SGW-60038
Revision 0

100-KR-4 and 100-HR-3 Groundwater Operable Units Aquifer Tracer Study Work Plan

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

The U.S. Department of Energy, Richland Operations Office (DOE-RL) has directed its contractor, CH2M HILL Plateau Remediation Company, to perform a groundwater tracer study in the Hanford Site 100-KR-4 and 100-HR-3 Operable Units (OUs) to assess aquifer characteristics and to quantify selected aquifer hydraulic parameters.
The quantification of aquifer mobile porosity is of particular interest for this study.
The results of the tracer study will be used to refine the transport simulations used for pump and treat (P&T) system optimization and forecasts for the remediation time frame.
This study will be performed as part of ongoing remedial process optimization activities.

The tracer study will be performed using a phased approach. Phase I will include using existing groundwater sulfate concentration data associated with ongoing P&T system operations. The Phase I analysis will include data collected in the 100-KR-4 OU from operation of the 100-KW P&T system and data collected in the 100-HR-3 OU from operation of the 100-DX P&T system. If Phase I results indicate that the estimated mobile porosity is not within approximately 20 percent of the mobile porosity currently assigned in the 100 Area groundwater model, then a Phase II study would be initiated. Phase II would include a tracer injection study at wells 199-K-112A and 199-K-129 to supplement the values derived during Phase I. If Phase II tracer test results indicate that the estimated mobile porosity is not within approximately 20 percent of the mobile porosity values estimated during Phase I sulfate analyses, then the need for additional tracer testing will be evaluated.

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Terms

bgs	below ground surface
COC	contaminant of concern
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
EPA	U.S. Environmental Protection Agency
ISE	ion-specific electrode
KBr	potassium bromide
OU	operable unit
P&T	pump and treat
QA	quality assurance
TIW	tracer injection well
TOW	tracer observation well

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1 Introduction

Groundwater tracer tests have been performed at the U.S. Department of Energy (DOE) Hanford Site in Washington State to provide quantification of aquifer hydraulic properties using both conservative ionic tracers (e.g., bromide [PNNL-13349, *100-D Area In Situ Redox Treatability Test for Chromate-Contaminated Groundwater*] to support planning of the in situ REDOX manipulation design at the 100-D Area) and fluorescent dyes (e.g., fluorescein [HW-60601, *Aquifer Characteristics and Ground-Water Movement at Hanford*] in the Central Plateau). This work plan describes the objectives and planned approach for additional groundwater tracer testing in the 100-K Area in the 100-KR-4 Operable Unit (OU) and in the 100-D Area in the 100-HR-3 OU along the Columbia River corridor. Appendix A provides the data quality objectives developed for this study. Previous studies in the 100 Areas have indicated that the porosity of the Ringold Formation unit E may range from 5 to nearly 23 percent (PNNL-13349). Because the average linear groundwater velocity is inversely proportional to the mobile porosity, this range of mobile porosity would result in a groundwater velocity difference of 130 percent. Because fate and transport modeling is used to evaluate potential contributions from secondary contaminant sources in the vadose zone and within the aquifer, accurate estimation of mobile porosity is essential to accurately depict the effects on groundwater plumes.

This test plan identifies two types of groundwater tracer studies used to refine the estimate of aquifer mobile porosity and related aquifer characteristics. The first measurement type will focus on using existing groundwater sulfate concentration data collected during routine groundwater monitoring in the 100-D and 100-K Areas. Sulfate concentration transients at some well locations are related to injection of pump and treat (P&T) system effluent water that contains elevated sulfate concentration. These data can provide a basis for a tracer analysis that includes a large spatial distribution of observation locations related to injection at known rates and known locations over a period of more than 4 years. The second measurement type focuses on providing data by using an injection of a known concentration and quantity of a bromide tracer solution into a well at a known distance from a selected observation well. The peak arrival time and resulting tracer concentration over time would be used to quantify the mobile porosity of the aquifer in the test location. The combination of measurement types will provide information regarding the spatial variability in mobile porosity at the 100-D and 100-K Areas.

The overall objective of this study is to collect information that will be used in conjunction with other site data and professional judgment to improve the consistency between the groundwater conceptual site model and the 100 Area groundwater model (SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*) with respect to subsurface flow and transport conditions. The more specific objective of tracer testing in the 100-K and 100-D Areas is to provide a basis for quantifying the mobile porosity within the screened depth intervals of the aquifer between each tracer injection well (TIW) and tracer observation well (TOW).

1.1 Scope

The scope of this effort is to identify tracer testing locations within the 100-K and 100-D Areas, define the testing and analytical parameters and procedures, implement the tracer tests in a phased manner, analyze data collected during these tests, and document the results in a report. Tracer studies will be performed in a phased approach, as follows:

- **Phase I:** Perform an assessment of aquifer properties at 100-D south plume area and 100-KW P&T area using historical groundwater sulfate concentration data resulting from routine groundwater monitoring. If results from the Phase I analysis indicate that the estimated mobile porosity is not within approximately 20 percent of the mobile porosity currently assigned in the 100 Area groundwater model (SGW-46279), then Phase II may be initiated. If the Phase I results indicate that mobile porosity is within 20 percent of the current estimates, then Phase II will not be implemented.
- **Phase II:** If necessary, perform a tracer injection test at one selected location in the 100-K Area to provide an independent subsurface tracer analysis that could be compared to the sulfate analysis results. If the mobile porosity estimates from the Phase II test results are not within approximately 20 percent of the mobile porosity estimates from the Phase I sulfate analyses, then the need for additional tracer testing will be evaluated.

Tracer testing will be implemented following approval of this work plan by the DOE Richland Operations Office (DOE-RL).

1.2 Overview

The first evaluation will be performed during Phase I activities and will focus on portions of the 100-KW P&T system and the southern portion of the 100-D south chromium plume in the 100-D Area that exhibit elevated groundwater sulfate concentrations resulting from the injection of P&T system effluent. Historical increases and decreases of groundwater sulfate concentration (i.e., breakthrough) at specific well locations in these areas can be correlated to P&T system injection locations, timing, discharge rates and effluent sulfate concentration data. Thus, sulfate will be evaluated as a surrogate tracer. No fieldwork is associated with the initial evaluation.

The second evaluation that may be performed during Phase II would require fieldwork. Fieldwork would include forced-gradient tracer testing, which involves injecting a calculated volume of tracer solution into a TIW at a measured pumping rate while monitoring groundwater quality at a TOW for the appearance of the tracer. Water-level, water quality monitoring, and sampling would be conducted at each TIW and at least one TOW at each testing area. In some cases, the TOW could operate as a P&T system extraction well.

The data analysis for the evaluations will include analytical methods, as well as two-dimensional and three-dimensional numerical groundwater flow and solute transport models to achieve the objectives described in Section 1.1.

2 Methodology

This chapter describes various aspects of the testing methodology, including test site selection, tracer selection, tracer test components, field implementation (if initiated as part of Phase II), data reduction and analysis, and reporting.

2.1 Test Site Selection

Testing locations have been selected based on the following criteria:

- At least one groundwater contaminant of concern (COC) present in the area
- Health and safety considerations
- Availability of historical constituent concentration data that could provide surrogate tracer data
- Availability of existing closely spaced wells (to avoid the need for installing and monitoring new wells)
- Accessibility for tracer testing equipment and personnel
- Availability of source water to mix with the tracer
- Avoidance (to the extent practical) of possible undesirable hydraulic influences from operation of the P&T system

For example, ideal tracer testing locations would be in areas with groundwater COCs and historical constituent concentration data that could provide surrogate tracer data. If such data are not available, then priority locations for conducting tracer testing would include the following:

- Areas with groundwater COCs that would not require enhanced health and safety measures during testing
- Existing wells spaced tens of feet apart or less, rather than hundreds of feet apart
- Easy access with adequate space for tracer testing equipment and personnel
- Easy access to source water for preparing the tracer solution
- Ability to control subsurface hydraulics in the testing area to improve the likelihood of detecting tracer at intended TOW within approximately one month

The following subsections describe the areas with available constituent concentration data that could serve as surrogate tracer data and areas selected for conducting tracer testing.

2.1.1 Phase I Tracer Sites

Several wells in the 100-KW P&T system area (Figure 2-1) and in the southern portion of the 100-D south chromium plume in the 100-D Area (Figure 2-2) have exhibited elevated sulfate concentrations in groundwater following initiation of ex situ treatment using ResinTech[1] SIR-700 ion-exchange resin and associated process stream pH adjustment. The observed groundwater sulfate concentration transients are directly correlated to the injection of P&T effluent water, indicating that sulfate at these locations can be

[1] ResinTech® is a registered trademark of ResinTech Inc., West Berlin, New Jersey.

used as a surrogate tracer. The P&T system injection locations and rates, and sulfate concentrations in the injected effluent, are well defined. The sulfate concentration in groundwater and the P&T system effluent will be evaluated during Phase I to derive refined estimates of mobile porosity using analytical and numerical methods. Additional details regarding the analysis of these sulfate data are provided in Section 2.5.1.

2.1.2 Phase II Candidate Tracer Testing Site

Candidate locations for tracer testing where surrogate (i.e. sulfate) tracer data are not currently available were evaluated using the criteria previously described. A tracer test location incorporating two existing wells (i.e., 199-K-112A and 199-K-129) was identified based on well proximity, similar screen length and construction, and availability for implementing testing at the location (Figure 2-3). Three additional candidate locations were identified (Figures 2-3 and 2-4) based largely on well proximity, but the locations were not selected for the initial Phase II study due to the relatively large estimated tracer volume that would be required (i.e., the distance between wells ranges from about 24 to 61 m [80 to 200 ft]) and the long testing period that would therefore be required. The candidate locations shown in Table 2-1 include one additional location in the 100-K Area and two locations in the 100-D Area that are not discussed further in this work plan.

2.2 Phase II Tracer Selection

Potassium bromide (KBr) was selected for use in Phase II tracer testing (if Phase II is initiated at the 100-K and 100-D Areas) for the following reasons:

- KBr is commonly used to evaluate subsurface flow and transport conditions at environmental sites that have low background bromide concentrations in groundwater. Review of recent bromide concentrations in groundwater at the 100-K and 100-D Areas indicates low bromide concentrations ranging from nondetect to 4.5 mg/L, with most concentrations at less than 1 mg/L.
- KBr can produce strong bromide and specific conductance signals in groundwater.
- Bromide has a low reactivity and sorptivity; thus, it is commonly used as a conservative tracer.
- Automated in situ logging is available by using a bromide ion-specific electrode (ISE) probe and a specific conductance probe. Using a bromide ISE probe as well as a specific conductance probe would provide some redundancy. However, readings from the bromide ISE probe can be unreliable and require frequent recalibration.
- KBr handling and storage is straightforward. A safety datasheet for KBr is provided in Appendix B.

2.3 Phase II Tracer Test Components

The general components of the Phase II groundwater tracer testing effort (if initiated) include the following:

- Injection equipment and associated mixing tanks and power generators will be mobilized, maintained, and operated by an injection subcontractor. The injection subcontractor will also be responsible for KBr procurement, delivery, handling, and storage during testing. The preliminary estimate of the volume of tracer solution required for the selected Phase II well pair (199-K-112A and 199-K-129) is 37,854 L (10,000 gal) injected at a rate of 75.7 L/min (20 gallons per minute [gpm]) for a duration of approximately 8 hours.

