Tank Farm Vadose Zone Program Characterization Processes

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Abstract: This report documents the methods and processes used by the Tank Farm Vadose Zone Program to gather data to support remediation decisions for the soils contaminated by release from Hanford Tank Farm facilities.

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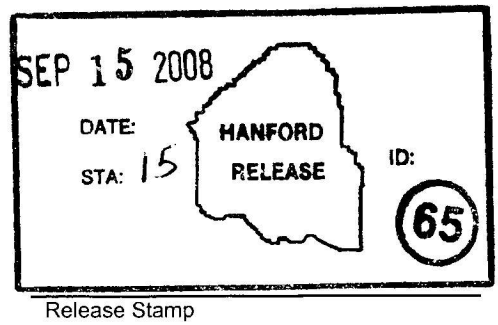

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TANK FARM VADOSE ZONE PROGRAM CHARACTERIZATION PROCESSES

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Executive Summary

This report documents the methods and processes used by the Tank Farm Vadose Zone Program to gather data to support remediation decisions for the soils contaminated by release from Hanford Tank Farm facilities. The methods included are the following:

- Boreholes (i.e., drilling)
- Direct push
- Near-surface sampling (e.g., test pits and trenching)
- Opportunistic measurements and sampling
- Geophysics using existing wells and laterals
- Surface geophysical exploration
- In-situ measurements
- Non-tank-farm field measurements
- Laboratory analyses
- Literature searches

For each method, the following are described:

- Purpose
- Description
- Relationship with other methods
- Benefits and limitations
- Future development
- Implementation processes

The report concludes with a discussion about the relationships with other Hanford Site contractors.

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ACRONYMS

BTR	Buyer's Technical Representative
CPC	Central Plateau Contractor
DOE	U.S. Department of Energy
DP	direct push
DQO	data quality objectives
DST	double-shell tank
Ecology	Washington State Department of Ecology
GPR	ground penetrating radar
GPS	global positioning system
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
ORP	U.S. Department of Energy, Office of River Protection
RCRA	*Resource Conservation and Recovery Act of 1976*
RL	U.S. Department of Energy, Richland Operations Office
RPP	River Protection Project
SGE	surface geophysical exploration
SST	single-shell tank
TFC	Tank Farm Contractor
TL	Drilling and Sampling Technical Lead
VZP	(tank farm) Vadose Zone Program
WMA	waste management area
WRCSOF	Work Release for Construction Service Organization Form

1. INTRODUCTION

1.1 PURPOSE

This report documents the methods and processes used by the tank farm Vadose Zone Program (VZP) to gather data to support remediation decisions for the soils contaminated by releases from Hanford tank farm facilities. Also included are methods to provide data for risk assessments dealing with past and future tank farm releases. The vadose zone is those sediments (but not the structures) between ground surface and the top of groundwater.

1.2 BACKGROUND

1.2.1 Hanford Site

The Hanford Site, a facility in the U.S. Department of Energy (DOE) nuclear waste complex, encompasses ~586 miles^2 (1517 km^2) northwest of the city of Richland along the Columbia River in southeastern Washington State. The federal government acquired the site in 1943 for the production of plutonium. Production of such special nuclear materials continued until the 1980s. Beginning in the 1990s, DOE has focused on cleaning up the Hanford Site.

Hanford Site operations have significantly impacted the environment. Hanford production reactors discharged cooling water containing hazardous chemicals and radionuclides into the Columbia River. Separation facilities in the Central Plateau released billions of gallons, including millions of gallons of tank waste, into ponds, cribs, and trenches. Tank farm operations released about a million gallons of tank waste.

1.2.2 Tank Farms

The role of the tanks was to store the most dangerous and hazardous waste produced during the processing of the irradiated fuel to obtain plutonium. Groups of tanks (known as farms) were located downhill from the chemical separations plants so that the wastes would flow to the tanks because of gravity; no pumps were required.

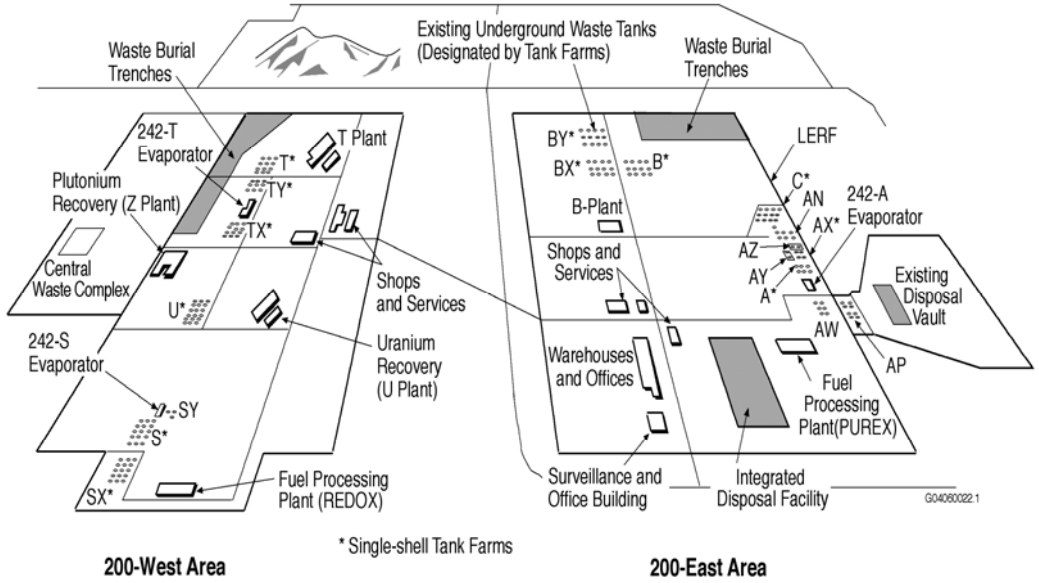
The tank farms were built as space was needed, the first being during World War II. The tank farms are located near the separation plants that they supported (Figure 1-1). Six single-shell tank (SST) farms (S, SX, T, TX, TY, and U) are located in the 200 West Area and six (A, AX, B, BX, BY, and C) are located in the 200 East Area. The double-shell tank (DST) farms, built to replace the older SST design, are located mainly in the 200 East Area (AN, AP, AW, AY, and AZ). However, the SY DST farm is located in the 200 West Area. These DST farms were constructed from 1968 through 1986.

For regulatory purposes, the SST farms are grouped into waste management areas (WMA). The seven WMAs are A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U. Inside an SST farm are various underground facilities:

a. Large storage tanks.

b. Smaller miscellaneous storage tanks.
c. Concrete vaults.
d. Pits.
e. Transfer pipelines.

Figure 1-1. Facilities in the 200 Areas of Hanford's Central Plateau



Over the years hundreds of millions of gallons of radioactive and chemically hazardous wastes have passed through the system. During this time, but mainly in the 1950s and 1960s, approximately 1 million gallons of waste were released from the system into sediments (HNF-P-0182). Some of this waste has reached groundwater (about 250 to 300 feet below ground surface). Washington State Department of Ecology (Ecology) determined (Wilson 1998) in the late 1990s that the groundwater at the Hanford Site had been impacted by the release of wastes contained in SSTs and placed these facilities under *Resource Conservation, and Recovery Act of 1976* (RCRA) Corrective Action. This formal process was codified with the introduction of the suite of Milestones M-045-51 through M-045-62 into the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) (Ecology et al. 2007). All retrievable liquids have been removed from the SSTs. Wastes from seven of the SSTs (C-103, C-106, C-201, C-202, and C-203, C-204, and S-112) have been removed such that residual wastes in these tanks meet the removal goals of the HFFACO (Ecology et al. 2007).

1.2.3 Tank Farm Vadose Zone Program

The VZP is responsible for implementing the tank farm RCRA Corrective Action Program to include the following scope:

a. Planning and implementing field characterization activities and laboratory analyses (with the explicit approval of Ecology).

b. Performing simulations to estimate impacts of contamination already lost to the environment.
c. Documenting results of efforts (including recommendations for future actions).
d. Implementing interim measures to mitigate future impacts.

The scope was expanded to include the following:

a. Performing data collection for tank farm performance assessments.
b. Performing simulations for tank farm performance assessments.
c. Creating the tank farm performance assessments.

1.3 DOCUMENT STRUCTURE

This chapter provides an introduction and background information. Chapters 2 and 3 provide additional background information on planning documents [particularly data quality objectives (DQO) and work plans] as well as the detailed questions that need to be addressed. Chapter 4 provides an overview of the data collection methods used by the VZP. The following chapters discuss each method individually:

a. Boreholes (drilling) (Chapter 5)
b. Direct push (DP) (Chapter 6)
c. Near-surface sampling (Chapter 7)
d. Opportunistic measurements and sampling (Chapter 8)
e. Geophysics using existing wells and laterals (Chapter 9)
f. Surface geophysical exploration (SGE) (Chapter 10)
g. In-situ measurements (Chapter 11)
h. Non-tank-farm field measurements (Chapter 12)
i. Laboratory analyses (Chapter 13)
j. Advanced science measurements and analyses science (Chapter 14)
k. Literature searches (Chapter 15)

For each method, the following are described:

a. Purpose (Section X.1)
b. Description (Section X.2)
c. Relationship with other methods (Section X.3)
d. Benefits and limitations (Section X.4)
e. Future development (Section X.5)
f. Implementation processes (Section X.6)

The document concludes with a discussion of the relationships with other Hanford Site contractors (Chapter 16) and the list of references (Chapter 17).

2. KEY DOCUMENTS

2.1 OVERVIEW

This chapter presents the general role of records (including documents) and of key planning documents that set the requirements for characterization.

2.2 RECORDS AND DOCUMENTS

A variety of documentation is generated during the activities to characterize the vadose zone or other data collection activities:

a. Records.
b. Documents.
c. In-process records.

The classification of reports is discussed when the process for each method is documented.

Records are materials that need to be kept for administrative, legal, research, scientific, or historical value and that have all required information entered and are signed, stamped, or otherwise validated or authenticated and dated, as required. The Tank Farm Contractor (TFC) has procedures to create, control, and maintain records materials.

Documents are formally issued materials. The TFC has procedures for the issuance of documents. Documents are also considered a record and are centrally maintained and controlled.

In-process records are materials that are expected to become part of a record but do not yet contain an authenticating stamp or signature. The TFC has procedures to create, control, and maintain in process records.

2.3 ROLE OF DATA QUALITY OBJECTIVES AND WORK PLANS

Planning is a major key to success for any effort trying to gain new data and information. For the Vadose Zone Program, such planning normally occurs at three levels:

a. General planning to set goals and requirements.
b. Specific planning to implement the characterization or data collection.
c. Detailed planning to implement one method of characterization or data collection.

The first level is often performed by a DQO process, the second by issuance of a work plan, and the third by issuance of a work package (called work control instructions in the tank farms). For this document, the first two processes are considered as providing requirements to the data collection efforts and are not explicitly discussed.

2.3.1 Data Quality Objectives Process

The U.S. Environmental Protection Agency established a formal process (known as the DQO process) (EPA 2006) to set the goals and reactions of characterization. Such a process can be used for any sort of data collection. DOE M 435.1, *Radioactive Waste Management*, requires such a process for the planning of data collection [Chapter 2L(1) for high-level waste, Chapter 3I(1) for transuranic wastes, and Chapter 4I(1) for low-level wastes]. The seven steps of the DQO process are the following:

a. **State the Problem**: Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.

b. **Identify the Decision**: Identify what questions the study attempts to resolve and what action may result.

c. **Identify Inputs to the Decision**: Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

d. **Define the Study Boundaries:** Specify the time periods and spatial area to which decisions applies. Determine when and where data should be collected.

e. **Develop a Decision Rule**: Define the statistical parameter of interest, specify the action level, and integrate the output of the previous DQO steps into a single statement that describes the logical basis for choosing among alternative actions.

f. **Specify Tolerable Limits on Decision Errors**: Define the tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

g. **Optimize the Design for Obtaining Data**: Evaluate information from the previous steps and generate a data collection design. Choose the most resource-effective design that meets the DQO requirements.

2.3.2 Work Plans

According to Section 11.6 of the HFFACO, work plans "shall describe in detail the work to be done and include performance standards to be met. They shall also include an implementation schedule with start and completion dates."

Work plans often contain sampling and analysis plans. Such plans describe how and where sampling occurs and how the samples are analyzed. For work only performed in a laboratory, work plans are often called test plans. The depth of a work plan or test reflects the amount of work to be performed.

Any deviations from an approved work plan will be documented in the report describing the work.

2.3.3 Work Packages

Work packages contained the most detailed instructions for how the work is actually performed. In tank farms, these work packages (called work control instructions) are quite detailed and include the procedural steps to get the work done. Work control instructions are released each day.

3. CHARACTERIZATION NEEDS

Characterization is needed to evaluate risk alternatives to select remediation options in each WMA. The characterization methods and types of information needed vary for the following conditions:

a. For known leaks (Section 3.1)
   1. Contamination 15 feet or less below the ground surface (Section 3.1.1).
      (a) Estimate peak concentration.
      (b) Estimate extent of contamination above cleanup action levels.
   2. Contamination more than 15 feet below the ground surface (Section 3.1.2).
      (a) Estimate how much waste that has been released.
      (b) Estimate the extent of plume.
      (c) Determine the equations and parameters describing moisture flow.
      (d) Estimate the transport parameters and relationships for various waste types and amounts.
      (e) Estimate vadose zone properties are needed to support treatability studies.

b. For suspected leaks (Section 3.2).
   1. Test whether leak exists by determining whether contamination is present.

c. For waste left in the tank after retrieval (Section 3.3).
   1. What inventory of waste left inside tanks and associated infrastructure.
   2. What are contaminant release rates as a function of key parameters.

d. To support the above efforts (Section 3.4).
   Aid future explorations (possible future retrieval loses, safety, optimization).

Table 3-1 displays the detailed questions and the key characterization data needed.

3.1 DETAILED CHARACTERIZATION NEEDS FOR KNOWN LEAKS

Every SST farm (and hence every WMA) has released contamination to the subsurface. Various sets of remediation efforts can be used within a WMA. The current location of the contamination drives the characterization needs, as contamination significantly below the surface (e.g., 15 feet or more) mainly impacts groundwater, while contamination nearer the surface is more significant for exposures due to intrusion (from humans, animals, and plants).

Table 3-1. Detailed Questions and the Key Field/Laboratory Characterization Data for Infrastructure and Deep Vadose Zones (3 sheets)

Question	Key Data Need	How Obtained
Known Leaks (contamination not more than 15 feet below ground level)		
What is the peak concentration in area? What is the extent of contamination above ? What are the effects of contamination on animal and plant communities?		• Vadose zone sampling followed by measurements over an extended area. • Measure density of plant and animal communities around tank farms
Known Leaks (contamination more than 15 feet below ground level)		
What is the inventory of key contaminants?	Origin of release	Combination of methods
	Amount of waste that has been released	• Primarily through literature searches • Rarely through vadose zone measurements
	Waste types of the leaks	• Literature searches • Confirmed by laboratory chemical measurements of collected sediments
	Concentration of key contaminant in a waste type	• Literature searches • Confirmed by laboratory chemical measurements
What is the extent of plume?	Horizontal extent of the plume	• For newly installed boreholes, gamma and neutron moisture log the borehole • For unlogged boreholes near waste sources, gamma and neutron moisture log the borehole • Based on suspected plume shape, use direct push (DP) probe holes to collect samples at key depths • As high resolution resistivity technology matures, use on plumes
	Vertical extent of the plume	• For newly installed boreholes, gamma and neutron moisture log the borehole • For unlogged boreholes near waste sources, log the borehole • Based on suspected plume shape, use borehole to collect samples at key depths • As high resolution resistivity technology matures, use on plumes
What is the water flow	Moisture content	• Geophysical logging • Perform laboratory measurements of collected samples
	Deep drainage (recharge) rates	• Continue lysimeter experiments • Measure tracer (e.g. chloride) profiles as a function of depth in key new boreholes • Continue improving and verifying computer simulations

Table 3-1. Detailed Questions and the Key Field/Laboratory Characterization Data for Infrastructure and Deep Vadose Zones (3 sheets)

Question	Key Data Need	How Obtained
	Vadose zone physical and hydraulic properties	• Measure hydraulic conductivity in sediment samples (particularly those of the Cold Creek Unit and the Ringold Formation)
	Lateral flow	• Continue large scale experiments • Investigate whether new field experiments are needed
What are the interactions between contaminants and sediments	Estimate geochemistry of the natural system	• Obtain samples from nonimpacted Hanford sites • Perform analyses to estimate geochemical properties • Perform analyses to estimate contaminant interactions with natural sediments
	Determine waste types	• Through literature searches • Confirmed by laboratory chemical measurements of collected sediments
Known Leaks (contamination more than 15 feet below ground level)		
	Determine how the contaminants in waste type alter the natural geochemistry	• Obtain samples from impacted Hanford sites • Perform laboratory measurements to estimate geochemical properties • Perform laboratory measurements to estimate contaminant interactions with altered sediments
	Estimate future behavior of contaminants	• Perform analyses to estimate how contaminants interact with the sediments and other contaminants in the waste streams as a function of time and position
What data are needed for technology deployment	General	• Estimate subsurface infrastructure interferences
	Grout (examples):	• Estimate flow of grout through a given region in the vadose zone • Estimate how grout sets up in vadose zone • Estimate the maturing, aging, and eventual breakdown of the grout
	Vitrification	• Estimate the electrical conductivity of the contaminated region • Estimate the type and amount of off gas that would be produced • Test the quality of the glass produced • Test the release of contaminants from the glass
	Chemical alteration	• Estimate the type of altered species or compounds produced • Estimate the properties of altered species • Test the conversion of altered species back into the original species or into a new species
	Desiccation	• Estimate air permeability of the impacted vadose zone

Table 3-1. Detailed Questions and the Key Field/Laboratory Characterization Data for Infrastructure and Deep Vadose Zones (3 sheets)

Question	Key Data Need	How Obtained
Suspected/ Unknown Leaks		
	Determine whether leak occurred	• In a DP probe hole, perform gamma logging • In a DP probe hole, perform moisture logging • Search for key parameters (e.g., sodium, nitrate, and pH) in a sample from a DP probe hole
Residual Waste		
What inventory is present in residual waste		Multiply volume of released material by laboratory-measured contaminant concentrations
What are contaminant release rates from residual wastes		Perform laboratory experiments on residual wastes to estimate empirical rates and, ultimately, the basic chemical reactions underlying the empirical rates
Support other Efforts		
What is the amount and extent of future loses		High resolution resistivity leak detection monitoring
What are safe placement locations of future boreholes		Gamma logging in new DP probeholes
What is the optimal location of new boreholes		Logging in DP probeholes and sample analysis

3.1.1 Detailed Characterization Needs for Contamination Present in the Top 15 Feet

The following actions address the information needed to select among the remediation options and then to optimize the selected remediation options for contamination near the surface:

a. Estimate the peak concentration.
b. Estimate extent of contamination above cleanup action levels.
c. Determine data for ecological assessments.

3.1.1.1 Estimate the peak concentration and estimate extent of contamination above cleanup action levels.

3.1.1.1.1 How used in remediation decisions. Near surface contamination levels are used to estimate the extent of the vadose zone region that must be removed, treated, and disposal or covered to protect the zone from intrusion. The peak concentration is used for worker safety evaluations and implementations as well as to determine if a corrective action is necessary.

3.1.1.1.2 How are peak concentrations and extent of contamination above cleanup action levels estimated? Concentrations are estimated by obtaining samples and measuring the concentrations of contaminants in the sample. Because small contaminant regions cannot be well predicted a priori, large regions must be investigated.

3.1.1.2 Determine data for ecological assessments.

3.1.1.2.1 How used in remediation decisions. Besides protecting human health and safety, remediation efforts must also protect animal and plant communities. An important aspect is to understand how actions have and may impact such communities.

3.1.1.2.2 How are data for ecological assessments obtained ? Much of the data needed for Hanford Central Plateau ecological assessments have been gathered for the general assessment of ecological impacts on the central plateau (DOE/RL-2007-50). However, more data on animal and plant communities just outside the tank farm fence may be necessary to supplement the data already obtained.

3.1.2 Detailed Characterization Needs for Contamination Present Below the Top 15 feet

The following actions address the information needed to select among the remediation options and then to optimize the selected remediation options for contamination that will impact groundwater:

a. Estimate the amount of each key contaminant.
b. Estimate the origin of the waste.
c. Estimate amount of waste that has been released.
d. Estimate waste types that have been released.
e. Estimate horizontal extent of plume.
f. Estimate vertical extent of plume.
g. Obtain data and information describing moisture flow.

h. Obtain data and information for transport relations of various waste types.
i. Obtain vadose zone properties needed for treatability studies.

3.1.2.1 Estimate the Amount of Each Key Contaminant

For groundwater protection, the single most important parameter is the amount of inventory released.

3.1.2.1.1 How Used in Remediation Decisions. For the infrastructure and deep vadose zone, groundwater protection is the primary goal. The amount of groundwater contamination, in almost all cases, is linearly proportional to the amount of the key contaminants released to the vadose zone. Exceptions are when contaminants are encapsulated with extremely good waste forms (like glass) or where the concentration is so high that release and transport become non-linear processes.

Thus, the inventory of a key contaminant (usually ^{99}Tc) is often used as an indicator for groundwater protection.

3.1.2.1.2 How is Inventory Estimated? In a confined system (e.g., a tank or pipeline), the inventory of a contaminant is estimated by multiplying the volume of the waste by the concentration of the contaminant in the system. The volume can be measured or, if necessary, bounded by the geometric volume of the container. The concentration can be measured (as is done for residual tank waste) or estimated by analogy (based on tank waste type).

However, for past waste releases to the vadose zone, the above approach does not work. The distribution of waste (or volume) in the vadose zone is uncertain and the concentrations differ by orders of magnitude across the volume. Even in the limited number of cases where many measurements of contaminant concentration are available (e.g., ^{137}Cs concentrations in the SX-108 plume), the measurements are much too sparse. Rather, the inventory is estimated by multiplying the reported volume released by the concentration of the contaminant in the waste at the time of release.

To start this process, the origin of the release must be evaluated. If in-tank liquid level measurements show an unexplained decrease and contamination is found directly outside of the tank, the source is likely the tank. However, in cases where the contamination is located far from the source (e.g., contamination in groundwater), or where liquid level decreases and vadose contamination observations are inconsistent, it is more difficult. For the latter case, a combination of analyses and data are needed to attribute the source.

The volume of material released can often be estimated from records. The Hanford Site retained good records of the amount of waste intentionally disposed to the ground. Similarly, the levels within tanks and pipeline transfer rates were closely monitored. In most cases, losses for the larger releases can be estimated, the inventory released from tank 241-A-105 being the most uncertain). Uncertainty does exist for small (~1000 gallon) releases.

The concentration of the contaminant in the release at the time of release is known if the waste type is known. Again, the Hanford records generally can be used to determine the waste type released. Similarly, many measurements exist for the concentrations for key contaminants for various waste streams. However, experience (^{99}Tc concentrations in metal wastes) has shown that some of the “measurements” are actually assumptions.

3.1.2.1.3 Key Characterization Data Needed. Thus, to estimate the inventory of key contaminants, the major needs include determining

a. Origin of the release.
b. Amount of waste that has been released.
    1. Primarily through literature searches.
    2. Rarely through vadose zone measurements.
c. Waste types of the leaks.
    1. Through literature searches.
    2. Confirmed by chemical analyses of collected sediments.
d. Concentration of key contaminants in a waste type.
    1. Through historical model estimates (e.g., Hanford Defined Waste model).
    2. Based on historical samples taken that are representative of the release.
    3. Confirmed by chemical analyses.

3.1.2.2 Estimate the Extent of Plume.

The horizontal extent of a plume is important in estimating the cost of remediating the plume. The vertical center of a plume can be important in remediation decisions (some technologies are not really feasible below certain depths).

3.1.2.2.1 How Used in Remediation Decisions. For groundwater protection, the more spread out a plume is, the lower the groundwater concentration, as spreading is a form of dilution. However, the more spread out a plume is, the more difficult and more costly is the treatment of a plume. For treatments that bind the contamination (grout, vitrification, chemical modification) or dry out the soil (desiccation), the larger the volume of the plume means a bigger volume to treat. For surface barriers, the horizontal extent is more important than the vertical extent, as the barrier creates (over time) a vertical drying. However, if the plume is too deep, then the drying front will not reach the plume before the plume reaches the groundwater.

3.1.2.2.2 How is the Extent of the Plume Estimated? Subsurface contaminant plumes do NOT have simple shapes (e.g., a sphere, a pile of pancakes, or a tear drop). The shape of a plume is estimated by many factors, including geology, the release event, subsequent moisture drivers, and the nature of other contaminants. Model simulations, although useful for determining generalized groundwater impacts, are not sophisticated enough to estimate extent for treatment purposes. Thus, field measurements are needed.

Initially in tank farms, gamma radiation monitoring in boreholes was used to assess the extent of a release. Once a tank leak was suspected, new boreholes were installed in key locations to supplement the existing network of boreholes. All of the boreholes in the tank farms and most of the boreholes associated with liquid disposal actions were logged with high precision gamma detectors. Gamma emission monitoring has provided a large database for some contaminants (primarily, ^{106}Ru for relatively young waste, ^{137}Cs and uranium isotopes/daughter products for aged waste) but no information for key mobile contaminants, such as ^{99}Tc and nitrate. Other problems with gamma monitoring can be boreholes that do not extend deep enough (most boreholes extend less than 100 feet below the ground surface) and sometimes there are no boreholes in locations that would benefit from gamma radiation logging.

Another approach often used to estimate extent is to collect subsurface sediments and analyze the sediments for key contaminants. The Hanford Site River Corridor and Central Plateau Remediation contractors use this method extensively. The advantage to this method is that the chemical analysis can estimate the concentration for all contaminants. The disadvantage is that relatively few locations can be sampled.

Recently, geophysical resistivity is being used at various locations on the Hanford Site. In this method, resistance between numerous pairs of points are measured and then inverted to estimate the electrical conductivity as a function of position in the vadose zone. As electrical conductivity is a function of salt content (an indicator of waste) and moisture, resistivity may be used to develop three-dimensional images of conductivity anomalies which may indicate the presence of subsurface plumes. Resistivity is still under development at the Hanford Site. Deployments at the BC Cribs (south of the 200 East Area) and in the S Farm have been favorable, whereas deployment elsewhere (B-BX-BY, C, T, TX-TY, and U Farms) seems to have a large noise component, thought to be from tank farm infrastructure. The key advantage of resistivity measurements is the potential of quantitative three-dimensional estimates of waste concentrations. The major disadvantage is that it is still under development.

