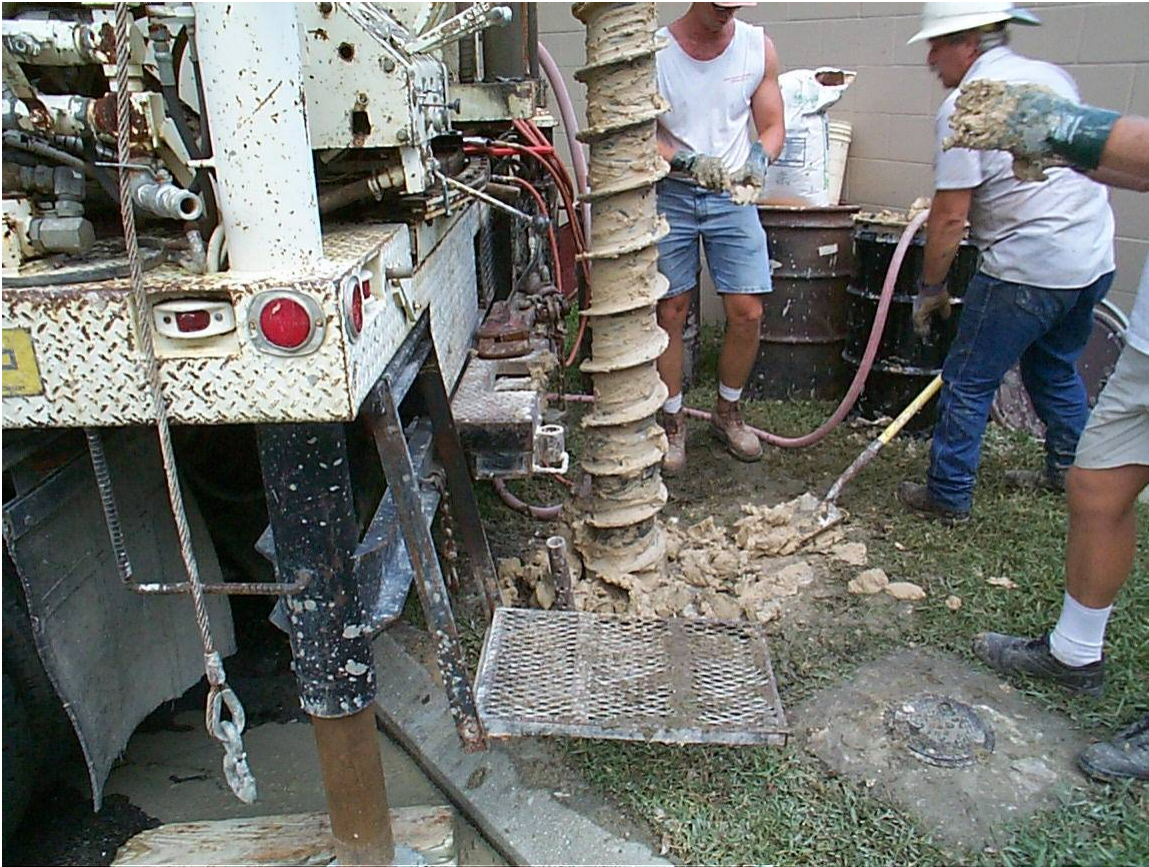
In many applications, it may be appropriate to grout the abandoned probe hole where a Screen Point® 15/16 sampler was installed. This probe hole decommissioning can be accomplished through two methods which are determined by location and contamination risk. In certain non-critical areas, boreholes may be decommissioned by filling the saturated zone with bentonite pellets and grouting the vadose zone with neat cement poured from the surface or Bentonite pellets properly hydrated in place. Probe holes in areas where poor borehole sealing could present a risk of contaminant migration should be decommissioned by pressure grouting through the probe rod during sampler retrieval. To accomplish this, the grout plug is knocked out of the bottom of the screen using a grout plug push adapter and a grout nozzle is fed through the probe rod, extending just below the bottom of the screen. As the probe rod and sampler

are pulled, grout is injected in the open hole below the screen at a rate that just fills the open hole created by the pull. Alternatively, the screen can generally be pulled and the hole re-probed with a tool string to be used for through-the-rod grouting.

Screen Material Selection

Screen selection is also a consideration in sampling with the Screen Point® 15/16 sampler. The screens are available in two materials, stainless steel and PVC. Because of stainless steel's durability, ability to be cleaned and re-used, and overall inertness and compatibility with most contaminants, it is the material typically used during EIB investigations.

Monitoring Well Design and Construction Guidance Manual



**Florida Department of Environmental Protection
Bureau of Water Facilities Regulation
2008**

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Monitoring Well Design and Construction Guidance Manual

1.0 Introduction

1.1 Purpose

This guidance manual provides the protocols and recommended procedures for the proper design and construction of monitoring wells such that quality ground water samples representative of actual conditions can be collected. A properly designed, installed and developed ground water monitoring well provides ground water samples that exhibit the physical and chemical properties of that portion of the aquifer screened by the well.

1.2 Planning

Each monitoring well within a network requires a design that considers project objective, site geology, hydrology, site history, waste site operational history (if applicable), ground water quality, and anticipated contaminants of concern. Prior to monitoring well design and installation, development of a conceptual hydrogeologic framework that identifies potential flow path and the target monitoring zone(s) is necessary. The following site characterization data elements should be utilized to form a conceptual model of the site:

- 1) Site geology and hydrology;
- 2) Potential contaminant sources, properties, and distribution;
- 3) Release mechanism and rates;
- 4) Fate and transport processes;
- 5) Current and potential receptors;
- 6) Potential remedial options; and
- 7) Other available site characterization data.

1.3 Design Considerations

The design and installation of monitoring wells should consider 1) permanence, 2) installation methodology, and 3) well construction requirements. Many factors

must be considered when evaluating each of these three components, utilizing only the most reliable data and information. Monitoring requirements and project timeline and objectives will, in part, determine the need for temporary and/or permanent wells. Site conditions, geological and hydrological settings will influence the types of required drilling method, installation procedures and well construction characteristics. When designing monitoring wells, the U.S. Environmental Protection Agency (USEPA) document, *Environmental Investigations Standard Operating Procedure and Quality Assurance Manual*, Section 6, (2001), recommends the following considerations:

- 1) Short- and long-term objectives,
- 2) Purpose(s) of the well(s),
- 3) Probable duration of the monitoring program,
- 4) Contaminants likely to be monitored,
- 5) Types of well construction materials to be used,
- 6) Surface and subsurface geologic conditions,
- 7) Properties of the aquifer(s) to be monitored,
- 8) Well screen placement,
- 9) General site conditions, and
- 10) Potential site health and safety hazards.

A ground water monitoring and well installation plan can be developed from these data and information. The plan should address all phases of the installation and monitoring program, including site access, health and safety, drilling techniques, decontamination protocol, well installation, well development, well abandonment, sample collection, waste management, and site surveys.

2.0 Drilling Operations

A driller, water well contractor or water well consultant should ensure that all materials and equipment for drilling and installing any given well are available and onsite prior to commencing drilling activities. For long schedules, it should be ensured that the above-mentioned materials needed for at least 2 days of operation are onsite prior to drilling. Site-specific factors that preclude the availability of needed secure storage areas should be identified and resolved in a ground water monitoring plan.

2.1 Logistics

2.1.1 Permitting, Licenses and Registration

The driller, water well contractor, and/or water well consultant is responsible for identifying all applicable permits, licenses, professional registration, rights-of-entry, and applicable State and local regulatory procedures for drilling, well installation, and well abandonment (to include any requirements for the submission of well logs, samples, etc). Acquisition and submittal of these items to State or local authorities should be coordinated between the driller, contractor, and/or consultant, with the responsibilities of each specified in a ground water monitoring plan and subcontract agreements.

2.1.2 Access and Security

The need for any rights-of-entry should be specified in a ground water monitoring plan along with the organization(s) responsible for their acquisition. The driller or water well contractor shall comply with all security policies at a project site. The driller is responsible for securing his own equipment, and should prepare for any special situations identified in a ground water monitoring plan.

2.1.3 Site Safety

Safety precautions should be implemented for any drilling operation and in particular for activities related to the investigation and monitoring of hazardous and potentially hazardous materials sites. When appropriate, a site health and safety plan should be developed and followed during all drilling activities. The driller or designated safety person should be responsible for the safety of the drilling team during all drilling activities. All personnel involved with drilling activities should be qualified in proper drilling and safety procedures. Guidance related to drilling activities is available in Occupational Safety and Health Administration (OSHA) documents, particularly 29 CFR 1910.120 and 29, CFR 1926.

2.1.4 Site Preparation, Well Installation and Restoration

2.1.4.1 Site Reconnaissance

Site visits should be made prior to drilling activities to evaluate physical conditions and equipment and logistical requirements. Particular interests include site access, proximal utilities, barriers and hindrances to movement of equipment, potential hazards, and geographical locations of support facilities (i.e., drilling supplies, drilling water, sample shipment facilities, and emergency facilities). Site modifications and adaptations to drilling plans should be made accordingly and as is practical.

2.1.4.2 Utility Clearances

Prior to drilling or excavation activities, the driller, water well contractor, water well consultant, or appropriate person must coordinate with the appropriate utility locator services to identify and locate all underground utilities and other subsurface features that could obstruct or be damaged by such activities. Digging permits may be required and a locator service given notice to allow adequate time to locate and mark utilities prior to any onsite operations. Overhead utilities and structures should also be considered with respect to clearance space required by the drilling equipment.

As appropriate, boreholes should be advanced to a minimum of two to three feet below land surface (or more as required or needed) with a hand auger or post hole digger. The diameter of the manually advanced borehole should be at least as wide as the largest auger or other equipment to be placed within the borehole.

2.1.4.3 Equipment

The driller should arrive at the site with all the necessary personnel, supplies, and equipment to complete the specified tasks described in Chapter 3.0, Well Design and Material Specifications. All equipment must have been properly inspected, serviced, maintained, and tested prior to relocation to the site to ensure that it is in proper working condition, and to minimize the potential for delays. Sufficient replacement or repair equipment and supplies shall be kept on hand or readily available in the event of mechanical failures or malfunctions.

2.1.4.4 Borehole Requirements

The borehole shall be drilled and constructed so as to 1) allow for the proper construction of the monitoring well, 2) properly monitor the parameters of interest and 3) meet the objectives of the ground water monitoring program. Generally, monitored parameters occur in ground water as aqueous (those dissolved in the ground water) non-aqueous phase liquids (NAPLS) and particulate matter (colloid-sized particles that may be inert or biologically active). The borehole must

allow for the proper placement of the well screen so as to allow for monitoring of parameters based upon chemical and physical characteristics.

The borehole shall be drilled as close to vertical as possible. Slanted boreholes are not acceptable unless specified in the design. The depth and volume of the borehole, including any overdrilling if applicable, should be calculated such that appropriate quantities of materials are procured and installed during well construction. Table A-1 Appendix A, provides several typical volume calculations for use during boring and well installation. If the well boring is drilled too deeply, it should be backfilled to the desired installation depth with pure bentonite pellets (for fine-grained aquifers) or filter sand (for coarse-grained aquifers). If bentonite pellets are used, a minimum of 1 foot of filter sand should be placed above the bentonite prior to screen installation. This will protect the bottom of the well screen from bentonite intrusion.

The selected hollow-stem augers, temporary casing, or permanent surface casing should have an inside diameter (I.D.) sufficient to allow the installation of the prescribed diameter screen and well riser plus annular space for a tremie pipe through which to place the filter pack and annular sealants. It is advantageous that the I.D. of the drill casing or hollow-stem auger be at least 4 inches greater than the outside diameter (O.D.) of the centered well riser and screen. This increased borehole size will allow placement of a wider filter pack, annular seal, and annular grout. This will also allow the use of a 1.5-inch O.D. tremie pipe for emplacing well construction materials. However, larger diameter augers will also result in additional drilling time, increased cost of well installation, and increased production of investigations-derived waste (IDW), including drill cuttings and fluids removed from the borehole and monitoring well. Depending upon the project objectives and regulatory requirements, the advantages must be weighed against the disadvantages such that the project objectives are met with the minimum cost incurred.

When telescoping outer casings (one casing within another), the specified annulus may not be practical or functional. In this case, a lesser spacing allowing for proper grout placement may be acceptable, depending on site specifics and project objectives.

A separate pilot boring should be advanced if significant drilling beyond the desired screen interval(s) is required (as for defining stratigraphy or locating a zone of interest). Upon completion of the exploration, the pilot boring should be properly abandoned and a new boring advanced for the placement of a monitoring well. ASTM Standard D5299 provides guidance for abandonment of boreholes and ground water wells.

2.1.4.5 Well Installation Schedule

Ideally, well installation should begin immediately after boring completion. Once installation has begun, no breaks in the installation process should be made until the well has been grouted and temporary drill casing removed. This includes interruptions due to the end of the driller's work shift, weekend, or holiday. This does not include the time required for proper hydration of the bentonite seal.

Unscheduled delays may occur, including personal injury, equipment breakdowns, or sudden inclement weather. Scheduled delays may also occur such as the time required for downhole geophysical surveys. In such cases, the type of delay, beginning and ending times of the delay, and the delay interval should be noted on a well construction diagram (Section 3.2). In instances where a cased hole into bedrock is to be partially developed prior to well insertion, well installation should begin within 12 hours after this initial development.

Temporary casing and hollow-stem augers may be withdrawn from the boring prior to well installation if the potential for cross-contamination is not likely and if the borehole wall will not slough during the time required for well installation. This procedure is usually successful in firm clays and in bedrock that is not intensely fractured or highly weathered.

Any materials, especially soils, blocking the bottom of the drill casing or hollow-stem auger should be dislodged and removed from the casing prior to well insertion. The use of a bottom plug, dove-tail bit, or internal drill rods during drilling may be beneficial for reducing and/or eliminating soil blocking and heaving sands. If used, the composition of any disposable bottom plug (such as stainless steel or wooden plug) must be appropriate considering the analytical parameters of interest.

2.1.4.6 Restoration

All work areas around the wells and/or borings should be restored to a condition equivalent to that prior to installation. This includes the disposal of borehole cuttings and rut repair. IDW, i.e., borehole cuttings, discarded samples, drilling fluids, equipment cleaning residue, water removed from a well during installation, development, or aquifer testing, and personal protection equipment (PPE) must be disposed of in a manner consistent with a waste management plan and all applicable Federal, State, and local regulations and ordinances. Restoration, disposal procedures, and responsibilities should be discussed in detail in a ground water monitoring plan.

2.2 Oversight

A site geologist, engineer or geotechnical engineer, suitably qualified to conduct hydrogeologic investigations should be present at each operating drill rig. The site geologist, engineer or geotechnical engineer must be familiar with all State,

Federal, and local laws, regulations, and requirements pertaining to the geologist's, engineer's or geotechnical engineer's duties and responsibilities. The geologist, engineer or geotechnical engineer shall be responsible for logging, acquisition, and shipment of samples, boring logs and well construction diagrams, and recording the well installation and abandonment procedures. Ideally, each site geologist, engineer or geotechnical engineer should be responsible for only one operating rig. The geologist, engineer or geotechnical engineer should have onsite sufficient tools, forms, and professional equipment in operable condition to efficiently perform the duties as outlined in this manual or other relevant project documents.

2.3 Drilling Methodology

2.3.1 Objectives

The objectives of selecting a drilling method for monitoring well installation are to use that technique which:

- 1) Provides representative data and samples consistent with project objectives;
- 2) Eliminates or minimizes the potential for subsurface contamination and/or cross-contamination; and
- 3) Minimizes drilling costs.

2.3.2 Methods

There are several drilling methods that can be used for site characterization and to install acceptable monitoring wells. Additional information and details on the various drilling methods can be found in Driscoll (1986), U.S. Army Corp of Engineers (USCOE) (1998), National Ground Water Association (1998) and Section 6.3 of the EPA manual, as well as numerous other sources. In addition, ASTM International maintains standards, ASTM D6286 and ASTM D5092, for selection of drilling methods for site characterization and the design and installation of ground water monitoring wells, respectively, as well as method-specific standards for many drilling techniques. The following drilling methods are most typically used in the installation of monitoring wells:

- 1) Hollow-stem augers;
- 2) Solid-stem augers;
- 3) Water/mud rotary;
- 4) Air/pneumatic rotary;

- 5) Sonic;
- 6) Direct Push; and
- 7) Casing or cable

The drilling method must be specified and described in a ground water monitoring plan. The plan should also contain detailed rationale for the selection of the specified method including, but not limited to, how the anticipated drilling conditions are accounted for by the selected method and how cross-contamination would be minimized.

2.3.3 Concerns Related to Drilling Methodology

Dry methods: Dry methods advance a boring using purely mechanical means without the aid of an aqueous or pneumatic drilling “fluid” for cuttings removal, bit cooling, or borehole stabilization. In this way, the chemical interaction with the subsurface is minimized, though not eliminated. Local aeration and heating of the borehole wall, for example, may occur simply by the removal of compacted or confining soil or rock (USCOE, 1998).

Aqueous methods: Aqueous drilling methods use fluid, usually either approved water or water and bentonite slurry, for cuttings removal, bit cooling, and borehole stabilization (USCOE, 1998). For environmental work, the use of these materials increases the potential to add a new contaminant or suite of contaminants to the subsurface environment adjacent to the boring. Even the removal of one or more volumes of water equal to the volume lost during drilling will not remove all of the lost fluid. The level of effort to be expended upon well development is directly related to the amount of fluid lost during drilling: a minimum of five times the volume lost should be removed during development. Therefore, the less fluid loss, the less the development effort, time, and cost.

Air/Pneumatic Rotary methods: Air/pneumatic rotary methods involve the use of compressed air to evacuate cuttings. Potential problems with this method include the introduction of pollutants such as hydrocarbons into the subsurface from the compressed air source, volatilization/stripping of contaminants from the subsurface, and mobilization of dust and/or vapor phase components to create a potential breathing hazard. However, this method may be advantageous in materials where circulation of other fluids cannot be maintained. Appropriate dust collection/suppression equipment must be provided. Wells installed using this method must be developed until the water becomes clear and free of sediment.

Sonic methods: The fundamental difference between the sonic drilling method and other rotary-type methods is that it employs a combination of rotation and high-frequency vibration for drill bit penetration. This method is suitable for use

in either consolidated or unconsolidated materials. The advantages of this technology are rapid drilling rates and relatively minimal amounts of waste generated. Disadvantages include potential disturbance to samples collected for geotechnical analyses and volatilization of chemical samples.

Direct push Technologies: Direct push technologies (DPT) utilize equipment that push or drive steel rods into the ground. They allow cost-effective, rapid sampling and data collection from unconsolidated soils and sediments. A tremendous variety of equipment is available, particularly in the type of attachments used at the end of rods to collect samples and data. These attachments may collect soil, soil gas, or ground water samples; they may conduct *in situ* analysis of contaminants; or they may collect geophysical data that are continuously logged as the DPT rods are advanced. Continuous logs of subsurface conditions are particularly valuable because they help to develop a three-dimensional conceptual site model.

Tables 1 and 2 provide a brief description and comparison of some common drilling methods.

Table 1: Drilling Methods for Monitoring Wells

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Auger, Hollow-Stem and Solid-Stem ASTM D5784, ASTM D1452	Successive 5-foot (1.5m) flights of spiral-shaped drill stem are rotated into the ground to create a borehole. Cuttings are brought to the surface by the rotation of the auger flights	150 (45)	<ul style="list-style-type: none"> • May be inexpensive • Fairly simple, quick setup time and moderately fast operation • Rigs are highly mobile and can reach most drilling sites • No drilling fluid or lubricants used, eliminating contamination from additives • Can be used to avoid hole caving • Hollow-stem allows formation water to be sampled during drilling via screened auger or advancing a well point ahead of the augers • Small-diameter wells can be built inside hollow-stem flights • Hollow-stem allows the collection of split-spoon samples, continuous sampling possible • Natural gamma-ray logging can be done inside hollow-stem flights 	<ul style="list-style-type: none"> • Limited to unconsolidated or semiconsolidated (weathered rock) materials Compact, gravelly materials may be hard to penetrate • Possible problems controlling heaving sands • Rips and smears borehole wall, creating problems with connecting to the aquifer during well development • Well points yields low rates of water • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • May not be able to run a complete suite of geophysical logs

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Water/Mud Rotary (Hydraulic Rotary) ASTM D5783	<p>Rotating bit breaks formation; cuttings are brought to the surface by a circulation fluid (mud). Mud (which should be contaminant-free water and bentonite without additives) is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and borehole wall.</p> <p>Cuttings are removed by settling in a mud pit at the ground surface and the mud is circulated back down the drill stem.</p>	5,000+ (1,500+)	<ul style="list-style-type: none"> • Drilling is fairly rapid in all types of geologic materials, unconsolidated and consolidated • Borehole may stay open from formation of a mud wall on the sides of borehole by the circulating mud • Geologic cores can be collected • A complete suite of geophysical logs can be obtained in the open borehole • Many options for well construction. Can use casing-advancement drilling method, or casing may not be required • Smaller rigs can reach most drilling sites • Borehole can be gravel packed and easily grouted 	<ul style="list-style-type: none"> • May be expensive, requires experienced driller and a fair amount of peripheral equipment; overburden casing required • Drilling fluids mix with formation water, may contaminate and can be difficult to remove. • Completed well may be difficult to develop, especially small diameter wells, due to mud cake invading the formation and is difficult to remove • Geological logging by visual inspection is only fair, can miss strata and composition • Location of water-bearing zones during drilling may be difficult to detect • Drilling fluid circulation is often lost and difficult to maintain in fractured rock, and gravel or cavernous zones • Difficult drilling in boulder and cobble zones • Circulation of drilling mud through a contaminated zone can create a hazard a ground surface and cross-contaminate clean zones • Organic drilling fluids can interfere with bacterial and/or organic-related analyses and are not allowed; bentonitic fluids with metal analyses, but may be necessary.

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Reverse Rotary ASTM D5781	Similar to hydraulic rotary, except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside; the reverse of the usual rotary method. Water is used as the drilling fluid and the borehole is kept open by the hydrostatic pressure of the water standing in the borehole.	5,000+ (1,500+)	<ul style="list-style-type: none"> • Drilling is readily accomplished in most geologic materials, unconsolidated and consolidated • Drilling is relatively fast and can be used for drilling large diameter boreholes • Large borehole diameter facilitates ease of well installation • Geophysical logs can be run prior to installation of well • Creates a "clean" borehole, not contaminated by introduced fluids • Split-spoon sampling possible 	<ul style="list-style-type: none"> • May be expensive, requires experienced driller and a fair amount of peripheral equipment; overburden casing required • May be difficult to drill in boulder, cobble or cavernous zones • The addition of drilling lubricants may be required: lubricants interfere with borehole wall composition and water chemistry • Cross-contamination from circulating water is likely • A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered • Geologic samples brought to surface are generally of poor quality; fine-grained materials are washed out
Air Rotary ASTM D5782	Similar to hydraulic rotary. Air is used as the primary drilling "fluid" as opposed to mud or water	5,000+ (1,500+)	<ul style="list-style-type: none"> • Can be used in all geologic formations; most successfully in highly fractured environments • Useful at almost any depth • Drilling rates are usually fast • Can use the casing-advancement method • Drilling mud or water is not required • Borehole is accessible to geophysical logging prior to well installation • Geologic sampling is excellent in hard, dry formations • First water zone easily detected • Well development is relatively easy 	<ul style="list-style-type: none"> • Relatively expensive, requires experienced drill crew • Overburden casing usually required • Air mixes with borehole water and blown from the hole, creating potential for cross-contamination, surface contamination, health and environmental risks • Water flow between zones with different hydrostatic pressures will occur between the time that drilling is completed and the hole is properly cased and grouted • Compressor discharge to air may contain hydrocarbons • Organic foam additives to aid cuttings removals may cause cross contamination

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Air-Per percussion Rotary or Down-the-Hole Hammer (DTH) ASTM D5781	Air rotary with a reciprocating hammer connecting to the bit used to fracture rock.	600 (2,00)	<ul style="list-style-type: none"> • Very fast drill rates • Useful in all geologic formations • Only small amounts of water need for dust and bit temperature control • Cross-contamination potential can be reduced by driving casing • Can use casing-advancement method • Well development relatively easy 	<ul style="list-style-type: none"> • Relatively expensive • As with most hydraulic rotary methods, the rig is large, heavy and has limited accessibility • Overburden casing usually required • Vertical mixing of water and air creates cross contamination potential • Hazard posed to surface environment if toxic compounds are encountered • DTH hammer drilling can cause hydraulic fracturing of borehole wall • The DTH hammer required lubrication during drilling • Organic foam additives for cuttings removal may contaminate samples
Sonic (Vibratory) ASTM D6914	Uses high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rocks.	500 (150)	<ul style="list-style-type: none"> • Can obtain large diameter, continuous and relatively undisturbed cores of almost any soil material without the use of drilling fluids • Can drill through boulders, wood, concrete and other construction debris • Can drill and sample most softer rock with a high percentage of core recovery • Drill rates are faster than most other methods • Large reduction of investigation-derived wastes 	<ul style="list-style-type: none"> • Relatively expensive • Equipment is not readily available • Rock drilling requires the addition of water or air or both to remove drill cuttings • Extraction of casing can smear borehole wall with clays and silts • Extraction of casing can damage well screen

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Direct Push ASTM D6724, ASTM D6725	Advances a sampling device into the subsurface by applying static pressure, impacts, or vibrations or any combination thereof to the above ground portion of the sampler extensions until the samples has been advanced its full length into the soil strata.	100 (30)	<ul style="list-style-type: none"> • Avoids use of drilling fluids and lubricants during drilling • Equipment is highly mobile • Disturbance of geochemical conditions during installation is minimized • Drilling and well screen installation is fast, considerably less labor intensive • Does not produce drill cuttings, reduction of investigation-derived wastes 	<ul style="list-style-type: none"> • Limited to fairly soft materials such as clay, silt, sand and gravel • Compact, gravelly materials may be hard to penetrate • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • The small diameter drive pipe generally precluded conventional borehole geophysical logging • The drive points yield relatively low rates of water
Cable-Tool (Percussion) ASTM D5875, ASTM D5872	<p>Borehole is created by dropping a heavy "string" of drill tools into well bore, crushing materials at the bottom.</p> <p>Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made</p>	1,000+ (300+)	<ul style="list-style-type: none"> • Can be used in consolidated and unconsolidated formations • Can drill boulder, cobble, fractured and cavernous zones • Fairly accurate logs can be made from cuttings if collected often enough • Core samples easily obtained • Driving casing ahead of hole minimizes cross-contamination via vertical leakage of formation waters, maintains borehole stability • Excellent method for drilling in soils and rock where loss of circulation fluids is problematic • Recovery of borehole fluid samples excellent • Excellent method for detecting thin water-bearing zones • Excellent for well development 	<ul style="list-style-type: none"> • The potential for cross-contamination of samples is very high • Steel casing must be used • Heavy steel drive pipe and drilling "tools" can limit accessibility • Heavier wall, larger diameter casing than that used for other drilling methods normally used • Cannot run a complete suite of geophysical logs due to the presence of the drive pipe • Temporary casing can cause problems with placement of effective filter pack and grout seal • Usually a screen must be set before a water sample can be collected • Heaving of unconsolidated sediment into bottom of casing can be problematic

Adapted from U.S. Army Corps of Engineers, November 1998

Table 2: Comparison of Drilling Methods

Drilling Method	Shallow and Intermediate Boreholes	Deep Boreholes	Water Sampling	Soil Sampling	Well Installation	Boulders and other obstructions	Control of Hydrostatic Pressure	Downhole Geophysics
Hollow-Stem Auger	E	P	E	E	E	P	F	L
Solid-Stem Auger	E	P	NA	NA	F	P	P	NA
Water/Mud Rotary	E	E	P	P	F	G	E	E
Reverse Rotary	E	E	P	P	F	P	E	E
Air Rotary	E	E	P	P	F	G	P	P
Sonic	E	G	E	E	E	E	E	E
Direct Push	E	F	E	E	G	L	E	L
Cable-Tool (Cased Boring)	E	F	E	E	E	G	E	L
Notes: E = Excellent G = Good F = Fair P = Poor L = Limited application NA = Not applicable								

2.3.4 Special Concerns

2.3.4.1 Recirculation Tanks and Sumps

Portable recirculation tanks should be used for mud or water rotary operations and similar functions. The use of dug sumps or pits (lined or unlined) are expressly prohibited to minimize cross-contamination and to optimize both personal safety and work area restoration (USCOE, 1998).

2.3.4.2 Surface Runoff

Surface runoff, e.g., precipitation, wasted or spilled drilling fluid, and miscellaneous spills and leaks, should not enter any boring or well either during or after construction. To help avoid such entry, the use of temporary casing, recirculation tanks, berms around the borehole, or temporary surficial bentonite packs is recommended (USCOE, 1998).

2.3.4.2 Drilling Fluids

To the extent practical, the use of water during drilling, and any other water used during well installation and completion, should be held to a minimum. When use of water is deemed necessary, the source of any water used must be specified in the ground water monitoring plan and approved by the appropriate authority. The driller should have the responsibility to procure, transport, and store the approved water required for project needs in a manner that avoids the chemical contamination or degradation of the approved water once obtained.

If there is a suitable source of approved water onsite, the source should be used. If no onsite approved water is available, a potential source must be located and water quality evaluated and approved prior to the arrival of any drilling equipment onsite. It is important that the approved water be free of site-related analytes. It is advantageous that the drilling water be pretested (sampled and analyzed) for the contaminants of interest. Knowledge of the water chemistry is the most important factor for water quality approval. Surface water bodies must not be used as a water source.

Pure bentonite (no additives) is the only drilling fluid additive that is typically allowed under normal circumstances. This includes any form of bentonite (powders, granules, or pellets) intended for drilling mud or sealants. The use of any bentonite shall be adequately discussed in the ground water monitoring plan, including documentation of the manufacturer's recommendations and product constituents. Bentonite shall only be used if absolutely necessary to ensure that the borehole will not collapse or to improve cuttings removal (USCOE, 1998).

2.4 Decontamination

ASTM Standard D5088 provides guidance for decontamination of field equipment. All drilling equipment that is utilized in drilling or sampling activities must be cleaned or washed with high pressure hot water and decontaminated prior to arriving at the site or at the designated decontamination area before entering the site. This includes drilling rigs, support vehicles, water tanks (inside and out), augers, drill casings, rods, samples, tools, and recirculation tanks. The initial cleaning must be adequate to remove all rust, soil, or other material that may have been transported from another site. Any downhole auguring, drilling, and sampling equipment with paint, rust, or scale that cannot be removed by pressure washing or steam cleaning must be sandblasted prior to arrival on site. All equipment shall be inspected prior to site entry to confirm that all seals and gaskets are intact; no fluids are leaking; and all oil, grease, and other fluids have been removed. No oils or grease may be used to lubricate drill rods or any other equipment being used above or in the borehole without specific approval from the site geologist, engineer or geotechnical engineer. Such approval must be recorded on the well construction form.

All drilling, sampling, and associated downhole equipment that contacts the sample medium shall be cleaned and decontaminated by the following procedures:

- 1) Clean with approved water, laboratory-grade, phosphate-free detergent, and brush to remove particulate matter and surface films. Steam cleaning or high pressure hot water washing may be used in lieu of, or in addition to, brushing. Equipment that is hollow or perforated to transmit water or drilling fluids must be cleaned inside and outside. The steam cleaner or high pressure hot water washer must be capable of generating a pressure of at least 2500 PSI and producing hot water or steam of at least 200 ° F;
- 2) Rinse thoroughly with approved water. Approved water may be applied with a pump sprayer. All other decontamination liquids must be applied with non-interfering containers made of glass, Teflon®, or stainless steel. Rinsing operations will be inspected by the site geologist, engineer or geotechnical engineer prior to initiation of work;
- 3) Rinse thoroughly with approved decontamination water;
- 4) Unless otherwise specified, rinse twice with pesticide-grade isopropanol;
- 5) Rinse thoroughly with approved decontamination water and allow to air dry;

- 6) Any equipment that will be stored or transported must be wrapped in aluminum foil (or clean plastic if equipment has been air dried);
- 7) Any printing or writing on well casing, tremie pipe, etc., arriving on site must be removed with sandpaper or emery cloth prior to initial cleaning; and
- 8) Well casing, tremie pipe, or other materials constructed of plastic or polyvinyl chloride (PVC) must be solvent rinsed during the cleaning and decontamination process.

After the onsite cleaning, only the equipment used or soiled at a particular boring or well should need to be cleaned between each boring or well at a given project. Paint applied by the equipment manufacturer may not have to be removed from drilling equipment, depending upon the paint composition and its contact with the environment and contaminants of concern. All equipment must be decontaminated before it is removed from the project site. If drilling requires telescoping casing because of differing levels of contamination in subsurface strata, then decontamination may be necessary before setting each string of smaller casing and before drilling beyond any casing. To the extent practical, all cleaning should be performed in a single remote area that is surficially cross gradient or downgradient and downwind from the clean equipment drying area and from any sited to be sampled. Waste solids and water from the cleaning and decontamination process shall be properly collected and disposed, as discussed in Chapter 5.0, Management of Investigation-Derived Waste. This may require that cleaning be conducted on a concrete pad or other surface from which the waste materials may be collected.

