ALABAMA ENVIRONMENTAL INVESTIGATION AND REMEDIATION GUIDANCE (AEIRG)

Revision 4.0

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NOTICE

This document has been prepared to assist individuals in understanding the minimum necessary elements of environmental investigations and remediation projects. It is not intended as a substitute for the regulations and should not be used as such. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. The hyperlinks and citations provided in this document are for helpful reference and may be used in the development of a facility's respective sampling, remediation plans, etc. It should be noted that use of the provided hyperlinks and citations alone does not ensure Departmental approval/acceptance of such sampling, remediation plans, etc.

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ALABAMA ENVIRONMENTAL INVESTIGATION AND REMEDIATION GUIDANCE

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List of Acronyms

ADEM – Alabama Department of Environmental Management
ADPH – Alabama Department of Public Health
AHWMMA – Alabama Hazardous Waste Management and Minimization Act
AOC – Area of Concern
APEG – Alkaline Polyethylene Glycol
ARBCA – Alabama Risk Based Corrective Action
ASTM – American Society of Testing and Materials
ASTSWMO – Association of State and Territorial Solid Waste Management Officials
AWWA – American Water Works Association
BCD – Base-Catalyzed Decomposition
BOD5 – 5-Day Biochemical Oxygen Demand
BTAG – Biological Technical Assistance Group
BTEX – Benzene, Toluene, Ethylbenzene, and Xylene
BTU – British Thermal Unit
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
CIR – Comprehensive Investigation Report
COC – Chemical of Concern
COD – Chemical Oxygen Demand
COPC – Chemicals of Potential Concern
CROW – Contained Recovery of Oil Waste
CSM – Conceptual Site Model
DDT – Dichlorodiphenyltrichloroethane
DNAPL – Dense Non-Aqueous Phase Liquid
DOC – Dissolved Organic Carbon
DP – Direct Push
DPE – Dual Phase Extraction
DU – Decision Unit
EC – Environmental Covenant
ED – Exposure Domain
EPA – Environmental Protection Agency – synonymous with "USEPA"
ER – Electrokinetic Remediation
ESV – Ecological Screening Value
FEC – Field Equipment Center
FID – Flame Ionization Detector
GAC – Granulated Activated Carbon
GC/MS – Gas Chromatography/Mass Spectrometry
GPS – Global Positioning System
GSA – Geological Survey of Alabama

HTTD – High Temperature Thermal Desorption
ICP – Inductively Coupled Plasma
IDW – Investigation Derived Waste
ISEE – *In-situ* Steam-Enhanced Extraction
ISM – Incremental Sampling Method
ISV – *In-situ* Vitrification
ITRC – Interstate Technology & Regulatory Council

LDPE – Low-Density Polyethylene
LNAPL – Light Non-Aqueous Phase Liquid
LTTD – Low Temperature Thermal Desorption
LUC – Land-Use Control
MCL – Maximum Contaminant Level
MDL – Method Detection Limit
MNA – Monitored Natural Attenuation
MTBE – Methyl Tertiary-Butyl Ether
NGVD – National Geodetic Vertical Datum
NOAA – National Oceanic and Atmospheric Administration
NPDES – National Pollutant Discharge Elimination System
NTU – Nephelometric Turbidity Unit
OB/OD – Open Burn/Open Detonation
ORC – Oxygen Releasing Compound
ORP – Oxidation-Reduction Potential
PAH – Polycyclic Aromatic Hydrocarbon
PCB – Polychlorinated Biphenyls
PCP – Pentachlorophenol
PDB – Passive Diffusion Bag
PE – Polyethylene
PF – Pneumatic Fracturing
PFA – Perfluoroalkoxy Alkane
PID – Photoionization Detector
PIR – Preliminary Investigation Report
ppb – Parts per Billion
PPE – Personal Protective Equipment
PRP – Potentially Responsible Party
psi – Pounds per Square Inch
RSL – Regional Screening Level
PVC – Polyvinyl Chloride
QA – Quality Assurance
QC – Quality Control
QSTP – Quality System and Technical Procedure
RBTL – Risk-Based Target Level
RCRA – Resource Conservation and Recovery Act
RDX – Royal Demolition Explosive – cyclotrimethylenetrinitramine (Hexogen (explosive))
RFH – Radio Frequency Heating
RM – Risk Management
RSL – Regional Screening Level
SARA – Superfund Amendments and Reauthorization Act
SERP – Steam-Enhanced Recovery Process
SID – State Indirect Discharge
SIVE – Steam Injection and Vacuum Extraction
SOP – Standard Operating Procedure
SQAG – Sediment Quality Assessment Guidelines
SSL – Soil Screening Level
SWMU- Solid Waste Management Unit
S/S – Solidification/Stabilization
s.u. – Standard Units

SVE – Soil Vapor Extraction
SVOC – Semi-Volatile Organic Compound
TCLP – Toxicity Characteristic Leaching Procedure
THQ – Target Hazard Quotient
TOC – Total Organic Carbon
TIC – Tentatively Identified Compound
TNT – Trinitrotoluene
TOX – Total Organic Halogens
TR – Target Risk
UCL – Upper Confidence Limit
UIC – Underground Injection Control
USEPA – United States Environmental Protection Agency
USGS – United States Geological Survey
UST – Underground Storage Tank
UV – Ultraviolet
UXO – Unexploded Ordnance
VOC – Volatile Organic Compound
XRF – X-ray Fluorescence

1.0 INTRODUCTION

This guidance document presents a comprehensive statement of the requirements for performing environmental investigations and remediation projects in Alabama. These requirements generally represent the Alabama Department of Environmental Management's (ADEM's) minimum expectations necessary for complete investigations and remediation projects for programs that manage contamination from hazardous constituents, hazardous waste, petroleum products, and/or petroleum wastes. Various programs administered by ADEM, which require investigation, monitoring and/or remediation, may have areas in which different or more specific requirements apply. This guidance document is designed to be used strictly as an aid for the development of adequate environmental investigations and remediation projects by individuals with the appropriate technical expertise and skill. This guidance document is not intended to be used as a substitute for existing program regulations and should not be used as such. Certain submissions required by ADEM involve the practice of engineering and/or land surveying, as those terms are defined in Code of Alabama 1975, as amended, § 34-11-1 to 34-11-37; and/or the practice of geology, as that term is defined in Code of Alabama 1975, as amended, § 34-41-1 to 34-41-24. It is the responsibility of any person preparing or submitting such information to ensure compliance with these laws and any regulations promulgated thereunder, as may be required by the State Board of Registration for Professional Engineers and Land Surveyors and/or the Alabama Board of Licensure for Professional Geologists. All submissions, or parts thereof, which are required by State law to be prepared by a licensed engineer, land surveyor, or geologist, must include the engineer's, land surveyor's and/or geologist's signature and/or seal, as required by the applicable licensure laws of the State of Alabama.

2.0 PRELIMINARY INVESTIGATION

2.1 Section Outline

2.2 Purpose of a Preliminary Investigation

A Preliminary Investigation is conducted to gain site information, identify conditions indicative of releases or threatened releases, confirm or deny that a release or releases of chemicals of potential concern (COPCs) has occurred, and determine what potential receptors exist in the area. The development of a dynamic conceptual site model (CSM) should begin at this point. The CSM should "support project decisions about exposure to contaminants, site cleanup and reuse, long term monitoring, etc. A detailed discussion regarding the CSM may be located in Section 2.4.3 of the ITRC "Technical and Regulatory Guidance for the Triad Approach – December 2003."

2.3 Elements of Preliminary Investigation Activities

A Preliminary Investigation Work Plan should be developed and, if required by a specific regulatory program, submitted to ADEM. The plan should include a detailed discussion of all applicable issues outlined in this section. The performance of the Preliminary Investigation should, at a minimum, include the following activities:

2.3.1 Surrounding Land Use - An accurate description of the surrounding land use should be made and should include, at a minimum, the following information:

(a) The type of surrounding population (rural vs. urban, residential/unrestricted vs. industrial, and population density),

(b) The location of the site (physical address, mailing address, latitude and longitude in decimal degrees with precision of six significant digits to the right of the decimal, and topographic map location (section, township and range)),

(c) A site map developed with information that includes, but is not limited to, all known:

i. Areas of concern (AOCs)
ii. Solid Waste Management Areas (SWMUs)
iii. Monitoring wells
iv. Sampling sites
v. Drainage patterns
vi. Utilities
vii. Buildings
viii. Property Boundaries
ix. North Arrow
x. Private & Public Supply Wells within a 1-mile radius of the property boundary
xi. Horizontal Scale

2.3.2 Well Inventory - A complete well inventory, both public and private, should be conducted within a 1 mile radius of the site boundaries using publicly available resources (*i.e.*, local water supply authorities, ADEM's Public Water Supply Branch, United States Geological Survey (USGS), Geological Survey of Alabama (GSA), *etc.*). Any pertinent information gleaned from a door-to-door survey of all residents within 500 feet of the property boundaries or as otherwise directed by the Department should also be included. A determination should also be made to identify if the site is located within a source water assessment area. Information on each identified well should include the following:

(a) The owner of the well
(b) The depth of the well
(c) The aquifer(s) of production
(d) The use of the well
(e) The screened interval
(f) The depth to groundwater

2.3.3 Surface Water Intake Inventory - A complete inventory of surface water intakes including both the potable springs and the surface water intakes should be conducted within a 1 mile radius of the site using publicly available resources (*i.e.*, local water supply authorities, ADEM's Public Water Supply Branch, USGS, GSA, *etc.*). Any pertinent information gleaned from a door-to-door survey of all residents within 500 feet of the property boundaries or as otherwise directed by the Department should also be included. A determination should also be made to identify if the site is located within a source water protection area. Information regarding source water protection areas may be found in ADEM Admin. Code r. 335-7 and on USEPA's website.

2.3.4 Surface Water Locations - The locations of all surface water bodies that may potentially be impacted by the subject property should be determined with a review of topographic or other area maps. Classification(s) of surface water stream(s) are listed in ADEM Admin. Code r. 335-6.

2.3.5 Records Search - A thorough records search concerning the current and historical activities and processes used on-site should be conducted. Corrective actions and response activities as well as institutional and engineering (land-use) controls at the site should be noted. The search should include an inventory list of all chemicals stored and used on site. The search should also include an inventory list of all types of wastes produced, managed, and/or disposed on site. These inventory lists will be essential in the determination of COPCs. The identification of COPCs is necessary in determining a sampling or analysis strategy. The inventory list of chemicals used and/or wastes produced on site should be compared with constituents listed in program-specific regulations to determine which, if any, may be of potential concern. A review of nearby and adjoining properties with potential environmental conditions or impacts should also be documented during the records search.

2.3.6 Utility Search - A thorough utilities survey should be conducted to identify and delineate all utilities that cross under the site or that are adjacent to the property. The utilities to be delineated should include sanitary sewers, storm sewers, water lines, electrical lines, gas lines, phone lines, or other utility lines. The delineation can be accomplished through use of "Line Locator" services, local utility personnel, personal communication with owner, ground penetrating radar, or other similar methods.

2.3.7 Sampling Strategy - A sampling strategy should be determined for each type of media to be sampled.

(a) The soil sampling strategy should include the following:

i. Soil sampling should be conducted in a manner expected to produce a representative concentration within each decision unit. A decision unit (also, sometimes referred to as an "exposure domain") is the defined area upon which a human receptor inhabits, works, plays, etc. The decision unit (DU) is the area upon which a representative concentration is defined for each of the COPCs and used to determine the exposure to the various receptors present in the defined area. In addition, an effort should be made to capture the maximum concentration of each of the COPCs within the DU(s) and along potential migration pathways (*i.e.*, utilities).

ii. A minimum of 4 soil borings for the collection of surface soil samples and subsurface soil samples should be conducted (See Appendix C of this document).

iii. To establish background surface and subsurface soil conditions (*i.e.*, for inorganic contamination or if a potential source of COPCs are upgradient of the site), the method described in Section 4.4 of this document should be followed.

iv. Soil borings should be extended to obtain samples that represent the zones most likely to have been impacted.

v. Soil borings should be extended to the top of the first continuous zone of saturation under the site or to bedrock if no groundwater is encountered. If it is determined that the water table or bedrock exists at significantly excessive depths, the Department should be notified for assistance.

vi. Soil samples should be collected in accordance with the methods outlined in Appendix C of this document. All soil samples should be analyzed in accordance with USEPA-approved methods included in the EPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition) or others.

vii. A minimum of 4 surface soil samples should be collected. All surface soil samples should be collected as grab samples and collected within the uppermost 12-inches of soil. These samples should be analyzed for the COPCs using Method Detection Limits (MDLs) that are less than or equal to the appropriate ADEM referenced Regional Screening Levels (RSLs) in accordance with Section 4.0 of this document.

viii. Subsurface soil samples should be collected at no more than 5-foot intervals from each boring. Subsurface soil samples may be field-screened (*i.e.*, PID, FID, XRF, and color-metric). If field screening methods are used, a minimum of 3 subsurface soil samples per boring (if possible) should be collected for laboratory analysis. The 3 subsurface soil samples should include, at a minimum, 2 samples exhibiting high field screening levels and 1 sample just above the water table. If soil borings are greater than 50 feet in depth, additional subsurface soil samples should be collected for laboratory analysis. All subsurface soil samples should be analyzed for COPCs using MDLs that are less than or equal to ADEM's RSLs selected in accordance with Section 4.0 of this document.

ix. All surface soil samples should be obtained by using appropriate equipment such as spoons, shovels, hand augers, push tubes, and post-hole diggers. Surface soil samples may also be collected in conjunction with the collection of subsurface soil samples using mechanical drilling equipment and/or ADEM-approved specialized sampling equipment (see Appendix C of this document).

x. All subsurface soil samples should be obtained using appropriate equipment such as Shelby Tubes, split spoon samplers or other specialized samplers (direct push technologies, EnCore^{TM} Samplers, *etc.*) (see Appendix C). The use of specialized samplers must be approved by ADEM prior to initiating all assessment activities. Auger cuttings are prohibited.

xi. Quality Assurance/Quality Control procedures and decontamination procedures outlined in Appendices D and E of this document should be utilized to ensure sample quality. USEPA's Guidance on Systematic Planning Using the Data Quality Objectives Process – EPA QA/G-4 may be helpful when considering such procedures.

xii. All Investigation-Derived Waste (IDW) should be collected, properly contained and stored, sampled and analyzed for a waste determination, and properly disposed of as outlined in Appendix D of this document and in accordance with ADEM Admin. Code r. 335-14-3-.08, 335-13-4-.21(1)(c), and 335-13-4-.26.

xiii. All analysis collected should be compared to the RSLs identified in Section 4.0 of this document.

(b) Installation of Groundwater Monitoring Wells should meet the following criteria:

i. Groundwater flow direction should be determined after the installation of 3 piezometers or Type-I temporary monitoring wells. All piezometers or Type-I temporary monitoring wells should be installed in accordance with the design, construction, and installation criteria addressed in Appendix B of this document.

ii. Based on the groundwater elevation/potentiometric surface data collected from the piezometers or Type-I temporary monitoring wells, a minimum of one permanent upgradient well located in an area that has not been impacted by the release or the site's activities should be installed.

iii. Typically a minimum of 3 permanent wells, located immediately down-gradient of the unit, structure, and/or at the release point, is appropriate.

iv. All permanent wells should be screened in the first saturated zone (or water-bearing zone) below the ground surface, or first saturated zone (or water-bearing zone) below the unit or structure under investigation. All permanent wells should have a maximum screened interval of 10-feet and should be placed at the appropriate interval to detect the COPCs. Nested well systems may be warranted and should be used if determined to be necessary.

v. All permanent monitoring wells should be installed, constructed, and developed in accordance with the appropriate drilling and monitoring well installation techniques (See Appendix B). Also, the ITRC's Technical & Regulatory Guidance, *The Use of Direct Push Well Technology for Long-Term Environmental Monitoring in Groundwater Investigations* may be used as a guide for direct push well installation.

(c) The collection of groundwater samples and flow measurements should adhere to the following procedures:

i. Groundwater samples should be collected from all permanent monitoring wells installed and analyzed for the COPCs.

ii. Groundwater samples should be collected in accordance with the approved methods documented in Appendix C of this document.

iii. All groundwater samples should be analyzed using USEPA-approved methods included in the USEPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition) with MDLs that are less than or equal to ADEM's RSLs selected in accordance with Section 4.0 of this document.

iv. Quality Assurance/Quality Control and decontamination procedures outlined in Appendices D and E of this document should be utilized to ensure sample quality. USEPA's *Guidance on Systematic Planning Using the Data Quality Objectives Process – EPA QA/G-4* may be helpful when considering such procedures.

v. All IDW (*i.e.*, groundwater and decontamination fluids) collected during the development and purging activities should be contained and disposed of as outlined in Appendix D.7 and in accordance with the ADEM Admin. Code r. 335-14-3-.08, 335-13-4-.21(1)(c), and 335-13-4-.26.

vi. A survey of the site should be conducted to establish well elevation, groundwater elevation, and ground elevation at each well; the locations of key structures; and the location of the release. The survey datum should be site-specific and based on a USGS-established benchmark or interpolated from a topographic map. Survey datum established to 100 feet artificial benchmark is prohibited.

(d) Surface water sampling should be conducted to collect representative sample(s) of the surface water(s) of interest. The sampling techniques and equipment used should ensure that the integrity of the sample is not compromised. The physical characteristics of the surface water and the location of access (*e.g.*, boat, pier, wading, bridge, *etc.*) should dictate the type of sampling equipment to be used in the sampling event. Surface samples can be collected by directly dipping the sample container into the water body. This can be done from a boat, pier, bridge, or by wading. Wading is appropriate if the water body has a noticeable current and the sample is collected in such a manner as to prevent biasing by the re-suspension of bottom sediments. Various types of primary sampling equipment such as peristaltic pumps, discreet depth samplers, bailers, buckets, and supplemental equipment may be necessary as conditions dictate.

For flowing water situations, samples should be collected from a minimum of three locations. If possible, the first sample should be collected downstream of an area of actual or suspected release, the second sample collected at the point of the actual or suspected release, and the third sample should be collected upstream of the area of the actual or suspected release. The upstream sample should be used to determine background levels. If an upstream sample is unattainable, a nearby site that has not been affected by the release should be used. Estuarine area samples are normally collected on successive slack tides. For water bodies that have a tendency to stratify and lack the mixing characteristics of flowing waters (*i.e.*, lakes, ponds, surface impoundments, *etc.*), the number of samples will be dependent upon the scope of the investigation. The following factors should be considered when conducting a surface water sampling event:

i. Water use
ii. Point source discharges

iii. Non-point source discharges (springs, seeps, storm-water runoff points, *etc.*)
iv. Tributary locations
v. Changes in stream characteristics
vi. Type of streambed
vii. Depth of stream, pond, lake, *etc.*
viii. Turbulence
ix. Presence of structures (weirs, dams, *etc.*)
x. Accessibility
xi. Tidal effect (estuarine)
xii. Gaining & loosing streams
xiii. Seasonal sampling (temporal) & area sampling (spatial) should be considered

(e) Sediment sampling should be conducted to collect representative sample(s) from affected or potentially affected surface water bodies. The physical characteristics of the sampling location should dictate the type of sampling equipment to be used to collect the sample. Wading is the preferred method for reaching shallow flowing water sampling locations. A number of sediment samples should be collected along a cross section of a water body in order to characterize the bed material.

The factors that should be considered when conducting a sediment sampling event are the same as when conducting a surface water sampling event. Additional information concerning sediment sampling and the remediation of sediment impacted sites may be found in ITRC's *Remediation of Contaminated Sediments* document.

2.3.8 Emergency Response and Free Product Recovery - Procedures for emergency response and free product recovery include, but are not limited to, the following:

(a) If free product is encountered or an immediate threat to human health and the environment occurs, free product recovery and emergency response activities should be implemented immediately.

(b) Results of the free product recovery and emergency response activities should be reported to ADEM in accordance with the applicable regulatory program.

(c) All free product recovery and emergency response activities should be conducted until all free product has been completely recovered, to the maximum extent possible and/or technically feasible; and/or immediate threat to human health and the environment has been eliminated. Affected programs (RCRA, CERCLA, UST, Industrial, UIC, *etc.*) should be referred to for specific recovery, remediation, and/or discharge requirements.

(d) Recovery of contaminated runoff should be conducted to the maximum extent possible, and/or technically feasible; and/or the immediate threat to human health and the environment has been eliminated. Affected programs (RCRA, CERCLA, UST, Industrial, UIC, *etc.*) should be referred to for recovery, remediation, and/or discharge requirements.

2.3.9 Management of Investigation-Derived Waste (IDW) - The management of all IDW (*i.e.*, soil cuttings, groundwater, decontamination fluids, and personal protective equipment (PPE)) generated during the Preliminary Investigation should include both the collection and the containment of such wastes. A waste determination should be performed for proper handling and disposal procedures. All wastes should be disposed of as outlined in Appendix D.7 of this document and in accordance with the ADEM regulations.

(a) *In-Situ* Waste Characterization (for disposal) Sampling – In an effort to allow for the efficient handling of remediation waste from a contaminated site, the Department will allow the *in-situ* characterization of those wastes following the guidance provided in this section. *In-situ* characterization is appropriate as long as the sampling can be completed in a manner that adequately characterizes the waste, as outlined below. *In-situ* characterization sampling will allow the remediation waste to be excavated and directly hauled to the disposal facility without onsite staging. *In-situ* characterization sampling may be conducted for two purposes:

1) Satisfying the investigation requirements to properly delineate and characterize a site for remedial evaluation and planning (see Section 3)
2) Satisfying waste approval requirements for disposal purposes

The *in-situ* characterization method described in this section applies to sampling conducted to satisfy the waste approval requirements and may differ from the sampling requirements established for investigation purposes. In order for the *in-situ* sampling to be accepted for waste characterization (for disposal) purposes, the sampling plan must be approved by the Department prior to sampling. Generally, it is anticipated that a higher number of samples, combined with smaller decision units, will be required when conducting sampling for disposal purposes to ensure adequate representativeness of site-wide variations, hot spots, and other factors which will affect the proper selection of disposal alternatives for remediation wastes generated from the site. Prior to the use of *in-situ* characterization sampling for disposal of remediation waste, the Department will require submittal of a Waste Characterization Sampling Plan that meets the minimum requirements as outlined in Appendix C, Section 2.1.(c) of this document (note that sieving is not allowed for disposal characterization sampling). To assist with the formulation of a Waste Characterization Sampling Plan, Chapter 9 of SW-846 or the Interstate Technology Regulatory Council (ITRC) Technical and Regulatory Guidance, Incremental Sampling Methodology or (with Department concurrence) other appropriate and statistically viable guidance, may be helpful for use as a guide. An appropriate sampling plan should specifically address the chemicals of concern (COCs) known or suspected to be in the contaminated media and the regulatory objective that the waste will be handled appropriately during final disposal. Once the objectives have been clearly identified, the sampling plan should be developed adhering to fundamental minimum concepts cited in the paragraphs below.