3.1.2.2.3 Key Characterization Data Needed. Thus to estimate the horizontal and vertical extent of a plume:

a. Estimate the horizontal extent of the plume.
    1. For newly installed boreholes, gamma and neutron moisture log the borehole.
    2. For unlogged boreholes near waste sources, gamma and neutron moisture log the borehole.
    3. Based on suspected plume shape, use direct push (DP) probe holes to collect samples at key depths.
    4. As high resolution resistivity resolution technology matures, use on plumes.
b. Estimate the vertical extent of the plume.
    1. For newly installed boreholes, gamma and neutron moisture log the borehole.
    2. For unlogged boreholes near waste sources, gamma and neutron moisture log the borehole.
    3. Based on suspected plume shape, use a borehole to collect samples at key depths.
    4. As geophysical resistivity technology matures, use on plumes.

3.1.2.3 Obtain Data and Information to Describe Moisture Flow

After an estimate is determined for vadose zone inventory, moisture flow conditions are key parameters to model future groundwater risk.

3.1.2.3.1 How Used in Remediation Decisions. Although contaminants can diffuse through the vadose zone, by far the most important process for contaminant movement is advective transport, i.e., the transport of contaminants by moving with the flowing water. Water flow is estimated by

a. Amount of water present (moisture content).

b. Amount of the source of water (known as recharge or deep drainage).

c. Physical and hydraulic properties of the sediments.

d. Whether the water flow is primarily downward or has significant horizontal spread.

e. As moisture flow is the driving force for contaminant transport, moisture flow is the first step in any simulation of contaminant transport. Moreover, as the contaminants move with water, those sediments with high water content have routinely been found to be the host of contamination.

3.1.2.3.2 How are Moisture Flow Parameters Estimated? Moisture flow depends on the amount of water present (the moisture content). Generally, the higher the moisture content, the faster is the flow. Moisture content can be measured by using neutron moisture gauges in existing boreholes or probeholes. Moisture content can be measured in samples retrieved from new boreholes or probeholes, but special (standard) precautions must be observed to minimize evaporation.

Recharge or deep drainage is difficult to measure in arid or semiarid climates like the Hanford Site. In western Washington or in the eastern United States, one can measure the amount of water passing beyond the root zone as the amount of this water (deep drainage) is fairly high. At Hanford, the deep drainage can often be less than 1% of the natural precipitation rate of about 6 inches a year. Deep drainage can be measured with specialized field equipment called lysimeters. Because the deep drainage at Hanford can occur sporadically, many years or decades of measurements are needed. Another way to measure recharge is to detect the depth profile of natural constituents (such as chloride) to infer a recharge rate. Finally, one can use computer simulations tested against lysimeter and tracer data. As estimates for recharge are desired hundreds and thousands of years into the future, a combination of the three techniques is the most likely approach to succeed.

The rate of moisture movement is also estimated by the hydraulic conductivity of the sediment volume. Hydraulic conductivity depends on the moisture content, the hydraulic pressure, the sediment type, and the amount of space available for the moisture (the pore volume). Because the natural (and expected) moisture contents of Hanford sediments are so low, it can take weeks for one measurement of hydraulic conductivity for a set of conditions. Also because the measurements are done on fairly small samples (a few inches in each dimension), the results must be upscaled. Fortunately, a large set of measurements exist, especially for the important sandy Hanford formation.

Ideally, the hydraulic conductivity is the same in all directions. Water flows down because of gravity. However, much of the Hanford Site was laid down in layers that are not homogenous. Thus, sediments of slightly different types lie atop of one another, causing water to flow horizontally. These effects are amplified in areas with low recharge (like the Hanford Site). Most laboratory experiments are too small to determine this effect [although experiments at the Oak Ridge National Laboratory (Mayes et al. 2003 and Pace et al. 2003) using large Hanford cores have measured this effect for various types of Hanford sediments]. Rather, field experiments [such as the Sisson/Lu experiments (Sisson and Lu 1984) and follow-on experiments at that site (Ward et al. 2002)] and observations are used to refine theoretical considerations.

3.1.2.3.3 Key Characterization Data Needed. Thus to estimate the water flow

a. Estimate deep drainage (recharge) rates.
   1. Continue lysimeter experiments.
   2. Measure chloride profiles as a function of depth in key new boreholes (provides historic recharge information).
   3. Continue improving and verifying computer simulations.
b. Measure vadose zone hydraulic conductivity.
   Measure hydraulic conductivity in sediment samples (particularly those of the Cold Creek Unit and the Ringold Formation).
c. Estimate lateral flow.
d. Continue large-scale experiments.
e. Investigate whether new field experiments are needed.

3.1.2.4 Obtain data and information to estimate transport relations for various waste types and amounts

Another factor important to modeling contaminant flow is the solubility of contaminants and movement in the vadose zone.

3.1.2.4.1 How Used in Remediation Decisions. Although contaminants are carried with the moving water in the vadose zone, the contaminants can also interact with the sediments. Some contaminants (e.g., most actinides) have very strong interactions with the sediment, and only a small fraction is carried with the host water. Other contaminants (e.g., nitrate and ^{99}Tc) have also no interaction with the sediments, and all or almost all of the contamination moves with the water. Some contaminants (e.g., uranium) are in between.

Thus, some contaminants stay in the near-surface zone, while others are a threat to groundwater. Moreover, some treatment technologies attempt to modify the chemical interactions between a contaminant and the sediments to decrease the contaminant mobility.

3.1.2.4.2 How are Transport Parameters Estimated? A large number of parameters can affect the interactions of contaminants with sediments:

a. Geochemistry of the natural system.
b. Mineralogy.
c. pH.
d. Eh.
e. Carbonates/bicarbonates.
f. Particle size.
g. Waste type of release.
h. pH.
i. Concentration of key elements.
j. Chelating elements.
k. Presence of colloids.

The natural system has a pH of ~8, is oxidizing (high Eh), and contains large amounts of carbonate and bicarbonate (depending on pH and Eh). The mineralogy is granite-based, as the sediments come from wash down from the Rocky Mountains. Particle sizes range from small-automobile-size boulders down to fine sands. Relatively little clay and silts are present in the Hanford formations as such small-size particles were washed away in the catastrophic glacier floods. The Ringold Formation has a much higher abundance of fine particles than does the Hanford formation. All of this information is based on detailed and extensive laboratory analyses.

Although the natural system eventually overcomes the chemical properties of the waste type released, it can take years and during that time, normally immobile contaminants (e.g., ^{137}Cs from high-sodium-concentration waste types) can be quite mobile. The properties of the waste types are often determined through literature searches, although laboratory analyses are sometimes needed to verify the literature. However, the interactions of waste types [particularly the extreme ones such as PUREX (plutonium extraction) waste] must be determined in the laboratory using Hanford sediments and tank waste. Again, this information is based on detailed and extensive laboratory analyses.

Such geochemical measurements are for a particular moment in time. The geochemical environment evolves as the system reacts to the intrusion of the waste plume. Because of the high pH, high temperatures, and high contaminant concentrations in some waste streams, it can take decades for the system to reach a new equilibrium. However, since contaminant transport can take hundreds, if not thousands of years, it is future conditions that can dominate future groundwater impacts.

3.1.2.4.3 Key Characterization Data Needed. Thus to estimate the interactions between contaminants and sediments

a. Estimate geochemistry of the natural system.
b. Obtain samples from nonimpacted Hanford sites.
    1. Perform analyses to estimate geochemical properties.
    2. Perform analyses to estimate contaminant interactions with natural sediments.
c. Estimate waste type.
    1. Through literature searches.
    2. Confirmed by chemical analyses of collected sediments.
d. Estimate how the contaminants in waste type alter the natural geochemistry.
    1. Obtain samples from impacted Hanford sites.
    2. Perform analyses to estimate geochemical properties.
    3. Perform analyses to estimate contaminant interactions with altered sediments.
e. Estimate future behavior of contaminants.

    Perform analyses to estimate how contaminants interact with the sediments and other contaminants in the waste streams as a function of time and position.

3.1.2.5 Obtain Vadose Zone Properties needed for Treatability Studies

3.1.2.5.1 How Used in Remediation Decisions? The goal of in-situ treatment is to decrease the mobility of contaminants via physical containment (grout encapsulation,

vitrification), chemical alteration (changing chemical species), or reducing the moisture flow. Much that has been learned about moisture flow and contaminant transport is relevant to treatment implementation. However, each treatment methodology requires additional data.

3.1.2.5.2 How Are Treatment Parameters Estimated? Vadose zone parameters needed to implement and optimize various treatment options generally start in the laboratory and then expand into field tests. The nature of the tests depends on the treatment technology.

3.1.2.5.3 Key Characterization Data Needed. Examples are

a. Obtain natural and impacted sediments for source material.
b. Determine infrastructure that may affect treatment options.
c. Grout.
    1. Flow of grout through a given region in the vadose zone
    2. Setting up of the grout.
    3. Maturing, aging, and eventual breakdown of the grout.
d. Vitrification.
    1. Electrical conductivity of the contaminated region.
    2. Type and amount of off gas produced.
    3. Quality of the glass produced.
    4. Release of contaminants from the glass.
e. Chemical alteration.
    1. Type of altered species or compounds produced.
    2. Properties of altered species.
    3. Conversion of altered species back into the original species or into a new species.
f. Desiccation.
    Air permeability of the impacted vadose zone.

3.2 DETAILED QUESTIONS FOR SUSPECTED OR UNKNOWN LEAKS

3.2.1 Nature of the Problem

A region of the vadose zone can be suspected of obtaining contamination. Alternatively, a regulatory agency may want to minimize the possibility that the region into which water is placed (e.g., from a surface barrier) is contaminated. Finally, there may be cases where releases have occurred and there are no signs of such a release. In such cases, the threshold is much lower for suspected or unknown leaks than for known leaks. Of course, if characterization shows that a source has leaked, then all of the detailed questions in Section 3.1 must be addressed.

3.2.2 Test Whether Contamination is Present

Since the existence of contaminated sediments is being sought, rather than the quantification of the leak, simple methods can be used:

a. Gamma radiation from man-made sources.

b. Unusual moisture levels.
c. Standard and rapid chemical analyses.

Moreover, since some of the contamination is likely to stay near the source, penetrations into the vadose zone can be quite shallow, thus allowing the use of DP technology.

If gamma-emitting radionuclides are expected to be part of the waste, then gamma logging is an ideal tool. Neutron moisture logging can also be performed to determine if there is excess water.

Because of the manner in which tank waste was created, the main ingredients are water, sodium, and nitrate. The contaminants of interest for intrusion or groundwater protection have, in fact, very low quantities (usually a few parts per million for uranium and usually lower for other contaminants). Thus, if samples are taken, the search for nitrate using simple tests can determine if the region has been contaminated with tank waste. Note that other Hanford waste sources may have little nitrate and hence other signatures must be used.

3.3 DETAILED QUESTIONS FOR WASTE LEFT IN THE TANK AFTER RETRIEVAL

Most of the waste currently being stored in underground tanks will be retrieved, treated, and disposed. However, some waste will remain in the tanks. In addition, some waste will remain in the infrastructure associated with the tanks. For the closure of the tank farms and waste management areas, two detailed questions must be addressed:

a. What is the inventory of waste left inside tanks and associated infrastructure?
b. How quickly do key contaminants leave the closed tanks and infrastructure?

3.3.1 Estimate Inventory of Waste Left inside Tanks and Associated Infrastructure

Appendix I of the HFFACO (Ecology et al. 2007) requires characterization of the residual waste left after retrieval. Samples of the residual waste are retrieved and chemically analyzed to estimate contaminant concentrations in the residual waste. The concentrations are then multiplied by the estimated volume of the residual waste to estimate the inventory of contaminants. Because of laboratory detection limits, the inventory for some contaminants (e.g., ^{129}I) is bounded or screened out based on historical model estimates.

3.3.2 Estimate Contaminant Release Rates as a Function of Key Parameters

The retrieval process normally consists of adding water to a tank and allowing the salt and suspended sludge in the tank to be dissolved and carried away by pumping. As a result, only relatively insoluble chemical compounds remain after retrieval. However, groundwater impacts are (for slowly released contaminants) proportional to the release rates. To estimate such release rates as a function of future conditions, a variety of laboratory tests on residual waste are performed to estimate empirical rates and, ultimately, the basic chemistry that estimates the empirical rates.

3.4 DETAILED QUESTIONS TO SUPPORT EFFORTS

Sometimes characterization is done to perform later characterization activities more safely or more efficiently. For example, shallow characterization of a large site (e.g., a crib) may be performed to estimate where the most concentrated contaminants are located to optimize the placement of a deep borehole. Alternatively, characterization (gamma logging) may occur to estimate if other characterization (sample retrieval) can be performed safely. In addition, as waste is retrieved from the tanks, losses to the vadose zone may occur. For operations and remediation, it is important to identify such releases quickly and estimate their extent.

4. OVERVIEW OF DATA COLLECTION METHODS

The VZP uses a variety of methods to collect samples, perform geophysical field measurements, and analyze the samples collected. Figure 4-1 shows a generic picture of the processes used. Through a planning effort (consisting of the DQO process and publication of a work plan), requirements are set. Usually a variety of techniques is used to implement the work plan:

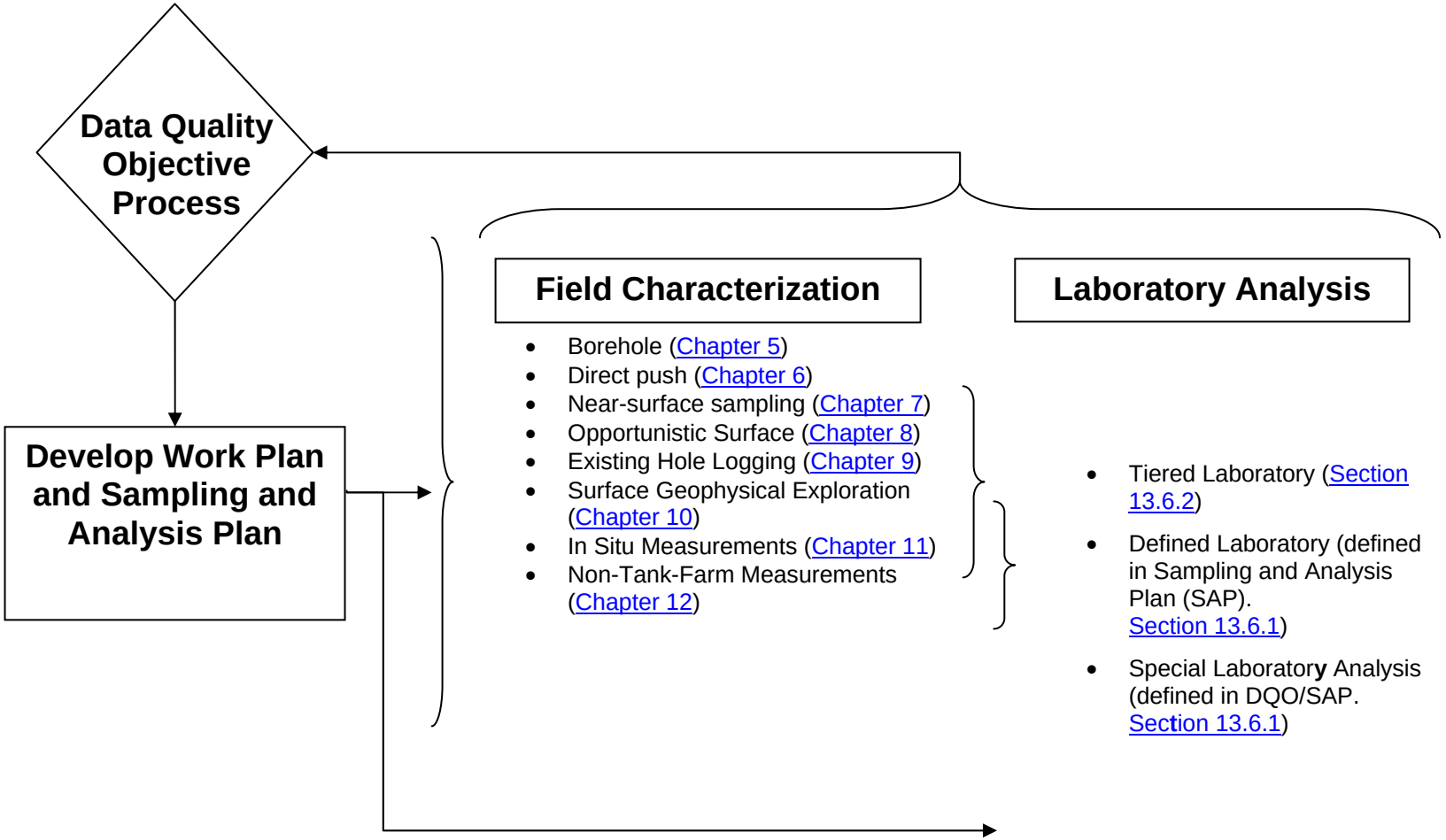
a. Sample collection.
b. Borehole (Chapter 5).
c. Direct push (Chapter 6).
d. Near surface (Chapter 7).
e. Opportunistic surface (Chapter 8).
f. Field measurements not part of sample collection.
g. Logging existing holes (Chapter 9).
h. Surface geophysical exploration (Chapter 10).
i. In-situ measurements (Chapter 11).
j. Non-tank-farm facilities (Chapter 12).
k. Laboratory analyses (Chapter 13).
    1. Predefined laboratory analyses (Section 13.6.1).
    2. Laboratory tiered analysis approach for contaminated sediments (Section 13.6.2).
    3. Laboratory tiered analysis approach for residual waste (Section 13.6.3).
l. Advanced science measurements and analyses (Chapter 14).
m. Literature searches (Chapter 15).

Key personnel are the following:

a. Director, Vadose Zone Program.
b. Drilling and Sampling Technical Lead.
c. Surface Geophysical Exploration Technical Lead.
d. Logging Technical Lead.
e. Laboratory Technical Lead.
f. Buyer's Technical Representative.

The technical leads and the Buyer's Technical Representative are selected by the Director of the VZP.

Figure 4-1. Field Characterization Processes



5. BOREHOLE TECHNOLOGIES

5.1 PURPOSE

Traditionally, at Hanford, boreholes have been the technology used to obtain samples from the subsurface.

5.2 DESCRIPTION

5.2.1 Definition

Boreholes are holes created (by pushing or drilling) into the vadose zone, groundwater, and underlying geologic structures. The holes vary from about 4 inches in diameter to 12 inches (sometimes in the same hole). However, some specialized holes have been larger. Because much of Hanford's vadose zone is sand, these holes are encased in steel to prevent collapse.

5.2.2 Uses

Boreholes are mainly used to obtain sediment or groundwater samples for laboratory analysis (see Chapters 13 and 14). On decommissioning, boreholes can be used to place deep electrodes for SGE (see Chapter 10) or as a platform for in-situ experiments (Chapter 9).

5.2.3 Types of Drilling

Because of the different type of sediments and levels of contamination, different types of drilling technologies have been used at Hanford. However, they can be divided into two major categories:

a. Using a hollow pipe and bringing up sediments to the surface.
b. Pushing a closed-end pipe into the ground.

In both cases, thick (~0.5 inch) hardened metal pipe is forced into the ground.

Most boreholes are created by bringing the material to the surface [through air, water, mud, or (rarely) by mechanical means]. Often the underlying material must be broken up (using drills). This category can have rapid advance rates (e.g., air rotary drilling at the Integrated Disposal Facility has progressed 250 feet in a day).

However, because of concern for spreading vadose zone contamination, air and slurry restrictions (such as the limitation of water or mud carriers) can sometimes be placed on drilling activities at the Hanford Site and almost always in tank farms. In such cases, closed-end pipe is used. In such cases, samples are obtained by removing the closed tip. Advancement rates are a few feet per day, and the total depths are limited (to the top of the Ringold Formation at the Hanford Site).

In areas of high contamination, there are severe limitations on bringing highly radioactive (up to $>10^8$ pCi/g of ^{137}Cs) and extremely hazardous waste to the surface. In such cases, a closed-end pipe is literally beaten (or pile driven) into the ground. When samples are desired, the endcap must be removed. However, a large number of such closed-end boreholes were placed inside tank farms to only allow geophysical logging through the pipe so that the endcap never needed to be removed. A special example of closed-end boreholes are horizontal pipes pushed under certain tanks in the A and SX Farms, which are known as laterals.

5.2.4 Type of Samples Obtained

Placing a borehole into the vadose zone is an intrusive act. Sediment samples can be obtained by

a. Using a split-spoon device to sample ahead of the drilling.
b. Collecting some of the material brought to the surface, known as grab samples.

The least disturbed sediment samples are obtained by a split-spoon device. This specially designed device is placed inside the pipe and hammered ahead of the main pipe to obtain the samples (~4 inches in diameter by 2 feet long) inside heat-resistant plastic liners. The split-spoon device is returned to the surface and the liners sealed and sent off to the laboratory. Because such sampling interrupts the drilling, it is relatively expensive. However, the depth of the sample is very well known and the sediment's structure and moisture integrity are only minimally disturbed. As this technique uses a smaller diameter device than the main drilling system, the sample can be brought to the surface through the existing pipe, thereby eliminating contact with contamination that could exist shallower in the vadose zone. Historically, the VZP has taken such split-spoon samples every 10 feet or so.

A less time-consuming sampling method is to collect samples from sediment tailings brought to the surface (known as grab samples). However, these samples have lost their structural integrity. The samples may also have been impacted (e.g., different moisture content) because of the means used to bring them to the surface. However, the geochemistry of the samples is not affected. Under Hanford Site practice, samples must be collected every 5 feet. The VZP normally collects grab samples every 2.5 feet.

5.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Currently, the major use of tank farm boreholes is to obtain sediment samples in the deep vadose zone, which are analyzed in the laboratory (see Chapter 13). Using split-spoon techniques, very high quality samples can be obtained. Such split-spoon samples can be analyzed in fine detail to provide information on contaminant concentrations, geology, hydrology, and geochemistry. Grab samples can be used to obtain information on contaminant concentrations and geochemistry.

Historically, the major use of boreholes in the tank farms was to provide access for geophysical equipment (see Chapter 9). Gamma emission detectors and neutron moisture tools were and are used to interrogate the ~18-inch-diameter zone around the borehole from the bottom of the borehole to the top.

Another major use for wells on the Hanford Site is to provide access to groundwater by converting the boreholes to RCRA-compliant groundwater wells. Such groundwater wells are routinely sampled to detect and measure contaminants in groundwater. In some cases, continuously reading gauges can measure groundwater properties.

On decommissioning of the borehole, deep electrodes can be placed for SGE (see Chapter 10) or the structure can be used as a platform for in-situ experiments (Chapter 9). It is believed that the use of electrodes buried below the tank bottoms increases the sensitivity of SGE.

5.4 BENEFITS AND LIMITATIONS

Boreholes provide access to depths that are impossible to reach any other way. At Hanford, boreholes have been drilled deep into the underlying basalt (over 1500 feet deep). However, boreholes are expensive.

The benefits of boreholes are that

a. Boreholes provide access to a variety of other technologies.
b. Open-end boreholes can go to groundwater.
c. Large diameters allow large volume of samples to be brought to the surface and large size tools to be placed in the vadose zone.
d. Boreholes have the capacity to operate in highly contaminated areas ($> 10^8$ Ci/g of ^{137}Cs).
e. Boreholes have the capacity to be placed at an angle to avoid surface features.

The limitations are

a. Costs are high (from $500/foot up to $3000/foot depending on contaminant, depth, and sampling requirements).
b. Drill rigs are big and heavy, making then difficult to use in tank farms.
c. Steel casing needed to avoid hole collapse makes many geophysical measurements impossible.
d. Closed-end boreholes have limited depth capabilities.

5.5 FUTURE DEVELOPMENT

Borehole technology is very mature. Costs have decreased and capabilities have improved over the last decade. The introduction of DP technology (see Chapter 6) has addressed further the issues of cost and usability inside the tank farms.

5.6 IMPLEMENTATION

Boreholes are normally used when large-diameter subsurface penetrations (>4 inch diameter) are needed because of equipment requirements (pumps are larger than 3 inches in diameter) and

geophysical logging or access is needed to depths not reachable by DP technology (i.e., the caliche layer in 200 West Area at about 120 feet below ground surface or the lower Hanford gravels in 200 East Area at about 200 to 250 below ground level). For other subsurface penetrations, either DP technology (see Chapter 6) or alternative methods are used (Chapter 7 or Chapter 8) as needed.

Figure 5-1 displays the processes associated with borehole activities. Sections 5.6.1 through 5.6.12 describe each step. Section 5.6.13 summarizes the decision points during the borehole activity, while Section 5.6.14 summarizes the documents and records produced.

5.6.1 Requirements from Data Quality Objectives and Work Plan

The DQO and/or work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Number of locations.
c. General locations of holes.
d. Whether holes are to be vertical or slanted.
e. Target depth of borehole.