2.5 Sampling and Coring

A sufficient number of soil or rock samples should be collected and evaluated by the site and/or project geologist. The purpose of this collection is to provide a sound basis for the design of the ground water monitoring system. A “sufficient number of samples” is dependent on project-specific objectives, and should be described in the ground water monitoring plan. Soil samples should be collected according to ASTM Standards D1452, D1586, D3550, or D1587, whichever is appropriate given the anticipated characteristics of the soil samples. Rock samples should be collected using ASTM Standard D2113. Additional guidance on both soil and rock sampling can be found in ASTM Standard D6169.

2.5.1 Soil Sampling

The primary purpose of collecting soil samples, other than for chemical analysis, is the characterization of the subsurface lithology and stratigraphy. Typically, intact soil samples for physical descriptions are collected every 5 feet (1.5

meters) or at each change of material, whichever occurs first. Alternate sampling plans, with supporting information, should be detailed in the ground water monitoring plan. Additionally, a sufficient number of representative samples of the intervals significant to well design and hydrogeologic characterization should be collected for physical analyses; these results should then be used to support well design. These samples should be representative of the geographic and geologic range of materials within the project area and should specifically include the screened interval of a representative number of wells. Samples should be obtained with driven (e.g., split spoon), pushed (e.g., thin-wall Shelby tube), or rotary (e.g., Dennison) type samplers. Borehole cuttings do not usually provide the desired information and, therefore, are not usually satisfactory. Sampling procedures should be detailed in the ground water monitoring plan. Lithological logging of samples should be recorded according to the procedures listed in Section 2.9. Disposition of samples should be in accordance with Chapter 5.0

2.5.2 Rock Coring

Bedrock should be cored unless the ground water monitoring plan specifies otherwise. Coring, using a diamond- or carbide-studded bit, produces a generally intact sample of the bedrock lithology, structure, and physical condition. The use of a gear-bit, tri-cone, etc., to penetrate bedrock should only be considered for the confirmation of the “top of rock” (where penetration is limited to a few feet), enlargement of a previously cored hole, or drilling of highly fractured intervals. Lithologic logging of the core should be conducted in accordance with Section 2.9, Documentation.

Rock cores should be retrieved and stored in such a way as to reflect natural conditions and relative stratigraphic position. Gaps in the core and intervals of lost core should be noted in the core sequence. Cores should be stored in covered core boxes to preserve their relative position by depth. Boxes should be marked on the cover (both inside and outside) and on the ends to provide project name, boring number, cored interval, and box number in cases of multiple boxes. Each box shall clearly denote the top and bottom of the rock core present in that box. Any core box known or suspected to contain contaminated core should be appropriately marked on the log and on the box cover, (inside and out), and on both ends. Storage of rock cores must be in accordance with the approved ground water monitoring plan, and disposition must be in accordance with Chapter 5.0.

If photographs of the core are taken, the core surface must be cleaned or peeled, as appropriate, and wetted. Photographs should be taken in color.

2.6 Drilling through Contaminated Zones

When drilling through contaminated strata to reach lower, possibly uncontaminated, strata, the potential for “drag down” of contamination should be minimized by drilling technique. In this procedure, an outer drill casing is set and sealed within an “impermeable” layer or at a level below which the underlying environment is thought to be “cleaner” than the overlying environment. The drill fluids used to reach this point are disposed of according to Chapter 5.0 and replaced by a fresh supply. This system can be repeated, resulting in telescopic drill casing through which the final well casing is placed. These situations should be specifically addressed in the ground water monitoring plan.

2.7 Drilling Fluid Loss and Removal

When a borehole, made with or without the use of drilling fluid, contains an excessively thick, particulate-laden fluid that would preclude or hinder the specified well installation, the borehole fluid should be removed. This removal should facilitate the proper placement of casing, screen, granular filter, and seal.

Note: Unless the borehole wall has been supported by casing, the wall is likely to partially or completely collapse during fluid removal. Therefore, when no casing is present the fluid must be removed with great caution and the condition of the borehole monitored. Fluid losses in this operation must be recorded on the well diagram or boring log and later on the well development record. Any fluid removal prior to well replacement should be contingent upon the site geologist, engineer or geotechnical engineer’s evaluation of hole stability (i.e. sufficient for the desired well and seal placement).

If large drilling fluid losses occur in bedrock, the drilling operator should remove some of this fluid loss prior to well insertion. The intent here is to allow the placement of a larger pump in the borehole than otherwise possible in the well casing, thereby reducing subsequent development time and removing the lost water closer to the time of the loss. Development of the completed well can then be reduced by a volume equal to that which was removed through the above procedure.

2.8 Abandonment

All soil borings not completed as wells must be abandoned in accordance with Chapter 7.0, Well and Boring Abandonment. In addition, wells that are deemed

to be unnecessary for continued site monitoring or remediation system performance or to be structurally unsound should be abandoned.

2.9 Documentation

2.9.1 General

Each boring log should fully describe the subsurface environment and the procedures used to gain that description. Unless otherwise specified in the ground water monitoring plan, a log shall be produced for every boring completed. The information in subsection 2.9.3, Routine Entries, is required on boring logs although not necessarily in the format illustrated. Example soil and rock parameters for logging are included in Tables B-1 and B-2, respectively.

2.9.2 Time of Recording

Boring logs should be recorded directly in the field without transcription from a field book or other document. This technique minimizes the chance of errors of manual copying and allows the completed document to be field-reviewed closer to the time of drilling.

2.9.3 Routine Entries

In addition to specific data required by the ground water monitoring plan, the following information should be routinely entered on the boring log:

- 1) Each boring and well (active and abandoned) should be uniquely numbered in accordance with an established well designation plan (discussed in Subsection 3.1.1);
- 2) Depths and heights (and reference to the appropriated datum) should be recorded in feet and decimal fractions (tenths of feet);
- 3) Field soil classification must be in accordance with the Unified Soil Classification System (USCS) or Standard D2487 and D2488, and shall be recorded in the field at the time of the sampling by the geologist. Such terms as “trace,” “some”, “several,” must be consistent with the USCS or ASTM Standard D2488;
- 4) Each soil sample collected should be fully described on the log. Sample colors should be described using a Munsell soil and/or rock color chart. Samples should be described when wetted;
- 5) When used to supplement other sampling techniques, disturbed samples (e.g., wash samples, cuttings, and auger flight samples) should be described in terms of the appropriated soil/rock parameters

- 6) Rock cores should be fully described on the boring log. Sample colors should be described using a Munsell rock color chart. Samples should be described when wetted;
- 7) For rock core the log will include, denoting by depth, the location, orientation, and nature (natural or mechanical) of all core breaks. Also mark the breaks purposely made to fit the core into the core boxes. If fractures are too numerous to be individually shown, their location may be drawn as a zone and described on the log. Also note, by depth, the intervals of all lost core and hydrologically significant details. This sketch should be prepared at the time of core logging, concurrent with drilling;
- 8) All special problems and their resolution should be recorded in the field logbook, with appropriated entries on the log form. Examples of problems include, hole squeezing, recurring problems at a particular depth, sudden tool drops, excessive grout takes, drilling fluid losses, unrecovered tools in hole, and lost casings;
- 9) The dates and times for the start and completion of borings should be recorded on the log;
- 10) Each sequential boundary between the various soils and individual lithologies should be noted on the log by depth and elevation;
- 11) The depth of the first encountered free water should be indicated. Before proceeding, the first encountered water should be allowed to partially stabilize for a minimum of 5 to 10 minutes and recorded along with the time between measurements. It is important to note if the measured water level increases or decreases over time;
- 12) The purpose and interval by depth for each sample collected, classified, and/or retained should be noted on the log;
- 13) A record of the blow counts, hammer type and weight, and length of hammer fall for driven samplers should be made when standard penetration samplers are used. For thin-wall samplers, indicate whether the sampler was pushed or driven and the pressure/blow count per drive. Blow counts should be recorded in half-foot increments when standard penetrations samplers (1- $\frac{3}{8}$ inch I.D. X 2

inch O.D.) are used. For penetration less than a half-foot, annotate the count with the distance over which the count was taken. Blow counts, in addition to their engineering significance and classification purpose, may be useful for stratigraphic correlation;

- 14) When drilling fluid is used, a quantitative record in the field logbook should be maintained of fluid losses and/or gains and the interval over which they occur. Adjustment should be made for fluid losses due to spillage and intentional wasting (e.g., recirculation tank cleaning) to more closely estimate the amount of fluid lost to the subsurface environment. Losses should be noted by time and depth interval;
- 15) Record the total depth of drilling and sampling on the log;
- 16) Record significant color and viscosity changes in the drilling fluid return, even when intact soil samples or rock core are being obtained. Include the color/viscosity change, depth at which change occurred, and a lithologic description of the cuttings before and after the change;
- 17) Soil gas and breathing zone readings, if taken, should be recorded on the log. Each notation should include interval sampled and reading. When possible, a general note on the log should indicate meter manufacturer, model, serial number, and calibration material. If several meters are used, key the individual readings to the specific meter; and
- 18) Special abbreviations used on the log and/or well diagram should be defined where used.

2.9.4 Soil Boring Abandonment

For each soil boring, its final status (abandoned; converted to a monitoring well, etc.) should be recorded on the boring log form. If the boring is abandoned, the date(s) of abandonment and the abandonment method should be included. The boring abandonment procedures should comply with Chapter 7.0 of the manual.

2.9.5 Well Abandonment

For each abandoned monitoring well or piezometers, a record of the abandonment must be provided on the Well Abandonment Form. An example of this form is included in Appendix B. Well abandonment procedures should comply with Chapter 7.0 of the manual.

3.0 Well Design and Material Specifications

3.1 Well Design Specifications

This section describes the design specifications for the various monitoring well components. Figure 1, Single-Cased Monitoring Well Schematic Diagram, illustrates typical single-cased well components described in the following subsections. Well construction specifications for monitoring wells installed with conventional drill rigs are outlined in Sections 6.4 through 6.6 of the USEPA guidance document (USEPA, 2001) and for direct-push micro wells in the ASTM Standard 6725. Variations from standard practices should be based upon site, geologic, and hydraulic conditions and must be approved prior to installation by the appropriate regulatory authorities and must follow appropriate regulatory procedures. Persons with authority to address and grant variances should be identified in the ground water monitoring plan. Circumstances and factors leading to variances must be properly documented.

3.1.1 Well Designation

Each well at a site should have a unique label that distinguishes it from all other wells located at the installation. Prior to assigning a well label, all wells at the site should be checked to ensure no duplication. An example of a naming convention is given below:

Site:	Johnson Bulk Tank Farm No. 2
Well Number (Name):	JBTF-N2-MW01;
Where:	JBTF = Johnson Bulk Tank Farm N2 = Farm No. 2 MW01 = monitoring well 01

It is preferred that wells be labeled with an identification tag. A metal tag containing the well designation should be attached to the protective casing of each monitoring well. Figure 2 presents a diagram of a well identification tag. The following specification can be applied to the use and installation of well tags:

Specifications:

4"x4"x0.032" stainless steel or aluminum
3/16" lettering
1/8" diameter mounting holes
black printed or stamped lettering

Printing:

A printing press can be used to complete as much information as possible before mobilizing to the site. Required information to be included in on a tag is shown in Figure 2. Information that is not available at the time of printing must be hand stamped in the field.

Figure 1: Typical Monitor Well Construction, Single-Cased Monitor Well

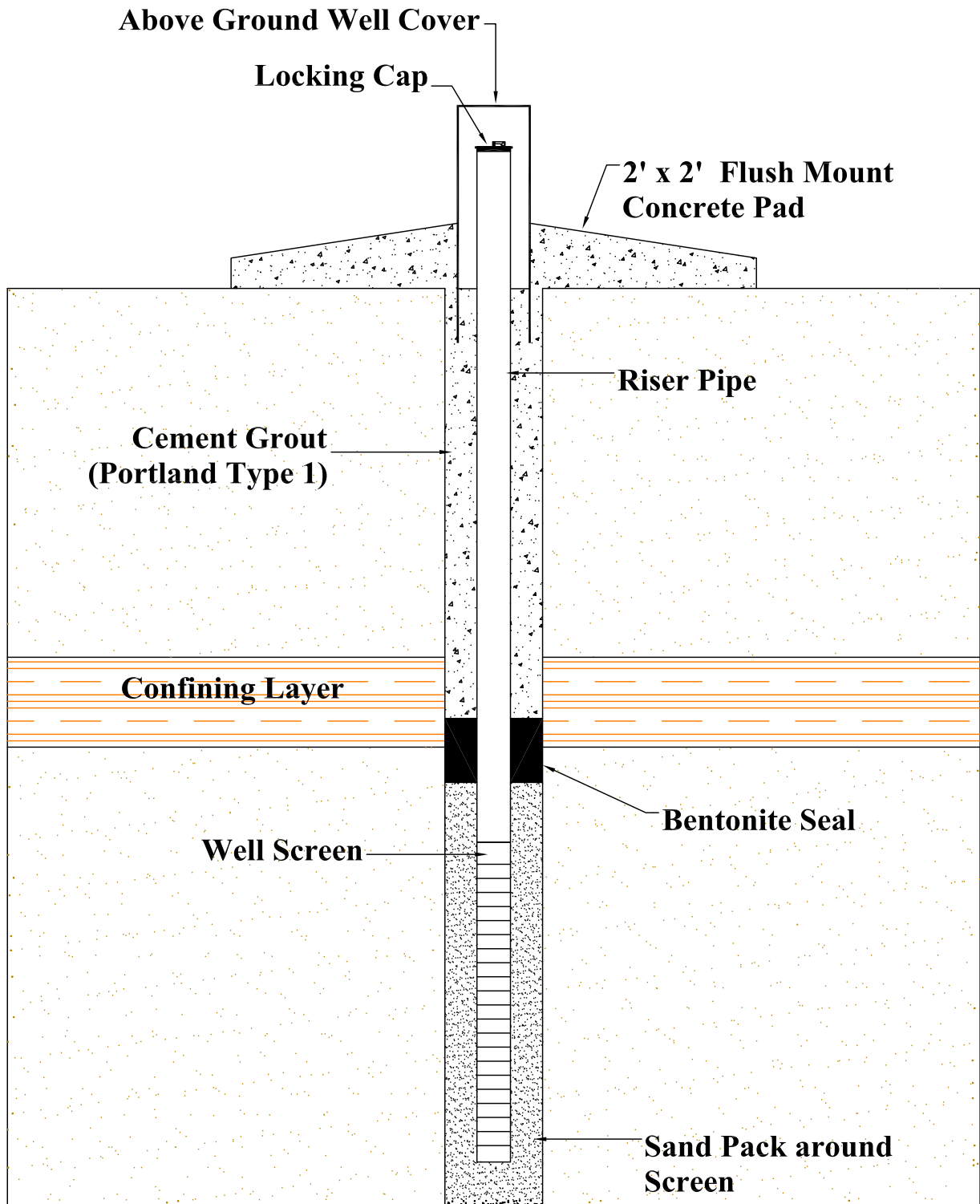


Figure 2: Monitoring Well Identification Tag



3.1.1.1 The Florida Unique Well Identification Program

The Florida Unique Well Identification (FLUWID) program provides a means to simplify the identification and exchange of water well information between state agencies and other interested parties. Under the program, water wells are assigned a unique alphanumeric code called the FLUWID identification number (example: AAA0000). The alphanumeric code is printed on a weather resistant adhesive tag/label and attached to a wellhead or pump house for identification. The FLUWID identification number serves as the primary water well identification number which enables different state agency water well databases to be cross referenced and queried. The FLUWID identification number is meant to be used in conjunction with any other numbering identification scheme such as the permit numbering system for water well construction and identification water well samples.

The naming convention in subsection 3.1.1 can still be used; however the FLUWID number can either replace the well number or be used in conjunction with the well number. For example a FLUWID number, AAB2123, queried from the database would show that this FLUWID number is associated to the original site name JBT-N2-MW01, and the FLUWID number would associate any sample identifications related to JBT-N2-MW01, as well as any other related data and information associated with that well.

The FLUWID Coordinator maintains the FLUWID Program Database (database). The database records the agency that is issued FLUWID tags, the date of issuance, differential global positioning system (DGPS) coordinates and other well information. The primary function of the database is to simplify water well

data inquires by directing all request to the party issued the FLUWID tags. The database is not a repository for water well historical data.

The FLUWID Program is not mandated by law, but implemented voluntarily to facilitate water well data collection. The FLUWID Program only works if all parties participate and report data associated to the FLUWID ID numbers that are issued to said parties. It is most important that all data be returned to the FLUWID coordinator in a timely fashion in order to maintain an up-to-date and accurate database.

3.1.2 Well Material Specifications

The selected well construction materials should be chosen based on site and hydrogeological conditions and the physical and chemical monitoring objectives. The prime concern when selecting well materials is that these materials will not contribute foreign constituents to the ground water quality sample or alter the surrounding environment, either by leaching or sorption. The introduction of foreign matter or alteration of ground water quality may compromise the integrity of the well and of any analytical data. Also, well materials must not absorb any of the contaminants of interest that may be present in the ground water. An additional concern is that all well materials must be durable enough to withstand installation and well development and endure for the entire designed monitoring period. ASTM Standard D5092 presents an excellent discussion of material terminology and definitions. Deviations from acceptable well material specifications should be specified the ground water monitoring plan and approved prior to installation.

PVC and stainless steel are the most commonly used monitoring well screen and riser materials. However, in some situations, other materials, such as Teflon®, or carbon steel (for riser pipe) may meet project objectives. Typically, the riser is constructed of the same material as the well screen. However, depending upon the project objectives, PVC or carbon steel riser pipe material may be used to reduce the material cost when stainless steel well screens are specified. Where a different riser material is used to produce a “hybrid” well, the materials anticipated to be in contact with the ground water must be consistent with the material of the well screen. Table A-2, Appendix A, provides a comparison of stainless steel and PVC material characteristics. Table A-3, Appendix A, provides a comparison of the relative compatibility of miscellaneous well materials to potentially reactive substances.

All PVC screens, casings, and fittings are typically Schedule 40 or 80 and shall conform to National Sanitation Foundation (NSF) Standard 14 for approved water usage or ASTM Standards F480 or D1785. If the driller uses a screen and/or casing manufacturer or supplier who removes or does not apply this logo, a written statement from the manufacturer/supplier that the screens and/or casing

have been appropriately rated by NSF or ASTM should be included in the ground water monitoring plan.

Stainless steel well screen is typically Type 316 or 304. The stainless steel well screen must have flush threaded joints, sealing “O” rings of compatible material with the project objectives, and conform to ASTM Standard A312/A312M.

A Teflon® well screen must have flush threaded joins, sealing Teflon® “O” rings, and conform to ASTM Standard D4894 or D4895. Specific materials must be specified in the ground water monitoring plan. All materials should be as chemically inert as technically practical with respect to the site environment. Marking, writing, or paint strips are not allowed.

All monitoring well joints must be water tight. Couplings with the casing and between the casing and screen must be compatibly threaded. Thermal- or solvent-welded couplings on PVC pipe shall not be used. This restriction also applies to threaded or to slip-joint couplings thermally welded to the casing by the manufacturer or in the field. Gaskets, pop rivets, or screws are not normally used on monitoring wells. Exceptions are: 1) manufactured flush-joint casing requiring an o-ring to seal the joint and 2) stainless steel screws required to attach a bottom cap to a nonstandard length of screen material where the normal joint structure is missing. Exceptions should be approved prior to installation and must be recorded in the well completion report. All screen bottoms must be securely fitted with a cap or plug of the same composition as the screen. Solvents or glues are not permitted in the construction of a monitoring well.

All well screens and well casings must be free of foreign matter (e.g., adhesive tape, labels, soil, grease, etc.). Typically, well casing and screen materials are prepared, wrapped, and boxed by the manufacturer with a certificate of being “clean”. If the cleanliness of the well materials is in doubt, the casing and screen must be decontaminated using an approved protocol. Cleaned materials must be stored in appropriate containers until just prior to installation. Pipe nomenclature stamped or stenciled directly on the well screen and/or blank casing within and below the bentonite seal must be removed by means of sanding, unless removable with approved water. Solvents, except approved water, must not be used for removal of markings.

3.1.3 Well Screen Usage

Each well should be constructed with new, machine-slotted or continuously-wound screen section. The end plug should be composed of the same material as the well screen. The screen assembly must be able to withstand installation and development pressures without collapsing or rupturing.

Although many wells set into bedrock could be installed as open-hole installations, the extra cost and effort for screen installation can be more than

offset by the assurance of an unobstructed opening to the required depth during repeated usage. Well integrity and consistent access to the original sample interval during prolonged monitoring is thereby maintained.

3.1.4 Well Screen Length

Well screen lengths should be selected based on the purpose of the well. Some wells are designed to determine the presence or absence of contaminants. Others are designed to monitor a discrete zone for a particular contaminant type. Design of screen length must take into account hydrostratigraphy, temporal considerations, environmental setting, analytes of concern, fate and transport of contaminants, and/or regulatory requirements.

In most situations, monitoring wells are designed to double as ground-water quality sampling points and as piezometers to monitor water levels or hydraulic head at that particular location and depth. In order to satisfy these dual roles, monitoring well screen lengths may range from as short as 2 feet to greater than 20 feet. Typically, though, well screen lengths are 5 or 10 feet, and rarely exceeding 20 feet. It is important that well screen lengths be specified in the ground water monitoring plan.

3.1.5 Well Screen Diameter

The inside diameter (I.D.) of the well screen should be chosen based on anticipated use of the well. Generally, a 2-inch I.D. well is sufficient to allow sampling with most types of sampling devices such as bailers or low-flow samplers. If the well may be used as part of a remedial system, a greater I.D. may be considered (e.g., 4-inch or 6 inch), however, the advantages of this increased diameter should be evaluated with respect to cost increases in drilling, material, and disposal of waste material.

The actual inside diameter of a nominally sized well is a function of screen construction and the wall thickness/schedule of the screen, casing, and joints. In the case of continuously-wound steel screens, their interior supporting rods may reduce the full inside diameter. Additionally, the welded couplings on 2-inch I.D. stainless steel well pipe frequently reduces the inside diameter to slightly less than 2 inches. This consideration is critical when sizing pumps, bailers, surge devices, etc.

All well screens must be commercially fabricated, slotted or continuously wound, and have an I.D. equal to or greater than the I.D. of the well casing. An exception may be warranted in the case of continuously-wound screens. No fitting should restrict the I.D. of the joined casing and/or screen.

3.1.6 Well Screen Slot Size

The grain size distribution of the screened formation and the filter pack gradation are the primary parameters that should be used when selecting a slot size for the well screen. Therefore, the grain size of the aquifer material should be the determining factor in selecting well screen slot size.

The largest practical slot size that is compatible with the aquifer and available filter material should be used. This will allow maximum intake volume per unit screen length. The slot size should retain at least 90 percent (preferably 99 percent) of the filter pack material. The method for determining the appropriate gradation of filter pack material is described in paragraph 3.1.11.2, Primary Filter Pack.

3.1.7 Well Screen Placement

The screen shall be placed such that the parameters of concern can be properly monitored. Chemical constituents with a specific gravity greater than water tend to sink and may accumulate as a dense non-aqueous phase liquid (DNAPL). If the well screen is to be installed in a location known or suspected to be impacted by DNAPLs, then the borehole must not be overdrilled and the screen must be placed at the bottom of the borehole. The screen must be placed with no filter pack beneath the base of the screen as this construction may provide a sediment trap and the DNAPLs may sink and not be detected. DNAPLs may exhibit an overall vertical migration, even with a predominant horizontal ground water flow. Therefore, screens need to be placed at the bottom of a saturated zone or just above a confining layer. Screen lengths should be as short as possible, at the most 10 feet and preferably 5 feet (or less), to decrease the likelihood of cross contamination of deeper portions of an aquifer.

Overdrilling of a borehole is sometimes performed for such activities as definition of stratigraphy, location of a confining unit or to creation of a sediment trap. It is preferred that exploratory activities (i.e., stratigraphic definition and strata location) are conducted in a pilot hole and then the borehole be properly abandoned. A separate borehole should be advanced for the monitoring well.

Overdrilling to create sediment traps is not encouraged. If, however, overdrilling is performed to create a sediment trap, the bottom of a well screen may be placed at a minimum of 6 inches, but no more than 3 feet above the bottom of the borehole. If bentonite pellets are used to seal the bottom of the borehole, a minimum of one foot of filter sand must be placed above the bentonite prior to screen placement. Overdrilling must be appropriate for site conditions and the monitoring parameters of concern. The use and style of sediment traps must be discussed in the ground water monitoring plan.

3.1.8 Well Riser

The I.D. of the riser should be chosen based on the anticipated use of the well. Usually a minimum of 2-inch I.D. riser is required to allow use of most sampling devices and water level indicators. In most cases, the well riser will be fabricated of the same material and be the same I.D. as the selected well screen. Couplings within casing segments and between the casing and screen must be compatibly threaded.

Each riser section should be installed as straight and level as possible. For deep installations (greater than 40 feet) centralizers should be used to ensure a constant annular spacing between the borehole and well materials. The top of the uppermost riser pipe, i.e., the top of the well, must be level. A point on the top of the well should be marked such that survey and water level measurements are collected from the same location. Traditionally, this mark is placed on the north side of the riser.

3.1.9 Surface Casing

Outer well casing used as a permanent part of the installation when multi-cased wells are installed must be composed of new material. The casing must be free of interior and exterior protective coatings and must be steam cleaned or washed with a high-pressure water device (if appropriate for the selected material) using approved water immediately before installation. The type of material and wall thickness of the casing must be adequate to withstand the installation process. Surface casing must consist of steel meeting ASTM Standard A53/A53M-06 or Schedule 40 or 80 PVC, and shall have a minimum wall thickness of 0.25 inch, unless otherwise specified. The ends of each casing section should be either flush-threaded or beveled for welding.

At sites where multiple aquifers may be penetrated or where a confined or semi-confined aquifer must remain isolated from potential surface water infiltration, surface casing is required to prevent cross-contamination between the separate zones. When used to seal a confining layer or bedrock surface, well casing is typically installed 3 feet to 5 feet into the top of the unit. This should provide a sufficient isolation of the aquifer to be protected. For thin confining layers or thin saprolite horizons, a shallower penetration depth may be appropriate.

Different casing sizes may be required depending on the types of geologic materials encountered at the drilling site and the anticipated purpose of the well. The site geologist, engineer or geotechnical engineer should anticipate these conditions and design the monitoring wells accordingly. Casing diameters for filter-packed wells should be selected so that a minimum annular space of 2 inches is maintained radially between the inside diameter of the surface casing and outside diameter of the monitoring well riser. Also, the diameter of all casings in multi-cased wells should be sized so that a minimum of 2 inches of

annular space is maintained between the surface casing and the borehole. For example, a 2-inch diameter well screen will require a 6-inch diameter casing inside a 10-inch diameter boring.

3.1.10 Granular Filter Packs

3.1.10.1 Filter Pack Materials

All granular filters should be discussed in a ground water monitoring plan, including composition, source, placement, and gradation. If the actual gradation is to be determined during drilling, then more than one filter pack gradation should be available so that well installation will not be unnecessarily delayed. A 1-pint representative sample should be collected for possible future analysis.

Granular filter packs must be at least 98 percent pure silica sand, visually clean (as seen through a 10-power hand lens), free of materials that would pass through a No. 200 U.S. Standard sieve, inert, composed of rounded grains, and of appropriated size for the well screen and host environment. The filter material should be packaged in bags by the suppliers and therein delivered to the site.

Filter packs are placed in the borehole and around the well screen to prevent natural formation material from entering the well screen. The use of a tremie pipe for filter pack placement is recommended; especially when the boring contains thick drilling fluid or mud or is sufficiently deep such that bridging is likely. Exceptions to the use of a tremie pipe for filter pack placement may include vadose zone wells or surficial well with less than approximately 10 feet of standing water.

The final depth to the top of the granular filter should be directly measured (by fiberglass or stainless steel tape measure or rod) and recorded on a well construction form. Final depths must not be estimated based on volumetric measurements of placed filter sand.

When installing a monitoring well in karst or highly fractured bedrock, the borehole configuration of void spaces within the formation surrounding the borehole is often unknown. Therefore, the installation of a filter pack becomes difficult and may not be feasible.

3.1.10.2 Primary Filter Pack

The primary filter pack consists of granular, siliceous material or glass beads. These materials should be clean and free of materials that would compromise the integrity of the representative ground water quality.

The filter pack shall extend from the bottom of the boring to a minimum of 3 feet above the top of the screen unless otherwise specified in the work plan. As mentioned in Subsection 2.1.4.4, Borehole Requirements, the filter pack is not

placed beneath the screen when potential contaminants with a specific gravity greater than that of water (i.e. DNAPLs) are suspected. Once the filter pack material is in place the well should be surged to break bridged filter pack materials in the borehole and to consolidate those materials around the screened interval.

As appropriate, up to 5 feet of filter pack can be placed above the top of the screen. This additional filter pack thickness will allow for settling from infiltration and compaction of the filter pack during development and repeated sampling events. The additional filter also helps to maintain a separation between the bentonite seal and well screen. The selected filter pack material should be uniformly graded and composed of siliceous particles that have been appropriately washed and screened. The filter pack grain-size is based on the smallest natural formation material. The following table presents a comparison of typical filter pack mesh sizes and appropriate screen size openings:

Table 3: Comparison of Screen Slot Size and Filter Pack

Screen Size Opening (Inches)	Screen Size Slot Number	Typical Sand Pack Mesh Size (U.S. Standard Sieve Number)
0.005	5	100
0.010	10	20 to 40
0.020	20	10 to 20
0.030	30	10 to 20

3.1.10.3 Secondary Filter Pack

As appropriate and as borehole depth and hydrogeologic conditions allow, a minimum 1- to 2-foot thick secondary filter pack should be used during well installation. A fine-grained sand (i.e. 30/65) may be used as a secondary filter pack.

The objective of a secondary filter pack is to prevent intrusion of the bentonite seal into the primary filter pack. Additionally, a secondary filter pack can also be used between the bentonite seal and the grout backfill to prevent intrusion of the grout into the bentonite seal. Finally, for wells completed with the seal located above the static ground water level, a secondary filter pack should be installed to replace the bentonite seal.

3.1.11 Annular Seal

The objective of an annular seal is to prevent intrusion of the annular grout into the primary and/or secondary filter pack. An annular seal of fine-grained,

washed silica sand is recommended in situations where monitor well screen sections are designed to intercept the water table. In situations where the annular seal is assured to remain below the water table and saturated, a bentonite seal is appropriate. Bentonite has the ability to expand when completely hydrated to form a dense clay mass with very low in-place permeability, thereby providing an effective barrier to water migration. However, bentonite is not effective when 1) improperly hydrated, 2) allowed to desiccate in place or 3) placed in high or low pH environments. To allow for adequate hydration and avoid desiccation bentonite seals must be placed at a depth below the lowest anticipated static ground water level in the well.

Because bentonite has a high cation exchange capacity and high pH, it may adversely affect water-quality samples that come in contact with, or have migrated through or past the bentonite seal. Additional concerns include the use of bentonite in ground water that exhibits high total dissolved solids or high chloride content, or may contain chemicals reactive to the bentonite's cation exchange capacity and pH. For these reasons, the rationale and design specifications for bentonite seals should be detailed in a work plan. If selected for use during the design process, the bentonite seal should have a minimum 2-foot thickness.

Bentonite used in drilling slurries and as annular sealant shall be powdered, granular, chipped or pelletized. Pelletized or chipped bentonite should be used for bentonite seals, whereas powdered or granular bentonite should be used when required in preparing slurries and grout. The materials must be a 100 percent pure sodium bentonite (montmorillonite) supplied in sacks or plastic buckets. The bentonite must be free of any additives or other material that may negatively affect water quality in the resulting monitoring well. The diameter of the bentonite pellets used should be less than one fifth the width of the annular space into which they are placed. This will help reduce the possibility of the material bridging in the annular space.

The preferred method of placing bentonite pellets or chips is by positive displacement or by use of a tremie pipe. Use of the tremie method minimizes the risk of pellets or chips bridging in the borehole, but time and care must be taken to prevent plugging of the tremie pipe. Pouring of the pellets is acceptable in shallow boreholes (less than 40 feet). In order to provide accurate measurement of bentonite pellet thickness in the well boring, the pellet seal should be tamped during measurement. Bentonite pellet/chips seals should be measured during and immediately after placement, without allowance for swelling. Granular or chip bentonite may be used if the seal is set in a dry condition.

If the proposed seal location is above the anticipated static ground water level, a bentonite seal should not be used. In this case, a 1- to 2-foot layer of fine-grained sand (secondary filter pack) placed atop the primary filter pack will enhance resistance to downward grout migration.