A sample collected for disposal purposes must represent all of the particle sizes present in the collected sample, not just the ≤2 millimeter (mm) fraction because all of the material is subject to disposal not exposure alone as in risk assessment. Therefore, sampling completed for the purposes of *in-situ* sampling for disposal should not be passed through a 2mm sieve. These samples are subjected to total concentration analyses and toxicity characteristic leaching procedure (TCLP) analyses for the chemicals of potential concern.

2.3.10 Local Geology – The results and interpretation of all site data collected including but not limited to soil and groundwater data, field reconnaissance and literature reviews should provide the following minimum local geology and hydrogeological characteristics:

(a) Description of the hydrogeological environment
(b) Type and nature of the site geologic material
(c) Determination and description of the uppermost aquifer
(d) Potential for interconnection with lower aquifers
(e) Susceptibility of underlying aquifers to surface contamination sources
(f) Depth to groundwater
(g) Groundwater flow direction and rate
(h) Preliminary determination of the extent of soil and groundwater contamination

2.4 Submission of a Preliminary Investigation Report

A Preliminary Investigation Report (PIR) should be developed and submitted to ADEM for review at the conclusion of the preliminary investigation. The PIR should include a detailed description of all investigation activities and information recommended by this guidance. An Investigation Checklist is located on the Department's website that indicates the appropriate components that should be included within a PIR.

3.0 COMPREHENSIVE INVESTIGATION

3.1 Section Outline

3.2 Purpose of a Comprehensive Investigation

A Comprehensive Investigation is conducted in order to determine the full horizontal and vertical extent of contamination (soil and groundwater) and/or free product plume in all media. Comprehensive Investigation is necessary when the results of the Preliminary Investigation confirm that contamination is present in any environmental media. A comprehensive investigation is necessary to design an accurate and complete CSM as discussed in Section 2.2 of this document.

3.3 Elements of a Comprehensive Investigation Work Plan

Develop a work plan prior to beginning a Comprehensive Investigation that includes detailed discussions of, at a minimum, all of the activities described below under soil investigation, groundwater investigation, and management of investigation-derived waste. If surface water has been determined to have been threatened or impacted by operations at the site, include surface water and sediment investigations. Refer to the applicable regulatory requirements for the specifics on the submittal of this plan to the Department.

At the conclusion of the Comprehensive Investigation, develop a Comprehensive Investigation Report (CIR) and submit to ADEM in accordance with the applicable regulatory requirements, and include a detailed description of all investigation activities conducted at the site. In addition to the copies of all original laboratory reports, include electronic versions of all analytical data (past and present) obtained from each monitoring well. Compile these data and report to the Department in a spreadsheet format. An Investigation Checklist is provided on the Department's website and should be referred to during the development of an Investigation Work Plan or Report.

If a previous Preliminary Investigation Report was not submitted to ADEM prior to initiation of any comprehensive investigation activities, include in the "CIR" a summary of all investigation activities conducted, with all respective soil boring logs, monitoring well diagrams, analytical data, and laboratory reports with copies of completed chain-of-custody forms.

3.4 Elements of a Comprehensive Investigation

A Comprehensive Investigation includes, at a minimum, the elements mentioned in the following sections. Additional information regarding investigation planning and environmental work in general may be found within a variety of guidance documents. The hyperlinks and citations provided in this document are for helpful reference and may be used in the development of a facility's respective investigation plan. It should be noted that use of the provided hyperlinks and citations alone does not ensure Departmental approval/acceptance of such sampling and investigation plan. Please note that reference to these guidance documents does not endorse the methods or technologies mentioned within.

- *Technical & Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management*
- *Improving Environmental Site Remediation Through Performance Based Environmental Management*
- *Accelerated Site Characterization*
- *An Introduction to Characterizing Sites Contaminated with DNAPLs*
- *The Use of Direct-Push Technology for Long-Term Environmental Monitoring in Groundwater Investigations*
- *Incremental Sampling Methodology*
- SW-846 Ch. 9
- *Use and Measurement of Mass Flux and Mass Discharge*
- *Vapor Intrusion Pathway: A Practical Guideline*
- *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* – June 2015
- *Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management*
- *Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* – June 2015
- *Environmental Molecular Diagnostics – New Tools for Better Decisions*
- *Groundwater Statistics and Monitoring Compliance – Statistical Tools for the Project Life Cycle*
- *Guide to the Assessment and Remediation of State-Managed Sediment Sites*
- *Geophysical Classification for Munitions Response – Introductory Fact Sheet*
- *Frequently Asked Questions about Wide-Area Assessment for Munitions Response Projects*
- *Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater*
- *Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites*
- *Characterization, Design, Construction, and Monitoring of Mitigation Wetlands*

3.4.1 Soil Sampling – Conduct a systematically-designed soil sampling investigation in order to define the horizontal and vertical extent of contamination in soils within each DU. Extend all soil borings to obtain samples that represent the zones most likely to have been impacted. Consequently, extend all soil borings to the water table or to bedrock if no water is encountered. If it is determined that the water table or bedrock exists at significantly excessive depths or other conditions exist at the site which preclude the need to have soil borings extend to the water table or bedrock, develop an alternative soil sampling plan and submit to ADEM for review and approval.

Collect all soil samples in accordance with the appropriate soil sampling methods outlined in Appendix C of this document. Analyze all soil samples in accordance with the USEPA-approved methods included in the EPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition) or other methods approved by the Department.

Collect surface soil samples from between the surface and 12 inches below ground surface (bgs). Collect all surface soil samples by one of the methods described in Appendix C of this document determined to be appropriate for the site. Analyze all samples for the COPCs. Alternative soil sampling methods other than those outlined in Appendix C of this document must be developed and submitted to ADEM for review and approval prior to the initiation of the Comprehensive Investigation.

Surface soil samples may be obtained by using spoons, scoops, shovels, hand-augers, push tubes, or post-hole diggers. Surface soil samples may also be collected in conjunction with the collection of subsurface soil samples using heavy mechanical drilling equipment and/or ADEM-approved specialized sampling equipment in accordance with Appendix C of this document.

Collect subsurface soil samples from each boring and field-screen (PID, FID, XRF, and color-metric). The number of samples collected should correspond with the applied sampling methodology selected for the site. Analyze all subsurface soil samples for the COPCs. Auger cuttings are prohibited from use as a soil sample.

In order to expedite the assessment process, specialized sampling methods can be used to collect subsurface soil samples. Specialized sampling methods and tools, which can be utilized, include immunoassay analyses, soil vapor survey, and field gas chromatographs. Appendix C of this document includes detailed discussions of various field screening methods. The use of specialized samplers must be approved by ADEM prior to initiating all assessment activities.

Utilize the Quality Assurance/Quality Control (QA/QC) procedures (Appendix D of this document) and EPA-required decontamination procedures (Appendix E of this document) to ensure sample quality. The USEPA has helpful guidance documents and tools to assist with this topic as does USEPA Region 4.

3.4.2 Groundwater Sampling – Conduct a systematically designed groundwater investigation in order to define the horizontal and vertical extent of contamination. Determine site-specific hydrogeologic conditions at the sites or area(s) of concern. Establish potential interconnection of an overlying aquifer or saturated zone with any deeper aquifer or saturated zone. Establish the hydrogeologic conditions and interconnection potential by all previous and proposed soil borings, all previous and proposed monitoring wells, hydraulic tests (slug and pump tests), geophysical survey investigations, and/or dye trace studies. If hydrogeologic conditions justify the need for a dye trace study (karst and highly fractured environments) and/or there is a potential risk to a public supply well or a significant spring, which is utilized as a public water supply, conduct a dye trace study to determine if a migration pathway from the area of contamination and the public supply well or spring exist. A "multiple lines of evidence" approach should be utilized when evaluating complex hydrogeologic conditions. A dye trace study is only a single line of evidence. In addition, it may be appropriate to conduct geophysical mapping of the karst or highly fractured geologic features by seismic, sounding, gravity, ground penetrating radar, and/or other approved geophysical methods that enhance the effectiveness of the sampling locations and three dimensional understanding of the bedrock features.

Installation of a sufficient number of monitoring wells down-gradient is necessary to determine the horizontal extent of contamination. Screen all monitoring wells in the same saturated zone, water bearing zone, or stratigraphic interval currently being monitored in the previous monitoring wells installed during the Preliminary Investigation.

At a minimum, locate one monitoring well within the source release area. It must be screened in an interval beneath the shallower contamination plume and show no evidence of contamination. Due to site-specific hydrogeologic and groundwater quality conditions encountered during the Preliminary Investigation, additional deep monitoring wells or well nests may be necessary to verify that the vertical extent of the contamination plume has been adequately investigated down-gradient of the contamination source area.

Methods, such as direct push technologies, can be used to locate monitoring wells more effectively, and to significantly expedite the assessment process. However, these methods when utilized to sample groundwater by temporary monitoring wells or well-points only provide point in time snapshots of the groundwater conditions at the time of sampling. If monitoring of groundwater conditions over time is required, the advancement of soil borings and the installation of permanent monitoring wells that meet the monitoring well design requirements discussed in this guidance document are necessary.

Install a sufficient number of monitoring wells to define the horizontal and vertical extent of any free product plume such as light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL). Install a sufficient amount of monitoring wells within the free-product plume to monitor the effectiveness of any free-product recovery efforts. Install and screen all permanent wells to adequately establish the thickness of the free-product plume.

Install, construct, and develop all permanent monitoring wells in accordance with the acceptable procedures described in Appendix B of this document.

Collect groundwater samples from all permanent groundwater monitoring wells in accordance with the procedures outlined in Appendix C of this document. Analyze all samples for COPCs using the analytical methods included in the EPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition). Any analytical method utilized must be capable of using MDLs that are less than or equal to the RSLs developed in accordance with Section 4 of this document. Utilize the QA/QC procedures outlined in Appendix D of this document to ensure sample quality.

Survey all permanent monitoring wells installed during the Comprehensive Investigation to establish top of casing elevations, ground elevations, latitude and longitude. Conduct all surveys to an established datum that is site-specific and based on a USGS-established benchmark or interpolated from a topographic map. Survey datum established to a 100 feet artificial benchmark is prohibited. Monitoring wells may be located utilizing Global Positioning System (GPS) technology.

Determine the groundwater flow direction and rate. Conduct a sufficient number of slug tests (slug in and slug out) or an aquifer pump test to establish the hydraulic characteristics of the uppermost aquifer (transmissivity, storativity, porosity, leakage, hydraulic gradient, hydraulic conductivity, and flow rate).

Design a groundwater monitoring schedule in accordance with regulatory requirements. Develop and submit to ADEM a Groundwater Monitoring Report during the first year of groundwater monitoring. The Groundwater Monitoring Reports include:

(a) A description of all sampling activities conducted

(b) Conclusions and interpretations drawn from the sampling event and analytical results

(c) A site map illustrating the location of all monitoring wells on site and off site

(d) A potentiometric map of the site illustrating the groundwater elevations at each well and the groundwater flow direction

(e) A site map illustrating the contamination plume and analytical results for the COPCs

(f) A table documenting all water levels and total depth of all wells measured, top of casing elevations, and groundwater elevations

(g) The original laboratory reports obtained from the contracted laboratory

(h) A table of current and historical groundwater analytical data obtained

(i) All completed chain-of-custody forms

3.4.3 Surface Water Sampling - If it is determined that a surface water body (rivers, streams, creeks, lakes, ponds, impoundment, wetlands and estuaries) is threatened or has been impacted by a release, conduct a complete investigation of that surface water body. The investigation includes, at a minimum, the following information:

(a) Water use

(b) Point source discharges

(c) Nonpoint source discharges (springs, seeps, storm-water runoff points, *etc.*)

(d) Tributary locations

(e) Changes in stream characteristics

(f) Type of streambed

(g) Turbulence

(h) Presence of structures (weirs, dams, *etc.*)

(i) Tidal effect (estuarine)

(j) The width and depth

(k) The flow velocity

(l) Surface water sampling upstream, downstream and at intermediate stations along the length of the potentially affected area of a stream, and when major changes occur in a stream reach

(m) Surface water sampling from any pond, lake, and impoundment potentially impacted

(n) Surface water sampling from estuarine or wetland areas potentially impacted

(o) If the site or sites is located within a complex hydrogeologic setting (*i.e.*, karst and fractured flow environments), a dye trace study should be conducted to identify all direct migratory pathways from the site to all potential surface water bodies in the area

(p) Figure or map showing the 100-year floodplain. These flooded areas indicate the potential for spatial and temporal contamination

Collect all surface water samples in accordance with the procedures outlined in Appendix C of this document and analyze for the COPCs using the analytical methods included in the EPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition) or other ADEM-approved methods. Utilize the *Quality Assurance*/*Quality Control* procedures identified in Appendix D of this document to ensure sample quality. Surface water samples should be compared to the values calculated and presented in ADEM Admin. Code r. 335-6-10 and to the appropriate values as indicated by the Department and the *Alabama Risk Based Corrective Action ARBCA Guidance Manual*.

3.4.4 Sediment Sampling – The assessment, risk management, and remedial decisions for sediment evaluation involve more complex scientific and policy concerns than the traditional soil-scenario. When conducting a sediment investigation, a number of factors should be considered. These factors have been outlined in the ITRC *Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites* Technical & Regulatory Guidance Document as well as the ASTSWMO *Guide to the Assessment and Remediation of State-Managed Sediment Sites*. In some cases it may be necessary to utilize passive polyethylene (PE) samplers in support of *in-situ* characterization and remediation of contaminated sediments. The link below provides information on this technology as well as links to the SOPs for the extraction and analysis of PE used in PE devices, deployment and retrieval of PE devices in sediment, and the preparation of PE devices.

Once the sediment sampling protocol for a site has been established, any sediment samples collected should be handled in accordance with the procedures outlined in Appendix C of this document and analyzed for the COPCs using the analytical methods included in the EPA document *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846* (latest edition) or analyzed using other ADEM-approved methods. Utilize the QA/QC procedures identified in Appendix D of this document to ensure sample quality.

3.4.5 Management of Investigation-Derived Waste (IDW) - Management of all IDW (*i.e.*, soil cuttings, groundwater, decontamination fluids, and personal protective equipment (PPE)) generated during the Comprehensive Investigation includes both the collection and the containment of such wastes. Perform a waste determination for proper handling and disposal procedures. Dispose of all wastes as outlined in Appendix D.7 and in accordance with ADEM Admin. Code r. 335-14-3-.08, 335-13-4-.21(1)(c), and 335-13-4-.26.

3.5 Submission of a Comprehensive Investigation Report

At the conclusion of the Comprehensive Investigation, develop a Comprehensive Investigation Report (CIR) and submit to ADEM for review in accordance with the applicable regulatory requirements. The CIR should include a detailed description of all investigation activities conducted at the site and information collected under this section or, if applicable, in accordance with any additional ADEM program requirements. In addition to the copies of all original laboratory reports, electronic versions of all analytical data (past and present) obtained from each sample collected should be included. This data should be compiled and submitted to the Department in a spreadsheet format. An Investigation Checklist is provided on the Department's website and should be referred to during the development of an Investigation Report.

If a Preliminary Investigation Report was not submitted to ADEM prior to initiation of any comprehensive investigation activities, a summary of all preliminary investigation activities conducted, with all respective soil boring logs, monitoring well diagrams, analytical data, and laboratory reports with copies of completed chain-of-custody forms should be included in the CIR.

4.0 RISK ASSESSMENT

4.1 Section Outline

4.2 Purpose of a Risk Assessment

At the completion of the Comprehensive Investigation, a sufficient amount of data must be available to support an assessment of baseline risks to human and ecological receptors. The risk assessment is intended to provide regulatory and site managers with information to:

1. Determine risk-based target levels (RBTLs) (*i.e.*, remediation levels) of contaminants of concern that can remain on-site and still be protective of human health and the environment;
2. Provide data to evaluate remedial alternatives for potential impacts to human health and the environment; and,
3. Effectively document and communicate to the public risks associated with contaminated properties.

4.3 Regional Screening Levels

It is common for environmental risk assessments to begin with a comparison of site-specific contaminant concentrations to Regional Screening Levels (RSLs). RSLs are conservative health-based concentrations of hazardous constituents determined to be indicators for the protection of human health or the environment. The RSLs are updated twice per year and are managed by the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) under an Interagency Agreement as a merger of the risk assessment information gathered and determined by EPA Regions 3, 6 and 9. When reviewing the RSL table, the Department recommends the use of the columns denoting a Target Hazard Quotient (THQ) of 0.1 and a Target Risk (TR) of 1E-06. The detection of a contaminant(s) at a concentration greater than an RSL does not necessarily trigger a requirement to perform remediation. Conversely, the absence of chemical concentrations greater than RSL does not necessarily mean that no further investigative or remedial action is warranted. These decisions are made on a case-by-case basis. RSLs simply provide a general and rapid measure of the overall risk to human health and the environment associated with a contaminated site. In some cases, RSLs are utilized as default remediation levels because they are based on highly conservative exposure assumptions. Additional information on the use of the RSLs within the State of Alabama may be found within the *Alabama Risk-Based Corrective Action (ARBCA) Guidance Manual*. RSLs for all affected media should be evaluated and/or developed in accordance with the *ARBCA Guidance Manual* for the following areas:

4.3.1 Groundwater – RSLs for constituents in groundwater are equivalent to the Maximum Contaminant Levels (MCLs) when available as cited in the ARBCA Guidance Manual and as listed by the USEPA's Drinking Water Standards. For constituents with no MCLs, RSLs have been calculated and are presented in tabular form on the RSL website.

4.3.2 Surface Water – RSLs for surface water must be consistent with the Alabama Water Quality Criteria (ADEM Admin. Code r. 335-6-10). For constituents with no Water Quality Criteria values, the Department should be consulted and a site-specific determination will be made.

4.3.3 Ambient Air - RSLs for ambient air must be consistent with the appropriate column of the most updated version of the RSL Table.

4.3.4 Soils – RSLs for soil must address several specific exposure routes and evaluated individually for: (1) ingestion, (2) inhalation, (3) dermal contact and (4) protection of groundwater (leachability). RSLs to address the direct contact routes of ingestion, inhalation and dermal contact are evaluated within the "Resident Soil" and "Industrial Soil" columns of the RSL Table. The RSLs to address in the indirect contact exposure pathway of protection of groundwater are found in the "Protection of Groundwater SSLs" (soil screening levels) column of the RSL Table. Where a value is present in the "MCL-based SSL" column that value should be used. In the absence of a "MCL-based SSL" value, the "Risk-based SSL" value should be used. In the case where ecological receptors are a concern, the USEPA's Ecological Soil Screening Levels (Eco-SSLs) should be used.

4.3.5 Sediment - RSLs for constituents in sediment are based on whether human health or ecological health is the major concern. If ecological concerns are deemed to predominate, the use of USEPA Region 4 Ecological Screening Values (ESVs) for sediments should be used. If human health is the prevailing concern, then the human health RSLs for sediment shall be consistent with those for soils.

4.3.6 Ecological – Compare surface water and sediment data collected to USEPA Region 4 Eco SSLs with respect to ecological receptors. Additionally, sediment that is not saturated year round must be evaluated as surficial soil as well as sediment. In the absence of a Region 4 ESV for surface water, compare the surface water concentrations to the Water Quality Criteria in accordance with ADEM Admin. Code r. 335-6-10 ("Aquatic Life Criteria"). If the surface water is a "water of the state" as defined in ADEM Admin. Code r. 335-6-10-.02(10), then the surface water concentrations should be compared to the Water Quality Criteria regardless of whether a Region 4 value exists, and the ADEM Water Division should be contacted. In the absence of a USEPA Region 4 ESV or an ADEM Water Quality Criteria Value, surface water sample results should be compared to the appropriate Region 3 Biological Technical Assistance Group (BTAG) screening value. In the absence of a USEPA Region 4 ESV for sediment, the sediment concentrations should be compared to the Florida Sediment Quality Assessment Guidelines (SQAGs). In the absence of a Florida SQAG value, sediment should be compared to a Region 3 BTAG screening value.

4.4 Evaluation of Background Conditions

While RSLs provide a general and rapid assessment of risk, many RSLs, particularly for inorganic constituents, may be substantially less than concentrations that are found in environmental media under ambient conditions. Site managers must consider background conditions during site characterization.

To determine if a natural background is present in the soils, a minimum of four background samples should be obtained in an area expected to be unaffected by current or historical processes, but within depositional environments similar to those in impacted areas. Two times the arithmetic mean of the background sample's concentrations must be screened against the on-site maximum detected concentration. If a the COPC's concentration is less than two times the background level, the contaminant of concern may be eliminated from the list of contaminants.

Up-gradient monitoring wells may be installed in order to provide a measure of ambient groundwater quality and an indication of up-gradient sources of contamination. The statistical procedures used to evaluate the groundwater samples are site-specific due to the variability of groundwater flow parameters throughout the State.

In some cases, it may be necessary to evaluate an anthropogenic background source. Anthropogenic substances are natural and human-made substances present in the environment as a result of human activities (not specifically related to the site in question). Some chemicals may be present in background as a result of both natural and man-made conditions such as naturally occurring arsenic and arsenic from pesticide applications or smelting operations.

Generally, the type of background substance (natural or anthropogenic) does not influence the statistical or technical method used to characterize background concentrations. For this reason, the anthropogenic background concentration should be determined in the same manner as described above for the naturally occurring background concentrations.

For other media or additional information concerning the determination of a background concentration, please contact the Department.

4.5 Comprehensive Risk Evaluation

If maximum detected site concentrations exceed background conditions and RSLs, a more comprehensive evaluation of risks to human health or the environment may be needed. The most recent edition of the ARBCA Guidance Manual should be utilized when a more comprehensive evaluation is determined necessary.

4.6 Risk Management Evaluation

In order to maximize the conservation of State resources, ADEM encourages sites to develop remediation levels based on an unrestricted land-use (residential) scenario. RSLs and remediation levels based on an alternate land-use scenario (*e.g.*, industrial) may be appropriate if the site owner/operator is willing to establish an appropriate combination of engineering and land-use controls (LUCs) to ensure against inappropriate uses of the property. Depending on the specific regulatory program, such controls may require some form of enforceable document issued by the State (*e.g.*, a permit, consent agreement, and/or an environmental covenant in accordance with ADEM Admin. r. 335-5) to ensure long-term maintenance of these controls. If the maximum site concentrations exceed the RSLs, these concentrations must be evaluated under the Risk Management (RM)-1 or RM-2 process.

4.6.1 **RM-1** - An RM-1 evaluation first requires the determination of whether the cumulative risk at a site exceeds appropriate risks levels (*i.e.*, Hazard Index = sum of HQs = 1.0, and Target Risk = 1E-05).

4.6.2 **RM-2** - The RM-2 is the most site-specific evaluation. An RM-2 evaluation may require the collection of additional site-specific data, use of alternate fate and transport models, or other risk assessment approaches. For additional details regarding the RM-1 and RM-2 processes refer to the ARBCA Guidance Manual.

5.0 REMEDIATION

5.1 Section Outline

5.2 Purpose

The purpose of this section is to outline specific activities that are necessary for sites that have been determined to be a threat to human health and the environment, and/or where elevated plumes and/or areas of contamination exceeding regulatory limits have been determined.

5.3 Necessary Elements

5.3.1 Remediation Levels – Provide a summary of the remediation goals, including acceptable RBTLs that apply to the site (see Section 4 of this document), to the Department.