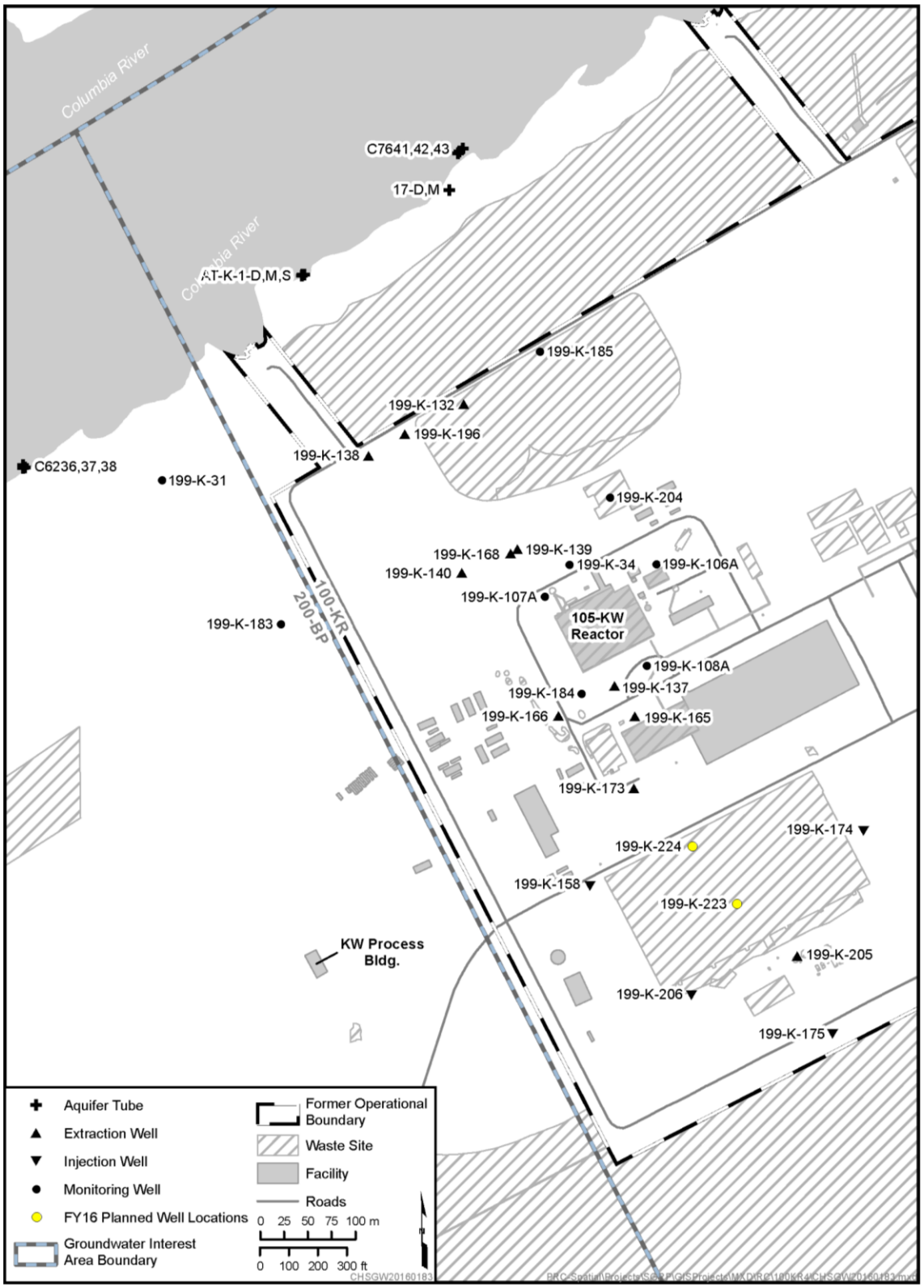


Figure 2-1. Phase I Tracer Study Area in the Vicinity of the 100-KW P&T System

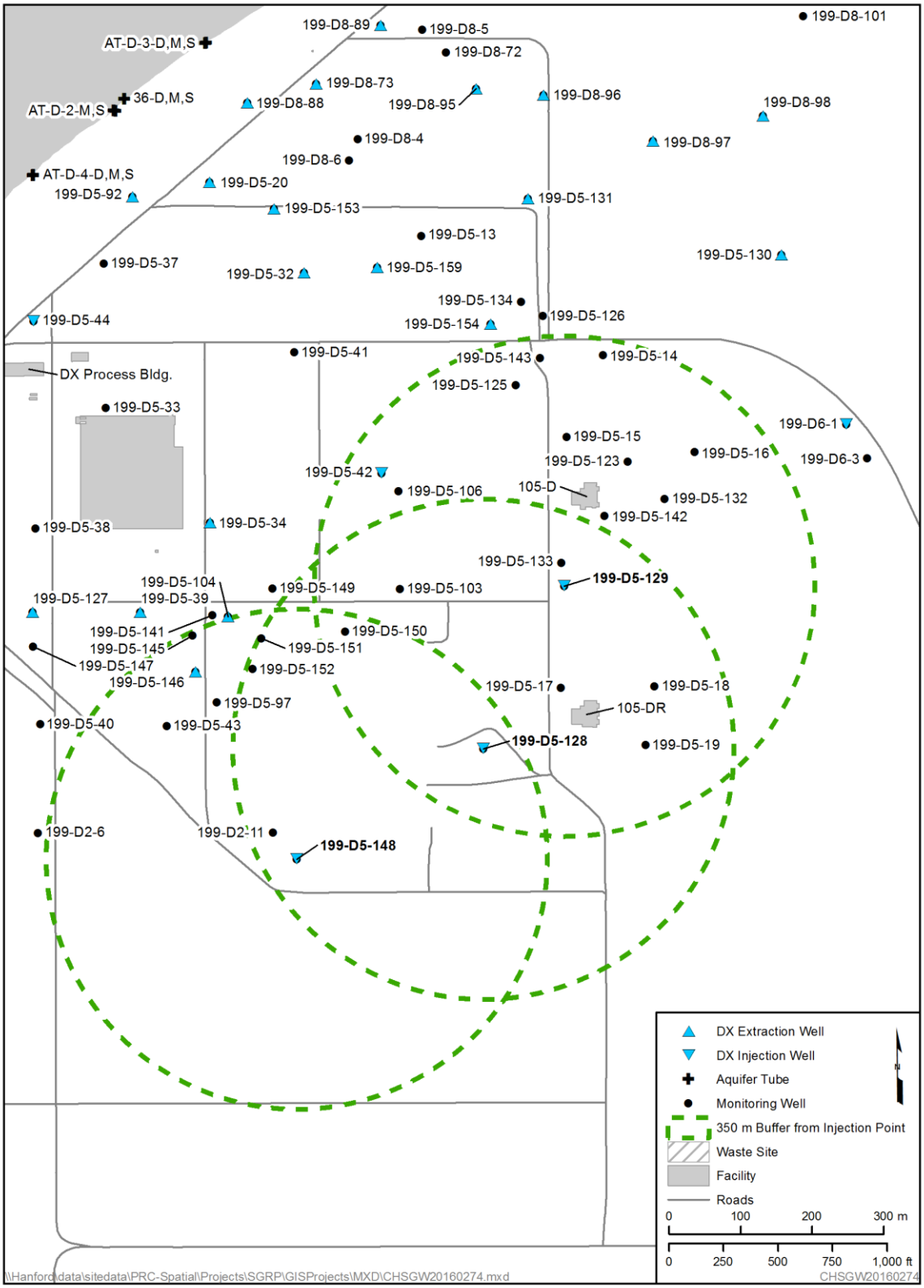


Figure 2-2. Phase I Tracer Study Area in the Vicinity of the 100-DX P&T System

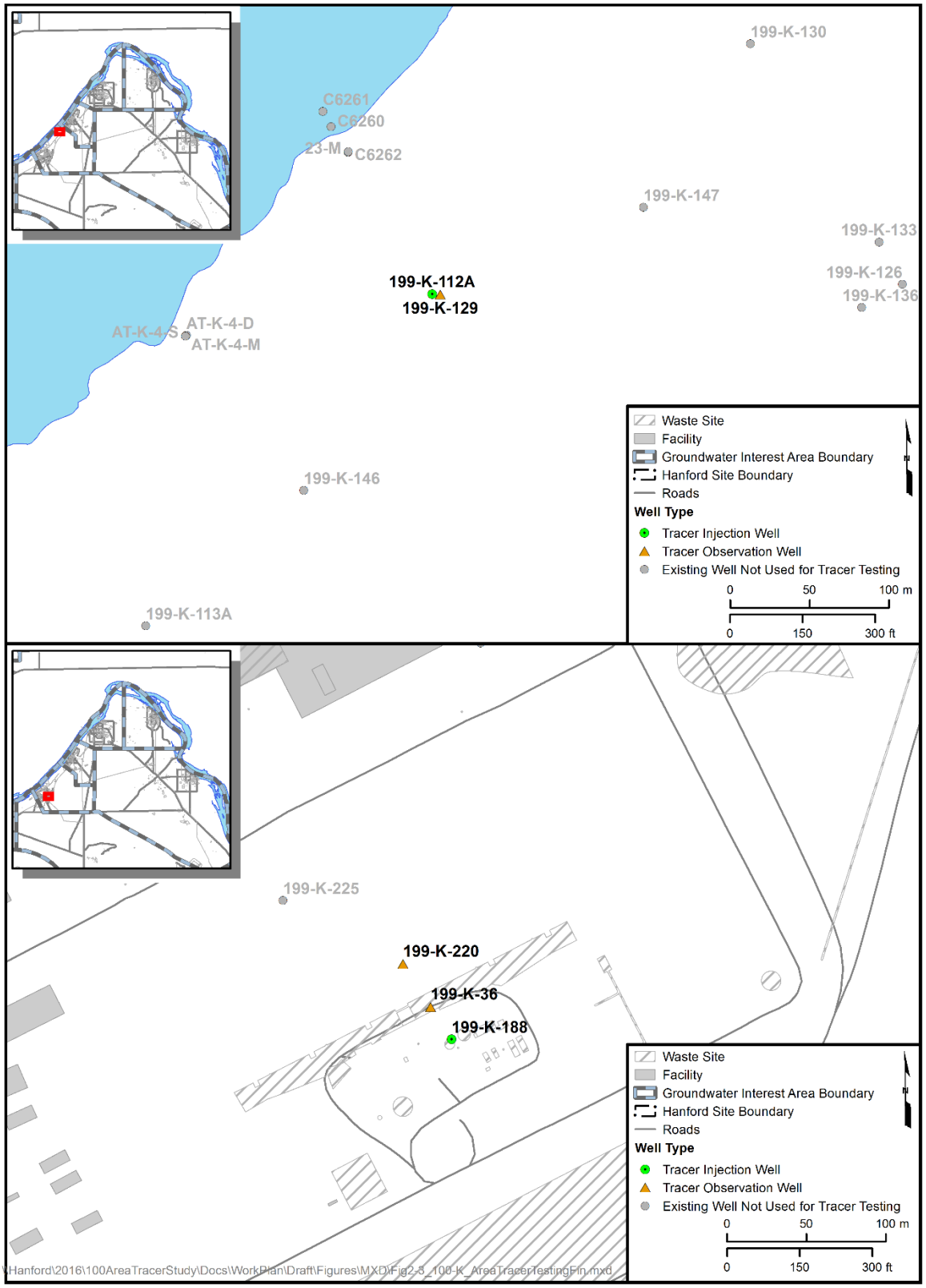


Figure 2-3. Phase II Selected and Candidate 100-K Area Tracer Wells

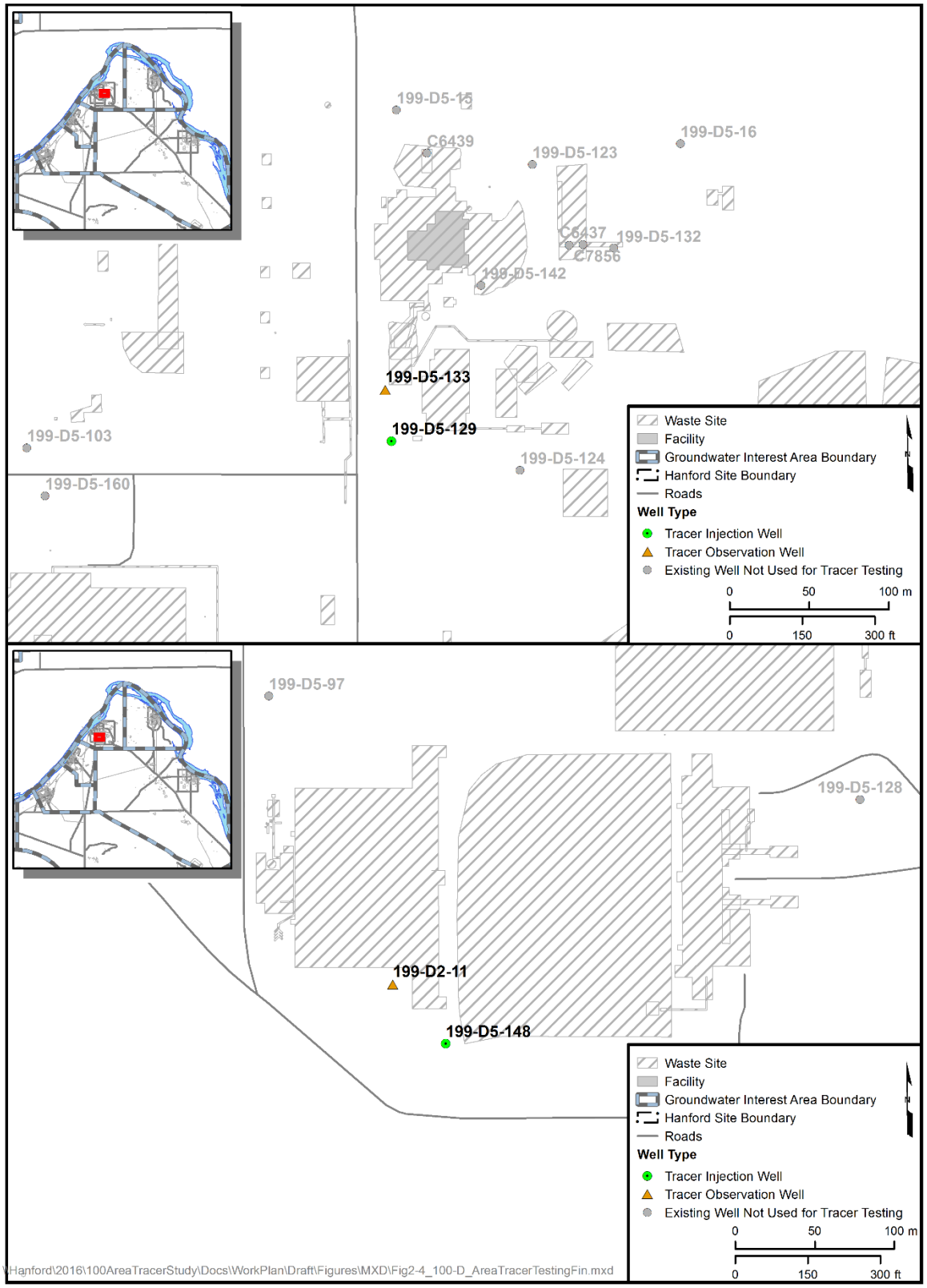


Figure 2-4. Phase II Candidate 100-D Area Tracer Wells

Table 2-1. Phase II Candidate Tracer Testing Locations

Area	Tracer Injection Well	Current Tracer Injection Well Function	Tracer Observation Well	Distance from Tracer Injection Well	Current Tracer Observation Well Function
100-K	199-K-188	Monitoring	199-K-36	24 m (79.7 ft)	Monitoring
			199-K-220	56 m (185.0 ft)	P&T extraction
100-K	***199-K-112A***	***Monitoring***	***199-K-129***	***5 m (16.7 ft)***	***P&T extraction***
100-D	199-D5-148	P&T injection	199-D2-11	50 m (164.0 ft)	Monitoring
100-D	199-D5-129	P&T injection	199-D5-133	33 m (106.6 ft)	Monitoring

Note: Row shown in bold/italics indicates location selected for Phase II tracer activities.
P&T = pump and treat

- The wells selected for Phase II are both equipped with water-level transducers. Well 199-K-112A is part of the automated water-level network, and well 199-K-129 is an operating extraction well for the 100-KR4 P&T system. Therefore, additional automated water-level monitoring is not required at these locations.
- Automatic data-logging water quality probes will be procured and deployed in wells 199-K-112A and 199-K-129. Both wells will be equipped with an automated ISE probe to measure bromide concentrations in groundwater. In addition, well 199-K-112A will be equipped with a specific conductance monitoring probe. Groundwater specific conductance for well 199-K-129 will be measured at the sample port in the P&T treatment plant.
- Water sampling at wells 199-K-112A and 199-K-129 (selected Phase II test wells listed in Table 2-1) will be performed prior to and during tracer testing. Samples will be preserved and temporarily stored at a secure location. A subset of these samples will be sent to an approved analytical laboratory to quantify the specific conductance and bromide concentrations in order to verify the accuracy of the data recorded by the water-quality and ISE probes.

2.4 Phase II Field Implementation

This section describes the procedures associated with data logger and sampler installation, tracer preparation and injection, monitoring and sampling, and quality assurance (QA) associated with Phase II activities (if initiated).

2.4.1 Instrument and Sampler Installation

Prior to conducting bromide tracer testing, selected wells will be instrumented with automatic data-logging water quality probes. Well 199-K-112A will be equipped with a dedicated water sampling device. Water quality samples will be collected from well 199-K-129 from the sample port of the P&T facility. The following subsections describe the devices that will be used during Phase II testing (if initiated).

2.4.1.1 Flow Meters

An effective analysis of subsurface flow and tracer transport will rely upon accurate flow measurements during tracer injection, as well as accurate groundwater-level and bromide concentration measurements because advection is the dominant transport process and advection is driven by groundwater flow. The injection subcontractor will be responsible for accurately measuring and logging the flows to well 199-K-112A.

2.4.1.2 Water Quality Probes

Prior to conducting bromide tracer testing, the TIW and TOW listed in Table 2-2 will be instrumented with two types of data-logging water-quality probes. The first type of water quality instrument will be an AquiStar[2] CT2X (or equivalent). This device will be used primarily to record specific conductance at the TIW. The steps required to calibrate and deploy this instrument are outlined in the product manual which can be obtained from the Instrumentation Northwest website. The second type of water-quality instrument will be an AquiStar TempHion[2] submersible smart ISE sensor (or equivalent), which is a data-logging ISE probe capable of recording bromide concentrations and water temperature in the TIW and TOW. If internal well configuration permits, these devices will also be deployed inside of 1 to 2 in. diameter polyvinyl chloride drop pipe down to the midpoint of the screened interval of the well, which will be secured to the well casing to avoid entanglement of the downhole devices and cables. The steps required to calibrate and deploy this instrument are outlined in the product manual which can be obtained from the Instrumentation Northwest website. Instruments will be placed at mid-screen depth.

Table 2-2. Phase II Tracer Well Construction Details

Area	Well	Casing Diameter (in.)	Nominal Screen Top (ft bgs)	Nominal Screen Bottom (ft bgs)	Screen Length (ft)
100-K	199-K-112A	6	32	72	40
100-K	199-K-129	6	32	72	40

bgs = below ground surface

2.4.1.3 Dedicated Water Samplers

Prior to conducting tracer testing, the TIW and TOW listed in Table 2-2 will be outfitted with dedicated 1 to 3 in. diameter bailers or small-diameter submersible pumps to facilitate collection of water samples from each well during testing. The bailers or pumps will require cables that are long enough to allow raising and lowering the device across the length of the well screen to mix the water column before collecting a water sample. Samples from the P&T extraction well used as a TOW will be collected from the sample port in the P&T treatment plant.

2.4.2 Tracer Preparation and Injections

The injection subcontractor will be responsible for procuring the KBr, which would likely be delivered by the manufacturer in powder form (see Appendix B for a safety data sheet for an example product). The injection subcontractor will also be responsible for preparing the KBr solution in a mixing tank using potable water to achieve an injection rate and a bromide injection concentration at the target bromide

[2] Aquistar® is a registered trademark, and TempHion™ is a trademark, of Instrumentation Northwest, Inc., Kirkland, Washington. User manuals for both products can be found at http://inwusa.com/.

injection concentration in the TIW (see Table 2-3). Tracer solution may be mixed onsite or mixed offsite and then delivered to the TIW.

Table 2-3. Phase II Target Tracer Injection Rates and Concentrations