Slurry seals should be used only as a last resort, as when the seal location is too far below water to allow for pellet or chips or containerized-bentonite placement or within a narrow well-borehole annulus. Typically, the specific gravity of cement grout placed atop the slurry seal will be greater than that of the slurry. Therefore, the intent to use a slurry seal should be detailed in the ground water monitoring plan, and details should include a discussion of how the grout will be precluded from migrating through the slurry. An option includes a secondary filter pack of fine-grained sand and the use of a side discharging tremie pipe. Slurry seals should have a thick, batter-like (high viscosity) consistency with a placement thickness of 3 feet to 5 feet.

The final depth of the top of the bentonite seal should be directly measured (by tape or rod) and recorded. Final depths should not be estimated based on volumetric measurements of placed bentonite.

In a well designed to monitor competent bedrock, the bottom of the bentonite seal should be located at 3 feet below the top of firm bedrock, as determined by drilling. "Competent bedrock" refers to that portion of solid or relative solid, moderately weathered to unweathered bedrock where the frequency of loose and fractured rock is markedly less than in the overlying, highly weathered bedrock. Special designs will be needed to monitor fractured bedrock.

3.1.12 Annular Grout

Grout used in monitoring well construction and borehole/well abandonment should be one of the five Portland cement types specified in ASTM Standard C150. Type I Portland cement is most commonly used for monitoring well construction. Bentonite-based grouts (30 percent solids) can be used when the grout needs to remain somewhat flexible. The cement-based grout should be composed of Type I Portland cement, 100 percent pure sodium bentonite (10 percent dry bentonite per 94-lb. sack of dry cement), and shall not exceed 6 gallons of water per 94 pounds of Portland cement. The amount of approved water used should be kept at a minimum. Use of 10 percent bentonite, by weight, added to a cement-based grout is advantageous when lower shrinkage, better workability, and reduced weight are important. The considerations of using bentonite include reduced set strength, increased set time, and potential incompatibility with some ground water chemistry conditions.

When a sulfate-resistant grout is needed, Types II or V cement should be used instead of Type I. Quick-setting cements containing additives must not be used for monitoring well installation. These additives may leach from the cement and adversely affect the chemistry of the water samples collected from the resulting monitoring well. Generally, the use of air-entrained cements should be avoided to negate potential analytical interference in ground water samples by the

entraining additives. Neither additives nor borehole cuttings shall be mixed with the grout.

3.1.13 Surface Completion

Protective casing should be installed around each monitoring well the same day as the initial grout placement. Any annulus formed between the outside of the protective casing and the borehole or between the monitoring well and protective casing should be filled to the ground surface with grout as part of the overall grouting procedure. Specific details of well protection should be detailed in the ground water monitoring plan. Details and specific elements of well protection should be included in well completion diagrams. Figures 3 and 4 present schematic diagrams for flush-mounted and stick-up protective casing, respectively. ASTM Standard D5787 provides guidance for monitoring well protection.

All protective casing should be steamed or hot-water-pressure cleaned prior to placement; free of extraneous openings; and devoid of any asphaltic, bituminous, encrusted, and/or coating materials, except the paint or primer applied by the manufacturer.

As specified in Subsection 3.1.1, Well Designation, a metal identification tag containing the well designation should be attached to the protective casing of each monitoring well or placed square on the protective concrete pad, centered on the northern or northwestern side of the pad, with the top of the tag toward the well head. For new pads, the tag shall be placed and pinned during pad construction. For existing pads, the tag should be epoxy grouted and cement screwed.

The material type of the surface completion casing should be adequate to protect the completed monitoring well. The surface completion materials need to be selected such that they provide adequate protection against physical destruction, tampering, natural degradation, and the environment.

Unless otherwise specified, surface completion materials should conform to the following specifications:

- 1) Locking 16-gauge steel or aluminum protective well cover, round or square and 5-feet in length, or flush-mounted 22-gauge steel, water resistant, welded box with 3/8-inch steel lid;
- 2) Cement consisting of one of the five Portland cement types that are specified in Standard C 150 as discussed in Paragraph 3.1.12, Annular Grout;
- 3) Brass, corrosion resistant, keyed-alike padlock;

- 4) Protective bumper posts constructed of 4-inch diameter and minimum 5-foot long steel or aluminum pipe (four per well). Each post must be set into concrete outside the corners of the concrete pad and filled with concrete;
- 5) Paint that matches existing monitoring wells at the installation. Where no wells exist, it is recommended to use high visibility yellow epoxy paint;
- 6) A well identification tag as detailed in Subsection 3.1.1, Well Designation; and
- 7) Cement consisting of one of the five Portland cement types that are specified in Standard C 150 as discussed in Paragraph 3.1.12, Annular Grout.

The primary purpose of a properly designed surface completion is to maintain the integrity of the well for the designed monitoring period. After the well is installed, it shall be completed at the ground surface in one of two ways:

- 1) Construct around the protective casing a 2-foot by 2-foot, 4-inch thick concrete pad, sloping from the casing to the perimeter such that water will drain away from the well. The bottom of the concrete pad should be installed partially or completely below grade to protect against undermining. Bentonite grout should then be placed in the annular space below ground level within the protective casing. Pea gravel should then be placed in the annular space above the bentonite to about 6 inches from the top of the well riser.
- 2) Where monitoring well protection must be flush-mounted with the ground, a locking security internal cap must be on top of the riser within the steel manhole or vault. This cap must be leak proof so that if the vault or manhole should fill with water, the water will not enter the well casing. A bolt-down manhole cover should be required for security. The manhole cover should be installed into a 6-inch thick, 2-foot square, concrete pad, sloped (1 inch per foot) to provide water drainage away from the well, and finished flush to existing grade. Ideally the manhole cover should also be leak-proof.

If the well is completed above ground the protective casing should extend from slightly above the well casing to below ground with a minimum of 2.5 feet below grade. The protective casing should be waterproof and held firmly in lean concrete placed around the outside of the protective casing. The casing should be placed in alignment with the well riser pipe.

Figure 3: Flush-Mounted Protective Casing

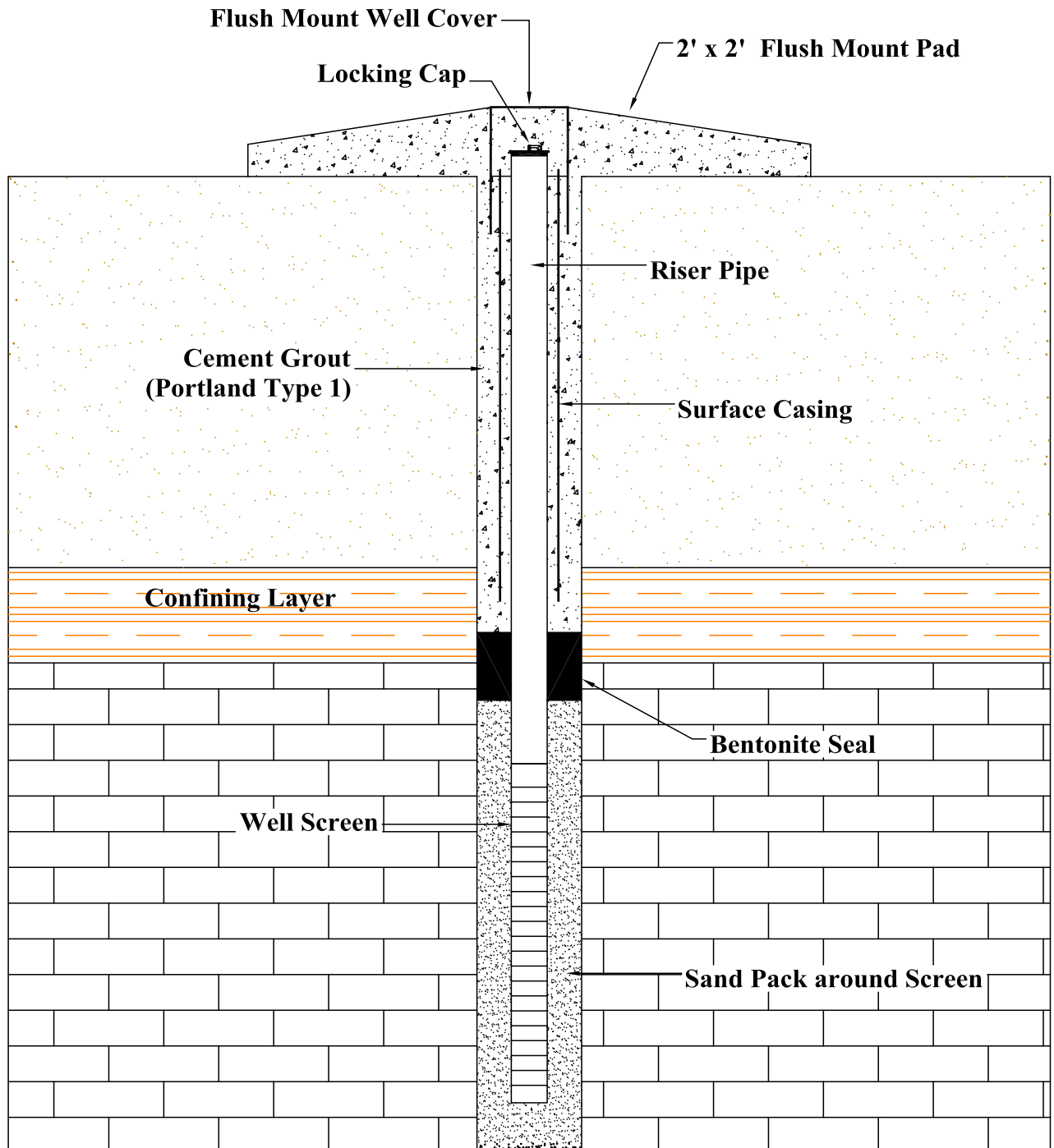
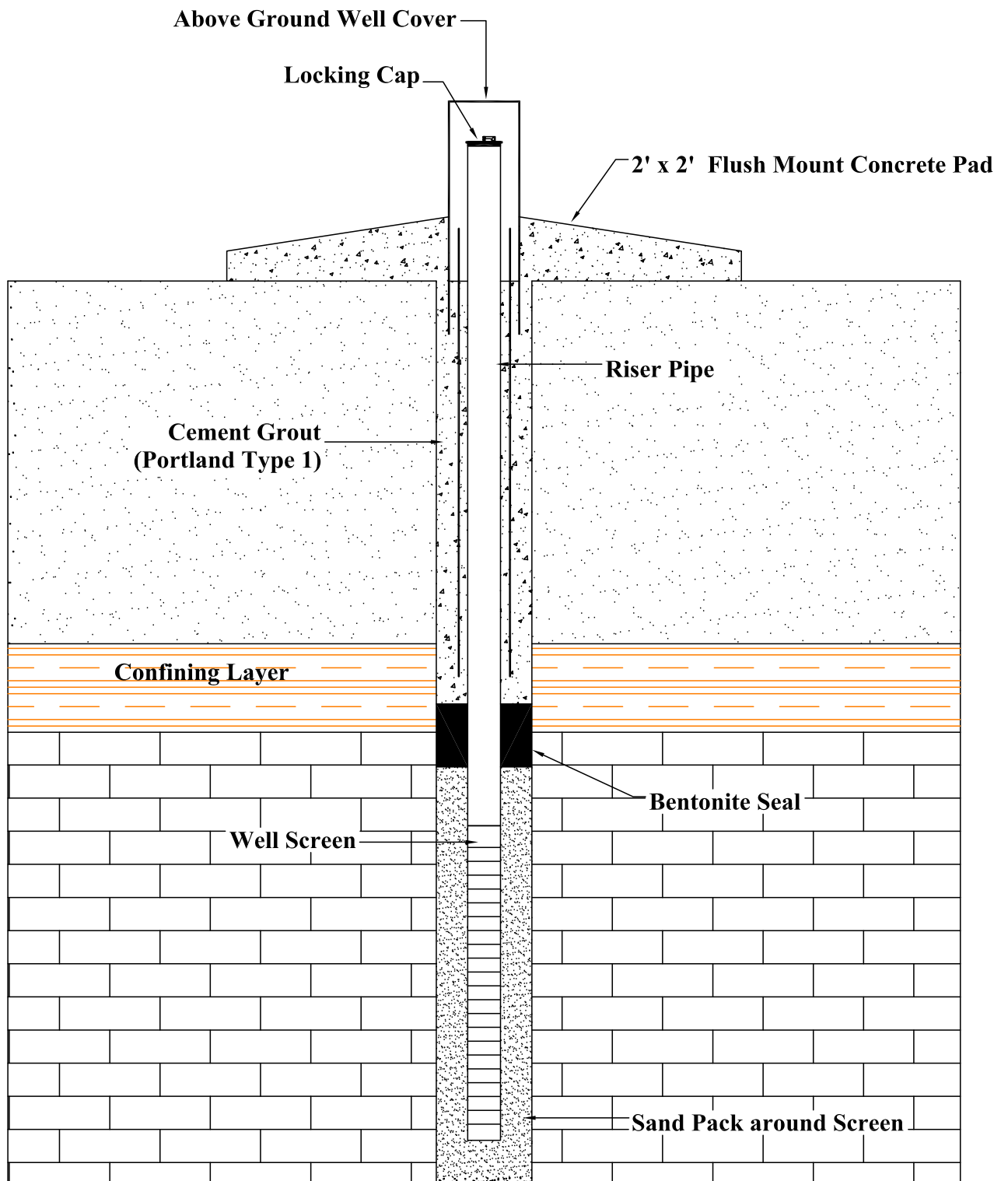


Figure 4: Above-Ground Protective Casing



Prior to protective casing installation, a 1/8-inch diameter vent hole should be drilled or slotted in the well riser approximately 6 inches below the cap to allow the well to vent. A second 1/4-inch diameter hole (or weep hole), should be drilled in the surface casing immediately above the concrete pad to allow water to drain from the inside of the protective casing. Vent holes should not be used for flush-mounted well completions. Enough clearance, usually 6 inches, should be left between the lid of the protective casing and the tip of the riser to allow the introduction of sampling equipment and/or pumps. All materials chosen shall be documented.

Monitoring wells located in high traffic areas should be flush mounted whenever possible. If a well can not be flush-mounted in high traffic areas or areas where heavy equipment is operated, the well should be protected with four steel bumper posts. This type of protection may not be necessary at all monitoring well locations.

Additional design details for a typical aboveground protective casing include the following:

- 1) A 5-foot minimum length of steel or aluminum protective casing shall extend approximately 2.5 feet above ground surface and set into the protective apron (aluminum should be used in coastal environments due to its corrosion resistant characteristics);
- 2) The protective casing inside diameter shall be at least 4 inches greater than the nominal diameter of the well riser;
- 3) An aluminum-hinged cover or loose-fitting telescopic slip-joint-type cap should be used to keep precipitation and cap runoff out of the casing;
- 4) All protective casing covers/caps shall be secured to the protective casing by means of a padlock at the time the protective casing is installed;
- 5) If practical, all padlocks at a given site should be keyed alike;
- 6) No more than a 2-inch clearance should be left between the top of the protective casing and the top of the well riser. This spacing may be required for installation of monitoring and/or pumping devices. If, however, acoustical equipment will be used for water-level determinations, a smaller spacing (2 inches or less) may be necessary;
- 7) Only the outside of the protective casing, hinges (if present), and covers/caps must be prepainted or painted with a paintbrush (no aerosol can). Paint shall dry prior to initially sampling that well;

- 8) A metal identification tag should be placed on the outside of the protective casing; and
- 9) In high traffic areas, install four steel or aluminum bumper posts. Each post should be radially located 4 feet from the well (immediately outside each corner of the concrete pad) and placed a minimum 2 feet below ground surface, having a minimum of 3 feet above ground surface. The posts should be set into and filled with concrete. Flagging or signposts in areas of high vegetation may be helpful. The bumper posts should be pre-painted or painted using a brush.

3.1.14 Quality Assurance Sampling

Certain well construction materials used during installation should be collected for quality assurance (QA) purposes. It is not always necessary to perform chemical analyses on collected materials. However, with the exception of the approved water, the materials should be archived until the chemical results are received from the environmental samples at that location in case that the results appear to be anomalous. In this case, it may be desirable to analyze some or all of the well construction materials. Such materials include drilling fluids (approved water and any additives, if used), annular filter pack, bentonite, and cement.

3.2 Documentation

Unless otherwise specified in the ground water monitoring plan, a well construction diagram and a certificate of conformance must be produced for every monitoring well constructed.

3.2.1 Well Construction Diagram

Each diagram must be attached to, or placed on the original boring log and maintained by the site geologist, engineer or geotechnical engineer until completion of the field effort. Figure 3-1 presents an example of a completed well construction diagram included on a soil boring log. The original diagram and boring log should be retained for later reference, as needed. Special abbreviations used on the well completion diagram must be defined on the diagram.

The following information should be attached to the original boring log and graphically denote, by the depth from ground surface:

- 1) The bottom of the boring (that part of the boring most deeply penetrated by drilling and/or sampling) and boring diameter(s);
- 2) Screen type and interval;

- 3) Joint type and depths;
- 4) Granular filter pack type and depth interval;
- 5) Seal type and depth interval;
- 6) Grout type and depth interval;
- 7) Cave-in, if any;
- 8) Centralizer locations;
- 9) Height of riser (stickup) without cap/plug above ground surface;
- 10) The following protective casing details; and
 - a. Height of protective casing, without cap/cover, above ground surface;
 - b. Base of protective casing below ground;
 - c. Weep hole location and size;
 - d. Concrete pad thickness, height, and extent, and;
 - e. Protective post configuration.
- 11) Water level immediately after completion and 24 hours after completion with date and time of measurement.

In addition to the graphical presentation discussed above, the following items should be described on each diagram:

- 1) The actual quantity and composition of the grout, bentonite seal, and granular filter pack used for each well;
- 2) The screen slot-size in inches, slot configuration type, total open area per foot of screen, outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer;
- 3) The material between the bottom of the boring and the bottom of the screen;
- 4) The outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer of the well casing;
- 5) The joint design and composition;
- 6) Centralizer design and composition;

- 7) Depth and description of any permanent pump or sampling device. For pumps, include the voltage, phase requirements, and electrical plug configuration;
- 8) Protective casing composition, length, and nominal inside diameter;
- 9) Special problems and their solutions; e.g., grout in well, lost casing and/or screens, bridging, casing repairs and adjustments, etc.; and
- 10) Dates and times for the start and completion of well installation.

3.3 Special Concerns

3.3.1 Shallow Wells

During shallow well construction (i.e., less than approximately 15 feet) sufficient depth may not be available to install the desired thickness of typical well components (filter pack, bentonite seal, grout, etc.). Tailored well designs and deviations from standard well construction requirements should be detailed in a ground water monitoring plan. The design, if modified, should minimize the potential infiltrations of surface water.

3.3.2 Well Clusters

Unless otherwise specified in an approved work plan, each well in a cluster shall be installed in a separate boring rather than co-located within one large-diameter boring. Each monitoring well is a mechanism through which to obtain a ground water sample representative of the aquifer zone monitored and, if so designed, to measure the potentiometric surface in that well. To ensure this representation, each well in a cluster must be constructed and installed in a separate boring. Multiple well placements in a single boring are too difficult for effective execution and evaluation to warrant single hole usage. One exception includes the intentional design and installation of well clusters such as bundled piezometers for DNAPL characterization. Such exemptions must be detailed in a ground water monitoring plan.

4.0 Well Development

4.1 General

Borehole drilling activities may retard the ability of an aquifer to transmit water to a monitoring well. Obstructions can be caused by physical alteration of the aquifer material, or by formation damage as a result of the introduction of drilling fluids or solids in the aquifer, causing reduced permeability adjacent to the borehole. Well development is necessary to correct this damage and improve hydraulic conductivity in the immediate vicinity of the monitoring well. The objective of well development is to remove all or as much as possible of the introduced drilling fluids, mud, cuttings, mobile particulates, and entrapped gases from within and adjacent to a newly installed well, thus providing an improved connection between the well screened interval and the aquifer. The resulting inflow to the well should be physically and chemically representative of that portion of the aquifer adjacent to the screened interval. The appropriate development method or procedure to use will vary according to the hydrologic characteristics of the aquifer, the drilling method used, and the type of well completion.

4.2 Development Methods

The method most appropriate for monitoring well development is dependent upon the construction material and size of the well screen and casing, design of the filter pack, characteristics of the formation material, disposal considerations of development fluids, borehole drilling method used, impact of development method on aquifer chemistry, well depth, and cost. ASTM Standard D5521 provides guidance for the development of monitoring wells in granular aquifers.

The following are some of the most commonly used methods:

Mechanical Surging This method involves use of a swedge (surge) block that is moved up and down the well screen and casing. Water is alternately forced in and out of the screen to loosen sediment bridges and draw fine-grained material into the well, which is then pumped out. This is the preferred method of well development. Fine-grained materials can become trapped between the swedge and the inner wall of the screen and well casing causing the swedge to freeze in the well as well as scouring the well materials.

Overpumping The well is pumped at a higher rate than when it will be purged and sampled. Theoretically, the high flow rates dislodge fine-grained materials, opening the flow paths between the well and the aquifer. This method is subject to sediment bridging, requires large pumps that may be difficult to fit into small

diameter wells, generates large volumes of water that must be disposed, and results in poor development of wells with long screen intervals.

Rawhiding In this method, the well is alternately pumped and stopped at intervals that draw water into the well and back out, developing the filter pack by fluid surging. The technique can cause a high rate of wear on the pump and in certain situations may not produce a sufficient surge action for development.

Jetting This method uses high velocity streams of water to loosen fine-grained material and drilling fluids from the formation. The material that enters the wells is then pumped out. This method requires an external water supply and high velocity streams can damage the well screen. Jetting may be appropriate for redevelopment of wells that have become fouled with silt and clay or other fine matter.

Air Lift Air Lift involves forcing air out through the screen and into the monitoring well to clean debris from the well. This method alters the chemistry of the aquifer, may introduce contaminants to the aquifer via the air supply, may release contaminants to the air via mists from the well, and may damage the screen and filter pack.

4.3 Timing and Record Submittal

The development of monitoring wells should not be initiated sooner than 12 hours after or longer than 7 days beyond placement of grout. Well development should be appropriately documented on a monitoring well development record and included with the boring log.

4.4 Oversight

The development of a monitoring well should be overseen and recorded by a site geologist, engineer or geotechnical engineer.

4.5 Development Criteria

Well development should continue until representative water; free of drilling fluids, cuttings, or other materials introduced during well construction is obtained. In other words, the well should be developed until the water is non-turbid. Well discharge water should be metered in the field until it can be established that development has attenuated and stabilized turbidity to the maximum degree possible. All turbidity sampling times and measurements should be recorded on a well completion form.

Suggested minimum volumes to be withdrawn from a well are:

- 1) For those wells where the boring was made without the use of drilling fluid, but approved water was added to the well installation, remove five times the amount of any water unrecovered from the well during installation (in addition to five times the standing volume).
- 2) For those wells where the boring was made or enlarged (totally or partially) with the use of drilling fluid, remove five times the measured, or estimated, amount of total fluids lost while drilling, plus five times that used for well installation (in addition to the five times the standing volume). Exceptions may be warranted during the drilling of deep well borings where significant water was lost in a previous hydrologic zone.

Note: Developing a well for too short a period is a common and major cause for poor well performance. Also, water should not be added to a well as part of the development once the initial bentonite seal atop the filter pack is placed.

If any of the following circumstances occur, the site geologist, engineer or geotechnical engineer should document the event in writing and use an alternate plan of action:

- 1) After extensive development, a non-turbid sample cannot be collected due to a significant fraction of fine-grained material in the surrounding aquifer;
- 2) Persistent water discolorations remain after the required volumetric development; and
- 3) Excessive sediment remains after the required volumetric removal.

4.6 Development – Sampling Break

Well development must be completed at least 24 hours before well sampling. The intent of this hiatus is to provide time for the newly installed well and backfill materials to sufficiently equilibrate to their new environment and for that environment to re-stabilize after disturbance of drilling. Applicable Federal, State, and local regulations may require up to 14 days before well sampling can begin.

4.7 Pump/Bailer Movement

During development, water should be removed throughout the entire water column in the well by periodically lowering and raising the pump intake (or bailer stopping point).

4.8 Well Washing

Well development should include the washing of the entire well cap and the interior of the well riser above the water table using only water from that well. The result of this operation will be a well casing free of extraneous materials (grout, bentonite, sand, etc.) inside the well cap and casing, between the top of the well and the water table. The washing should be conducted before and/or during development, and not after development.

4.9 Well Development Record

The following data shall be recorded on a monitoring well development record during development:

- 1) Name of the responsible site geologist, engineer or geotechnical engineer;
- 2) Well designation and location;
- 3) Site name and location;
- 4) Date(s) of well installation;
- 5) Date(s) and time of well development;
- 6) Description of surge/development technique;
- 7) Type, size, capacity, and pumping rate of pump and/or bailer used;
- 8) Depth from top of well casing to bottom of well;
- 9) Well and casing inside diameter;
- 10) Static water level (equilibrium) from top of well casing before and after development;
- 11) Field measurements of pH, specific conductance, temperature, and turbidity before, at least twice during, and after development;
- 12) Screen length and interval;

- 13) Physical character of removed water, to include changes during development in clarity, color, particulates, and any noted incidental odor;
- 14) Cumulative water volume or pumping rate;
- 15) Quantity of fluids/water removed and time interval for removal (present both incremental and total values); and
- 16) Drilling company.

4.10 Determination of Hydraulic Conductivity from Specific Capacity

Immediately following well development, estimates of hydraulic conductivity can be obtained by conducting specific capacity tests. Specific capacity of a well is the well yield per unit drop of water level in the well. Immediately after monitoring well development, the specific capacity can be measured and used to provide an estimate of the hydraulic conductivity. If the well does not sustain pumping rates of at least 0.5 gallons per minute without excessive drawdown, other aquifer tests, such as slug tests, should be conducted.

Inherent in the calculation of hydraulic conductivity from specific capacity data are certain assumptions, therefore the responsible site geologist, engineer or geotechnical engineer should account for the following potential sources of error when calculating the hydraulic conductivity from specific capacity data:

- 1) Effects of variable discharge;
- 2) Effects of partial penetration of the well;
- 3) Calculation of well losses;
- 4) Appearance of delayed yield in the aquifer; and
- 5) Estimates of aquifer storativity.

Appendix C presents details on the performance of specific capacity tests.

5.0 Management of Investigation-Derived Waste

Investigation-Derived Waste (IDW) is defined as waste materials generated during environmental field activities. IDW may include drilling muds, cuttings, and purge water from test pit and well installation; purge water, soil, and other materials from sample collection; residues such as ash, spent carbon, well development purge water for testing of treatment technologies; contaminated PPE; and solution used to decontaminate equipment and non-disposable PPE. An IDW management plan should be developed as part of a ground water monitoring plan.

5.1 IDW Management Requirements

The fundamental purpose of IDW management is to choose options that are:

- 1) Protective of human health and the environment; and
- 2) In compliance with regulations and applicable or relevant and appropriate requirements (ARARs).

5.2 General Objectives for IDW Management

General objectives that site managers should consider include:

- 1) Protectiveness;
- 2) Minimization of IDW generation; and
- 3) Management of IDW consistent with the final remedy for the site.

To the extent that the objectives can be achieved is highly dependent on site-specific conditions.

5.2.1 Protectiveness

Factors that should be considered in determining if a specific management or disposal option is protective include the following:

- 1) The contaminants, their concentrations, and total volume of IDW;
- 2) Potentially affected media under management options;

- 3) Location of the nearest population(s) and likelihood or degree of site access;
- 4) Potential exposure to workers; and
- 5) Potential for environmental impacts.

Generally, best professional judgment will be required to make this determination.

5.2.2 IDW Management

Site managers should attempt to minimize the generation of IDW to reduce the need for special storage or disposal requirements that may result in substantial additional costs yet provide little or no reduction in site risks relative to the final remedial action. Generation of IDW can be minimized through proper planning of all remedial activities that may generate IDW, as well as through use of screening information during the site inspection. The potential problems of managing IDW should be a factor in choosing an investigation method.

5.2.3 Consistency with Final Remedy

Most IDW generated during the course of an investigation are intrinsic elements of the site. If possible, IDW should be considered part of the site and should be managed with other wastes from the site, consistent with the final remedy. This will avoid the need for separate treatment and/or disposal arrangements. Because early planning for IDW can prevent unnecessary costs and the use of treatment and disposal capacity, IDW management should be considered as early as possible during the remedial process. A key decision to be made is whether the waste will best be treated or disposed of immediately or addressed with the final remedy. In addition, when IDW is stored on site, it should be managed as part of the first remedial action that addresses the affected media.

5.3 Selection of IDW Disposal Options

The manner of waste disposal must be consistent with applicable Federal, State, and local regulations. Actual disposal and/or treatment techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, deposition in a landfill, treatment, etc. Protocols and the parties responsible for the handling and disposal of IDW should be included in the ground water work plan.

Disposal option selection should be based on the previously discussed factors:

- 1) The type and quantity of IDW generated;
- 2) Risk posed by managing the IDW on site;
- 3) Compliance to regulations, standards, and ARARs;
- 4) IDW minimization; and
- 5) Whether the final remedy is anticipated to be an off site or and onsite remedy.

6.0 Topographic Survey

6.1 Licensing

When practical or if site circumstances require, topographic survey efforts should be conducted by a Florida-licensed surveyor. Exceptions may include low resolution surveys, temporary point locations, and relative location surveys performed by personnel familiar with land surveying but not state certified.

6.2 Horizontal Control

Each boring and/or well installation should be topographically surveyed to determine its location referenced to either a Universal Transverse Mercator (UTM) grid or the State Plane Coordinate System (SPCS). These surveys should be connected to the UTM or SPCS by third order, Class II control surveys in accordance with the Standards and Specifications for Geodetic Control Networks (Federal Geodetic Control Committee, 1984). If the project is an area remote from UTM or SPCS benchmarks and such horizontal control is not warranted, then locations measured from an alternate system depicted on project plans may be acceptable. An accuracy of ± 0.10 foot is expected for monitoring well locations. Under typical conditions, all borings, temporary wells, temporary and/or permanent markers should also have an accuracy of ± 1.0 .

6.3 Vertical Control

Elevations for a designated point (marked measuring point) on the rim of the uncapped well casing (not the protective casing) for each bore/well site should be surveyed to within ± 0.010 foot and referenced to the National Geodetic Vertical Datum (NGVD) of 1988. If elevations for the natural ground surface at the bore/well site (not the top of the concrete pad) are required, the survey should be within ± 0.10 foot and referenced to the NGVD 1988. These surveys should be connected by third order leveling to the NGVD in accordance with the Standards and Specification for Geodetic Control Networks. If the project is in an area remote to NGVD benchmarks and such vertical control is not warranted, then elevations measured from a project datum may suffice, at least on a temporary basis.

6.4 Benchmark Placement

Temporary benchmarks may be installed to perform survey work. Temporary benchmarks typically consist of one or more of the following:

- 1) Iron pin (#4 rebar minimum, 24 inches in length);

- 2) Railroad spike in utility pole or tree;
- 3) Masonry nail driven in pavement;
- 4) Chiseled square on a concrete structure; and
- 5) Painted portion of a fixed object, such as a specific part of a fire hydrant.

Permanent benchmarks may be required to provide future control at a site. Permanent benchmarks will consist of a concrete monument a minimum of 5 inches square and two feet in depth with an iron pin imbedded full depth of the concrete and set flush with the top of the concrete, or a brass marker set in a five inches square, two-foot deep concrete monument.

6.5 Field Data

The topographic survey should be completed as near to the time of the last well completion as possible. Survey field data (as corrected), should include loop closures and other statistical data in accordance with the Standards and Specifications. Closure should be within the horizontal and vertical limits referenced above. These data shall be clearly listed in tabular form; the coordinates (and system) and elevation (ground surface and top of riser) for all borings, wells, and reference marks. All permanent and semi permanent reference marks used for horizontal and vertical control (benchmarks, caps, plates, chiseled cuts, rail spikes, etc.) should be described in terms of their name, character, physical location, and reference value. These field data should become part of the project records maintained by the site geologist, engineer, geotechnical engineer, project manager, or other appropriate person.

6.6 Survey Reports

The survey report should include the following:

- 1) A map showing the locations of the monitoring wells, reference points, and benchmarks. Elevations must be included for all wells (ground surface and top of well riser) and benchmarks;
- 2) A copy of all checked field notes taken during the field work; and
- 3) A copy of all coordinates and elevations for the monitoring wells, soil borings, surface water/sediment locations, etc., and temporary control points (baseline and traverse points).

6.7 Geographic Positioning System

As an alternative to conventional land surveying, a Geographic Positioning System (GPS) may be used to determine the horizontal and vertical location of points in the field. GPS may provide greater convenience, reduce equipment and personnel demands, and reduce the time required to conduct a survey as opposed to more traditional methods. GPS is particularly suited for point positioning in remote locations away from established benchmarks. Adequate GPS units must be employed, though, as typical well location and elevation determinations require high resolution surveying.