5.6.2 Determine Tank Farm Requirements for Borehole Campaign

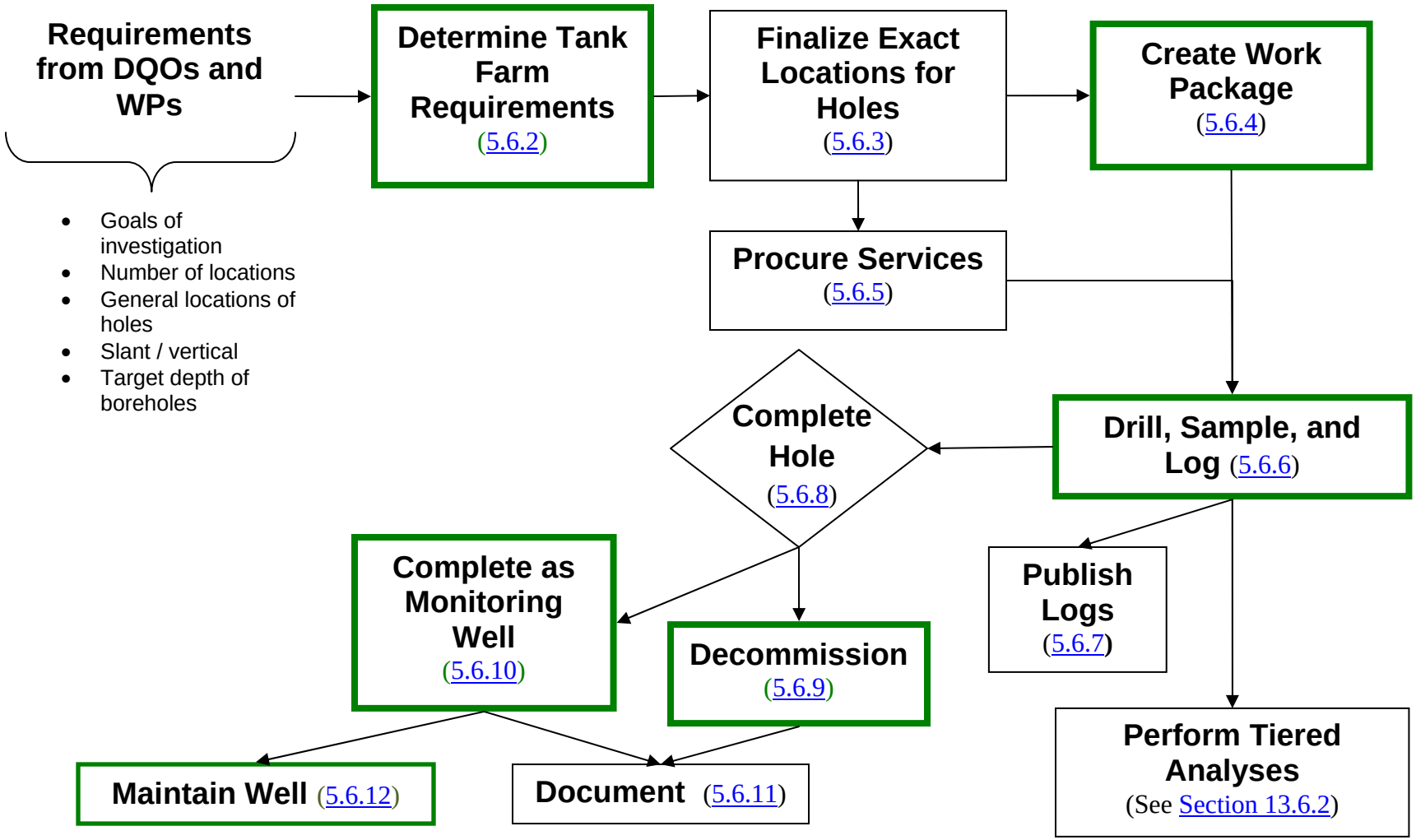
Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and are documented in the borehole work control instructions (work package) (Section 5.6.4).

If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate custodians must be determined.

5.6.3 Finalize Exact Locations for Borehole

Because it is necessary to protect existing piping/wiring networks from damage and to workers during intrusive sampling activities, a ground-penetrating radar (GPR) survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinates via Global Positioning System (GPS) survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). Presently, surface features are being constructed and

Figure 5-1. Borehole Processes



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

conveyance line laid, and these features are not necessarily accurately captured on engineering documents. The Vadose Zone Drilling and Sampling Technical Lead (TL) selects the location of the borehole to meet the program needs as defined in Section 5.6.1 and the tank farm requirements developed in Section 5.6.2.

The work plan may not specify all details needed for implementation. In such cases, the TL consults the relevant technical experts and specifies needed details.

The TL documents the final decisions and its reasons via e-mail to all participants in the work plan approval [including the current U.S. Department of Energy, Office of River Protection (ORP) representative] and forwards the e-mail to the Buyer's Technical Representative (BTR), who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 5.6.11) is issued.

5.6.4 Create Borehole Work Control Instructions (Work Packages)

Based on the work plan (Section 5.6.1), the tank farm requirements (Section 5.6.2), and the exact location of the proposed borehole and other implementing details (Section 5.6.3), a draft work controls instructions (informally known as a work package) are prepared. This work package is finalized after borehole services are procured and the drilling subcontractor submittals and work details are incorporated. This work package is signed off by subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

5.6.5 Procure Borehole Services

If a subcontractor is used to provide borehole services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

5.6.6 Drill, Sample, and Log

Drilling, sampling, and logging (both geologic and geophysical) are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 5.6.11). Before the borehole is started, the drilling contractor obtains a Start Card from Ecology (WAC 173-160-151). For sample tracking, generating sample identification numbers, and generating chain-of-custody forms, establish a vadose zone sampling task for the Hanford Environmental Information System.

Geologic logging is to be performed by a Washington-state-licensed field geologist having Hanford experience, with particular attention being paid to nuances of grain-size, texture, and other features that might impact the flow of water through the vadose zone.

Grab samples are obtained at least every 5 feet (conforming to Hanford standards) from boreholes that are drilled with techniques that generate drill cuttings as the hole is advanced. However, if the work plan specifies, grab samples may be obtained more frequently. Grab sampling of zones that show changes in geologic structure is encouraged, regardless of sampling intervals specified in project documents. For samples collected by a sampling device, the sampler is removed from the drill/drive string and passed over to approved sampling technicians. The samplers prepare the sample following established procedures for transport, including

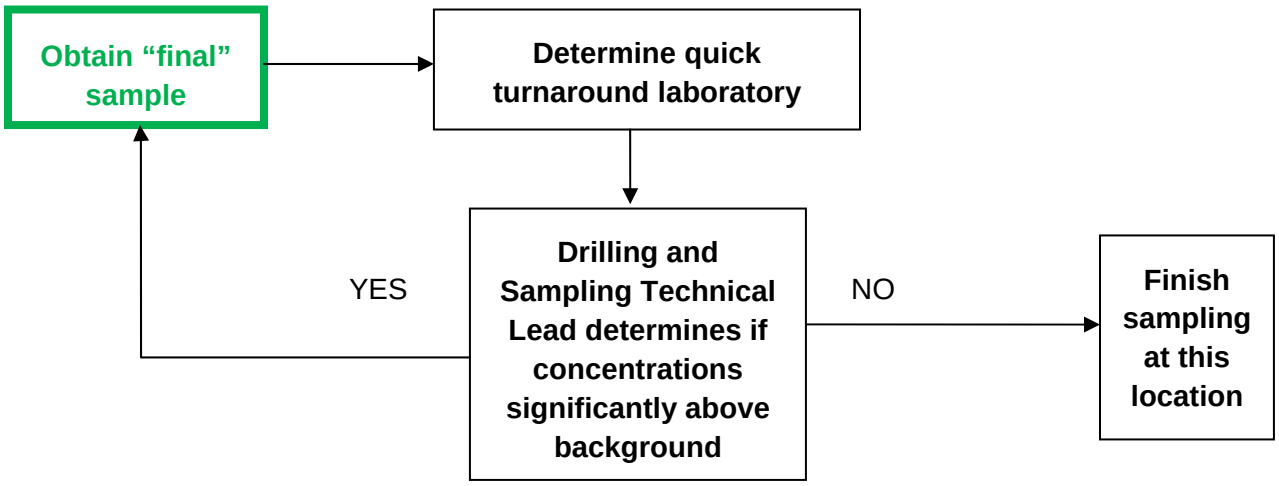
Chain-of-Custody forms, and transport the sample material to the appropriate laboratory (usually within 24 hours). Once the samples are sent to the laboratory for analysis, that laboratory maintains record responsibility for the Chain-of-Custody forms.

Geophysical (passive gamma radiation detection and moisture content determination by neutron scattering) logging is normally done prior to any change in size of drill casing and at total depth. The geophysics contractor performs the logging of the borehole in conformance to the specified work plan. The geophysics contractor maintains the raw geophysics data as in-process data until the geophysical logging report (Section 5.6.7) is issued.

If a layer with perched water (a zone where water has completely filled the pores of the sediments) is detected, the drilling is halted until the TL directs the drilling to be continued. Such a decision will be based on conversations with the DOE and Ecology and is documented by an e-mail, which is treated as an in-process record until the Completion Report (Section 5.6.11) is issued.

The work plan may specify that drilling is to be continued until mobile contaminants are no longer present above background levels. In such cases, the proposed last sample of a quick (nominally 24 hour) analysis of nitrate is sent to the laboratory. Based on the results of the analysis, the TL decides whether additional drilling is necessary. The TL documents the final decisions via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 5.6.11) is issued. This process is repeated until the TL decides that the drilling has passed beyond the zones of contamination but before the hole reaches groundwater. See Figure 5-2.

Figure 5-2. Steps in Determining "Last" Sample



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

5.6.7 Publish Borehole Logging Report

On completion of the logging of the borehole, the subcontractor performing the logging prepares a report describing the methods used and analyses of the geophysical logs. This report is provided to the BTR and subsequently published separately or as part of the borehole Completion Report (Section 5.6.11) as a TFC document [River Protection Project (RPP)], normally within 3 months of the completion of logging.

5.6.8 Decision on How to Complete Borehole

Characterization boreholes drilled for the VZP, which penetrate groundwater, may or may not be completed as a groundwater monitoring well. Criteria that establish the basis for making this decision are generally set in the applicable work plan. Based on these criteria, the TL documents the final decision via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 5.6.11) is issued.

5.6.9 Decommission Borehole

Decommissioning of boreholes is performed in compliance with the requirements of WAC 173-160. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records, until they are issued as part of the Completion Report (Section 5.6.11).

Based on work plan requirements or by the direction of the Director of the VZP, deep SGE electrodes or other instrumentation could be placed into the borehole during decommissioning. The locations of these boreholes are surveyed using GPS technology to complete the required Engineering Change Notices for tank farms.

5.6.10 Complete Borehole as a Monitoring Well

Completion of a borehole as a groundwater monitoring well is performed in compliance with the requirements of WAC 173-160, as a resource protection well. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records until they are issued as part of the Completion Report (Section 5.6.11).

During the decision-making meeting (Section 5.6.8) details on the construction (diameter of completed well, screened interval, etc.) are determined and documented. This information is provided in the subcontract to the drilling vendor or to the BTR in the same transmittal that directs the hole to be completed as a monitoring well.

5.6.11 Document Completion/Decommissioning of Borehole

Completion is documented by formal submittal of a completed Ecology Water Well Report for each borehole (whether the borehole is completed as a water well or is decommissioned). A

copy is also provided to the Hanford Site contractor [currently the Central Plateau Contractor (CPC)] charged with maintaining well records.

In addition, a Completion Report that documents the borehole drilling activities is published as an RPP document. The report includes the following:

a. Copy of the Start Card.
b. Daily activity logs.
c. Geological logs.
d. Copy of the initial chain of custody forms.
e. Copy of the Well Completion Report or the Decommissioning Report (as appropriate).
f. Copy of the e-mails documenting the technical reasons for decisions (Sections 5.6.3, 5.6.8, and 5.6.9).

Deviations from the approved work plan are documented.

5.6.12 Maintain Monitoring Well

Groundwater monitoring wells are generally subject to periodic maintenance. Required maintenance is identified by the groundwater monitoring program (currently the CPC) and is communicated to the TFC when the well is located within the boundary of a tank farm. Work is then subjected to the same process as drilling a borehole to meet the identified need.

5.6.13 Summary of Borehole Decision Points

Table 5-1 presents the summary of decision points during the borehole drilling activity.

Table 5-1. Summary of Decision Points during the Borehole Drilling Activity

Decision	Decision Maker	Section
Goals of borehole drilling activity	DQO/work plan	5.6.1
Exact location and details of drilling activity	TL	5.6.3
Drilling after perched water detected	TL	5.6.6
Decommissioning or completion of borehole	TL	5.6.8
Placement of deep SGE electrodes or other instruments during decommission	Director, Vadose Zone Program	5.6.9

TL = Vadose Zone Drilling and Sampling Technical Lead

5.6.14 Summary of Records and Documents Generated during Borehole Activity

Table 5-2 displays the records and documents generated during the borehole drilling activity.

Table 5-2. Data, Documents, and Records Generated during the Borehole Drilling Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	5.6.1
Work plan [a,b]	Characterization requirements	VZP	5.6.1
E-mail (input to Statement of Work and work package)[c]	Technical description of borehole location and reasoning	TL	5.6.3
Work control instructions [d]	Tank farm approval and duties for borehole	SST Closure organization	5.6.4
Statements of work [c] (input to contract)	Technical description of work to be done	TL	5.6.5
Contracts [e]	Contract with borehole driller and geophysics contractor	Procurement	5.6.5
Start Card [b]	State approval for borehole	Borehole contractor	5.6.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	Borehole contractor	5.6.6
Geophysical raw data (input into Geophysics Report)[c]	Raw data from field measurements	Geophysics contractor	5.6.6
Chain of Custody [f]	Sample history	Sampling crew	5.6.6
E-mail (input to Completion Report [c]	Document that continued drilling/sampling is required	TL	5.6.6
Geophysics Report [a]	Reduction of geophysical data into interpreted data	Geophysics contractor	5.6.7
E-mail (input to Completion Report)[c]	How borehole is to be completed	TL	5.6.8
Water Well Report [b]	Completion of borehole well construction or decommissioning	Borehole contractor	5.6.11
Completion Report [a]	Document borehole activity	Borehole contractor	5.6.11

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
[f] Laboratory record
TL = Vadose Zone Drilling and Sampling Technical Lead

6. DIRECT PUSH TECHNOLOGY

6.1 PURPOSE

Recently, DP technology has fulfilled many of the vadose zone sampling needs on the Hanford Central Plateau previously performed by boreholes. Direct push technology applications are more limited than boreholes (e.g., smaller volume of sample, depth of sampling is more limited in some cases), but DP is also faster and much less costly.

6.2 DESCRIPTION

6.2.1 Definition

The DP drill casing is a small diameter, currently ranging from 2.5- to 2.62-inch outside diameter and 1.12- to 1.75-inch inside diameter. The technology has undergone generational improvements from geoprobes to cone penetrometer to the current technology. Current capabilities allow probeholes to go vertically down ~120 feet (in the Hanford sandy formation unit) or a similar distance at an angle (up to 60 degrees from vertical). Slim-line gamma emission and neutron moisture tools have been developed and deployed. Initially, the DP technology allowed only one sample to be retrieved per probehole, but multiple samples can routinely be collected using a single probe hole.

6.2.2 Uses

Direct push probeholes are mainly used

a. As a platform for in-situ measurements (see Chapter 11).
b. To obtain sediment samples for laboratory analysis (see Chapter 13).

On decommissioning, deep electrodes can be placed in probeholes for SGE (see Chapter 10).

A typical campaign is to push a probehole to maximum depth and then gamma and moisture log the hole. From existing information and the new logging information, sampling depths are then selected. A second probehole is pushed down to the first desired depth, the tip removed, a sample collected, the tip replaced, and the probehole pushed to the next sampling depth (until all the desired samples are collected). The probeholes are then decommissioned (filled in according to Ecology regulations).

Type of Samples Obtained. Current sample size is relatively small (~1-inch diameter by 6 inches long).

6.3 RELATIONSHIP TO OTHER TECHNOLOGIES

The current DP technology is a down-sized version of closed-end boreholes. As noted in Section 6.2, DP probeholes

a. Act as a platform for geochemical measurements.
b. Obtain sediment samples for laboratory analysis.

6.4 BENEFITS AND LIMITATIONS

Direct push probeholes allow many more locations in a tank farm to be investigated as compared to a closed-end borehole. Direct push technology is cheaper and much easier to deploy in multiple locations inside a tank farm. Unlike a drill rig, a DP unit can sit on top of an underground storage tank.

The benefits of DP boreholes are

a. Lower cost than boreholes (~$100 per foot).
b. Much better access to locations in cluttered tank farms.
c. Providing access to a variety of other technologies (e.g. geophysical sensors), although not as many as closed-end boreholes.
d. Having the ability to be placed at an angle to avoid surface features.

The limitations are

a. Limited depth capabilities (i.e., the extent of the Hanford sand unit, ~100 to 120 feet in depth in the 200 West Area and ~200 to 250 feet in the 200 East Area).
b. Smaller sample size than boreholes.
c. Sampling frequency is generally less often.
d. Inability to retrieve highly radioactive samples (>10^3 pCi/g of ^{137}Cs).
e. Inability to use large diameter geophysical tools.
f. Not having the ability to operate in highly contaminated areas.
g. Steel casing needed to avoid hole collapse makes many geophysical measurements impossible.

6.5 FUTURE WORK REQUIRED

At present, DP technology can be used in highly contaminated areas, but samples cannot be brought to the surface because of health and safety concerns. The development of shielded sample holders, although reducing sample size, would allow more highly contaminated samples to be brought to the surface.

6.6 IMPLEMENTATION

Direct push technology is used when small diameter (<3-inch diameter) rods and depths requirements (down to the caliche layer in 200 West Area at about 120 feet below ground surface or the lower Hanford gravels in 200 East Area at about 200 to 250 below ground level).

Direct push technology can be used in a variety of other ways. Depending on the goal, slightly different processes are involved in implementing DP technology:

a. Sampling based on logging results (Section 6.6.1).
b. Sampling at previously defined depth only (Section 6.6.2).
c. Establishing a new hole for logging (Section 6.6.3).
d. Using DP technology only to install new instruments (Section 6.6.4).

6.6.1 Sampling Based on Logging Results

Figure 6-1 displays the process used for DP when the sampling is based on logging results. This process is the most complicated as it provides the most flexibility. The main distinguishing feature of this submethod is that sample locations are decided based on logging results obtained during the implementation.

Sections 6.6.1.1 through 6.6.1.11 describe each step. Section 6.6.1.12 summarizes the decision points during the DP activity, while Section 6.6.1.13 summarizes the documents and records produced.

6.6.1.1 Requirements from DQO and Work Plan. The DQO and work plan covering the laboratory analyses describe

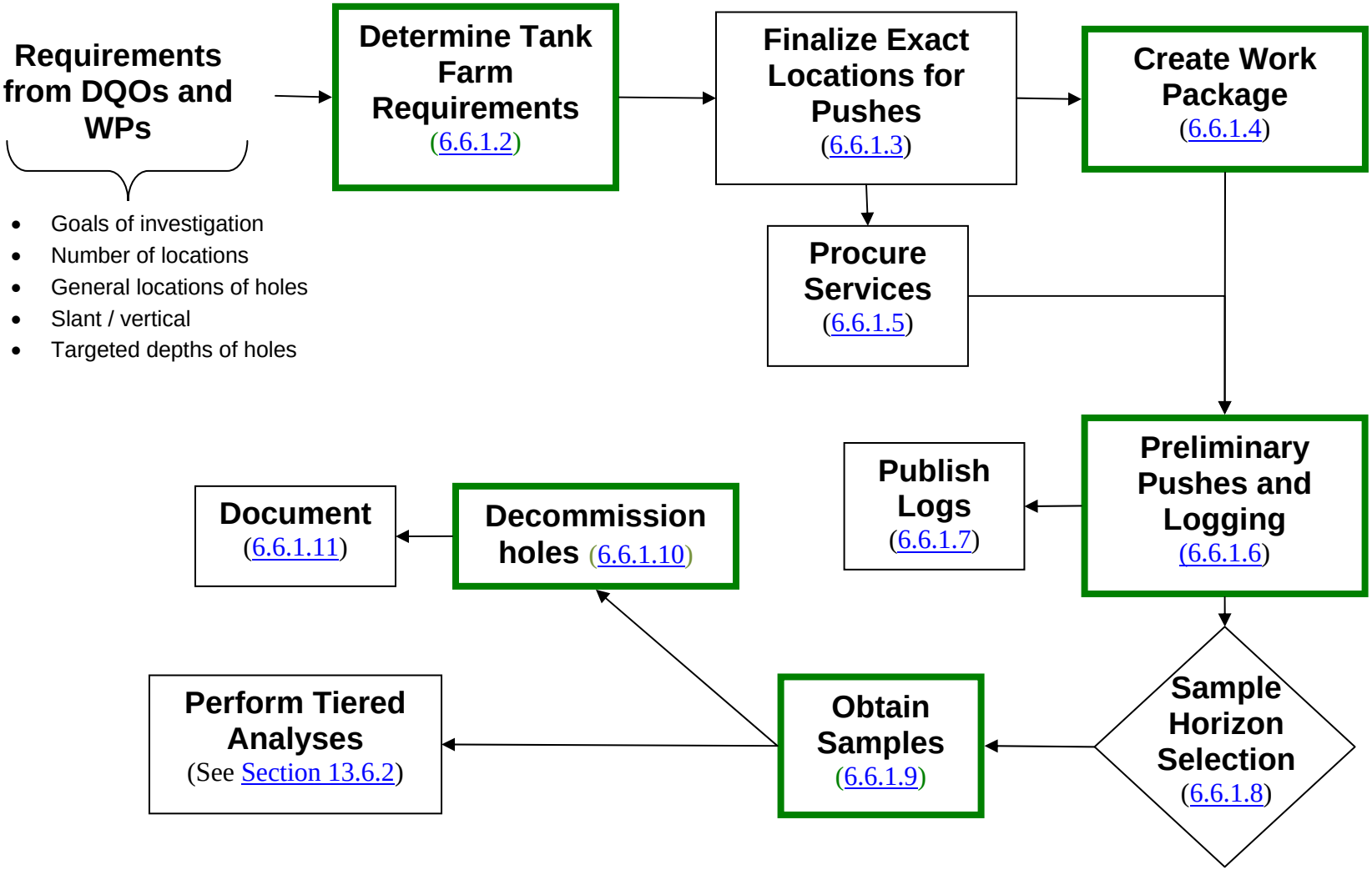
a. General goals of the analyses.
b. Number of locations.
c. General locations of holes.
d. Whether holes are to be vertical or slanted.
e. Targeted depth of pushes.

6.6.1.2 Determine Tank Farm Requirements for Direct Push Campaign.

Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Determination of Tank farm requirements are determined by the SST Closure organization and documented in the DP work package (Section 6.6.1.4).

If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate contractors must be determined.

Figure 6-1. Direct Push Processes for Obtaining Samples at Depths Determined during the Process



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

6.6.1.3 Finalize Exact Locations for Pushes. Because it is necessary to protect existing piping/wiring networks from damage and to workers during intrusive sampling activities, a GPR survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinate via GPS survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). The TL selects the location of the DPs to meet the program needs as defined in Section 6.6.1.1 and the tank farm requirements developed in Section 6.6.1.2.

The work plan may not specify all details needed for implementation. In such cases, the TL consults the relevant technical experts and specifies needed details. The TL documents the final decisions and its reasons via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 6.6.1.11) is issued.

6.6.1.4 Create Direct Push Work Control Instructions (Work Package). Based on the work plan (Section 6.6.1.1), the tank farm requirements (Section 6.6.1.2), and the exact location of the proposed DP campaign and other implementing details (Section 6.6.1.3), a draft work controls instructions (informally known as a work package) is prepared. This work package is finalized after DP services are procured and the drilling subcontractor submittals and work details are incorporated. This work package is signed off by designated subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

6.6.1.5 Procure Direct Push Services. If a subcontractor is used to provide DP services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

6.6.1.6 Preliminary Pushes and Logging. The strategy for conducting tank farm characterization using DP technology is to use a preliminary push hole to assess subsurface conditions via geophysical logging. All such activities are performed according to the approved work plan, procedures, and contract documents. The logs that are usually run consist of total (gross) gamma and neutron moisture gage. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.1.11). Before each DP is started, the drilling contractor obtains a Start Card from Ecology (WAC 173-160-151).

The intent of the gross gamma log is to identify regions where vadose zone gamma energy is sufficiently large to create a potentially unacceptable exposure to workers as the drive casing is removed from the ground or to select sampling intervals than can be safely managed at the surface. Secondarily, the gamma log provides an indication of the distribution of tank wastes that are held in the vadose zone. Additional gamma logging runs may be needed to identify specific radionuclides contributing to the signal.

Neutron moisture gage logs are run to identify horizons in the vadose zone with high moisture content. These "wet" zones may be targeted for sampling (Section 6.6.1.8) as water-mobilized non-gamma-emitting contaminants are more likely to be residing at these horizons. Gamma and moisture logs are provided to the TL for selection of sample horizons (Section 6.6.1.8). The geophysics contractor maintains the raw geophysics data as in-process data until the geophysical logging report (Section 6.6.1.7) is issued.

The TL decides whether additional drilling is necessary. The TL documents the decision via e-mail to all participants in the work plan approval (Section 6.6.1.1) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor.

6.6.1.7 Publish Direct Push Logs. On completion of the logging of all DP holes in a given campaign, the subcontractor performing the logging prepares a report describing the methods used and analyses of the geophysical logs. This report is provided to the BTR and subsequently published separately as a TFC document (RPP) or as part of the well completion report (Section 6.6.1.11), normally within 3 months of the completion of logging.

6.6.1.8 Determine Sampling Horizons from Characterization Efforts Using Direct Push Technology

6.6.1.8.1 Approach. The VZP has determined that a cost-effective means of obtaining near-surface zone samples (down to ~120 feet below surface in the 200 West Area and down to ~200 feet in the 200 East Area) is DP technology. An investigation campaign consists of two types of pushes:

a. Preliminary (to determine whether it is safe to obtain samples and to provide data to pick elevations for sampling).
b. Sampling (to actually obtain the vadose zone samples).

During the decommissioning of the preliminary probehole, additional tasks (such as the installation of deep vadose zone electrodes) can occur.

Sampling horizons are chosen at a meeting based on the results of the preliminary DPs.

6.6.1.8.2 Background. Mobile contaminants drive the long-term risk associated with releases from tank farm structures. The most notable of these contaminants are ^{99}Tc, nitrate, and hexavalent chromium; none of these contaminants are gamma emitters. Gamma-emitting radionuclides, as estimated by passive gamma logging, serve as indicators of wastes present in the environment. The distribution and relative concentration of gamma-emitting contaminants may be used to evaluate the inventory and volume of the causative release.

The working hypothesis for selecting sampling horizons is that mobile constituents such as ^{99}Tc, NO_3, and Cr^{+6} are most likely to be associated with higher moisture content sediments because water is the mobilizing parameter. Principles of unsaturated zone hydrology also show that water flow is preferentially contained within these finer grained sediments. In fact, these fine-grained sediments must become saturated before vertical flow can be established between them and underlying coarser grained sediments. In addition, characterization performed as part

of Phase 1 of the Tank Farm RCRA Corrective Action Program has repeatedly shown this correlation between mobile contaminants and moisture content. Hence, the relative moisture content of the subsurface sediments is the primary tool to be applied to selecting sampling horizons.

The distribution of moisture throughout the vadose zone has also been found to correlate to fine-grained strata. These fine-grained strata, by their nature, have an enhanced capacity to retain less mobile contaminants that are chemically absorbed to the surfaces of individual particles.

All preliminary investigation pushes are geophysically logged to ascertain the distribution of gamma-emitting radionuclides and to ascertain the relative distribution of moisture in the subsurface. These gamma logs are used to assess as-low-as-reasonably-achievable (ALARA) issues and ensure that field personnel are not exposed to unnecessary levels of radiocontaminants.

Note: Neither of these logs is absolute; they are used as indicators of what can be expected when handling samples that are collected from an adjacent push and when retrieving the casing used to advance the probehole.