Area	Tracer Injection Well	Nearest Tracer Observation Well	Distance from Tracer Injection Well (ft)	Target Tracer Injection Rate (gpm)*	Target Maximum Tracer Injection Duration (hrs)	Target Bromide Injection Concentration (mg/L)
100-K	***199-K-112A***	***199-K-129***	***16.7***	***20***	***8***	***2,000***

Note: Row shown in bold/italics indicates location selected for Phase II tracer activities.

* Injection rate for emplacement of tracer solution as well as the potable water "chase" following tracer emplacement if necessary.

gpm = gallons per minute

KBr is commonly injected at concentrations resulting in a bromide signal-to-noise ratio of approximately 1,000 (Payne et al., 2008, *Remediation Hydraulics*) for closely spaced wells. Because of the fairly close distance between the wells selected for the Phase II test, a bromide signal-to-noise ratio of 1,000 to 2,000 has been targeted. Thus, using a background bromide concentration in groundwater of 1 mg/L, the target bromide injection concentration for the tracer is 2,000 mg/L. This concentration will be sufficiently low to avoid undesirable tracer density transport effects and high enough to enhance detection in the TOW.

The tracer injection pumping rate and the estimated tracer injection duration (and the resulting estimated volume of tracer solution) are based on a range of assumed mobile porosity values between 0.10 and 0.18 and target bromide injection concentrations of 1,000 to 2,000 mg/L. The further the TOW is from the TIW, the longer the period for the tracer injection phase of the test. The selection of tracer concentration, injection rates, and injection durations is intended to increase the probability of tracer detection at the TOW within a manageable time period. The increased sulfate concentrations observed at 100-KW P&T wells that define the data set for the Phase I analysis resulted from injecting about 2.65 billion L (700 million gal) of P&T system effluent over a period of 4.6 years.

The source water used by the injection subcontractor to prepare the mixed tracer solution will be potable water if the TIW is not currently operating as an injection well (e.g., 199-K-112A).

2.4.3 Monitoring and Sampling

The primary goals of monitoring and sampling are to characterize the bromide "front" moving through the aquifer. Because aquifer hydraulics are sensitive to operation of P&T injection and extraction wells in the 100-K and 100-D Areas, it is difficult to accurately forecast an appropriate sampling frequency. Therefore, because of the inherent uncertainty associated with this type of test, manual water samples will be collected more frequently than may be needed to ensure that the bromide arrival times are adequately characterized at the TOW. The timing of manual water sample collection will be determined by the technical lead based on real-time bromide and specific conductance readings from the water quality probes. When water quality probes indicate that the bromide front is beginning to reach the TOW, manual water samples will be collected at the frequency identified in Table 2-4 to confirm accuracy of the data loggers. However, not all manual water samples will be sent to the laboratory. The monitoring and sampling period will continue for a period of no more than 30 days after the peak arrival of bromide

tracer, and the frequency of sample collection after the peak arrival of tracer will likely be reduced to 1 to 2 times per week.

The monitoring period will begin after the TIW and TOW are equipped with data-logging devices. It is imperative that all field staff record data using consistent time units. Prior to installing any instrumentation, the instrument clock shall be set to local standard time. After setting the instrument clock, the operator will verify that this time is consistent with the other instruments and timekeeping devices (e.g., watches and cell phones) that might be used to log times during testing. Furthermore, if new staff come onsite, they should set their personal timekeeping devices by one of the synchronized instruments onsite. This will ensure that all automatic and manual measurements are set to the same time. Table 2-4 summarizes the monitoring types and frequencies.

Table 2-4. Phase II Monitoring Type and Frequency

Parameter	Collection Method	Initial Collection Frequency[a]	Comment
Physical Fluid Parameters			
Groundwater level	Data logger Manual	Every 1 minute Two times daily at 199-K-112A	Automatically recorded with data logger. Manual readings must be taken from consistent measuring points to within 0.01 ft accuracy.
Water temperature	Data logger	Every 1 minute	Automatically recorded with data logger.
Pumping rate	Mechanical device Data logger	2 to 4 times daily Every 1 minute	Should include a combination of different types of observations to confirm accuracy of measurement.
Chemical Fluid Parameters			
Specific conductance	Manual probe Data logger	2 to 4 times daily Every 1 minute	Check calibration of probe daily. Data will serve as indication of bromide front moving through that location.
Bromide concentration	Manual sample Data logger	2 to 4 times daily Every 1 minute	Check calibration of probe daily. Data will serve as indication of bromide front moving through that location.

* The manual frequency values represent the recommended frequencies upon evidence that the tracer front is beginning to reach the tracer observation well and may be reduced at the discretion of the technical lead based on test observations.

2.4.3.1 Groundwater Levels

Manual measurement of groundwater levels will be performed at the frequency listed in Table 2-4 in conjunction with downloading data from the downhole transducers to verify the accuracy of the transducers and to supplement the transducer data with data from wells that will not be instrumented. The procedure for downloading the downhole transducers is outlined in the product user manual.

2.4.3.2 Flow Measurements

Frequent flow measurements will be needed to support the analysis. Measurements and readings of instantaneous flow rate and total flow volume will be needed at the frequency listed in Table 2-4 from flow measurement devices at the injection and extraction wells. Continuous flow measurement is already in place for well 199-K-129 as part of P&T system operations. Flow rates will be estimated by noting the time required to fill a calibrated vessel of known volume, if feasible without compromising P&T system operations (e.g., 5 gal bucket or 55 gal drum, depending on the magnitude of the flow rate).