7.0 Well and Boring Abandonment

7.1 General

Abandonment procedures are designed to permanently close a boring or monitoring well. As such they are designed to preclude current or subsequent fluid media from entering or migrating within the subsurface environment along the borehole vertical axis. It is therefore important that a borehole be sealed in such a manner that it cannot act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers.

All soil borings not completed as monitoring wells must be abandoned in accordance with the following procedures and must be documented on the boring log as such. The date(s) of abandonment and the abandonment method must be included on the boring log.

7.2 Methodology

Each boring to be abandoned should be sealed by grouting from the bottom of the boring/well to ground surface. This should be done by placing a tremie pipe to the bottom for the boring (i.e., to the maximum depth drilled) and pumping grout through the pipe until undiluted grout flows from the boring at ground surface. The ground sealant must consist of high-solids, 100 percent-pure sodium bentonite grout. The amount of approved water used should be kept to a minimum. Neither additives nor borehole cuttings should be mixed with the grout. No borehole shall be backfilled with cuttings.

After 24 hours, the driller, site geologist, engineer, geotechnical engineer, or other field representative, should check the abandoned site for grout settlement. Any settlement depression should be immediately filled even with the ground surface and rechecked 24 hours later. Additional grout should be added using a tremie pipe inserted to the top of the firm grout, unless the depth of the unfilled portion of the hole is less than 5 feet and that portion is dry. The process should be repeated until firm grout remains at the ground surface. It may be necessary to grout the boring to a depth of 2 feet below grade and complete the backfill with lean concrete or asphalt, depending upon the composition of the original surface.

References Cited

29 CFR 1910,120, Code of Federal Regulations, 29 CFR 1910,120, Hazardous Waste Operations and Emergency Response

29 CFR 1926, Code of Federal Regulations, 29 CFR 1926, Safety and Health Regulations for Construction

ASTM A53/A53M, "Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless," ASTM International

ASTM A312/A312M, "Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipe," ASTM International

ASTM C150, "Standard Specification for Portland Cement", ASTM International

ASTM, D1452, "Standard Practice for Soil Investigation and Sampling by Auger Borings," ASTM International

ASTM D1586, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils," ASTM International

ASTM D1587, "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes," ASTM International

ASTM D1785, "Standard Specification for Poly Vinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120," ASTM International

ASTM D2113 Historical Standard, "Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation," ASTM International

ASTM D2487, "Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)," ASTM International

ASTM D2488, "Standard Practice for Description and Identification of Soils," ASTM International

ASTM D3550, "Standard Practice for Thick Wall, Ring-lined, Split Barrel, Drive Sampling of Soils," ASTM International

ASTM D4894, "Standard Specification of Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials," ASTM International

ASTM D4895, "Standard Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion," ASTM International

ASTM D5088, “Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites,” ASTM International

ASTM D5092, “Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers,” ASTM International

ASTM D5299, “Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities,” ASTM International

ASTM D5521, “Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers,” ASTM International

ASTM D5781, “Standard Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5782, “Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5783, “Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5784, “Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5787, “Standard Practice for Monitoring Well Protection,” ASTM International

ASTM D5872, “Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5875, “Standard Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D6169, “Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations,” ASTM International

ASTM D6286, “Standard Guide for Selection of Drilling Methods for Environmental Site Characterization,” ASTM International

ASTM D6724, "Standard Guide for Installation of Direct Push Ground Water Monitoring Wells", ASTM International

ASTM D6725, "Standard Guide for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers," ASTM International

ASTM D6914, "Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices," ASTM International

ASTM F480, "Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80, ASTM International

Driscoll, Fletcher, Ph.D., Ground water and Wells, Johnson Division, St. Paul, MN, 1996.

National Ground Water Association, Stuart Smith, ed., Manual of Water Well Construction Practices, NGWA, Westerville, OH (1998)

U.S. Army Corps of Engineers (USCOE), Engineering and Design, Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites, EM 1110-1-4000, 1 November 1998

USCOE, EM 385-1-1, Safety and Health Requirements Manual

USCOE, ER 385-1-92, Safety and Occupational Health Document Requirements for Hazardous, Toxic, and Radioactive (HTRW) and Ordnance and Explosive Waste (OEW) Activities

U. S. Environmental Protection Agency, Environmental Investigations Standard Operating Procedure and Quality Assurance Manual, Section 6: Design and Installation of Monitoring Wells, November 2001

Other Suggested References

ASTM D 5876, "Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices," ASTM International

ASTM D 5978, "Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells," ASTM International

ASTM D 5979, "Standard Guide for Conceptualization and Characterization of Ground-Water Systems," ASTM International

U.S. Environmental Protection Agency, Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation, (EPA/540/S-95/503, July, 1995) <http://www.epa.gov/ada/download/issue/napl.pdf>

Appendix A – Tables

- Table 4: Typical Borehole and Annulus Volume Calculations
- Table 5: Comparison of Stainless Steel, PVC, and Teflon® for Monitoring Well Construction
- Table 6: Relative Compatibility of Rigid Well Casing Material (Percent)

Table 4: Typical Borehole and Annulus Volume Calculations

Inside Diameter of Borehole (inches)	Outside Diameter of Casing Within Borehole (inches)	Cubic Feet per Foot of Depth	U.S. Gallons per Foot of Depth
1.0	NA	0.005	0.04
1.5	NA	0.012	0.09
2.0	NA	0.022	0.16
2.5	NA	0.034	0.25
3.0	NA	0.049	0.37
3.5	NA	0.067	0.50
4.0	NA	0.087	0.65
4.0	2.5	0.053	0.40
4.5	NA	0.110	0.83
5.0	NA	0.136	1.02
5.5	NA	0.165	1.23
6.0	NA	0.196	1.47
6.0	2.5	0.162	1.21
6.0	4.5	0.086	0.64
6.5	NA	0.230	1.72
7.0	NA	0.267	2.00
8.0	NA	0.349	2.61
8.0	2.5	0.315	2.36
8.0	4.5	0.239	1.78
8.0	6.5	0.119	0.89
9.0	NA	0.442	3.30
10.0	NA	0.545	4.08
10.0	2.5	0.511	3.82
10.0	4.5	0.435	3.25
10.0	6.5	0.315	2.36
11.0	NA	0.660	4.94
12.0	NA	0.785	5.87
12.0	2.5	0.751	5.62
12.0	4.5	0.675	5.05
12.0	6.5	0.555	4.15
14.0	NA	1.069	8.00
14.0	4.5	0.959	7.17
14.0	6.5	0.839	6.27
16.0	NA	1.396	10.44
16.0	4.5	1.286	9.62
16.0	6.5	1.186	8.72

Table 5: Comparison of Stainless Steel, PVC, and Teflon® for Monitoring Well Construction

Characteristic	Stainless Steel	Schedule 40 PVC	Teflon
Strength	Use in deep wells to prevent compression and closing of screen and/or riser	Use when shear and compression strength are not critical	Low-strength capabilities limit deep-well construction
Weight	Relatively heavier	Light-weight	Relatively light
Cost	Relatively expensive	Relatively inexpensive	Expensive
Corrosivity	Deteriorates more rapidly in corrosive water, particularly when exposed to H ₂ SO ₄	Non-corrosive – may deteriorate in presence of high concentrations of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons	Nearly totally resistant to chemical and biological attack, oxidation, weathering and ultraviolet radiation
Ease of Use	Difficult to adjust size or length in the field	Easy to handle and work with in the field	Fairly 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 fillings – pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells is not certified clean	Should be steam cleaned if not wrapped by manufacturer and if organics will be subsequently sampled
Interaction with contaminants	May sorb organic or inorganic substances when oxidized	May sorb or release organic substances	Almost completely chemically inert; may react to halogenated compounds, and sorption of some organic compounds, (Reynolds and Gillham, 1985). Except in the case of very low yield wells which preclude purging prior to sampling, these reactions are unlikely to cause significant sample bias.

Table 6: Relative Compatibility of Rigid Well Casing Material (Percent)

Potentially- Reactive 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®*
2. Stainless Steel 316
3. Stainless Steel 304
4. PVC
5. Lo-Carbon Steel
6. Galvanized Steel
7. Carbon Steel

*Teflon is a registered product of DuPont

Appendix B – Forms

- Form 1: Soil Parameters for Logging
- Form 2: Rock Parameters for Logging
- Form 3: Monitoring Well Completion Report
- Form 4: Application to Construct, Repair, Modify or Abandon a Well

Form 1: Soil Parameters for Logging

Parameter	Example
Classification	
Depositional Environment and formation, if known	
ASTM D 2488 Group Symbol	
Secondary Components and estimated percentages	
Color: <i>Give both narrative and numerical description and what chart was used – Munsell Soil and/or GSA Rock Color</i>	
Plasticity	
Consistency (cohesive soil)	
Density (non-cohesive soil)	
Moisture content (use relative terms)	
Structure and orientation	
Grain angularity	

Source: U.S. COE, 1988

Form 2: Rock Parameters for Logging

Parameter	Example
Rock Type	
Formation	
Modifier denoting variety	
Bedding/banding characteristics	
Color: <i>Give both narrative and numerical description and what chart was used – Munsell Soil and/or GSA Rock Color</i>	
Hardness	
Degree of cementation	
Texture	
Structure and orientation	
Degree of Weathering	
Solution or Void Conditions	
Primary and secondary permeability, including estimates and rationale	
Rock quality designation	

Source: U.S. COE, 1988

Form 3: Monitoring Well Completion Report

DEP Form # 62-520.900(3)

Form Title MONITORING WELL COMPLETION REPORT

Effective Date

DEP Application No.
(Filled in by DEP)

Florida Department of Environmental Protection

Bob Martinez Center, 2600 Blair Stone Road Tallahassee, Florida 32399-2400

MONITORING WELL COMPLETION REPORT

PART I: GENERAL INFORMATION

Well ID:	Site Name:	Well Install Date	
Facility ID	Alternate ID	FLUWID #	WMD Permit #
Well Purpose <input type="checkbox"/> Background <input type="checkbox"/> Intermediate <input type="checkbox"/> Compliance <input type="checkbox"/> Other (explain)			
Latitude (to nearest 0.1 seconds)		Longitude (to nearest 0.1 seconds)	
Latitude and Longitude collection method: <input type="checkbox"/> DGPS <input type="checkbox"/> AGPS <input type="checkbox"/> MAP <input type="checkbox"/> ZIPCODE <input type="checkbox"/> DPHO <input type="checkbox"/> UNKNOWN <input type="checkbox"/> OTHER			

PART II: WELL CONSTRUCTION DETAILS

Water Well Contractor Name				Contractor License #	
Company Name					
Construction Method: <input type="checkbox"/> Hollow Stem Auger <input type="checkbox"/> Solid Stem Auger <input type="checkbox"/> Water/Mud Rotary <input type="checkbox"/> Air Rotary <input type="checkbox"/> Cable Tool <input type="checkbox"/> Direct Push <input type="checkbox"/> Sonic <input type="checkbox"/> Other (describe)				Aquifer Monitored	
Top of Casing Elevation (NVGD or NAVD)			Ground Surface Elevation (NVGD or NAVD)		
Casing					
Material	Inside Diameter	Outside Diameter	Depth (ft.)		
			From	To	
Screen					
Material	Inside Diameter	Outside Diameter	Depth (ft.)		Slot Size
			From	To	
Annulus					
Material including additives for sealant	Size of Material	Amount (# of bags)	Depth (ft.)		Installation Method
			From	To	

PART III: WELL DEVELOPMENT DETAILS

PART III: WELL DEVELOPMENT DETAILS				
Well Development Date	Well Development Method: <input type="checkbox"/> Surge/Pump <input type="checkbox"/> Pump <input type="checkbox"/> Compressed Air <input type="checkbox"/> Other (explain)			
Development Duration				
Pumping Rate	Maximum Drawdown	Well Purged Dry <input type="checkbox"/> yes <input type="checkbox"/> no	Pumping Condition <input type="checkbox"/> continuous <input type="checkbox"/> intermittent	
Turbidity (if Measured):			Stabilized Water Level (BLS)	
Start:		End:		
Water appearance (color and odor) at start of development:				
Water appearance (color and odor) at end of development:				

Report Prepared By:	Date
Title/Company	License #

PLEASE ATTACH BORING LOG

[illegible]

Form 4: Application to Construct, Repair, Modify or Abandon a Well

STATE OF FLORIDA PERMIT APPLICATION TO CONSTRUCT,
REPAIR, MODIFY, OR ABANDON A WELL

- ☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River

THIS FORM **MUST** BE FILLED OUT COMPLETELY.

The water well contractor is responsible for completing this form and forwarding the permit to the appropriate delegated county where applicable.

CHECK BOX FOR APPROPRIATE DISTRICT. ADDRESS ON BACK OF PERMIT FORM.

Permit No. _____
Florida Unique I.D. _____
Permit Stipulations Required (See attached)
62-524 well <input type="checkbox"/>
CUP/WUP Application No. _____

ABOVE THIS LINE FOR OFFICIAL USE ONLY

Fold at this line in order that address is visible through envelope window

1. Owner, Legal Name of Entity if Corporation _____		Address _____		City _____		Zip _____		Telephone Number _____	
2. Well Location — Address, Road Name or Number, City _____									
3. Well Drilling Contractor _____		License No. _____		Telephone No. _____		<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">NW</div> <div style="text-align: center;">NE</div> </div> <div style="border: 1px dashed black; width: 100px; height: 100px; margin: 0 auto; position: relative;"> <div style="position: absolute; top: 0; right: 0; width: 50%; height: 50%; border: 1px dashed black;"></div> </div> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">SW</div> <div style="text-align: center;">SE</div> </div>			
Address _____		4. $\frac{1}{4}$ of (smallest) _____ $\frac{1}{4}$ of (biggest) _____		1/4 of Section _____					
City _____		State _____		Zip _____					
5. Township _____		Range _____							
6. County _____		Subdivision Name _____		Lot _____		Block _____		Unit _____	
7. Number of proposed wells _____ Check the use of well: (See back of permit for additional choices) _____ Domestic _____ Monitor (type) _____ _____ Irrigation (type) _____ Public Water Supply (type) _____ List Other _____ (See Back) (See Back) Distance from septic system _____ ft. Description of facility _____ Estimated start of construction date _____									
8. Application for: _____ New Construction _____ Repair/Modify _____ Abandonment _____ (Reason for Abandonment) _____									
9. Estimated: Well Depth _____ Casing Depth _____ Screen Interval from _____ to _____ Casing Material: Blk-Steel / Gal / PVC Casing Diameter _____ Seal Material _____									
10. If applicable: Proposed Grouting Interval From _____ to _____ Seal Material _____ From _____ to _____ Seal Material _____ From _____ to _____ Seal Material _____									
11. Telescope Casing _____ or Liner _____ (check one) Diameter _____ Blk-Steel / Galvanized / PVC Other (specify): _____									
12. Method of Construction: _____ Rotary _____ Cable Tool _____ Combination _____ _____ Auger _____ Other (specify): _____									
13. Indicate total No. of wells on site _____ List number of unused wells on site _____									
14. Is this well or any other well or water withdrawal on the owner's contiguous property covered under a Consumptive/Water Use Permit (CUP/WUP) or CUP/WUP Application? ___No___ ___Yes___ (If yes, complete the following) CUP/WUP No. _____ District well I.D. No. _____ Latitude _____ Longitude _____ Data obtained from GPS _____ or map _____ or survey _____ (map datum NAD 27 _____ NAD 83 _____)									
15. I hereby certify that I will comply with the applicable rules of Title 40, Florida Administrative Code, and that a water use permit or artificial recharge permit, if needed, has been or will be obtained prior to commencement of well construction. I further certify that all information provided on this application is accurate and that I will obtain necessary approval from other federal, state, or local governments, if applicable. I agree to provide a well completion report to the District within 30 days after drilling or the permit expiration, whichever occurs first.									
I certify that I am the owner of the property, that the information provided is accurate, and that I am aware of my responsibilities under Chapter 373, Florida Statutes, to maintain or properly abandon this well; or, I certify that I am the agent for the owner, that the information provided is accurate, and that I have informed the owner of his responsibilities as stated above. Owner consents to personnel of the WMD or a representative access to the well site.									
Signature of Contractor _____		License No. _____		Owner's or Agent's Signature _____		Date _____			

DO NOT WRITE BELOW THIS LINE — FOR OFFICIAL USE ONLY

Approval Granted By: _____ Issue Date: _____ Hydrologist Approval _____

Owner Number: _____ Fee Received: \$ _____ Receipt No.: _____ Check No.: _____

THIS PERMIT NOT VALID UNTIL PROPERLY SIGNED BY AN AUTHORIZED OFFICER OR REPRESENTATIVE OF THE WMD. IT SHALL BE AVAILABLE AT THE WELL SITE DURING ALL DRILLING OPERATIONS. **This permit is valid for 90 days from date of issue.**

Appendix C- Specific Capacity Testing

The purpose of specific capacity testing can be multi-fold, and depends on project demands. Specifically, some of the objectives of specific capacity testing include:

- 1) Determine the maximum pumping rate for a given well;
- 2) Obtain data to calculate first estimate of hydraulic conductivity and storativity; and
- 3) Obtain data to determine well efficiency.

Specific capacity tests can be conducted during or following development, or during purging for sampling. Specific capacity testing should be considered if the well is capable of sustaining a measurable yield, and if the test well pump is capable of sustaining a constant rate discharge. Specific capacity is defined as yield divided by drawdown, and is normally expressed as gallons per minute/feet of drawdown. Both pumping rate and drawdown are measured simultaneously in the tested well after a given amount of time has elapsed. Dividing the yield rate by the stabilized drawdown, gives the specific capacity. Specific capacity can vary with pumping duration, with specific capacity decreasing as pumping time increases. Additionally, specific capacity also generally decreases as discharge rate increases. Both of these responses are due to the dewatering of the aquifer within the domain of the cone of depression; for a given amount of drawdown, the yield progressively becomes less as the saturated thickness of the aquifer is reduced. Specific capacity may also vary with yield as function of the system efficiency, including the pump, well, discharge piping, well efficiency, etc., which all add an element of friction to the process.

The analysis of specific capacity test data is relatively straightforward, and based on equations presented in Jacob (1946) and Lohman (1972). Bradbury and Rothschild (1985) compiled a computer program to accept specific capacity data and output aquifer transmissivity. This program accounts for well loss and partial penetration, and is easily compiled from the reference. The treatment of partial penetration in the program is straightforward, and is treated mathematically in the reference. Well loss is less apparent, and is discussed further.

Well loss is an important factor in the analysis of specific capacity data when yield rate is substantially high. Well loss, or head loss due to well inefficiency, is due to turbulent flow of water through the well bore, into the well, and into the pump. Well loss is expressed as a percentage, or as a coefficient.

The equation representing general well loss (Walton, 1987) is expressed as:

Equation 1 $S_w = CQ^2$

Where:

S_w = drawdown component due to well loss, in feet

C = well coefficient, in sec^2/ft^5

Q = production well discharge rate, in cubic feet per second (cfs) (1 cfs = 449 gallons per minute [gpm])

Values of the well loss coefficient as used in the Bradbury and Rothschild program for production wells are generally less than 10 and are more often than not less than 2 (Walton, 1987). Typically, well loss is calculated using step drawdown test data. During a step drawdown test, yield rate and drawdown are measured synoptically while the pump is operated at successive stages at some fraction of full capacity. Using a step test data, the well loss coefficient may be estimated by the following equation (Walton, 1987):

Equation 2
$$C = \frac{(\Delta S_n / \Delta Q_n) - (\Delta S_{n-1} / \Delta Q_{n-1})}{(\Delta Q_{n-1} + \Delta Q_n)}$$

The following example illustrates a typical well loss coefficient calculation: A step drawdown test was performed. The pumping rates and times are shown below:

<u>Start Time</u>	<u>End Time</u>	<u>Pumping Rate (gpm)</u>
10:30	12:40	13.3
12:40	14:00	25.0
14.00	14.20	42.0

During the pumping periods, the water levels in the pumping well were recorded using an electronic water/level indicator. Data required to calculate the well loss coefficient are shown below:

<u>Step # (n)</u>	<u>Q (gpm)</u>	<u>Q (cfs)</u>	<u>ΔQ (cfs)</u>	<u>s (ft)</u>	<u>Δs (ft)</u>
1	13.3	0.0296	0.0296	5.6	5/.6
2	25.0	0.0557	0.0261	11.6	6.0
3	42.0	0.0935	0.0378	21.2	9.6

Where:

Q = Actual discharge for the time step

ΔQ = Increase in discharge for the time step

S = Drawdown at the time step pumping rate

ΔQ = Increase in drawdown from the previous time step

Using Equation 2, the well loss coefficients are:

$$\begin{array}{lcl} \text{C 1.2} & = & 730.7 \text{ sec}^2 / \text{ft}^5 \\ \text{C 2.3} & = & 377.1 \text{ sec}^2 / \text{ft}^5 \end{array}$$

Therefore, the average well loss coefficient is $553.9 \text{ sec}^2 / \text{ft}^5$. Using Equation 1, the well loss at 42 gpm is theoretically calculated to be 4.8 feet.

The importance of determining the well loss coefficient will depend on the yield rate of the test. Because of the association with turbulent flow, calculation of the well loss coefficient may be impractical and unnecessary for a yield rate of a few gallons per minute or less.

The procedure for conducting a specific capacity test is quite simple, and consists of the following general steps:

- 1) Open the well to vent;
- 2) Measure the static water level;
- 3) Insert pump into well and allow to equilibrate;
- 4) Remeasure water level to ensure equilibration following pump insertion;
- 5) Initiate pumping;
- 6) Measure yield rate and drawdown synoptically at regular and frequent intervals, and record on the specific capacity test form;
- 7) Pump until drawdown stabilized (subjective determination; generally measurements within 0.03 feet over a ten minute interval can be considered stable);
- 8) Terminate pumping; and
- 9) Measure water levels at frequent intervals during recovery to ensure original static water level is reached; the water level measured when residual drawdown stabilized should be used as the static water level.

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Website: www.testamericainc.com

Phone: (912) 354-7858

Fax: (912) 352-0165

[illegible]

BORING LOG TEMPLATE

[illegible]

SOIL SAMPLING FORM

GENERAL INFORMATION

Project:	Date:
Boring/Hole ID	Weather:
Sampling Team:	Sampler's Signature:

MEASUREMENTS

Core Interval Depth (ft bgs):	PID Reading (ppm)_____
Location in Core (from top in inches):_____	FID Reading (ppm)_____
Formation (circle): Surficial Aquifer Upper Hawthorne Lower Hawthorn Floridan	Other: _____

SAMPLE COLLECTION INFORMATION

Sample ID:	Split Sample (circle): YES / NO
Sample Date & Time:	Organization:
Duplicate: YES/NO	
Field Blank: YES/NO	
Parameters (circle): VOC's SVOC's Metals	Parameters: SAME/OTHER
Terpenes TOC Grain Size FOC TPH	
Porosity, Moisture, Bulk Density	
Other:	

COMMENTS

[illegible]

GROUNDWATER EVACUATION/SAMPLING FORM

GENERAL INFORMATION

Project:	Date:
Well/Boring No.:	Weather:
Sampling Team:	Sampler's Signature:

MEASUREMENTS

Screen Interval Depth:	Comments:
Length of Screen:	
Screen Interval Formation: Surficial Aquifer , Upper Hawthorn, Lower Hawthorn, Floridan	

WELL EVACUATION INFORMATION

Comments:	Evacuation Method (Submersible, Peristaltic, other):
	Begin Evacuation (Time):
	Evacuation Rate (GPM or LPM):
	Stop Evacuation (Time/Reason):
	Restart Time:

INDICATOR PARAMETERS

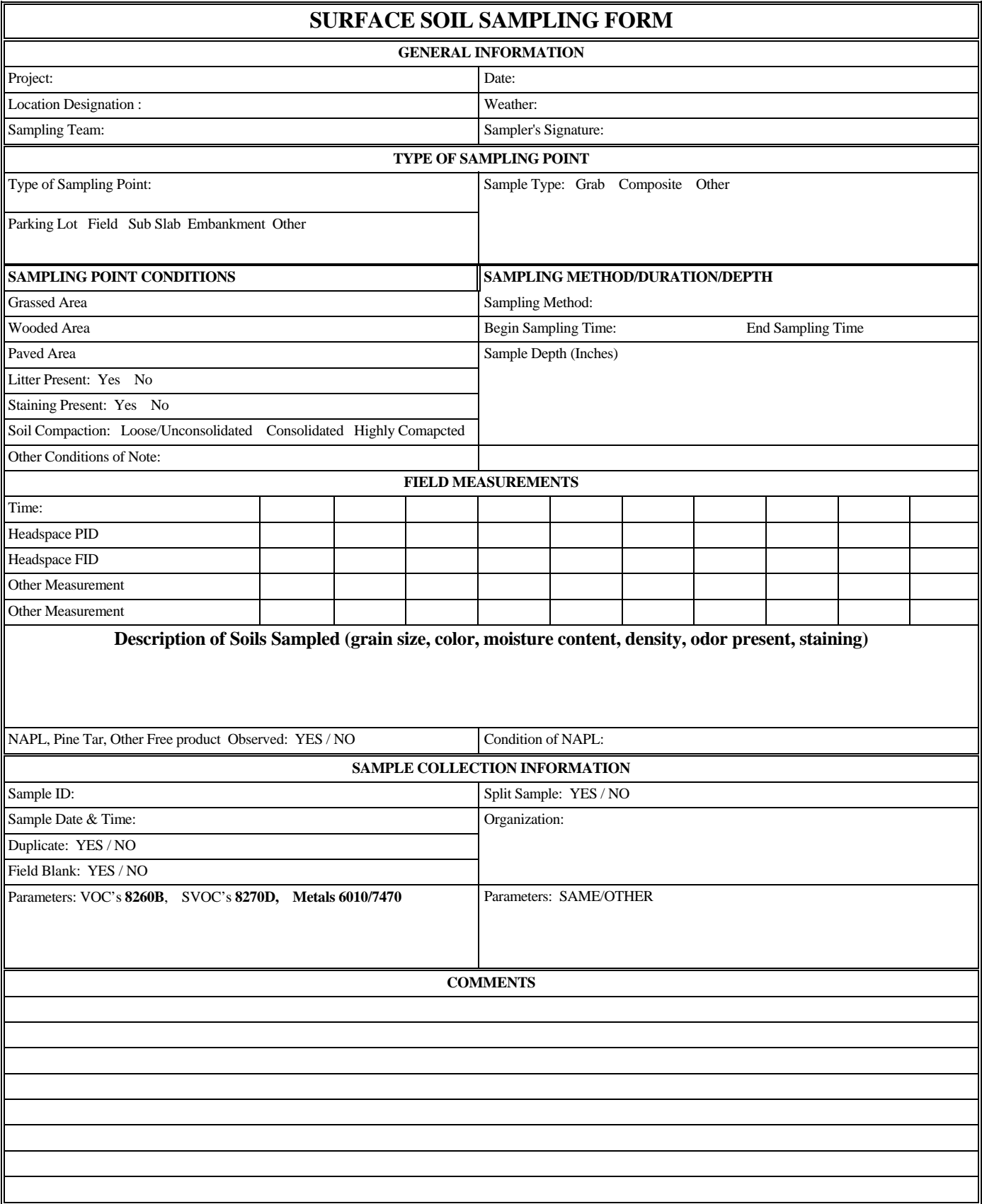
Time:									
Volume Purged (Gallons.):									
Temperature (°C):									
Specific Conductivity (mS/cm):									
pH:									
ORP/Eh (mv):									
Turbidity (NTU):									
D.O. (mg/L):									
Headspace (ppm):									
NAPL, Pine Tar, Observed: YES / NO				Drawdown Observed (ft):					
Odor: YES / NO				Pumped Dry: YES / NO					
End Well Evacuation (Time):				Total Volume Purged (Gallons):					

SAMPLE COLLECTION INFORMATION

Sample ID:	Split Sample: YES / NO
Sample Date & Time:	Organization:
Duplicate: YES / NO	
Field Blank: YES / NO	
Parameters: VOC's 8260B , SVOC's 8270D , Metals 6010/7470	Parameters: SAME/OTHER

COMMENTS

[illegible]



EXAMPLE



DAILY PRODUCTION & QUALITY CONTROL REPORT

Project No./Contract No.	Project Title / Location		Day of Report	Report No.
Site Mgr/ Field Team Leader	Phone	E-Mail		
Project Manager	Phone	E-Mail		

WEATHER CONDITIONS

--

WESTON PERSONNEL

Name	Position	Trade / Work Performed	Hrs	Signed HASP
Total WESTON Man-Hours			-	

SUBCONTRACTOR PERSONNEL

Name	Company	Trade / Work Performed	Hrs	Signed HASP
Total SUBCONTRACTOR Man-Hours			-	

VEHICLES and HEAVY EQUIPMENT

Equipment	Vendor / Tag No.	Work Performed	Operating Hours			
			Used	Idle	Repair	Total
						-

INSTRUMENTATION and SUPPLIES

Equipment	Vendor/ Tag No.	USE				
						-
						-
						-
						-
						-

DAILY PRODUCTION & QUALITY CONTROL REPORT

Project No./Contract No.	Project Title / Location	Day of Report	Report No.
--------------------------	--------------------------	---------------	------------

WORK COMPLETED

Description of Work Executed Today

HEALTH & SAFETY

Description of Health & Safety Actions Taken Today / Safety Inspections Conducted; Include # of HRs if work was performed in Levels A,B, or C

SAMPLING

Sampling completed, included required analysis

QUALITY CONTROL

Description of Quality Control Actions Taken Today / Quality Inspections Conducted

ISSUES AND/OR ITEMS OF DISCUSSION

Discussion of Issues / Concerns / Conversations / Topics

SITE VISITORS

Name	Organization	Purpose of Visit	In	Out	Signed HASP

Contractor Verification: On behalf of WESTON SOLUTIONS, INC., I certify this report is complete and correct, and all work performed and materials and equipment used during this reporting period are in compliance with the contract requirements, specifications, and standards, to the best of my knowledge, except as noted herein.

Report Prepared By / Title	Date Prepared	Signature

DAILY FIELD TAILGATE SAFETY MEETING REPORT

Project No./Contract No.	Project Title / Location	Day of Report
Hospital Name	Address/Phone	Nearest Phone



WORK ACTIVITIES (THIS SHIFT)									
Refer to Health & Safety Plan / Activities Hazard Analysis									
Act. No.	Task Description	Specs.	Risk Level		PPE Requirement			Topic Covered	
			Chem	Phys	Level	Modifications			
1									
2									

ADDITIONAL SITE HAZARDS	
Risks not identified within Health & Safety Plan / Activities Hazard Analysis	

CHEMICAL HAZARDS		
Description of Potential Hazards / Risks	Safety Procedures & Special Equipment/Techniques	Topic Covered

PHYSICAL HAZARDS		
Description of Potential Hazards / Risks	Safety Procedures & Special Equipment/Techniques	Topic Covered

SPECIAL TOPICS	
Additional / Special Topics (Incidents, Actions Taken, Items of Concerns, Etc.) Circled if Discussed Today	
Inclement Weather , Lifting, Decontamination Procedures, House Keeping, Traffic, Fatigue, PPE, Bio Hazards, Situational Awareness, Drill Rig Safety, Site Security, Driving Safety, Employee Working Alone,	

ATTENDEES		
Print Name	Organization	Sign Name

Additional Comments:


Example Airbills

Example Electronic Airbill

From: (904) 261-3085 Mark Taylor WESTON SOLUTIONS 94072 Summer Breeze Drive FERNANDINA BEACH, FL 32034	Origin ID: NIPA  315121502030300	Ship Date: 23FEB15 ActWgt: 50.0 LB CAD: 1055917754NET3610 Dims: 25 X 14 X 14 IN
SHIP TO: (912) 354-7858 Lisa Harvey Test America Inc-Savannah 5102 LAROCHE AVE SAVANNAH, GA 31404		Delivery Address Bar Code 
BILL SENDER Ref # 05791.004.010.0004 Invoice # PO # Dept #		TRK# 7729 7101 1551 0201 XX SAVA  5374203030EE4B
		TUE - 24 FEB 10:30A PRIORITY OVERNIGHT 31404 GA-US SAV

Example Paper Airbill

fedex.com 1.800.GoFedEx 1.800.463.3339



FedEx Tracking Number: 8070 3942 9338

1 From Please print and press hard.

Date _____ Sender's FedEx Account Number _____

Sender's Name _____ Phone () _____

Company _____

Address _____ Dept./Floor/Suite/Room _____

City _____ State _____ ZIP _____

2 Your Internal Billing Reference
Printed characters will appear on invoice.

3 To

Recipient's Name _____ Phone () _____

Company _____

Address _____ Dept./Floor/Suite/Room _____

We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address _____

Use this line for the HOLD location address or for continuation of your shipping address.