5.3.2 Plans/Designs – Submit a remediation plan to the Department for review prior to implementation, in accordance with applicable requirements. Cleanup/remediation plans must include, but not be limited to, the following list. The Remediation Checklist provides a more specific list and can be downloaded from the Department's website.

(a) A description of the cleanup objectives with discussions of the remediation technology (or technologies) to be applied at the site for the contaminants of concern in all affected media.

(b) If free-phase product is present and extraction is the method for remediation, a description of the technique and placement of the extraction point(s) or a description of existing extraction is appropriate when applicable.

(c) Detailed plans and an engineering report with a description of the proposed cleanup method to remediate soils, sediments, and groundwater, and to mitigate potential hazardous discharges into a surface water source.

(d) A detailed description of the proposed groundwater remediation system including plans describing sampling points, monitoring well locations, analytical methods, and any other procedures or systems used for evaluating the effectiveness of the remediation plan, if applicable.

(e) A detailed description of how all treated wastewater or soils removed will be handled.

(f) The institutional requirements such as State or local permit requirements, or other environmental or public health requirements that may substantially affect implementation of the remediation system.

(g) An itemized schedule for implementation of the cleanup plan.

(h) A site plan map showing:

   i. A North directional arrow

   ii. A horizontal scale

   iii. Culture relevant to the site (buildings, structures, *etc.*)

   iv. The location of the point source of the contaminant release

   v. All sumps, above ground storage tanks, pipelines, *etc.*

   vi. The horizontal and vertical extent of free-product and/or dissolved phase contaminants in groundwater to above the regulatory levels

   vii. The horizontal and vertical extent of the soils and/or sediments that are contaminated at levels in exceedance of the RSLs

   viii. The location of the groundwater monitoring well system, which defines the horizontal and vertical extent of contamination

   ix. The location of the proposed remediation system extraction/injection wells or points

   x. The proposed locations of an adequate number of wells to monitor the effectiveness of the remediation system

(i) A potentiometric surface map contoured to equal mean sea level elevations of the static water level taken during the same measuring event in all groundwater monitoring wells and/or piezometers at the site. The potentiometric surface map should include:

   i. A North directional arrow

   ii. A horizontal scale

   iii. The direction of groundwater flow indicated by arrows pointing down-gradient and perpendicular to the contours of equal groundwater elevation

   iv. Groundwater elevations for the event in each well

(j) The format of the remediation plan effectiveness report will vary depending on the type of remediation technology utilized and the program under which the site is operating. The report should be prepared in accordance with applicable program requirements. The general report format must include, at a minimum, the following:

i. A detailed description of all remediation and/or groundwater sampling activities

ii. A detailed description including summary tables of all analysis collected and conclusions developed

iii. A site map showing the location of the groundwater monitoring system (if groundwater is being remediated)

iv. Potentiometric surface maps for all applicable aquifers or separate saturated zones being monitored (if groundwater is being remediated)

v. Time vs. Concentration graphs of selected wells and parameters to demonstrate the effectiveness of the groundwater remediation system (if groundwater is being remediated)

vi. Capture zone modeling results indicating the area of influence

vii. Recommendations for upgrade, modification of the system, or any additional remediation activities

(k) If appropriate, a detailed cost estimate based on the cost to the owner or operator of hiring a third party to conduct all corrective actions required. The corrective action cost estimate is calculated by multiplying the annual corrective action cost estimate by the total number of years in the corrective action period. Estimation of the required corrective action period shall be made on a case-by-case basis, shall be based on the corrective action methods specified in the cleanup/remediation plan and shall be certified by an independent registered professional engineer and/or independent licensed professional geologist. The corrective action cost estimate may not include any salvage value that may be realized through the sale of any assets sold by the facility. In addition, the owner or operator may not incorporate a zero cost for hazardous waste or non-hazardous wastes that might have an economic value.

5.3.3 Decontamination - Prior to utilization of sampling equipment, decontaminate all equipment in accordance with Appendix E of this document. All personnel must wear clean disposable sampling gloves when obtaining or handling samples. Change gloves between each sampling event.

5.3.4 Case Studies on New Technologies - For new remediation technologies that are not currently discussed in Appendix F of this document, or have not been previously utilized in the State of Alabama, an effectiveness report or case study report developed from other sites utilizing the proposed remediation system must be submitted to the Department. The report must demonstrate the effectiveness of the proposed remediation system and comparable environmental conditions.

5.3.5 Management of Remediation Waste (All Media) - Remediation of sites under various corrective action programs may involve the management of large amounts of waste such as contaminated soils, recovered groundwater, debris, sludges, discarded PPE and used disposable sampling equipment. Manage all remediation wastes generated during site activities in accordance with Divisions 13 and 14 of the ADEM regulations. There may be special management options for on-site generated remediation wastes. Site managers must consult ADEM for the appropriate requirements. For waste being disposed in Alabama, a waste approval must be obtained in accordance with ADEM Admin. Code r. 335-13-4-.21(1)(c), 335-13-4-.26, and 335-14-3-.08.

5.3.6 Regulatory Requirements (SID, NPDES, UIC, Air, UST, *etc.*) - Many remediation technologies may be subject to special regulatory and/or permitting requirements including, but not limited to:

(a) National Pollutant Discharge Elimination System (NPDES) permitting (ADEM Water & Field Operations Divisions);

(b) State Indirect Discharge (SID) permitting (ADEM Water & Field Operations Divisions);

(c) Underground Injection Control (UIC) permitting (ADEM Land Division);

(d) Source Water Assessment Program (ADEM Water Division);

(e) Air Emissions (ADEM Air Division); and,

(f) Waste Disposal Approval (ADEM Waste/Remediation Division).

Site managers must consult with ADEM for any specific regulatory requirements associated with the proposed remediation technology.

5.4 Remedy Selection

5.4.1 Source Control - Source control measures must be evaluated as part of the remedy decision process at all sites, particularly where Monitored Natural Attenuation (MNA) is under consideration as the remedy or as a remedy component. Source control measures include removal, treatment, containment, or a combination of these approaches.

Contaminant sources that are not adequately addressed complicate the long-term cleanup effort. For instance, following free-product recovery, residual contamination from a petroleum fuel release may continue to leach significant quantities of contaminants into the groundwater posing unacceptable risks to humans and/or the environment. Such a lingering source often extends the time necessary to reach remediation objectives. This leaching can occur even while contaminants are being naturally attenuated in other parts of the plume. If the rate of attenuation is lower than the rate of replenishment of contaminants to the groundwater, the plume can continue to expand, contaminating additional groundwater and potentially posing a threat to down-gradient receptors.

Control of source materials is the most effective means of ensuring the timely attainment of remediation objectives. The Department, therefore, expects that source control measures will be taken at most sites where practicable. At many sites, it will be appropriate to implement source control measures during the initial stages of site remediation (“phased remedial approach”), while collecting additional data to determine the most appropriate remedy.

5.5 Land-Use Controls

The purpose of land-use controls (LUCs) is to ensure that risks to human health and/or the environment are properly managed by imposing activity and use restrictions, in the form of engineering and/or institutional controls, on the portion(s) of a site that contains contamination above unlimited use/unrestricted exposure levels. For sites where contamination is left in-place above unrestricted reuse exposure levels, an environmental covenant (EC) is required in accordance with the Uniform Environmental Covenants Act, and its associated regulations found in ADEM Admin. Code r. 335-5. An EC may also be required for sites with long-term remedies (*i.e.*, groundwater remedy sites).

5.5.1 Initial Phase - During the initial phase of cleanup, the site manager should:

(a) Establish clear objectives (*i.e.*, goals to be accomplished through the use of LUCs)

(b) Discuss future land-use plans with the community and local government to assist in analyzing the appropriate LUCs and other remedial alternatives

(c) Evaluate LUCs using the appropriate threshold criteria (used to determine if the possible solution to an environmental problem protects human health and the environment and meets the state regulations), balancing criteria (used to determine which of the criteria meeting the threshold criteria will work), and modifying criteria (used to determine if the recommended solution is acceptable to the Department)

(d) Coordinate with regional attorneys on legal matters, the Department, and any other state agency as appropriate

5.5.2 Remedy Selection - During remedy selection, the site manager should:

(a) Present information that assists the public to understand the impacts of the specific LUCs and their relationship with the overall remedy

(b) Clearly describe the objectives to be attained by LUCs

(c) Specify performance standards (*e.g.*, prevent exposure to contaminated groundwater by prohibiting well drilling)

(d) Consider layering LUCs to enhance their overall effectiveness

(e) Discuss with entities (*e.g.*, local/state governments) involved in implementing LUCs

(l) Discuss the kinds of controls envisioned and include enough information to show that effective implementation of the LUCs can reasonably be expected

(m) Discuss plans for monitoring land use and other aspects of the remedy that depend on LUCs

(n) Discuss the enforcement mechanisms that are anticipated to ensure the long-term reliability of the LUCs (*e.g.*, universal environmental covenant, notice to the deed to the property)

(i) Continue coordination with the attorneys

5.5.3 Remedy Implementation - During remedy implementation, the site manager must ensure that appropriate measures are taken to implement the LUCs (*e.g.*, arrange discussions between potentially responsible parties (PRPs), other property owners, and local government/state officials).

5.5.4 Post-Remediation Activities - During Post-Remediation activities (*e.g.*, a CERCLA 5-year review), the site manager should:

(a) Evaluate both the administrative/legal components as well as the physical evidence to ensure that LUCs are implemented and fully effective;

(b) Ensure that any LUCs are available for inspection by any person performing a standard title search on the property and that the objectives of the LUCs are clearly presented; and,

(c) Ensure that the site is listed on the Alabama Cleanup Properties Inventory List.

Appendix A

Glossary

APPENDIX A GLOSSARY

ADEM – The Alabama Department of Environmental Management, as established by Code of Alabama 1975, § 22-22A-4.

Administrator – The Administrator of the United States Environmental Protection Agency.

AHWMMA – The Alabama Hazardous Wastes Management and Minimization Act of 1978, as amended, Code of Alabama 1975, §§ 22-30-1 et seq.

ASTM – American Society for Testing and Materials. A technical society that publishes national standards for the testing and quality assurance of materials.

CERCLA – The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.

Certification – A statement of professional opinion based upon knowledge and belief.

Commission – The Alabama Environmental Management Commission, as established by Code of Alabama 1975, § 22-22A-6.

Contaminant – Any man-made or man-induced alteration of the chemical, physical or biological integrity of soils, sediments, air, surface-water or groundwater including, but not limited to, such alterations caused by:

1. Hazardous substance (as defined in the CERCLA , 42 USC § 9601(14));
2. Hazardous waste (as defined in ADEM Administrative Code r. 335-14);
3. Hazardous constituent (as defined in ADEM Administrative Code r. 335-14-2-Appendix VIII and/or ADEM Administrative Code r. 335-14-5-Appendix IX);
4. Solid waste (as defined in ADEM Administrative Code r. 335-13); or,
5. Petroleum product.

COPC – Constituent of Potential Concern

Director – The Director of ADEM, appointed pursuant to Code of Alabama 1975, § 22-22A-4, or his designee.

Disposal – The discharge, deposit, injection, dumping, spilling, leaking, or placing of any hazardous waste into or on any land or water so that such hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters including groundwater.

DNAPL – Dense Non-Aqueous Phase Liquid.

Endangered or Threatened Species – Any species listed as such pursuant to Section 4 of the Endangered Species Act.

Global Positioning System (GPS) – The location of items on the earth's surface determined by their coordinates in relation to a series of satellites.

GPS Method – The process of determining the latitude and longitude of a point on the earth's surface using GPS, collected and differentially-corrected data to an EPA-accepted accuracy of 25 meters at a specified datum (*i.e.,* NAD 83).

Land-Use Controls (LUCs) – Engineered (such as fencing, land caps, *etc*.) and/or non-engineered control instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use.

LNAPL – Light Non-Aqueous Phase Liquid.

National Pollutant Discharge Elimination System (NPDES) – The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits for the discharge of pollutants into waters of the state.

RCRA – The Federal Resource Conservation and Recovery Act of 1976, as amended, (42 U.S.C. §§ 6901 et seq.).

Regional Administrator – The Regional Administrator for the EPA Region in which the facility is located, or his designee.

Regulated Substance – Any substance defined in section 101(14) of the CERCLA of 1980 (but not including any substance regulated as a hazardous waste under Division 14 of the ADEM Administrative Code); and petroleum, including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure (60 degrees Fahrenheit and 14.7 pounds per square inch absolute). The term "regulated substance" includes, but is not limited to, petroleum and petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation, conversion, upgrading, and finishing, such as motor fuels, jet fuels, distillate fuel oils, residual fuel oils, lubricants, petroleum solvents, and used oils.

Remediation waste – All solid and hazardous wastes, and all media (including groundwater, surface water, soils, and sediments) and debris that contain listed hazardous wastes or those that exhibit a hazardous characteristic and are managed for implementing cleanup.

Solid waste – means a waste as defined by ADEM Admin. Code r. 335-14-2-.01(2) and 335-13-1-.03(126).

Spill – An unplanned, accidental, or unpermitted discharge, deposit, injection, leaking, pumping, pouring, emitting, dumping, placing, or releasing of hazardous wastes, or materials which when spilled become hazardous wastes, into or on the land, the air, or the water.

State Health Officer – The Health Officer for the State of Alabama as set out in § 22-2-8, Code of Alabama 1975, or his designee provided by law.

Appendix B

Monitoring Well Installation/Development/Abandonment Guidelines

APPENDIX B - MONITORING WELL INSTALLATION/DEVELOPMENT/ABANDONMENT GUIDELINES

B.1 Appendix Outline

B.2 Monitoring Well Drilling Methods

The following are commonly utilized drilling methods that should be considered when plans are being made to install a permanent monitoring well. The final drilling method selection should be based on site-specific conditions.

B.2.1 Hollow-Stem Auger – This type of auger consists of a hollow, steel stem or shaft with a continuous, spiraled steel flight, welded onto the exterior side of the stem and connected to an auger bit that transports cuttings to the surface when rotated. This method is best suited in soils that have a tendency to collapse when disturbed. A monitoring well can be installed inside of the hollow-stem augers with little or no concern for the caving of soils and/or water table.

B.2.2 Solid-Stem Auger – This type of auger consists of a solid stem or shaft with a continuous spiraled steel flight, welded on the outer side of the stem and connected to an auger bit that transports cuttings to the surface when rotated. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed.

B.2.3 Rotary Method – This method consists 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 consists 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. The type of rotary method used is dependent upon site-specific conditions and the information desired for the investigation (the mud rotary method provides good information on soil strength properties).

B.2.4 Rotosonic Drilling – This method combines high frequency vibrations, downward pressure, and relatively slow rotations to advance a dual string of drill pipe. This combination of forces advances the drill pipe through soil and rock without the use of drilling fluids. The dual string of drill pipe is used to sample and advance the hole and consists of an inner core barrel sampler and an outer pipe casing. The core barrel is driven ahead of the outer casing and is used to collect a representative continuous core sample. Once the core barrel is driven to the required depth, the outer casing is driven down over the core barrel. The outer casing prevents the hole from collapsing when the core barrel is extracted for sample retrieval. Drilling can be completed without the use of fluids, but water is commonly used during the driving of the outer casing to flush material from the annular space between the core barrel and the pipe casing.

B.2.5 Other Methods – Other methods such as the cable-tool method, the jetting method, the boring (bucket auger) method, and direct push technologies (*e.g.*, GeoProbe®) are available. If these and/or other methods are proposed for installing monitoring wells, specific details, with respect to the equipment and drilling fluids that will be used and the activities that will be performed, should be included in the work plan. Proposed method(s) would also require approval by the Department prior to implementation.

B.3 Monitoring Well Construction Methods

B.3.1 Type-I Temporary Monitoring Wells or Piezometers – A temporary monitoring well is any well that is used for the establishment of groundwater flow conditions, the delineation of contaminant plumes at a point in time, and for some site screening purposes. It is not intended to replace a permanent monitoring well. The best use for temporary wells is in conjunction with a mobile laboratory, where quick analytical results can be used to delineate contaminant plumes. Temporary monitoring wells locations are not permanently marked and their elevations are not determined. Sand pack materials may or may not be used but there is no bentonite seal, grout surface completion, or extensive development (as normally applies to permanent monitoring wells). Temporary wells are generally installed, purged, sampled, removed and backfilled in a matter of hours. A temporary well may be left overnight for sampling the following day, but the well must be secured if it is not immediately sampled after construction.

The materials used in construction of temporary monitoring wells or piezometers are the same standard materials used in the construction of permanent monitoring wells. Sand used for the filter pack (if any) must be as specified in the *USEPA's Field Branches Quality System and Technical Procedures (QSTPs)*. These documents are dynamic and are periodically reviewed and updated. The user must ensure that the most current version is used.

There are 6 types of temporary monitoring well installation techniques that have been demonstrated as acceptable. The type selection is dependent upon the site conditions. The project leader and site geologist must be prepared to test temporary well installations on site and select the best solution. Temporary wells are cost effective, can be installed quickly, and provide a synoptic picture of groundwater quality. Types of temporary wells include:

(a) No Filter Pack – After the borehole is completed, the casing and screen are inserted. This type is extremely sensitive to turbidity fluctuations, because there is no filter pack. This is the most inexpensive and fastest well to install.

(b) Inner Filter Pack – This type differs from the "No Filter Pack" only in that the filter pack is placed outside 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 of well to function properly, the static water level must be 6 to 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.

(c) Traditional Filter Pack – The screen and casing is inserted into the borehole. Sand is poured into the annular space surrounding the screen and casing. The well should be developed to establish *in-situ* aquifer or saturated conditions.

(d) 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 are inserted until the tip 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 of temporary well construction is very effective in aquifers where fine silts or clays predominate.

(e) Well-in-a-Well – The borehole is advanced to the desired depth. 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 placed into the annular space surrounding the 1-inch well screen, to approximately 6 inches above the well screen. The well is inserted into the borehole.

(f) Geoprobe® Screen Point 15 Groundwater Sampler – The Geoprobe® Screen Point 15 Groundwater Sampler is a discrete interval groundwater sampling device that can be pushed to pre-selected sampling depths in saturated, unconsolidated materials, opened and sampled as a temporary well. It is a sealed sample device and opened at the desired depth, yielding 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 after sample collection.

For additional information refer to the *USEPA's Field Branches QSTPs*. These documents are dynamic and are periodically reviewed and updated. The user must ensure that the most current version is used.

B.3.2 Type-II Permanent Monitoring Wells – The following are requirements for constructing Type-II Monitoring Wells:

(a) The borehole must 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 50 feet of depth. Slanted boreholes are prohibited unless specified in the design.

(b) Secure the well casings to the well screen by flush-jointed threads and place into the borehole and plumb by the use of centralizers and/or a plumb bob and level. Another method is to suspend the string of well screen and casings in the borehole by means of wire-line on the drill rig. Teflon tape or buna O-rings can 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. Use of any type of glue to secure casing joints is prohibited.

(c) Before placing the well screen and casing onto the bottom of the borehole, place at least 6 inches of filter material at the bottom of the borehole to serve as a firm footing.

(d) Place the string of well screen and casings into the borehole and plumb. Centralizers can be used to plumb a well but must be placed below the well screen and above the bentonite pellet seal.

(e) All permanent wells must have a maximum screened interval of 10 feet, a minimum inside diameter of 2 inches, and must be constructed of materials that are based on the geologic conditions and resistant to leaching and deterioration from the COPCs. If there is reason to believe that the water table can undergo large fluctuations in elevation, particularly seasonally, a longer screen may be warranted. Some exceptions are allowed but must be approved by the Department on a case-by-case basis. Permanent wells installed utilizing direct push technologies is program-dependent and site specific. A plan must be submitted to and approved by the Department prior to any small diameter permanent well installation.

(f) When placing the well screen and casing through hollow stem augers, extract the augers as the filter pack, bentonite seal, and grout are tremied into place. After the string of well screen and casing is plumbed in the open borehole, place the filter material around the well screen, by tremie method, to a minimum of 2 feet above the top of the well screen.

(g) Tremie a bentonite seal onto the filter pack to a minimum thickness of 2 feet. Allow the bentonite seal to hydrate for a minimum of 8 hours or the manufacturer's recommended hydration time, whichever is longer.

(h) After hydration of the bentonite seal has been completed, pump the grout (bentonite/grout mixture) by tremie method into the annular space around the casing up to 2 feet below ground surface or below the frost line, whichever is greater. Allow the grout to set for a minimum of 24 hours before the surface pad and protective casing are installed.

(i) Install a protective casing with a locking cap around the monitoring well and build concrete or neat cement surface pad around the protective casing. At a minimum, the surface pad must have the dimensions of 2 feet by 2 feet and an approximate thickness of 6 inches (4 inches above ground surface). The surface pad must be angled such that water is diverted away from the monitoring well.

(j) Place bumper guards around the concrete surface pad in a configuration that provides maximum protection to the well. Extend the bumper guards above the ground surface at a minimum of 3 feet and a total minimum length of 5 feet.

(k) If the monitoring wells are installed in a high traffic area, the monitoring wells may be finished to the ground surface and installed with watertight flush-mounted traffic and/or manhole covers. The flush-mounted covers must be installed as far above grade as practical to minimize standing water and promote runoff.

(l) All monitoring wells must include a padlock or specialized lock and permanently marked with the well number and well depth.

B.3.3 Type-III Permanent (Double-Cased) Monitoring Wells – The following are requirements for constructing Type III Monitoring Wells:

(a) Construct type-III or double-cased monitoring wells when there is a reason to believe that interconnection of the two aquifers by well construction may cause cross contamination and/or when flowing sands make it impossible to install monitoring wells using conventional methods.

(b) Drill a pilot borehole through the overburden and/or the contaminated zone into a confining layer, bedrock or through the first saturated zone. Extend the borehole into the confining layer, bedrock or unsaturated zone underlying the initial saturated zone at a minimum of 2 feet, if possible (1 foot into bedrock is adequate). The final depth must be approved by a senior field geologist.

(c) Place an outer casing into the borehole and seal with grout. The size of the outer casing must be of sufficient inside diameter to contain the inner casing, and the 2-inch minimum annular space.

(d) Grout the outer casing by tremie method from the bottom to within 2 feet of the ground surface. Pump the grout into the annular space between the outer casing and the borehole wall. The grout plug (seal) must be cured for a minimum of 24 hours before attempting to drill through it. Use grout mixture of neat cement, cement/bentonite, cement/sand, or a 30% solids bentonite to seal the outer annular space. However, the seal or plug at the bottom of the borehole and outer casing must consist of a Type-I Portland cement/bentonite or cement/sand mixture. The use of pure bentonite grout for a bottom plug or seal is prohibited. After the grout plug has been allowed to cure, advance the boring for the inner casing to the next saturated zone or aquifer followed by the installation of a permanent monitoring well. When drilling through the seal, care should be taken to avoid cracking, shattering, and/or washing out the seal. Removal of the outer casing after the well screens and casings have been installed and grouted is prohibited.

(e) Additional outer casings (telescoping methods) may be required when determining the vertical extent of contamination. Each outer casing must be installed in accordance with the above guidance.