2.4.3.3 Water Chemistry

Specific conductance, water temperature, and bromide concentrations will be manually recorded at the frequency listed in Table 2-4 in conjunction with downloading data from the downhole water quality probes. The procedure for downloading the water quality probes is outlined in Appendices C and D.

2.4.3.4 Water Sampling

Groundwater will be sampled at the frequency listed in Table 2-4 and will be analyzed for the parameters listed in Table 2-5 as a cross-check against the parameters recorded by downhole water-quality probes. Although the technical lead may not request the submittal all of the water samples for laboratory analysis, the frequent sample collection will allow the laboratory to obtain data from certain time frames that may be of interest after evaluating test data from earlier stages of testing. As described in Section 2.4.1.3, groundwater samples will be collected using dedicated bailers or pumps during testing. The general steps for sample collection will include raising and lowering the weighted bailer a couple of times across the screened depth interval to mix the water column, retrieving the bailer, containerizing collected water in an approved container for later disposal, lowering the bailer back into the well, collecting a mixed water sample and retrieving it to the surface, and then filling an approved sample bottle. If using a low-volume submersible pump, the pump will be raised and lowered through the water column to mix the water before collecting a sample of the mixed water column from mid-screen depth.

Table 2-5. Phase II Sampling and Analysis Summary

Parameter	Method	Sample Container	Sample Preservation	Holding Time (days)
Bromide	EPA 300	500 mL polyethylene	Store at ≤6°C	28
Specific conductance	EPA 120.1	500 mL polyethylene	Store at ≤6°C	28

EPA = U. S. Environmental Protection Agency

Naming and labeling of samples will adhere to the following format: “well name–date–time.” For example, a sample collected from well 199-K-129 on October 3, 2016, at 13:30 would be named, “199-K-129–03Oct16–1330.”

The samples shall be initially stored on ice in a cooler and then moved to a secure facility refrigerator until the samples are either shipped to the analytical laboratory or disposed in an approved manner and location. Table 2-5 outlines the sample requirements for each parameter. Sample containers will be labeled, and samples will be maintained under chain of custody.

2.4.4 Measurement Quality Assurance

The QA requirements for measurements and samples collected during the Phase II studies (if initiated) are described in the QA project plan (see Appendix C).

2.5 Data Reduction and Analysis

Data collected during monitoring activities will provide the necessary information to evaluate the target aquifer conditions and achieve the objectives described in Section 1.1. Data evaluation is summarized in the following subsections.

2.5.1 Phase I Sulfate Tracer Evaluation

As described in Section 2.1.1, several wells in the 100-KW P&T system area (Figure 2-1) and in the southern portion of the 100-D south chromium plume in the 100-D Area (Figure 2-2) have exhibited elevated sulfate concentrations in groundwater following initiation of ex situ treatment using SIR-700 ion-exchange resin and associated process stream pH adjustment. The P&T system injection locations and rates, and the sulfate concentrations in groundwater and the P&T system effluent, will be evaluated during Phase I using multiple methods.

2.5.1.1 Analytical Method

A simple volume-calculation approach will initially be executed to back-calculate a mobile porosity (θ_m) that best fits the timing of a relative concentration (C/C_0) of sulfate of 0.5 at the TOW, assuming continuous injection of sulfate. In this example, C equals the sulfate concentration in the aquifer at a given time after injection, and C_0 equals the concentration of sulfate in the injection fluid. To begin this evaluation, the P&T injection well deemed responsible for increased sulfate concentrations in groundwater at a given monitoring or P&T system extraction well will be identified. The radial sulfate movement from the P&T injection well screen will be conceptualized as a symmetrical cylinder shape with a growing radius (r), within which there exists a θ_m and an associated mobile pore volume (V_m) according to Equation 2-1, as follows:

$$V_m = \pi r^2 b \theta_m \qquad \textbf{(Equation 2-1)}$$

where:

V_m = mobile pore volume

r = radius

b = injection well screen length

θ_m = mobile porosity

The time required for the tracer (i.e., sulfate) at a C/C_0 of 0.5 to reach r (t_{50}) can be computed using to Equation 2-2:

$$t_{50} = \frac{V_m}{Q_{inj}} \qquad \textbf{(Equation 2-2)}$$

where:

t_{50} = time of travel to radius r

V_m = mobile pore volume

Q_{inj} = injection rate at an injection well

By combining and rearranging Equations 2-1 and 2-2 in Equation 2-3, one can back-calculate the mobile porosity that adequately matches the t_{50} at selected monitoring and extraction wells, as follows:

$$\theta_m = \frac{Q_{inj} t_{50}}{\pi r^2 b} \qquad \textbf{(Equation 2-3)}$$

where:

θ_m = mobile porosity

Q_{inj} = injection rate at an injection well

t_{50} = time of travel to radius r

r = radius

b = injection well screen length

All of the variables on the right-hand side of Equation 2-3 would be known dependent variables, with θ_m the only independent variable on the left-hand side of the equation. For example, if the injection rate was 193 L/min (51 gpm) (277.5 m^3/d [9,800 ft^3/d]) in an injection well with a screen length of 15.2 m (50 ft), and it took 83 days for sulfate at a C/C_0 of 0.5 to reach a monitoring well located 68.6 m (225 ft) away from the effluent injection well, then θ_m would equal the following (Equation 2-4):

$$\theta_m = \frac{(9{,}800)(83)}{\pi(225^2)(50)} \approx 0.10 \qquad \textbf{(Equation 2-4)}$$

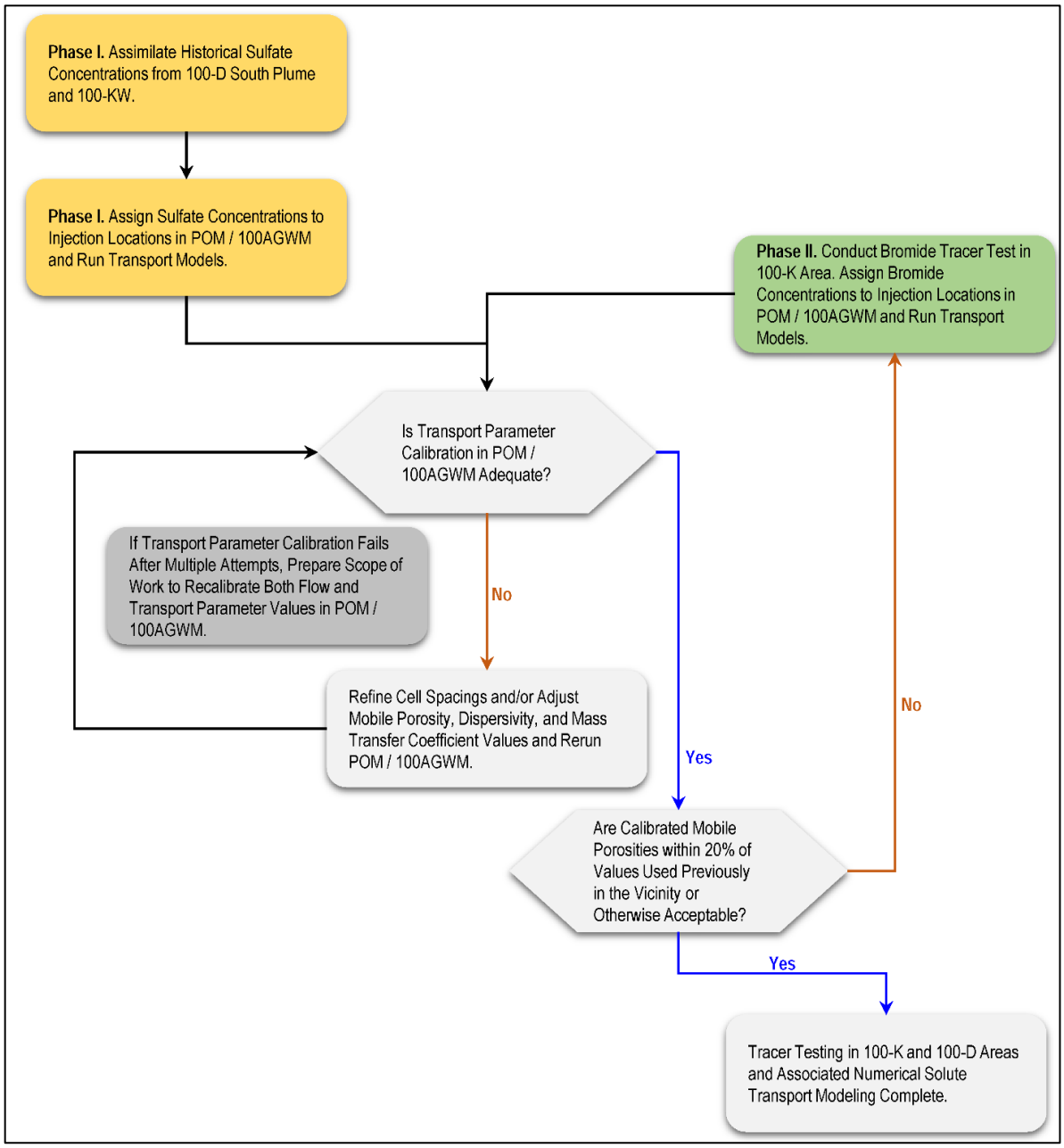
where:

θ_m = mobile porosity

Thus, an θ_m estimate for this example would be approximately 0.10 or 10 percent. This type of analysis provides a good starting point for estimating θ_m. However, spatial heterogeneity in grain size and hydraulic conductivity in the aquifer, noncontinuous injection of tracer, and hydraulic interferences among multiple P&T system extraction and injection wells will require more advanced methods of analysis, as described in the following subsection.

2.5.1.2 Numerical Methods

Numerical analysis methods are not bound by as many simplifying assumptions as are inherent with analytical methods. Thus, numerical methods are more flexible and capable of addressing a wider variety of subsurface conditions than analytical methods. For this study, a combination of two-dimensional and three-dimensional numerical groundwater flow and solute transport modeling will be used. The two- and three-dimensional numerical models that will form the basis for this effort include the two-dimensional 100 Area pumping optimization model and the three-dimensional 100 Area groundwater model (SGW-46279). These models will be reviewed to assess whether they can be used “as is” or if the number of model rows and columns needs to be increased in portions of the grid representing tracer injection areas in order to achieve adequate spatial resolution and achieve the objectives described in Section 1.1. Additional decisions regarding the use and modification of these tools is shown in Figure 2-5.



Note: POM = pumping optimization model 100AGWM = 100 Area groundwater model

Figure 2-5. Tracer Evaluation Process

2.5.2 Phase II Bromide Tracer Evaluations

The process shown in Figure 2-5 and described in Section 2.5.1.2 would also be implemented to evaluate the bromide tracer test data. Thus, initial calibration efforts would be focused only on transport parameters and transport-related boundary conditions (no groundwater flow parameters or flow-related boundary conditions). The number of model rows and columns will be increased in portions of the grid representing wells 199-K-112A and 199-K-129 to achieve adequate spatial resolution. If adequate calibration to tracer observations is not achieved, then a scope of work would be developed to expand the

list of calibration variables from transport-only to both flow and transport parameters and boundary conditions.

2.5.3 Reporting

Following completion of field activities, a technical report will be prepared to discuss the data collection and the reduction and analysis of the tracer tests. The report will include the following elements:

- **Introduction:** Describe the objectives and an overview of results.
- **Methodology:** Describe the materials and methods used.
- **Phase I tracer results:** Present the results of the sulfate tracer test evaluation from Phase I.
- **Phase II tracer results:** Present the results of the bromide tracer testing evaluation from Phase II (if initiated).
- **Discussion:** Describe the meaning results and discuss how the results in regard to the purpose of the testing.
- **Conclusions and recommendations:** Discuss the conclusions from tracer testing and the proposed next steps.

Field logbooks documenting activities associated with bromide tracer testing during Phase II (if initiated) may also be included in one or more appendices of the technical report.

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3 Project Management and Schedule

This chapter discusses the roles of project management and provides preliminary schedule information.

3.1 Project Organization and Resources

An overview of the project organization is illustrated in Figure 3-1 is discussed in further detail in Appendix C.