City _____ State _____ ZIP _____

4 Express Package Service *To most locations.

NOTE: Service order has changed. Please select carefully.

Next Business Day	2 or 3 Business Days
<input type="checkbox"/> FedEx First Overnight <small>Earliest next business morning delivery to select locations. Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.</small>	<input type="checkbox"/> FedEx 2Day A.M. <small>Second business morning. Saturday Delivery NOT available.</small>
<input type="checkbox"/> FedEx Priority Overnight <small>Next business morning. * Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.</small>	<input type="checkbox"/> FedEx 2Day <small>Second business afternoon. * Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.</small>
<input type="checkbox"/> FedEx Standard Overnight <small>Next business afternoon. * Saturday Delivery NOT available.</small>	<input type="checkbox"/> FedEx Express Saver <small>Third business day. * Saturday Delivery NOT available.</small>

5 Packaging *Declared value limit \$500.

☐ FedEx Envelope*
 ☐ FedEx Pak*
 ☐ FedEx Box
 ☐ FedEx Tube
 ☐ Other

6 Special Handling and Delivery Signature Options

☐ **SATURDAY Delivery**
NOT available for FedEx Standard Overnight, FedEx 2Day A.M., or FedEx Express Saver.

☐ **No Signature Required**
Package may be left without obtaining a signature for delivery.

☐ **Direct Signature**
Someone at recipient's address may sign for delivery. **Fee applies.**

☐ **Indirect Signature**
If no one is available at recipient's address, someone at a neighboring address may sign for delivery. For residential deliveries only. **Fee applies.**

Does this shipment contain dangerous goods?

☐ No
 ☐ Yes as per attached Shipper's Declaration.
 ☐ Yes Shipper's Declaration not required.
 ☐ Dry Ice UN 1845 x _____ kg

Dangerous goods (including dry ice) cannot be shipped in FedEx packaging or placed in a FedEx Express Drop Box.
☐ **Cargo Aircraft Only**

7 Payment Bill to:

☐ Sender Account in Section 1 will be billed.
☐ Recipient
☐ Third Party
☐ Credit Card
☐ Cash/Check

FedEx Acct. No. _____
 Credit Card No. _____
 Exp. Date _____

Total Packages _____
 Total Weight _____ lbs.
 Total Declared Value* _____

Your liability is limited to US\$100 unless you declare a higher value. See back for details. By using this Airbill you agree to the service conditions on the back of this Airbill and in the current FedEx Service Guide, including terms that limit our liability.


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Easy new Peel-and-Stick airbill. No pouch needed.
 Apply airbill directly to your package. See directions on back.

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Example Sample Documentation

Example Custody Seal

 Official Custody Seal	Name _____
	Date: _____

Example Sample Container Label

Project Name:	
Client:	Sample Date:
Sample ID:	Sample Time:
Preservative:	Sampled By:
Analysis Requested:	

FS 2200. Groundwater Sampling

1. INTRODUCTION AND SCOPE

1.1 Use these Standard Operating Procedures to collect groundwater samples. They are designed to ensure that the collected samples will be representative of water in the aquifer or target formation and that the samples have not been altered or contaminated by the sampling and handling procedures. These procedures apply to permanently and temporarily installed monitoring wells, wells constructed using “direct-push” techniques, wells with installed plumbing, remedial groundwater treatment systems and excavations where groundwater is present. Use of alternative, DEP-approved and properly documented procedures (e.g., Corporate SOP, ASTM Standards, alternative equipment, etc.) is acceptable if they meet the intent (e.g., sample representativeness and integrity) of this standard (see FA 1000).

1.2 The topics in this SOP include equipment and supply selection, equipment construction materials, and purging and sampling techniques.

1.3 Use the following DEP SOPs in conjunction with FS 2200:

- FA 1000 Regulatory Scope and Administrative Procedures for Use of DEP SOPs
- FC 1000 Cleaning/Decontamination Procedures
- FD 1000 Documentation Procedures
- FQ 1000 Field Quality Control Requirements
- FS 1000 General Sampling Procedures
- FS 2000 General Aqueous Sampling
- FT 1000 Field Testing and Measurement
- FT 1100 Field pH
- FT 1200 Field Specific Conductance
- FT 1400 Field Temperature
- FT 1500 Field Dissolved Oxygen
- FT 1600 Field Turbidity

2. Groundwater samples may be collected from a number of different configurations. Each configuration is associated with a unique set of sampling equipment requirements and techniques:

3. Wells without Plumbing: These wells require that equipment be brought to the well to purge and sample unless dedicated equipment is placed in the well.

4. Wells with In-Place Plumbing: Wells with in-place plumbing do not require that equipment be brought to the well to purge and sample. In-place plumbing is generally considered permanent equipment routinely used for purposes other than purging and sampling, such as for water supply. They are generally found at wellfields, industrial facilities, and private residences. See FS 2300 for procedures to sample potable water wells. Air Strippers or Remedial Systems: These types of systems are installed as remediation devices. Sample these wells like drinking water wells (see FS 2300).

FS 2201 *Equipment and Supplies*

Use groundwater purging and sampling equipment constructed of only non-reactive, non-leachable materials that are compatible with the environment and the selected analytes. In selecting groundwater purging and sampling equipment, give consideration to the depth of the

well, the depth to groundwater, the volume of water to be evacuated, the sampling and purging technique, and the analytes of interest. Refer to Tables FS 1000-1, FS 1000-2, FS 1000-3 and FS 2200-1 for selection of appropriate equipment.

Additional supplies such as reagents, preservatives, and field measurement equipment are often necessary.

1. FLOW CONTAINER: DEP recommends using a flow-through cell or container when collecting measurements for purging stabilization. The design must ensure that fresh formation water continuously contacts the measuring devices and does not aerate the sample or otherwise affect the groundwater properties.
2. PUMPS: All pumps or pump tubing must be lowered and retrieved from the well slowly and carefully to minimize disturbance to the formation water. This is especially critical at the air/water interface. Avoid the resuspension of sediment particles (turbidity) at the bottom of the well or adhered to the well casing during positioning of the pump or tubing.

2.1 Above-Ground Pumps

2.1.1 Variable Speed Peristaltic Pump: Use a variable speed peristaltic pump to purge groundwater from wells when the static water level in the well is no greater than 20-25 feet below land surface (BLS). If the water levels are deeper than 18-20 feet BLS, the pumping velocity will decrease.

2.1.1.1 A variable speed peristaltic pump can be used for normal purging and sampling (see FS 2213 and FS 2221), sampling low permeability aquifers or formations (see FS 2222) and collecting filtered groundwater samples (see FS 2225, section 1).

2.1.1.2 Most analyte groups can be sampled with a peristaltic pump if the tubing and pump configurations are appropriate. See Table FS 1000-3 for proper tubing selection and pump configurations.

2.1.2 Variable Speed Centrifugal Pump: A variable speed centrifugal pump can be used to purge groundwater from 2-inch and larger internal diameter wells. Do not use this type of pump to collect groundwater samples.

2.1.2.1 When purging is complete, do not allow the water that remains in the tubing to fall back into the well. Install a check valve at the end of the purge tubing, and withdraw the tubing slowly from the well while the pump is still running.

2.1.2.2 See Table FS 1000-3 for proper tubing selection and allowable analyte groups.

2.2 Submersible Pumps

2.2.1 Variable Speed Electric Submersible Pump: A variable speed submersible pump can be used to purge and sample groundwater from 2-inch and larger internal diameter wells.

2.2.1.1 A variable speed submersible pump can be used for normal purging and sampling (see FS 2213 and FS 2221), sampling low permeability aquifers or formations (see FS 2222) and collecting filtered groundwater samples (see FS 2225, section 1).

2.2.1.2 Make sure that the pump housing, fittings, check valves and associated hardware are constructed of stainless steel. Make sure that any other materials are compatible with the analytes of interest. See Table FS 1000-3 for restrictions.

2.2.1.3 Install a check valve at the output side of the pump to prevent backflow.

2.2.1.4 If purging and sampling for organics:

- The entire length of the delivery tube must be Teflon, Polyethylene or Polypropylene tubing. Do not use low-density polyethylene for the collection of samples for analysis of volatile organic compounds (VOCs).
- The electrical cord must be sealed in Teflon, Polyethylene or Polypropylene and any cabling must be sealed in Teflon, Polyethylene or Polypropylene, or be constructed of stainless steel.
- All interior components that contact the sample water (impeller, seals, gaskets, etc.) must be constructed of stainless steel or Teflon.

2.2.2 Variable Speed Bladder Pump: A variable speed positive displacement bladder pump (no-gas contact) can be used to purge and sample groundwater from 3/4-inch and larger internal diameter wells.

2.2.2.1 A variable speed bladder pump can be used for normal purging and sampling (see FS 2213 and FS 2221), sampling low permeability aquifers or formations (see FS 2222) and collecting filtered groundwater samples (see FS 2225, section 1).

2.2.2.2 The bladder pump system is composed of the pump, the compressed air tubing, the water discharge tubing, the controller and a compressor or compressed gas supply.

2.2.2.3 The pump consists of a bladder and an exterior casing or pump body that surrounds the bladder and two (2) check valves. These parts can be composed of various materials, usually combinations of polyvinyl chloride (PVC), Teflon, Polyethylene, and stainless steel. Other materials must be compatible with the analytes of interest. See Table FS 1000-3 for restrictions.

2.2.2.4 If purging and sampling for organics:

- The pump body must be constructed of stainless steel and the valves and bladder must be Teflon, Polyethylene or Polypropylene.
- The entire length of the delivery tube must be Teflon, Polyethylene or Polypropylene. Do not use low-density polyethylene for VOCs.
- Any cabling must be sealed in Teflon, Polyethylene or Polypropylene, or be constructed of stainless steel.
- Permanently installed pumps may have a PVC pump body as long as the pump remains in contact with the water in the well.

3. BAILERS:

3.1 Purging: DEP does not recommend using bailers for purging unless no other equipment can be used or purging with a bailer has been specifically authorized by a DEP program, permit, contract or order (see Table FS 2200-3). Use a bailer if there is non-aqueous phase liquid (free product) in the well or non-aqueous phase liquid is suspected to be in the well. If in doubt about the appropriateness of using a bailer at a site or during a particular sampling event, contact the appropriate DEP program or project manager. If a bailer is used, follow FS 2213, section 4, with no deviations.

3.2 Sampling: Bailers may be used to routinely collect some analyte groups or under specific circumstances for other analyte groups (see Table FS 2200-3).

3.3 Construction and Type:

3.3.1 Bailers must be constructed of materials compatible with the analytes of interest. See Table FS 1000-3 for restrictions.

3.3.2 Stainless steel, Teflon, Polyethylene and Polypropylene bailers may be used to sample all analytes. Low-density polyethylene is not suitable for the collection of VOCs.

3.3.3 Use disposable bailers when sampling grossly contaminated sample sources.

3.3.4 DEP recommends using dual check valve bailers when collecting samples.

3.3.5 Use bailers with a controlled flow bottom when collecting volatile organic samples.

3.3.6 Use bailers that can be pressurized when collecting filtered samples for metals.

3.4 Contamination Prevention:

3.4.1 Keep the bailer wrapped (foil, butcher paper, etc.) until just before use.

3.4.2 Use protective gloves to handle the bailer once it is removed from its wrapping.

3.4.3 Handle the bailer by the lanyard to minimize contact with the bailer surface.

4. LANYARDS

4.1 Lanyards must be made of non-reactive, non-leachable material such as cotton twine, nylon, or stainless steel; or, coated with Teflon, Polyethylene or Polypropylene.

4.1.1 Evaluate the appropriateness of the lanyard material with analyses of equipment blanks for the analytes of interest, as necessary.

4.2 Discard cotton twine, nylon, and non-stainless steel braided lanyards after sampling each monitoring well.

4.3 Decontaminate stainless steel, coated Teflon, Polyethylene and Polypropylene lanyards between monitoring wells (see FC 1003). They do not need to be decontaminated between purging and sampling operations.

4.4 Securely fasten lanyards to downhole equipment (bailers, pumps, etc.).

4.5 Do not allow lanyards used for downhole equipment to touch the ground surface.

FS 2210. GROUNDWATER PURGING

Perform procedures in the following sections to calculate purging parameters and to purge groundwater from monitoring wells, wells with installed plumbing, high-volume wells, air stripper systems and other remedial treatment systems.

FS 2211 *Water Level and Purge Volume Determination*

Collect representative groundwater samples from the aquifer. The amount of water that must be purged from a well is determined by the volume of water and/or field parameter stabilization.

1. GENERAL EQUIPMENT CONSIDERATIONS

1.1 Selection of appropriate purging equipment depends on the analytes of interest, the well diameter, transmissivity of the aquifer, the depth to groundwater and other site conditions.

1.2 Use a pump to purge the well.

1.3 Use a bailer if there is non-aqueous phase liquid in the well or non-aqueous phase liquid is suspected to be in the well.

1.4 Bailers may be used if approved by a DEP program, or if bailer use is specified in a permit, contract or DEP order (see Table FS 2200-3). If used, bailers must be of appropriate type and construction, and the user must follow the procedure outlined in FS 2213, section 4, with no deviations. If in doubt about the appropriateness of using a bailer at a site or during a particular sampling event, contact the appropriate DEP program or project manager. DEP does not recommend using bailers because improper bailing:

- 1.4.1 Introduces atmospheric oxygen which precipitates metals (i.e., iron) or causes other changes in the chemistry of the water in the sample (i.e., pH)
- 1.4.2 Agitates groundwater which biases volatile and semi-volatile organic analyses due to volatilization
- 1.4.3 Agitates the water in the aquifer and resuspends fine particulate matter
- 1.4.4 Surges the well, loosening particulate matter in the annular space around the well screen
- 1.4.5 Introduces dirt into the water column if the sides of the casing wall are scraped

2. INITIAL INSPECTION

- 2.1 Verify the identification of the monitoring well by examining markings, sign plates, placards or other designations.
- 2.2 Remove the well cover and remove all standing water around the top of the well casing (manhole) before opening the well cap.
- 2.3 Inspect the exterior protective casing of the monitoring well for damage and document the results of the inspection if there is a problem.
- 2.4 It is recommended that you place a protective covering around the well head. Replace the covering if it becomes soiled or ripped.
- 2.5 Inspect the well lock and determine whether the cap fits tightly. Replace the cap if necessary.

3. WATER LEVEL MEASUREMENTS: Use an electronic probe or chalked tape to determine the water level.

3.1 General Procedures

Perform these steps using either the electronic probe or chalked tape method.

- 3.1.1 Decontaminate all equipment that will contact the groundwater in the well before use.
- 3.1.2 Measure the depth to groundwater from the top of well casing to the nearest 0.01 foot and always measure from the same reference point or survey mark on the well casing. If there is no reference mark, measure from the north side of the casing.
- 3.1.3 Record the measurement and the reference point.

3.2 Electronic Probe

- 3.2.1 Follow the manufacturer's instructions for use.
- 3.2.2 Record the measurement.

3.3 Chalked Line Method: This method is not recommended if collecting samples for organic or inorganic parameters.

- 3.3.1 Lower chalked tape into the well until the lower end is in the water (usually determined by the sound of the weight hitting the water).
- 3.3.2 Record the length of the tape relative to the reference point (see section 3.2 above).
- 3.3.3 Quickly remove the tape from the well.
- 3.3.4 Record the length of the wetted portion to the nearest 0.01 foot.
- 3.3.5 Determine the depth to water by subtracting the length of the wetted portion (see section 3.5.3 above) from the total length (see section 3.5.2 above). Record the result.

4. WATER COLUMN DETERMINATION

4.1 Do not determine the total depth of the well by lowering the probe to the bottom of the well immediately before purging and sampling. If the well must be sounded, delay purging and sampling activities for at least 24 hours after the well was sounded or for a time sufficient to meet the purge stabilization criterion for turbidity. Alternatively, collect samples before sounding the well.

4.2 Subtract the depth to the top of the water column from the total well depth to determine the length of the water column.

4.3 The total well depth depends on the well construction. Some wells may be drilled in areas of sinkhole or karst formations or rock leaving an open borehole. Attempt to find the total borehole depth in cases where there is an open borehole below the cased portion.

5. WELL WATER VOLUME

5.1 Calculate the total volume of water in gallons in the well using the following equation:

$$V = (0.041)d \times d \times h$$

Where: V = volume in gallons

d = well diameter in inches

h = height of the water column in feet

5.2 The total volume of water in the well may also be determined with the following equation by using a casing volume per foot factor (Gallons per Foot of Water) for the appropriate diameter well:

$$V = [\text{Gallons per Foot of Water}] \times h$$

Where: V = volume in gallons

h = height of the water column in feet

Casing Internal Diameter	Approximate Gallons per Foot of Water
0.75"	0.02
1"	0.04
1.25"	0.06
2"	0.16
3"	0.37
4"	0.65
5"	1.02
6"	1.47
12"	5.88

5.3 Record all measurements and calculations in the field records.

6. Purging Equipment Volume

Calculate the total volume of the pump, associated tubing and container that is used for in situ measurements (flow container), if used, using the following equation:

$$V = p + ((0.041)d \times d \times l) + fc$$

Where: V = volume in gallons

p = volume of pump in gallons

d = tubing diameter in inches

l = length of tubing in feet

fc = volume of flow cell in gallons

7. When collecting samples from multiple wells on a site, if the groundwater elevation data are to be used to construct groundwater elevation contour maps, all water level measurements must be taken within the same 24-hour time interval unless a shorter time period is required by a DEP program. If the site is tidally influenced, complete the water level measurements within the time frame of an incoming or outgoing tide.

FS 2212 *Well Purging Techniques*

The selection of the purging technique and equipment is dependent on the hydrogeologic properties of the aquifer, especially depth to groundwater and hydraulic conductivity. The intent of proper purging is to stabilize the water level in the well and minimize the hydraulic stress to the hydrogeologic formation.

Every attempt must be made to match the pumping rate with the recharge rate of the well before evaluating the purging completion criteria.

A flowchart which summarizes purging procedure options is presented in Figure FS 2200-2.

Select equipment using the construction and configuration requirements specified in Table FS 2200-1. See the discussions in FS 2201.

1. MEASURING THE PURGE VOLUME: The volume of water that is removed during purging must be recorded. Measure the volume during the purging operation.

1.1 Collect the water in a graduated container and multiply the number of times the container was emptied by the volume of the container, or

1.2 Estimate the volume based on pumping rate. Use this technique only if the pumping rate is constant. Determine the pumping rate by measuring the amount of water that is pumped for a fixed period of time or use a flow meter.

1.2.1 Calculate the amount of water that is discharged per minute:

$$D = \frac{\text{Measured amount}}{\text{Total time in minutes}}$$

1.2.2 Calculate the time needed to purge one (1) well volume or one (1) purging equipment volume:

$$\text{Time} = \frac{V}{D}$$

Where: V = well volume determined from FS 2211, section 5, or purging equipment volume

D = discharge rate calculated in section 1.2.1. above

1.2.3 Make new measurements (see section 1.2.1 above) each time the pumping rate is changed, or

1.3 Use a totalizing flow meter.

1.3.1 Record the reading on the totalizer prior to purging.

1.3.2 Record the reading on the totalizer at the end of purging.

1.3.3 Subtract the reading on the totalizer prior to purging from the reading on the totalizer at the end of purging to obtain the volume purged.

1.4 Record in the field records the times that purging begins and ends.

2. Stabilization Measurement Frequency

2.1 Begin to record stabilization measurements after pumping the minimum volume as prescribed in options 2.3 – 2.5 below. Every attempt must be made to match the pumping rate with the recharge rate of the well before evaluating the purging criteria.

2.2 If the well screened interval is not known, use option 2.3, below.

2.3 Wells with Fully Submerged Screen and Pump or Intake Tubing Placed at the Top of the Water Column (conventional purge): Purge until the water level has stabilized (well recovery rate equals the purge rate), then purge a minimum of one (1) well volume prior to collecting measurements of the stabilization parameters. Allow at least one quarter (1/4) well volume to purge between subsequent measurements.

2.4 Wells with Fully Submerged Screen and Pump or Intake Tubing Placed Within the Screened Interval (minimizing purge volume): Purge until the water level has stabilized (well recovery rate equals the purge rate), then purge a minimum of one (1) volume of the pump, associated tubing and flow container (if used) prior to collecting measurements of the stabilization parameters. Take measurements of the stabilization parameters no sooner than two (2) minutes apart. Purge at least three (3) volumes of the pump, associated tubing and flow container, if used, prior to collecting a sample.

If the water level drops into the screened interval during purging, lower the pump or tubing intake as in FS 2213, section 1.3 below and follow purging procedures for partially submerged well screens (2.5 below).

2.5 Wells with a Partially Submerged Well Screen: Purge until the water level has stabilized (well recovery rate equals the purge rate), then purge a minimum of one (1) well volume prior to collecting measurements of the stabilization parameters. Take measurements of the stabilization parameters no sooner than two (2) minutes apart.

3. PURGING COMPLETION: DEP recommends the use of a flow-through container to measure the stabilization parameters discussed below. Alternatively, measure all parameters *in situ* by inserting measurement probes into the well at the depth appropriate for the purging option. Purging is considered complete if the criteria in section 3.1, 3.2 or 3.3 below are satisfied. Make every attempt to satisfy the criteria in section 3.1. Every attempt must be made to match the pumping rate with the recharge rate of the well before evaluating the purging criteria.

3.1 Three (3) consecutive measurements of the five (5) parameters listed below must be within the stated limits. The measurements evaluated must be the last three consecutive measurements taken before purging is stopped. The range between the highest and the lowest values for the last three measurements of temperature, pH and specific conductance cannot exceed the stated limits. The last three consecutive measurements of dissolved oxygen and turbidity must all be at or below the listed thresholds.

- Temperature: $\pm 0.2^{\circ} \text{C}$
- pH: ± 0.2 Standard Units
- Specific Conductance: $\pm 5.0\%$ of reading
- Dissolved Oxygen: $\leq 20\%$ Saturation
- Turbidity: ≤ 20 NTU

3.2 Naturally occurring conditions may prevent attaining the $\leq 20\%$ saturation criterion for dissolved oxygen, typically in surficial aquifers. See section 3.5, below.

3.3 Naturally occurring conditions may prevent attaining the ≤ 20 NTU criterion for turbidity. However, when collecting groundwater samples for metals or certain inorganic (e.g., phosphorus forms) or extractable organic (e.g. polynuclear aromatic hydrocarbons) chemicals, make every attempt to reduce turbidity to ≤ 20 NTU to avoid a potential turbidity-associated bias for these analytes. See section 3.5, below.

3.4 Document and report the following, as applicable, except that the last four (4) items only need to be submitted once:

- Purging rate.
- Drawdown in the well, if any.
- Pump or tubing intake placement.
- Length and location of the screened interval.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

3.5 If the criteria in section 3.1 above for dissolved oxygen and/or turbidity cannot be met, then three (3) consecutive measurements of the five (5) parameters listed below must be within the stated limits.

3.5.1 The measurements evaluated must be the last three consecutive measurements taken before purging is stopped. The range between the highest and the lowest values for the last three measurements cannot exceed the stated limits.

- Temperature: $\pm 0.2^{\circ} \text{C}$
- pH: ± 0.2 Standard Units
- Specific Conductance: $\pm 5.0\%$ of reading
- Dissolved Oxygen: $\pm 0.2 \text{ mg/L}$ or 10% , whichever is greater
- Turbidity: $\pm 5 \text{ NTUs}$ or 10% , whichever is greater

3.5.2 Additionally, document and report the following, as applicable, except that the last four (4) items only need to be submitted once:

- Purging rate.
- Drawdown in the well, if any.
- Pump or tubing intake placement.
- Length and location of the screened interval.
- A description of conditions at the site that cause the dissolved oxygen to be high and/or dissolved oxygen measurements made within the screened or open borehole portion of the well with a downhole dissolved oxygen probe.
- A description of conditions at the site that cause the turbidity to be high and any procedures that will be used to minimize turbidity in the future.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

3.5.3 If from review of the submitted data the Department determines that both the elevated Dissolved Oxygen and Turbidity measurements are due to naturally occurring

conditions, then only the first four (4) items are required to be submitted in future reports. However, if the Department cannot determine if the Dissolved Oxygen or Turbidity is elevated due to naturally occurring conditions, then in addition to the first four (4) items, a description of the conditions at the site that caused the affected parameter(s) to be high is required to be submitted in future reports.

3.6 If the stabilization parameters in either section 3.1 or 3.2 cannot be met, and all attempts have been made to minimize the drawdown, check the instrument condition and calibration, purging flow rate and all tubing connections to determine if they might be affecting the ability to achieve stable measurements. All measurements that were made during the attempt must be documented. The sampling team leader may decide whether or not to collect a sample or to continue purging after five (5) well volumes (conventional purge section 2.1 or 2.3 above) or five (5) volumes of the screened interval (minimizing purge volumes in section 2.2 above).

Further, the report in which the data are submitted must include the following, as applicable, except that the last four (4) items only need to be submitted once:

- Purging rate.
- Pump or tubing intake placement.
- Length and location of the screened interval.
- Drawdown in the well, if any.
- A description of conditions at the site that caused the dissolved oxygen to be high and/or dissolved oxygen measurements made within the screened or open borehole portion of the well with a downhole dissolved oxygen probe.
- A description of conditions at the site that caused the turbidity to be high and any procedures that will be used to minimize turbidity in the future.
- A description of the process and the data used to design the well.
- The equipment and procedure used to install the well.
- The well development procedure.
- Pertinent lithologic or hydrogeologic information.

If from review of the submitted data the DEP determines that both the elevated Dissolved Oxygen and Turbidity measurements are due to naturally occurring conditions, then only the first four (4) items are required to be submitted in future reports. However, if the DEP cannot determine if the Dissolved Oxygen or Turbidity is elevated due to naturally occurring conditions, then in addition to the first four (4) items, a description of the conditions at the site that caused the affected parameter(s) to be high is required to be submitted in future reports.

3.7 One fully dry purge (not recommended). This criterion applies only if purging was attempted per FS 2212, FS 2213, and section 3.4.1 below, and if it is impossible to balance the pumping rate with the rate of recharge at very low pumping rates (< 100 mL/minute).

3.7.1 If wells have previously and consistently purged dry, when purged according to FS 2212 and FS 2213, and the current depth to groundwater indicates that the well will purge dry during the current sampling event, minimize the amount of water removed from the well by using the same pump to purge and collect the sample:

3.7.1.1 Place the pump or tubing intake within the well screened interval.

3.7.1.2 Use very small diameter Teflon, Polyethylene or Polypropylene tubing and the smallest possible pump chamber volume to minimize the total volume of

water pumped from the well and to reduce drawdown. If samples will be collected for VOCs, do not use low-density polyethylene tubing.

3.7.1.3 Select tubing that is thick enough to minimize oxygen transfer through the tubing walls while pumping.

3.7.1.4 Pump at the lowest possible rate (100 mL/minute or less) to reduce drawdown to a minimum.

3.7.1.5 Purge at least two (2) volumes of the pumping system (pump, tubing and flow cell, if used).

3.7.1.6 Measure pH, Specific Conductance, Temperature, Dissolved Oxygen and Turbidity and begin to collect the samples (see FS 2222).

4. Collect samples immediately after purging is complete.

4.1 The time period between completing the purge and sampling cannot exceed six (6) hours.

4.2 If sample collection does not occur within one (1) hour of purging completion, re-measure the five (5) field parameters Temperature, pH, Specific Conductance, Dissolved Oxygen and Turbidity just prior to collecting the sample.

4.2.1 If the measured values are not within 10 percent of the previous measurements, re-purge the well.

4.2.2 See section 3.4 above when collecting samples from wells that have purged dry.

FS 2213 *Purging Wells Without Plumbing (Monitoring Wells)*

1. TUBING/PUMP PLACEMENT

1.1 Do not lower the pump or intake hose (tubing) to the bottom of the well. Pump or tubing placement procedures will be determined by the purging option selected in FS 2212, section 2 above or FS 2214 below.

1.1.1 Minimizing Purge Volume: If the following conditions can be met, position the intake hose (tubing) or pump in the screened or open borehole interval.

- The same pump must be used for both purging and sampling,
- The well screen or borehole interval must be less than or equal to 10 feet, and
- The well screen or borehole must be fully submerged.

1.1.2 If the position or length of the screened interval or open borehole is unknown or estimated, place the intake hose (tubing) or pump to perform conventional purging in 1.2 below.

1.1.3 Position the pump or intake hose when purging large-diameter deep wells with open boreholes using the procedure in FS 2214 below.

1.2 Conventional Purging: Position the pump or intake tubing in the top one foot of the water column or no deeper than necessary for the type of pump.

1.2.1 If purging with a bailer, see section 4 below.

1.3 Partially Submerged Screened Interval: If the well screen or open borehole is partially submerged, and the pump will be used for both purging and sampling, position the pump or intake hose (tubing) in the portion of the water column within the submerged screened or open borehole interval.

1.3.1 If the position or length of the screened interval or open borehole is unknown or estimated, place the intake hose (tubing) or pump to perform conventional purging in 1.2 above.

1.3.2 Purge large-volume, high-recharge wells as in FS 2214 below.

1.3.3 If purging with a bailer, see section 4 below.

2. NON-DEDICATED (PORTABLE) PUMPS

2.1 Variable Speed Peristaltic Pump

2.1.1 Install a new, 1-foot maximum length of silicone tubing in the peristaltic pump head.

2.1.2 Attach a short section of tubing to the discharge side of the pump-head silicone tubing and into a graduated container.

2.1.3 Attach one end of a length of new or precleaned transport tubing to the intake side of the pump head silicone tubing.

2.1.4 Place the transport tubing in the monitoring well per one of the options in FS 2213, section 1 above.

2.1.5 Measure the depth to groundwater at frequent intervals.

2.1.6 Record these measurements.

2.1.7 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.

2.1.8 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.

2.1.9 If the water table continues to drop during pumping, lower the tubing at the approximate rate of drawdown so that the water is removed from the top of the water column.

2.1.10 Record the purging rate each time the rate changes.

2.1.11 Measure the purge volume by one of the methods outlined in FS 2212, section 1.

2.1.12 Record this measurement.

2.1.13 Decontaminate the pump and tubing between wells (see FC 1000) or only the pump if precleaned tubing is used for each well.

2.2 Variable Speed Centrifugal Pump

2.2.1 Position fuel powered equipment **downwind** and at least 10 feet from the well head. Make sure that the exhaust faces downwind.

2.2.2 Place the decontaminated suction hose so that water is always pumped from the top of the water column.

2.2.3 Equip the suction hose with a foot valve to prevent purge water from re-entering the well.

2.2.4 Measure the depth to groundwater at frequent intervals.

2.2.5 Record these measurements.

2.2.6 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.

2.2.7 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.

2.2.8 If the water table continues to drop during pumping, lower the tubing at the approximate rate of drawdown so that the water is removed from the top of the water column.

2.2.9 Record the purging rate each time the rate changes.

2.2.10 Measure the purge volume by one of the methods outlined in FS 2212, section 1.

2.2.11 Record this measurement.

2.2.12 Decontaminate the pump and tubing between wells (see FC 1000) or only the pump if precleaned tubing is used for each well.

2.3 Variable Speed Electric Submersible Pump

2.3.1 Position fuel powered equipment downwind and at least 10 feet from the well head. Make sure that the exhaust faces downwind.

2.3.2 Carefully position the decontaminated pump per one of the options in FS 2213, section 1 above.

2.3.3 Measure the depth to groundwater at frequent intervals.

2.3.4 Record these measurements.

2.3.5 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.

2.3.6 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.

2.3.7 If the water table continues to drop during pumping, lower the tubing or pump at the approximate rate of drawdown so that the water is removed from the top of the water column.

2.3.8 Record the purging rate each time the rate changes.

2.3.9 Measure the purge volume by one of the methods outlined in FS 2212, section 1.

2.3.10 Record this measurement.

2.3.11 Decontaminate the pump and tubing between wells (see FC 1000) or only the pump if precleaned tubing is used for each well.

2.4 Variable Speed Bladder Pump

2.4.1 Position fuel powered equipment **downwind** and at least 10 feet from the well head. Make sure that the exhaust faces downwind.

2.4.2 Attach the tubing and carefully position the pump per one of the options in FS 2213, section 1 above.

2.4.3 Measure the depth to groundwater at frequent intervals.

2.4.4 Record these measurements.

2.4.5 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.

2.4.6 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal rate with the recharge rate.

2.4.7 If the water table continues to drop during pumping, lower the tubing or pump at the approximate rate of drawdown so that the water is removed from the top of the water column.

2.4.8 Record the purging rate each time the rate changes.

2.4.9 Measure the purge volume by one of the methods outlined in FS 2212, section 1.

2.4.10 Record this measurement.

2.4.11 Decontaminate the pump and tubing between wells (see FC 1000) or only the pump if precleaned tubing is used for each well.