B.3.4 Permanent Bedrock Wells – The following are standards for constructing bedrock monitoring wells:

(a) If bedrock is greater than six feet, the first method is to drill or bore a pilot borehole through the soil overburden into the bedrock (1 foot minimum).

(b) Install an outer casing into the borehole by setting it into the bedrock and grouting it into place as described in the previous sections.

(c) After the grout has been allowed to set (minimum of 24 hours), advance the borehole through the grout seal or plug into a water-producing zone in the bedrock by rock coring methods.

(d) Install an inner casing and well screen with a filter pack, bentonite seal and annular grout.

(e) Complete the well with a surface protective casing and concrete pad.

B.3.5 Nested or Cluster Wells

(a) Nested or Cluster Wells are two or more wells that are screened at different elevations in a single aquifer or multiple aquifers and installed within 5 feet of each well.

(b) Nested or Cluster Wells consist of one Type-II well and one or more Type-III well(s) (see above construction requirements for Type-II and Type-III wells).

B.4 Monitoring Well Development Methods

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 that may have been disturbed by the well construction activities.

B.4.1 Time Period – A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed.

B.4.2 Development – 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 (see Section C.3.1.). In some cases, this may require continuous flushing or development activities over a period of several days.

B.4.3 Methods – Well development can be performed by the following methods. The methods listed below can be used individually or in combination. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a 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.

(a) Over-pumping – Over-pumping is the most commonly employed well development technique. Install a pump into a well and initiate pumping to induce groundwater flow towards the well. Insert the pump to the screened interval in the well prior to initiating pumping (in instances of shallow aquifers a surface pump may be used with properly decontaminated inlet tubing inserted to screen depth). Fine particulate material that moves into the well is discharged by the pump. Operate the pump at a capacity that substantially exceeds the ability of the formation to deliver water. This flow velocity into the well usually exceeds the flow velocity that will subsequently be induced during the sampling process. The increased velocity causes rapid and effective migration of particulates toward the pumping well and enhances the development process. Proper design is needed to avoid well collapse, especially in deep wells. The USEPA recognizes over-pumping as an effective development method if flow reversal or surging activities are also conducted to avoid the occurrence of bridging in the well pack. Bridging in the well pack is a phenomenon where the materials used do not settle fully causing the materials not to completely fill the voids between the formation and the well screen. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

(b) Backwashing – Install a pump into a well and initiate pumping to induce groundwater flow towards the well. Fine particulate material that moves into the well is discharged by the pump. Where there is no backflow prevention valve installed, the pump is alternately started and stopped. This starting and stopping process allows the column of water that is initially picked up by the pump to be alternately dropped and raised up in a surging action. Each time the water column falls back into the well, an outward surge of water flows into the formation. This surge tends to loosen the bridging of the fine particles so that the upward motion of the column of water can move the particles into and out of the well. In this manner, the well can be pumped, over-pumped and back-flushed alternately until such time as satisfactory development has been attained. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

(c) Surge Block – Surge blocks can be used effectively to destroy bridging and to create the agitation that is necessary to develop a well. A surge block is used alternately with either a bailer or pump so that material that has been agitated and loosened by the surging action is removed. The cycle of surging-pumping/bailing is repeated until satisfactory development has been attained. The surge block is lowered to the top of the well intake and then operated in a pumping action with a stroke of approximately 3 feet. The surging is initiated at the top of the well intake and gradually works downward through the screened interval. The surge block is removed at regular intervals and the fine material that has been loosened is removed by bailing and/or pumping. Surging begins at the top of the well intake so that sand or silt loosened by the initial surging action cannot cascade down on top of the surge block and prevent removal of the surge block from the well. Surging is initially gentle and the energy of the action is gradually increased during the development process.

(d) Bailer – In relatively clean, permeable formations where water flows freely into the borehole, bailing is an effective development technique. The bailer is allowed to fall freely through the borehole until it strikes the surface of the water. The contact of the bailer produces a strong outward surge of water that is forced from the borehole through the well intake and into the formation. This tends to break up bridging that has developed within the formation. As the bailer fills and is rapidly withdrawn, the drawdown created in the borehole causes the particulate matter outside the well intake to flow through the well intake and into the well. Subsequently, bailing removes the particulate matter from the well. To enhance the removal of the sand and other particulate matter from the well, the bailer can be agitated by rapid short strokes near the bottom of the well. This agitation makes it possible to bail the particulates from the well by suspending or slurrying the particulate matter. Bailing should continue until the water is free from suspended particulate matter and until stabilization (see section C.3.1 of this document) of all field parameters (pH, specific conductivity, temperature, and turbidity) is achieved.

(e) Airlift Pumping – Air lifting, without exposing the formations being developed directly to air, can be accomplished by properly implemented pumping. To do this, the double pipe method of air lifting is preferred. The bottom of the airlift must be lowered to no more than 10 feet from the top of the well intake and must not be used within the well intake. If the airlift is used to surge the well by alternating the air on and off, there will be mixing of aerated water with the water in the well. Therefore, if the well is to be pumped by airlifting, the action should be one of continuous, regulated discharge. This can be effectively accomplished in relatively permeable aquifers. The introduction of air into the aquifer, such as conducting air surging activities, is prohibited. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

B.4.4 Completion – The onsite geologist should make the decision as to the development completion of each well. All field decisions must be documented in the field logbook.

B.5 Well Abandonment Procedures

The objectives of the abandonment procedure are to: (1) eliminate physical hazards, (2) prevent groundwater contamination, (3) conserve aquifer yield and hydrostatic head, and (4) prevent intermixing of desirable and undesirable waters.

The Department recommends that all test holes, including test wells, partially completed wells, and completed wells, be properly plugged and abandoned upon completion of either the site investigation phase or remediation phase. The purpose of sealing an abandoned boring or monitoring well is to prevent any further disturbance to the pre-existing hydrogeologic conditions in the subsurface. No materials that could impart taste, odor or toxic compounds to water may be used in the sealing process. The guiding principle to be followed by the contractor in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed.

Selection of the appropriate method of well abandonment should be made after considering the following: (1) casing material, (2) casing condition, (3) casing diameter, (4) quality of the original seal, (5) well depth, (6) well plumbness, (7) hydrogeologic setting, and (8) the level of contamination and the zone(s) where contamination occurs. If no cross-contamination can occur between various zones and contamination cannot enter from the surface, grouting the well from bottom to top without removing the casing may be sufficient.

Regulatory requirements and accepted procedures for the abandonment of monitoring wells, public water supply wells and domestic water wells vary depending upon the regulatory program. Additionally, the geologic environment in which the well is located, the purpose and use of the well, and the type of well installed will determine the procedures used during the abandonment processes employed. The appropriate subsection listed below should be consulted prior to planning a well abandonment program. *Some regulatory programs require a plan to be submitted prior to attempting well abandonment. In situations where a plan is not required before well abandonment is performed, consultation with the appropriate ADEM personnel is highly recommended*.

B.5.1 Soil Borings – Soil borings are recommended to be abandoned in accordance with the following:

(a) Measure a boring for depth before it is sealed to ensure freedom from obstructions that may interfere with effective sealing operations.

(b) Seal all borings by backfilling with concrete, grout, neat cement or a grout/cement mixture.

(c) Place all backfill material into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method).

(d) Pour concrete on the top 2 feet of the borehole to ensure a surface seal (plug).

ADEM will review alternative soil boring abandonment proposals on a site-by-site basis. All alternative soil boring abandonment proposals must be approved by ADEM prior to implementation.

B.5.2 Monitoring Wells – Regulatory requirements and accepted procedures for the abandonment of monitoring wells, public water supply wells and domestic water wells vary depending upon the regulatory program. The appropriate subsections listed below must be consulted prior to developing a well abandonment plan. To view an acceptable outline for a well abandonment plan, see Appendix B, Attachment 1 – Water Supply Well Abandonment Plan.

(a) Solid Waste Program Sites

The requirements for monitoring well abandonment at facilities permitted under the Solid Waste Regulations, ADEM Admin. Code r. 335-13, include the following:

i. The owner or operator must notify the Department that the design, installation, development, and/or abandonment of any monitoring wells, piezometers and other measurement, sampling, and analytical devices have been documented and placed in the operating record.

ii. The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to design specifications throughout the life of the monitoring program.

iii. Abandoned wells and boreholes are recommended to be abandoned in accordance with the procedures outlined in this document in order to prevent contamination of groundwater resources. An abandonment work plan may be required to be submitted to and approved by the Department prior to implementing abandonment of any well. Consultation with ADEM should occur to determine the necessity of such a plan.

iv. A well must be measured for depth prior to sealing to ensure that it is free from any obstructions that may interfere with effective sealing operations.

v. Where feasible, wells should be completely filled with neat cement. If the well cannot be completely filled, the sealing material for the top 20 feet must be neat cement and no material that could impart taste, odor, or toxic components to water may be used in the sealing process.

vi. The casing must be removed from each well in order to ensure placement of an effective seal. If the casing cannot be readily removed, it should be perforated to ensure that proper sealing is obtained. If the well is installed in unconsolidated lithologies, and there is the potential for collapse, the casing must be left in place.

vii. Concrete, cement grout, or neat cement must be used as primary sealing materials and placed from the bottom upwards using methods that will avoid segregation or dilution of material.

viii. Complete and accurate records of the abandonment procedure must be kept for each well abandoned. The record of abandonment include, at a minimum, the depth of each layer of all sealing and backfill material, the quantity of sealing materials used, measurements of static water levels and depths, and any changes made in the well during the plugging or sealing such as perforating casing. A copy of these records must be submitted to the Department and a copy placed in the operating record.

(b) Public Water Supply Wells

Public water supply wells must be abandoned only after consultation with the ADEM Water Supply Branch. ADEM Admin. Code r. 335-7-5-.16 states that abandoned wells, partially completed wells, and boreholes should be filled and sealed to prevent contamination of groundwater formations. Where feasible, or when required by the Department, wells must be completely filled with neat cement. Other wells must be sealed in accordance with American Water Works Association (AWWA) Standard A100 Section 13 as outlined in the following:

American Water Works Association Standards A100 (latest edition)

Section 13.1 General

Seal abandoned test holes, including test wells, partially completed wells, and completed wells.

Section 13.1.1 Need for sealing wells

Wells need to be sealed for the following reasons:

- To eliminate physical hazards,
- To prevent contamination of groundwater,
- To conserve yield and hydrostatic head of aquifer, and
- To prevent intermingling of desirable and undesirable waters.

Section 13.1.2 Restoration of geological conditions

The guiding principle to be followed by the contractor in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed.

Section 13.2 Sealing requirements

Measure well for depth before it is sealed to ensure freedom from obstructions that may interfere with effective sealing operations.

Section 13.2.1 Casing removal

Removal of casing from some wells may be necessary to ensure placement of an effective seal.

Section 13.2.2 Exception to casing removal

If the casing cannot be readily removed, it must be perforated to ensure the proper sealing required.

Section 13.2.3 Sealing materials and placement

Use concrete, cement grout, sealing clay or neat cement as primary sealing materials and place from the bottom upward by methods that will avoid segregation or dilution of material.

Section 13.3 Records of Abandonment Procedures

Keep complete, accurate records of the entire abandonment procedure to provide detailed records for possible future reference and to demonstrate to the governing state or local agency that the hole was properly sealed.

Section 13.3.1 Depths sealed

Record the depth of each layer of all sealing and backfilling materials.

Section 13.3.2 Quantity of sealing material used

Record the quantity of sealing materials, measurements of static water levels, and depths.

Section 13.3.3 Changes recorded.

Record in detail any changes in the well made during the plugging or sealing, such as perforating casing.

(c) Hazardous Waste Management Sites

i. The ADEM Hazardous Waste Program considers improperly abandoned monitoring wells to be a serious concern. Any boreholes or monitoring wells that are improperly constructed or unused are recommended to be properly abandoned after notifying ADEM and receiving guidance from the Department.

ii. Consult experienced geologists, geotechnical engineers and drillers prior to abandonment.

iii. If the well to be abandoned is contaminated, the owner/operator must ensure safe removal and proper disposal of the well materials.

iv. Take appropriate measures to protect the health and safety of individuals when abandoning a well or borehole.

v. Seal the monitoring well or borehole so that it cannot act as a conduit for the migration of contaminants from the ground surface to the water table or between aquifers.

vi. The preferred method is 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 can be removed from the hole with the drill rig or other appropriate equipment. If it is determined that the well casing cannot be removed, approval must be sought from the Department to perforate the casing to ensure that a proper seal is obtained when backfilling and leave the casing in place. Approval will be granted on a case-by-case basis and is dependent upon the unique conditions that may exist at a site preventing the removal of the casing.

vii. The clean borehole can be backfilled with the appropriate grout material (*e.g.*, concrete, bentonite grout, or neat cement). The backfill material must be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method).

viii. The top 2 feet of the borehole must be poured with concrete to ensure a secure surface seal (plug). If the area has very heavy traffic use, and/or the well locations need to be permanently marked, a protective surface pad and/or steel bumper guards must be installed. The concrete surface plug can also be recessed below ground surface if the potential for construction activities exists.

ix. Because of its brittleness, polyvinyl chloride (PVC) wells may be more difficult to remove than metal casing wells. 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 the selected drilling fluid. Another method is to use a solid-stem auger with a carbide auger head 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 must be cleaned out and pressure-grouted with the approved grouting materials. As previously stated, the borehole must be finished with a concrete surface plug and adequate surface protection, unless directed otherwise.

(d) State Groundwater Program Sites

i. The State Groundwater Program is administered by the Groundwater Branch of ADEM. For the abandonment of monitoring wells, the Groundwater Branch generally follows the USEPA's Field Branches QSTPs. These documents are dynamic and are periodically reviewed and updated. The user must ensure that the most current version is used.

ii. Submit a well abandonment plan to the Department prior to implementing any well abandonment activities. Take appropriate measures to protect the health and safety of individuals when abandoning a well or borehole.

iii. While this document is typically used to prepare an abandonment plan, it is understood that factors may arise that make the methods given below impractical or inappropriate for a given site. For this reason, methods other than those listed may be undertaken if prior approval is obtained.

a) As indicated in the USEPA's Field Branches QSTPs, when a decision is made to abandon a monitoring well, the borehole must 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 abandon 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.

b) Abandonment Procedures

i) 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. Remove the well casing from the hole with the drill rig.

ii) Backfill the clean borehole with the appropriate grout material.

iii) Place the backfill material into the borehole from the bottom to the top by pressure-grouting with the positive displacement method (tremie method).

iv) Pour the top 2 feet of the borehole with concrete to ensure a secure surface seal (plug). If the area has heavy traffic use, and/or the well locations need to be permanently marked, install a protective surface pad(s) and/or steel bumper guards. The concrete surface plug can also be recessed below ground surface if the potential for construction activities exists.

v) For 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.

vi) Wells with little or no grouted annular space and/or sound well casings can be removed by forcing a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extracting it out of the borehole.

vii) 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. Retract the tremie tube slowly as the grout fills the casing. Cut off the well casing even with the ground surface and fill with concrete to a depth of 2 feet below ground surface. If the casing has been broken off below the surface, tremie the grout to within 2 feet of the surface and finish to the ground surface with concrete. Install the surface pad or specified surface protection.

c) The following information must be included with the well abandonment plan submitted to ADEM:

i) Site name and address

ii) Type of well(s) (monitoring, piezometer, extraction, *etc.*) to be abandoned and reason for abandoning

iii) Latitude and longitude of well(s)

iv) Topographic map and site map illustrating the location of well(s)

v) Soil boring and well construction logs

vi) Diameter and length of well(s) including length of screen and interval(s) screened prior to well abandonment

vii) Description of method to be employed to abandon well(s)

viii) Type of grout used and method used to place grout in well

ix) Quantity of grout used to seal well

d) The following information must be included in the final well abandonment report upon completion of all approved activities:

i) Site name and address

ii) Type of well(s) (monitoring, piezometer, extraction, *etc.*) abandoned and reason for abandoning

iii) Identification of the well(s)

iv) Date well(s) was abandoned and the name of person(s) overseeing abandonment

v) Latitude and longitude of well(s)

vi) Site map illustrating the location of the well(s)

vii) Description of method employed to abandon the well(s)

viii) Photograph(s) of abandoned well(s)

ix) Date of well abandonment activities

(e) Individual (Private) Potable Water Supply Wells

Individual water supply wells are relatively shallow in depth and serve one to several households with enough water for domestic purposes. These wells are typically one of three types: 1) shallow-dug wells, 2) driven or sand point wells, or 3) drilled or augered wells. As with other types of wells, the type and depth of the well should be determined prior to plugging. Any obstructions in the well should be removed prior to initiating the plugging operation and under no circumstances should any part of the casing be allowed to remain above the surface of the ground after plugging.

Keep accurate records (See Appendix B, Attachment 1 – Water Supply Well Abandonment Plan of the document) of the well location, depth, filling material, date of plugging, *etc.*

i. Shallow-Dug Wells – Hand-dug wells that extend down to the aquifer and are sometimes blasted or chipped into bedrock to reach the aquifer. Stone or concrete walls called curbing sometimes are necessary to keep the well from collapsing. These wells are rarely deeper than 40 feet and have diameters that are usually several feet across.

a) Remove pumps, piping or debris and break up the top 3 to 5 feet of curbing prior to filling.

b) Fill any portion of the well that extends into bedrock with a concrete-bentonite grout.

c) Fill the remainder of the well with clean native materials that approximate the permeability of the aquifer and overlying soils in the vicinity of the well.

d) Compact the soil to prevent settling and ponding of water in the location of the former well.

ii. Driven or Sand Point Wells - A well that is driven to the desired depth either by hand or machine and may employ a well-point or alternative equipment. These wells typically have a small diameter (2 inches or less) with a short screen near the pointed end and can only be used in soft sandy sediments or soils.

a) Remove driven or sand point wells if their diameter is 2 inches or less and their depth is 25 feet or less.

b) Fill the hole with a bentonite-cement grout.

c) If greater than 25 feet in depth, larger than 2 inches in diameter, or cannot be removed, fill the well with a bentonite-cement grout from bottom to top using the pump-down method with a tremie pipe.

iii. Drilled Wells - Diameters of 2 inches to 20 inches are typical for these wells, which are installed with the use of a drilling rig and may be 40 feet to several thousand-feet deep. In Alabama, drilled domestic wells are generally less than 250 feet deep and are often unique in design and depth and must be abandoned only by a licensed well driller.

a) If possible, remove the casing and fill the borehole with cement-bentonite slurry.

b) If the casing cannot be removed, fill the entire well with cement-bentonite slurry using the pump-down method with a tremie pipe.

c) In areas subject to subsidence and/or farming, cut off the top of the casing a minimum of 3 feet below ground surface before plugging operations begin.

d) After filling the well with the cement-bentonite slurry, fill the excavation above the top of the cement plug with compacted soil to minimize future hazards to farming equipment, *etc.* In other areas, cut off the top of the casing at or below the ground surface.

(f) Underground Storage Tank (UST) Petroleum Sites

The Department may require that all installed monitoring wells be properly plugged and abandoned upon completion of either the site investigative phase or remediation phase in accordance with ADEM Admin. Code r. 335-6-15-.29(8). The purpose of sealing an abandoned boring or monitoring well is to prevent any further disturbance to the pre-existing hydrogeologic conditions that exist in the subsurface. In accordance with this purpose, no material that could impart taste, odor, or toxic components to water may be used in the sealing process.

Allowable procedures for abandonment of the various types of wells which may be installed at a UST site are as follows:

i. Abandonment of Borings:

a) Unconsolidated Formations

Borings extending into unconsolidated formations may be adequately sealed by filling with concrete, grout, neat cement or a grout/cement mixture.

The boring may be backfilled with cuttings if all of the following conditions are met:

i) The boring is in a well-drained area with no tendency to have standing surface water

ii) The boring is 25 feet or less in depth

iii) The boring does not penetrate an aquifer, and is not in an area of contamination

If the boring is filled with concrete, grout, neat cement or a grout/cement mixture, the sealing material should be brought up to about two or three feet below grade and finished with clay or excavated cuttings. If the boring is located in a paved area, the finishing fill must include a final covering comparable to the original surface such as concrete or asphalt patching. Materials that could crack and provide a vertical conduit must be avoided.

b) Competent Rock

Borings that extend into competent bedrock must be filled from the bottom with concrete, grout, neat cement or a grout/cement mixture. If the bedrock is overlain by residual soils, the sealing material should be brought up to about two or three feet below grade and finished with clay or cuttings as in unconsolidated formations.

ii. Abandonment of Monitoring Wells

Wells are abandoned either by removing the casing or by leaving all or part of the casing in place and cutting the casing off below ground level. Because the primary purpose of well abandonment is to eliminate vertical fluid migration along the borehole, the preferred method of abandonment involves casing removal. Abandonment methods for various types of wells are as follows:

a) Temporary Monitoring Wells

Temporary monitoring wells must have the casing pulled and the borehole sealed as with a boring.

b) Permanent Monitoring Wells

Permanent monitoring wells must have the casing pulled and the borehole sealed as with a boring.

Casing material, depth of the well, deviation of the well, or other reasons may make pulling the casing impossible. In this situation, the casing is cut off two or three feet below grade and completely filled with concrete, grout, neat cement, and/or a grout/cement mixture to prevent channeling. Finish up the hole to the ground as with a soil boring.

Remove the casing by over-drilling, if necessary. Remove the casing and debris and seal borehole as with a boring.

c) Multiple Casing Monitoring Wells

Multiple casing monitoring wells are built to ensure that vertical migration does not affect groundwater quality. If the construction design is known to be satisfactory and the casing integrity has not been affected, the well may be left in the ground and filled with concrete, grout, neat cement or a grout/cement mixture. Cut off the casing two or three feet below grade and fill from the bottom up as with a permanent monitoring well. Finish up the hole up to the ground surface as with a boring.

ATTACHMENT 1 - WATER SUPPLY WELL ABANDONMENT PLAN

Name/Telephone # of well owner: ______________________________________

Name/Telephone # of person owning property on which the well is located (If different from the owner): ____

*Stage of construction: _________

Location of Well: Latitude: +Degrees_ _ Minutes _ _ _ Seconds _ _ ._ _ _
Longitude: +Degrees_ _ Minutes _ _ _ Seconds _ _ ._ _ _

Name/Telephone # of person who knows the location of the well:
____

Attach an 8 ½ x 11 copy of a 7.5 Minute USGS Topographic Map and mark the location of the well. Give the name of the topographic map (usually located in the upper right hand corner of the original map). Attach an 8½ x 11 cross sectional drawing showing the details of the well.

Type of geological formation: ___Consolidated ___Unconsolidated ___Other (Explain):____
Screen: Diameter _______Type ______ Length ______
Depth of the well: ______Diameter of the casings ________________________
Casing to be removed: ___Yes ___No If no, explain:
____
Method proposed to remove casing:_____________________________________
Depth of casing grouting:________________**Type of well:________________
Describe the proposed plan for abandoning the well: _______________________
____
____
____
____
____
____
____
____
Note: Add additional pages as needed to provide complete information
* 1= Test Hole; 2=Test Well; 3=Partially Completed Well; 4=Completed Well
** A=Rock Wall; B=Gravel wall; C=Other-Explain

Appendix C

Sampling Methods

APPENDIX C - SAMPLING METHODS

C.1 Appendix Outline

C.2 Soil Sampling Methods

C.2.1 Sampling Methods - There are numerous methods available for site soil sampling. Soil samples are collected utilizing a variety of methods dependent on the depth, the type sample required (disturbed or undisturbed), current native or non-native characteristics of the surficial and/or subsurface media, or other site specific conditions. Design a sampling plan to adequately sample soils to define both the vertical and horizontal extent of contamination of COPCs. The following is a list of methods utilized and approved by the Department. The methods are not all inclusive but outline those that are most likely to be used during regular sampling events. Alternative methods must be developed and submitted to ADEM for review and approval prior to initiation of the Comprehensive Investigation.