6.6.1.8.3 Strategy. Selection of individual horizons for sampling is accomplished using a general agreement basis by a committee as determined by the Committee Leader. Members of the committee are selected by the Committee Leader and are derived from VZP staff and management, subcontractors, regulators, DOE, and other site contractors. The decisions of the committee are implemented by having the BTR formally communicate the sampling horizons to the DP contractor.

Committee Membership Pool:

Leader: The leader of the selection committee is the TL. This person is most familiar with all aspects of the DP data that are reviewed by the committee and is knowledgeable concerning the capabilities and limitations of the methodology.

The TL

a. Selects the time and location of the meeting.
b. Sends out invitations to the meeting.
c. Sends out background information prior to the meeting.
d. Chairs the meeting.
e. Documents the conclusions of the meeting.
f. Sends out the documented conclusions.

Other participants at the meeting should include

a. VZP field representatives: These persons provide the knowledge regarding conduct of other field projects and serve as back-up to the TL in his absence. Because the DP sampling is one element of the field characterization, and all elements are intended to be used to unravel the complex nature of tank farm contaminant releases, input from these persons is needed for integrating all VZP field efforts.

b. VZP Laboratory Technical Lead: Samples that are to be collected are transferred to the laboratory for a series of chemical and radiological analyses, the laboratory TL is responsible for ensuring that the appropriate analyses are conducted.

c. VZP Risk Analysis Technical Lead: Laboratory analyses that are conducted serve as input to the analysis of risk associated with the tank farm release being investigated. Full VZP integration necessitates this person being part of the decision-making process.

d. VZP management: Management ensures sample horizons will meet needs for work plans, data packages, and/or RCRA Field Investigation/Corrective Measures Study Corrective Actions.

e. Analytical laboratory staff: These team members bring the experience and knowledge of what can and cannot be done with the samples that are to be collected. Foreknowledge of what samples are to be directed to the laboratory helps ensure that those samples are handled in an expeditious manner.

f. DP contractor representative: It is essential that the DP contractor be represented in this decision process so that the background as to why and where a sample is to be taken is understood and accepted. This representative also serves to provide another reality check for the TL.

g. Central Plateau Contractor staff: In an effort to ensure integration between the TFC and the CPC, a representative of the CPC Operable Unit management or technical staff are invited to participate. In the event that CPC concerns indicate that an adjustment should be made to provide additional value to the sampling effort, those issues can be raised by the CPC representative(s). Other site contractors can be included, such as the designated site geophysical logging subcontractor.

h. ORP representative: Inclusion of the ORP representative provides assurance that the sponsoring agency is involved in the decision-making process.

i. Ecology: Continued involvement of Ecology technical staff in the sampling and decision-making process helps to ensure regulatory acceptance of the final product.

Timing of the Meeting and Necessary Information. The timing of the meeting should be as soon as practicable following the receipt of geophysical logging results from the preliminary pushes to be used in sample horizon selection.

Information that is provided to committee members (either before the meeting or at the meeting) includes the following:

a. Gamma and moisture logs from initial pushes and any nearby wells.
b. Any leak or loss inventory information that is available.
c. Geologic summary of the region being investigated.
d. Operational history of the facility or structure being investigated.
e. Any historical characterization data that are available and the results of any simulations that have been made of the targeted release.

When feasible, these data are to be provided to committee members in advance of the meeting. The TL may provide direction as to where this information can be found in an electronic format.

At the meeting:

a. The TL or a designee presents geophysical logging results and summarize other appropriate information.
b. The committee decides the horizons to be sampled for each DP location. Note that some DP locations may not be sampled.
c. The committee decides whether deep SGE electrodes should be placed in the probeholes as they are being decommissioned.
d. The committee discusses and provides justification for each decision made.
e. The committee discusses further recommendations based on the discussions as appropriate.

Actions following meeting. After the meeting, the TL documents the meeting via e-mail to the Director - Vadose Zone Program, Manager - Closure, and to the BTR of the DP contract with copies to the team participants. The documentation includes

a. List of those persons in attendance.
b. Description of the data discussed.
c. Listing of the options discussed.
d. Description of the selected option with justification for its selection.

The e-mail is treated as an in-process record until the Completion Report (Section 6.6.1.11) is issued.

On receipt of VZP management concurrence, the BTR formally communicates the minutes to the DP contractor; a copy of the correspondence is sent to the assigned Field Work Supervisor.

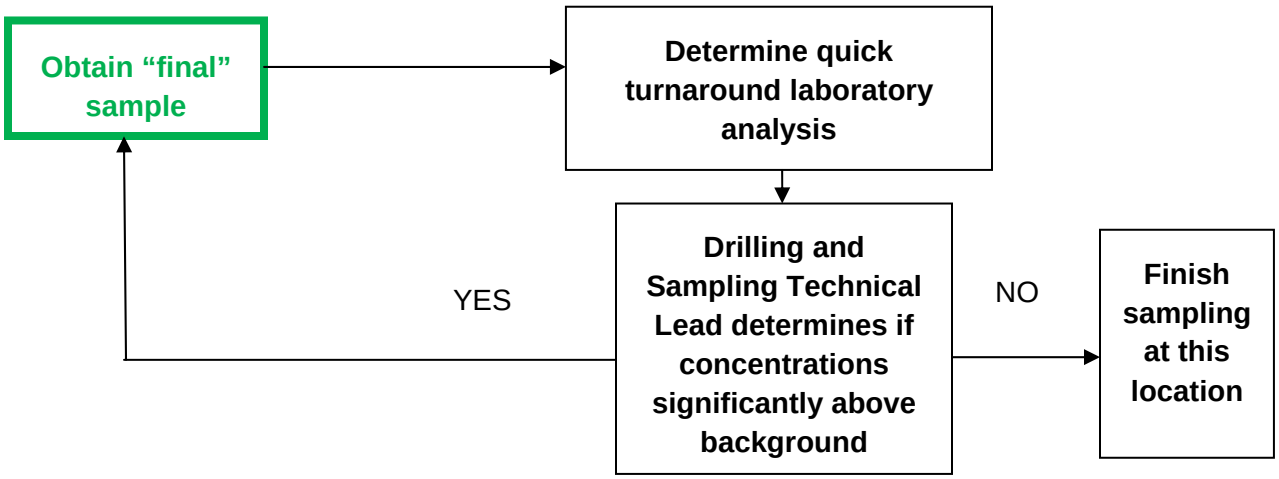
6.6.1.9 Obtain Direct Push Samples. For sample tracking, generating sample identification numbers and generating Chain-of-Custody forms, the TL establishes a vadose zone sampling task for the Hanford Environmental Information System.

The DP equipment is relocated to a pre-approved position that is near to the preliminary hole for which the sampling horizon decision has been made. Generally, samples are obtained using a dual-string configuration allowing multiple, depth-separated samples to be collected. The DP contractor drives the sampler to the selected depth and retrieves the sample. Once the sampling device is retrieved to the surface, the sampler is removed from the drill/drive string and passed over to approved sampling technicians. The samplers prepare the sample following established procedures for transport, including Chain-of-Custody forms, and transport the sample material to the appropriate laboratory (usually within 24 hours). Once the samples are sent to the laboratory for analysis, that laboratory maintains record responsibility for the Chain-of-Custody forms. This process is repeated until all samples are collected.

Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.1.11). Before each DP is started, the drilling contractor obtains a Start Card from the Ecology (WAC 173-160-151).

The work plan (Section 6.6.1.1) or minutes from the sample selection committee (Section 6.6.1.8) may specify that DP holes be continued until mobile contamination is no longer present above background levels. In such cases, the proposed last sample is sent to the laboratory for a quick (normally 24 hour) analysis of nitrate. Based on the results of the analysis, the VZP Drilling and Sampling TL decides whether additional drilling is necessary. The TL documents the final decisions via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 6.6.1.11) is issued. This process is repeated until the TL decides that the drilling has passed before contamination of the drilling as reach groundwater. This process is visually shown in Figure 6-2.

Figure 6-2 Steps in Determining "Last" Sample



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

6.6.1.10 Decommission Probeholes. All probeholes are decommissioned in compliance with WAC 173-160 unless a written variance to those requirements is received from Ecology. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.1.11)

Based on work plan requirements or by the decision of the sample selection committee, deep SGE electrodes or other instrumentation could be placed into the probehole during decommissioning. The locations of these probeholes are surveyed using GPS technology to complete the required Engineering Change Notices for tank farms.

6.6.1.11 Document Installation and Decommissioning of Probeholes. Completion is documented by formal submittal of a completed Ecology Water Well Report for each DP. A copy is provided to the Hanford Site contractor (currently the CPC) charged with maintaining well records.

In addition, a Completion Report that documents the DP activities is published as an RPP document. The report includes

a. Copy of the Start Card.
b. Daily activity logs.
c. Copy of the initial Chain-of-Custody forms.
d. Copy of the Water Well Report as decommissioning.
e. Copy of the e-mails documenting the technical reasons for decisions (Sections 6.6.1.3 and 6.6.1.8).

Deviations from the approved work plan are documented.

6.6.1.12 Summary of Direct Push Activity Decision Points for Sampling Based on Logging Results. Table 6-1 presents the summary of decision points during the DP activity.

Table 6-1. Summary of Decision Points during the Direct Push Activity for Sampling Based on Logging Results

Decision	Decision Maker	Section
Goals of DP activity	DQO/work plan	6.6.1.1
Exact location and details of each DP hole	TL	6.6.1.3
Sample horizons	TL	6.6.1.8
Terminate sampling at a given hole	TL	6.6.1.9

TL = Vadose Zone Drilling and Sampling Technical Leader

6.6.1.13 Summary of Records and Documents Generated During Direct Push Activity for Sampling Based on Logging Results. Table 6-2 displays the records and documents generated during the DP activity.

Table 6-2. Data, Documents, and Records Generated during the Direct Push Activity for Sampling Based on Logging Results (2 sheets)

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	6.6.1.1
Work plan [a,b]	Characterization requirements	VZP	6.6.1.1
E-mail [c]	Technical description of DP locations and reasoning	TL	6.6.1.3
Work control instructions [d]	Tank farm approval and duties for DP activity	SST Closure organization	6.6.1.4
Statements of work (input to contract) [e]	Technical description of work to be done	TL	6.6.1.5
Contracts [e]	Contract with driller and geophysics contractor	Procurement	6.6.1.5

Table 6-2. Data, Documents, and Records Generated during the Direct Push Activity for Sampling Based on Logging Results (2 sheets)

Document	Purpose	Author	Section
Start Card [b]	State approval for DP	DP contractor	6.6.1.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	DP contractor	6.6.1.6
Geophysical raw data (input into geophysics report)[c]	Raw data from field measurements	Geophysics contractor	6.6.1.6
Geophysics report [a]	Reduction of geophysical data into interpreted data	Geophysics contractor	6.6.1.7
E-mail [c]	Technical justification for sample selection	TL	6.6.1.8
Daily records (input into Completion Report)[c]	Daily activities, released as part of Decommissioning Report	DP contractor	6.6.1.9
Chain of Custody [f]	Sample history	Sampling crew	6.6.1.9
E-mail [c]	Document that continued drilling/sampling is required	TL	6.6.1.9
Water Well Report [b]	Completion of decommissioning of DP probehole	DP contractor	6.6.1.11
Completion Report [a]	Document DP activity	DP contractor	6.6.1.11

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
[f] Laboratory record
TL = Vadose Zone Drilling and Sampling Technical Leader

6.6.2 Sampling at Predefined Depths

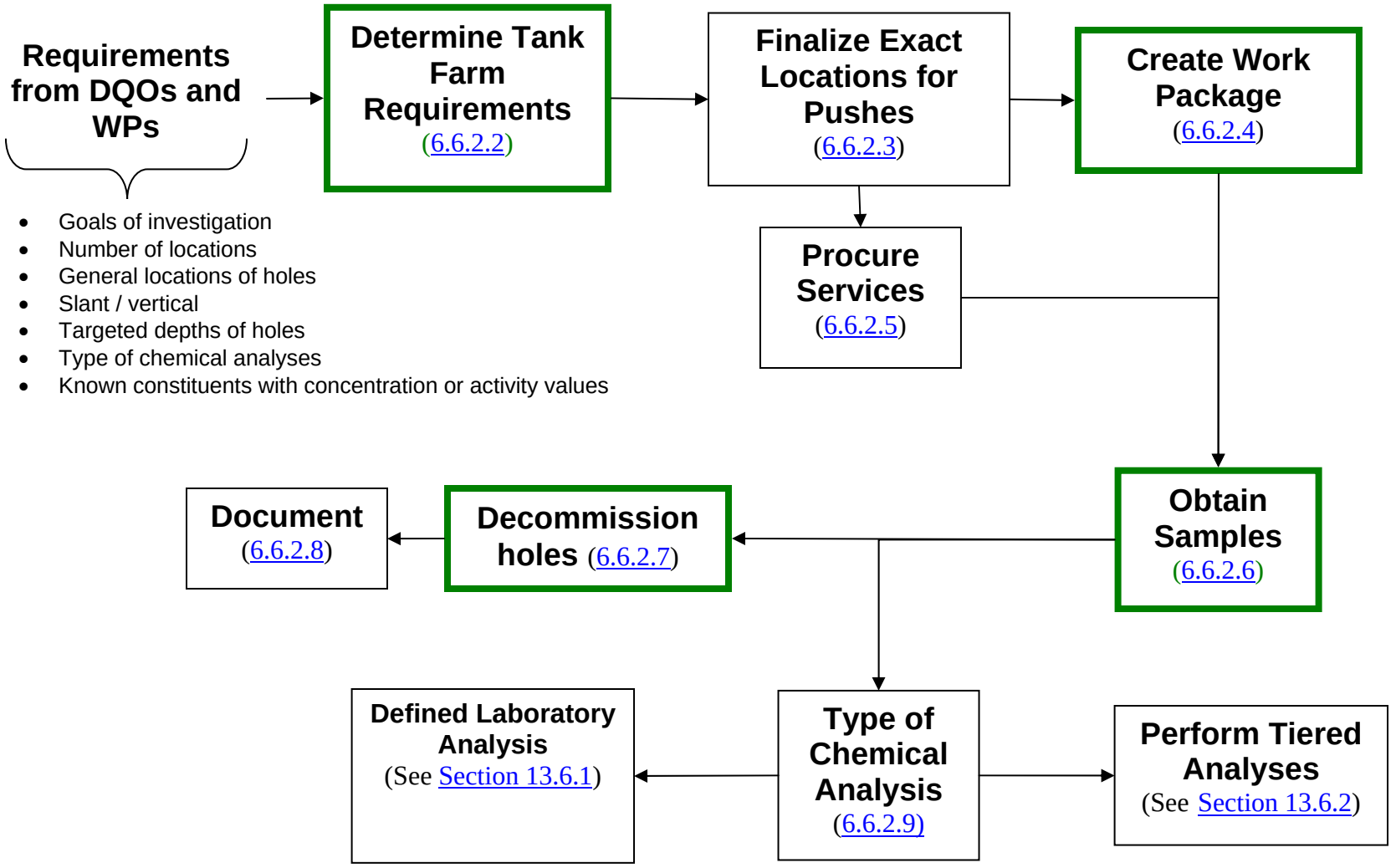
Figure 6-3 displays the process used for DP when the sampling is predefined (usually in the work plan). Sections 6.6.2.1 through 6.6.2.9 describe each step. Section 6.6.2.10 summarizes the decision points during the DP activity, while Section 6.6.2.11 summarizes the documents and records produced.

6.6.2.1 Requirements from DQO and Work Plan. The DQO and work plan covering the laboratory analyses describes

a. General goals of the analyses.
b. Number of locations.
c. General locations of sampling holes.
d. Whether holes are to be vertical or slanted.
e. Depth of pushes.
f. Type of laboratory analysis.
g. Known constituents with concentration or activity values.

6.6.2.2 Determine Tank Farm Requirements for Direct Push Campaign. Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the DP work package (Section 6.6.2.4).

Figure 6-3. Direct Push Processes to Obtain Samples at Predefined Depths



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate contractors must be determined.

6.6.2.3 Finalize Exact Locations for Pushes. Because it is necessary to protect existing piping/wiring networks from damage and to workers during intrusive sampling activities, a GPR survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinate via GPS survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). The TL selects the location of the DPs to meet the program needs as defined in Section 6.6.2.1 and the tank farm requirements developed in Section 6.6.2.2.

The work plan (Section 6.6.2.1) may not specify all details needed for implementation. In such cases, the TL consults the relevant technical experts and specifies needed details.

The TL documents the final decisions and its reasons via e-mail to all participants in the work plan (Section 6.6.2.1) approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 6.6.2.8) is issued.

6.6.2.4 Create Direct Push Work Control Instructions (Work Package). Based on the work plan (Section 6.6.2.1), the tank farm requirements (Section 6.6.2.2), and the exact location of the proposed DP campaign and other implementing details (Section 6.6.2.3), draft work controls instructions (informally known as a work package) are prepared. To proceed, the TL shall decide that the sampling can be performed without exposure to the crew. If insufficient data exists for such a decision, then the process discussed in Section 6.6.1 shall be used. This work package is finalized after DP services are procured and the drilling subcontractor submittals and work details are incorporated. This work package is signed off by designated subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

6.6.2.5 Procure Direct Push Services. If a subcontractor is used to provide DP services, the standard TFC procedures for procuring services is followed. Close coordination with the BTR is required.

6.6.2.6 Obtain Direct Push Samples. For sample tracking, generating sample identification numbers, and generating Chain-of-Custody forms, establish a vadose zone sampling task for the Hanford Environmental Information System.

Direct pushes and sample handing is performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records

and are part of the Completion Report (Section 6.6.2.8). Before each DP is started, the drilling contractor obtains a Start Card from Ecology (WAC 173-160-151).

The DP equipment is located to the position defined in the work package (Section 6.6.2.4). Generally, samples are obtained using a dual-string configuration allowing multiple, depth-separated samples to be collected. The DP contractor drives the sampler to the selected depth and retrieves the sample. Once the sampling device is retrieved to the surface, the sampler is removed from the drill/drive string and passed over to approved sampling technicians. The samplers prepare the sample following established procedures for transport, including Chain-of-Custody forms, and transport the sample material to the appropriate laboratory (normally within 24 hours). Once the samples are sent to the laboratory for analysis, that laboratory maintains record responsibility for the Chain-of-Custody forms. This process is repeated until all samples are collected.

6.6.2.7 Decommission Probeholes. All probeholes are to be decommissioned in compliance with WAC 173-160 unless a written variance to those requirements is received from Ecology. All decommissioning tasks are to be performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.2.8).

Based on work plan requirements (Section 6.6.2.1) or by the direction of the Director of the VZP, deep SGE electrodes or other instrumentation could be placed into the probehole during decommissioning). The locations of these probeholes will be surveyed using GPS technology to complete the required Engineering Change Notices for tank farms.

6.6.2.8 Document Installation and Decommissioning of Probeholes. Completion of probeholes is documented by formal submittal of a completed Ecology Water Well Report for each DP. A copy is provided to the Hanford Site contractor (currently the CPC) charged with maintaining well records.

In addition, a Completion Report that documents the DP activities is published as an RPP document. The report includes

a. Copy of the Start Card.
b. Daily activity logs.
c. Copy of the initial Chain-of-Custody forms.
d. Copy of the Water Well Report as a decommissioning.
e. Copy of the e-mails documenting the technical reasons for decisions (Section 6.6.2.3).

Deviations from the approved work plan are documented.

6.6.2.9 Type of Chemical Analysis. The work plan (Section 6.6.2.1) covering this activity normally specifies the type of chemical analyses to be performed on the samples. In the rare instance when the work plan is unclear, the Director of the VZP (in consultation with ORP) determines the type of chemical analysis:

a. Predefined chemical analysis (See Section 13.6.1).
b. Tiered chemical analyses (See Section 13.6.2).

6.6.2.10 Summary of Decision Points during the Activity to Collect Samples at Predefined Depths using Direct Push. Table 6-3 presents the summary of decision points during the activity to collect samples at predefined depths using DP.

Table 6-3. Summary of Decision Points during the Activity to Collect Samples at Predefined Depths Using Direct Push

Decision	Decision Maker	Section
Goals of DP activity	DQO/work plan	6.6.2.1
Exact location and details of each DP hole	TL	6.6.2.3

TL = Vadose Zone Drilling and Sampling Technical Lead

6.6.2.11 Summary of Records and Documents Generated During Activity to Collect Samples at Predefined Depths using Direct Push. Table 6-4 displays the records and documents generated during the activity to collect samples at predefined depths using DP.

Table 6-4. Data, Documents, and Records Generated during the Activity to Collect Samples at Predefined Depths Using Direct Push.

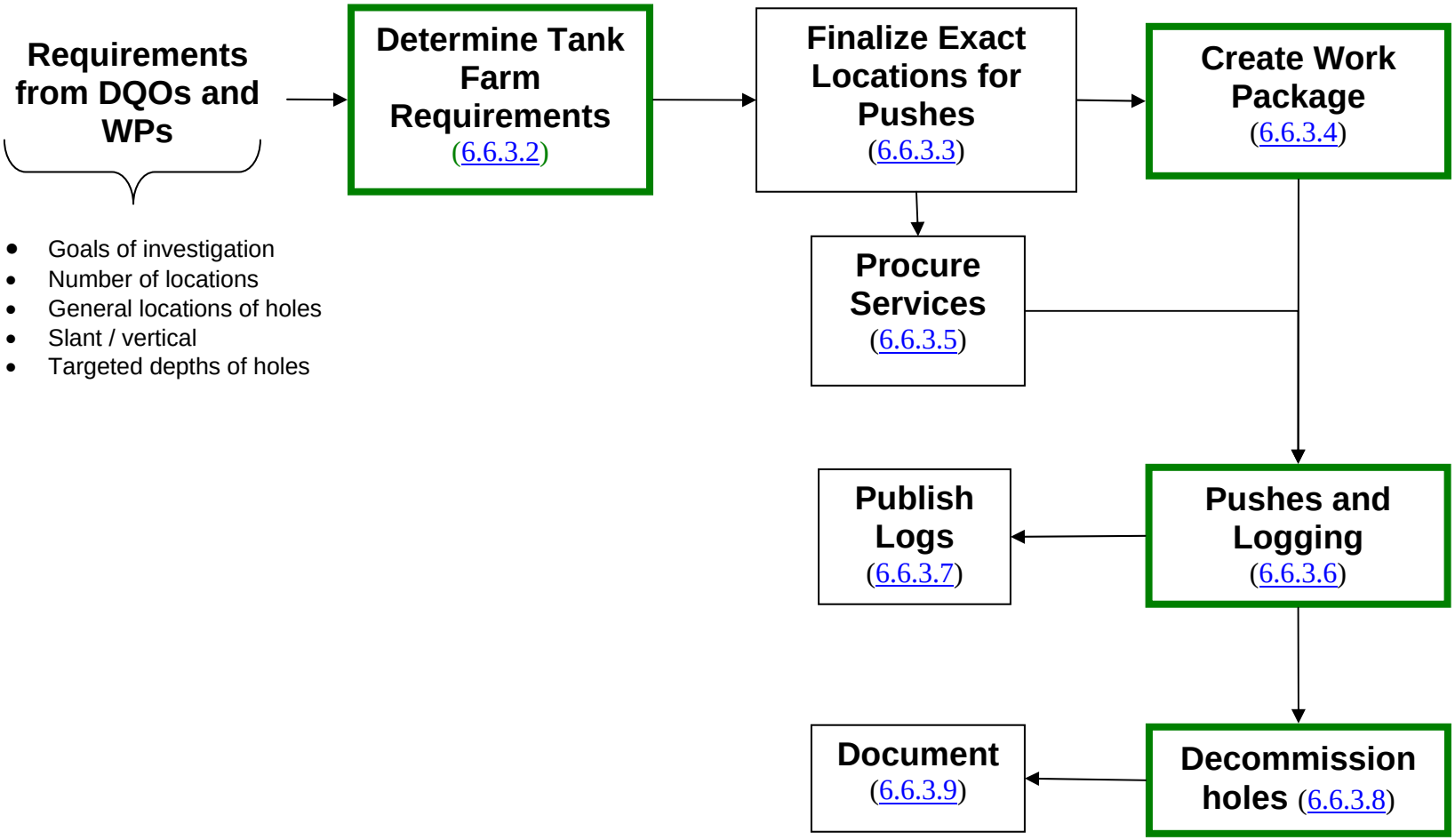
Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	6.6.2.1
Work plan [a,b]	Characterization requirements	VZP	6.6.2.1
E-mail [c]	Technical description of DP locations and reasoning	TL	6.6.2.3
Work control instructions [d]	Tank Farm approval and duties for direct DP activity	SST Closure organization	6.6.2.4
Statements of work [c] (input to contract)	Technical description of work to be done	TL	6.6.2.5
Contracts [e]	Contract with driller and geophysics contractor	Procurement	6.6.2.5
Start Card [b]	State approval for DP	DP contractor	6.6.2.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	DP contractor	6.6.2.6
Chain of Custody [f]	Sample history	Sampling crew	6.6.2.6
Water Well Report [b]	Completion of decommissioning DP probeholes	DP contractor	6.6.2.8
Completion Report [a]	Document DP activity	DP contractor	6.6.2.8

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
[f] Laboratory record
TL = Vadose Zone Drilling and Sampling Technical Lead

6.6.3 Logging Only

Figure 6-4 displays the process used when DP is used to create a logging hole and the subsequent initial logging. Section 6.6.3.10 summarizes the decision points during the DP activity, while Section 6.6.3.11 summarizes the documents and records produced.

Figure 6-4. Direct Push Processes for Logging Only



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

6.6.3.1 Requirements from DQO and Work Plan. The DQO and Work Plan covering the laboratory analyses describes

a. General goals of the analyses.
b. Number of locations.
c. General locations of holes.
d. Whether holes are to be vertical or slanted.
e. Targeted depth of pushes.

6.6.3.2 Determine Tank Farm Requirements for Direct Push Campaign. Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the DP work package (Section 6.6.3.4).

If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate contractors must be determined.

6.6.3.3 Finalize Exact Locations for Pushes. Because it is necessary to protect existing piping/wiring networks from damage and to workers during intrusive sampling activities, a GPR survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinate via GPS survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). The TL selects the location of the DPs to meet the program needs as defined in Section 6.6.3.1 and the tank farm requirements developed in Section 6.6.3.2.

The work plan may not specify all details needed for implementation. In such cases (e.g., the exact type of instrument or the precise logging rates), the TL consults the relevant technical experts and specific needed details.

The TL documents the final decisions and its reasons via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 6.6.3.9) is issued.