3. DEDICATED PORTABLE PUMPS: Place dedicated pumps per one of the options in FS 2213, section 1 above.

3.1 Variable Speed Electric Submersible Pump

- 3.1.1 Position fuel powered equipment **downwind** and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
- 3.1.2 Measure the depth to groundwater at frequent intervals.
- 3.1.3 Record these measurements.
- 3.1.4 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.
- 3.1.5 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal with the recharge rate.
- 3.1.6 Record the purging rate each time the rate changes.
- 3.1.7 Measure the purge volume by one of the methods outlined in FS 2212, section 1.
- 3.1.8 Record this measurement.

3.2 Variable Speed Bladder Pump

- 3.2.1 Position fuel powered equipment **downwind** and at least 10 feet from the well head. Make sure that the exhaust faces downwind.
- 3.2.2 Measure the depth to groundwater at frequent intervals.
- 3.2.3 Record these measurements.
- 3.2.4 Adjust the purging rate so that it is equivalent to the well recovery rate to minimize drawdown.
- 3.2.5 If the purging rate exceeds the well recovery rate, reduce the pumping rate to balance the withdrawal with the recharge rate.
- 3.2.6 Record the purging rate each time the rate changes.
- 3.2.7 Measure the purge volume by one of the methods outlined in FS 2212, section 1.
- 3.2.8 Record this measurement.

4. BAILERS: DEP recommends against using bailers for purging except as a last contingency, or if free product is present in the well or suspected to be in the well. However, they may be used if approved by a DEP program, or specified in a permit, contract or DEP order (see Table FS 2200-3 and FS 2211, section 1.3). If in doubt about the appropriateness of using a bailer at a site or during a particular sampling event, contact the appropriate DEP program or project manager.

- 4.1 Minimize handling the bailer as much as possible.
 - 4.1.1 Remove the bailer from its protective wrapping just before use.
 - 4.1.2 Attach a lanyard of appropriate material (see FS 2201, section 4).
 - 4.1.3 Use the lanyard to move and position the bailer.
- 4.2 Lower and retrieve the bailer slowly and smoothly.
- 4.3 Lower the bailer carefully into the well to a depth approximately a foot above the water column.
 - 4.3.1 Do not lower the top of the bailer more than one (1) foot below the top of the water table so that water is removed from the top of the water column. Ensure that the length of the bailer does not exceed the length of the water column.
 - 4.3.2 Allow time for the bailer to fill with aquifer water as it descends into the water column.
- 4.4 Carefully raise the bailer.
 - 4.4.1 Retrieve the bailer at the same rate of 2 cm/sec until the bottom of the bailer has cleared to top of the water column.

4.5 Measure the purge volume by one of the methods outlined in FS 2212, section 1.

4.5.1 Record the volume of the bailer.

4.6 Continue to carefully lower and retrieve the bailer as described above until the purging completion conditions specified in FS 2212, section 3, have been satisfied.

4.6.1 Remove at least one (1) well volume before collecting measurements of the field parameters. Take each subsequent set of measurements after removing at least one quarter (1/4) well volume between measurements.

FS 2214 *Purging Large-Volume, High-Recharge Wells With Portable Pumps*

If a well originally constructed for high-flow-rate pumping will be sampled as a monitoring well, use these guidelines to develop a purging procedure applicable to the specific details of the well construction. Typical wells constructed for this purpose may be deep, large-diameter wells with a section of open borehole. Evaluate each well on a case-by-case basis and consider any available information on the construction and hydraulic performance of the well.

1. PURGING PROCEDURE

1.1 Place the pump at the top of the open borehole segment of the well.

1.2 Start purging while monitoring stabilization parameters as in FS 2212, section 3 above.

1.3 Purge at least one equipment volume before measuring stabilization parameters.

1.4 If the well is being purged for the first time using these guidelines, monitor stabilization parameters for an extended period until confident that sufficient volume has been pumped from the open borehole to draw fresh formation water into the pump tubing and flow-through container. Use the information obtained from the first-time purging of the well to determine the pumping rate and duration of purging required for future sampling events at the well.

1.5 Purge at least three equipment volumes before evaluating purging completion.

2. PURGING COMPLETION

2.1 Complete the purging of the well when the last three consecutive measurements of the purge stabilization parameters have met the applicable criteria specified in FS 2212, section 3 above.

3. Collect samples from the well using the procedures in FS 2221, section 1 below.

FS 2215. *Purging Wells With Plumbing (production wells or permanently installed pumps equipped with sampling ports or sampling spigots)*

Wells with in-place plumbing are commonly found at municipal water treatment plants, industrial water supplies, private residences, etc. Depending on the sampling objective for collecting samples using installed plumbing, purge the system and collect samples closest to the point of consumption, or, as close to the source well as possible. When purging is required and the purge volume of the plumbing system is not known, purge the system until the purging completion criteria in FS 2212, section 3, have been met.

1. CONTINUOUSLY RUNNING PUMPS

1.1 Select the spigot that is closest to the pump and before any storage tanks (if possible).

1.2 Remove all hoses, aerators and filters (if possible).

1.3 Open the spigot and purge at maximum flow.

- 1.4 If a storage tank is located between the pump and the spigot, purge the volume of the tank, lines and spigot.
- 1.5 If the spigot is before any storage tank, purge until sufficient volume is removed to flush the stagnant water from the spigot and the tap line to the spigot.
- 1.6 Reduce the flow rate to ≤ 500 mL/minute (a 1/8" stream) or approximately 0.1 gal/minute before collecting samples. When sampling for volatile organic compounds, reduce the flow to ≤ 100 mL/minute before collecting the samples.

2. INTERMITTENTLY RUNNING PUMPS

- 2.1 Select the spigot that is closest to the pump and before any storage tanks (if possible).
- 2.2 Remove all hoses, aerators and filters (if possible).
- 2.3 Open the spigot and purge sufficient volume at a maximum, practical flow rate to flush the spigot and lines and until the purging completion criteria in FS 2212, section 3, have been met.
- 2.4 If a storage tank is located between the pump and the spigot, purge the volume of the tank, lines and spigot.
- 2.5 Ensure that the purge stabilization measurement of dissolved oxygen is not biased with aeration of the sample by a high flow rate in the flow-through container.
- 2.6 Reduce the flow rate to ≤ 500 mL/minute (a 1/8" stream) or approximately 0.1 gal/minute before collecting samples. When sampling for volatile organic compounds, reduce the flow to ≤ 100 mL/minute before collecting the samples.

FS 2216. *Purging Airstrippers and Remedial Treatment Systems*

If collecting samples for groundwater contamination monitoring, follow FS 2215 above.

FS 2220. GROUNDWATER SAMPLING TECHNIQUES

1. Purge wells using the techniques outlined in FS 2210.
2. Replace the protective covering around the well if it is soiled or torn after completing the purging operations.
3. GENERAL CONSIDERATIONS FOR SAMPLING EQUIPMENT AND PROCEDURES

Follow all notes and restrictions as indicated in Table FS 2200-1 and as discussed in FS 2201.

NOTE: The only pumps that are currently approved for use in collecting samples for the analysis of volatile organic compounds (VOCs) through the pump without additional restrictions are stainless steel and Teflon variable speed submersible pumps; stainless steel and Teflon or Polyethylene variable speed bladder pumps; and, permanently installed variable speed bladder or submersible pumps with PVC bodies, as long as the PVC pump remains in contact with the water in the well at all times. Peristaltic pumps may be used for VOC sample collection only according to the requirements in this SOP.

- 3.1 Collect the sample into the sample container to be sent to the laboratory directly from the sampling tap or spigot, the pump delivery tubing or other sampling device. **Do not** use intermediate containers.
- 3.2 In order to avoid contaminating the sample or loss of analytes from the sample:
 - 3.2.1 Handle the sampling equipment as little as possible.
 - 3.2.2 Minimize the amount of equipment that is exposed to the sample, where possible.

3.2.3 Employ precautions and procedures specific to the collection of samples for VOC analysis.

3.2.3.1 Minimize aeration of samples collected for VOC analysis.

3.2.3.2 Reduce flow rates to 100 - 400 mL/minute when using a pump to collect VOC samples. Attempt to maximize the flow rate within this range. Do not sample at flow rates lower than 100 mL/minute or higher than 400 mL/minute.

3.2.3.3 See subpart FS 2221, section 1, including subsections 1.1 – 1.1.3.9, 1.2 – 1.2.3.3, 1.3.2 – 1.3.3.1, 1.3.4 – 1.3.4.2 and 1.4 for additional VOC sampling instructions, restrictions, precautions and criteria.

3.3 Dedicated Sampling Equipment

3.3.1 Whenever possible, use dedicated equipment because it significantly reduces the chance of cross-contamination.

3.3.2 Dedicated is defined as equipment that is to be used solely for one location for the life of that equipment (e.g., permanently mounted pump).

3.3.3 All material construction and restrictions from Table FS 2200-1 also apply to dedicated equipment. Purchase equipment with the most sensitive analyte of interest in mind.

3.4 Cleaning/Decontamination

3.4.1 Clean or ensure dedicated pumps are clean before installation. They do not need to be cleaned prior to each use but must be cleaned if they are withdrawn for repair or servicing.

3.4.2 Clean or make sure any permanently mounted tubing is clean before installation.

3.4.3 Change or clean tubing when the pump is withdrawn for servicing.

3.4.4 Clean any replaceable or temporary parts as specified in FC 1000.

3.4.5 Collect equipment blanks on dedicated pumping systems when the tubing is cleaned or replaced.

3.4.6 Clean or ensure dedicated bailers are clean before placing them into the well.

3.4.7 Collect an equipment blank on dedicated bailers before introducing them into the water column.

3.4.8 Suspend dedicated bailers above the water column if they are stored in the well.

FS 2221. *Sampling Wells Without Plumbing*

1. SAMPLING WITH PUMPS: Variable speed stainless steel and Teflon submersible pumps; stainless steel, Teflon or Polyethylene bladder pumps; and, permanently installed variable speed submersible or bladder pumps with PVC bodies (as long as the pump remains in contact with the water in the well at all times), may be used to sample for all organics. The pump tubing must be Teflon, polyethylene or polypropylene. Do not use low-density polyethylene (LDPE) bladders or tubing to collect samples for volatile organic compounds (VOCs). **Extractable organics** may be collected through a peristaltic pump if ≤ 1 foot of silicone tubing is used in the pump head or a vacuum trap is used (see Figure FS 2200-1 for specific configuration). Samples for **volatile organic compounds** (VOCs) may be collected through the peristaltic pump roller tubing if ≤ 1 foot of silicone tubing is used in the pump roller head, according to the instructions and restrictions listed in section 1.1.1, below. Follow all notes and restrictions as defined in Table FS 2200-1 and discussed in Equipment and Supplies (FS 2201) when using pumps to collect samples. Do not lower the pump or tubing to the bottom of the well.

1.1 Peristaltic Pump

1.1.1 Volatile Organics Collected Through the Pump Roller Tubing: Ensure that no more than a maximum length of one foot of new silicone tubing is installed in the peristaltic pump roller head assembly before the well is purged, if the same pump and tubing assembly is used to purge and sample the well. Otherwise, install a new length of silicone roller tubing as described above before beginning to sample (see NOTE below). If the pump will be used to sample more than one well, replace the silicone roller tubing before purging and sampling each new well. Use Teflon, Kynar, high-density polyethylene (HDPE) or similarly inert material for the drop (down-hole) and delivery tubing. Do not use low-density polyethylene (LDPE) tubing. Minimize aeration of the sample during collection. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible. For low-recharge wells, collect VOCs first after purging is completed, where excessive drawdown or dry purging occurs. **NOTE**: Depending on the recharge characteristics of the well and sampler skill, attempt to maximize the flow rate for VOC sample collection within the range stipulated below in sections 1.1.1.1 and 1.1.1.2. Collect the VOC sample directly into the sample container from the discharge flow exiting from the pump delivery tubing. Disconnect flow-through containers, manifolds, valves or other devices from the delivery tubing before collecting the VOC samples, if applicable. If the tubing assembly intended for VOC sample collection was not used to purge the well, begin pumping using the new sampling tubing assembly, adjust the pumping rate for the maximum possible flow rate for VOC sampling and pump a minimum of 3 equipment volumes (pump and tubing volume) through the entire tubing assembly before collecting the VOC samples. If the pump tubing is placed within the screened interval, new tubing cannot be reinserted into the well and the same tubing must be used for purging and sampling.

1.1.1.1 For wells with sufficient recharge where the pumping rate can be matched with the recharge rate, use tubing with the smallest practical inside diameter and collect VOC samples with a pumping rate in the range of 100 mL/minute – 400 mL/minute. Attempt to maximize the flow rate within this range. Do not reduce the flow rate below 100 mL/minute or exceed 400 mL/minute while sampling. Minimize aeration of the sample during collection, and observe all other precautions as indicated in FS 2000, subpart FS 2004. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible.

1.1.1.2 For low-recharge wells, use tubing with the smallest practical inside diameter and collect VOC samples with a pumping rate in the range of 100 mL/minute – 400 mL/minute. Attempt to maximize the flow rate within this range. Do not reduce the flow rate below 100 mL/minute (if possible) or exceed 400 mL/minute while sampling. Minimize aeration of the sample during collection, and observe all other precautions as indicated in FS 2000, subpart FS 2004. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible. Collect VOCs first after purging is completed, where excessive drawdown or dry purging occurs. See subpart FS 2212, section 3.7 for wells that purge dry.

1.1.2 Volatile Organics Using Manual Fill and Drain Method: This method is also denoted as the “straw” method (with gravity drain). Collect volatile organics last. If the pump tubing is placed within the screened interval, do not reinsert the tubing into the well after withdrawing, and do not repeat steps 1.1.2.3 through 1.1.2.6.

1.1.2.1 Insert sufficient length of drop tubing to provide enough sample volume to fill all necessary VOC sample containers, if possible.

- 1.1.2.2 Remove the drop tubing from the inlet side of the pump.
- 1.1.2.3 Submerge the drop tubing into the water column and allow it fill.
- 1.1.2.4 Remove the drop tubing from the well.
- 1.1.2.5 Prevent the water in the tubing from flowing back into the well.
- 1.1.2.6 Carefully allow the groundwater to drain by gravity into the VOC sample containers. Avoid turbulence. Do not aerate the sample.
- 1.1.2.7 Repeat steps 1.1.2.3 - 1.1.2.6 until enough sample containers are filled.

1.1.3 Volatile Organics Using the Pump to Fill and Drain the Tubing: This method is also denoted as the “straw” method with reverse-flow. Collect volatile organics last. If the pump tubing is placed within the screened interval, do not reinsert the tubing into the well after withdrawing, and do not repeat steps 1.1.3.2 through 1.1.3.8, below. Do not reduce the flow rate below 100 mL/minute or exceed 400 mL/minute while pumping. Do not collect sample that has passed through the pump roller head silicone tubing.

- 1.1.3.1 Insert sufficient length of drop tubing to provide enough sample volume to fill all necessary VOC sample containers, if possible.
- 1.1.3.2 Submerge the drop tubing into the water column.
- 1.1.3.3 Use the pump to fill the drop tubing.
- 1.1.3.4 Quickly remove the tubing from inlet side of the pump.
- 1.1.3.5 Prevent the water in the tubing from flowing back into the well.
- 1.1.3.6 Remove the drop tubing from the well and fill the VOC sample containers using the reverse-flow or gravity-drain methods in steps 1.1.3.7 or 1.1.3.8 below.
- 1.1.3.7 Reverse the flow on the peristaltic pump to deliver the sample into the VOC sample containers at a slow, steady rate. Avoid turbulence. Do not aerate the sample.
- 1.1.3.8 Or, remove the drop tubing from the inlet side of the pump and carefully allow the groundwater to drain into the VOC sample containers. Avoid turbulence. Do not aerate the sample.
- 1.1.3.9 Repeat steps 1.1.3.2 - 1.1.3.8 until enough VOC sample containers are filled.

1.1.4 Extractable Organics Collected Through Silicone Pump-Head Tubing:

- 1.1.4.1 Ensure that a 1-foot maximum length of new silicone tubing was installed in the peristaltic pump head assembly before the well was purged if the same pump is being used to purge and sample the well. Otherwise, install a new length of tubing as described above.
- 1.1.4.2 Collect extractable organic samples directly from the effluent delivery tubing (attached to discharge side of the silicone pump head tubing) into the sample container.
- 1.1.4.3 If there is a concern that sample analytes are absorbed, adsorbed, leached or otherwise affected or lost by pumping through the silicone pump-head tubing, sample the well using the organic trap assembly in 1.1.4 below.

1.1.5 Extractable Organics Using an Optional Organic Trap Assembly

- 1.1.5.1 Assemble the components of the pump and trap according to Figure FS 2200-1.
- 1.1.5.2 The sample container should be the trap bottle.

1.1.5.3 All equipment that contacts the groundwater **before** the sample container must be constructed of Teflon, Polyethylene, Polypropylene, stainless steel or glass, including the transport tubing to and from the sample container, the interior liner of the container cap and all fittings. **Do not use a rubber stopper as a cap.**

1.1.5.4 Connect the outflow tubing from the container to the influent side of the peristaltic pump.

1.1.5.5 Prevent the water in the down-hole delivery tubing from flowing back into the well while performing this connection.

1.1.5.6 Turn the pump on and reduce the flow rate to a smooth and even flow.

1.1.5.7 Discard a small portion of the sample to allow an air space.

1.1.5.8 Preserve (if required), label and complete the field notes.

1.1.6 Inorganics

1.1.6.1 Inorganic samples may be collected from the effluent tubing.

1.1.6.2 If samples are collected from the pump, decontaminate all tubing (including the tubing in the head) or change it between wells.

1.1.6.3 Preserve (if required), label and complete field notes.

1.2 Variable Speed Bladder Pump

1.2.1 If sampling for organics the pump body must be constructed of stainless steel and the valves and bladder must be Teflon, polyethylene or polypropylene. All tubing must be Teflon, Polyethylene, or Polypropylene and any cabling must be sealed in Teflon, Polyethylene or Polypropylene, or made of stainless steel. Do not use low-density polyethylene (LDPE) tubing or bladders for the collection of VOC samples.

1.2.2 After purging to a smooth even flow, reduce the flow rate.

1.2.2.1 When sampling for volatile organic compounds, reduce the flow rate to 100 – 400 mL/minute, if possible. Attempt to maximize the flow rate within this range.

1.2.3 Sampling for Volatile Organic Compounds (VOCs)

1.2.3.1 Use Teflon, Kynar, HDPE or similarly inert material for the bladder or tubing. Do not use LDPE bladders or tubing. Minimize aeration of the sample during collection. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible. For low-recharge wells, collect VOCs first after purging is completed, where excessive drawdown or dry purging occurs. Depending on the recharge characteristics of the well and sampler skill, attempt to maximize the flow rate for VOC sample collection within the range stipulated above in section 1.2.3. Collect the VOC sample directly into the sample container from the discharge flow exiting from the pump delivery tubing. Disconnect flow-through containers, manifolds, valves or other devices from the delivery tubing before collecting the VOC samples, if applicable.

1.2.3.2 If the pump and/or tubing assembly intended for VOC sample collection was not used to purge the well, begin pumping using the sampling pump and/or tubing assembly, adjust the pumping rate for the maximum possible flow rate for VOC sampling and pump a minimum of 3 equipment volumes (pump and tubing volume) through the entire tubing assembly before collecting the VOC samples.

1.2.3.3 If the pump is placed within the screened interval, use the same pump and tubing assembly for both purging and sampling.

1.3 Variable Speed Submersible Pump

1.3.1 The housing must be stainless steel.

1.3.2 If sampling for organics, the internal impellers, seals and gaskets must be constructed of stainless steel, Teflon, Polyethylene or Polypropylene. The delivery tubing must be Teflon, Polyethylene or Polypropylene. Do not use low-density polyethylene (LDPE) for the collection of VOC samples. The electrical cord must be sealed in Teflon, Polyethylene or Polypropylene, and any cabling must be sealed in Teflon, Polyethylene or Polypropylene, or constructed of stainless steel.

1.3.3 After purging to a smooth even flow, reduce the flow rate.

1.3.3.1 When sampling for volatile organic compounds, reduce the flow rate to 100 – 400 mL/minute, if possible. Attempt to maximize the flow rate within this range.

1.3.4 Sampling for Volatile Organic Compounds (VOCs)

1.3.4.1 Use Teflon, Kynar, HDPE or similarly inert material for the pump tubing. Do not use LDPE tubing. Minimize aeration of the sample during collection. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible. For low-recharge wells, collect VOCs first after purging is completed, where excessive drawdown or dry purging occurs. Depending on the recharge characteristics of the well and sampler skill, attempt to maximize the flow rate for VOC sample collection within the range stipulated above in section 1.3.4. Collect the VOC sample directly into the sample container from the discharge flow exiting from the pump delivery tubing. Disconnect flow-through containers, manifolds, valves or other devices from the delivery tubing before collecting the VOC samples, if applicable.

1.3.4.2 If the pump and/or tubing assembly intended for VOC sample collection was not used to purge the well, begin pumping using the sampling pump and/or tubing assembly, adjust the pumping rate for the maximum possible flow rate for VOC sampling and pump a minimum of 3 equipment volumes (pump and tubing volume) through the entire tubing assembly before collecting the VOC samples.

1.4 For all analytes, if the pump is placed within the screened interval, use the same pump and tubing assembly for both purging and sampling.

2. SAMPLING WITH BAILERS: A high degree of skill and coordination are necessary to collect representative samples with a bailer. When properly used, bailers may be used to collect samples for certain analyte groups and under specific conditions (see Table FS 2200-3). They must be of an appropriate type and construction (see FS 2201, section 3), and must be used as outlined below. If in doubt about the appropriateness of using a bailer at a site or during a particular sampling event, contact the appropriate DEP program or project manager.

2.1 General Considerations

2.1.1 Minimize handling the bailer as much as possible.

2.1.1.1 Wear sampling gloves.

2.1.1.2 Remove the bailer from its protective wrapping just before use.

2.1.1.3 Attach a lanyard of appropriate material (see FS 2201, section 4).

2.1.1.4 Use the lanyard to move and position the bailers.

2.1.2 Do not allow the bailer or lanyard to touch the ground.

2.1.3 Rinsing

2.1.3.1 If the bailer is certified precleaned, no rinsing is necessary.

2.1.3.2 If both a pump and a bailer are to be used to collect samples, rinse the exterior and interior of the bailer with sample water from the pump before removing the pump.

2.1.3.3 If the purge pump is not appropriate for collecting samples (e.g., non-inert components), rinse the bailer with by collecting a single bailer of the groundwater to be sampled. Use the technique described in section 2.2, Bailing Technique, below.

2.1.3.4 Discard the water appropriately.

2.1.3.5 **Do not** rinse the bailer if Oil & Grease, TRPHs, etc., (see FS 2006) are to be collected.

2.2 Bailing Technique

2.2.1 Collect all samples that are required to be collected with a pump before collecting samples with the bailer.

2.2.2 Raise and lower the bailer gently to minimize stirring up particulate matter in the well and the water column which can increase sample turbidity.

2.2.3 Lower the bailer carefully into the well to a depth approximately a foot above the water column. Ensure that the length of the bailer does not exceed the length of the water column.

2.2.3.1 When the bailer is in position, lower the bailer into the water column at a rate of 2 cm/sec until the desired depth is reached (see section 2.2.3 above).

2.2.4 Do not lower the top of the bailer more than one (1) foot below the top of the water table so that water is removed from the top of the water column.

2.2.5 Allow time for the bailer to fill with aquifer water as it descends into the water column.

2.2.6 Do not allow the bailer to touch the bottom of the well or particulate matter will be incorporated into the sample.

2.2.6.1 Carefully raise the bailer (see section 2.2.2 above). Retrieve the bailer at the same rate of 2 cm/sec until the bottom of the bailer has cleared to top of the water column.

2.2.7 Lower the bailer to approximately the same depth each time.

2.2.8 Collect the sample.

2.2.8.1 Install a device to control the flow from the bottom of the bailer and discard the first few inches of water. Reduce the flow to ≤ 100 mL/minute when collecting VOC samples.

2.2.8.2 Fill the appropriate sample containers by allowing the sample to slowly flow down the side of the container. Minimize aeration of VOC samples.

2.2.8.3 Discard the last few inches of water in the bailer.

2.2.9 Repeat steps 2.2.1 through 2.2.8.3 for additional samples.

2.2.10 Measure the DO, pH, temperature, turbidity and specific conductance after the final sample has been collected.

2.2.10.1 Record all measurements and note the time that sampling was completed.

3. SAMPLING WELLS WITH FLOATING NON-AQUEOUS PHASE LIQUID: DEP does not recommend the sampling of wells with floating non-aqueous phase liquid for trace contaminants. This concerns primarily petroleum related sites, but includes any chemical product (e.g., solvent) that floats on the water table. Sampling is acceptable if the information is to be used for the purpose of remedial design.

Sample data from such wells cannot provide useful information regarding the level of contamination. Furthermore, these wells typically do not provide legitimate data because of

permanent chemical contamination from product contact with the well casing for an extended period of time.

DEP does reserve the right to require sampling of these wells, not for levels of trace contaminants, but for confirmation of an appropriate remediation technique. This type of sampling is performed **below** the non-aqueous phase layer (see section 3.2 below).

3.1 Non-Aqueous Phase Liquid Sampling: Non-aqueous phase liquid may be evident in a cased monitoring well or in an open excavation.

3.1.1 Non-aqueous phase liquid is normally sampled for two reasons:

- Documentation for its existence and thickness; and
- Determination of the type of product so that the proper analyses can be performed to determine extent. This is only feasible for relatively recent releases as it may not be possible to identify weathered product.

3.1.2 Disposable plastic (acrylic, clear PVC) bailers are recommended for sampling. Disposable Polyethylene and Polypropylene bailers are also acceptable. Other wide mouth vessels may be used for sampling non-aqueous phase liquid in an excavation.

3.1.3 Monitoring Well

3.1.3.1 If a non-aqueous phase liquid is identified in a monitoring well during the water level measurement, measure its thickness in the well. If the thickness of the non-aqueous phase liquid is greater than 0.01 foot or product globules are present, collect a sample using a precleaned disposable bailer.

3.1.3.2 Measure the product thickness to the nearest 0.01 foot after withdrawing the bailer.

3.1.3.3 Pour a portion of the product into a glass sample container.

3.1.3.4 This sample is considered a concentrated waste. Therefore, package the container in protective wrapping to prevent breakage, isolate from other samples, and ice to 4°C.

3.1.4 Excavation

3.1.4.1 If non-aqueous phase liquid is observed in an open excavation, a glass sample container or a precleaned intermediate vessel may be used to collect the sample.

3.1.4.2 Securely tie a lanyard to the container and lower it into the excavation.

3.1.4.3 Gently lower and retrieve the container so that no solid material is released or collected.

3.1.4.4 If sufficient water is available, a bailer can be used.

3.1.4.5 Although not recommended, screened casing can be placed (or augered and placed) in the bottom of the excavation and the product sampled with a bailer.

3.1.4.6 Avoid dangerous situations, such as standing too close to the edge of an excavation, riding in the backhoe bucket, or entering a trench or excavation that may collapse.

3.1.4.7 DEP recommends following all applicable OSHA regulations.

3.2 Sampling Below Product

3.2.1 This type of depth-specific sampling to attempt to sample the dissolved constituents in the water column below the product layer is performed only at the request of DEP or its designee.

3.2.2 These data provide information that helps define adequate groundwater treatment. Without these data, incorrect (and sometimes unnecessarily expensive) remediation techniques may be designed for a situation where they are not required.

3.2.3 There are some substantial logistical problems involved with sending a sampler through non-aqueous phase liquid to sample the groundwater below. Although there are some products designed specifically for this type of sampling, they are expensive and the results may not be commensurate with their cost. The use of “self-engineered” equipment or coverings may be the best option.

3.2.4 These data are only to be used for qualitative use and will aid in deciding on an appropriate remediation technique.

3.2.5 Wrapping bailers and tubing in plastic seems to be the most popular technique in getting past the product layer.

3.2.6 Although not recommended, some have wrapped submersible pumps in several layers of plastic and retrieved each layer by a separate lanyard. One suggestion would be to use a rigid piece of stainless steel tubing wrapped in plastic.

3.2.6.1 Once the covered tubing is past the layer, pull up on the plastic, piercing the plastic and exposing the (somewhat) clean tubing inlet.

3.2.6.2 Introduce the wrapped hose slowly to not entrain any more product into the dissolved layer located below.

3.2.6.3 Also, perform this procedure with a peristaltic pump or a vacuum pump linked to a trap bottle. To use this setup, the water table must be no deeper than 15-20 feet, realizing that actual sampling may be occurring several feet below the product layer.

FS 2222. *Sampling Low Permeability Aquifers or Wells That Have Purged Dry*

1. Collect the sample(s) after the well has been purged according to FS 2212, section 3.4. Minimize the amount of water removed from the well by using the same pump to purge and collect the sample. If the well has purged dry, collect samples as soon as sufficient sample water is available. If samples for additional analytes other than VOCs will be collected, fill the VOC sample containers last, if possible. However, collect VOCs first after purging is completed, where excessive drawdown or dry purging occurs.
2. Measure the five (5) field parameters Temperature, pH, Specific Conductance, Dissolved Oxygen and Turbidity at the time of sample collection.
3. Advise the analytical laboratory and the client that the usual amount of sample for analysis may not be available.

FS 2223. *Sampling Wells With In-Place Plumbing*

1. If a storage tank is present, locate a cold water spigot, valve or other sampling point close to the well head between the pump and the storage tank. If there is no sampling location between the pump and the storage tank, locate the spigot, valve or other sampling point closest to the tank.
 - 1.1 Depending on the sampling objective for collecting samples using installed plumbing, purge the system and collect samples closest to the point of consumption, or, as close to the source well as possible.
2. Remove all screens or aerators and reduce the flow rate to no more than 500 mL/minute. If collecting samples for volatile organic compounds, reduce the flow rate to 100 mL/minute or less. Collect the samples directly into the appropriate containers.

FS 2224. *Sampling Airstripper and Remedial Treatment System Sampling*

1. Reduce the flow rate to less than 500 mL/minute and begin sample collection.
2. If collecting samples for volatile organic compounds, reduce the flow rate to 100 mL/minute or less.
3. Collect the samples directly into the appropriate containers.

FS 2225. *Filtering Groundwater Samples*

Filtered groundwater samples can only be collected after approval from the DEP program or project manager. If filtering is approved, the DEP program or permit condition may require both filtered and unfiltered samples to be collected, analyzed and reported.

1. FILTERING GROUNDWATER FOR METALS:

1.1 Unless specified otherwise by the DEP program, use a new, disposable, high capacity, 1- μ m in-line filter.

1.2 Use a variable speed peristaltic, bladder or submersible pump with the in-line filter fitted on the outlet end.

1.2.1 Peristaltic pumps, bladder pumps or submersible pumps can be used when water levels are no greater than 20 to 25 feet deep.

1.2.2 Bladder pumps or submersible pumps must be used when water levels are greater than 20 to 25 feet deep.

1.3 Ensure that a 1-foot maximum length of new, silicone tubing was installed in the peristaltic pump head assembly before the well was purged if the same pump is being used to purge and sample the well. Otherwise, install a new length of tubing as described above.

1.4 Ensure that new or precleaned delivery tubing was assembled with the peristaltic pump before the well was purged if the same pump is being used to purge and sample the well. Otherwise, assemble the pump with new or precleaned delivery tubing and the new filter.

1.5 Insert the filter on the high pressure side (i.e., on the delivery side) of the pump.

1.5.1 Flush the filter before attaching to the pump tubing assembly with 30-50 mL of analyte free water or an inert gas (nitrogen) to remove atmospheric oxygen;

1.5.2 Or, with the filter attached to the pump tubing assembly, hold the filter upright with the inlet and outlet in the vertical position and pump water from the aquifer through the filter until all atmospheric oxygen has been removed.

1.6 Collect the filtered samples directly into the sample container from the high-pressure (delivery) side of the pump tubing assembly.

1.6.1 Collect filtered samples by either of the methods in 1.6.1.3 or 1.6.1.4 below if the static water level in the well is too deep for a variable speed peristaltic pump and a variable speed electric submersible pump or variable speed bladder pump is not available.

1.6.1.1 Do not agitate the sample or expose it to atmospheric oxygen.

1.6.1.2 **Do not** pour the sample into any intermediate vessel for subsequent filtration.

1.6.1.3 Collect the sample in a Polyethylene, Teflon or Polypropylene bailer that can be pressurized. When the bailer has been retrieved, immediately connect the filter and begin to pressurize the bailer;

- 1.6.1.4 Or, collect the sample with a bailer and immediately place the intake tube of the peristaltic pump into the full bailer and begin pumping the water through the filter as described in section 1.2 above.
- 1.7 **Do not** use the following equipment for filtering groundwater samples for metals:
- 1.7.1 Any pump and apparatus combination in which the filter is on the vacuum (suction) side of the pump.
- 1.7.2 Any type of syringe or barrel filtration apparatus.
- 1.7.3 Any filter that is not encased in a one-piece, molded unit.
2. Filtering groundwater for non-metallic analytes
- 2.1 The following analytes cannot be filtered:
- Oil and Grease
 - Total Recoverable Petroleum Hydrocarbons (TRPH)
 - FL-PRO
 - Volatile Organic Compounds (VOC)
 - Microbiological Analytes
 - Volatile Inorganic Compounds (e.g., Hydrogen Sulfide)
- 2.2 Unless specified otherwise by the regulatory program, use a new, disposable, high capacity, 0.45 µm in-line filter.
- 2.3 Assemble the pump, tubing and filter as in 1.2 – 1.5 above.
- 2.4 Flush the filter as in 1.5.1 or 1.5.2 above.
- 2.5 Collect the samples as in 1.6 – 1.6.1.4 above.