(a) Grab Sample **–** An individual sample collected at one location, usually over a period not to exceed 15 minutes. A grab sample is normally associated with water or waste water sampling; however, soil, sediment, liquid hazardous waste samples, *etc.*, may also be considered grab samples. No particular time limit would apply for the collection of these type samples. Grab samples are used to characterize the medium of one particular location at one instant in time. As such, a large number (30-50 or more) of grab samples are required to adequately define the representativeness of the soil for a given decision unit and/or site as a whole. Soil boring grab samples should be collected, for laboratory analysis, at intervals of not more than five (5) feet. The soil samples from each boring must include, at a minimum, one sample within the first one foot below ground surface, one sample within two feet above the water table and sample(s) every five feet thereafter including within the depth-interval most likely to be contaminated.

(b) Composite Sample – A composite sample is composed of several sampling events collected at points within a vertical or horizontal track that will be analyzed as one sample. The individual sample aliquots are combined and thoroughly mixed to obtain a homogenous representative sample of the entire sampling interval. This type of sampling is frequently used by various programs for confirmatory sampling after excavations, removal of underground storage tanks, and other types of actions.

(c) Incremental Sampling Methodology (ISM) **–** ISM sampling is a process by which the site is divided into decision units/exposure domains (DU/ED). ISM is a structured composite sampling and processing protocol that reduces data variability and provides a reasonably unbiased estimate of mean contaminant concentrations in a volume of soil targeted for sampling. A sample (usually composed of 30-50 or more aliquots for surficial samples) is collected from a systematic grid with a random starting point and is analyzed to give a statistical representation of the soil in each DU/ED. Sample aliquots are collected by pre-cleaned scoops, augers, or other appropriate sampling tools for the appropriate depths being assessed. The sample aliquots are placed in a stainless steel, plastic, or other clean or lined container. The soil is passed through a 2mm sieve and into a lined container (note: soil should not be sieved when utilizing this method for *in-situ* waste characterization as described in Section 2.3.9 of this guidance manual). Soil properties at the time of sampling may determine that drying or grinding is necessary to assist in sieving (sample processing must be performed within 24 hours after sample collection). Upon completion of sieving, remove the sieved sample to a clean or lined homogeneous container and thoroughly mix. Using a sectorial splitter, divide the sample into appropriate containers. To assist with the formulation of an Incremental Sampling Methodology (ISM) Plan, Chapter 9 of SW-846, the ITRC Technical and Regulatory Guidance, *Incremental Sampling Methodology*, or (with Department concurrence) other appropriate and statistically viable guidance, may be helpful for use as a guide. Regardless of the guidance used to develop the plan, the ISM Plan should include the minimum requirements identified below. An appropriate sampling plan should specifically address the COPCs or COCs known or suspected to be in the contaminated media and the regulatory objective to achieve vertical and horizontal delineation and characterization of contamination. If ISM is to be utilized for the purpose of *in-situ* characterization of waste soil for disposal, the ISM Plan will have to be submitted to the Department for approval prior to the sampling being conducted, as discussed in Section 2.3.9(a) of this document.

Minimum Requirements for ISM Plan:

Regardless of the purpose of the ISM characterization activity (e.g., whether for the purpose of satisfying the investigation requirements to properly delineate and characterize a site for remedial evaluation and planning (see Section 3 of the document), or for satisfying the waste approval requirements for disposal purposes) or the guidance used to develop an ISM Plan (e.g., SW-846, ITRC, or other), the ISM Plan should include the following requirements:

i. Soil is considered to be composed of particle sizes, on or below land surface. For purposes of risk assessment and use with the ARBCA Guidance Manual, a particle size of two millimeters or less (≤2mm) is typically recommended for use. However, as discussed in Section 2.3.9 of the document, all particle sizes should be represented in a soil sample collected for *in-situ* disposal characterization.

ii. A defined area (*i.e.*, the decision unit (DU) or exposure domain (ED)) should be established for each site.

   a. As stated in Section 6.5 of the ARBCA, the ED or DU is the area over which the receptor may be exposed to the contaminated medium (surficial soil, subsurface soil, groundwater, and soil vapor). This area must be established for the on-site scenario as well as any off-site impacted or potentially impacted properties. The identification and delineation of the DU or ED is critical. The DU or ED shape and size is site specific and a site could potentially be divided into multiple DUs or EDs. Consequently, three-dimensional decision units may be necessary when conducting sub-surface site characterizations since the contaminants most likely are not distributed evenly, horizontally or vertically. Section B.2.2 of the ARBCA provides details on further considerations for determining appropriate DUs or EUs for a site. All of the identifiable DUs or EDs should be defined and listed for the primary decision-maker to decide which DUs or EDs to assess. If the location of a source area is unknown or has been removed, all available means must be used to delineate the decision unit, including historic photos, site information, interviews with knowledgeable parties, and field screening techniques.

iii. A sample (usually composed of 30-50 or more aliquots for surficial samples) is taken from a systematic grid with a random starting point and is analyzed to give a statistical representation of the soil in each DU or ED.

a. This sampling is restricted to one DU or ED.

b. The 95th Upper Confidence Limit about the Mean (UCL) should be used when it is necessary to calculate the upper statistical limits of a data set. The USEPA software package, ProUCL may be used to provide statistical support for characterization of soils at a site for the determination of the 95% UCL.

c. This collection method applies to the analysis of most parameters except those which require special sample collection methods (i.e., volatile organic compounds – see paragraphs "d." and "e." below).

i. Sample aliquots are collected along a systematic grid (triangular recommended) with a random starting point

ii. Sample aliquots are collected by pre-cleaned scoops, augers, or other appropriate sampling devices for the appropriate depths being assessed

iii. The sample aliquots are placed in a stainless steel, plastic, or other clean, lined container

iv. The soil is processed by crushing/pulverizing or grinding the sample and placing into a clean, lined container. Soil properties at the time of sample collection may require that drying (overnight at room temperature under a vent hood; except for VOC analysis) is necessary to assist in sample processing. Sample processing should be performed within 24 hours after sample collection.

v. Upon completion of sieving (NOTE: samples for characterization for disposal purposes should not be sieved), a scoop, spatula, or sectional splitter (paper or other appropriate material) may be employed to divide the sample into appropriate sample containers. Subsequent splitting of the sample may be necessary for the reduction of sample volume.

d. This sampling and analysis method is acceptable for VOC concentrations exceeding 200μg/kg (200 ppb in soil) (see EPA Test Method 5030).

i. Soil samples are initially obtained via a primary core-barrel sampling device along a triangular systematic grid with a random starting point.

ii. Sub-sample aliquots are then obtained from the primary soil core utilizing a secondary, typically smaller, coring device such as a 10 mL disposable syringe with the tip cut off. One 5-gram (+-0.5g), ≈3mL/cc, aliquot is collected from each primary core sample.

iii. Each aliquot is added to an amber glass bottle of an appropriate size to contain the volume of sample to be collected. Each bottle is prepared with purge and trap grade methanol at a ratio of 5mL of methanol to 5g of soil (1:1 ratio). For example if a 50 point grid was to be sampled that grid would theoretically result in 250 grams (+-10%) of soil; therefore, 250 mL of methanol would be placed in the bottle prior to the sampling event and the bottle weight with methanol recorded on the bottle. The methanol acts as both a preservative and extraction solvent. The theory in this extraction method is that the organics present in the sample leave the soil to reside in the methanol (organic solvent). A portion of the methanol extract is what is analyzed.

iv. After all of the aliquots are added to the container for a DU or ED, weigh and record the bottle weight containing the sample composed of methanol and soil. The difference in weights will reveal the amount of soil mass composing the sample for analysis.

v. The mass of soil and volume of methanol are necessary for the calculations following the analysis in order to report the mass/mass (μg/g) result. In this analytical method up to 100 μL of the methanol extract is placed in 25 mL of analyte-free water (or ratio of: i.e., 80 μL to 20 mL, etc.) and analyzed by an appropriate method, SW-846 Method 8260 for example.

vi. The remaining soil from the primary soil cores is retained for sample processing if other analyses are necessary. The total weight of this soil is recorded before and after drying in order to determine the percent (%) moisture in the soil. If soil moisture is >10%, then a corresponding dilution factor is applied to the concentration calculations.

vii. Secure bottle with a screw-cap with PTFE-lined lid, label and preserve.

e. This sampling and analysis method is acceptable for VOC concentrations less than 200μg/kg (200 ppb in soil)

i. Soil samples are initially obtained via a primary core-barrel sampling device.

ii. Sub-sample aliquots are then obtained from the primary soil core utilizing a secondary, typically smaller, coring device such as a 10 mL disposable syringe with the tip cut off.

iii. One 5-gram (+-0.5g), ≈3mL/cc, aliquot is collected from the primary core sample for each 40 mL sample vial.

iv. Each sample set consists of two to three 40 mL vials with 5 g (+-0.5 g) of soil and 1g sodium bisulfate preservative and a magnetic stirring bar. One additional empty vial containing 5g (+-0.5 g) of soil is collected for each sample set for dry weight analysis (% moisture). This method requires 5 mL of water to be added to the vial by the automatic sampling device on the analytical instrument (GC/MS) at the time of analysis.

v. Secure each vial with a screw-cap and septum seal lid, label and preserve.

C.2.2 Soil Boring Drilling and Sampling Techniques - Soil borings are advanced for sampling by either manual techniques, mechanical equipment, or by specialized equipment.

(a) Manual Techniques - Manual techniques are usually selected for surface or subsurface soil sampling. The more commonly used manual equipment are stainless steel spoons, shovels, hand-augers, post-hole diggers, push tubes and disposable syringes. As the depth of the sampling interval becomes greater, some type of power sampling equipment is necessary to overcome the torque induced by soil resistance.

i. Stainless Steel Spoons, Shovels, Hand-Augers and Post-Hole Diggers - These sampling devices must be properly decontaminated and wrapped in aluminum foil prior to all soil sampling activities at the beginning of each day. They must also be properly decontaminated in accordance with Appendix E of this document between each sample collected and each soil boring such that cross-contamination does not occur.

ii. Split spoon samplers are manually pushed into the surface soils for the collection of a surface soil samples. Split spoon samplers are approximately 3-inches to 5-inches in diameter and 2 feet to 3 feet in length. The sample is transferred from the split spoon sampler to a pan where the soil is mixed prior to being placed in the appropriate sample containers. Split spoon samplers are appropriate for use when the sample is analyzed for volatile organic constituents; however, certain precautions must be taken. When sampling soil for VOCs using a split spoon sampler, immediately place the collected sample either in the final sample container (*e.g.*, 40 mL pre-prepared vial) or into an intermediate sample container with no head space. If an intermediate container (usually 2 oz. soil jar) is used, transfer the sample to the final sample container as soon as possible and not to exceed 30 minutes. After collection of the sample into an approved container, immediately store the sample in an ice chest for cooling.

iii. Shelby tubes (or an equivalent) are thin-walled tubes, generally of stainless steel construction and having a beveled leading edge, which is twisted and pushed directly into the soil. This type of sampling device is particularly useful if a relatively undisturbed sample is required. The sampling device is removed from the push-head, and the sample is extruded from the tube into the pan with a spoon or special extruder. Even though the push-head is equipped with a check valve to help retain samples, the Shelby tube will not retain loose and watery soils, particularly if collected at lower depths.

iv. EnCore™ Samplers (or an equivalent) can be used when total VOC concentrations in the soil/sediment are expected to be less than 200 μg/kg. Samples may be collected directly with EnCore™ samplers (or an equivalent). Once the sample has been collected, cap and secure the sampler in a plastic bag. The sampler provides accurate *in-situ* VOC results without the loss of VOCs that may occur during transfer of the samples from the sampling device to the sample container. Extract and analyze all soil samples collected by EnCore™ Samplers (or an equivalent) in accordance with the USEPA-approved SW-846 test method.

v. Disposable plastic syringes are also used when total VOC concentrations in the soil/sediment are expected to be less than 200 μg/kg. If using non-tared sample containers, place the sample container on the scale and zero out the weight of the container. Add approximately 3.7 cc of the sample material to the 40-mL containers and 0.5 cc to the 5-mL containers and record weight to the nearest 0.01 gram on the sample tag and in field notes. The final weight of the added sample material should be between 4.5 to 5.5 grams for the 40-mL containers and 0.5 to 1.5 grams for the 5-mL containers. The procedure is the same for tared containers but the recorded weight need only be to the nearest 0.5 gram. Secure the containers in a plastic bag. When using the syringes, it is important that air is not allowed to become trapped behind the sample prior to extrusion as this will adversely affect the sample. Extract and analyze all soil samples collected by disposable plastic syringes in accordance with the USEPA-approved SW-846 test method.

(b) Mechanical Equipment - Mechanical equipment is typically used for collection of subsurface soil samples and to advance a soil boring to depths that do not allow the use of manual boring devices. Mechanical equipment is commonly used with two-man power augers, drill rigs and backhoes.

i. Power augers of the Little Beaver variety (or an equivalent) are used to aid in the collection of subsurface soil samples at depths where hand augering is impractical. This type of equipment is a sampling aid, not a sampling device and, on rare occasions, has been used to advance holes as deep as 40 feet below ground surface. It is used to advance a hole to the required sampling depth, at which point a hand auger, push tubes, or split spoons are used to collect the samples.

ii. Drill rigs offer the capacity of collecting soil samples from great depths. When used in conjunction with drilling, split spoon samplers are driven either inside a hollow stem auger or inside an open borehole after rotary-drilling equipment has been removed temporarily. The spoon is driven with a 140-pound hammer through a distance of up to 24 inches and removed. Continuous split-spoon samplers are used to obtain 5-foot long continuous samples.

iii. Backhoes are used in shallow to deep subsurface soil sampling programs. Samples are collected from the large chunks of soil removed by the backhoe bucket or from the trench wall, if proper safety protocols are followed. Trenches offer the ability to collect samples from very specific intervals and allow visual correlation with vertically and horizontally adjacent material. Prior to collecting samples from trench walls, dress the wall surface with a stainless steel shovel, spatula knife, or spoon to remove the surface layer of soil that was smeared across the trench wall by the backhoe bucket. Collect the samples from the bucket within the large chunks that have not come into contact with the bucket surface.

(c) Specialized Direct Push Technology includes Geoprobe® and Cone Penetrometer Rigs (or their equivalents). This technology allows the sampler to obtain soil samples from the desired depths without producing drill cutting and other Investigation-Derived Waste (IDW), and to collect *in-situ* geophysical measurements of the subsurface material. Direct push technologies are most applicable in unconsolidated soils to depths less than 100 feet and have played a major role in the development of expedited site assessments. Direct push systems are composed of two different systems: a single-rod system, and a cased system. Soil sampling tools used with the direct push systems include non-sealed soil samplers such as barrel samplers, split-barrel samplers, thin-wall tube samplers, and sealed soil (piston) samplers.

Direct push technology may be used to establish the boundaries of a groundwater contamination plume, to collect soil samples, to determine subsurface conditions through the use of various geophysical tools, and for assessing groundwater quality conditions. It should be noted that direct push technology only gives a point in time snapshot of those groundwater quality conditions. If monitoring of groundwater conditions over time is required, permanent monitoring wells must be installed.

Following the collection of a soil sample, immediately place the sample container in an ice chest for cooling.

C.3 Groundwater Purging Methods

Groundwater sampling is required for a variety of reasons such as examining potable or industrial water supplies, checking for and/or tracking contaminant plume movement in the vicinity of a land disposal or spill site, Resource Conservation Recovery Act (RCRA) compliance monitoring, and/or evaluating a site where historical information is minimal or non-existent but where groundwater contamination may have occurred.

Groundwater samples are usually obtained from either temporary or permanent groundwater monitoring wells. Groundwater samples can also be obtained from a drilled boring or from a boring produced by various direct push techniques. All groundwater samples from borings produced by drilling or direct push techniques show only a snapshot of the groundwater conditions at the time of sampling. A permanent groundwater monitoring well, in accordance with Appendix B of this document, is required for long-term monitoring.

C.3.1 Purging and Purge Adequacy – Purging is a process of removing stagnant water from a monitoring well immediately prior to sampling. Purging is conducted to ensure that all stagnant water has been removed from the well and that groundwater samples that are representative of actual aquifer conditions will be collected. In order to determine when a well has been adequately purged, field investigators must monitor the pH, specific conductance, temperature, and turbidity of the groundwater removed during purging. In addition, a minimum of 3 to 5 total well volumes must be removed. Prior to purging, determine the amount of water standing in the water column (water inside the well riser and screen). Initially, the field investigator should determine the diameter of the well and then measure and record the water level and total well depth. Specific methods to obtain the water level and total well depth are outlined in Section C.3.2 of this Appendix. The volume of water to be purged is determined by using several methods. One equation is $V=0.041d^2h$, where h = depth of water in feet, d = diameter of well in inches, and V = volume of water in gallons. Alternatively, the volume is determined using a casing volume per foot factor for the appropriate diameter well. The water level is subtracted from the total depth, providing the length of the water column. This length is multiplied by the factor in the table below that corresponds to the appropriate well diameter, providing the amount of water (in gallons) contained in the well. Other appropriate methods include the use of nomographs or other equations or formulas.

Casing Diameter (ft.)	Water Volume (gal./ft.)
1	0.041
2	0.163
3	0.367
4	0.653
5	1.02
6	1.469
7	1.999
8	2.611
9	3.305
10	4.08
11	4.934
12	5.875

An adequate purge is achieved when a minimum of 3 to 5 total well volumes of standing water have been removed and when the pH, specific conductance, and temperature of groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs). Stabilization of the groundwater chemistry parameters occurs when pH measurements remain constant within 0.1 Standard Unit (SU), variability, specific conductance varies by no more than 10 percent, and the temperature is constant for at least three consecutive readings. Standard procedure is to collect an initial set of the groundwater chemistry parameters prior to all purging activities with a set of parameters measured after each well volume has been removed. The conditions of all purging and sampling activities must be noted in the field log and on a Groundwater Sampling Data Form. If a well is pumped or bailed dry, it is considered an adequate purge and the well can be sampled following sufficient recovery (enough volume to allow filling of all sample containers). It is not necessary to evacuate the well to dryness three times before it is sampled. The pH, specific conductance, temperature, and turbidity must be measured during collection of the sample from the recovered volume as the measurements of record for the sampling event. Wells should not be purged to a level that creates a dry well. In order to avoid purging monitoring wells to dryness a slower purge rate should be considered.

It is particularly important that wells be sampled as soon as possible after purging. If adequate volume is available immediately upon completion of purging, the well must be sampled immediately. Otherwise, sampling must occur as soon as adequate volume has recovered. Sampling of wells that have a slow recovery must be scheduled so that they can be purged and sampled in the same day, after adequate volume has recovered. Wells of this type must not be purged at the end of one day and sampled the following day.

C.3.2 Water Level and Total Well Depth Measuring Techniques

(a) Measuring the depth to the free groundwater surface can be accomplished by utilizing one of the following methods: electronic water level indicators, weighted tape, chalked tape, and/or other methods. The sliding float method, airline pressure method, and electrical and automatic recording methods can be used for closed systems or permanent wells. Acoustic water level indicators are also available. The method chosen to measure water levels must be capable of measuring to the nearest 0.1 foot. All water levels must be made to an established reference point on the well casing. The reference point must be tied in with the NGVD (National Geodetic Vertical Datum). Document all water levels in the field records and on a Groundwater Sampling Data Form.

(b) The total well depth measurement techniques, which can be used to determine the total well depth, include the bell sounder, weighted tape, and electronic water level indicators. This is accomplished by lowering the tape or cable until the weighted end is felt resting on the bottom of the well. All total well depth measurements should be made and recorded to the nearest 0.1 foot. All total well depth measurements must be made to an established reference point on the well casing. The reference point must be tied in with the NGVD. Document all total well depth measurements in the field records and on a Groundwater Sampling Data Form. All water level and total-depth-measuring equipment must be decontaminated in accordance with the decontamination procedures outlined in Appendix E of this document.

C.3.3 Purging Techniques – Monitoring well purging is accomplished by using in-place plumbing and dedicated pumps, or by using portable pumps/equipment when dedicated systems are not present. The equipment may consist of a variety of pumps including peristaltic, large and small diameter turbine (electrical submersible), bladder, centrifugal, gear-driven positive displacement, or other appropriate pumps. The use of any of these pumps is usually a function of the depth of the well being sampled and the amount of water that is to be removed during purging. Whenever the head difference between the sampling location and the water level is less than the limit of suction and the volume to be removed is reasonably small, a peristaltic pump must be used for purging. Bailers may also be used for purging in appropriate situations. Use a closed-top bailer to attempt to inhibit turbid conditions.

Lower the pump/hose assembly or bailer into the top of the standing water column to pull water from the formation into the screened area of the well and up through the casing so that the entire static volume can be removed. If the pump is placed deep into the water column, the water above the pump will remain and the subsequent samples, particularly if collected with a bailer, are not representative of the groundwater. Clean all wetted portions of the hose and the pump after the pump is removed from the well as outlined in Appendix E of this document. Use extreme care when using pumps to purge wells that are excessively contaminated with oily compounds because it is difficult to adequately decontaminate severely contaminated pumps under field conditions. When wells of this type are encountered, alternative purging methods, such as bailers, should be considered.

(a) Wells Without Plumbing or In-Place Pumps

i. Purging with Pumps - When peristaltic or centrifugal pumps are used, only the intake line is placed into the water column. The line placed into the water should be either standard-cleaned Teflon® tubing for peristaltic pumps (See Appendix E) or standard-cleaned stainless steel pipe attached to a hose for centrifugal pumps. When submersible pumps (bladder, turbine, displacement, *etc.*) are used, the pump itself is lowered into the water column. The pump must be cleaned as specified in Appendix E of this document.

ii. Purging with bailers - Standard-cleaned, closed-top Teflon® bailers with Teflon® leaders and arid new nylon rope are lowered into top of the water column, allowed to fill, and removed. The water must be contained and managed as IDW. It is critical that bailers are slowly and gently immersed into the tip of the water column, particularly during the final stages of purging, to minimize turbidity and disturbance of volatile organic constituents.

iii. General Low Flow/Low Stress Method Preference - Low flow/low stress purging is a procedure using a device with the lowest pump or water removal rate, and creating the least amount of stress to a well. If a bailer and a peristaltic pump both works in a given situation, the pump should be selected because it will greatly minimize turbidity, thereby, providing a higher quality sample. If several pumps are considered to be used, the one with speed control may be given preference in order to provide a lower pump rate; thereby minimizing turbidity.

iv. Low flow/low volume purging techniques/procedures are used to minimize purged water volumes. Flow rates should not exceed the recharge rate of the aquifer (*i.e.*, no decrease in the water level in the monitoring well). The pump intake is placed within the screened interval at the zone of sampling, preferably, the zone with the highest flow rate. The water level is monitored with a water level recorder or similar device while pumping. These techniques are only acceptable under certain hydraulic conditions and are not considered standard procedures. A plan documenting that the required hydraulic conditions do exist at the site under investigation will be required for ADEM review and approval determination.