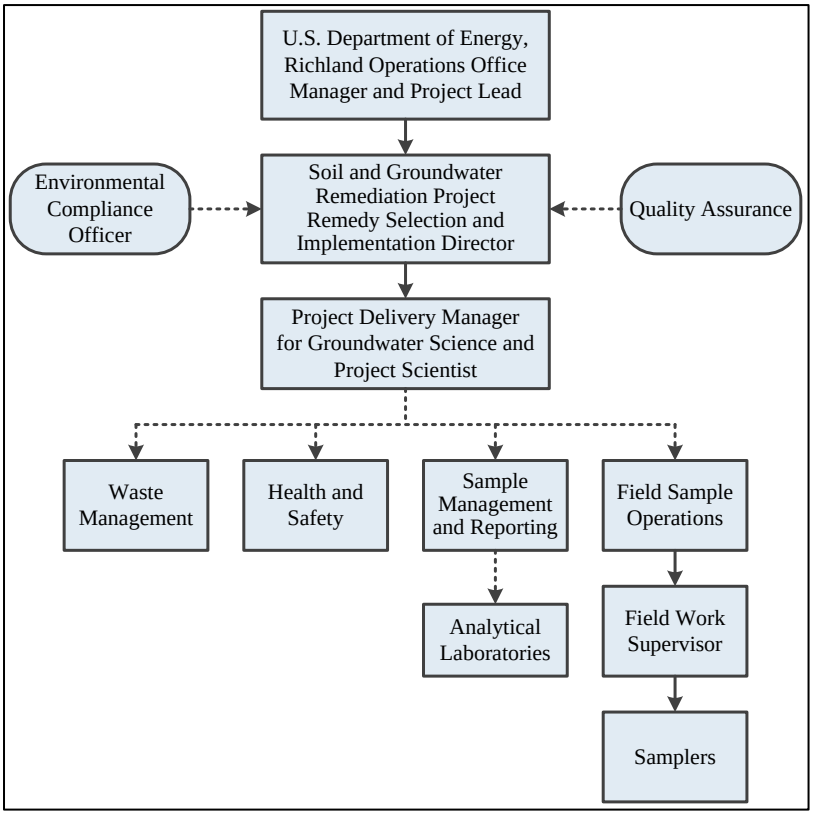

Figure 3-1. Project Organization Overview

3.2 Preliminary Study Schedule

The preliminary schedule for the tracer study is shown in Figure 3-2. The preliminary schedule includes development and approval of the study work plan, procurement of materials and required technical support contractors, implementation of field activities, and data reduction and reporting. This schedule assumes implementation of both Phase I and Phase II activities, although Phase II activities are dependent upon the outcome of the Phase I study.

Task Name		
Phase I Activities	7/11/2016	11/15/2016
Submit Draft Work Plan	7/11/2016	7/11/2016
Work Plan Approved	8/1/2016	8/1/2016
Initiate Phase I Tracer Analysis	8/1/2016	
Perform Sulfate Tracer Analysis	8/1/2016	9/30/2016
Prepare Technical Report (assume no subsequent Phase	10/1/2016	10/30/2016
Submit Technical Report	11/15/2016	11/15/2016
Phase II Activites (if initiated)	9/15/2016	3/15/2017
Procurement	9/15/2016	9/30/2016
Fieldwork	10/5/2016	11/30/2016
Bromide Analysis	12/1/2016	1/30/2017
Prepare Technical Report (Phase II)	2/1/2017	3/15/2017
Submit Technical Report	03/15/2017	03/15/2017

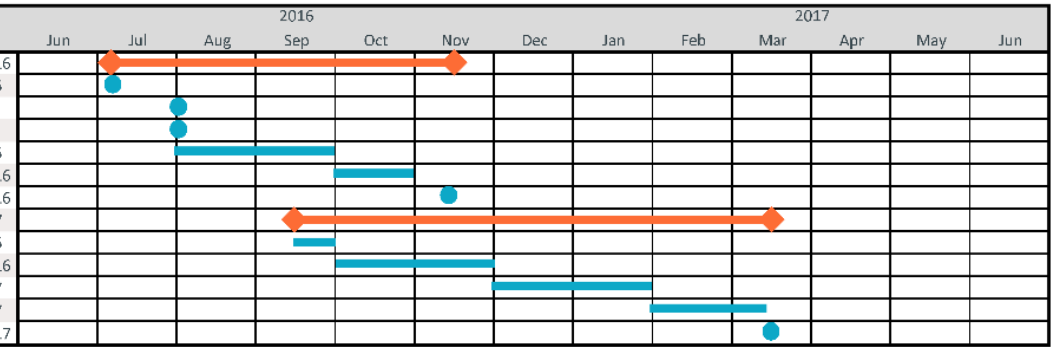

Figure 3-2. Tracer Studies Preliminary Schedule

4 References

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Appendix A

Systematic Planning Record

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Terms

N/A	not applicable
OU	operable unit
PSQ	principal study question
P&T	pump and treat

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A1 Project Summary

The elements of project problem identification, organization, schedule, and study goals are presented in the following subsections.

A1.1 Project Background

Some degree of uncertainty remains in the evaluation of groundwater movement in the 100-K and 100-D Areas, particularly with respect to groundwater flow and solute transport velocity under the dynamic conditions induced by active pump and treat (P&T) systems. This goal of this project is to assess the feasibility of the design and implementation of groundwater tracer testing to provide site-specific estimates of mobile porosity. These estimates can be used to enhance the representativeness of the 100 Area groundwater model with respect to subsurface contaminant transport.

This uncertainty in groundwater velocity focuses on two aquifer hydraulic parameters that may exhibit substantial spatial variability: formation hydraulic conductivity, and formation mobile (or effective) porosity. Variability in these two factors produce correspondingly large variations in local groundwater flow velocity. In its most basic relationship, groundwater velocity is equal to the hydraulic conductivity multiplied by the gradient, divided by the mobile (or effective) porosity. Therefore, velocity is directly proportional to the hydraulic conductivity and inversely proportional to the mobile porosity (i.e., as hydraulic conductivity increases, velocity increases; as mobile porosity increases, velocity decreases). Multiple existing measurements of hydraulic conductivity indicate substantial spatial variability at the 100-K and 100-D Areas (i.e., ranging over about a factor of 50 times). The spatial variability of mobile porosity has not been clearly defined, and current modeling activities use an average value of 0.18 to represent all areas. If mobile porosity is actually substantially different from the value used (i.e., 0.18), then the effective groundwater velocity (as well as the fraction of the aquifer into which contaminants from secondary sources may transfer) may be substantially different.

Recent evaluation of transient sulfate concentrations in groundwater related to operation of the 100-KW and 100-DX P&T systems indicates that a tracer analysis using available sulfate concentrations may provide useful information regarding aquifer transport properties and groundwater movement characteristics. Thus, the sulfate present in the P&T system effluent in these areas may function as a surrogate tracer since millions of gallons of effluent have been injected at known locations, rates, and sulfate concentration. Therefore, the plan is to use existing sulfate concentration data as surrogate tracer data. If results from the sulfate analysis indicate substantial changes in estimated mobile porosity, then one or more ionic or dye tracer tests will be conducted, where tracer would be injected into the aquifer at selected wells and tracer breakthrough would be monitored at selected observation wells. The subsequent tracer emplacement testing would provide further information regarding the apparent spatial variability in mobile porosity of the Ringold Formation unit E aquifer in the 100-D and 100-K Areas.

A1.2 Planning Type

This activity will apply the systematic planning approach to identify data needs and the data collection approach.

A2 Problem Statement, Principal Study Questions, and Goals

Elements of the study, including the principal study questions (PSQs), are described in the following subsections.

A2.1 State the Problem

The 100 Area groundwater model is used to forecast contaminant movement and remediation time frame. The need to analyze contaminant mass transfer from secondary contaminant sources has recently been identified. Improved estimation of the mobile porosity can be obtained from tracer testing; this in turn can improve the representativeness of the 100 Area groundwater model with respect to subsurface contaminant transport. Flow and transport simulations currently use a single value for mobile porosity that was derived from an average of multiple values. This current value may not be the best representation of mobile porosity, particularly in the event that this parameter exhibits spatial variability.

The tracer tests proposed for this study are assumed to be performed using existing wells and infrastructure; no new wells or monitoring locations will be constructed to support the study. The consideration of tracer studies in 100-D Area of the 100-HR-3 Operable Unit (OU) and the 100-K Area of the 100-KR-4 OU includes the assumption that the field portion of the tracer study (i.e., deploying instrumentation, injecting the tracer solution into the aquifer, and monitoring arrival of the tracer at the tracer observation well) can be completed within 1 to 2 weeks after beginning the study at each selected location.

Tracer assessments that are likely to require months to years of execution and monitoring or that have a high likelihood of providing ambiguous results will not be included in the planning effort. Such assessments include passive, wide-area tracer studies that would include travel distances of hundreds of meters with likely interception and reinjection associated with the P&T system.

A2.2 Principal Study Questions

The PSQs for the 100 Area tracer study are as follows:

- **PSQ #1:** Do mobile porosity values estimated through analysis of recent groundwater sulfate concentration data at 100-KW and 100-DX P&T systems differ substantially from those currently assigned in the 100 Area groundwater model?
- **PSQ #2:** Do mobile porosity values estimated through analysis of ionic or dye tracer in the 100-D Area of the 100-HR-3 OU and 100-KR-4 OU differ substantially from those estimated using the sulfate concentration data as a surrogate tracer, indicating additional range of spatial variability?

A2.3 Goals of the Study

The alternative outcomes and actions to conditions observed during the tracer study are summarized in Table A-1.

Table A-1. PSQs and Alternative Actions

PSQ #	PSQs	Alternative Outcomes/Actions
1	Do mobile porosity values estimated through analysis of recent groundwater sulfate concentration data at 100-KW and 100-DX P&T systems differ substantially from that currently assigned in the 100 Area groundwater model?	No. Sulfate-derived mobile porosity values are within 20 percent of the value currently assigned in the 100 Area groundwater model. Derived mobile porosity values should be assessed for indication of spatial variability and used as inputs for sensitivity analyses in model runs. Yes. Sulfate-derived mobile porosity values are not within 20 percent of the value currently assigned in the 100 Area groundwater model. Derived mobile porosity values are substantially different from current estimate and should be incorporated into the model to represent spatial variability. Implement an emplaced tracer test at selected location to further assess spatial variability of mobile porosity.
2	Do mobile porosity values estimated through analysis of surrogate (i.e., sulfate) and direct tracer testing in the 100 Areas indicate substantial spatial variability in mobile porosity of the shallow unconfined aquifer. ionic or dye tracer in the 100-D Area of the 100-HR-3 OU and 100-KR-4 OU differ substantially from those estimated using the sulfate concentration data as a surrogate tracer?	No. Tracer-derived mobile porosity values are within 20 percent of the sulfate-derived mobile porosity values estimated for the 100-KW and 100-DX Areas. Apply the tracer-derived mobile porosity values for sensitivity analysis in the model. Yes. Tracer-derived mobile porosity values are not within 20 percent of the sulfate-derived mobile porosity values estimated for the 100-KW and 100-DX Areas. Use the tracer-derived mobile porosity values to infer a spatial distribution of porosity in the fate and transport model to better represent aquifer conditions in simulations.

OU = operable unit
P&T = pump and treat
PSQ = principal study question

A2.3.1 Decision Statements or Estimation Statements

- **PSQ #1:** If sulfate-derived mobile porosity values are within 20 percent of the value currently assigned in the 100 Area groundwater model, then no additional tracer testing is required in the test areas. However, if sulfate-derived mobile porosity values are not within 20 percent of the value currently assigned in the 100 Area groundwater model, then additional tracer testing is required to provide supplemental estimates of mobile porosity to compare against the sulfate-derived estimates and provide further information on spatial variability. The derived values will be used for sensitivity analyses in the fate and transport model.

- **PSQ #2:** If tracer-derived mobile porosity values (i.e. sulfate-based, or emplaced tracer-based) are not within 20 percent of the sulfate-derived mobile porosity values, then the derived porosity values will be used to develop a spatial distribution of porosity to better represent aquifer conditions in the 100-D and 100-K Areas.

A3 Data Needs

Sulfate concentration transient data already exist for the 100-KW P&T vicinity, as well as in the 100-D south plume portion of the 100-DX P&T vicinity. The data will be used for the initial surrogate tracer analysis. For subsequent tracer emplacement testing (if indicated), one tracer injection well and one associated tracer observation well will constitute a sampling unit. In some cases, the tracer observation well may operate as a P&T system extraction well.

The smallest unit for estimating mobile porosity and making decisions is one tracer injection well and one associated tracer observation well.

A3.1 Data Needs Summary

Table A-2 provides the inputs to answer the PSQs identified in Section A2.2.

A4 Performance or Acceptance Criteria

A subset of the population data set deemed reliable and representative will be used rather than a summary statistic for the population.

Measurement data will be subject to the acceptance criteria established in the quality assurance project plan for this testing activity.