Appendix FS 2200
Tables, Figures and Forms

Table FS 2200-1 Equipment for Collecting Groundwater Samples

Table FS 2200-2 Dissolved Oxygen Saturation

Table FS 2200-3 Allowable Uses for Bailers

Figure FS 2200-1 Pump and Trap for Extractable Organics

Figure FS 2200-2 Groundwater Purging Procedures

Table FS 2200-1
Equipment for Collecting Groundwater Samples

Activity	Equipment Type
Well Purging	Variable speed centrifugal pump Variable speed submersible pump Variable speed bladder pump Variable speed peristaltic pump Bailer with lanyard: Not Recommended
Well Stabilization	pH meter DO meter Conductivity meter Thermometer/Thermistor Turbidimeter Flow-through cell Multi-function meters
Sample Collection	Variable speed peristaltic pump Variable speed submersible pump Variable speed bladder pump Bailer with lanyard (See Table FS 2200-3)
Filtration	Variable speed peristaltic pump Variable speed submersible pump Variable speed bladder pump Pressurized bailer 1.0 µm high capacity molded filter 0.45 µm high capacity molded filter
Groundwater Level	Electronic sensor Chalked tape

Table FS 2200-2
Dissolved Oxygen Saturation

TEMP	D.O.	mg/L	TEMP	D.O.	mg/L	TEMP	D.O.	mg/L	TEMP	D.O.	mg/L
deg C	SAT.	20%	deg C	SAT.	20%	deg C	SAT.	20%	deg C	SAT.	20%
15.0	10.084	2.017	19.0	9.276	1.855	23.0	8.578	1.716	27.0	7.968	1.594
15.1	10.062	2.012	19.1	9.258	1.852	23.1	8.562	1.712	27.1	7.954	1.591
15.2	10.040	2.008	19.2	9.239	1.848	23.2	8.546	1.709	27.2	7.940	1.588
15.3	10.019	2.004	19.3	9.220	1.844	23.3	8.530	1.706	27.3	7.926	1.585
15.4	9.997	1.999	19.4	9.202	1.840	23.4	8.514	1.703	27.4	7.912	1.582
15.5	9.976	1.995	19.5	9.184	1.837	23.5	8.498	1.700	27.5	7.898	1.580
15.6	9.955	1.991	19.6	9.165	1.833	23.6	8.482	1.696	27.6	7.884	1.577
15.7	9.934	1.987	19.7	9.147	1.829	23.7	8.466	1.693	27.7	7.870	1.574
15.8	9.912	1.982	19.8	9.129	1.826	23.8	8.450	1.690	27.8	7.856	1.571
15.9	9.891	1.978	19.9	9.111	1.822	23.9	8.434	1.687	27.9	7.842	1.568
16.0	9.870	1.974	20.0	9.092	1.818	24.0	8.418	1.684	28.0	7.828	1.566
16.1	9.849	1.970	20.1	9.074	1.815	24.1	8.403	1.681	28.1	7.814	1.563
16.2	9.829	1.966	20.2	9.056	1.811	24.2	8.387	1.677	28.2	7.800	1.560
16.3	9.808	1.962	20.3	9.039	1.808	24.3	8.371	1.674	28.3	7.786	1.557
16.4	9.787	1.957	20.4	9.021	1.804	24.4	8.356	1.671	28.4	7.773	1.555
16.5	9.767	1.953	20.5	9.003	1.801	24.5	8.340	1.668	28.5	7.759	1.552
16.6	9.746	1.949	20.6	8.985	1.797	24.6	8.325	1.665	28.6	7.745	1.549
16.7	9.726	1.945	20.7	8.968	1.794	24.7	8.309	1.662	28.7	7.732	1.546
16.8	9.705	1.941	20.8	8.950	1.790	24.8	8.294	1.659	28.8	7.718	1.544
16.9	9.685	1.937	20.9	8.932	1.786	24.9	8.279	1.656	28.9	7.705	1.541
17.0	9.665	1.933	21.0	8.915	1.783	25.0	8.263	1.653	29.0	7.691	1.538
17.1	9.645	1.929	21.1	8.898	1.780	25.1	8.248	1.650	29.1	7.678	1.536
17.2	9.625	1.925	21.2	8.880	1.776	25.2	8.233	1.647	29.2	7.664	1.533
17.3	9.605	1.921	21.3	8.863	1.773	25.3	8.218	1.644	29.3	7.651	1.530
17.4	9.585	1.917	21.4	8.846	1.769	25.4	8.203	1.641	29.4	7.638	1.528
17.5	9.565	1.913	21.5	8.829	1.766	25.5	8.188	1.638	29.5	7.625	1.525
17.6	9.545	1.909	21.6	8.812	1.762	25.6	8.173	1.635	29.6	7.611	1.522
17.7	9.526	1.905	21.7	8.794	1.759	25.7	8.158	1.632	29.7	7.598	1.520
17.8	9.506	1.901	21.8	8.777	1.755	25.8	8.143	1.629	29.8	7.585	1.517
17.9	9.486	1.897	21.9	8.761	1.752	25.9	8.128	1.626	29.9	7.572	1.514
18.0	9.467	1.893	22.0	8.744	1.749	26.0	8.114	1.623	30.0	7.559	1.512
18.1	9.448	1.890	22.1	8.727	1.745	26.1	8.099	1.620	30.1	7.546	1.509
18.2	9.428	1.886	22.2	8.710	1.742	26.2	8.084	1.617	30.2	7.533	1.507
18.3	9.409	1.882	22.3	8.693	1.739	26.3	8.070	1.614	30.3	7.520	1.504
18.4	9.390	1.878	22.4	8.677	1.735	26.4	8.055	1.611	30.4	7.507	1.501
18.5	9.371	1.874	22.5	8.660	1.732	26.5	8.040	1.608	30.5	7.494	1.499
18.6	9.352	1.870	22.6	8.644	1.729	26.6	8.026	1.605	30.6	7.481	1.496
18.7	9.333	1.867	22.7	8.627	1.725	26.7	8.012	1.602	30.7	7.468	1.494
18.8	9.314	1.863	22.8	8.611	1.722	26.8	7.997	1.599	30.8	7.456	1.491
18.9	9.295	1.859	22.9	8.595	1.719	26.9	7.983	1.597	30.9	7.443	1.489

Derived using the formula in Standard Methods for the Examination of Water and Wastewater, Page 4-101, 18th Edition, 1992

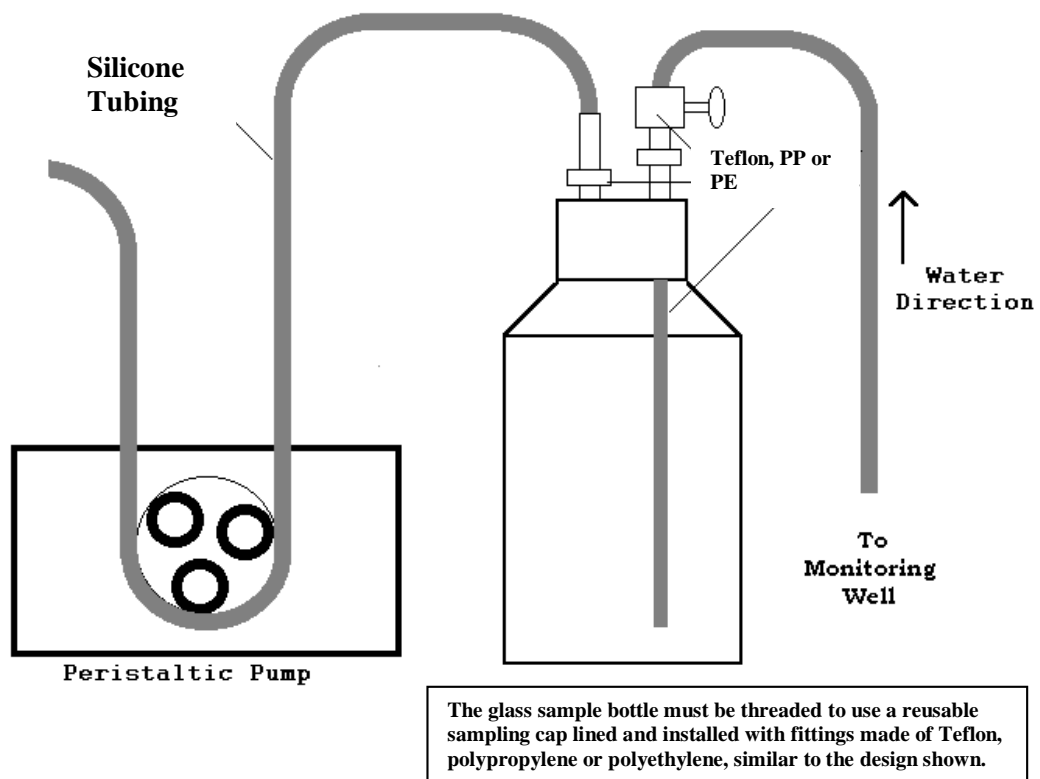
Table FS 2200-3
Allowable Uses for Bailers

• ANALYTE GROUP(S)	• PURGING (Not Recommended)	• SAMPLING	
	Use:	Use:	Not Recommended:
Volatile Organics Extractable Organics Radionuclides, including Radon Metals Volatile Sulfides	If allowed by permit, program, contract or order or If operated by a skilled individual with documented training in proper techniques. Field documentation must demonstrate that the procedure in FS 2213, section 4 was followed without deviation.	If concentrations exceed action levels, the purpose is to monitor effective treatment, and the DEP program allows the use of bailers; or If specified by DEP permit, program, contract or order. or If operated by a skilled individual with documented training in proper techniques and using appropriate equipment. Field documentation must demonstrate that the procedure in FS 2221, section 2 was followed without deviation.	If concentrations are near or below the stated action levels; or If a critical decision (e.g., clean closure) will be made based on the data; or If data are to demonstrate compliance with a permit or order.
Petroleum Hydrocarbons (TRPH) & Oil & Grease	If allowed by permit, program, contract or order or If operated by a skilled individual with documented training in proper techniques. Field documentation must demonstrate that the procedure in FS 2213, section 4 was followed without deviation.	Only if allowed by permit, program, contract or order as samples should be collected into the container without intermediate devices.	Unless allowed by permit, program, contract or order.

DEP-SOP-001/01
FS 2200 Groundwater Sampling

• ANALYTE GROUP(S)	• PURGING (Not Recommended)	• SAMPLING	
	Use:	Use:	Not Recommended:
Biologicals Inorganic Non-Metallics Aggregate Organics Microbiological Physical and Aggregate Properties	If allowed by permit, program, contract or order or If operated by a skilled individual with documented training in proper techniques. Field documentation must demonstrate that the procedure in FS 2213, section 4 was followed without deviation.	If all analytes collected from the well can be collected with a bailer; or If collected <u>after</u> collecting all analytes that require the use of a pump.	Before collecting any analytes that must be collected with a pump.
Ultra-Trace Metals	Never	Never	

Figure FS 2200-1
Pump and Trap for Extractable Organics



Groundwater Purging Procedures

Figure FS 2200-2

Scenario 1: WELL SCREEN COMPLETELY SUBMERGED

Option 1a: Minimal Purge Volume: Pump or tubing is placed within the middle of the screen interval. The following conditions must be met to use this option:

1. The well screen interval is ≤ 10 feet.
2. Although drawdown may occur in the well when purging is initiated, the drawdown has to stabilize (Aquifer Recovery Rate = Purge Rate).
3. The samples will be obtained with the same equipment that was used to purge the well. Therefore, centrifugal pumps and bailers are not suitable for use in Option 1a.

If one or more of these conditions do not apply, use Option 1b.

Option 1b: Conventional Purge: Pump, tubing, or bailer¹ is placed above the screen at the top of the water column.

¹ DEP does not recommend the use of a bailer for purging; however, if a bailer is used it shall be lowered and raised at the rate of 2 cm/sec in the top of the water column.

Scenario 2: WELL SCREEN PARTIALLY SUBMERGED

Option 2a: A bailer¹ is placed at the top of the water column and is used to purge and sample the well.

Option 2b: Pump or tubing is placed within the middle of the saturated portion of the screen interval.

If the pump or tubing that was used for purging will not be used to obtain the sample, then position the pump or tubing at the top of the water column for purging.

Purging Procedure #1

1. After the drawdown in the well stabilizes, purge at least one equipment volume then collect the first set of stabilization parameters.
2. Thereafter, collect stabilization parameters ≥ 2 to 3 minutes apart.
3. Purge at least three equipment volumes before sampling.

Purging Procedure #2

1. Purge at least one well volume then collect first set of stabilization parameters.
2. Thereafter, collect stabilization parameters \geq every 1/4 well volume.

Purging Procedure #3

1. Purge at least one well volume then collect first set of stabilization parameters.
2. Thereafter, collect stabilization parameters ≥ 2 to 3 minutes apart.

Purging Completion

If **Dissolved Oxygen** is $\leq 20\%$ of saturation for the measured temperature and **Turbidity** is ≤ 20 NTUs, then purging is complete when **three** consecutive readings of the parameters listed below are within the following ranges:

Temperature ± 0.2 °C
pH ± 0.2 Standard Units
Specific Conductance $\pm 5.0\%$ of reading

If **Dissolved Oxygen (DO)** is $> 20\%$ of saturation for the measured temperature and/or **Turbidity** is > 20 NTUs after every attempt has been made to reduce DO and/or turbidity, then purging is complete when **three** consecutive readings of the parameters listed below are within the following ranges:

Temperature ± 0.2 °C
pH ± 0.2 Standard Units
Specific Conductance $\pm 5.0\%$ of reading
Dissolved Oxygen ± 0.2 mg/L or readings are within 10% (whichever is greater).
Turbidity ± 5 NTUs or readings are within 10% (whichever is greater).

If the well is expected to purge dry, position the pump or tubing within the screened interval and purge at ≤ 100 mL/minute until two equipment volumes are removed. Use the same pump for purging and sampling.

If the well **purges dry** at the lowest achievable flow rate (pumping at 100 mL/minute or less), then after a sufficient amount of water recharges in the well, collect the samples.

In either case listed above, before samples are collected, measure (once) pH, temperature, specific conductance, dissolved oxygen, and turbidity.

If one or more parameters do not stabilize after 5 volumes of the screened interval (purging procedure #1) or 5 well volumes (purging procedure #s 2 & 3) are removed, purging may be discontinued at the discretion of the sampling team leader.

FS 3000. SOIL

See also the following Standard Operating Procedures:

- FA 1000 Administrative Procedures
- FC 1000 Cleaning/Decontamination Procedures
- FD 1000 Documentation Procedures
- FM 1000 Field Planning and Mobilization
- FQ 1000 Field Quality Control Requirements
- FS 1000 General Sampling Procedures
- FT 1000 – FT 2000 Field Testing and Calibration

1. Introduction and Scope

1.1. Use these SOPs during field investigations to collect soil samples that are representative of current site conditions. It is very important to ensure that the collected samples are neither altered nor contaminated by sampling and handling techniques.

1.2. The following topics include: equipment choice, equipment construction materials, grab and areal or depth composite sampling techniques. Sample collection methods fall into three general depth classifications: surface, shallow subsurface, and deep subsurface. Once the samples are acquired, the handling procedures are very similar and are described below.

2. GENERAL

2.1. Select sampling equipment based on the type of sample to be collected and the analytes of interest. Choose soil sampling locations such that a representative portion of the soil is collected with minimal disturbance. Locations where natural vegetation is stressed or dead and/or areas that have surficial soil staining may be indicative of improper waste disposal practices.

2.2. If background and/or quality control sampling is warranted and feasible as determined in the site's work plan or by the project manager, select an up gradient, undisturbed location for obtaining the background and/or quality control samples. Be aware that differences in soil types may affect these background samples (e.g., sands vs. clays).

2.3. **Do not collect** samples for chemical analysis from auger flights or cuttings from hollow stem auger flights, except for waste characterization purposes for disposal.

2.4. Do not use samples that are collected for geological/lithological or vapor meter determinations for chemical analyses.

3. EQUIPMENT AND SUPPLIES

3.1. All equipment must be constructed of materials consistent with the analytes of interest. Refer to FS 1000, Tables FS 1000-1, FS 1000-2 and FS 1000-3 for selection of appropriate equipment and materials.

3.2. For information on sample container size and construction, see FS 1000, Table FS 1000-6.

3.3. For information on sampling equipment cleaning requirements, see FC 1000.

3.4. For information on preservation and holding time requirements, see FS 1000, Table FS 1000-6.

3.5. For information on documentation requirements, see FD 1000.

4. PROCEDURES FOR COMPOSITING

4.1. The following is not a complete discussion regarding all available sampling protocols nor the appropriateness or inappropriateness of compositing soil samples. The appropriateness of compositing soil samples will depend on the data quality objectives of the project. However, it is sometimes advantageous to composite soil samples to minimize the number of samples to be analyzed when sampling highly contaminated areas. Obtain permission from the DEP program.

4.1.1. Select sampling points from which to collect each aliquot.

4.1.2. Using the appropriate sampling technique, collect equal aliquots (same sample size) from each location and place in a properly cleaned container.

4.1.3. **Combine the aliquots of the sample directly in the sample container with no pre-mixing.**

4.1.4. Record the amount of each aliquot (volume or weight).

4.1.5. Label container, preserve on wet ice to 4°C and complete field notes.

4.1.6. Notify the laboratory that the sample is an unmixed composite sample, and request that the sample be thoroughly mixed before sample preparation or analysis.

5. SPECIFIC PROCEDURES FOR VOLATILE ORGANIC COMPOUNDS

Follow the procedures specified for sample collection and sample preparation in EPA Method 5035, Revision 0, December, 1996 (in SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods). The protocols listed below **do not replace Method 5035** but clarify and/or modify certain method procedures. Therefore, it is essential that all organizations have a copy of Method 5035 as a reference document.

5.1. Container Preparation

5.1.1. All containers must be cleaned according to the FC 1000 sample container cleaning procedures for volatile organics.

5.1.2. Sample Vials: If sample vials are filled in the field, they must be provided with all reagents, stirring devices, label **and vial cap** to be used during sample analysis. These vials must be preweighed by the laboratory and records must be maintained so that there is an unambiguous link between the tare weight and the filled sample vial.

5.2. Collection Procedure

5.2.1. The sample vials (when used) will contain a premeasured amount of liquid. The laboratory must weigh the vials before sending into the field, and must weigh them again after receipt. Therefore:

- Do not lose any of the liquid either through evaporation or spillage
- Do not use a vial if some of the contents has spilled, or if it appears that some has leaked during transport
- Use the laboratory-supplied container label for identification information. **DO NOT apply any additional labels to the container**
- Do not interchange vial caps or septa

5.2.2. Minimize exposure to air by obtaining the sample directly from the sample source, using a coring device or a commercially designed sampling tool.

5.2.2.1. The sample collection device must be designed to fit tightly against the mouth of the vial or be small enough to be inserted into the vial. Use:

- EnCore or equivalent sampling devices or
- Disposable plastic syringes with the syringe end cut off prior to sampling (use **once** per sampling location).

5.2.2.2. Extrude the sample directly into the sample container.

5.2.3. Follow the method procedures for field transfer into the vial.

5.2.4. Procedures for determining the sample weight in the field are not required unless the project manager requires an accurate determination of the 5-gram sample size.

5.2.4.1. If the vials are returned to the laboratory for weighing, the sampler must be proficient in estimating the requisite 5-gram weight necessary for each sample.

5.2.4.2. If an accurate estimate of the 5-gram sample size is desired prior to starting sample collection activities, use a balance with a sensitivity of 0.1 gram.

Check the balance calibration before each day's use with a set of weights that have been calibrated against NIST-traceable weights at least annually.

5.2.5. If the sampling device is transported to the laboratory with a sample, make sure the seals are intact, especially if collecting samples from sandy soils.

5.2.6. Collect at least two replicate samples from the same soil stratum and within close proximity to the original sample location.

5.2.7. Collect an additional aliquot of sample for screening and dry weight determinations.

5.3. Preservation (see FS 1000, Table FS 1000-7)

5.3.1. Low Level (≤ 200 $\mu\text{g/kg}$ volatile organics)

5.3.1.1. Method 5035 discusses the use of sodium bisulfate, which is an acid. Since Florida soils contain significant amounts of calcium carbonate that reacts with acids, DEP does not recommend using this preservative.

5.3.1.2. Properly pack the samples (see FS 2004, section 5), and place all samples on wet ice.

5.3.1.3. Analyze unpreserved samples (no acid) within 48 hours.

5.3.1.4. Analyze acid-preserved samples within the specified 14-day holding time.

5.3.1.5. Analyze unpreserved samples that have been collected in a septum vial with premeasured analyte-free water within 48 hours.

5.3.1.6. If unpreserved samples collected in a septum vial with premeasured analyte-free water are frozen to -10°C at the laboratory within 48 hours of sample collection, analyze the samples within 14 days.

5.3.1.7. Analyze samples that have been collected with and transported in a sealed coring device within 48 hours.

5.3.1.8. If unpreserved samples collected in a sealed coring device are extruded from the corer into an appropriate liquid and frozen to -10°C at the laboratory within 48 hours of sample collection, analyze the samples within 14 days.

5.3.2. High Level (> 200 $\mu\text{g/kg}$ volatile organics)

5.3.2.1. Properly pack the samples (see FS 2004, section 5), and place all samples on wet ice.

5.3.2.2. Analyze samples that have been collected with and transported in a sealed coring device within 48 hours.

5.3.2.3. If unpreserved samples collected in a sealed coring device are extruded from the corer into an appropriate liquid and stored at 4°C at the laboratory within 48 hours of sample collection, analyze the samples within 14 days.

5.3.2.4. Analyze samples that have been preserved in methanol in the field within 14-days.

6. **BULK SAMPLES:** The collection of bulk samples will depend on the data quality objectives of the project.

6.1. Do not composite or mix VOC samples unless required by the DEP program or if mandated by a formal DEP document (permit, order or contract).

6.2. Select sampling points from which to collect each aliquot.

6.3. Using the appropriate sampling technique, collect equal aliquots (same sample size) from each location and place in a properly cleaned container.

6.3.1. **Combine the aliquots of the sample directly in the sample container with no pre-mixing.**

6.3.2. Pack soil tightly minimizing as much headspace as possible in the sample container.

6.3.3. Cap container tightly with Teflon side facing sample.

6.4. Record the amount of each aliquot (volume or weight) in the field notes.

6.5. Label container. Refer to FS 1000, Table FS 1000-7 for preservation and holding time requirements.

6.6. Notify the laboratory that the sample is an unmixed composite sample, and request that the sample be thoroughly mixed before sample preparation or analysis.

FS 3100. Surface Soil Sampling

Surface soil is generally classified as soil between the ground surface and 6-12 inches below ground surface.

1. Remove leaves, grass and surface debris from the area to be sampled.
2. Collect samples for volatile organic analyses as described in FS 3000, section 5.
3. Select an appropriate precleaned sampling device and collect the sample.
4. Transfer the sample to the appropriate sample container.
5. Clean the outside of the sample container to remove excess soil.
6. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.

FS 3200. Subsurface Soil Sampling

Interval begins at approximately 12 inches below ground surface.

FS 3210. SAMPLE COLLECTION PROCEDURE

Use the following after the desired depth has been reached by one of the methods outlined in FS 3220.

1. Collect samples for volatile organic analyses as described in FS 3000, section 5.
2. For other analyses, select an appropriate precleaned sampling device and collect the sample.
3. Transfer the sample to the appropriate sample container.
4. Clean the outside of the sample container to remove excess soil.

5. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.

FS 3220. REACHING THE APPROPRIATE DEPTH

1. SHOVELS AND DIGGERS: Used for soils from approximately 12 inches to a point when using the implement becomes impractical.

1.1. Dig a hole or trench to the required depth.

1.2. Follow the sample collection procedures outlined in FS 3210.

2. BACKHOE: Used for soils from approximately 12 inches to a point when using the implement becomes impractical.

2.1. Dig a trench to the appropriate depth.

2.2. Expose the sample, in the trench, by using a precleaned spoon, spatula or equivalent to clean away the soil that came in contact with the backhoe bucket.

2.3. Use a **second** precleaned utensil to actually collect the sample from the trench.

2.4. Follow the procedures outlined in FS 3210 to collect the sample.

3. BUCKET AUGERS AND HOLLOW CORERS: Suitable to reach soils from approximately 12 inches to a point when using the implement becomes impractical.

3.1. Push and rotate the auger into the soil until the bucket is filled.

3.2. Addition of a non-contaminating sleeve may allow an undisturbed soil sample to be obtained.

3.2.1. The device consists of a standard auger head with a removable sleeve, which is inserted into the auger barrel. In this case it is the sleeve, which fills with soil.

3.2.2. Remove the sleeve from the auger and cap.

3.3. If the auger hole is prone to collapse due to low cohesion in some soils, DEP recommends inserting a temporary rigid PVC casing into the hole. The casing prevents hole collapse and minimizes cross-contamination between soil zones as the auger is advanced. After collecting the samples, remove the temporary casing (if used) and fill the hole filled with the excavated soil.

3.4. Remove the sample from the sampler by pushing or scraping the soil with an appropriate precleaned utensil into an appropriately precleaned tray or aluminum foil.

3.5. Remove any portion of the sample that has been disturbed and discard.

3.6. Follow the sample collection procedures outlined in FS 3210.

NOTE: If a confining layer has been breached during sampling, grout the hole to land surface with Type-1 Portland cement. This requirement may be different throughout Florida; contact the local Water Management District office for local requirements.

4. SPLIT SPOON SAMPLER: Suitable for reaching soils from approximately 12 inches to depths greater than 10 feet.

4.1. A split spoon sampler, useful for sampling unconsolidated soil, consists of two half cylinders (spoons) that fit together to form a tube approximately two feet in length and two inches in diameter.

4.1.1. The cylindrical arrangement is maintained by a retaining head and bit rings that screw on at each end of the split spoon.

4.1.2. The bit ring has beveled edges to facilitate sampling as the split spoon is forced into the ground.

- 4.1.3. Advance the sampler using the weight of the drilling stem and rods or a mechanical hammer.
 - 4.1.4. Insert a catcher device in the head ring to prevent loss of unconsolidated sample during recovery.
 - 4.2. After retrieving the split spoon sampler, expose the soil by unscrewing the bit and head rings and splitting the barrel.
 - 4.3. If the recovery is enough to accommodate discarding a portion of the sample, discard the top and bottom two to three inches of the sample.
 - 4.4. For volatile organic compounds collect the sample immediately from the **center portion of the split spoon** using the procedures described in FS 3000, section 5.
 - 4.5. For other analyses, slice the sample from the center portion of the split spoon using a clean, decontaminated utensil.
 - 4.6. Select an appropriate precleaned sampling device and collect the sample.
 - 4.7. Transfer the sample to the appropriate sample container.
 - 4.8. Clean the outside of the sample container to remove excess soil.
 - 4.9. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.
5. DIRECT PUSH RIGS: May be used for depths greater than 10 feet below ground surface.
 - 5.1. Liners: The clear liners are used with direct push rigs. This method is appropriate only for unconsolidated materials. The sampling depth that can be achieved varies depending on the rig and the lithologies that are encountered. Typically, the rig operator will:
 - Place the liner inside the metal probe rod
 - Select a point holder with an opening appropriate for the site lithology and screw it on the probe rod
 - Advance the rod a full rod length
 - Retrieve the rod
 - Remove the point holder
 - Remove the liner, and
 - Slice the liner to expose the soil.
 - 5.2. After the liner has been sliced, follow the procedures outlined in FS 3210, collecting volatile organic samples (if needed) immediately after the liner is sliced.
 - 5.3. If samples for organic vapor analysis screening are required, collect them by slicing the sample(s) using a clean, decontaminated utensil and place them in 8-ounce (preferred) or 16-ounce jars, immediately cover the opening with aluminum foil and screw on the lid ring. If the contamination is derived from petroleum products, it is acceptable to use a clean gloved hand to transfer the sample(s) to the sample container(s).
 - 5.4. For other analyses, slice the sample from the center portion of the split spoon using a clean, decontaminated utensil.
 - 5.5. Select an appropriate precleaned sampling device and collect the sample.
 - 5.6. Transfer the sample to the appropriate sample container.
 - 5.7. Clean the outside of the sample container to remove excess soil.
 - 5.8. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.

6. SHELBY TUBE SAMPLER

- 6.1. The Shelby tube sampler is used to sample unconsolidated soil and consists of a tube approximately 30 inches long and two inches (or larger) in diameter.
- 6.2. One end of the tube has edges beveled into a cutting edge. The other end can be mounted to an adapter, which allows attachment to the drilling rig assembly.
- 6.3. After drilling to the required depth with an auger or rotary drill bit, a soil sample is obtained through the auger or directly in the borehole.
- 6.4. Push the Shelby tube into the soil using the drilling rig's hydraulic ram or manually with a sledge hammer.
- 6.5. Remove the tube from the sampler head.
- 6.6. Extrude the sample from the Shelby tube.
- 6.7. Use a decontaminated utensil to remove any portion of the sample that has been disturbed.
- 6.8. Collect samples for volatile organics immediately from the center portion of the Shelby tube using the procedures described in FS 3000, section 5.
- 6.9. For other analyses, slice the sample from the center portion of the Shelby tube using a clean, decontaminated utensil.
- 6.10. Transfer the sample to the appropriate sample container.
- 6.11. Clean the outside of the sample container to remove excess soil.
- 6.12. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.

7. CORE BARREL

- 7.1. A standard core barrel is utilized when consolidated samples (such as limestone or dolomite) are to be sampled.
 - 7.1.1. The core barrel is a cylinder approximately three feet long and two inches in diameter.
 - 7.1.2. The barrel has a removable head ring with small embedded diamonds which allow the device to cut through rock or consolidated soil as the drilling rods are rotated.
- 7.2. Retrieve the sample core by unscrewing the head ring and sliding the sample into a precleaned container.
- 7.3. Use a decontaminated utensil to remove any portion of the sample that has been disturbed.
- 7.4. Remove the sample from the sampler (corer) with a precleaned tool.
- 7.5. Transfer the sample to the appropriate sample container.
- 7.6. Clean the outside of the sample container to remove excess soil.
- 7.7. Label the sample container, place on wet ice to preserve to 4°C and complete the field notes.

FS 5000. WASTE SAMPLING

1. INTRODUCTION: Use the procedures in FS 5000 to sample media and matrices of industrial origin.

1.1. Use the following DEP SOPs in conjunction with FS 5000:

- FA 1000 Regulatory Scope and Administrative Procedures for Use of DEP SOPs
- FC 1000 Cleaning / Decontamination Procedures
- FD 1000 Documentation Procedures
- FM 1000 Field Planning and Mobilization
- FQ 1000 Field Quality Control Requirements
- FS 1000 General Sampling Procedures
- FT 1000 – FT 2000 General Field Testing and Measurement

1.1.1. Use additional DEP SOPs as required for specific applications.

2. EQUIPMENT AND SUPPLIES: Refer to Table FS 5000-1 for approved waste sampling equipment.

3. PRESERVATION, TRANSPORT AND HANDLING OF WASTE SAMPLES

3.1. Do not preserve waste samples with chemical preservatives or cool waste samples where the potential for an inadvertent chemical reaction of samples with the preservative might occur, or where cooling might otherwise alter the original sample characteristics. Protect samples from sunlight in order to minimize any potential reaction due to possible light sensitivity of samples. Appropriate handling and storage precautions should be taken if samples have the potential to be shock sensitive.

3.2. After the samples have been collected and containerized, clean the outside of the containers with water, paper towels or other absorbent materials to remove any spilled sample from the exterior of the container.

3.3. Place each labeled container in a separate, resealable plastic bag and then repackage in a second resealable plastic bag. Apply an evidentiary custody seal to container closure before bagging, if applicable. If transporting the samples presents a possibility for breaking glass sample containers, pack the sample containers with non-combustible, absorbent cushioning material and place in a shipping container that has been lined with plastic. Waste samples that are suspected of being acutely toxic or extremely hazardous must be packed in paint cans or other suitable containers and filled with absorbent materials prior to being placed in a cooler.

3.4. See Table FS 1000-6 for preservation procedures.

4. DOCUMENTATION

4.1. See FD 5300 for a complete listing of documentation requirements specific to waste sampling.

4.2. Additional guidance on documentation requirements specific to each type of waste sampling is included in the associated DEP SOPs below.