6.6.3.4 Create Direct Push Work Control Instructions (Work Package). Based on the work plan (Section 6.6.3.1), the tank farm requirements (Section 6.6.3.2), and the exact location of the proposed DP campaign and other implementing details (Section 6.6.3.3), draft work controls instructions (informally known as a work package) are prepared. This work package is finalized after DP services are procured and the drilling subcontractor submittals and work

details are incorporated. This work package is signed off by designed subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

6.6.3.5 Procure Direct Push Services. If a subcontractor is used to provide DP services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required. A detailed statement of work is prepared, reviewed, and approved before submittal to Procurement.

6.6.3.6 Pushes and Logging. Direct push and logging activities are done according to the approved work plan, procedures, and contract documents. The logs that are usually run consist of total (gross) gamma and neutron moisture gage. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.3.9). The type and extent of logging are determined by the work plan or work package. Before each DP is started, the drilling contractor obtains a Start Card from the Ecology (WAC 173-160-151).

6.6.3.7 Publish Direct Push Logs. On completion of the logging of all DP holes in a given campaign, the subcontractor performing the logging prepares a report describing the methods used and analyses of the geophysical logs. This report is provided to the BTR and subsequently published as an RPP document or as part of the Water Well Report (Section 6.6.3.9), normally within 3 months of the completion of logging. This effort is generally needed to support any performance-based incentive deliverable.

6.6.3.8 Decommission Probeholes. All probeholes are decommissioned in compliance with WAC 173-160 unless a written variance to those requirements is received from Ecology. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.3.9).

Based on work plan requirements or by the direction of the Director of the VZP, deep SGE electrodes or other instrumentation could be placed into the probehole during decommissioning. The locations of these probeholes are surveyed using GPS technology to complete the required Engineering Change Notices for tank farms.

6.6.3.9 Document Installation and Decommissioning of Probeholes. Completion is documented by formal submittal of a completed Ecology Water Well Report for each DP. A copy is provided to the Hanford Site contractor (currently the CPC) charged with maintaining well records.

In addition, a Completion Report that documents the DP activities is published as an RPP document. The report includes

a. Copy of the Start Card.
b. Daily activity logs.
c. Copy of the initial Chain-of-Custody forms.
d. Copy of the Water Well Report as a decommissioning.
e. Copy of the e-mails documenting the technical reasons for decisions (Section 6.6.3.3).
f. Deviations from the approved work plan are documented.

6.6.3.10 Summary of Decision Points during the Activity to Log New Direct Push Probeholes. Table 6-5 presents the summary of decision points during the activity to log new DP probeholes.

Table 6-5. Summary of Decision Points during the Activity to Log New Direct Push Probeholes

Decision	Decision Maker	Section
Goals of DP activity	DQO/work plan	6.6.3.1
Exact location and details of each DP hole	TL	6.3.3.3

TL = Vadose Zone Drilling and Sampling Technical Lead

6.6.3.11 Summary of Records and Documents Generated During the Activity to Log New Direct Push Probeholes. Table 6-6 displays the records and documents generated during the activity to log new DP probeholes.

Table 6-6. Data, Documents, and Records Generated during the Activity to Log New Direct Push Probeholes

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	6.6.3.1
Work plan [a,b]	Characterization requirements	VZP	6.6.3.1
E-mail [c]	Technical description of DP locations and reasoning	TL	6.6.3.3
Work control instructions [d]	Tank farm approval and duties for DP activity	SST Closure organization	6.6.3.4
Statements of work [c] (input to contract)	Technical description of work to be done	TL	6.6.3.5
Contracts [e]	Contract with driller and geophysics contractor	Procurement	6.6.3.5
Start Card [b]	State approval for DP	DP contractor	6.6.3.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	DP contractor	6.6.3.6
Geophysical raw data (input into geophysics report)[c]	Raw data from field measurements	Geophysics contractor	6.6.3.6
Geophysics report [a]	Reduction of geophysical data into interpreted data	Geophysics contractor	6.6.3.7
Water Well Report [b]	Completion decommissioning of DP probeholes	DP contractor	6.6.3.8
Completion Report [a]	Document DP activity	DP contractor	6.6.3.8

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
TL = Vadose Zone Drilling and Sampling Technical Lead

6.6.4 Installation of Only Instruments

Figure 6-5 displays the processes used for DP technology is used only to install instruments. Sections 6.6.4.1 through 6.6.4.8 describe each step. Section 6.6.4.9 summarizes the decision points during the DP activity, while Section 6.6.4.10 summarizes the documents and records produced.

6.6.4.1 Requirements from DQO and Work Plan. The DQO and Work Plan covering the laboratory analyses describes

a. General goals of the analyses.
b. Number of locations.
c. General locations of holes.
d. Whether holes is to be vertical or slanted.
e. Targeted depth of pushes.

6.6.4.2 Determine Tank Farm Requirements for Direct Push Campaign. Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the DP work package (Section 6.6.4.4).

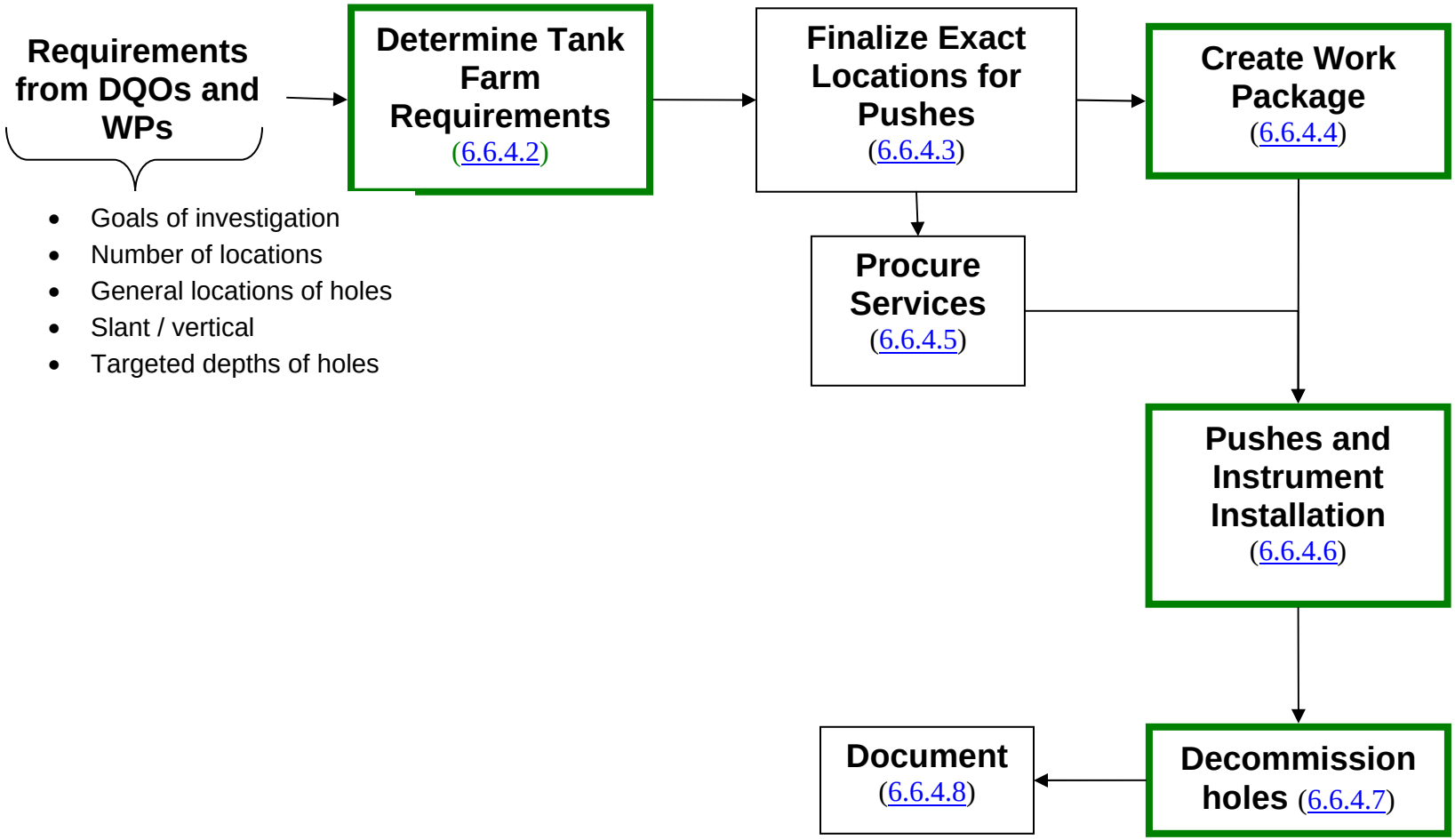
If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate contractors must be determined.

6.6.4.3 Finalize Exact Locations for Pushes. Because it is necessary to protect existing piping/wiring networks from damage and to protect workers during intrusive sampling activities, a GPR survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinate via GPS survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). The TL selects the location of the DPs to meet the program needs as defined in Section 6.6.4.1 and the tank farm requirements developed in Section 6.6.4.2.

The work plan may not specify all details needed for implementation. In such cases (e.g., the exact model of instrument or the precise placement depth), the TL consults the relevant technical experts and specify needed details.

The TL documents the final decisions and its reasons via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 6.6.4.8) is issued.

Figure 6-5. Direct Push Processes for Instrument Installation Only



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

6.6.4.4. Create Direct Push Work Control Instructions (Work Package). Based on the work plan (Section 6.6.4.1), the tank farm requirements (Section 6.6.4.2), and the exact location of the proposed DP campaign and other implementing details (Section 6.6.4.3), draft work controls instructions (informally known as a work package) are prepared. This work package is finalized after DP services are procured and the drilling subcontractor submittals and work details are incorporated. This work package is signed off by designated subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

6.6.4.5 Procure Direct Push Services. If a subcontractor is used to provide DP services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required. A detailed statement of work is prepared, reviewed, and approved before submittal to Procurement.

6.6.4.6 Pushes and Instrument Installation. Direct push and instrument installation activities are done according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 6.6.4.8). Before each DP is started, a Start Card is obtained from Ecology (WAC 173-160-151). The type and placement of the instruments are determined by the work plan or work package.

6.6.4.7 Decommission Probeholes. All probeholes are decommissioned in compliance with WAC 173-160, unless a written variance to those requirements is received from Ecology. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are be part of the Completion Report (Section 6.6.4.8).

6.6.4.8 Document Installation and Decommissioning of Probeholes. Completion is documented by formal submittal of a completed Ecology Water Well Report for each DP. A copy is provided to the Hanford Site contractor (currently the Central Plateau Contractor [CPC]) charged with maintaining well records.

In addition, a Completion Report that documents the DP activities is published as an RPP document. The report includes

a. Copy of the Start Card
b. Daily activity logs
c. Copy of the initial Chain-of-Custody forms
d. Copy of the Water Well Report as a decommissioning.
e. Copy of the e-mails documenting the technical reasons for decisions (Section 6.6.4.3)

Deviations from the approved work plan are documented.

6.6.4.9 Summary of Decision Points during Instrument Installation Using New Direct Push Probeholes. Table 6-7 presents the summary of decision points during instrument installation using new DP probeholes.

Table 6-7. Summary of Decision Points during Instrument Installation Using New Direct Push Probeholes

Decision	Decision Maker	Section
Goals of DP activity	DQO/work plan	6.6.4.1
Exact location and details of each DP hole	TL	6.6.4.3

TL = Vadose Zone Drilling and Sampling Technical Lead

6.6.4.10 Summary of Records and Documents Generated during Instrument Installation Using New Direct Push Probeholes. Table 6-8 displays the records and documents generated during instrument installation using new DP probeholes.

Table 6-8. Data, Documents, and Records Generated during Instrument Installation Using New Direct Push Probeholes

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	6.6.4.1
Work plan [a,b]	Characterization requirements	VZP	6.6.4.1
E-mail [c]	Technical description of DP locations and reasoning	TL	6.6.4.3
Work control instructions [d]	Tank farm approval and duties for DP activity	SST Closure organization	6.6.4.4
Statements of work [c] (input to contract)	Technical description of work to be done	TL	6.6.4.5
Contracts [e]	Contract with driller and geophysics contractor	Procurement	6.6.4.5
Start Card [b]	State approval for DP	DP contractor	6.6.4.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	DP contractor	6.6.4.6
Water Well Report [b]	Completion decommissioning of DP probeholes	DP contractor	6.6.4.8
Completion Report [a]	Document DP activity	DP contractor	6.6.4.8

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
TL = Vadose Zone Drilling and Sampling Technical Lead

7. NEAR-SURFACE SAMPLING

7.1 PURPOSE

The sampling discussed so far is normally far below the ground surface. However, surface and near-surface samples are required for direct exposure risk analyses. Because such samples are obtained near the surface, less robust techniques can be employed. However, any penetration 12 inches or more requires an excavation permit from the Ecology.

This chapter deals with near-surface sampling not performed by DP techniques, which is discussed in Chapter 6, or opportunistic near-surface sampling, which is discussed in Chapter 8.

7.2 DESCRIPTION

Samples on the surface or near the surface (approximately the top 5 feet) can provide information useful for ecological and worker safety assessments. Such a sampling campaign usually covers a large area and often employs randomly selected locations.

Technologies that are covered in this chapter are

a. Hand excavation.
b. Auger excavation.
c. Surface collection.

If the excavation is 12 inches or more below the ground surface, then an excavation permit ("Start Card") must be obtained from Ecology (WAC 173-160-151).

7.3 RELATIONSHIP TO OTHER TECHNOLOGIES

This sampling technique complements the other borehole, direct push, and opportunistic sampling techniques (Chapter 5, Chapter 6, and Chapter 8, respectively). The samples obtained are analyzed in a laboratory (Chapter 13) usually using predefined methods (Section 13.6.1).

7.4 BENEFITS AND LIMITATIONS

Because samples are collected near the surface, simple tools can be used. The principal limitation is that sampling is limited in depth, and depth control can be difficult using manual methods (such as hand excavation by shoveling).

7.5 FUTURE DEVELOPMENT

Surface and near-surface sampling is quite mature.

7.6 IMPLEMENTATION

Figure 7-1 displays the process used for near-surface sampling not performed by DP technology. Sections 7.6.1 through 7.6.11 describe each step. Section 7.6.10 summarizes the decision points during the near-surface sampling activity, while Section 7.6.11 summarizes the documents and records produced.

7.6.1 Requirements from Data Quality Objectives and Work Plan

The DQO and work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Number of locations.
c. General locations of sampling holes (including depth).
d. Type of laboratory analysis to be performed.

7.6.2 Determine Tank Farm Requirements for Near-Surface Sampling Campaign

Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the near-surface sampling work package (Section 7.6.4).

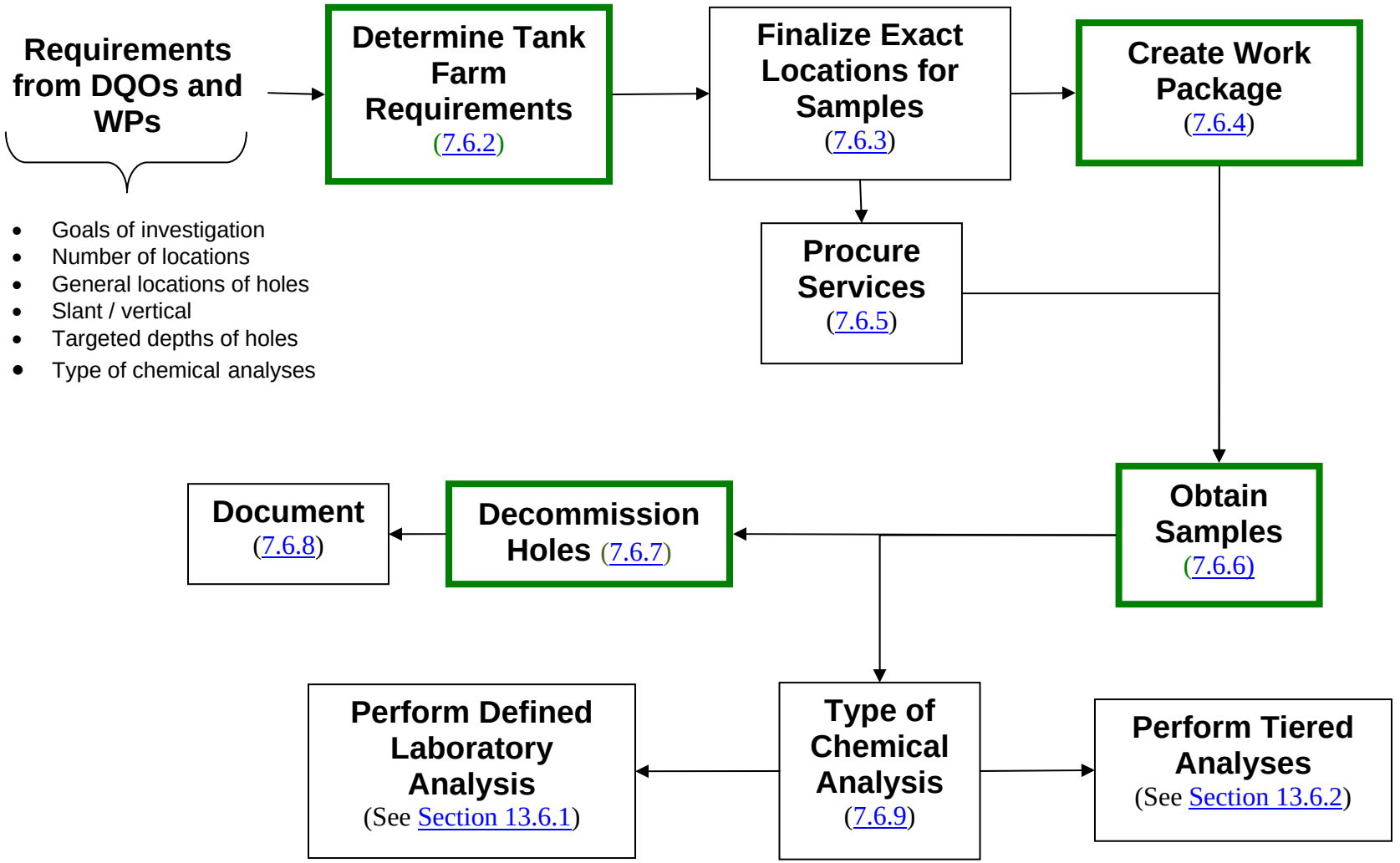
If any of the activities are to be performed outside of land assigned to the TFC, then the requirements of the appropriate contractors must be determined.

7.6.3 Finalize Exact Locations for Samples

Because it is necessary to protect existing piping/wiring networks from damage and to workers during intrusive sampling activities, additional activities are needed for samples gathered 12 inches or more below the surface. A GPR survey of the region(s) to be investigated is performed to confirm the positions of the pipes. These surveys are performed under a subcontract, using an orthogonal grid. All GPR data are referenced to State Planer coordinate via GPS survey and then transformed to tank farm coordinates. These data are analyzed to pick parabolas indicating subsurface structure; linear parabola picks are indicative of farm infrastructure. The GPR grid and identified subsurface structures are then electronically plotted on a composite map of underground and aboveground static features compiled from Hanford controlled drawings (the exact location of retrieval construction and piping is not always accurately shown on the figure and aerial photographs are not to scale and not completely reliable). The TL selects the location of the sampling to meet the program needs as defined in Section 7.6.1 and the tank farm requirements developed in Section 7.6.2.

The work plan may not specify all details needed for implementation. In such cases, the TL consults the relevant technical experts and specifies needed details.

Figure 7-1. Near-Surface Sampling



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

The TL documents the final decisions and the reasons via e-mail to all participants in the work plan approval (including the current ORP representative) and forwards the e-mail to the BTR, who formally informs the drilling subcontractor as to the action to be taken. The e-mail is treated as an in-process record until the Completion Report (Section 7.6.8) is issued.

7.6.4 Create Near-Surface Sampling Work Control Instructions (Work Package)

Based on the work plan (Section 7.6.1), the tank farm requirements (Section 7.6.2), and the exact location of the samples and other implementing details (Section 7.6.3), draft work controls instructions (informally known as a work package) are prepared. This work package is finalized after services are procured and the drilling subcontractor submittals and work details are incorporated. This work package is signed off by designated subject matter experts and managers and is released through the Shift Office on a daily basis when work is underway.

7.6.5 Procure Near-Surface Sampling Services

Sample collection may be performed by tank farm personnel. In such cases, samples are obtained following tank farm procedures and methods.

If the work is to be performed by non-tank-farm personnel, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

7.6.6 Obtain Near-Surface Samples

Sample collection and handling are performed according to the approved work plan, procedures, and contract documents. For sample tracking, generating sample identification numbers and generating Chain-of-Custody forms, the lead will establish a vadose zone sampling task for the Hanford Environmental Information System. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 7.6.8).

Before each excavation 12 inches or more below the surface, an excavation permit is needed and a Start Card (WAC 173-160-151) shall be obtained from Ecology when drilling equipment is used for borehole advancement and sample collection. Samples are obtained following the requirements of the work plan (Section 7.6.1) and the work package (Section 7.6.4). Once the samples are out of the sampling device, they are passed over to approved sampling technicians. The samplers prepare the sample following established procedures for transport, including Chain-of-Custody forms, and transport the sample material to the appropriate laboratory (usually within 24 hours). Once the samples are sent to the laboratory for analysis, that laboratory maintains record responsibility for the Chain-of-Custody forms. This process is repeated until all samples are collected.

7.6.7 Decommission Excavations

All borings requiring a Start Card will be decommissioned in compliance with WAC 173-160, unless a written variance to those requirements is received from Ecology. All decommissioning tasks are performed according to the approved work plan, procedures, and contract documents. Daily activity logs are maintained as in-process records and are part of the Completion Report (Section 7.6.8).

7.6.8 Document Installation and Decommissioning of Probeholes

A Completion Report that documents the near-surface sampling activities is published as a TFC document (RPP). The report includes

a. Copy of the Start Card, if needed.
b. Daily activity logs.
c. Copy of the initial Chain-of-Custody forms.
d. Copy of the Water Well Report as a decommissioning, as needed.
e. Copy of the e-mails documenting the technical reasons for decisions (Section 7.6.3).

Deviations from the approved work plan are documented.

All decommissioned borings requiring a start card will be documented by formal submittal of a completed Ecology Water Well Report for each excavation. A copy will be provided to the Hanford Site contractor (currently the CPC) charged with maintaining well records.

7.6.9 Type of Chemical Analysis

The work plan (Section 7.6.1) covering this activity normally specifies the type of chemical analyses to be performed on the samples. When the work plan is silent, the Director of the VZP (in consultation with ORP), determines the type of chemical analysis:

a. Predefined chemical analysis (see Section 13.6.1).
b. Tiered chemical analyses (see Section 13.6.2).

7.6.10 Summary of Near-Surface Sampling Activity Decision Points

Table 7-1 presents the summary of decision points during the near-surface sampling activity.

Table 7-1. Summary of Decision Points during the Near-Surface Sampling Activity

Decision	Decision Maker	Section
Goals of near-surface sampling activity	DQO/work plan	7.6.1
Exact location and details of each excavation	TL	7.6.3

TL = Vadose Zone Drilling and Sampling Technical Lead

7.6.11 Summary of Records and Documents Generated during Near-Surface Sampling Activity

Table 7-2 displays the records and documents generated during the near-surface sampling activity.

Table 7-2. Data, Documents, and Records Generated during the Near-Surface Sampling Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	7.6.1
Work plan [a,b]	Characterization requirements	VZP	7.6.1
E-mail [c]	Technical description of sampling location and reasoning	TL	7.6.3
Work control instructions [d]	Tank farm approval and duties for sampling	SST Closure organization	7.6.4
Statements of work [c] (input to contract)	Technical description of work to be done	TL	7.6.5
Contracts [e]	Contract with sampling contractor	Procurement	7.6.5
Start Card [b]	State approval for excavations greater than 12 inches in depth	Excavation contractor	7.6.6
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	Excavation contractor	7.6.6
Chain of Custody [f]	Sample history	Sampling crew	7.6.6
Water Well Report [b]	Completion of decommissioning, if excavations greater than 12 inches in depth	Excavation contractor	7.6.8
Completion Report [a]	Document excavation activity	Excavation contractor	7.6.8

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] SST Closure organization record
[e] Procurement record
[f] Laboratory record
TL = Vadose Zone Drilling and Sampling Technical Lead

8. OPPORTUNISTIC MEASUREMENTS AND SAMPLING

8.1 PURPOSE

This chapter describes the process used by the VZP when such opportunities arise to obtain subsurface samples because other tank farm activities have penetrated the surface.

8.2 DESCRIPTION

During tank waste retrieval construction and operations, the SST Closure organization performs surface measurements as well as disturb the surface (particularly trenching to lay hose-in-hose waste transfer lines). Such measurements may indicate surface or subsurface hot spots deserving of additional characterization. In addition, disturbing the surface may enable additional measurements below the normal tank farm surface.

8.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Samples are obtained for laboratory analyses, usually using predefined methods (Section 13.6.1).

8.4 BENEFITS AND LIMITATIONS

The benefit is that access to sampling zones can be increased. Also, the VZP can make use of routine measurements done by tank farm personnel.

The limitation is that other groups set priorities and timing.

8.5 FUTURE DEVELOPMENT

Closer cooperation between the VZP and the SST Closure organization will optimize these opportunities.

8.6 IMPLEMENTATION

This process is new and its process will be defined in Revision 1 of this document.

9. GEOPHYSICS USING EXISTING WELLS AND LATERALS

9.1 PURPOSE

The Hanford Site has a long history of detecting gamma radiation to estimate the extent of gamma radionuclides in the vadose zone. Gross gamma radiation measurements started in the 1940s in the tank farms and continued into the 1990s when spectral gamma radiation measurements began.

Many boreholes exist in the SST farms (from the tank farm surface down to 80 to 150 feet below the surface, with a few penetrating the vadose zone to groundwater). Most of the boreholes were installed to monitor whether tanks leaked and, if so, how far did contamination (particularly gamma-emitting contamination) extend. Such boreholes are also logged to support retrieval operations.

9.2 DESCRIPTION

Geophysics technology uses the measurement of energy or of scattered particles to infer properties of the vadose zone. The two most common techniques used at Hanford are measurement of

a. Gamma radiation emitted by radionuclides in the vadose zone sediments to infer the radionuclide concentration.
b. Scattered neutrons to infer the amount of hydrogen (and hence water) in the vadose zone sediments.

Both techniques can obtain information in an area about 18 inches in diameter around the borehole (or lateral). Beyond that distance, the shielding of the vadose zone sediments degrades the signal too much. Other geophysical measurement techniques have been tried at Hanford, but have not yet been successful.

Gamma radiation measurements have long been used in the tank farms. Total gamma radiation detectors were routinely (several times a quarter) placed in the boreholes surrounding the tanks to determine whether there was a trend of increasing radiation in the vadose zone. Many leaks from tanks were confirmed in this way. This effort was stopped in the early 1990s, although the complete set of measurements since the early 1970s was analyzed at the end of the 1990s.