(b) Wells with In-Place Plumbing

i. Permanent Monitoring Wells - Permanent monitoring wells are occasionally sampled and require purging as described for wells without in-place pumps (*i.e.*, 3 to 5 well volumes and stable parameters).

ii. Continuous Running Pumps - If the pump runs continuously, purging is not necessary (other than opening a valve and allowing it to flush for a few minutes). If a storage tank is present, a spigot, valve or other sampling point must be located between the pump and the storage tank. Otherwise, locate the valve closest to the tank. Measurements of pH, specific conductance, temperature, and turbidity are recorded at the time of sampling.

iii. Intermittently Running Pumps - If the pump runs intermittently, it is necessary to determine the volume to be purged, including storage/pressure tanks that are located prior to the sampling location. Run the pump continuously until the required volume has been purged. If construction characteristics are not known, use best judgment in establishing how long to run the pump prior to collecting the sample. Generally, 30 minutes is adequate under these conditions. Record the pH, specific conductance, temperature and turbidity at intervals during the purging, and the final recording made during sampling.

(c) Temporary wells are installed for immediate sample acquisition. Wells of this type include standard well screens and risers placed in boreholes created by hand-augering, power-augering, or drilling. They also consist of a rigid rod and screen that is pushed, driven, or hammered into place to the desired sampling interval. Removing volumes of water to replace stagnant water is not necessary because stagnant water is generally non-existent. However, the longer a temporary well is in place and not sampled, the more the standard permanent monitoring well purging criteria would apply. Temporary wells to be sampled immediately require purging to mitigate the impacts of the installation activities that have resulted in increased turbidity. Therefore, purging may be conducted to reduce the turbidity and remove the volume of water in the area directly impacted by the installation activities. If the water level is no greater than 25 feet below the pump head elevation, a peristaltic pump is used to purge temporary monitoring wells and collect low turbidity samples by low-flow purging and sampling techniques. At the onset of purging, slowly lower the tubing to the bottom of the screen and use the tubing to remove any formation material that may have entered the well screen. After formation material is removed from the bottom of the well, slowly raise the tubing through the water column to near the top of the column. If the water level is determined to be stable, secure the tubing and maintain the pumping rate until relatively clear, low turbidity water samples can be collected. If the water level is lowered, and the pump is not in a variable speed, continue to lower the tubing as the water level is lowered. If the water level continues to lower, “chase” the water column until the well is evacuated. The recovered water column, after complete evacuation of the well, should be relatively free of turbidity and can be sampled. It may take several episodes of recovery to provide an adequate volume of water for all required samples. If a variable speed peristaltic pump is being used and drawdown is observed on initiation of pumping, reduce the pump speed and attempt to match the drawdown of the well. Sustain the pumping at these slow rates until relatively clear, low turbidity water samples can be collected. Purging is not conducted with any of the direct push sampling techniques. The sampling device in this technique is simply pushed to the desired depth, opened, and the sample is collected and retrieved.

C.4 Groundwater Sampling

Groundwater sampling is the process of obtaining, containerizing, and preserving a groundwater sample after the purging process is complete. Appropriate devices to be used to collect groundwater samples from monitoring wells are: peristaltic pump/vacuum jug assembly, stainless steel and Teflon® bladder pump, and closed-top Teflon® bailer (or its equivalent). Industrial or municipal supply wells or private residential wells, where a well is equipped with a dedicated pump from which a sample would not normally be collected, must be sampled in accordance with this guidance document and the USEPA's Field Branches QSTPs. These documents are dynamic and are periodically reviewed and updated. The user must ensure that the most current version is followed. Collect groundwater samples in the order of volatilization (highest to lowest). Collect groundwater samples for VOC analysis prior to all other samples. Decontaminate all sampling equipment including pumps, bailers, water level measurement equipment, *etc.*, that come into contact with the water in the well in accordance with the decontamination procedures described in Appendix E of this document prior to its use in all subsequent monitoring wells. When conducting groundwater sampling, the following evaluations must also be conducted and noted in the field logbook and in the Groundwater Sampling Data Form.

(a) Determine the order in which the wells will be sampled (from least to most contaminated).

(b) Note the construction and condition of the well (*i.e.,* pad condition, ponding of water, and vertical openings between the casing and the backfill material).

(c) Note any standing water inside the protective casing (casing may collapse if water freezes). Weep hole must be present at the bottom of the protective casing to prevent standing water.

(d) Note if the well is locked and the condition of the lock (*i.e.,* broken, rusted, or missing).

(e) Note the condition of all well construction materials and any damage that may need to be repaired, or if the well should be abandoned and replaced.

(f) Check for dangerous vapors with the proper air monitoring equipment.

(g) Note the time of the sampling, the sample station location, the method of sampling, the color of sample, any odors detected, and any sediment observed.

C.4.1 Sampling Techniques

(a) Monitoring wells with in-place plumbing - Following all purging activities, reduce the flow rate to minimize sample disturbance (particularly if VOCs are the COPCs). If the well is purged to dryness, shut off the pump and allow the well to recharge such that the required groundwater samples can be collected. Collect all groundwater samples from dedicated, decontaminated Teflon® tubing directly into the appropriate sample containers.

(b) Potable water supply wells with in-place plumbing - Purge the system for at least 15 minutes. If the samples are to be collected at a point in the water line beyond pressurization or holding tank, purge a sufficient volume of water to provide a complete exchange of fresh water into the tank and at the location where the sample is collected. After purging for 15 minutes, measure the turbidity, pH, specific conductivity and temperature of the groundwater. Continue to monitor these parameters until three consistent readings are obtained. Disconnect any hoses, filters, or aerators attached to the tap before sampling. Reduce the flow rate of the tap or spigot and collect all groundwater samples directly into the appropriate sample containers (see Table 1, Appendix G of this document). When sampling for bacterial content, rinse the sample container before use due to possible contamination of the sample container or removal of the thiosulfate dechlorinating agent (if used). When filling the sample container, care should be taken to avoid splashing water into either the bottle or cap. Obtain the name(s) of the resident or water supply owner/operator, the resident's mailing address, and the resident's home and work telephone numbers.

(c) Wells Without Pumps

i. A peristaltic pump/vacuum jug can be used for sample collection because it does not allow the sample to come into contact with the pump tubing. Place a Teflon® transfer cap assembly onto the neck of a clean standard 4-liter (1-gallon) glass container. Connect Teflon® tubing (1/4-inch outside diameter) from the glass container to both the pump and the sample source. The pump creates the vacuum in the container, thereby drawing the sample into the container without it coming in contact with the pump tubing. Collect samples for VOC analysis using a bailer or by filling the Teflon® tube and allow it to drain into the sample vials. The tubing is momentarily attached to the pump to fill the tube with water. After the water is discharged through the pump head, quickly remove the tubing from the pump and place a gloved thumb on the tubing to prevent the water from draining. Remove the tubing from the well and allow the water to drain into the sample vials. The sample for VOC analysis must not be collected from the content of any other previously filled container.

ii. Bladder Pumps - After purging is completed with the bladder pump, collect the sample directly from the pump discharge. If the discharge rate of the pump during the purging is too great so as to make sample collection difficult, care must be taken to reduce the discharge rate at the onset of actual sample collection. This is necessary to minimize sample disturbance, particularly with respect to samples collected for VOC analysis.

iii. Bailers - Place new plastic sheeting on the ground around each well to provide a clean working area. Attach nylon rope to the bailer. Lower the bailer slowly and gently into the top of the water column until just filled. Carefully remove the bailer and empty its contents into the appropriate sample containers (see Table 1, Appendix G of this document).

iv. Micropurge or low-flow purge sample collection – These methods involve flow rates of less than 0.5 L/min during purging and sampling. Devices that are suitable for low-flow purging and sampling include bladder pumps, electrical submersible pumps, gas driven pumps and peristaltic pumps. The latter is discouraged due to degassing and ORP (Oxidation-Reduction Potential) and pH changes. The sampling program should use thick-walled tubing and minimal tubing length. Bailers and inertial-lift devices should not be used for low flow sampling. Bailers and other grab type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of stagnant water in the casing and the dynamic water in the screened interval. Similarly, the use of inertial-lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

The pumping device should be capable of meeting the low-flow flow rate requirements (*i.e.*, minimal disturbance of the sample across a range of low-flow rates (0.1 to 0.5 L/min)). Consistency in operation is critical to meet accuracy and precision goals. Dedicated sampling systems are preferred since they minimize turbidity and avoid the need for decontamination. If the sampling device is not dedicated, the pump should be gently lowered gently to the desired sampling point, which is 3 to 5 feet below the top of the well screen in a well with a 10-ft screened interval. Sampling personnel must have a water-level indicator capable of measuring to +/- 0.01 feet and should make adjustments to stabilize the flow rate as soon as possible with a goal of less than 0.1m of drawdown. During purging, water-level measurements must be taken regularly at 30-second to 5-minute intervals (depending on hydraulic conductivity, diameter of the well, and pumping rate) to document the amount of drawdown during purging. Water quality indicators should be monitored during purging. It is recommended that an in-line water quality measurement device (*e.g.*, flow-through cell) be used to establish stabilization of pH, redox potential, specific conductance, dissolved oxygen and turbidity as per Section C.3.1 of this Guidance document (specific conductance, dissolved oxygen, and turbidity are most sensitive). Measurements of water levels should be collected carefully prior to monitoring and at 3- to 5-minute intervals during the purging. Total well depths should be measured after well sampling so as to minimize well disturbance and resuspension of settled solids.

v. Passive Sampling - The passive sampling procedures (i.e. no purge) are usually employed when groundwater conditions are such that purging hinders the collection of a representative sample. These techniques are only acceptable under certain hydraulic conditions and are not considered standard procedures. Sampling devices must be evaluated for appropriateness for analytes of concern. A plan documenting that the required hydraulic conditions do exist at the site under investigation will be required for ADEM review and approval determination. Among the passive sampling procedures are the following:

a. Passive diffusion bag (PDB) samplers are bags comprised of low-density polyethylene (LDPE) plastic and containing analyte-free water, preferably with no headspace. The principle behind passive diffusion is that compounds will migrate or diffuse through a semi-permeable membrane until a concentration equilibrium is established on either side of the membrane. The bags are deployed, with stainless steel weights, to the desired sample interval and are allowed to equilibrate with the water at the point of deployment in the well. A minimum deployment period of a minimum of 14 days is recommended to ensure equilibration prior to removal. After 14 days, the bags are opened with a puncture device or other cutting implement, and the contents are transferred to containers for sampling or field measurement.

b. HydraSleeve*TM* samplers are grab groundwater sampling devices that are deployed in a closed configuration then opened in the desired interval for sample collection. The following is a summary of its operation:

   i) Sampler Placement – A reusable weight is attached and the HydraSleeve*TM* is lowered and placed at the desired position in the well screen. *In-situ* water pressure keeps the reed valve closed, preventing water from entering the sampler. The well is allowed to return to equilibrium.
   ii) Sample Collection - The reed valve opens to allow filling when the sampler is moved upward faster than 1 foot per second, either in one continuous upward pull or by cycling the sampler up and down to sample a shorter interval. There is no change in water level and only minimal agitation during collection.
   iii) Sample Retrieval - When the flexible sleeve is full, the reed valve closes and the sampler can be recovered without entry of extraneous overlying fluids. Samples are removed by puncturing the sleeve with the pointed discharge tube and draining the contents into containers for sampling or field measurement.

c. Snap Sampler*TM* is a grab groundwater sampling device that employs a double-end-opening bottle with "Snap" sealing end caps. This dedicated, in-well equipment is deployed at the desired position in the screen interval with up to six Snap Samplers and six individual sampling bottles. The design allows for the collection of groundwater samples that are in dynamic equilibrium with the aquifer through a simple, no purge/passive technique. The following is a summary of its operation:

   i) Snap Samplers*TM* are loaded with Snap Sampler*TM* bottles and the "Snap" caps are set into an open position. Samplers are deployed downhole with an attachment/trigger line and left to equilibrate downhole for days, weeks, months - even possibly a year or more.

   ii) To collect samples, the Snap Sampler bottles seal under the water surface by simply pulling the mechanical trigger line, pushing the electric trigger button, or pressuring up the pneumatic trigger system. The trigger releases PFA (Teflon) "Snap Caps" that seal the double-ended bottles. The end caps are specially designed to seal the water sample within the bottles with no headspace vapor.

iii) Once the closed vial is retrieved from the well, the bottles are prepared with standard septa screw caps and labeled for laboratory submittal.

(d) Direct-Push Technologies – Groundwater sampling using direct push (DP) technology is generally used during a one-time sampling event. Once the contamination plume is delineated using DP technology, conventionally-installed permanent monitoring wells must be used if long-term groundwater monitoring is required. The DP sampling of temporary monitoring wells or well-points only provides a snapshot of the groundwater conditions at the time of the one-time sampling event. Permanent wells installed utilizing DP technologies are program-dependent and site-specific. A plan must be submitted to and approved by the Department prior to any small-diameter permanent well installation (see Appendix B.3 of this document). DP technology may also be used for determining groundwater gradients. DP tools used for single-event sampling are divided into two groups: exposed-screen samplers and sealed-screen samplers. Exposed-screen samplers have a short (*e.g.*, 6 inches to 3 feet) interval of exposed fine mesh screens, narrow slots, or small holes at the terminal end of the tool. There are several varieties of exposed-screen samplers: well point, drive-point profiler, and innovative exposed-screen sampler used in conjunction with cone penetrometer testing. The advantage of the exposed-screen sampler is that it allows multi-level sampling in a single DP hole without withdrawing the DP rods. The disadvantages of the exposed screen are the following:

i. Dragging down of NAPLs, contaminated soil, and/or contaminated groundwater in the screen can occur

ii. Clogging of the exposed screen (by silts and clays) typically occurs as it passes through sediments

iii. Significant purging of sampler and/or the sampling zone because of drag down and clogging concerns are necessary

iv. The fragility of the sampler because of the perforated open area

Sealed-screened samplers are groundwater samplers that contain a well screen nested inside a watertight sealed body. The screen is exposed by retracting the probe rods once the desired sampling depth has been reached. The design of sealed-screen samplers is extremely variable. The advantages of sealed-screen samplers are the following:

i. The well screen is not plugged or damaged because it is not exposed to soil while the tool is being deeply pushed

ii. The potential for sample cross-contamination is greatly reduced

iii. Able to collect depth-discrete groundwater samples beneath areas with soil in the vadose zone

iv. Screened samplers do not require purging

v. Allow sample collection by bailers, check-valve pumps, peristaltic pumps, and bladder pumps

vi. Able to use in DP systems for the collection of deeper groundwater samples

The disadvantages of sealed-screen samplers are:

i. The O-rings must be replaced frequently

ii. Sealed-screened samplers that collect groundwater in sealed chambers

   a. If the storage chamber is above the screen intake, groundwater samples must be collected sufficiently below the water table to create enough hydrostatic pressure to fill the chamber

   b. Only sample chambers located below the screen intake are useful for collecting groundwater or LNAPL samples at or above the water table

C.4.2 Sample Preservation - The minimum amount of preservative needed must be added to the sample immediately (See Table 1, Appendix G of this document). Care must be taken not to touch the preservative container to the sample bottle. After preserving, check the sample pH by pouring a small volume over a piece of pH paper. Do not place pH paper or probe into the sample container. Sample preservation must be done immediately. Laboratories that supply the required sample containers should submit all containers with the required preservative. These sample containers are appropriate; however, the pH of the final sample should be checked with the results recorded in the field logbook and Groundwater Sampling Data Form.

C.4.3 Special Sample Collection Procedures

(a) Trace Organic Compounds and Metals – Decontaminate all sampling equipment, including pumps, bailers, water level measurement equipment, *etc.*, that comes into contact with the water in the well, in accordance with the decontamination procedures described in Appendix E of this document. Pumps must not be used for sampling unless the interior and exterior portions of the pump and the discharge hoses are thoroughly decontaminated. Collect blank samples to determine the adequacy of cleaning prior to collection of any sample using a pump. Filtered groundwater sample results will not be accepted as representative of existing aquifer conditions.

(b) Filtering will only be used for flow system analysis and for the purpose of geochemical speciation modeling. Filtration is not allowed to correct improperly-designed or improperly-constructed monitoring wells, inappropriate sampling methods, or poor sampling technique.

(c) Bacterial Sampling - Whenever wells (normally potable wells) are sampled for bacteriological parameters, care must be taken to ensure the sterility of all sampling equipment and all other equipment entering the well.

C.4.4 Specific Sampling Equipment Quality Assurance Techniques - Clean and repair, if necessary, all equipment used to collect groundwater samples before storing at the conclusion of field studies, as outlined in Appendix E of this document. Cleaning procedures or repairs utilized in the field must be thoroughly documented in the field records or field logbook.

C.5 Surface Water and Sediment Sampling

Prior to any sampling events, conduct initial reconnaissance to locate suitable sampling locations. Bridges and piers are normally good choices since they provide ready access and permit water sampling at any point across the width of the water body. However, these structures may alter the nature of the water flow and thus influence sediment deposition or scouring. Additionally, bridges and piers are not always located in desirable locations with reference to waste sources, tributaries, *etc.* Wading for water samples in lakes, ponds and slow-moving rivers and streams must be done with care since bottom deposits are easily disturbed, thereby resulting in increased sediments in the overlying water column. On the other hand, wadeable areas may be best for sediment sampling. In slow-moving or deep water, a boat is usually required for sampling.

C.5.1 Sampling Site Selection

(a) Rivers, Streams and Creeks – Locate areas that exhibit the greatest degree of cross-section homogeneity in the selection of a surface water sampling site in rivers, streams, or creeks. When collecting a series of samples in close proximity to each other, always collect the most downstream location first to prevent substrate disruption. When several locations along a stream reach are to be sampled, they must be strategically located at the following locations:

i. At intervals based on time-of-water travel, not distance [*e.g.*, sampling stations may be located about one-half day time-of-water travel for the first three days downstream of a waste source (the first six stations) and approximately one day through the remaining distance].

ii. At the same locations, if possible, when the data collected are to be compared to a previous study.

iii. Wherever a marked physical change occurs in the stream channel. When major changes occur in a stream reach, an upstream, downstream, and intermediate station must be selected. Major changes may consist of:

a. A wastewater discharge;

b. A tributary flow;

c. Non-point source discharge (farms or industrial sites); or,

d. A significant difference in channel characteristics.

iv. At isolated major discharges and tributaries. Dams and weirs cause changes in the physical characteristics of a stream. They usually create quiet, deep pools in river reaches that previously were swift and shallow. Bracket such impoundments with sampling stations. When time-of-water-travel through the pools is long, establish stations within the impoundments. To determine the effects of certain discharges or tributary streams on ambient water quality, locate the stations both upstream and downstream from the discharges. In addition to the upstream and downstream stations bracketing a tributary, establish a station on the tributary at a location upstream and out of the influence of the receiving stream. Sample tributaries as near the mouth as feasible and utilize a boat, if necessary. Care should be exercised to avoid collecting water samples from stratified locations that are due to difference in density resulting from temperature, dissolved solids, or turbidity.

v. Actual sampling locations will vary with the size of the water body and the mixing characteristics of the stream or river. For streams less than 20 feet wide, select a sampling site where the water is well mixed. In such cases, a single grab sample taken at mid-depth at the center of the channel is adequate to represent the entire cross-section. A sediment sample could also be collected in the same vicinity if applicable.

vi. For slightly larger streams, collect at least one vertical composite from mid-stream. Collect samples just below the surface, at mid-depth, and just above the bottom. For much larger streams and rivers, collect at least quarter point (¼, ½, and ¾ width) composite samples. Measure dissolved oxygen, pH, temperature, and conductivity from each aliquot of the vertical composite.

vii. For large rivers, several locations across the channel width should be sampled. Vertical composites across the channel width should be located in a manner that is roughly proportional to the flow (*i.e.*, they should be closer together toward mid-channel where most of the flow is, than toward the banks where the proportion of total flow is less).

In most circumstances, collect a number of sediment samples along a cross section of a river or stream in order to adequately characterize the bed material. A common procedure is to sample at quarter points along the cross-section. When the sampling technique or equipment requires that the samples be extruded or transferred on-site, they may be combined into a single composite sample. However, samples of dissimilar composition must not be combined and must be stored for separate analysis in the laboratory. To ensure representative samples, the preferred method is diver-deployed coring tubes.

(b) Lakes, Ponds, and Impoundments - Lakes, ponds, and impoundments have a much greater tendency to stratify than rivers and streams. The relative lack of mixing generally requires that more samples be obtained. Occasionally, an extreme turbidity difference may occur where a highly turbid river enters a lake. For these situations, each layer of the vertically stratified water column needs to be considered. The number of water sampling stations on a lake, pond, or impoundment varies with the objective of the investigation as well as the size and shape of the basin. In ponds and small impoundments, a single vertical composite at the deepest point is sufficient. Dissolved oxygen, pH, and temperature are measured for each vertical composite aliquot. In naturally-formed ponds, the deepest point is usually near the center; in impoundments, the deepest point is usually near the dam. In lakes and larger impoundments, several vertical subsamples must be composited to form a single sample. These vertical sampling locations are often collected along a transection or grid. In lakes with irregular shapes and with several bays and coves that are protected from the wind, additional separate composite samples are needed to adequately determine water quality. Similarly, collect additional samples where discharges, tributaries, land-use characteristics, *etc.*, are suspected of influencing water quality. When collecting sediment samples in lakes, ponds, and reservoirs, the sampling site should be approximately at the center of the water mass. Consider the shape, inflow pattern, bathymetry, and circulation when selecting sediment-sampling sites in lakes or reservoirs.

(c) Estuarine Waters – Conduct a reconnaissance investigation for each estuarine study unless prior knowledge of the estuarine type is available. Focus the reconnaissance on the freshwater and oceanic water dynamics with respect to the study objective of the National Oceanic Atmospheric Administration (NOAA) tide tables and United States Geological Survey (USGS) freshwater surface water flow records that provide valuable insights into the estuary hydrodynamics. Water sampling in estuarine areas is normally based upon the tidal phases, with samples collected on successive slack tides. Include vertical salinity measurements at one to five-foot increments coupled with vertical dissolved oxygen and temperature profiles in all estuarine sampling events. A variety of water sampling devices are used but the Van Dorn (or similar type) horizontal sampler or peristaltic pump is suitable. Samples are collected at mid-depth areas where the depths are less than 10 feet unless the salinity profile indicates the presence of a halocline (salinity stratification). In this case, samples are collected from each stratum. Depending upon the study objective, when depths are greater than 10 feet, collect water samples at the one-foot depth from the surface, mid-depth, and one-foot from the bottom. Estuarine investigations are two-phased, with study investigations conducted during wet and dry periods. Depending upon the freshwater inflow sources, estuarine water quality dynamics cannot normally be determined by a single season study.