FS 5010. SAMPLING HAZARDS AND PERSONNEL SAFETY

Waste sampling requires specialized training, safety protocols and personal protective equipment (PPE). The degree and type of safety measures and PPE required depends on the unique characteristics of the waste to be sampled.

1. REFERENCE FOR REQUIRED SAFETY PROTOCOLS, TRAINING AND PPE: As applicable, adhere to safety procedures, training requirements and prescribed PPE described in Occupational Safety and Health Administration (OSHA) Rule 29 CFR 1910.120 (Hazardous Waste Operations and Emergency Response), 7-1-13 Edition.
2. MINIMUM SAFETY PLANNING AND PROCEDURES: It is beyond the scope of this field sampling SOP to describe safety protocols for every contingency. Follow the listed minimum safety procedures below, where applicable:
 - 2.1. Ensure that all personnel are appropriately trained and qualified per OSHA requirements.
 - 2.2. Ensure that sampling personnel meet employer and OSHA medical requirements.
 - 2.3. Conduct site reconnaissance and identify hazards.
 - 2.4. Produce a written site safety plan and review with all personnel.
 - 2.5. Designate a site safety and health officer.
 - 2.6. Produce a written sampling plan and review with all personnel.
 - 2.7. Provide appropriate PPE and sampling equipment to all samplers.
 - 2.8. Establish site control (exclusion zones, access corridors, etc.).
 - 2.9. Conduct preliminary and continuous on-site air monitoring (combustible gases, oxygen deficiency, toxic gases, radiation).
 - 2.10. Establish decontamination areas for samplers.
 - 2.11. Prepare for emergencies (backup personnel, spill containment, fire equipment, first aid, evacuations, etc.).
 - 2.12. Follow additional health and safety procedures developed by the facility owner, as applicable.

FS 5020. PRELIMINARY WASTE CHARACTERIZATION

1. Conduct a preliminary waste characterization prior to collecting samples for laboratory analysis. Use the waste characterizations to establish proper safety protocols and protections for sampling personnel, to make decisions regarding staging, bulking, compositing, segregation, shipping and disposal of wastes and to refine the selection of appropriate laboratory analyses for collected waste samples.
2. Classify the wastes into the following general categories: reactive wastes, explosives, acids, bases, ignitable wastes, heavy metals, pesticides, halogenated compounds, cyanides and oxidizers. In cases where sufficient information is not available, conduct further analyses to identify the material.
3. The field waste characterization tests listed below are designed to gain a quick, preliminary assessment of the types and levels of chemicals in the wastes. Perform the field methods below according to the manufacturers' instructions.
 - HazCat Chemical Identification System
 - Dräger Tubes
 - Clor-N-Oil Test Kit
 - Spill-fyter Chemical Classifier Strips
 - Setaflash (ignitability)
4. Record the results of the preliminary characterization, including the results of any field waste characterization tests performed.

FS 5100. Drum Sampling

1. PRECAUTIONS FOR DRUM SAMPLING

1.1. Opening closed containers and drums of unknown content is a hazardous activity. Give maximum attention to sampling team safety by establishing and following clear and proper procedure and wearing appropriate personal protection equipment. ***Remote sampling technique may be required for some situations. Conduct all sampling activities using appropriate personal protective equipment (PPE) for the level of hazard encountered. See FS 5010. If the contents of drums or their hazards are unknown, use Level B protection at a minimum.***

1.2. Exercise caution when excavating, inspecting, staging and sampling drums because of the potential presence of explosive or flammable gases, toxic vapors or other hazardous materials. Assume that labeled drums are mislabeled. In general, assume that all drums contain hazardous material until the contents have been independently characterized.

1.3. Refer to 29 CFR Part 1910.120(j) for OSHA standards required for drum and container handling.

2. DRUM EXCAVATION: ***All excavation activities must include appropriate personal protective equipment for the level of hazard encountered. See FS 5010. If the contents of drums or their hazards are unknown, wear Level B protection, at a minimum.***

2.1. Utilize geophysical techniques to approximate buried drum locations and depths.

2.2. Locate all utility lines, poles and pipes above and below ground. Ensure adequate clearance between all utilities or structures and the drum excavation area.

2.3. Use heavy equipment and equipment operators with drum removal experience to excavate, remove or handle drums. Avoid digging directly into drums. Final excavation must be done manually, using non-sparking hand tools.

2.4. Monitor the area around exposed drums for volatile organic compounds, explosives or radioactive materials before proceeding.

2.5. Identify each drum that will be opened. Use paint sticks, spray paint, traffic cones, etc.

3. DRUM INSPECTION: ***All inspection activities must include appropriate personal protective equipment for the level of hazard encountered. See FS 5010. If the contents of drums or their hazards are unknown, wear Level B protection, at a minimum.***

3.1. Visually inspect all drums that are being considered for sampling for the following:

- Pressurization (bulging/dimples)
- Crystals around the drum opening
- Leaks, holes, stains
- Labels, markings, hazard warnings
- Composition and type (steel/plastic and open/bung)
- Dead vegetation around drum
- Condition, age, rust, potential shock sensitivity
- Sampling accessibility

3.1.1. Drums showing evidence of pressurization and crystals must be furthered assessed to determine if remote drum opening is needed. Do not tap or knock the drums to determine drum contents or volume.

3.2. Uniquely identify each drum with a tag, label, bands, spray paint or other means. Indicate drum category, as determined by visual inspection. Use color-coding as needed to distinguish categories of drums.

3.3. Record all observations made during drum inspection.

4. DRUM STAGING: ***All staging activities must include appropriate personal protective equipment for the level of hazard encountered. See FS 5010. If the contents of drums or their hazards are unknown, wear Level B protection, at a minimum.***

4.1. Use heavy equipment and qualified equipment operators with drum handling experience to stage drums, if necessary.

4.2. If ignitable, explosive or reactive characteristics are indicated by initial characterization of drum contents, locate the staging area away from the drum-opening area to prevent chain reaction should an opened drum explode or ignite.

4.3. The procedures for handling and sampling drums differ by drum category. Separate drums into the following categories, based on determination of contents:

- Liquids
- Lab packs
- Solids
- Empty

4.3.1. Segregate drums containing radioactive, explosive or shock-sensitive material from other drums and the drum-opening area. Place drums containing these hazards in a diked and fenced area where practical.

4.3.2. Separate drums containing acids or bases from each other. Similarly separate drums containing other wastes known to react with each other.

4.4. Move drums from the staging area to the opening area one at a time using forklift trucks equipped with drum grabbers or barrel grapples or, move by roller conveyor or other means.

5. DRUM OPENING PROCEDURES:

5.1. General Considerations:

5.1.1. ***Wear personal protective equipment (PPE) as prescribed in the reference cited in FS 5010 for the level of hazard encountered with each drum.***

5.1.2. Use remote drum-opening procedures when possible to maximize personnel safety.

5.1.3. Use manual bung wrench or deheader drum-opening procedures only with structurally sound drums that are capable of withstanding the forces applied during bung opening or deheading.

5.1.4. Do not attempt to use a manual bung wrench or deheader on drums that contain shock-sensitive, reactive, explosive or flammable materials.

5.2. Procedures Required Prior to Drum Opening: Before opening, ground each metal drum that is not in direct contact with the earth using grounding wires, alligator clips and a grounding rod or metal structure. If a metal drum is in an overpack drum, ensure the metal drum is grounded.

5.2.1. Touch the drum opening equipment to the bung or lid and allow an electrically conductive path to form. Slowly remove the bung or drum ring and/or lid with spark resistant tools (brass/beryllium).

5.2.2. Screen drums for explosive gases and toxic vapor with air monitoring instruments as bung or drum lid is removed.

5.2.3. Record the results of all monitoring of drums.

5.3. Tools for Opening Drums: See specific instructions below for use of various drum opening tools.

All manual procedures require appropriate personal protective equipment (PPE) for all personnel working with the drum. The puncture or deheading of any drum may present a chemical splash hazard. The level of protection required is described in the reference cited in FS 5010 for the type of hazards encountered with each drum. If drum contents or hazards are unknown, wear Level B protection, at a minimum.

5.3.1. Manual Bung Wrench

5.3.1.1. ***Wear appropriate protective gear per FS 5010.***

5.3.1.2. Position top or side mounted bungs in upright position.

5.3.1.3. Pull slowly and steadily across the drum.

5.3.1.4. Use a handle extension for increased wrench leverage where necessary.

5.3.1.5. Watch for sparking even when using non-sparking bung wrenches.

5.3.2. Manual Drum Deheader

5.3.2.1. Position the cutting edge of the deheader just inside the top chime and tighten the deheader adjustment screw to hold the device tight against the side of the drum.

5.3.2.2. Slowly make an initial cut into the drumhead to release pressure (or use remote techniques to relieve pressure prior to deheading procedures).

5.3.2.3. Move the deheader handle up and down while sliding the device along the chime.

5.3.2.4. Decontaminate the drum deheader between drums, if contact between the deheader and drum contents have occurred. See FC 1000.

5.3.3. Hand Pick, Pickaxe and Hand Spike

5.3.3.1. Anticipate potential splashing with the use of these tools. ***Wear proper personal protective gear per FS 5010.***

5.3.3.2. Use these devices where the bung cannot be opened or the drumhead cannot be removed.

5.3.3.3. Decontaminate hand tools between drums. See FC 1000.

5.3.4. Remote Opening Using a Backhoe Spike: Use this procedure for greater personal safety. Mount a splash shield in front of the backhoe operator cage. ***The operator must wear appropriate personal protection gear per FS 5010.*** Provide air supply gear to the operator, if applicable.

5.3.4.1. Place drums in rows such that the backhoe can be maneuvered between them.

5.3.4.2. Punch a hole in the drumhead with the backhoe spike.

5.3.4.3. Decontaminate the backhoe spike between drums. See FC 1220.

5.3.5. Remote Opening Using Hydraulic Devices

5.3.5.1. Follow manufacturer's instructions to puncture the drum.

5.3.5.2. ***This procedure presents a splash hazard. Wear personal protective gear per FS 5010, as applicable.***

5.3.6. Remote Bung Opening Using Pneumatic Devices: ***This procedure does not allow slow release of accumulated pressure in the drum. Wear personal***

protective gear per FS 5010 and take safety precautions during this procedure, as applicable.

- 5.3.6.1. Do not attempt to remove rusted bungs with this device.
- 5.3.6.2. Place drums in level, upright position.
- 5.3.6.3. Follow manufacturer's instructions to fit the opener to the bung, remotely remove the bung and detach the device.

5.4. Inspecting Drum Contents

- 5.4.1. Note the state, quantity, phases, and color of the drum contents.
- 5.4.2. Review the screening results with any pre-existing data to determine which drums will be sampled.
- 5.4.3. Monitor headspace gases from opened drums. Use an oxygen meter and explosimeter first, followed by organic vapor analyzer (OVA) monitoring.
- 5.4.4. Record all results from the inspection of drums.

5.5. General Instructions for Drum Sampling

5.5.1. If applicable for the sampling plan, account for any stratification of drum contents by appropriate choice of sampling tools and techniques. If the entire depth of the drum must be represented by the sample(s), collect all phases and strata of the drum either as a composite or as discrete phase and stratum samples, as required. Only profiling samplers such as COLIWASA (COMPOSITE LIQUID WASTE SAMPLER), thieves, sludge judges, etc. allow proportional sampling of strata and phases.

5.5.1.1. Filling Multiple Sample Containers Where Strata or Phases are Composited: Using a proportional sampler, dispense an entire sampler volume of waste into each required sample container in succession until all containers are adequately filled.

5.5.1.2. Filling Multiple Sample Containers Where Discrete Stratum or Phase Samples are Required: Fill the required number of containers in succession using a discrete sampler to collect samples from the appropriate phase or stratum.

5.5.2. Account for sludge depth in the drum by measuring depth to apparent bottom and subtracting from drum total depth (height).

5.5.3. Select the appropriate sampling equipment based on the physical state of the material and the type of container. Sampling equipment must be made of non-reactive materials that will not alter the chemical or physical properties of the material that is to be sampled.

5.5.4. Place absorbent pads, sampling equipment and sample containers near drum(s) to be sampled.

5.5.5. Record all observations made during sampling. Document sampling per FD 5300.

<i>CONDUCT AIR MONITORING FOR TOXIC VAPORS, EXPLOSIVE GASES AND OXYGEN-DEFICIENT ATMOSPHERES DURING DRUM SAMPLING.</i>

FS 5110. SAMPLING LIQUIDS FROM DRUMS

1. GLASS THIEF (TUBE)

1.1. General Considerations for Glass Thief

- 1.1.1. Use disposable glass tubes only.
- 1.1.2. Typical dimension for the glass thief is 6mm-16mm I.D. and 48 inches long.

1.2. Sampling Procedure for Glass Thief

- 1.2.1. Remove cap from sample container.
- 1.2.2. Insert thief into drum almost to bottom or until solid layer is reached. Allow one foot of tubing to extend out of the top of the drum.
- 1.2.3. Let the waste in the drum rise to its natural level in the thief.
- 1.2.4. Cap the top of the thief with a stopper or gloved thumb. Do not let waste liquid contact the stopper or thumb.
- 1.2.5. Withdraw the thief from the drum.
- 1.2.6. Insert open end of thief into the sample container and allow thief contents to drain into the container. Fill container 2/3 full.
- 1.2.7. When finished with the thief, break the thief into pieces and insert into the drum (if permitted by the sampling and disposal plans).

2. COLIWASA (COMPOSITE LIQUID WASTE SAMPLER)

2.1. General Considerations for COLIWASA Sampling

- 2.1.1. Use the COLIWASA to collect representative multiphase samples from the full depth of a drum, as applicable.
 - 2.1.1.1. If it is not a disposable model, the COLIWASA may be too expensive for some applications and cannot be easily decontaminated in the field.
 - 2.1.1.2. Variations in design of this sampling device may be available from different vendors but the operational principle is the same.

2.2. Sampling Procedure for COLIWASA

Follow manufacturer's directions for use if different from the following:

- 2.2.1. Configure the COLIWASA in the open position by lifting the stopper rod several inches above the closed position.
- 2.2.2. Slowly lower the sampler into the liquid waste at a rate that permits the levels of liquid inside and outside the sampler tube to rise to about the same heights. Failure to maintain equal heights inside and outside the tube will affect the representativeness of the sample. If the liquid level inside the tube is lower than the waste level outside the tube, the sampling rate is too fast.
- 2.2.3. When the sampler stopper hits the bottom of the drum, push the stopper rod to the closed position.
- 2.2.4. Slowly withdraw the sample from the waste liquid and simultaneously wipe the outside of the device with a disposable wipe.
- 2.2.5. Position the lower end of the COLIWASA in the sample container. Lift the stopper rod and carefully drain the waste liquid into the container.

2.3. Sampling Procedures for Other Devices: (Reserved)

FS 5120. SAMPLING SOLIDS AND SLUDGES FROM DRUMS

1. GENERAL CONSIDERATIONS

- 1.1. Use a long-handled dipper, push tube or other coring device, scoop, spoon, bucket auger, screw auger or, if conditions necessitate, a pneumatic hammer/drill to obtain samples of solids in drums.
- 1.2. If necessary for the sampling plan, take multiple samples from different areas of the drum.

2. PROCEDURE FOR CORING DEVICE OR PUSH TUBE

- 2.1. Insert device to bottom of drum. T-handle and extension attachments, where applicable, must extend above the top of the drum.
 - 2.2. Rotate the corer or push the sampling tube to cut a core of material.
 - 2.3. Slowly withdraw the device to retain the sample.
 - 2.4. Use stainless steel laboratory spatulas or scoops to transfer the sample to containers.
3. PROCEDURES FOR OTHER SAMPLING DEVICES: (Reserved)

FS 5130. CLOSING DRUMS AND SEGREGATION OF EQUIPMENT AND WASTES AFTER SAMPLING

1. Close each drum when sampling of the drum is complete.
2. Segregate contaminated sampling equipment and investigation-derived wastes (IDW) containing incompatible materials as determined by the drum screening procedure.
3. Handle and dispose of IDW and contaminated disposable equipment according to local, state and federal regulations.
4. As required, wrap or bag contaminated reusable equipment in protective material or store in containers until cleaned.

FS 5200. Tank, Sump and Leachate Sampling

1. INTRODUCTION: Some procedures for tank, sump and leachate sampling will be identical to those for drum sampling. The depth or physical configuration of some waste units will prevent the use of some equipment or techniques, depending on the unit to be sampled.
2. EQUIPMENT AND SUPPLIES: See Table FS 5000-1 for approved sampling equipment.

FS 5201. *Presampling Considerations and Procedures for Tanks*

1. PRESAMPLING CONSIDERATIONS FOR TANKS
 - 1.1. Sampling tanks is considered hazardous due to the potential for tanks to contain large volumes of hazardous materials. Follow appropriate safety protocols. Some tank sampling requires physical agility and manual dexterity in order to access the tank sampling points, carry equipment and supplies, open tank hatches and collect and containerize samples while wearing personal protective equipment. Personnel must be able to perform the appropriate procedures under these conditions.
 - 1.1.1. ***Wear personal protective equipment (PPE) as prescribed in the reference cited in FS 5010 for the level of hazard encountered with each tank. If the contents of a tank or its hazards are unknown, wear Level B protection while working in proximity to the tank.***
 - 1.2. Unlike drums, tanks may be compartmentalized or have complex designs. Review preliminary information about the tank contents and configuration prior to the sampling operation to ensure the safety of sampling personnel and to ensure that study design objectives can be achieved.
 - 1.3. In addition to having discharge valves near the bottom, most tanks and bulk storage units have hatches at the top. Collect samples from the top hatch because of the potential for tank contents to be stratified. *Do not collect samples from valves unless necessary and only if part of the sampling plan. See section 1.4 below.*
 - 1.4. When sampling from the discharge valve, there is a possibility of a stuck or broken valve that could cause an uncontrolled release. Do not utilize valves on tanks or bulk storage devices unless the owner or operator of the facility operates them, or a containment

plan is in place should the valve stick or break. If a tank must be sampled from a discharge valve, clearly understand the valving arrangement of the particular tank to ensure that the compartment of interest is sampled. Make sure that sampling from valves is specified in the sampling plan. *Valve sampling will not allow sampling of individual strata in the tank.*

1.5. If stratification of tank contents must be accounted for, choose appropriate sampling tools and techniques so that the entire depth of the tank is represented by the sample(s) collected. Sample all phases and strata of the tank either as a composite or as discrete phase and stratum samples, as required by the sampling plan. Only profiling samplers such as COLIWASA, thieves, sludge judges, etc. allow proportional composite sampling of strata and phases. If proportional composite sampling of a tank is not practical, collect discrete samples from each phase or stratum in order to characterize the entire contents of the tank. If the sampling plan requires only approximate sampling or screening, collect a simple grab sample from the contents of the tank.

2. PRESAMPLING PROCEDURES FOR TANKS

2.1. Perform a structural integrity survey of the tank. Inspect the ladder, stairs, and catwalk that will be used to access the top hatch of larger tanks to ensure that they will support the combined weight of personnel and equipment.

2.2. Evaluate tank sampling points for safety, accessibility and sample quality.

2.3. Before opening, ground each metal tank using grounding wires, alligator clips and a grounding rod or metal structure.

2.4. Remove all sources of ignition from the immediate area.

2.5. Open any vents or pressure release valves slowly to allow the unit to vent to atmospheric pressure.

2.5.1. *Monitor for explosive or flammable gases and toxic vapors during venting. If dangerous concentrations of gases evolve from the vent or the pressure is too great, close the system and leave the area immediately.*

2.6. Touch tank opening equipment to the bolts in the hatch lid and allow an electrically conductive path to form. Slowly remove bolts and/or hatch with spark resistant tools (brass/beryllium).

2.6.1. *If a pressure build up is encountered or detected, cease opening activities and leave the area.*

2.7. *Screen the interior of tanks for explosive or flammable gases and toxic vapors with air monitoring instruments.*

2.8. Depending on the study objectives and site conditions, conduct characteristic screening (e.g., pH, halogen, etc.) as required. Collect a small volume of sample for flash point testing, if warranted.

2.8.1. Note the state, quantity, number of phases and color of the tank contents.

2.8.2. Compare the screening results with any pre-existing data to determine if the tank should be sampled.

2.9. Determine depth of any and all liquids, solids and liquid/solid interfaces. Measure depth of any sludge. Use weighted tape measures, probe lines, sludge judges or other appropriate equipment to characterize tank stratification with depth.

2.10. Determine the inside diameter of the tank and calculate the volume of wastes in the tank using the depth measurements above. Do not assume that the external diameter of the tank approximates the inside diameter, since the tank construction may have insulation or support structures hidden under the external surface.

2.11. Record all observations, measurements and calculations made at the time of tank inspection. See FD 5300.

FS 5210. GENERAL SAMPLING INSTRUCTIONS FOR TANKS

1. GENERAL CONSIDERATIONS: Because of the many different types of designs and materials that may be encountered, only general sampling procedures that outline sampling a tank from the top hatch are listed below:

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1.1. Select the appropriate sampling equipment based on the physical state of the material and the type of tank. Use sampling equipment constructed of non-reactive materials that will not alter the chemical or physical properties of the material that is to be sampled. See Table FS 5000-1.

1.2. ***Wear required personal protective equipment (PPE) as prescribed in the reference cited in FS 5010 for the level of hazard encountered with each tank. If tank contents or hazards are unknown, wear Level B protection, at a minimum.***

1.3. Where tanks are compartmented, collect at least one sample from each compartment.

1.4. Place absorbent pads, sampling equipment and sample containers near tanks(s) to be sampled.

1.5. Document all observations and procedures associated with sample collection per FD 5300.

2. SAMPLING LIQUIDS FROM TANKS

2.1. Collect liquid samples according to the objectives of the sampling plan, using appropriate samplers.

2.2. Slowly lower the bailer, bacon bomb, Dipstick™, COLIWASA, or Teflon® tubing to the desired sampling depth. ***In work areas where explosive or flammable atmospheres could occur, do not use peristaltic pumps powered by batteries.***

2.2.1. Close the sampling device or start pump.

2.2.2. Slowly remove the sampling device from the tank.

2.2.3. Release or pump the sample from the device into the sample container(s).

2.2.4. Repeat the procedure until a sufficient sample volume is obtained.

2.3. Inspect samples for phase differences or stratification.

2.3.1. If separate phases or strata are observed in any sample container, perform repeated iterative sampling, if discrete phase or stratum sampling is required by the sampling plan. Systematically collect additional samples by halving the depth between two discreet sampling points to determine the next sampling depth. Repeat this procedure until no phase difference or stratification is noted in the sample. Calculate phase and stratum boundary depths from these samplings.

2.3.2. If discrete phase or stratum sampling is not required by the sampling plan, collect composite samples using appropriate profiling samplers or collect simple grab samples, depending on sampling plan objectives.

2.4. If additional sampling ports are available, verify phase and stratum information with additional samples from the other ports, if practical.

2.5. If more than one sample container will be used to collect for the analytes of interest, use the following procedures for filling multiple sample containers.

2.5.1. Filling Multiple Sample Containers Where Strata or Phases are Composited: Using a proportional sampler, dispense an entire sampler volume of waste into each required sample container in succession until all containers are adequately filled.

2.5.2. Filling Multiple Sample Containers Where Discrete Stratum or Phase Samples are Required: Fill the required number of containers in succession using a discrete sampler to collect samples from the appropriate phase or stratum.

3. SAMPLING SOLIDS/SEMI-SOLIDS FROM TANKS

3.1. Use a long-handled dipper, push tube, bucket auger, screw auger, Mucksucker™, or if conditions permit, a pneumatic hammer/drill to obtain the sample. See specific instructions for each applicable sampling device in FS 5211 below.

3.2. Carefully extrude the sample from the sampling device or use a clean stainless steel spoon to place the sample into containers for analyses.

3.3. Close the tank when sampling is complete.

4. WASTE DISPOSAL AND CONTAMINATED EQUIPMENT

4.1. Segregate contaminated sampling equipment and investigation-derived wastes containing incompatible materials.

4.2. Manage all waste according to applicable local, state and federal regulations.

FS 5211. *Tank Sampling Instructions for Specific Sampling Devices*

Select the equipment described below for use based on the specific sampling requirements of the tank.

1. BACON BOMB SAMPLER: Use the bacon bomb sampler for discrete depth sampling in a tank.

1.1. Attach sampler retrieval line and plunger line, if necessary. The sampling line must be measured and marked for the predetermined collection depth required.

1.2. Slowly lower the bacon bomb to the required depth in the tank and pull and hold the plunger line to actuate filling of the sampler. Release the plunger line to stop filling and seal the sampler closed.

1.3. Retrieve the sampler by the sample line. Do not pull on the plunger line, or the sample will be lost or exchanged with the contents of the tank or a different phase or stratum. Wipe or rinse the exterior of the sampler before filling sample containers. Collect any rinsate for proper disposal.

1.4. Release contents into the sample container by pulling on the plunger line.

2. SLUDGE JUDGE: Use the sludge judge to obtain an accurate reading of the depth of settleable solids in any liquid and for collection of the sample for laboratory analysis.

2.1. Lower the sludge judge to the bottom of the tank and allow the sampler to fill to surface level and seat the check valve on the sampler.

2.2. Retrieve the sludge judge and raise it completely out of the tank liquid for determination of sludge depth.

2.3. Actuate release pin at the bottom of the sampler to release contents or fill a sample container.

3. SUBSURFACE GRAB SAMPLER: Use the subsurface grab sampler to collect samples at discreet depths in the tank.

3.1. Screw sample bottle onto the sampler head assembly.

3.2. Lower the sampler to the required depth and actuate the plunger mechanism.

- 3.3. Release the plunger to close the sampling head after filling the sample bottle and retrieve the sampler from the tank.
- 3.4. Remove and cap the sample bottle.
- 3.5. Decontaminate the exterior of the sample bottle.
4. GLASS THIEF (TUBE)
 - 4.1. General Considerations for Glass Thief
 - 4.1.1. Use disposable glass tubes only.
 - 4.1.2. Typical dimension for the glass thief is 6mm - 16mm I.D. and 48 inches long.
 - 4.1.3. Tanks greater than about 3 feet in depth cannot be sampled with a glass thief.
 - 4.2. Sampling Procedure for Glass Thief
 - 4.2.1. Remove cap from sample container.
 - 4.2.2. Insert thief into tank almost to bottom or until solid layer is reached. Allow one foot of tubing to extend out of the top of the tank.
 - 4.2.3. Let the waste in the tank rise to its natural level in the thief.
 - 4.2.4. Cap the top of the thief with a stopper or gloved thumb. Do not let waste liquid contact the stopper or thumb.
 - 4.2.5. Withdraw the thief from the tank.
 - 4.2.6. Insert open end of thief into the sample container and allow thief contents to drain into the container. Fill container 2/3 full.
 - 4.2.7. When finished with the thief, break the thief into pieces and insert into the tank (if permitted by the sampling and disposal plans).
 - 4.2.8. Close tank cover.
5. BAILER
 - 5.1. Slowly lower bailer into tank contents using non-reactive bailer line. Do not splash bailer into the liquid.
 - 5.2. Retrieve the bailer after the bailer fills completely.
 - 5.3. Slowly pour bailer contents into the sample container.
 - 5.4. Close tank cover.
6. COLIWASA:

Follow manufacturer's directions for use if different from the following:

 - 6.1. Configure the COLIWASA in the open position by lifting the stopper rod several inches above the closed position.
 - 6.2. Slowly lower the sampler into the liquid waste at a rate that permits the levels of liquid inside and outside the sampler tube to rise to about the same heights. Failure to maintain equal heights inside and outside the tube will affect the representativeness of the sample. If the liquid level inside the tube is lower than the waste level outside the tube, the sampling rate is too fast.
 - 6.3. When the sampler stopper hits the bottom of the drum, push the stopper rod to the closed position.
 - 6.4. Slowly withdraw the sample from the waste liquid and simultaneously wipe the outside of the device with a disposable wipe.
 - 6.5. Position the lower end of the COLIWASA in the sample container. Lift the stopper rod and carefully drain the waste liquid into the container.
7. ADDITIONAL SAMPLING DEVICES: Reserved

FS 5220. LEACHATE AND SUMP SAMPLING

1. As applicable, follow DEP SOP procedures for tank, drum, groundwater, surface water and sediment sampling. See FS 5100 and FS 5200 above, as well as FS 2100, FS 2200 and FS 4000.
2. Document leachate and sump sampling according to the documentation requirements for the respective DEP SOPs employed to collect samples, per the above. Document additional items per FD 1000.

FS 5300. Waste Pile Sampling

1. The number of samples, the type of sample(s) and the sample location(s) or sampling point(s) for waste pile sampling will be based on sampling plan objectives as determined by permitting or other regulatory criteria and according to the size, shape, material composition, compactness or other characteristics of the pile and the distribution of analytes, analyte concentrations and strata in the waste pile.
2. Follow directives of the sampling plan specific to the project.
3. Document waste pile sampling according to associated regulatory requirements for the project. Document additional items per FD 1000, as applicable.
4. Refer to FS 3000 for soil sampling procedures applicable to waste pile sampling.

FS 5400. Impoundment and Lagoon Sampling

1. Surface impoundments vary in size, shape, and waste content, and may vary in distribution of hazardous constituents and characteristics (strata). The number of samples, the type of sample(s), and the sample location(s) will be based on the sampling design objectives.
2. Commonly used equipment to collect samples from surface impoundments are listed in Table FS 5000-1. All equipment must be compatible with the waste to prevent any alteration of the sample.
3. ***Because of the potential danger of sampling waste units suspected of containing elevated levels of hazardous constituents, do not attempt to sample surface hazardous waste impoundments from a boat. Conduct all sampling from the banks or piers of surface impoundments. Any exception must be approved per specific provisions in the applicable health & safety plans and sampling plans.***
4. Refer to FS 2100 and FS 4000 for general surface water and sediment sampling procedures applicable to waste impoundment sampling.
 - 4.1. Additionally, some procedures and equipment applicable to drum and tank sampling may be useful for waste impoundment sampling. See FS 5100 and FS 5200 above.
5. Document impoundment and lagoon sampling procedures and observations per FD 1000 for the applicable procedures employed.

Appendix FS 5000
Tables, Figures and Forms

Table FS 5000-1 Waste Sampling Equipment

Table FS 5000-1 Waste Sampling Equipment

Equipment	Construction Material ¹	Phases	Waste Units or Sources	Limitations
Scoop with bracket and handle	Stainless Steel	Liquids, Solids, Sludges	Impoundments, Piles, Drums and Containers, Tanks	Depth constraint. Cannot collect deeper phase or stratum in stratified waste
Spoon	Stainless Steel	Solids, Sludges	Impoundments, Piles, Drums and Containers, Tanks	Depth constraint. Cannot collect deeper strata
Push Tube	Stainless Steel	Cohesive Solids, Sludges	Impoundments, Piles, Drums and Containers, Tanks	Depth constraints. Do not use to sample solids with dimensions >½ the diameter of the tube
Auger	Stainless Steel	Solids	Piles	Unusable for solidified wastes
Sediment Sampler	Stainless Steel	Solids, Sludges, Sediment	Impoundments, Piles	Do not use to sample solids with dimensions >½ the diameter of the tube
Ponar Dredge	Stainless Steel	Solids, Sludges, Sediments	Impoundments	Deployment constraints. Must have means to position equipment to desired sampling location. Difficult to decontaminate
COLIWASA, Drum Thief	Glass	Liquids, Sludges	Impoundments, Drums and Containers, Tanks	Depth constrained to length of sampling device. Not effective with viscous wastes
Mucksucker™ Dipstick™	Teflon	Liquids Sludges	Impoundments, Drums and Containers, Tanks	Not recommended for tanks >11 feet deep
Bacon Bomb	Stainless Steel	Liquids	Impoundments, Tanks	Not effective with viscous wastes
Bailer	Stainless Steel Teflon	Liquids	Impoundments, Tanks	Do not use with heterogeneous wastes. Not effective with viscous wastes
Peristaltic Pump with Vacuum Trap Assembly ²²	Teflon Glass	Liquids	Impoundments, Drums and Containers, Tanks	Do not use in flammable atmospheres. Not effective with viscous wastes
Backhoe Bucket	Steel	Solids Sludges	Piles	May be difficult to access desired sampling location. Difficult to clean. Loss of VOCs possible
Split Spoon	Stainless Steel	Solids	Piles	Requires drill rig
Roto-Hammer	Steel	Solids	Piles, Drums, Containers	Physically breaks up sample. May release volatiles. Not for flammable atmospheres

¹ If disposable equipment of alternative material construction is used, ensure that the equipment is compatible with the chemical composition of the waste and will not alter the characteristics of the waste sample in any way.

² A peristaltic pump may be used without an optional vacuum trap assembly if the flexible tubing used in the pump head is one foot or less in length. See FS 2200, subpart FS 2221 for information concerning the choice of tubing and pumping rate for the collection of samples for VOCs using a peristaltic pump.