In the late 1990s, the boreholes were relogged using high-resolution spectral gamma radiation detectors. These detectors allowed individual gamma emissions to be detected, allowing the identification of the radionuclide that was present. Using calibration models (to correct for detector placement, borehole wall thickness, and other items), actual concentrations for ^{137}Cs, ^{60}Co, ^{154}Eu, and uranium isotopes can be estimated. The system was even able to detect ^{90}Sr near tank B-110 because of its continuous brehmstralung spectrum. The system also has the capacity to detect the naturally occurring gamma emissions, which can aid in identifying geological transitions.

Gamma radiation detection is still being used for the following:

a. In new boreholes.
b. To detect vadose zone contamination from retrieval activities.
c. Estimate movement (by comparing new results to previous results).

Hydrogen (and hence water – H_2O) effectively backscatters neutrons. Thus, moisture logging tools can scatter neutrons and detect the presence of water by detecting scattered neutrons. Like gamma emission detectors, neutron moisture tools have a long history in Hanford tank farms. However, moisture measurements and changes are a less sensitive indicator of contamination than gamma emissions. Nevertheless, measurements showing higher contaminant concentrations are generally observed in regions of elevated water content in the sediment.

9.3 RELATIONSHIP TO OTHER TECHNOLOGIES

These tools need a free space to move. Boreholes (Chapter 5) and DP probeholes (Chapter 6) provide such a space.

Gamma radiation detection of man-made radionuclides demonstrates that a release of radioactive contamination has occurred. Thus, because of its relatively low cost, such detectors act as an excellent indicator for a release event. However, as the contaminants of most interest to groundwater protection are mobile contaminants (nitrate, hexavalent chromium, ^{99}Tc, and ^{129}I) that do not emit gamma radiation, gamma detection cannot estimate their presence or their concentration.

When releases have occurred, higher moisture zones point to zones where mobile contaminants (as they follow the water) are most likely to be found.

9.4 BENEFITS AND LIMITATIONS

Geophysics technology is relatively inexpensive and has important but limited uses.

Benefits include

a. Gamma detection is very sensitive (~0.1 pCi/g of ^{137}Cs).
b. Relatively low cost (can use existing boreholes).
c. Detection of man-made radionuclides indicates a release.
d. High moisture in a contamination area is usually associated with the contaminants of most interest in the protection of groundwater.

The limitations are

a. Limited to existing boreholes or new boreholes emplaced for another purpose.
b. Does not detect non-gamma-emitting contaminants (although these are the most important ones for groundwater protection).
c. High moisture content can occur from a variety of sources (including water line leaks).

9.5 FUTURE DEVELOPMENT

A variety of geophysical techniques have been tried at Hanford, including neutron activation. In this geophysical application, neutrons are sent into the vadose zone where they are captured. The new nuclide may emit gamma radiation which is detected by a gamma radiation detector. Such a system is quite sensitive to sodium and nitrogen, which are mobile and which are the main constituents of tank waste (sodium nitrate). If the sensitivity of this technique could be improved, this should be a valuable additional tool.

The metal-encased boreholes and probeholes prevent the detection of beta radiation, which is emitted by ^{99}Tc and ^{129}I, the two major radionuclides of interest in the protection of groundwater. However, it may be possible to develop a beta detector that could be used as part of probehole decommissioning. Such a system would allow the measurement of the concentrations of the key contaminants as a function of depth.

9.6 IMPLEMENTATION

Figure 9-1 displays the process used for logging activities. Sections 9.6.1 through 9.6.7 describe each step. Section 9.6.8 summarizes the decision points during the DP activity, while Section 9.6.9 summarizes the documents and records produced.

9.6.1 Requirements from Data Quality Objectives and Work Plan

The DQO and work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Determine technologies to be used.
c. Location of wells to be logged.

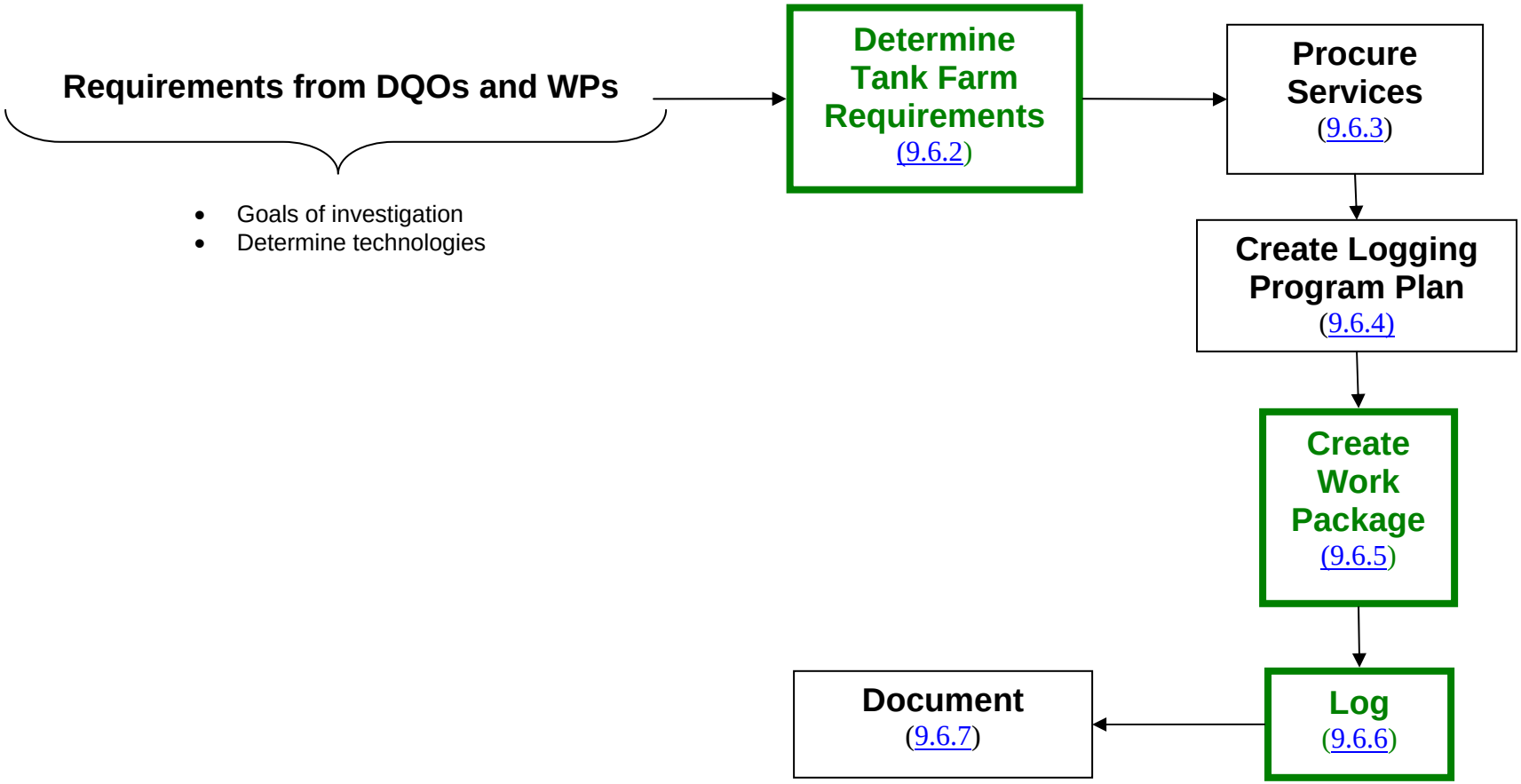
9.6.2 Determine Tank Farm Requirements

Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Determination of Tank farm requirements are determined by the SST Closure organization and documented in the logging work package (Section 9.6.7).

9.6.3 Procure Logging Services

If a contractor is to provide logging services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

Figure 9-1. Existing Hole Logging



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

9.6.4 Create Logging Program Plan

Based on retrieval monitoring needs and VZP characterization needs (as determined by the appropriate DQO and work plan, see Section 9.6.1), a program plan is produced annually that documents what logging of existing holes is to be performed and how it is to be performed. The logging program plan is issued as a TFC (RPP) document.

9.6.5 Create Work Package

Because logging is a repetitive process, it is anticipated that general work controls instructions (work package) are prepared to cover this work. Retrieval and Closure Planning would prepare the general work package based on the work plan (Section 9.6.1), the tank farm requirements (Section 9.6.2), and the logging program plan (Section 9.6.3). This work package can then be released through the Shift Office as needed to ensure that the needed logging is performed.

9.6.6 Log Existing Holes

Logging of existing holes in the tank farms is performed in accordance with logging subcontractor's approved procedures. Logging efforts anticipated, but not limited to, are the following:

a. Spectral gamma logging.
b. High-rate spectral gamma logging.
c. Neutron moisture gage logging.
d. Formation density.
e. Cased borehole resistivity.

A well logging request form is used to request and arrange for geophysical logging services. Raw geophysical data and daily activity logs are treated as in-process records until the logging document (Section 9.6.7) is issued.

9.6.7 Document Logging Activities

All logging activities are reported in an RPP document. Copies of logs with all header sheets and interpretations are provided to the requesting VZP scientist. Logging reports may be included in Water Well Report documentation. All logs are to be entered into the Hanford Environmental Information System in accordance with established procedures for that activity.

9.6.8 Summary of Logging Activity Decision Points

Table 9-1 presents the summary of decision points during the logging activity.

Table 9-1. Summary of Decision Points during the Logging Activity

Decision	Decision Maker	Section
Goals of logging activity	DQO/work plan	9.6.1
Determine logging requirements	Logging Technical Lead	9.6.4

9.6.9 Summary of Records and Documents Generated during Logging Activity

Table 9-2 displays the records and documents generated during the logging activity.

Table 9-2. Data, Documents, and Records Generated during the Logging Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	9.6.1
Work plan [a,b]	Characterization requirements	VZP	9.6.1
Statements of work [c] (input to contract)	Technical description of work to be done	TL	9.6.3
Contracts [d]	Contract with sampling contractor	Procurement	9.6.3
Logging program plan [a]	Documents planned implementation of logging	TL	9.6.4
Work control instructions [e]	Tank Farm approval and duties for logging	SST Closure organization	9.6.5
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	Logging contractor	9.6.6
Logging report [a]	Document logging	TL	9.6.7

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] Procurement record
[e] SST Closure record
TL = Vadose Zone Drilling and Sampling Technical Lead

10. SURFACE GEOPHYSICAL EXPLORATION

10.1 PURPOSE

Surface geophysical exploration uses electromagnetic waves and measurements to explore subsurface contamination. Initially, all electrodes and equipment were at the surface. Surface geophysical exploration has evolved to utilize existing boreholes as well as electrodes placed deep (~50 to 100 feet below ground surface) in the vadose zone.

10.2 DESCRIPTION

10.2.1 Definition.

Surface geophysical exploration is a set of electrical and magnetic measurements connected to a surface collector to infer subsurface infrastructure and contamination. The measurements typically are

a. GPR.
a. Magnetic field measurement.
b. Electromagnetic induction.
c. Earth resistivity measurement.

The first three techniques are designed to locate infrastructure that may interfere with the high-resolution resistivity investigation of deep vadose zone contamination.

Earth resistivity is based on the conceptual model that moisture and salts reduce the conductivity of sediments. As tank waste is mostly sodium nitrate, tank wastes in the vadose zone should reduce the conductivity of the soil and hence be visible to resistivity technology.

10.2.2 Uses and Potential Uses.

Surface geophysical exploration has proven uses and some potential uses if verification efforts prove the results of the technology:

a. Locating subsurface metal structures.
b. Locating other anomalies in the subsurface (e.g., contamination).
c. Determining the extent of contamination.
d. Indicating the presence and approximating concentration of key contaminants.

The use of GPR, magnetic field measurements, and electromagnetic induction measures to determine the presence of subsurface metal structures are well established. Tank farm procedures require that GPR be used before intrusions are made into the tank farm surface so as to avoid buried metal structures.

Early versions of resistivity techniques were successfully tested in the tank farms during the 1970s. Interest increased when high-resolution resistivity was used in the BC Cribs and

Trenches Zone, south of the 200 East Area, and found widespread resistivity anomaly between 100 and 150 feet below ground surface. Slightly earlier, laboratory analyses of borehole samples indicated such a high concentration at the same site. These results overturned the previous conceptual model that the mobile contaminants had already moved through the entire 300-foot vadose zone and had been flushed to groundwater.

Surface geophysical exploration was then tested in tank farms with mixed results. Results at T Farm showed contamination from the cribs and trenches outside of the farm but only signal noise under the tanks, which is thought to be due to the extensive set of buried pipelines. With the addition of using boreholes as electrodes, such noise was greatly reduced at the cost of losing all elevation information. Tests at S Farm revealed three-dimensional information (the S-104 leak plume extending southwest into groundwater). Borehole electrode tests at U Farm and C Farm show results basically consistent with previous gamma logging information.

However, how to quantitatively use the high-resolution resistivity data is still being assessed. Field verification (obtaining samples and subsequent laboratory analysis) is ongoing. Experiments are being performed to assess correlations of conductivity with moisture content, contaminant concentration, particle size, and geology (collectively known as petrophysics). Such information may allow SGE to be used in the future to estimate plume extent and potentially contaminant concentration.

10.3 RELATIONSHIP TO OTHER TECHNOLOGIES

At present, SGE is used as one of the sources of information used to guide placement of boreholes and DP probeholes. In the future, it may be used with waste stream information to infer subsurface contaminant concentrations.

10.4 BENEFITS AND LIMITATIONS

The benefits of surface geophysical exploration are

a. Spatial coverage can be large (e.g., the B/BX/BY tank farms and surrounding cribs and trenches, an area of over 4 M ft^2).
b. The depth coverage can extend from the surface to and into groundwater
c. When adapted to be used as a leak detection system, releases as low as 200 gallons can be detected.
d. The cost is relatively low.

The limitations are

a. Technology is still under development and is being tested for validity.
b. Subsurface metallic structures can mask signals.
c. Technology measures conductivity, which does not uniquely correspond with the concentration of any contaminant.

10.5 FUTURE DEVELOPMENT

Much work is needed to address the limitations cited in Section 10.4. Surface geophysical exploration is being tested and extended in a variety of tank farms and other Hanford facilities. Boreholes and DP probeholes are being used to obtain samples for laboratory measurement so that results of SGE can be compared to laboratory results. Experiments are being performed to assess correlations between conductivity and sediment moisture, contaminant concentration, particle size, and geology. Surface geophysical exploration is useful now as an aid to guide placement of boreholes and probeholes; however, to meet the full potential of SGE, more work is needed.

Because subsurface metallic structures can mask signals, some electrodes must be placed deep in the vadose zone. Experience must be gained to determine the optimal placement.

10.6 IMPLEMENTATION

Figure 10-1 displays the process used for SGE activities. Sections 10.6.1 through 10.6.12 describe each step. Section 10.6.13 summarizes the decision points during the DP activity, while Section 10.6.14 summarizes the documents and records produced.

10.6.1 Requirements from Data Quality Objectives and Work Plan

The DQO and work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Depth and extent of coverage.
c. Precision of results.

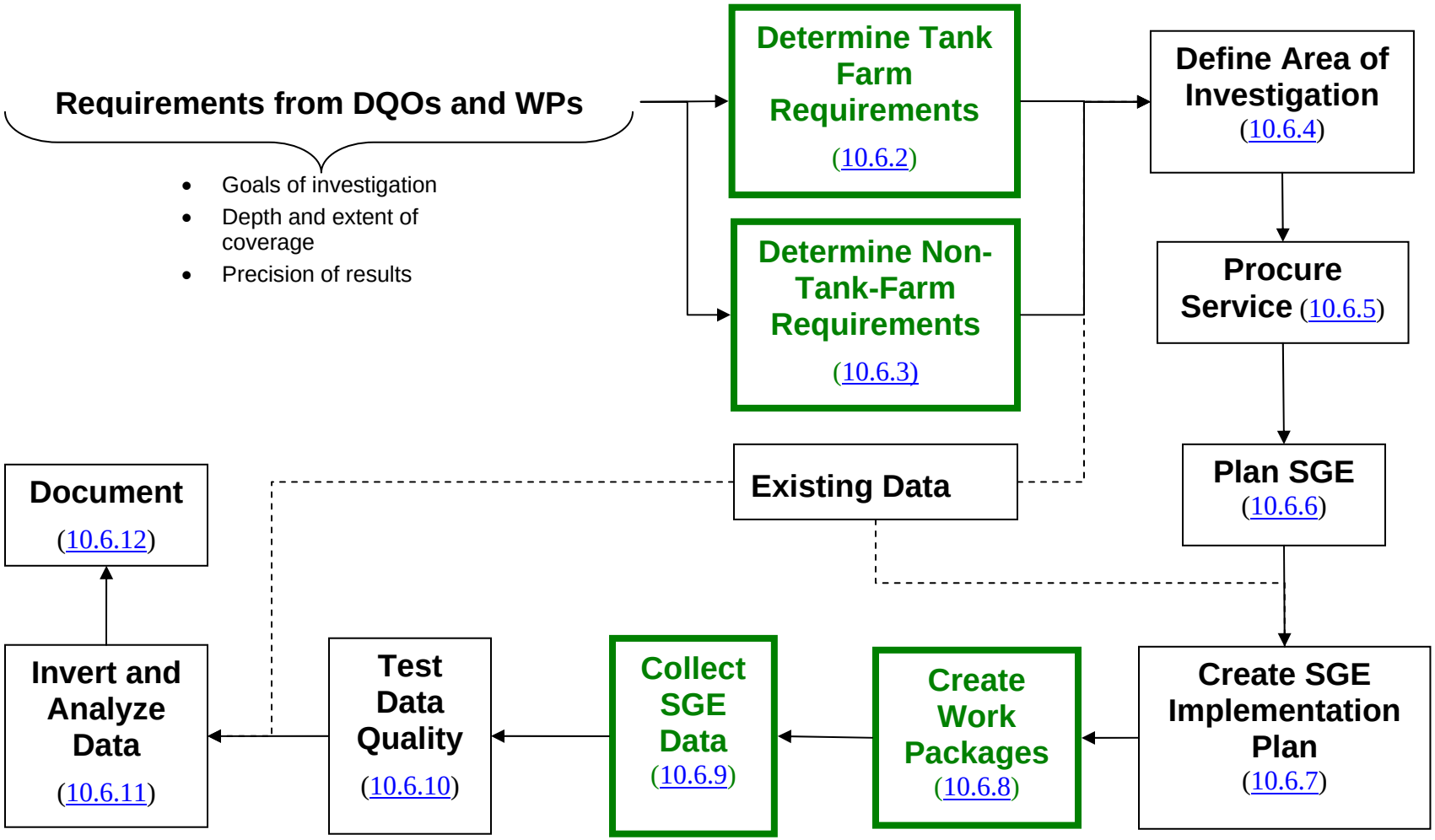
10.6.2 Determine Tank Farm Requirements

Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the SGE work package (Section 10.6.8).

10.6.3 Determine Non-Tank-Farm Requirements

Non-tank-farm requirements may be based on either health or safety or may be on information need. These requirements are determined through the Multi-Project Team associated with the area to be assessed using SGE. For help in determining land boundaries, the Facilities Services organization of the CPC should be contacted. The requirements are documented in the SGE work package (Section 10.6.8)

Figure 10-1. Surface Geophysical Exploration



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

10.6.4 Define Area of Investigation

Based on the requirements defined by both the TFC and the CPC, the basic area to be investigated is developed and provided to Procurement so that the appropriate services are obtained.

10.6.5 Procure Surface Geophysical Exploration Services

If a contractor provides SGE services, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

10.6.6 Plan Surface Geophysical Exploration

Planning the deployment of a geophysical survey requires the involvement of the subcontractor actually performing the work. Because geophysical surveys consist of indirect measurements of the environment, it is appropriate and cost effective to involve the subcontractor in the planning effort.

10.6.7 Create Surface Geophysical Exploration Implementation Plan

An implementation plan describing the extent and conduct of the SGE survey to be accomplished is developed jointly by the contractor and contracting organization. This plan is reviewed by appropriate Hanford Site entities [likely ORP, U.S. Department of Energy, Richland Operations Office (RL), the CPC, and the TFC] having interest in the data and interpretations to be made. It is likely that any SGE surveys conducted for the TFC include large areas that lie outside the tank farm boundaries. All formal SGE implementation plans for geophysical surveys contain a sign-off page so that concurrence by appropriate Hanford Site participants can be documented. The SGE implementation plan is published as a TFC (RPP) document.

10.6.8 Create Surface Geophysical Exploration Work Packages

Because geophysical surveys performed for the TFC extend beyond the boundaries of the tank farm being surveyed, a dual suite of work release packages must be prepared:

a. Work controls instruction (informally known as a work package) is needed for work inside the farm.

b. Work Release for Construction Service Organization Form (WRCSOF) for work outside the fences.

This dual release scenario requires at least 2 days longer to implement.

Based on the work plan (Section 10.6.1), the tank farm requirements (Section 10.6.2), non-tank-farm requirements (Section 10.6.3), and the SGE implementation plan (Section 10.6.7), the work package and WRCSOF are prepared. These work release documents are signed off by designated subject matter experts and managers and are released through the Shift Office on a daily basis when work is underway.

10.6.9 Collect Surface Geophysical Exploration Data

Surface geophysical exploration data consists of electromagnetic and magnetic data, GPR data, well-to-well resistivity data, surface-to-surface resistivity data, and well-to-surface resistivity data. Experience has shown that using permanent electrodes is both cost and time effective. Use of high precision GPS should be used during the electromagnetic and magnetic data collection, as well as GPR surveys, and is essential to precisely ascertain the three-dimensional positions of electrodes. The total time required to collect resistivity field data can be estimated at about 4 days per surface line.

10.6.10 Test Data Quality

Transient electrical fields, as well as interference from infrastructure, can influence the quality of resistivity data collected. It is imperative that data collection include repeat lines (data collection separated in time) as well as reciprocal collection. These data are then visually examined to ensure that interference does not obliterate the meaningful data. The SGE contractor determines whether data fail quality standards and must be retaken.

10.6.11 Invert and Analyze Data

Numerical analysis is necessary to convert the raw data into usable information. Data analysis routinely takes longer than data collection. Analysis is best conducted under the direct supervision of persons trained in geophysics as the number of variables that must be addressed exceeds the number of equations available to solve. Erroneous or physically impossible assumptions can render the analysis of a complete data set useless.

10.6.12 Document Surface Geophysical Exploration Activity

Analysis of SGE activity is documented in RPP documents. These documents contain descriptions of the findings as well as descriptions of how the data were handled and any caveats associated with use of the analyses. Raw data are preserved and provided in electronic format for archiving within the Hanford Environmental Information System. Due to the complexity of the full suite of SGE data, separate reports covering the electromagnetic, magnetic, and GPR data are often prepared and published individually.

10.6.13 Summary of Surface Geophysical Exploration Activity Decision Points

Table 10-1 presents the summary of decision points during the SGE activity.

Table 10-1. Summary of Decision Points during the SGE Activity

Decision	Decision Maker	Section
Goals of SGE activity	DQO/work plan	10.6.1
Determine area to investigate	SGE Technical Lead	10.6.4
Determine SGE implementation details	SGE Technical Lead	10.6.7
Determine adequacy of field data	SGE contractor	10.6.10

10.6.14 Summary of Records and Documents Generated during Surface Geophysical Exploration Activity

Table 10-2 displays the records and documents generated during the SGE activity.

Table 10-2. Data, Documents, and Records Generated during the SGE Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	10.6.1
Work plan [a,b]	Characterization requirements	VZP	10.6.1
Statements of work [c] (input to contract)	Technical description of work to be done	TL	10.6.5
Contracts [d]	Contract with sampling contractor	Procurement	10.6.5
SGE Implementation Plan [d]	Documents planned implementation of SGE	TL	10.6.7
Work control instructions [e]	Tank farm approval and duties for SGE	SST Closure organization	10.6.8
WRCSOF	CPC approval and duties for SGE	CPC	10.6.8
Daily records (input into Completion Report)[c]	Daily activities, released as part of Completion Report	SGE contractor	10.6.9
SGE report [a]	Document SGE measurements and processing	TL	10.6.12

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] Procurement record
[e] SST Closure record
TL = Vadose Zone Drilling and Sampling Technical Lead

11. IN-SITU MEASUREMENTS

11.1 PURPOSE

In-situ measurement results are derived from instruments placed in the vadose zone. Examples are moisture meters and moisture flow meters placed in the decommissioned borehole near tank B-110 and in T Farm via DP probeholes.

11.2 DESCRIPTION

So far, such instruments have been installed to measure infiltration rates in the tank farms. In particular, the moisture instruments in T Farm (one set outside the interim barrier, one just inside, and two well under the barrier) are to gauge how well the interim surface barrier performs.

11.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Such measurements are done on a continuous or near-continuous basis. Thus, these measurements at isolated depths supplement the more spatially continuous moisture logging measurements that are taken four times a year.

As noted, in-situ measurement devices have been installed in decommissioned boreholes or DP probeholes (see Section 5.2.2 and Section 6.2.2).

11.4 BENEFITS AND LIMITATIONS

The benefits of in-situ measurements are that they provide continuous or near-continuous readings.

The limitations of in-situ measurements are

a. Readings at a few (one to four) isolated depths.
b. Types of instruments are limited.
c. Malfunctions are difficult to repair.

11.5 FUTURE DEVELOPMENT

It would be beneficial to expand the type of instrumentation available.

11.6 IMPLEMENTATION

Figure 11-1 displays the process used for in-situ measurements. Sections 11.6.1 through 11.6.9 describe each step. Section 11.6.10 summarizes the decision points during the DP activity, while Section 11.6.11 summarizes the documents and records produced.

11.6.1 Requirements from DQO and Work Plan

The DQO and work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Determine technologies to be used.

11.6.2 Determine Tank Farm Requirements

Tank farm requirements are subject to regular updates as conditions inside the farms are regularly monitored and changes in working conditions recognized. Tank farm requirements are determined by the SST Closure organization and documented in the logging work package (Section 11.6.5).

11.6.3 Procure Services

If a contractor installs the in-situ instruments or performs the measurements, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

11.6.4 Create Test Plan

Based on program needs (established in Section 11.6.1) and tank farm requirements (established in Section 11.6.2), a test plan that describes the design, installation, and operation of the in-situ measurements is created and issued as a TFC (RPP) document.

11.6.5 Create Work Package

One or more work controls instructions (work package) are prepared to cover this work. A separate work package may be created for the installation of the instruments, while a general work package may be created for the operation/monitoring of the instruments. Retrieval and Closure Planning prepares the work package based on the work plan (Section 11.6.1), the tank farm requirements (Section 11.6.2), and the test plan (Section 11.6.4). The Shift Office releases the appropriate work package as necessary.