A5 Plan for Obtaining the Data

The general plan for implementing the tracer study is as follows:

1. Sulfate concentration transient analysis:
    a. Select target observation wells for the sulfate concentration-based analysis by inspecting the groundwater monitoring records for wells in the 100-KW P&T system vicinity, as well as in the 100-D south plume area associated with 100-DX P&T system.
    b. Identify the associated P&T injection wells and assemble the effluent concentration measurements, pumping rates, and operating periods for the target injection wells.
    c. Assemble the data, load the source-term (e.g., effluent) sulfate data into the 100 Area groundwater model, run the model, and iterate with local changes to mobile porosity until the output approximates the observed sulfate concentration transient conditions.
    d. Assemble the data and perform analytical solution calculations using the sulfate data to evaluate the transient concentrations and observed arrival times.
    e. Identify the range of mobile porosity estimates derived from these steps.

Table A-2. Data Needs Summary

PSQ #	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	Tracer injection rates, P&T system injection and extraction rates, tracer concentrations in tracer injection and observation wells, and groundwater levels during testing	Groundwater in shallow unconfined aquifer	Candidate sites in the 100-D or 100-K Area	In situ measurement and high-frequency sampling and analysis	N/A	Estimated by site-specific conditions; adequate frequency to detect tracer breakthrough curves.	Access to injection wells, limited field season with drier weather, injection rates, distance between injection and observation wells, and coordination and hydraulic interference with P&T operations.	Method dependent on tracer selected. Ionic tracers (e.g., bromide) may be detected by in situ ion-selective electrode and by laboratory ion chromatography. Fluorescent dye tracers are typically detected using laboratory spectrophotometry.	Available sulfate concentration data and the associated P&T system injection and extraction locations and rates; possibly including ionic or dye tracer injection tests with appropriate monitoring.
2	Same as identified for PSQ#1.	Same as identified for PSQ #1.	Same as identified for PSQ #1.	Same as identified for PSQ #1.	N/A	Same as identified for PSQ #1.	Same as identified for PSQ #1.	Same as identified for PSQ#1.	Same as identified for PSQ #1.

N/A = not applicable
P&T = pump and treat
PSQ = principal study question

2. Perform emplaced tracer study at selected location(s):
    a. Develop criteria for selecting tracer study locations.
    b. Identify general areas of interest for tracer studies using criteria developed in step 2a.
    c. Select wells to be used for injection and monitoring during testing.
    d. Estimate the study duration and the tracer dose and volume requirements based on existing knowledge of aquifer parameters. The target study duration is less than 30 days for each testing location.
    e. Select a tracer for each location that meets the study requirements for availability, nontoxicity, and detectability. Based on general availability and common history of usage, potassium bromide is the tracer of choice.
    f. Implement bromide tracer testing at selected location(s).

Note that because of the large distances between wells in the 100-H Area, no tracer testing sites have been identified in 100-H. Based on well configuration and proximity, and associated anticipated tracer test duration, the candidate tracer testing locations for PSQs #1 and #2 are as follows:

- 100-K Area:
    - **Candidate bromide tracer injection well:** 199-K-188 (existing monitoring well)
        - **Bromide tracer observation well:** 199-K-36 (existing monitoring well located about 24 m [79 ft] from 199-K-188)
        - **Bromide tracer observation well:** 199-K-220 (existing KX extraction well located about 56 m [184 ft] from 199-K-188)
    - **Candidate bromide tracer injection well:** 199-K-112A (existing monitoring well)
        - **Bromide tracer observation well:** 199-K-129 (existing KR-4 extraction well located about 5 m [16 ft] from 199-K-112A)
- 100-D Area
    - **Candidate bromide tracer injection well:** 199-D5-148 (existing DX injection well)
        - **Bromide tracer observation well:** 199-D2-11 (existing DX monitoring well located about 50 m [164 ft] from 199-D5-148)
    - **Candidate bromide tracer injection well:** 199-D5-129 (existing DX injection well)
        - **Bromide tracer observation well:** 199-D5-133 (existing DX monitoring well located about 33 m [108 ft] from 199-D5-129)

Selected candidate location for bromide tracer emplacement study is well pair 199-K-112A (tracer injection well) and 199-K-129 (tracer observation well). The primary reasons for selection of this well pair for the study are as follows:

- The wells are in close proximity (approximately 5 m [16 ft] apart), so the tracer test may be performed in a relatively short period of time with a relatively small volume of tracer solution required to be injected.
- The wells are located so a tracer test at this location will provide additional information regarding the spatial variability of mobile porosity (i.e., these wells are not close to the sulfate transient concentration study areas).

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Appendix B

Potassium Bromide Safety Data Sheet

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SIGMA-ALDRICH

sigma-aldrich.com

SAFETY DATA SHEET

Version 5.1
Revision Date 07/22/2015
Print Date 05/30/2016

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name	:	Potassium bromide, anhydrous, free-flowing, Redi-Dri(TM), ReagentPlus(R), >=99%
Product Number	:	793604
Brand	:	Sigma-Aldrich
CAS-No.	:	7758-02-3

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses	:	Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich 3050 Spruce Street SAINT LOUIS MO 63103 USA
Telephone	:	+1 800-325-5832
Fax	:	+1 800-325-5052

1.4 Emergency telephone number

Emergency Phone #	:	(314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Eye irritation (Category 2A), H319

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word: Warning

Hazard statement(s)

H319	Causes serious eye irritation.

Precautionary statement(s)

P264	Wash skin thoroughly after handling.
P280	Wear eye protection/ face protection.
P305 + P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337 + P313	If eye irritation persists: Get medical advice/ attention.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substances

Formula	:	BrK
Molecular weight	:	119.01 g/mol
CAS-No.	:	7758-02-3
EC-No.	:	231-830-3

Hazardous components

Component	Classification	Concentration
Potassium bromide		
	Eye Irrit. 2A; H319	<= 100 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Hydrogen bromide gas, Potassium oxides

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
No data available

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Use personal protective equipment. Avoid dust formation. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Avoid breathing dust.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.Avoid contact with skin and eyes. Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place.

hygroscopic
Storage class (TRGS 510): Non Combustible Solids

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body Protection
impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator.For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: crystalline Colour: colourless
b)	Odour	odourless
c)	Odour Threshold	No data available
d)	pH	5.0 - 6 at 119 g/l at 25 °C (77 °F)
e)	Melting point/freezing point	Melting point/range: 734 °C (1,353 °F)

f)	Initial boiling point and boiling range	1,435 °C (2,615 °F) at 1,013.20 hPa (759.96 mmHg)
g)	Flash point	No data available
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	No data available
k)	Vapour pressure	1 hPa (1 mmHg) at 795 °C (1,463 °F)
l)	Vapour density	No data available
m)	Relative density	2.750 g/cm3
n)	Water solubility	119 g/l at 20 °C (68 °F) - completely soluble
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information
No data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
No data available

10.5 Incompatible materials
Strong oxidizing agents, Strong acids, Heavy metal salts, Aluminum, Potassium

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
LD50 Oral - Rat - male and female - > 2,000 mg/kg
(OECD Test Guideline 401)

Inhalation: No data available

Dermal: No data available

No data available

Skin corrosion/irritation
Skin - Rabbit
Result: No skin irritation - 4 h
(OECD Test Guideline 404)

Serious eye damage/eye irritation
Eyes - Rabbit
Result: Irritating to eyes.
(OECD Test Guideline 405)

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
Laboratory experiments have shown mutagenic effects.

Ames test
Salmonella typhimurium
Result: negative

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data available

No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information

Repeated dose toxicity	Rat - male - Oral - NOAEL : 16.5 mg/kg

RTECS: TS7650000

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

Liver - Irregularities - Based on Human Evidence
Liver - Irregularities - Based on Human Evidence

12. ECOLOGICAL INFORMATION

12.1 Toxicity

Toxicity to fish	LC50 - Pimephales promelas (fathead minnow) - > 30 mg/l - 96 h
Toxicity to daphnia and other aquatic invertebrates	Immobilization EC50 - Daphnia magna (Water flea) - > 100 mg/l - 48 h (OECD Test Guideline 202)

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

No data available

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
Not dangerous goods

IATA
Not dangerous goods

15. REGULATORY INFORMATION

SARA 302 Components
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards
Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components
No components are subject to the Massachusetts Right to Know Act.

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Potassium bromide	7758-02-3	

New Jersey Right To Know Components

	CAS-No.	Revision Date
Potassium bromide	7758-02-3	

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Eye Irrit.	Eye irritation
H319	Causes serious eye irritation.

HMIS Rating

Health hazard:	2
Chronic Health Hazard:	*
Flammability:	0
Physical Hazard	0

NFPA Rating

Health hazard:	2
Fire Hazard:	0
Reactivity Hazard:	0

Further information

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Appendix C

Quality Assurance Project Plan

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Terms

CAS	Chemical Abstracts Service
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQA	data quality assessment
DQI	data quality indicator
DQO	data quality objective
DUP	laboratory sample duplicate
EB	equipment blank
ECO	environmental compliance officer
EPA	U.S. Environmental Protection Agency
FSO	Field Sample Operations
FTB	full trip blank
FWS	field work supervisor
FXR	field transfer blanks
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
HEIS	Hanford Environmental Information System
LCS	laboratory control sample
MB	method blank
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
N/A	not applicable
OU	operable unit
PQL	practical quantitation limit
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RDR	request for data review

RPD	relative percent difference
S&GRP	Soil and Groundwater Remediation Project
SMR	Sample Management and Reporting
SPLIT	field split
SUR	surrogate
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a)
VOC	volatile organic compound

C1 Introduction

A quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection. It includes planning, implementation, and assessment of sampling tasks, field measurements, laboratory analysis, and data review. This appendix describes the applicable environmental data collection requirements and controls based on the quality assurance (QA) elements found in EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5), and DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD). Sections 6.5 and 7.8 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*) require the QA/quality control (QC) and sampling and analysis activities to specify QA requirements for past-practice processes. This QAPjP also describes the applicable requirements and controls based on guidance provided in EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans* (EPA QA/G-5). This QAPjP is intended to supplement the contractor's environmental QA program plan.

This QAPjP is intended to support data collection associated with aquifer tracer studies to be conducted in the Hanford Site 100-D and 100-K Areas. Data collection activities include focused sampling and analysis of groundwater for common analytes and the collection of automated measurements of groundwater elevation and chemical constituents using in situ data logging instruments and selected manual measurements (e.g., groundwater elevation). This QAPjP is divided into the following four sections, which describe the quality requirements and controls applicable to tracer injection testing in the 100-D and 100-K Areas: project management, data generation and acquisition, assessment and oversight, and data review and usability.

C2 Project Management

The following sections addresses the management approaches planned, project goals, and planned output documentation.

C2.1 Project/Task Organization

Project organization (regarding groundwater sampling and analysis) is described in the following subsections and is illustrated in Figure C-1.

C2.1.1 DOE-RL Manager

Hanford Site cleanup is the responsibility of U.S. Department of Energy, Richland Operations Office (DOE-RL). The DOE-RL manager is responsible for authorizing the contractor to perform activities at the Hanford Site under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; *Resource Conservation and Recovery Act of 1976*; *Atomic Energy Act of 1954*; and Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement).

C2.1.2 DOE-RL Project Lead

The DOE-RL project lead is responsible for providing day-to-day oversight of the contractor's performance of the workscope, working with the contractor to identify and work through issues, and providing technical input to DOE-RL management.