(d) Control Stations - In order to have a basis for comparison of water quality, the collection of samples from control stations is always necessary. A control station upstream from the waste source is as important as the station(s) down-gradient, and should be chosen with equal care to ensure representative results. In some situations it is desirable to have background stations located in similar, nearby estuaries that are not impacted by the phenomena or pollutants being investigated. At times, it may be desirable to locate two or three stations downstream from the waste inflow to establish the rate at which the unstable material is changing.

C.5.2 Surface Water Sampling Equipment

(a) Dipping Using Sample Container – Collect a sample directly into the sample container when the surface water source is accessible by wading or other means. Face the sampler upstream and collect the sample without disturbing the sediment. Always collect the surface water sample prior to a sediment sample at the same location. Do not displace the preservative from a pre-preserved sample container such as the 40-ml VOC vial.

(b) Scoops - Stainless steel scoops are useful for reaching out into a body of water to collect a surface water sample. Use the scoop to directly collect and transfer a surface water sample to the sample container, or it may be attached to an extension in order to access the selected sampling location. The scoop is one of the most versatile sampling tools available to the field investigator.

(c) Peristaltic Pumps - Another device that can be effectively used to sample a water column is the peristaltic pump/vacuum jug system. The use of a metal conduit to which the tubing is attached allows for the collection of a vertical sample (up to about a 25-foot depth) that is representative of the water column. Commercially available pumps vary in size and capability with some being designed specifically for the simultaneous collection of multiple water samples.

(d) Discrete Depth Samplers - When discrete samples are desired from a specific depth, and the parameters to be measured do not require a Teflon® coated sampler, a standard Kemmerer or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position, allowing free passage of water through the cylinder. The plastic Van Dorn sampler is lowered in a horizontal position. A messenger is sent down a rope when the sampler is at the designated depth to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill respective sample containers. With a rubber tube attached to the valve, dissolved oxygen sample bottles can be properly filled by allowing an overflow of the collected water. With multiple depth samples, care should be taken not to stir up the bottom sediment and thus bias the sample.

(e) Bailers - Teflon® bailers may also be used for surface water sampling if the study objectives do not necessitate a sample from a discrete interval of the water column. A closed top bailer with a bottom check-valve is sufficient for many studies. As the bailer is lowered through the water column, water is continually displaced through the bailer until the desired depth is reached, at which point the bailer is retrieved. This technique may not be successful where strong currents are found.

(f) Buckets - A plastic bucket can be used to collect samples for *in-situ* analyses (*e.g.*, pH, temperature and conductivity). However, the bucket must be rinsed twice with the sample water prior to collection of the sample.

C.5.3 Sediment Sampling Equipment

(a) Scoops and Spoons - If the surface water body is wadeable, collect sediment samples by using a stainless steel scoop or spoon. The sample is collected by wading into the surface water body and, while facing upstream (into the current), scooping the sample along the bottom of the surface water body in the upstream direction. Remove excess water from the scoop or spoon. However, this may result in the loss of some fine particle size material associated with the bottom of the surface water body. Place the sample aliquots in a glass pan and homogenize. In surface water bodies that are too deep to wade, but less than eight feet deep, use a stainless steel scoop or spoon attached to a piece of conduit either from the banks if the surface water body is narrow or from a boat. Place the sediment into a glass pan and homogenize. Use a BMH-60 sampler if the surface water body has a significant flow and too deep to wade. The BMH-60 is not efficient in mud or other soft substrates because its weight will cause penetration to deeper sediments, missing the most recently deposited material at the sediment-water interface. It is also difficult to release secured samples in an undisturbed fashion that would readily permit sub-sampling. Use BMH-60 only on subsamples that have not been in contact with the metal wall of the sampler.

(b) Dredges

i. Peterson Dredge – For routine analyses, use the Peterson dredge when the bottom is rocky, in very deep water, or when the stream velocity is high. Slowly lower the dredge as it approaches bottom since it can displace and miss fine particle-sized sediment if allowed to drop freely.

ii. Ekman Dredge – The Ekman dredge has only limited usefulness. It performs well where the bottom material is soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky and hard bottoms, and is too light for use in streams with high velocities. Do not use it from a bridge that is more than a few feet above the water because the spring mechanism, which activates the sampler, can be damaged if the Ekman dredge is dropped from too great a height.

iii. Ponar Dredge – The Ponar dredge is a modification of the Peterson dredge and is similar in size and weight. It has been modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends, reducing turbulence around the dredge. The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

iv. Mini Ponar Dredge – The "mini" Ponar dredge is a smaller, much lighter version of the Ponar dredge. It is used to collect smaller sample volumes when working in industrial tanks, lagoons, ponds, and shallow water bodies. It is a good device to use when collecting sludge and sediment containing hazardous constituents because the size of the dredge makes it more amenable to field cleaning.

(c) Coring – Core samplers are used to sample vertical columns of sediment. They are particularly useful when a historical picture of sediment deposition is desired since they preserve the sequential layering of the deposit, and the loss of material at the sediment-water interface is minimized. Many types of coring devices have been developed depending on the depth of the water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. They vary from hand push tubes to weight or gravity-driven devices. Coring devices are also useful in pollutant monitoring because turbulence created by descent through the water is minimal, and fines of the sediment-water interface are also minimally disturbed. The sample is withdrawn intact permitting the particular removal of layers of interest. Core liners made of glass or Teflon® can be purchased, reducing possible sample contamination. The samples are delivered to the lab for analysis in the tube in which they are collected. The disadvantage of coring devices is that a relatively small surface area and sample size is obtained, necessitating repetitive sampling to achieve the required amount of material needed for analysis. The advantages offset the disadvantage that coring devices are recommended in sampling sediments for trace organic compounds or metals analyses. In shallow, wadeable waters, the direct use of a core liner or tube made of Teflon®, plastic, or glass is recommended by the USEPA Region 4 for the collection of sediment samples. Teflon® or plastic is preferred to glass because they are less fragile and reduce the possibility of sample loss. Stainless steel push tubes are also appropriate and provide a better cutting edge and higher strength than Teflon®. The use of glass or Teflon® tubes eliminates metal contamination from core barrels, cutting heads, and retainers. The tube is approximately 12 inches in length if recently deposited sediments (8 inches or less) are to be sampled. Use longer tubes when the depth of the substrate exceeds 8 inches. Soft or semi-consolidated sediments such as mud and clays have a greater adherence to the inside of the tube and can be sampled with larger diameter tubes. A small-diameter tube is required for coarse or unconsolidated sediments such as sands and gravel, because of their tendency to fall out of the tube. A 2 inch diameter tube is usually the best size. The wall thickness of the Teflon®, plastic or glass tube is about 1/3 inch. The core tube is pushed into the substrate until 4 inches or less of the tube is above the sediment-water interface. When sampling hard or coarse substrates, a gentle rotation of the tube, while being pushed, will facilitate greater penetration and decrease core compaction. The top of the tube is capped to provide suction and reduce the chance of losing the sample. A Teflon® plug or a sheet of Teflon® held in place by a rubber stopper or cork may be used. After capping, slowly extract the tube with the suction and adherence of the sediment keeping the sample in the tube. Cap the other side of the tube before pulling the bottom part of the core above the water surface.

Appendix D

Quality Assurance/Quality Control

APPENDIX D - QUALITY ASSURANCE/QUALITY CONTROL

D.1 Appendix Outline

D.2 QA/QC Requirements

Utilize Quality Assurance/Quality Control (QA/QC) procedures and EPA-required decontamination procedures to ensure sample quality. For additional information, see the USEPA's Field Branches QSTPs. These documents are dynamic and are periodically reviewed and updated. The user must ensure that the most current version is followed. It is the responsibility of the field sampling staff to ensure that the samples collected arrive at the laboratory in the appropriate container, with the appropriate preservative, and within the holding times for each analysis.

D.3 Sample Containers and Preservation

Place all samples in the appropriate containers and preserve as recommended in Table 1, Appendix G of this document. All sample containers must be new, pre-cleaned or properly decontaminated with the appropriate certification.

D.4 Sample Handling

Measure the effectiveness of sample handling techniques by collecting split and blank samples. Blanks are required of water systems, grout, preservatives, sand, bentonite, soil trip blanks, and field cleaned equipment. The following samples are examples of Quality Control Samples that may be collected or required:

D.4.1 Control Sample – A discrete grab sample collected to isolate a source of contamination. Isolation of a source require the collection of both an upstream sample at a location where the medium being studied is unaffected by the site being studied, as well as a downstream control affected by contaminants from the site under study.

D.4.2 Background Sample – A sample (usually a grab sample) collected from an area, water body, or site similar to the one being studied, but located in an area known or thought to be free from the constituents of concern.

D.4.3 Split Sample – A sample that has been portioned into two or more containers from a single sample container or sample mixing container. The primary purpose of a split sample is to measure sample handling variability.

D.4.4 Duplicate Sample – Two or more samples collected from a common source. The purpose of a duplicate sample is to estimate the variability of a given characteristic or contaminant associated with a population.

D.4.5 Trip Blanks – A sample that is prepared prior to the sampling event in the actual container and is stored with the investigative samples throughout the sampling event. They are shipped with the other samples and submitted for analysis. Do not open trip blanks after preparation before they reach the laboratory. Trip blanks are used to determine if samples were contaminated during storage and/or transport back to the laboratory (a measure of sample handling variability resulting in positive bias in contaminant concentration). If samples are to be shipped, provide trip blanks with each shipment but not for each cooler. (NOTE: If trip blanks are needed to accompany soil samples, prepare them in the same manner as aqueous trip blanks.)

D.4.6 Spike – A sample with known concentrations of contaminants. Spike samples are often packaged for shipment with other samples and sent for analysis. Do not open spike samples after preparation before they reach the laboratory. Spike samples are used to measure negative bias due to sample handling or analytical procedures or to assess the performance of a laboratory.

D.4.7 Equipment Field Blank – A sample collected using organic-free water that has been run over/through sample collection equipment. These samples are used to determine if contaminants have been introduced by contact of the sample medium with sampling equipment. Equipment field blanks are often associated with collecting rinse blanks of equipment that has been field-cleaned.

D.4.8 Pre- and Post-Preservative Blank – A sample prepared in the field to determine if the preservative was contaminated during field operations causing a positive bias in the contaminant concentration. On small studies, usually only a post-preservative blank is prepared at the end of all sampling activities. On studies extending beyond one week, prepare a pre-preservative blank prior to beginning sampling activities. At the discretion of the project leader, additional preservative blanks can be prepared at intervals throughout the field investigation. These blanks are prepared by putting organic/analyte-free water in the container and preserving the sample with the appropriate preservative.

D.4.9 Field Blank – A sample prepared in the field to evaluate potential sample contamination by the site contaminants from a source not associated with the sample collected (*e.g.*, air-borne dust or organic vapors that could contaminate a soil sample). Organic-free water is taken to the field in sealed containers or generated on-site. The water is poured into the appropriate sample containers at pre-designed locations at the site. Collect field blanks in dusty environments and/or in areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled.

D.4.10 Material Blanks – Samples of sampling materials, construction materials, or reagents collected to measure any positive bias from sample handling variability. Commonly collected material blanks are:

(a) Wipe Sample Blank – a sample of the material used for collecting wipe samples

(b) Grout Blank – a sample of the material used to make seals around the annular space in monitoring wells

(c) Filter Pack Blank – a sample of the material used to create an interface around the screened interval of a monitoring well

(d) Construction Water Blank – a sample of the water used to mix or hydrate construction material such as monitoring well grout

(e) Organic-Free/Analyte-Free Water Blank – a sample collected from a field organic-free/analyte-free water-generating system. The sample is collected at the end of sampling activities since the organic-free/analyte-free water system is recharged prior to use on a study. On large studies, samples can be collected at intervals at the discretion of the project leader. The purpose of the organic-free/analyte-free water blank is to measure positive bias from the sample handling variability due to possible localized contamination of the organic-free/analyte-free water-generating system or contamination introduced to the sample containers during storage at the site. Organic-free/analyte-free water blanks differ from field blanks in that the sample is collected in as clean an area as possible

D.5 Sample Identification

Record samples collected for specific field analysis or measurement data directly in bound field logbooks, sample collection forms, or directly on the Chain-of-Custody Record.

D.5.1 Labels – Include labels or tags on samples collected for laboratory analyses. Write the following information on the sample labels or tags using waterproof, non-erasable ink:

(a) Project number

(b) Field identification or sample station number

(c) Date and time of sample collection

(d) Designation of the sample as a grab or composite

(e) Type of sample (water, wastewater, leachate, soil, sediment, *etc.*)

(f) The preservative used (if any)

(g) The general types of analyses to be performed

D.5.2 Logbook - Information to be retained in a bound logbook or sample collection form must include:

(a) Project number

(b) Field identification or sample station number

(c) Date and time of sample collection

(d) Designation of the sample as a grab or composite

(e) The signature of either the sampler(s) or the designated sampling team leader and the field sample custodian

(f) Whether the sample was preserved (identify preservative) or unpreserved

(g) The general types of analyses to be performed

(h) All field measurements collected during the purging of monitoring wells (pH, specific conductivity, temperature, and turbidity)

(i) Water levels and total well depths measured during the sampling event

(j) Any relevant comments (such as readily detectable or identifiable odor, color, or known toxic properties)

D.6. Chain-of-Custody

Submit the original chain-of-custody forms with all the original laboratory reports to the Department. If copies are submitted, the copies must represent the same data and information that are present on the original chain-of-custody forms. Record all information on the chain-of-custody forms legibly. Chain-of-custody forms must originate in the field immediately upon sampling the soils, groundwater, sediment, or surface water. The chain-of-custody forms must stay with the samples at all times until properly relinquished to the laboratory for analysis. The following information must be present on all chain-of-custody forms:

(a) Site name and address

(b) Date and time of sampling of each sample

(c) Sample identification numbers

(d) Name of samplers

(e) Analytical laboratory to be utilized

(f) Analytical methods to be used

(g) Type of sample (composite, grab, *etc.*)

(h) Matrix sampled (soil, water sludge, *etc.*)

(i) Number and type of sample container

(j) Remarks regarding sampling, if applicable

(k) Preservatives used for each sample (indicate if placed on ice)

(l) Personnel relinquishing samples; times and dates

(m) Personnel receiving samples; times and dates

D.7. Investigation-Derived Waste (IDW)

A number of materials become IDW. Handle and dispose of all hazardous and non-hazardous IDW in accordance with Table 2, Appendix G of this document. In addition, EPA's Guidance Document, *Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Wastes – Final* dated April 2015 should be consulted.

Examples of IDW:

1. Personnel protective equipment (PPE) (disposable coveralls, gloves, booties, respirator canisters, splash suits, *etc.*)
2. Disposable equipment (plastic ground and equipment covers, aluminum foil, conduit pipe, composite liquid waste samplers, Teflon® tubing, disposable bailers, broken or unused sample containers, sample container boxes, tape, *etc.*)
3. Soil cuttings from drilling or hand augering
4. Drilling mud or water used for water rotary drilling
5. Ground water obtained through well development or well purging
6. Cleaning fluids such (spent solvents, wash-water, *etc.*)
7. Packing and shipping materials

Appendix E

Field Decontamination Procedures

APPENDIX E - FIELD DECONTAMINATION PROCEDURES

E.1 Appendix Outline

E.2 Standard Cleaning Liquids

E.2.1 Detergent – Use a standard brand of phosphate-free laboratory detergent, such as Liquinox®, for equipment cleaning purposes. Use of another detergent must be justified and documented in the field logbooks and in the inspection or investigative reports.

E.2.2 Solvent - Solvent must be pesticide-grade isopropanol. Use of other solvent for equipment cleaning purposes must be justified in the study plan. Otherwise, its use must be documented in the field logbooks and in the inspection or investigative reports.

E.2.3 Water - Tap water from any municipal water treatment system may be used. Untreated potable water is not a substitute for tap water. Analyte-free water (deionized water) is tap water that has been treated by passing it through a standard deionizing resin column. The finished water must contain no detectable heavy metals or other inorganic compounds (*i.e.*, at or above analytical detection limits) as defined by a standard inductively coupled Argon Plasma Spectrophotometer (ICP) (or equivalent) scan. Analyte-free water obtained by other methods is appropriate as long as it meets the above analytical criteria.

Organic-free/analyte-free water is defined as tap water that has been treated with activated carbon and deionizing units. A portable system to produce organic-free/analyte-free water under field conditions is available. The finished water must meet the analytical criteria of analyte-free water and contain no detectable pesticides, herbicides, or extractable organic compounds; and no VOCs above minimum detectable levels. Organic-free/analyte-free water obtained by other methods is appropriate as long as it meets the above analytical criteria.

E.2.4 Other Solvents - Other solvents may be substituted for a particular purpose if required. For example, removal of concentrated waste materials may require the use of either pesticide-grade hexane or petroleum ether. After the waste material is removed, the equipment is subject to the standard cleaning procedure. Because these solvents are not miscible with water, the equipment must be completely dry prior to use.

E.3 Decontamination Pad

E.3.1 Decontamination Pad Specifications – Construct the pad in an area known or believed to be free of surface contamination. The pad must retain all decontamination fluids and site contaminants. If possible, locate the pad on a level, paved surface that is well drained. Pads located off pavement are subject to being shut down for extended periods following rain events due to standing water, equipment mired in mud, excessive mud on the pad, *etc.* The pavement also provides a firm support for heavy items such as augers. Surround the pad with a berm or wall that is 8 to 12 inches high. Low-cost walls can be constructed of un-mortared concrete blocks, railroad ties, lumber, *etc.* Include a small shallow sump dug in one corner of the pad. A hole can be made in the pavement or a corner of the pad extended beyond the paved area. The sump must be deep enough to contain the intake line of a pump. Line the pad with an impervious material with no seams within the pad. The material must be easily replaced (disposable) or repaired. If a disposable liner is not used, a patch kit must be available to repair holes and tears. Sweep or pressure-wash the area prior to laying down the liner. The sawhorses or racks used to hold equipment while being cleaned must be high enough above the ground to prevent equipment from being splashed. Cushion the bottom of the legs of the sawhorses or racks with small pieces of lumber, rubber, *etc.*, to avoid puncturing the liner.

E.3.2 Operation of the Decontamination Pad - When drilling wells, generate organic-free water on-site to provide a sufficient quantity to avoid project delays. Apply both organic-free water and solvent using Teflon® spray nozzles. Unless specifically cited in the approved study plan, keep the hazardous spent solvent separate from other decontamination fluids. The decontamination pad must be drained frequently to keep standing water from splashing onto clean equipment. Move clean equipment away from the working area of the pad and completely wrap to avoid being splashed. Keep gasoline-powered equipment (pump, steam jenny, generator, *etc.*) downwind of the decontamination pad while it is running. Wear safety glasses with splash shields or goggles and latex gloves during all cleaning operations and decontamination procedures. Conduct solvent rinsing operations in an open area and never in a closed room. Eating, smoking, drinking, chewing, or any hand-to-mouth contact is prohibited during cleaning operations. At the completion of site activities, deactivate the decontamination pad. Backfill the pit or sump with the appropriate material designated by the site project leader but only after all waste/rinse water has been pumped into containers for disposal. No solvent rinsates will be placed in the pit. Collect solvent rinsates in separate containers for proper disposal. See Appendix D.7 of this document for proper handling and disposal of these materials. If the decontamination pad has leaked excessively, soil sampling is required.

E.4 Decontamination of Drilling Equipment

E.4.1 Introduction - Equipment cleaning and decontamination must be conducted at a designated area on site. Tap water (potable) brought on-site for drilling and cleaning purposes must be contained in a pre-cleaned tank of sufficient size to avoid drilling activities delays by obtaining additional water. Obtain a steam cleaner and/or high pressure hot water washer capable of generating a pressure of at least 2500 psi and producing hot water and/or steam of at least 200°F, with a soap compartment.

E.4.2 Preliminary Cleaning and Inspection - All drilling and sampling equipment must be sandblasted before use if painted, and/or there is a buildup of rust, hard or caked matter, *etc.*, that cannot be removed by steam cleaning (soap and high pressure hot water) or wire brushing. Perform sandblasting prior to arrival on-site or away from the decontamination pad and areas to be sampled. Any portion of the drill rig, backhoe, *etc.*, that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chain pull-downs, spindles, cathead, *etc.*) must be steam-cleaned (soap and high pressure hot water) and wire-brushed (as needed) to remove all rust, soil, and other material that may have come from other hazardous waste sites before being brought on-site. Remove printing and/or writing on well casing, tremie tubing, *etc.* with emery cloth or sandpaper before use. Most well material suppliers can supply materials without the printing and/or writing if specified when ordered. Inspect the drill rig and other equipment associated with the drilling and sampling activities to ensure that all oils, greases, hydraulic fluids, *etc.*, have been removed and all seals and gaskets are intact with no fluid leaks. Inspect the PVC or plastic materials such as tremie tubes. Items that cannot be cleaned are prohibited and should be discarded.

E.4.3 Drill Rig Field Cleaning Procedure - Any portion of the drill rig, backhoe, *etc.*, that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chin pull-downs, spindles, cathead, *etc.*) must be steam-cleaned (soap and high pressure hot water) between boreholes.

E.4.4 Field Cleaning Procedure for Drilling Equipment - This is the standard procedure for field-cleaning augers, drill stems, rods, tools, and associated equipment and does not apply to well casings, well screens, or split spoon samplers used to obtain samples for chemical analyses. Clean with tap water and soap using a brush, if necessary, to remove particulate matter and surface films. Steam cleaning (high pressure hot water with soap) is necessary to remove matter that is difficult to remove with the brush. Place drilling equipment that is steam-cleaned on racks or sawhorses at least two feet above the floor of the decontamination pad. Stem augers, drill rods, *etc.*, that are hollow, have holes, or transmit water or drilling fluids, must be cleaned on the inside with vigorous brushing. Rinse thoroughly with tap water. Remove from the decontamination pad and cover with clean, unused plastic. If stored overnight, secure the plastic to ensure that it stays in place.

E.5 Decontamination Procedures for Sampling Equipment

E.5.1 Trace Organic and Inorganic Constituent Sampling Equipment (Teflon® and Glass) - Wash equipment thoroughly with soap and hot tap water using a brush or scrub pad to remove any particulate matter or surface film. Rinse equipment thoroughly with hot tap water and with 10% nitric acid solution. Small and awkward equipment such as vacuum bottle inserts and well bailer ends may be soaked in the nitric acid solution instead of rinsed. Prepare fresh nitric acid solution for each cleaning session. Rinse equipment thoroughly with analyte-free water and/or with solvent and allow to air dry for at least 24 hours. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a “tab” to allow for easy removal. Seal the foil-wrapped equipment in plastic and label.

NOTE: If the sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials before proceeding with the first step. In extreme cases, it is necessary to steam-clean the field equipment before proceeding with the first step. Equipment that cannot be cleaned by these procedures must be discarded.

E.5.2 Stainless Steel or Steel – Wash equipment thoroughly with soap and hot tap water using a brush or scrub pad to remove any particulate matter or surface film. Rinse equipment thoroughly with hot tap water, analyte-free water, and solvent and allow to air dry for at least 24 hours. Wrap equipment in one layer of aluminum foil and roll edges into a “tab” to allow for easy removal. Seal the foil-wrapped equipment in plastic and label.