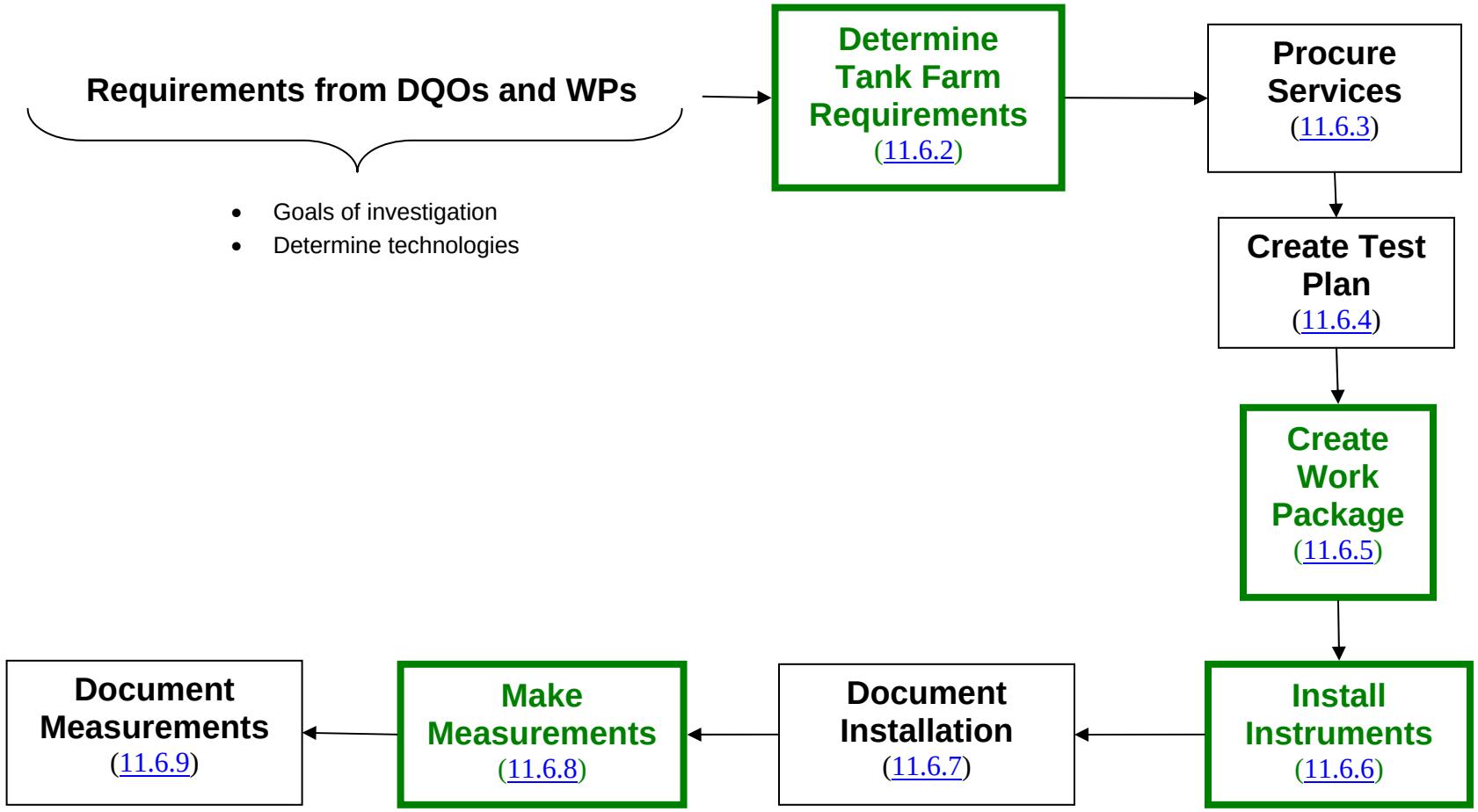
11.6.6 Install Instruments

The instruments are designed/manufactured or purchased based on the requirements of the test plan (Section 11.6.4). The instruments are installed in accordance with the work package.

11.6.7 Document Instrument Installation

The installation of the in-situ instruments is documented via a formally issued report (normally an RPP document).

Figure 11-1. In-Situ Measurements



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

11.6.8 Make Measurements

Measurements are made consistent with the test plan (Section 11.6.4). If access to the tank farms is required, the effort is also performed consistent with the appropriate work package. Logs are treated as in-process records until formally documented and released (Section 11.6.9). Copies of logs with all header sheets and interpretations are to be provided to the requesting VZP scientist. Logging reports may be included in Water Well Report documentation. As determined by the Director, VZP, the logs are entered into the Hanford Environmental Information System in accordance with established procedures for that activity.

11.6.9 Document Measurements

The measurements are formally documented and released [normally as a TFC report (RPP)]. The report should be issued at least annually.

11.6.10 Summary of Logging Activity Decision Points

Table 11-1 presents the summary of decision points during the logging activity.

Table 11-1. Summary of Decision Points during the Logging Activity

Decision	Decision Maker	Section
Goals of in-situ measurements activity	DQO/work plan	11.6.1
Determine in-situ measurements requirements	Director, VZP	11.6.4
Determine whether data go into Hanford Environmental Information System	Director, VZP	11.6.8

11.6.11 Summary of Records and Documents Generated during Logging Activity

Table 11-2 displays the records and documents generated during the logging activity.

Table 11-2. Data, Documents, and Records Generated during the Logging Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	11.6.1
Work plan [a,b]	Characterization requirements	VZP	11.6.1
Statements of work [c] (input to contract)	Technical description of work to be done	TL	11.6.3
Contracts [d]	Contract with subcontractors	Procurement	11.6.3
Test plan [a]	Planned implementation of in-situ measurement	TL	11.6.4
Work control instructions [e]	Tank farm approval and duties for in-situ measurement	SST Closure organization	11.6.5
Daily records (input into installation report)[c]	Daily activities, released as part of installation report	Contractor	11.6.6
Installation report [a]	Documents installation of instruments	TL	11.6.7
Raw measurement data [c]	Raw data taken from instruments	Contractor	11.6.8
Measurements report	Documents measurements	Contractor	11.6.9

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] Procurement record
[e] SST Closure record
TL = Vadose Zone Drilling and Sampling Technical Lead

12. NON-TANK-FARM FIELD MEASUREMENTS

12.1 PURPOSE

Because of their past operations, tank farms tend to be heavily contaminated. Other facilities (primarily on Hanford's Central Plateau) can provide different environmental conditions (often natural or uncontaminated), which can fill important gaps needed for the closure of the tank farms.

12.2 DESCRIPTION

Field measurements away from the tank farms can provide very valuable information on the fate and transport of tank farm contamination. Examples are

a. Characterization activities at the Integrated Disposal Facility.
b. Characterization activities at the BC Cribs and Trenches.
c. Measurements at the Field Lysimetry Test Facility.
d. Groundwater monitoring.
e. Other field measurements in the Central Plateau.
f. Other field measurements on or off the Hanford Site.

The Integrated Disposal Facility is located in an uncontaminated area in the south central part of the 200 East Area. Seven boreholes, most continuously split-spoon sampled, were constructed around the site. In addition, site geologists studied the large excavation (50 feet deep by 1300 feet east to west and 1000 feet north to south), and large core samples were taken during the excavation. Because of their uncontaminated nature, the samples were extensively tested using a variety of geological, hydraulic, and geochemical experimental techniques, resulting in new conceptual models as well as an extensive database. The VZP has made extensive use of this information and understanding of moisture flow and contaminant movement through uncontaminated sediments.

The BC Cribs and Trenches, located south of the 200 East Area, received overflow tank wastes. The Hanford Site CPC is characterizing this region as it contains the largest inventory of ^{99}Tc in the vadose zone. Characterization includes samples from discrete borehole elevations and SGE. More characterization is planned as are deep vadose zone remediation tests. The VZP has been actively partnering as the understanding of how tank wastes moved in this area are relevant to how tank wastes moved under tank farms.

The Field Lysimetry Test Facility, located between the 200 West and 200 East Areas, was built as an experimental field station to measure moisture infiltration in support of the Hanford Surface Barrier Program. It consists of 24 cylinders (known as lysimeters), which are filled with a variety of sediments, topped with various surface treatments, and are heavily instrumented. This facility has and is continuing to provide a wealth of information over its two-decade life on how water moves through and is stored in Hanford's surface and near surface. The VZP is using this knowledge to estimate past and future moisture drivers.

The Hanford Site has monitored the groundwater for radionuclides and chemicals since the 1950s, with increased effort and discipline since 1990. Hundreds of wells are monitored. Although groundwater contamination lags vadose zone contamination, the presence of the extensive groundwater network combined with its long time history provide a rich database as to the identification of key contaminants and their movement. The VZP has used this information to understand possible sources and their importance. In addition, there is extensive characterization of other Hanford Central Plateau sites. The VZP integrates with other site contractors (see Chapter 16) on planning, implementation, and analysis.

12.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Often samples are obtained from such activities for VZP that are analyzed following the methods of Chapter 13.

12.4 BENEFITS AND LIMITATIONS

The main benefits of non-tank-farm field measures are

a. Characterization can be performed in a less crowded environment.
b. Characterization of noncontaminated soils can be performed to obtain natural vadose zone properties.
c. Minimal cost to the program.
d. Exposure to new and different approaches.

The use of the SGE at the BC Cribs and Trenches is an excellent example of the last benefit.

The main limitation of non-tank-farm efforts is that the efforts are not tank farm site specific. However, as the tank farms are scattered in the 200 West and East Areas and as the waste streams investigated are often related to tank waste streams, the information is usually extremely useful.

12.5 FUTURE DEVELOPMENT

Characterization of Hanford non-tank-farm facilities will continue. Through integration (Chapter 16), tank farm and other field characterizations will be optimized.

12.6 IMPLEMENTATION

The data are determined to be needed based on a DQO or work plan (see Section 2.3). However, how the data are obtained is normally established by the organization responsible for the obtaining the data. In some cases, the VZP provides full or partial funding.

13. LABORATORY ANALYSES

13.1 PURPOSE

Laboratory analyses allow the use of much higher quality instrumentation (capability, accuracy, precision, thresholds) than field analyses.

13.2 DESCRIPTION

Vadose zone samples include

a. New sediments.
b. Archived sediments.
c. Tank residual samples.
d. Archived tank waste samples.

Once vadose zone samples are obtained (from boreholes, DP probeholes, excavations, or retrieval), a wide variety of tests can be performed in the laboratory:

a. Geological data.
b. Visual inspection.
c. Particle size.
d. Density.
e. Constituent concentrations.
    1. Moisture content.
    2. pH and electrical conductivity.
    3. Contaminant concentrations.
    4. Speciation.
    5. Chemical form.
f. Hydraulic Data.
    1. Moisture retention curves.
    2. Unsaturated and saturated conductivity.
    3. Impacts of contaminants on hydraulic data.
    4. Effects of layering.
g. Geochemical.
    1. Mineralogy.
    2. Contaminant chemical interactions with sediments affecting transport.
    3. Contaminant interactions with sediments affecting sediment structure.
    4. Contaminant interactions with other contaminants in the waste.
h. Chemical.
    1. Contaminant release rates and models from residual waste.
    2. Verification of past waste processing flow sheets.

Geological units are the major physical units in any vadose zone conceptual model. The hydraulic and geochemical processes and parameters depend on the geologic units. Except when there is a deep extended excavation (such as the excavation for the Integrated Disposal Facility), geologists must rely on samples brought to the surface.

A major part of Hanford's laboratory activities are devoted to measuring the concentration of contaminants in vadose zone and groundwater media. For the vadose zone, the moisture content, pH, and electrical conductivity can provide important indications of the past presence or influence of contaminant plumes. A variety of analytical instrumentation is used, including pH meters, conductivity detectors, alkalinity titrator, carbon analyzers, ion chromatography, inductively coupled plasma-mass spectrometers, inductively coupled plasma-optical emission spectrometers, and X-ray diffraction and fluorescence units.

Hydraulic data estimate how moisture moves through the system. As moisture enhances contaminant release (in most instances) and is the major driver for contaminant movement, understanding moisture flow is critical. The movement of moisture through the vadose zone is a complicated nonlinear system with feedback and hysteresis. The parameters in the equations describing the flow processes must be estimated through laboratory measurements, upscaled for layering and other effects. Highly waste-impacted sediments show different behavior than natural sediments.

Because contaminants interact with vadose zone sediments, most contaminants do not move with the moisture but rather are retarded. Such geochemical retardation depends on moisture content, sediment density, contaminant speciation, chemical form, and mineralogy of the sediments. Again, highly waste-impacted sediments show different properties than natural sediments. A very wide variety of advanced instrumentation is used in such studies, including the use of high-energy particle accelerators and other unique equipment only available in certain national laboratories.

Chemical measurements and analyses are performed on other materials as well. The contaminant release rate from residual waste or package waste can be a complicated function of the surrounding moisture environment and the waste. Again the equations are complicated and nonlinear. Chemical experiments tease out the information to estimate the future releases. Additional chemical analyses are performed to imitate the fuel reprocessing previously done at the Hanford Site that created the various tank waste streams. Although this fuel processing chemistry was very well understood and inventories for the major constituents measured, assumptions were often made for trace elements. However, some of these trace elements (like technetium) are now very important for groundwater intrusion and protection. Thus, new efforts are occurring to validate the prior assumptions.

13.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Boreholes and DP probeholes are the major means for obtaining vadose zone samples. Excavation is sometimes used to obtain shallow samples. Residual waste samples are normally obtained as part of the tank waste retrieval activities.

13.4 BENEFITS AND LIMITATIONS

Laboratory analyses provide data that are not available in any other way. The limitations are that samples must be obtained and that some contaminants (e.g., ^{129}I) and parameters (hydraulic properties at very low moisture content) are difficult and expensive to obtain.

13.5 FUTURE DEVELOPMENT

Lower detection limits (e.g., ^{129}I) and less expensive approaches are always desired. The advance in the last decade in using leading edge technology and instruments for vadose zone problems is remarkable.

13.6 IMPLEMENTATION

The traditional method to perform laboratory analyses for environmental investigations is to predefine the measurement methods and requirements before the analyses begin. This works very well when one is simply trying to obtain data on the concentration level of suspected contaminants.

During its initial phase (DOE/ORP 2008), the VZP found that to provide understanding for a poorly understood environment, a tiered approach of laboratory analyses (Section 13.6.2) is much more efficient and useful. In such an approach, Tier I analyses are performed to determine whether the sample is contaminated and to estimate the concentrations of key contaminants. A Tier II analysis is then performed to estimate concentrations of other contaminants and to perform tests on the migration of contaminants and other key properties to support remediation of contaminated sediments.

A similar test process is used in the analysis of residual samples remaining after tank waste retrieval.

13.6.1 Processes for Predefined Laboratory Analyses

Predefined laboratory analyses are defined in the work plan, usually in a sample and analysis plan. Such an approach works well when the goals of the laboratory analyses are simple and well defined. Examples of such predefined laboratory analyses are to

a. Determine when contamination is present in sediments or has passed through them.
b. Obtain supporting data (such as petrophysical data in support of SGE).

If the analyses are not described in a work plan (for example, most work plans deal with contaminant concentrations), then a test plan is written. Figure 13-1 displays the typical process for predefined laboratory analyses.

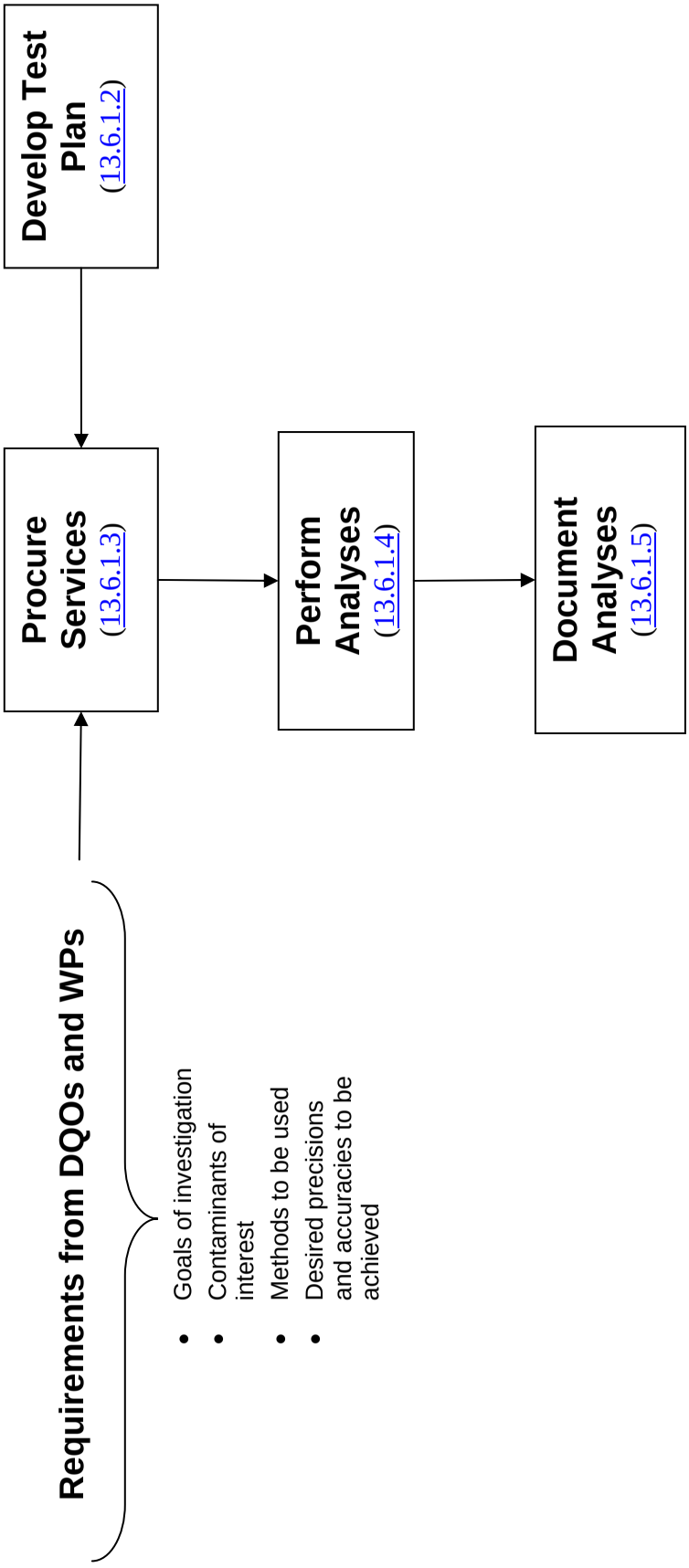


Figure 13-1. Predefined Laboratory Analyses

13.6.1.1 Requirements from Data Quality Objectives and Work Plan. The DQO and work plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Contaminants of interest.
c. Methods to be used.
d. Desired precisions and accuracies to be achieved.

13.6.1.2 Develop Test Plan. Particularly to support technology development or to estimate physical and geochemical properties, the DQO or work plan may not address needed laboratory measurements. In such cases, the Director, VZP, can decide that measurements beyond those mandated by the work plan are needed. A test plan is then developed to describe the needed analyses and how they are performed.

13.6.1.3 Procure Services. If a contractor performs the chemical analyses, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required.

All laboratory analyses must meet the requirements of the *Hanford Analytical Services Quality Assurance Requirements Documents* (DOE/RL 2007).

13.6.1.4 Perform Measurements. Measurements are made consistent with the work plan's sampling and analysis plan (Section 13.6.1.1) or with the test plan (Section 13.1.6.2). Raw data and logs are treated as in-process records until formally documented and released (Section 13.6.1.5). Concentration data are to be entered into the Hanford Environmental Information System in accordance with established procedures. For other data, the Director, VZP, determines whether the data are to be entered into the Hanford Environmental Information System in accordance with established procedures for that activity.

13.6.1.5 Document Measurements. The measurements are formally documented and released [normally as a TFC document (RPP)].

13.6.1.6 Summary of Logging Activity Decision Points. Table 13-1 presents the summary of decision points during the logging activity.

Table 13-1. Summary of Decision Points during the Predefined Laboratory Analyses

Decision	Decision Maker	Section
Goals of in-predefined laboratory measurements	DQO/work plan	13.6.1.1
Determine whether a test plan is needed	Director, VZP	13.6.1.1
Determine test plan requirements	Director, VZP	13.6.1.2
Determine whether data go into Hanford Environmental Information System	Director, VZP	13.6.1.4

13.6.1.7 Summary of Records and Documents Generated during Logging Activity. Table 13-2 displays the records and documents generated during the logging activity.

Table 13-2. Data, Documents, and Records Generated during the Predefined Laboratory Analyses Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	13.6.1.1
Work plan [a,b]	Characterization requirements	VZP	13.6.1.1
Test plan	Alternative to work plan	VZP	13.6.1.2
Statements of work [c] (input to contract)	Technical description of work to be done	Laboratory Technical Lead	13.6.1.3
Contracts [d]	Contract with subcontractors	Procurement	13.6.1.3
Raw measurement data [c])	Raw data taken from instruments	Contractor	13.6.1.4
Measurements report	Documents measurements	Contractor	13.6.1.4

[a] Published document
[b] Regulatory approval necessary
[c] In-process record
[d] Procurement record
[e] SST Closure record

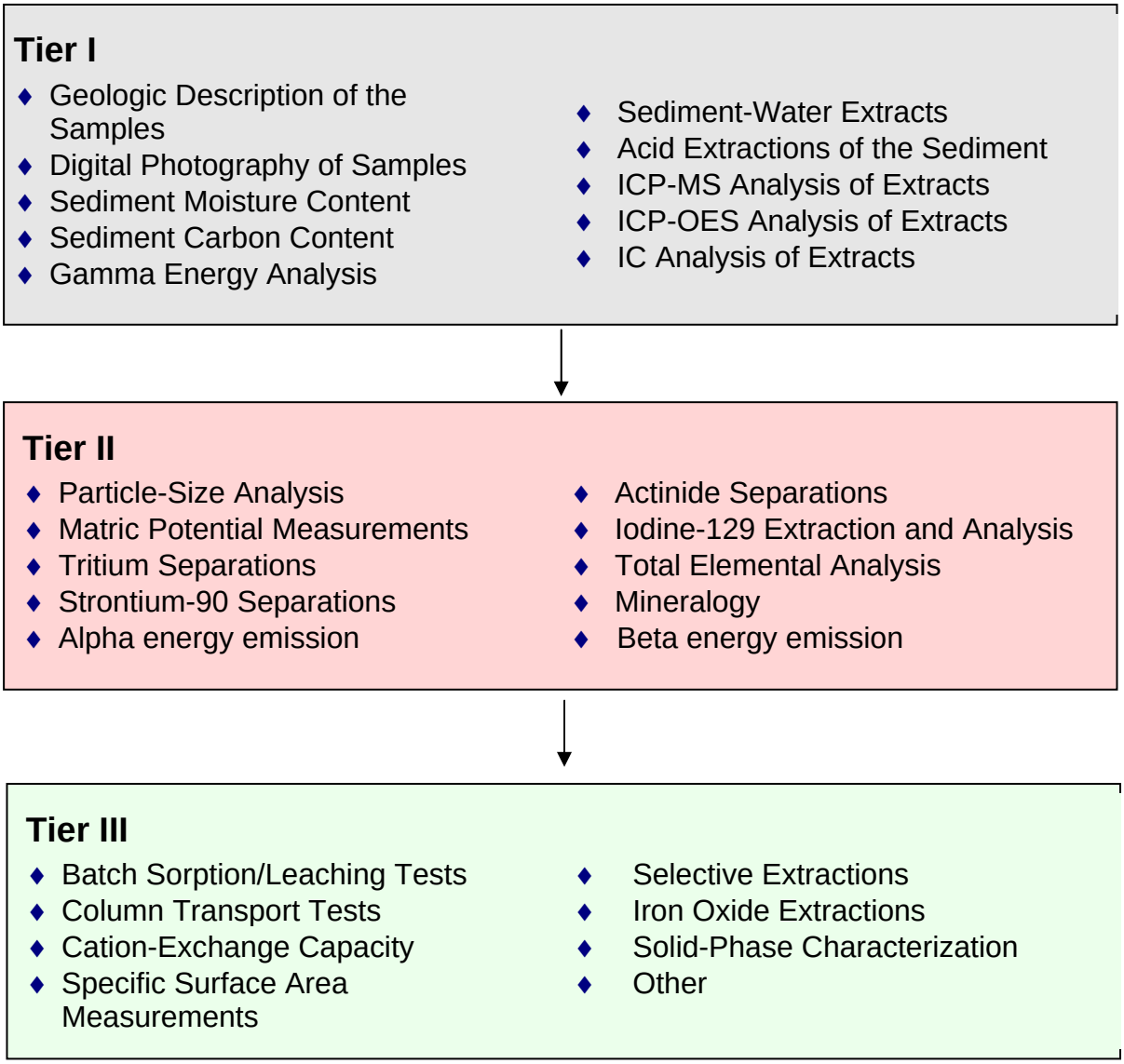
13.6.2 Processes for Tiered Laboratory Measurements of Sediments

Performing a tiered analysis, where initial measurements can fine tune the choice of subsequent analyses, has proved very useful to the VZP. Sample size is often very limited, particularly samples from DP technology. Moreover, the samples can be very hazardous to handle, making unnecessary measurements potentially costly in human impacts. The tier laboratory protocol optimizes the selection of analyses.

The basic premise of the three-tiered approach (see Figure 13-2) is to acquire the largest amount of scientific information, through an incremental process, that can be used to best meet program objectives while conserving resources and limiting risk to workers. Another factor that must be considered when working with sediment samples is that sample mass often is limited as a function of the field techniques used to acquire the sediment from beneath the tank farms. Depending on the drilling or coring technique, sediment samples range in mass from a few hundred grams to several kilograms. When only a few hundred grams of sample material are available, it is increasingly important to judiciously select the order in which the analyses are performed.