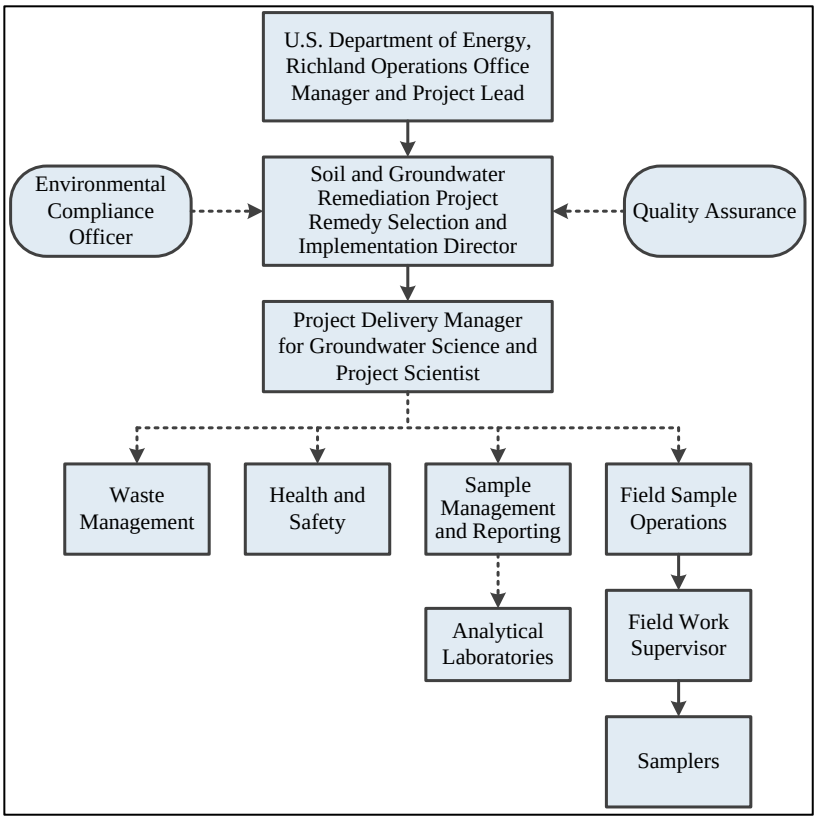

Figure C-1. Project Organization

C2.1.3 Soil and Groundwater Remediation Project Remedy Selection and Implementation Director

The Soil and Groundwater Remediation Project (S&GRP) remedy selection and implementation director provides oversight and coordinates with DOE-RL and primary contractor management in support of sampling and reporting activities. The remedy selection and implementation director also provides support to the project delivery manager for groundwater science to ensure that work is performed safely and cost effectively.

C2.1.4 Project Delivery Manager for Groundwater Science

The Project Delivery Manager for Groundwater Science is responsible for direct management of activities performed to meet groundwater monitoring requirements. The Project Delivery Manager for Groundwater Sciencecoordinates with and reports to DOE-RL and primary contractor management regarding groundwater monitoring requirements. The Project Delivery Manager for Groundwater Science(or designee) works closely with the environmental compliance officer (ECO) and the QA, Health and Safety, and Sample Management and Reporting (SMR) organizations to integrate these and other technical disciplines in planning and implementing the work scope. The Project Delivery Manager for Groundwater Scienceassigns scientists to provide technical expertise.

C2.1.5 Sample Management and Reporting

The SMR organization oversees offsite analytical laboratories, coordinates laboratory analytical work to ensure that laboratories conform to the requirements of this plan, and verifies that laboratories are qualified for performing Hanford Site analytical work. The SMR organization generates field sampling documents, labels, and instructions for field sampling personnel and develops the sampling authorization

form, which provides information and instruction to the analytical laboratories. SMR ensures that field sampling documents are revised to reflect approved changes. The SMR organization receives analytical data from the laboratories, ensures that data are appropriately reviewed, performs data entry into the Hanford Environmental Information System (HEIS) database, and arranges for data validation and recordkeeping. SMR is responsible for resolving sample documentation deficiencies or issues associated with Field Sample Operations (FSO), laboratories, or other entities. SMR is responsible for informing the Project Delivery Manager for Groundwater Science of any issues reported by the analytical laboratories.

C2.1.6 Field Sample Operations

FSO is responsible for planning and coordinating field sampling resources and provides the field work supervisor (FWS) for routine groundwater sampling operations. The FWS directs the nuclear chemical operators (samplers), who collect groundwater samples in accordance with the groundwater monitoring plan and corresponding standard procedures and work packages. The FWS ensures that deviations from field sampling documents or issues encountered in the field are documented appropriately (e.g., in the field logbook). The FWS ensures that samplers are appropriately trained and available. Samplers collect samples in accordance with sampling documentation. Samplers also complete field logbooks, data forms, and chain-of-custody forms, including any shipping paperwork, and enable delivery of the samples to the analytical laboratory.

Pre-job briefings are conducted by the FSO, in accordance with work management and work release requirements, to evaluate activities and associated hazards by considering the following factors:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Facility where the job will be performed
- Equipment and material required

C2.1.7 Quality Assurance

The QA point of contact provides independent oversight and is responsible for addressing QA issues on the project and overseeing implementation of the project QA requirements. Responsibilities include reviewing project documents, including the QAPjP, and participating in QA assessments on sample collection and analysis activities, as appropriate.

C2.1.8 Environmental Compliance Officer

The ECO provides technical oversight, direction, and acceptance of project and subcontracted environmental work and also develops appropriate mitigation measures with the goal of minimizing adverse environmental impacts.

C2.1.9 Health and Safety

The Health and Safety organization is responsible for coordinating industrial safety and health support within the project as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulations or internal primary contractor work requirements.

C2.1.10 Waste Management

Waste Management is responsible for identifying waste management sampling/characterization requirements to ensure regulatory compliance and for interpreting data to determine waste designations and profiles. Waste Management communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner.

C2.1.11 Analytical Laboratories

The analytical laboratories analyze samples in accordance with established procedures and the requirements of this plan and provide necessary data packages containing analytical and QC results. Laboratories provide explanations of results to support data review and in response to resolution of analytical issues. The laboratories are evaluated under the U.S. Department of Energy (DOE) Consolidated Audit Program for the analyses performed for S&GRP.

C2.2 Problem Definition/Background

The purpose of this groundwater sampling and analysis activity is to collect measurements and observations that will provide information quantifying the timing and concentration of the tracer breakthrough in groundwater from implementing tracer injection tests in the 100-D and 100-K Areas.

C2.3 Project/Task Description

The focus of this plan is to monitor and evaluate parameters that will support derivation of estimates of mobile porosity within the unconfined aquifers in the 100-D and 100-K Areas. The parameters to be monitored, as well as the monitoring wells and frequency of sampling, are provided in Chapter 2 of the main text. Information on the collection and analyses of groundwater from the monitoring network is provided in this appendix and discussed in Chapter 2.4 of the main text.

C2.4 Quality Assurance Objectives and Criteria

The QA objective of this plan is to ensure that the generation of analytical data of known and appropriate quality are acceptable and useful in order to meet the evaluation requirements stated in the monitoring plan. In support of this objective, data descriptors known as data quality indicators (DQIs) are used to help determine the acceptability and usefulness of the data to the user. Principal DQIs are precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity. These DQIs are defined for the purposes of this document in Table C-1.

Data quality is defined by the degree of rigor in the acceptance criteria assigned to DQIs. The applicable QC guidelines, DQI acceptance criteria, and levels of effort for assessing data quality are dictated by the intended use of the data and requirements of the analytical method. DQIs are evaluated during the data quality assessment (DQA) process (Section C5.3).

C2.5 Special Training/Certification

Workers receive a level of training that is commensurate with their responsibility for collecting and transporting groundwater samples according to the organizational training plan. The FWS, in coordination with line management, will ensure that special training requirements for field personnel are met.

Table C-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Precision (field duplicates, laboratory sample duplicates, and matrix spike duplicates)	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of field duplicates. Analytical precision is estimated by duplicate/replicate analyses, usually on laboratory control samples, spiked samples, and/or field samples. The most commonly used estimates of precision are the relative standard deviation and, when only two samples are available, the RPD.	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory. Acquire replicate field samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	If duplicate data do not meet objective: • Evaluate apparent cause (e.g., sample heterogeneity). • Request reanalysis or remeasurement. • Qualify the data before use.
Accuracy (laboratory control samples, matrix spikes, and surrogates)	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. QC analyses used to measure accuracy include standard recoveries, laboratory control samples, spiked samples, and surrogates.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample).	If recovery does not meet objective: • Qualify the data before use. • Request reanalysis or remeasurement.

Table C-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Representativeness (field duplicates)	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring that the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for results not being representative. • Flag for further review. • Review data for usability. • If data are usable, qualify the data for limited use and define the portion of the system that the data represent. • If data are not usable, flag as appropriate. • Redefine sampling and measurement requirements and protocols. • Resample and reanalyze, as appropriate.
Comparability (field duplicates, field splits, laboratory control samples, matrix spikes, and matrix spike duplicates)	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and quality assurance protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Qualify the data, as appropriate. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future comparability.

Table C-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Completeness (no QC element; addressed in data quality assessment)	Completeness is a measure of the amount of valid data collected compared to the amount of data planned. Measurements are considered to be valid if they are unqualified or qualified as estimated data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (data quality objectives or performance/acceptance criteria).	If data set does not meet the completeness objective: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future completeness.

Table C-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Bias (equipment blanks, full trip blanks, laboratory control samples, matrix spikes, and method blanks)	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools. • Institute correct sampling and subsampling procedures to limit preferential selection or loss of sample media. • Use sample handling procedures, including proper sample preservation, that limit the loss or gain of constituents to the sample media. • Analytical data that are known to be affected by either sampling or analytical bias are flagged to indicate possible bias. • Laboratories that are known to generate biased data for a specific analyte are asked to correct their methods to remove the bias as best as practicable. Otherwise, samples are sent to other laboratories for analysis.

Table C-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Sensitivity (method detection limit, practical quantitation limit, and RPD)	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation[b] is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet objective: • Request reanalysis or remeasurement using methods or analytical conditions that will meet required detection or limit of quantitation. • Qualify/reject the data before use.

Source: SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*, as amended.

a. Acceptance criteria for QC elements are provided in Table C-5.

b. For purposes of this tracer test project plan, the lower limit of quantitation is interchangeable with the practical quantitation limit.

QC = quality control

RPD = relative percent difference

Training has been instituted by the contractor management team to meet training and qualification programs that satisfy multiple training drivers imposed by applicable *Code of Federal Regulations* and *Washington Administrative Code* requirements, as appropriate. Training records are maintained for each employee in an electronic training record database. The contractor's training organization maintains the training records system. Line management confirms that an employee's training is appropriate and up to date prior to performing any fieldwork.

C2.6 Documents and Records

The Project Delivery Manager for Groundwater Science(or designee) is responsible for ensuring that the current version of the groundwater monitoring plan is used and any updates are provided to field personnel. Version control is maintained by the administrative document control process. Table C-2 defines the types of changes that may impact the tracer test project plan and the associated approvals, notifications, and documentation requirements.

Table C-2. Change Control for Sampling Projects

Type of Change[a]	Type of Change[b]	Action	Documentation
Minor change: Change has no impact on the sample or field analytical result, and little or no impact on performance or cost. Furthermore, the change does not affect the DQOs specified in the tracer test project plan.	**Minor field change:** Changes that have no adverse effect on the technical adequacy of the job or the work schedule.	The field personnel recognizing the need for a field change will consult with the OU project scientist prior to implementing the field change.	Minor field changes will be documented in the field logbook. The logbook entry will include the field change, reason for the field change, and names and titles of those approving the field change.
Significant change: Change has a considerable effect on performance or cost, but still allow for meeting the DQOs specified in the tracer test project plan.	**Minor change**: Changes to approved plans that do not affect the overall intent of the plan or schedule.	The OU project manager will inform the DOE-RL project manager and the regulatory lead of the change and seek concurrence at a unit managers' meeting or comparable forum. The lead regulatory agency determines there is no need to revise the document.	Documentation of this change approval would be in the unit managers' meeting minutes or comparable record, such as a change notice.[c]

Table C-2. Change Control for Sampling Projects

Type of Change[a]	Type of Change[b]	Action	Documentation
Fundamental change: Change has significant effect on the sample or the field analytical result, performance, or cost, and the change does not meet the requirements specified in the DQOs in the sampling document.	**Revision necessary:** Lead regulatory agency determines changes to approved plans require revision to document.	If it is anticipated that a fundamental change will require the approval of the regulatory lead, the applicable DOE-RL project manager will be notified by the S&GRP project manager and will be involved in the decision prior to implementation of a fundamental change. The lead regulatory agency determines that the change requires a revision to the document.	Formal revision of the sampling document.

a. Consistent with DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD).

b. Consistent with Sections 9.3 and 12.4 of Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan* (Tri-Party Agreement Action Plan).

c. Section 9.3 of the Tri-Party Agreement Action Plan defines the minimum elements of a change notice.

DOE-RL = U.S. Department of Energy, Richland Operations Office
DQO = data quality objective
OU = operable unit
S&GRP = Soil and Groundwater Remediation Project

Logbooks and data forms are required for field activities. The logbook must be identified with a unique project name and number. Individuals responsible for the logbooks will be identified in the front of the logbook, and only authorized individuals may make entries into the logbooks. Logbooks will be controlled in accordance with internal work requirements and processes.

The FWS, SMR organization, and any field crew supervisors are responsible for ensuring that field instructions are maintained and aligned with any revisions or approved changes to this tracer test project plan. SMR will ensure that any deviations from the plan are reflected in revised field sampling documents for the samplers and analytical laboratory. The FWS or appropriate field crew supervisors will ensure that deviations from the plan or problems encountered in the field are documented appropriately (e.g., in the field logbook).