NOTE: (See E.5.1 Note above)

E.5.3 Cleaning Procedures for Tubing (Silastic® Pump Tubing) – Replace the Silastic® pump tubing in the automatic samplers and peristaltic pumps after each study. After installation, cap the exposed ends with clean, unused aluminum foil. Use only new Teflon® for the collection of samples for trace organic compounds or ICP analyses and pre-clean as follows:

(a) Precut Teflon® tubing in 10-, 15-, or 25-foot lengths before cleaning

(b) Rinse outside of tubing with solvent

(c) Flush interior of tubing with solvent

(d) Dry tubing overnight in the drying oven

(e) Coil and cap tubing ends with aluminum foil

(f) Wrap tubing in one layer of aluminum foil

(g) Roll edges of foil into a “tab” to allow for easy removal

(h) Seal the foil-wrapped tubing in plastic and label

E.5.4 Stainless Steel Tubing - Wash with soap and hot tap water using a long, narrow bottle brush. Rinse equipment thoroughly with hot tap water, analyte-free water, and solvent and allow to air dry for at least 24 hours. Cap tubing ends with aluminum foil and wrap in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil-wrapped tubing in plastic and label.

Note: (See E.5.1 Note above)

E.5.5 Glass Tubing – Clean new glass tubing by rinsing thoroughly with solvent and air dry for at least 24 hours. Wrap tubing completely with aluminum foil and seal in plastic (one tube per pack) to prevent contamination during storage.

E.5.6 Cleaning Procedures for Miscellaneous Equipment

(a) Well Sounders and Tapes - Wash with soap and tap water. Rinse with hot, analyte-free tap water and allow to air dry overnight. Wrap equipment in aluminum foil, seal in plastic, and label.

(b) Fultz® Pump -To avoid damage, never run pump when dry and never switch directly from forward to reverse mode without pausing in the "OFF" position. Pump a sufficient amount of hot soapy water through the hose to flush out any residual purge water. Using a brush or scrub pad, scrub the exterior of the contaminated hose and pump with hot soapy water. Rinse hose with analyte-free water and recoil onto the spool. Pump a sufficient amount of tap water through the hose to flush out soapy water (approximately one gallon). Pump a sufficient amount of analyte-free water through the hose to flush out the tap water, and empty the pump and hose by placing pump in reverse. Do not allow pump to run dry. Rinse the pump housing and hose with analyte-free water. Place pump and reel in clean polyethylene bag or wrap in clean polyethylene film. Ensure that a complete set of new rotors, tow fuses and a set of cables are attached to the reel.

(c) Goulds® Pump -Remove garden hose (if attached) and clean separately. Using a brush or scrub pad, scrub the exterior of the hose, electrical cord, and pump with soap and tap water. Rinse with analyte-free water and air dry. Place pump and hose in clean plastic bag and label.

(d) Redi-Flo® Pump -Wipe the controller box with a damp cloth but never wet. Remove any excess water immediately. Allow the controller box to completely dry. Remove garden hose (if attached) and ball check valve and clean separately. Using a brush or scrub pad, scrub the exterior of the pump and electrical cord with soap and tap water. Do not wet the electrical plug. Rinse with tap water and with analyte-free water, and completely air dry. Place equipment in clean plastic bag. Completely dismantle ball check valve. Check for wear and/or corrosion, and replace as needed. Using a brush, scrub all components with soap and hot tap water. Rinse with analyte-free water and completely air dry. Reassemble the ball check valve, and re-attach to Redi-Flo® pump head. Change the analyte-free water within the Redi-Flo® pump head upon return from the field, according to the manufacturer's instructions.

(e) Little Beaver® - Clean the engine and power head with a power washer, steam jenny, or hand wash with a brush using soap to remove oil, grease, and hydraulic fluid from the exterior of the unit. Do not use degreasers. Rinse thoroughly with tap water. Inspect auger flights and bits thoroughly. If severe rust, corrosion, paint, or hardened grout is present, the equipment will require sandblasting prior to cleaning. Clean with tap water and soap using a brush, if necessary, to remove particulate matter and surface films. Steam-cleaning (high pressure hot water with soap) is necessary to remove matter that is difficult to remove with the brush. Place steam-cleaned augers on racks or sawhorses at least 2 feet above the ground. Rinse thoroughly with tap water and completely air dry. Remove and wrap with clean, unused plastic and return to storage.

(f) Field Analytical Equipment – Wipe field instruments for *in-situ* water analysis with a clean, damp cloth. Rinse the probes on these instruments (pH, conductivity, dissolved oxygen (DO), *etc.*) with analyte-free water and completely air dry. Check and replace, if necessary, any desiccant in these instruments each time the equipment is cleaned.

(g) Ice Chests and Shipping Containers – Wash ice chests and reusable containers with soap (interior and exterior), and rinse with tap water and completely air dry before storage. If in the opinion of the field investigators the container is severely contaminated with concentrated waste or other toxic material, it must be cleaned as thoroughly as possible, rendered unusable, and properly disposed.

(h) Garden Hose - Brush exterior with soap and tap water. Rinse with tap water. Flush interior with tap water until clear (minimum of one gallon) and drain. Completely air dry. Coil and place in clean plastic bag.

E.6 Preparation of Disposable Sample Containers

No disposable sample container (with the exception of the glass and plastic composite containers) may be reused. Store all disposable sample containers in their original packing containers. Place opened packages of uncapped sample containers in new plastic garbage bags and seal to prevent contamination during storage.

E.6.1 Plastic Containers used for "Classical" Parameters – Plastic containers used for oxygen demand, nutrients, classical inorganics, and sulfides have no pre-cleaning requirement. However, use only new containers.

E.6.2 Glass Bottles for Semi-Volatile GC/MS Analytes – Use these procedures only if the supply of pre-cleaned, certified sample bottles is disrupted. If desired, substitute pesticide-grade methylene chloride for pesticide-grade isopropanol. In addition, substitute 1:1 nitric acid for the 10% nitric acid solution. Wash bottles, jugs, Teflon® liners, and caps with hot tap water and soap. Rinse three times with tap water. Rinse with 10% nitric acid solution. Rinse three times with analyte-free water. Rinse bottles, jars, and liners (not caps) with solvent. Oven-dry bottles, jars, and liners at 125°C and allow to cool. Place liners in caps and close containers. Store in contaminant-free area.

E.6.3 Glass Bottles for Volatile GC/MS and TOX Analyses – Use these procedures only if the supply of pre-cleaned, certified sample bottles is disrupted. Wash vials, bottles, jars, Teflon® liners and septa, and caps with hot tap water and laboratory detergent. Rinse all items with analyte-free water. Oven-dry at 125°C and allow to cool. Seal vials, bottles, and jars with liners or septa as appropriate and cap. Store in a contaminant-free area.

E.6.4 Plastic Bottles for ICP Analytes – Use these procedures only if the supply of pre-cleaned, certified sample bottles is disrupted. Wash bottles and caps with hot tap water and soap. Rinse both with 10% nitric acid solution. Rinse three times with analyte-free water. Invert bottles and dry in contaminant-free environment. Cap bottles and store in a contaminant-free area.

Appendix F

Remediation Technologies

APPENDIX F - REMEDIATION TECHNOLOGIES

F.1 Appendix Outline

F.2 Introduction
F.3 Remediation Technologies

F.2 Introduction

This appendix addresses various remediation technologies that are available to facilities and consultants when determining the most effective remedial technology for a site. The various remediation technologies have been reviewed/utilized by representatives from the USEPA, various state environmental regulatory agencies, Department of Energy, Department of Defense, U.S. Department of the Interior, the Federal Remediation Technologies Roundtable, the Interstate Technology & Regulatory Council, the Association of State and Territorial Solid Waste Management Officials, and various private industries and consultants. The technologies have been evaluated to establish each technology's effectiveness with respect to the type of contaminant and the type of media impacted. The following list is not intended to be comprehensive, but has been provided in order to provide regulators, the regulated community, and consultants with methods for consideration. Each technology contains a link where more information may be found. The documents linked are in no way considered to be the only guidance that should be used nor do they encompass all of the requirements that the Department may impose. Each link is considered useful by the Department for informational purposes and may be used to support information provided within a remediation/cleanup plan submitted to the Department for review. Additionally, information regarding many of the following technologies can be obtained in the document "Remediation Technologies Screen Matrix and Reference Guide, Version 4.0, Federal Remediation Technologies Roundtable" which can be accessed by the following URL:
http://www.frtr.gov/matrix2/top_page.html

F.3 Remediation Technologies

i. *In-Situ* Bioremediation
ii. Bioremediation of Dense Non-Aqueous Phase Liquids (DNAPLs)
iii. Enhanced Attenuation: Chlorinated Organics
iv. Enhanced *In-Situ* Biodenitrification
v. Natural Attenuation
vi. DNAPLs – Surfactant/Cosolvent Flushing, Source Reduction
vii. Integrated DNAPL Site Strategy
viii. Environmental Molecular Diagnostics – Remediation Enhancement Tools
ix. Green and Sustainable Remediation - assists the remediation practices with the integration of green and sustainable practices.
x. Groundwater Statistics & Monitoring Compliance
xi. *In-Situ* Chemical Oxidation
xii. LNAPLs – Remedial Technologies
xiii. Attenuation Processes for Metals & Radionuclides
xiv. Remediation of Metals in Soils
xv. MTBE & Other Fuel Oxygenates – Groundwater Remediation Technologies
xvi. Small Arms Firing Ranges – Strategies for Removing the Metal Contamination Threat
xvii. Unexploded Ordnance (UXO) – Characterization, Remediation, & Management

xviii. Perchlorate – Selection & Implementation of Remedial Technologies
xix. Permeable Reactive Barrier: Technology Update version 1.01
xx. Decontamination and Decommissioning of Radiologically Contaminated Facilities
xxi. Decision Making at Contaminated Sites: Issues and Options in Human Health Risk Assessment
xxii. Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites
xxiii. Remedy Selection for Contaminated Sediments
xxiv. Environmental Management at Operating Outdoor Small Arms Firing Ranges
xxv. Characterization and Remediation of Soils at Closed Small Arms Firing Ranges
xxvi. Development of Performance Specifications for Solidification/Stabilization

Appendix G

Tables

APPENDIX G - TABLES

Table 1 - Recommended Containers, Holding Times, & Preservatives

The following tables summarize the amount of sample required, typical containers, preservative (if any) and holding times for many analyses, by media.

Soil and Sediment – *Organic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Dioxin/Dibenzofurans	8 oz	G	ice	30
Extractable Organic Compounds/ pesticides/PCBs	8 oz	G	ice	14
Extractable Organic Compounds - TCLP	8 o.	G	ice	14
Organic Halide	8 oz	G	ice	28
VOC ≤ 200 μg/kg (water suspension)	120 ml	G/S	ice	48 hours
VOC ≤ 200 μg/kg	15 g	E	ice	48 hours
VOC ≤ 200 μg/kg(water suspension)	120 ml	G/S	$NaHSO_4$ (pH<2), ice	14
VOC ≥ 200 μg/kg	120 ml	G/S	CH_3OH, ice	14
VOC ≥ 200 μg/kg	15 g	E	ice	48 hours
VOC ≥ 200 μg/kg	2 oz	G/S	ice	48 hours
VOC – TCLP Analysis	2 oz	G	ice	14

Soil and Sediment – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Chloride	8 oz	G	NA	NS
Chromium – hexavalent	8 oz	G	ice	30
Cyanide	8 oz	G	ice	NS
COD	8 oz	G	ice	NS
Fluoride	8 oz	G	NA	NS
Grain size	8 oz	G	NA	NS
Mercury	8 oz	G	ice	28
Mercury – TCLP	8 oz	G	NA	28
Metals	8 oz	G	ice	180
Metals – TCLP	8 oz	G	NA	180
Metals – EP	8 oz	G	NA	180
Nitrate	8 oz	G	ice	NS
Nitrite	8 oz	G	ice	NS
Nutrients (ammonia, TKN, NO2, NO3, N, total phosphate	8 oz	G	ice	NS
pH	8 oz	G	NA	NS
Sulfates	8 oz	G	NA	NS
Sulfides	8 oz	G	ice	NS
TOC	8 oz	G	ice	NS

Water and Waste Water - *Biological*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Bacteriological	150 ml	P, G, W	ice	6 hours
Toxicity, acute	1 gal	C	ice	36 hours
Toxicity, chronic	1 gal	C	ice	36 hours

Water and Waste Water – *Organic Compounds*				
Analysis	Amt.[1]	Container Type (2)	Preservative[3]	Holding Time[4]
Alcohol – Percent	1 gal	G/A	ice	NS
Dioxin/Dibenzofurans	2 L	L/A	ice (0 - 4 °C)	365
Dioxin/Dibenzofurans – residual chloride	2 L	L/A	ice (0 - 4 °C) 80 mg. sodium thiosulfate /L	365
Methane/Ethane/Ethene	120 ml	G/S	HCL (pH<2), ice	14
Extractable Organic Compounds/ pesticides/ PCBs	1 gal	G/A	ice	7
Extractable Organic Compounds/ pesticides/ PCBs – residual chlorine present	1 gal	G/A	3 ml. of 10% sodium thiosulfate per gallon	7
Extractable Organic Compounds	1 gal	G/A	ice	14
Organic Halide	1 L	G/A	H_2SO_4 (pH<2), ice	28
Phenols	1 L	G/A	H_2SO_4 (pH<2), ice	28
Volatile Organic Compounds	120 ml	G/S	ice	7
Volatile Organic Compounds	120 ml	G/S	HCl (ph<2), ice	14
Volatile Organic Compounds	120 ml	G/S	$NaHSO_4$ (pH<2), ice	14
Volatile Organic Compounds – residual chlorine present	120 ml	G/S	HCl (pH<2), ice	14
Volatile Organic Compounds - TCLP	120 ml	G/S	ice	14

Water and Waste Water – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Ammonia	1 L	P	H_2SO_4 (pH<2), ice	28
Alkalinity	1 L	P	ice	14
BOD5	2 L	P	ice	2
Bromide	1 L	P	ice	28
Chlorine – Residual	500 ml	P	NA	ASAP
Chloride	1 L	P	NA	28
Chromium - hexavalent	1 L	P	ice	24hours
COD	1 L	P	H_2SO_4 (pH<2), ice	28
Color	1 gal	G/A	ice	2
Conductivity	500 ml	P	ice	28
Cyanide	1 L	P	NaOH (pH>12), ice	14
Cyanide – Residual chlorine	1 L	P	see footnote 6	14
DOC	1 L	P	$NaHSO_4$ (pH<2), ice	28
Fluorine	1 L	P	NA	28
Hardness	1 L	P	HNO_3 (pH<2)	180
Iron (Fe^{2+})	1 L	P	NA	ASAP
Mercury	1 L	P	HNO_3 (pH<2)	28
Mercury – TCLP	1 L	P	NA	28
Metals	1 L	P	HNO_3 (pH<2)	180
Metals – TCLP	1 L	P	NA	180
Metals – EP	1 L	P	NA	180
Nitrate	2 L	P	ice	2
Nitrite	1 L	P	ice	2
Nutrients (Ammonia, TKN, NO2, NO3, -N, total phosphorous)	2 L	P	H_2SO_4 (pH<2), ice	28

Water and Waste Water – *Inorganic Compounds (continued)*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Oil and Grease	1 L	P	H_2SO_4 (pH<2), ice	28
Oxygen – dissolved	40 ml	G	NA	ASAP
pH	500 ml	P	NA	ASAP
Phenols	1 L	P	H_2SO_4 (pH<2), ice	28
Phosphate – ortho	1L	P	ice	2
Phosphate – dissolved	1L	P	H_2SO_4 (pH<2), ice	28
Solids Series	2 L	P	ice	7
Solids – Settleable	2 L	P	ice	2
Sulfates	1 L	P	ice	28
Sulfides	1 L	P	2 ml zinc acetate, NaOH (pH>9), ice	7
Temperature	500 ml	P	none	ASAP
TOC	1 L	P	H_2SO_4 (pH<2), ice	NS
Turbidity	500 ml	P	ice	2

Waste – *Organic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Alcohol – Present	Please consult with the laboratory and *USEPA's Hazardous Waste Test Methods / SW-846*			
Dioxin/Dibenzofurans				
Extractable Organic Compounds/pesticides/PCBs				
Extractable Organic Compounds – TCLP				
VOC ≤ 200 µg/kg				
VOC ≤ 200 µg/kg				
VOC ≥ 200 µg/kg				
Volatile Organic Compounds – TCLP				

Waste – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Ash Content	8 oz	G	NA	NS
BTU Content	8 oz	G	NA	NS
Chromium – hexavalent	8 oz	G	NA	NS
Cyanide	8 oz	G	NA	NS
Dermal Corrosion	8 oz	G	NA	NS
Flashpoint	8 oz	G	NA	NS
Mercury	8 oz	G	NA	180
Mercury – TCLP	8 oz	G	NA	NS
Metals	8 oz	G	NA	28
Metals – TCLP	8 oz	G	NA	NS
Metals – EP	8 oz	G	NA	28
pH	8 oz	G	NA	NS
Sulfides	8 oz	G	NA	NS

Footnotes:

1. Amount - The amounts listed must be considered approximate requirements that are appropriate for most media. If a particular media to be sampled is very light, more samples may be required to obtain the necessary mass for the analysis.

2. Container Type:
   - G = Glass
   - P = Polyethylene
   - E = Encore™
   - C = Cubitainer
   - S = Septum Seal
   - A = Amber
   - W = Whirl-Pak™

3. Ice - Sufficient ice must be placed in the shipping/transport container to ensure that ice is still present when the samples are received at the laboratory

   $NaHSO_4$ -The proper amount of $NaHSO_4$ (Sodium Bisulfate) is added to the sample container at the laboratory prior to sampling.

   CH_3OH -The proper amount of CH_3OH (Methanol) is added to the sample container at the laboratory prior to sampling.

   HCl - (Hydrochloric Acid) used as a preservative must be present at concentrations of 0.04% or less by weight (pH about 1.96 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. The proper amount of HCl is added to the sample container at the laboratory prior to sampling.

   H_2SO_4 - H_2SO_4 (Sulfuric Acid) used as a preservative must be present at concentrations of 0.35% or less by weight (pH about 1.15 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 ml of the laboratory-prepared preservative is added to the sample.

   NaOH - NaOH (Sodium Hydroxide) used as a preservative must be present at concentrations of 0.080% or less by weight (pH about 12.30 or less), as specified in 40 CFR 136.3, Table II, footnote 3. Four tablets are added to the sample after collection.

   HNO_3 - HNO_3 (Nitric Acid) used as a preservative must be present at concentrations of 0.15% or less by weight (pH about 1.62 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 ml of the laboratory-prepared preservative is added to the sample.

   NA - Not Applicable; no sample preservation is required

4. Holding Time – Holding time is stated in days unless marked otherwise. A holding time of ASAP indicates the sample is to be analyzed within 15 minutes. A holding time of NS indicates that no holding time is specified in the analytical method.

5. Collect sample in 8 oz. glass container containing ascorbic acid solution prepared by the laboratory. Gently mix sample and transfer to sample containers prepared by the laboratory with the proper amount of HCl.

6. Use ascorbic acid only if the sample contains residual chlorine. To test for residual chlorine, place a drop of sample on potassium iodide-starch test paper. If the test paper turns blue, residual chlorine is present. Add a few crystals of ascorbic acid and re-test until the test paper no longer turns blue. Add an additional 0.6 grams of ascorbic acid for each liter of sample.

Table 2 - Disposal of IDW

Type	Hazardous	Non-Hazardous
PPE – disposable	Containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to the Field Equipment Center (FEC) for proper disposal.	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to the Field Equipment Center (FEC) for disposal in dumpster.
PPE – non-disposable	Decontaminate as per Appendix E of this document, if possible. If the equipment cannot be decontaminated, containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to FEC for proper disposal.	Decontaminate as per Appendix E of this document.
Spent Solvents	Containerize in original containers. Clearly identify contents. Leave on-site with permission of site operator, otherwise return to FEC for proper disposal.	NA
Soil Cuttings	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.
Groundwater	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.

Decontamination Water	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.
Disposable Equipment (D.7)	Containerize in 55-gallon drum or 5-gallon plastic bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to the FEC for disposal in dumpster.
Trash	NA	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to FEC for disposal in dumpster.

Appendix H

References

Chapter Nine of the SW-846 Compendium: Sampling Plans. (1986, September). Retrieved from http://www.epa.gov/hw-SW846/chapter-nine-sw-846-compendium-sampling-plans .

Characterization, Design, Construction, and Monitoring of Mitigation Wetlands. (2005, February). Retrieved from http://www.itrcweb.org/GuidanceDocuments/WTLND-2-pdf .

Frequently Asked Questions about Wide-Area Assessment for Munitions Response Projects. (2010, May). Retrieved from http://www.itrcweb.org/GuidanceDocuments/UXO-6.pdf .

Fundamentals of Screening, Investigation, and Management. (2014, October). Retrieved from http://www.itrcweb.org/PetroleumVI-Guidance/ .

Geophysical Classification for Munitions Response. (2012, October).

Guide to the Assessment and Remediation of State-Managed Sediment Sites. (2007, June). Retrieved from http://www.astswmo.org/Files/Policies_and_Publications/CERCLA_and_Brownfields/SedimentStatesSitesPaper_final.pdf .

Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites. (2011, February). Retrieved from http://www.itrcweb.org/contseds-bioavailability/ .

Incremental Sampling Methodology. (2012, February). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=44&SubTopicID=16

Interstate Technology and Regulatory Cooperation Work Group (ITRC)/US Environmental Protection Agency Consortium for Site Characterization Technology(CSCT) Partnership. (1998, January). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=44&SubTopicID=35

New Tools for Better Decisions. (2013, December). In Environmental Molecular Diagnostics. Retrieved from http://www.itrcweb.org/emd-2/ .

Performance-Based Management. (2006, March). Retrieved from http://www.itrcweb.org/Guidance/SiteDocuments?TopicID=38&SubTopicID=28

Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater. (2007, February). Retrieved from http://www.itrcweb/GuidanceDocuments/DSP_5.pdf .

Statistical Tools for the Project Life Cycle. (2013, December). In Groundwater Statistics for Monitoring and Compliance. Retrieved from http://www.itrcweb.org/gsmc-1/ .

Strategies for Monitoring the Performance of DNAPL Source Zone Remedies. (2004, August). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=44&SubTopicID=9 .

Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management. (2003, December). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=27&SubTopicID=42

Technical Resources. (n.d.). In Vapor Intrusion. Retrieved from http://www.epa.gov/vaporintrusion .

The Use of Direct-push Well Technology for Long-term Environmental Monitoring in Groundwater Investigations. (2006, March). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=44&SubTopic=43 .

Use and Measurement of Mass Flux and Mass Discharge. (2010, August). Retrieved from http://www.itrcweb.org/Guidance/ListDocuments?TopicID=44&SubTopicID=11

Vapor Intrusion Pathway: A Practical Guideline. (2007, January). Retrieved from http://www.itrcweb.org/GuidanceDocuments/VI-1.pdf .