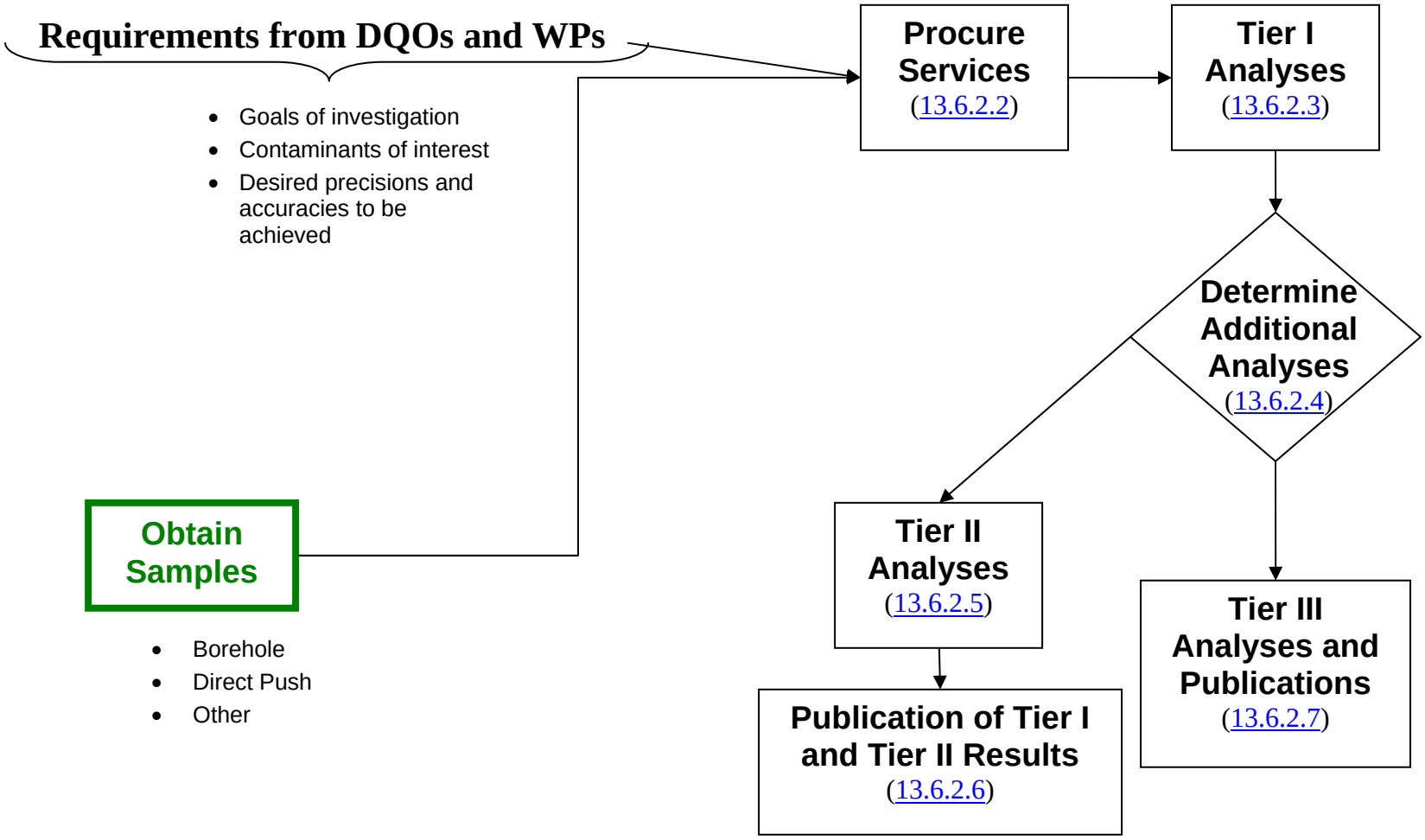
Figure 13-3 displays the process used for logging activities. Sections 13.6.2.1 through 13.6.2.7 describe each step. Section 13.6.2.8 summarizes the decision points during the DP activity, while Section 13.6.2.9 summarizes the documents and records produced.

Figure 13-2. Typical Tiered Approach to Sample Analysis and Characterization.



ICP-MS = inductively coupled plasma–mass spectrometer
ICP-OES = inductively coupled plasma–optical emission spectrometer
IC = ion chromatography

Figure 13-3. Tiered Laboratory Analysis Processes



Green boxes and lettering indicate that field operations perform activity.
Black boxes and lettering indicate that planning group performs activity.

13.6.2.1 Requirements from DQO and Work Plan. The DQO and Work Plan covering the laboratory analyses describe

a. General goals of the analyses.
b. Contaminants of interest.
c. Desired precision and accuracies to be achieved.

13.6.2.2 Procure Services. If a contractor performs the chemical analyses, the standard TFC procedures for procuring services are followed. Close coordination with the BTR is required. All laboratory analyses must meet the requirements of the *Hanford Analytical Services Quality Assurance Requirements Documents* (DOE/RL 2007).

13.6.2.3 Tier I Analyses. In the tiered analysis approach, Tier I includes analyses that

a. Provide information paramount to identifying contaminants present in the samples.
b. Help estimate the basic chemical properties of the sediments.

Additional analyses may be done during Tier I analyses to support the goals stated in the DQO. For example, when suspected ^{90}Sr contaminated samples were being analyzed, beta energy analysis was performed during Tier I.

Additionally, several of the Tier I analyses are nondestructive (that is, the tests do not alter the properties of the samples), so these samples can be used again in other tests. The concentration profiles of contaminants measured in the sediment as a function of the sample depth and sediment geology are one of the most important results from Tier I testing. These concentration profiles provide a measure of the extent of migration and relative mobility of each detected contaminant along the borehole length.

To expedite reporting and subsequent analysis, the preliminary results of Tier I analyses are initially reported. These results are discussed at a meeting (see Section 13.6.2.4.6). Tier I results are published in a formal report containing both Tier I and II analyses.

13.6.2.4 Determine Additional Analyses

13.6.2.4.1 Approach. A key objective of certain VZP field characterization activities (e.g., boreholes or DP probeholes) is to obtain samples from the subsurface. Recognizing the high cost of obtaining these samples coupled with the limited mass of individual samples, they are analyzed in a tiered fashion:

a. Tier I (basic measurements and determination of key contaminant concentrations).
b. Tier II (advanced chemical and physical measurements).
c. Tier III (measurements requiring highly specialized/unique equipment).

After Tier I measurements are completed, the results are presented at a meeting to

a. Identify any problems or concerns with the measurements.
b. Provide interpretation of the results within the context of basic physical and chemical properties of the sediments as well as nature and extent of key contaminants of concern.

a. Identify the need for and plan future Tier II/III efforts.
b. Memorialize information needed for future VZP activities.

13.6.2.4.2 Background. Analyses of sediment samples provide data on

a. Chemical and isotopic compositions (particularly important for contaminant plumes).
b. Geological, physical, and chemical properties of the sediments (which are needed to explain how contaminants reached a certain point and how contaminants may move in the future).
c. Mechanistic understanding of the mobility of contaminants in the sediment.

Obtaining and analyzing vadose zone samples from tank farms is expensive due to the operational and safety requirements that must be met. Thus, the analysis plans for those samples need to be as flexible as possible while still meeting the requirements set out in the specific data objectives process.

Samples are delivered to the laboratory where Tier I analyses are performed in accordance with the relevant sampling and analysis plan. The general procedure or process for obtaining these Tier I analyses is

a. Extrusion of sample from field container.
b. Geologic interpretation of the sample.
c. Digital photography of the sample.
d. Gamma energy analysis of the sample or subsamples.
e. Weight of the sample or subsamples.
f. Moisture content of the sample of subsamples.
g. Total organic and total inorganic carbon.
h. 1:1 water extraction of the pore fluid.
i. Chemical analyses of the 1:1 water extract to identify key constituent concentrations.

In addition, if sufficient material is available, then 1:1 acid extracts of the sediments are performed and subsequently analyzed for key constituents.

These Tier 1 analyses provide basic information about the sediments and provide key information leading to further analyses. The weight of the sample provides a means to normalize measurements to unit sediment mass. Combining the weight with moisture content provides the mass of water to be used in the 1:1 extracts. The analyses of the 1:1 extracts provide the constituent/contaminant concentration.

However, the samples can also provide information important in the estimation of past and future water and contaminant movement. Key information needed for this phase is

a. Geology.
b. Particle size distribution.
c. Hydraulic conductivity (as a function of moisture content and matric potential).
d. Hydraulic matric potential.

e. Chemical interactions between water ions and the soil (often parameterized by a partitioning coefficient or K_d value).
f. Mineralogy.
g. Cation exchange capacity.
h. Semi-selective sediment extractions.
i. Iron oxide extractions.
j. Location of contaminants within minerals or other sediment structures.

Such data are usually obtained during either Tier II or Tier III analyses (geology being the main exception). Tier III analyses are focused on measurements requiring state-of-the-art systems, often unique in the United States. Example of such instruments are the Advanced Photon Source[1] (a particle accelerator), a high-precision multi-collector magnetic sector inductively coupled plasma-mass spectrometer at the Lawrence Berkeley National Laboratory, and various instruments at the Environmental and Molecular Science Laboratory [at the Pacific Northwest National Laboratory (PNNL)]. PNNL has a DOE Office of Science grant to coordinate Hanford environmental studies with other DOE laboratories. Tier II analyses often require advanced equipment, sometimes equipment that was state-of-the-art just a few years before.

13.6.2.4.3 Strategy. Recommendation of additional analyses (Tier II and Tier III) is accomplished using a general agreement basis by a committee as determined by the Committee Leader. Members of the committee are selected by the Committee Leader and are derived from VZP staff and management, subcontractors, regulators, DOE, and other contractors.

Once the recommendations are approved by VZP management, procurement paperwork is adjusted by the BTR to initiate laboratory activity.

13.6.2.4.4 Committee Membership Pool. Leader: The leader of the Tier I Chemical Analysis meeting is the TL. The meeting leader

a. Selects the time and location of the meeting.
b. Sends out invitations to the meeting.
c. Sends out the results of the Tier I measurements to the meeting participants.
d. Chairs the meeting.
e. Documents the conclusions of the meeting.
f. Sends out the documented conclusions.

Other participants at the meeting should include

a. VZP field representatives: These persons provide the knowledge regarding conduct of field projects. Because the DP sampling is one element of the field characterization, and all elements are intended to be used to unravel the complex nature of tank farm contaminant releases, input from these persons is needed for integrating all VZP field efforts.

[1] Advanced Photon Source at Argonne National Laboratory is a national synchrotron X-ray research facility funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, Argonne, Illinois.

b. VZP Risk Analysis TL: Laboratory analyses that are conducted serve as input to the analysis of risk associated with the tank farm release being investigated. Full VZP integration necessitates this person being part of the decision making process.

c. VZP Management: Management ensures sample horizons will meet needs for work plans, data packages and/or RCRA Field Investigation/Corrective Measures Study Corrective Actions.

d. Analytical Laboratory staff: These team members are responsible for the analytical results being discussed and are the critical component for this decision-making meeting. These team members also bring the experience and knowledge of what additional analyses can and cannot be done with the remaining portions of samples that have been collected.

e. PNNL staff: The PNNL staff has knowledge of unique capabilities found in the DOE complex and represent DOE's Office of Science for Tier III activities.

f. CPC staff: In an effort to ensure integration between the TFC and the CPC, a representative of the CPC Operable Unit management or technical staff is invited to participate. In the event that CPC concerns indicate that an adjustment should be made to provide additional value to the sampling effort, those issues can be raised by the CPC representative(s). Other site contractors can be included.

g. ORP representative: Inclusion of the ORP representative provides assurance that the sponsoring agency is involved in the decision making process.

h. Ecology: Continued involvement of Ecology technical staff in the sampling and decision-making process helps to ensure regulatory acceptance of the final product.

13.6.2.4.5 Timing of the Meeting and Necessary Information. The Tier I chemical analysis meeting should occur within 2 weeks following the release of the Tier I analyses.

13.6.2.4.6 At the meeting.

a. Analytical laboratory staff presents Tier I results as well as their interpretation of the results and discuss any problems or concerns with the measurements or data.
b. Committee decides whether the data are acceptable to meet the Tier I goals of the measurements.
c. Committee discusses and recommends potential additional work (Tier II and/or Tier III) for these samples at this time.
d. Committee discusses insights gained from the Tier I measurements, especially those affecting current and near-term activities.

13.6.2.4.7 Actions following meeting. After the meeting, the Laboratory Technical Lead documents the meeting via e-mail to the Director, VZP, and to the BTR of the laboratory contract with copies to the team participants. The documentation includes a

a. List of those persons in attendance.
b. Description of the data discussed.
c. Listing of the options discussed.
d. Description of the selected option with justification for its selection.

The e-mail is treated as an in-process record until the Tier I results are formally published in the Tier II document (Section 13.6.2.6).

With management concurrence, the BTR e-mails the laboratory performing Tier II work a description of the work to be performed. If Tier II work is performed, the Tier I and Tier II are combined and formally documented and released; otherwise, just the Tier I work is formally documented and released. Prior to release the document is reviewed by the VZP.

If Tier III work is recommended, the Laboratory Technical Lead meets with the PNNL Office of Science liaison to discuss possible options. As funding for such work comes from a variety of sources, publication of such work follows standard principles of scientific conduct.

If the committee decides that the document containing the preliminary Tier I results needs modification, the Laboratory Technical Lead ensures the revision of the document.

13.6.2.5 Tier II Analyses. Tier II analyses are focused on better resolving the type and extent of contamination present in the samples. Tests performed during Tier II characterization activities include specialized sediment chemical-dissolution (that is, extraction) and analytical techniques, in addition to tests focused on identifying differences in the physical properties of the sediments.

The number and type of Tier II analyses are determined in the meeting that reviews the Tier I results (Section 13.6.2.3). Publication of the results from Tier II analyses is in a formal report that combines the results of Tier I and Tier II analyses.

13.6.2.6 Publication of Tier I and II Results. The methods used and the results of the Tier I and Tier II analyses are issued in a unified formal report. As appropriate, interpretation of such data for vadose zone contamination location and movement is provided. The results of the analyses can also be used in peer-reviewed journal articles.

1**3.6.2.7 Tier III Analyses and Publications.** Tier III analyses are reserved for those analyses and experiments that provide detailed information on the type of contamination present (e.g., its oxidation state or its physical/chemical state within the sample), as well as information on the transport properties of the contaminants. These are normally performed in state-of-the-art facilities at DOE national laboratories or major universities. Funding for these activities may come from VZP funds but usually come from the DOE Office of Science funding or other external funds. See Chapter 14 for more information.

Results of such analyses are published as formal reports and as peer-reviewed journal articles.

13.6.2.8 Summary of Tiered Laboratory Activity Decision Points. Table 13-3 presents the summary of decision points during the tiered laboratory activity.

Table 13-3. Summary of Decision Points during the Tiered Laboratory Activity

Decision	Decision Maker	Section
Goals of SGE activity	DQO/work plan	13.6.2.1
Determine Tier II and III activities	Laboratory TL	13.6.2.3

13.6.2.9 Summary of Records and Documents Generated during Tiered Laboratory Activity. Table 13-4 displays the records and documents generated during the tiered laboratory activity.

Table 13-4. Data, Documents, and Records Generated during the Tiered Laboratory Activity

Document	Purpose	Author	Section
DQO report [a]	Goals of characterization	VZP	13.16.2.1
Work plan [a,b]	Characterization requirements	VZP	13.16.2.1
E-mail [c]	Accepting Tier I results and specifying Tier II analyses	Laboratory Technical Lead	13.16.2.3
Tier I/II report [a]	Documents results from Tier I and II analyses	Laboratory	13.16.2.5
Tier III report [a]	Document opportunistic sample	Various	13.16.2.6

[a] Published document
[b] Regulatory approval necessary
[c] In-process record

13.6.3 Processes for Tiered Laboratory Measurements of Residual Waste

Based on the experience of performing tiered laboratory measurements for sediments (Section 13.6.2), a similar process has been developed for tier laboratory measurements for residual wastes (wastes left after tank waste retrieval from a tank). Again, the basic premise of the three-tiered approach is to acquire the largest amount of scientific information, through an incremental process, that can be used to best meet program objectives while conserving resources and limiting risk to workers.

The major differences between residual waste and sediments are that

a. It is the contaminant release rate that is key for residual wastes, rather than contaminant concentration.
b. There is no geology in residual waste, although there may be structure.

Thus, there is no geological analysis in Tier I and a leaching test is added to Tier I.

The process to determine additional testing tends to be more technical and usually focuses on what analyses would be best to determine the underlying release mechanisms (often differently by the presence of key minerals, whose importance may change over time due to the changing chemical environment and the amount of minerals present). See Section 13.6.2.

14. ADVANCED SCIENCE MEASUREMENTS AND ANALYSES

14.1 PURPOSE

Although some advanced techniques are used in the laboratory analyses described in Chapters 12 and 13, the DOE national laboratory system has truly state-of-the-art equipment. The purpose of advanced science measurements and analyses are to bring the tank farm vadose zone sediments to some of the most powerful equipment and people available.

14.2 DESCRIPTION

Advanced science involves the most complex analyses using some of the most advanced instrumentation available in the United States. Such research is conducted by DOE's national laboratories and the leading research universities. Funding sources include

a. The VZP.
b. DOE's Environmental Management Office of Engineering and Technology.
c. DOE's Office of Science.

Advanced science has included

a. Measuring isotopic ratios of groundwater and vadose zone samples to determine waste streams that could have lead to the contamination.
b. Performing experiments to understand the basic geochemistry underlying contaminant transport (particularly cesium and uranium).
c. Understanding the dependency of sediment electrical conductivity on moisture content and various contaminant concentrations to aid the use of SGE.
d. Developing chemical reaction models to understand contaminant release from waste forms and residual waste.

The various applications and use of advanced science are only limited by the ability to use advanced scientific techniques to solve VZP problems.

14.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Advanced science has a close relationship with other parts of the VZP:

a. Many researchers uses the sediment samples gathered by the program (Chapters 5 and 6).
b. The Tier III analyses described in Sections 13.6.2 and 13.6.3 are usually considered advanced science.
c. The needs of the VZP have been and are expected to be reflected in calls for proposals from DOE's Office of Science and DOE's Office of Environmental Management.

Because of the expense of obtaining borehole and DP samples, such samples have been archived. Researchers from around the country can request the use of such samples, and on approval of the Director of the VZP, the samples are sent to the researchers. Similar samples from the Integrated Disposal Facility (Section 12.2) are also archived for future use.

As noted in Sections 13.6.2 and 13.6.3, the VZP identifies additional laboratory analyses that are beyond the instrumentation capabilities of the program's scientists. Access to the country's best facilities has greatly aided the program.

DOE Headquarters has issued several calls for proposals dealing with Hanford vadose zone problems (particularly tank farm problems). These calls have resulted in headquarters' funded research that has proven valuable to the program.

14.4 BENEFITS AND LIMITATIONS

The benefits are significant:

a. Access to facilities and scientists that otherwise would be unavailable.
b. Leveraging of other funding to meet VZP needs.
c. National reputation for VZP efforts.

The main limitation is since much of the advanced science is funded by others, the priorities and time schedules are set by others. However, these efforts during the VZP Phase 1 program lead to significant progress, many awards, and invaluable understandings.

14.5 FUTURE DEVELOPMENT

The *Science Road Map for Phase 2 of the Tank Farm Vadose Zone Program* (Zachara et al. 2008) describes further efforts in advanced science. Areas included are

a. Source term identification and contaminant release.
b. Recharge and moisture flow.
c. Contaminant mobility and transport.
d. Tank farm closure technologies.

14.6 IMPLEMENTATION

Problems investigated in advanced science are (usually) chosen by the principal investigators. The principal investigators write a proposal containing a test plan to the funding agency. If the funding agency funds the activity, data are collected and published in peer-reviewed journals.

15. LITERATURE SEARCHES

15.1 PURPOSE

The Hanford Site has large numbers of records in its archive (operational records, testing records, laboratory results). These records can be mined to provide useful information.

15.2 DESCRIPTION

There is a large amount of data and information that the Hanford Site has already obtained. When the tank farms and other facilities were built, the excavations were investigated by geologists. On every new borehole, a field geologist is assigned to document what is seen. The fuel reprocessing stages were carefully investigated and documented. When releases from tank farm facilities occurred, boreholes were installed and measurements were made, all of which was documented. Groundwater and vadose zone monitoring has occurred over the last 50 years.

Before any field characterization is planned, past information is analyzed and documented (e.g., the Subsurface Characterization Description reports). Past inventory information was carefully analyzed to determine what contaminants were in what waste streams and where the waste streams went.

Operations records were studied to determine where infrastructure is and when and where releases were expected. The operations records also document key observations that were made.

15.3 RELATIONSHIP TO OTHER TECHNOLOGIES

Literature searches are usually the first step in a characterization process. There are also times when new literature searches are begun, when new data indicate that a literature search would provide useful data.

15.4 BENEFITS AND LIMITATIONS

Literature searches are inexpensive compared to field and laboratory efforts. However, if the data were not documented or the documentation is lost, literature searches are not helpful. In addition, as technology has improved, there are many measurements that, although feasible now, were not feasible in the past. Finally, many of the contaminants are controlled by mechanisms that are site specific; therefore, data gained via a literature search may not be representative of the study site.

15.5 FUTURE DEVELOPMENT

Literature searches are used whenever they are beneficial.

15.6 IMPLEMENTATION

Because of their relative low cost, only the approval of the Director, VZP, is needed to start a literature search.

16. INTEGRATION WITH CENTRAL PLATEAU CONTRACTOR

16.1 LEGAL BACKGROUND

By congressional direction, the Hanford Central Plateau is managed by two offices of the DOE. ORP deals with the storage and treatment of tank waste. The other, RL, deals with the rest of the plateau. However, there are many cases where current tank storage facilities (e.g., BY Farm) is connected (and was the source of waste) to nearby cribs (for example BY Cribs). Releases from these two systems may mix in the vadose zone, and they certainly do mix in groundwater.

16.2 PRESENT EFFORTS

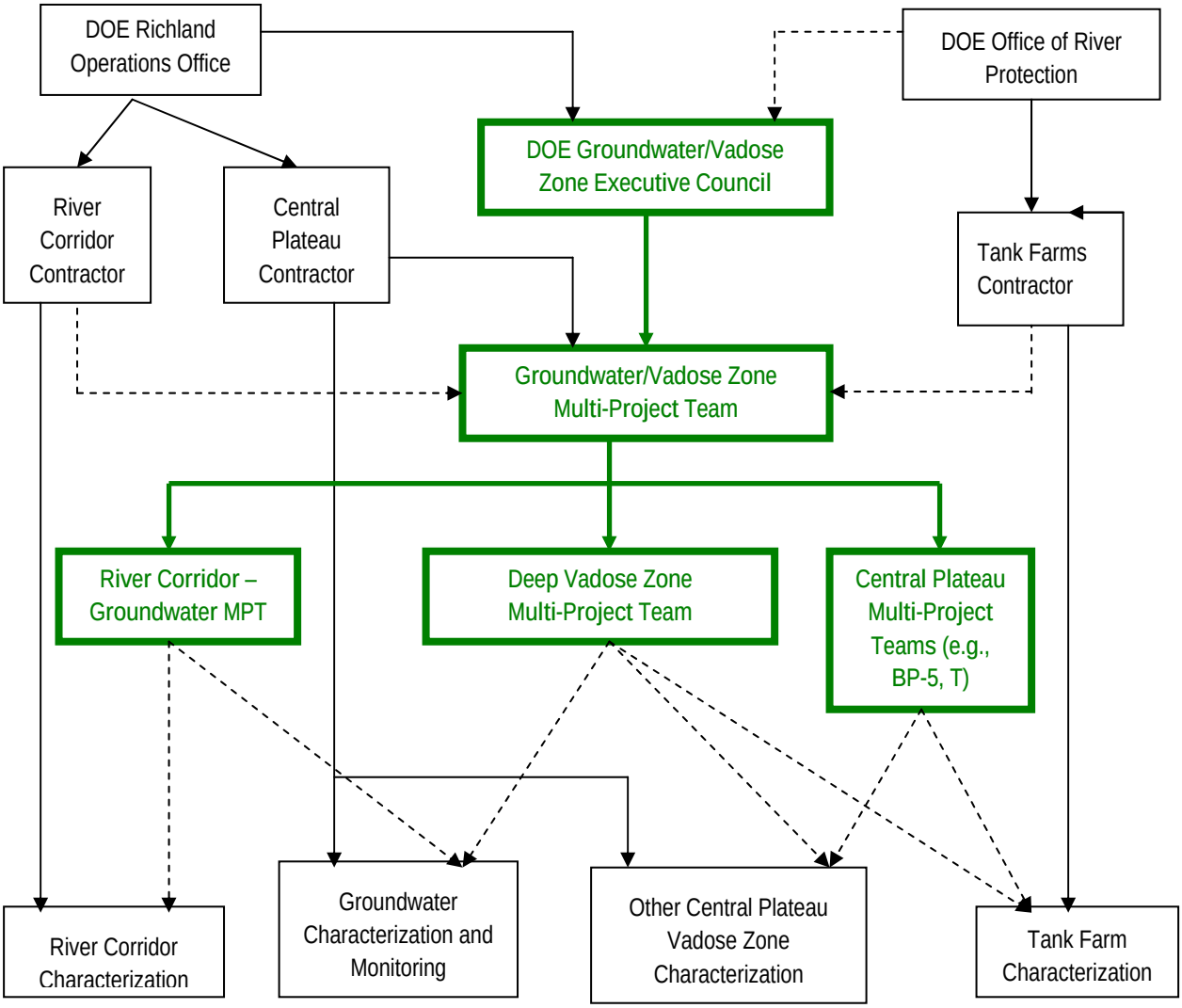
The *Hanford Integrated Groundwater and Vadose Zone Management Plan* (DOE/RL 2007a) describes the present integration efforts and requirements. The central piece of these efforts is a set of Multi-Project Teams as shown in Figure 16-1. Central leadership is provided by RL with direct participation by ORP. At the contractor level, the lead is the Groundwater Remediation Project that is responsible for

a. Development and maintenance of an integrated project plan and schedule.
b. An integrated field work plan for all groundwater and vadose zone characterization activities.
c. Annual reviews of the integrated field work plan to DOE.
d. Development and maintenance of an integrated set of priorities for conducting deep vadose zone characterization activities that are driven by the need to protect groundwater and compliance with regulatory requirements.
e. Aggressive internal peer review of technical results, interpretation, and vetting of results that address the nature and extent and fate and transport of subsurface contamination.
f. Coordination of sitewide science and technology development and deployment needs applicable to groundwater/vadose zone investigation and remediation.
g. Conducting deep vadose zone treatability studies.

For characterization activities about 100 feet below ground surface, RL and the Groundwater Remediation Project reviews and approves

a. DQOs.
b. Sampling and analysis plans.
c. Work plans.

Figure 16-1. Hanford Groundwater/Vadose Zone Integrated Management



RL (with the support of the Groundwater Remediation Project) establishes and maintains configuration control for all groundwater/vadose zone assessment parameters, key assumptions, approaches, and data bases.

However, ORP (along with TFC) retains responsibility for tank farm RCRA Corrective Action activities.

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