The Project Delivery Manager for Groundwater Science, FWS, or designee is responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities. The Project Delivery Manager for Groundwater Science is also responsible for ensuring that project files are set up as appropriate and/or maintained. The project files will contain project records or references to their storage locations. Project files generally include, as appropriate, the following information:

- Operational records and logbooks
- Data forms
- Global positioning system data (a copy will be provided to the SMR organization)

- Inspection or assessment reports and corrective action reports
- Field summary reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," and the master drilling contract

The following records are managed and maintained by SMR personnel:

- Completed field sampling logbooks
- Groundwater sample reports and field sample reports
- Chain-of-custody forms
- Sample receipt records
- Laboratory data packages
- Analytical data verification and validation reports
- Analytical data case file purges (i.e., raw data purged from laboratory files) provided by offsite analytical laboratories

The laboratory is responsible for maintaining, and having available upon request, the following items:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Instrument calibration information

Convenience copies of laboratory analytical results are maintained in the HEIS database. Records may be stored in either electronic (e.g., in the managed records area of the Integrated Document Management System) or hardcopy format (e.g., DOE Records Holding Area). Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes that ensure accuracy and retrievability of stored records. Records required by the Tri-Party Agreement (Ecology et al., 1989a) will be managed in accordance with the requirements therein.

The results of groundwater sampling and analysis are reported annually in the annual Hanford Site groundwater monitoring report. The results of this tracer study will be document in a separate report, as well as potentially summarized in the annual Hanford Site groundwater monitoring report.

C3 Data Generation and Acquisition

This chapter addresses data generation and acquisition to ensure that the project's methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are appropriate and documented. Requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

C3.1 Analytical Method Requirements

Analytical method requirements for samples collected are presented in Table C-3. Updated U.S. Environmental Protection Agency (EPA) methods may be substituted for the analytical methods identified in Table C-3.

Table C-3. Analytical Requirements for Groundwater Analysis

CAS #	Analyte/Parameter	Analytical Method[a]	Highest Allowable Practical Quantitation Limit[b] (µg/L, unless stated otherwise)
Anions			
24959-67-9	Bromide	EPA Method 300.0	250
Field Measurements			
N/A	Dissolved oxygen	Field measurement instrument/meter	N/A
N/A	Oxidation-reduction potential		N/A
N/A	pH		N/A
N/A	Specific conductance		N/A
N/A	Temperature		N/A
N/A	Turbidity		N/A
24959-67-9	Bromide ion (Br^-)	In situ ion-selective electrode (manufacturer's instructions)	1 mg/L

Note: Analytical methods and highest allowable PQLs provided in this table do not represent EPA requirements but are intended solely as guidance.

a. For EPA Method 300.0, see EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*. Equivalent methods may be substituted.

b. For purposes of this plan, the highest allowable PQL is interchangeable with the lower limit of quantitation, which is the lowest level that can be routinely quantified and reported by a laboratory. The highest allowable PQLs are not to be exceeded and are specified in contracts with analytical laboratories. Actual quantitation limits vary by laboratory and may be lower than required contractually. Method detection limits are three to five times lower than quantitation limits.

CAS = Chemical Abstracts Service
EPA = U.S. Environmental Protection Agency
N/A = not applicable
PQL = practical quantitation limit

C3.2 Field Analytical Methods

Field screening and survey data will be measured in accordance with HASQARD (DOE/RL-96-68) requirements (as applicable). Field analytical methods may also be performed in accordance with manufacturer manuals. Table C-3 provides the parameters identified for field measurements. The tracer study work plan further describes field measurements.

C3.3 Quality Control

QC requirements specified in the plan must be followed in the field and analytical laboratory to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Field and laboratory QC samples are summarized in Table C-4. Acceptance criteria for field and laboratory QC are shown in Table C-5. Data will be qualified and flagged in the HEIS database, as appropriate.

Table C-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Field QC		
Field duplicates	One from each well in tracer test.	Precision, including sampling and analytical variability
Field splits	As needed. When needed, the minimum is one for every analytical method, for analyses performed.	Precision, including sampling, analytical, and interlaboratory
Full trip blanks	One in 20 well trips.	Cross-contamination from containers or transportation
Field transfer blanks (for VOCs only)	One each day VOCs are sampled. Not required for this study; no VOCs collected.	Contamination from sampling site
Equipment blanks	As needed. If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment blank is not required; otherwise, one for every 20 samples.[a] Not required for this study; dedicated sampling devices will be used.	Adequacy of sampling equipment decontamination and contamination from nondedicated equipment
Analytical QC[b]		
Laboratory sample duplicates	One per analytical batch.[c]	Laboratory reproducibility and precision
Matrix spikes	One per analytical batch.[c]	Matrix effect/laboratory accuracy
Matrix spike duplicates	One per analytical batch.[c]	Laboratory accuracy and precision
Laboratory control samples	One per analytical batch.[c]	Laboratory accuracy
Method blanks	One per analytical batch.[c]	Laboratory contamination
Surrogates	Added to each sample and QC sample.[c]	Recovery/yield
Tracers	Added to each sample and QC sample.[c]	Recovery/yield

Table C-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Carriers[d]	Added to each sample and QC sample.[c]	Recovery/yield

Note: The information in this table does not represent EPA requirements but is intended solely as guidance.

a. For portable pumps, equipment blanks are collected one for every 10 well trips. Whenever a new type of nondedicated equipment is used, an equipment blank will be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination methods for the nondedicated equipment.

b. Batching across projects is allowed for similar matrices (e.g., Hanford Site groundwater).

c. Unless not required by, or different frequency is called out in, laboratory analysis methods.

d. Carriers are typically nonradioactive (e.g., natural strontium) substances added in known quantities to samples to determine the overall chemical yield for the analytical preparation steps. As with a tracer, carrier recovery is a measure of the amount of analyte lost in performing the method.

EPA = U.S. Environmental Protection Agency

QC = quality control

VOC = volatile organic compound

Table C-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte	QC Element	Acceptance Criteria	Corrective Action
Anions			
Anions by ion chromatography	MB	<MDL <5% sample concentration	Flag with “C”
	LCS	80 to 120% recovery	Review data[a]
	DUP[b]/MSD[c]	≤20% RPD	Review data[a]
	MS/MSD[c]	75 to 125% recovery	Flag with “N”
	EB, FTB	<2 times MDL	Flag with “Q”
	Field duplicate/split	≤20% RPD[b]	Review data[a]

Note: This table only applies to laboratory analyses. Dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity are not listed because they are measured in the field.

a. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the data as suspect (“Y” flag) or rejected (“R” flag).

b. Applies when at least one result is greater than the laboratory practical quantitation limit (chemical analyses) or greater than five times the MDL/minimum detectable concentration.

c. Either a DUP or MSD is to be analyzed to determine measurement precision.

Data flags:

B, C = possible laboratory contamination; analyte was detected in the associated MB

N = result may be biased; associated MS result was outside the acceptance limits

Q = problem with associated field QC blank; results were out of limits

T = result may be biased; associated MS result was outside the acceptance limits (gas chromatography/mass spectrometry only)

Table C-5. Field and Laboratory QC Elements and Acceptance Criteria

Analyte	QC Element	Acceptance Criteria	Corrective Action

DUP	= laboratory sample duplicate	MDL	= method detection limit
EB	= equipment blank	MS	= matrix spike
FTB	= full trip blank	MSD	= matrix spike duplicate
LCS	= laboratory control sample	QC	= quality control
MB	= method blank	RPD	= relative percent difference

C3.3.1 Field Quality Control Samples

Field QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field sampling variability and laboratory performance to help ensure that reliable data are obtained. Field QC samples include field duplicates, field split (SPLIT) samples, and two types of field blanks (full trip blanks [FTBs] and equipment blanks [EBs]). Field blanks are typically prepared using high-purity reagent water. QC sample definitions and their required frequency for collection are described as follows:

- **Field duplicates:** Independent samples collected as close as possible to the same time and same location as the scheduled sample and intended to be identical. Field duplicates are placed in separate sample containers and analyzed independently. Field duplicates are used to determine precision for both sampling and laboratory measurements.
- **Field splits (SPLITs):** Two samples collected as close as possible to the same time and same location and intended to be identical. SPLITs will be stored in separate containers and analyzed by different laboratories for the same analytes. SPLITs are interlaboratory comparison samples used to evaluate comparability between laboratories.
- **Full trip blanks (FTBs):** Bottles prepared by the sampling team before travel to the sampling site. The preserved bottle set is either for volatile organic analysis only or identical to the set that will be collected in the field. It is filled with high-purity reagent water,[1] and the bottles are sealed and transported (unopened) to the field in the same storage containers used for samples collected that day. Collected FTBs are typically analyzed for the same constituents as the samples from the associated sampling event. FTBs are used to evaluate potential contamination of the samples attributable to the sample bottles, preservative, handling, storage, and transportation.
- **Field transfer blanks (FXRs):** Preserved volatile organic analysis sample vials filled with high-purity reagent water at the sample collection site where volatile organic compounds (VOCs) are collected. Samples will be prepared during sampling to evaluate potential contamination attributable to field conditions. After collection, FXR sample vials will be sealed and placed in the same storage containers with samples collected the same day for the associated sampling event. FXR samples will be analyzed for VOCs only.

[1] High-purity water that is generally defined as water that has been distilled, deionized, or any combination of distillation, deionization, reverse osmosis, activated carbon filtration, ion exchange, particulate filtration, or other polishing techniques (DOE/RL-96-68).

- **Equipment blanks (EBs):** Reagent water passed through or poured over the decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the sample authorization form. The EB sample bottles are placed in the same storage containers with samples from the associated sampling event. EB samples will be analyzed for the same constituents as samples from the associated sampling event. EBs are used to evaluate the effectiveness of the decontamination process. EBs are not required for disposable sampling equipment.

C3.3.2 Laboratory Quality Control Samples

Internal QA/QC programs are maintained by laboratories used by the project. Laboratory QA includes a comprehensive QC program that includes the use of laboratory sample duplicates (DUPs), matrix spikes (MSs), matrix spike duplicates (MSDs), laboratory control samples (LCSs), method blanks (MBs), surrogates (SURs), carriers and tracers. These QC analyses are required by EPA methods (e.g., those in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*) and will be run at the frequency specified in the respective references unless superseded by agreement. QC checks outside of control limits are documented in analytical laboratory reports during DQAs, if performed. Laboratory QC checks and their typical frequencies are listed in Table C-4. Acceptance criteria are shown in Table C-5. The various laboratory QC samples are as follows:

- **Laboratory sample duplicate (DUP):** An intralaboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.
- **Matrix spike (MS):** An aliquot of a sample spiked with a known concentration of target analyte(s). An MS is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.
- **Matrix spike duplicate (MSD):** A replicate spiked aliquot of a sample that is subjected to the entire sample preparation and analytical process. MSD results are used to determine the bias and precision of a method in a given sample matrix.
- **Laboratory control sample (LCS):** A control matrix (e.g., reagent water) spiked with analytes representative of the target analytes or a certified reference material that is used to evaluate laboratory accuracy.
- **Method blank (MB):** An analyte-free matrix to which the same reagents are added in the same volumes or proportions as used in the sample processing. The MB is carried through the complete sample preparations and analytical procedure and is used to quantify contamination resulting from the analytical process.
- **Surrogate (SUR):** A compound added to every samples in the analysis batch (field samples and QC samples) prior to preparation. SURs are typically similar in chemical composition to the analyte being determined, yet they are not normally encountered. SURs are expected to respond to the preparation and measurement systems in a manner similar to the analytes of interest. Because SURs are added to every standard, samples, and QC samples, they are used to evaluate overall method performance in a given matrix. SURs are used only in organic analyses.
- **Laboratory tracer:** A laboratory tracer is a known quantity of radioactive isotope that is different from that of the isotope of interest but is expected to behave similarly and is added to an aliquot of sample. Sample results are generally corrected based on tracer recovery.

- **Carrier:** Carriers are typically nonradioactive (e.g., natural strontium) substances added in known quantities to samples to determine the overall chemical yield for the analytical preparation steps. As with a tracer, carrier recovery is a measure of the amount of analyte lost in performing the method.

Laboratories are required to analyze samples within the holding time specified in Table C-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilizing, decomposing, or other chemical changes. Data from samples analyzed outside the holding times are flagged in the HEIS database with an "H."

Table C-6. Preservation, Container, and Holding-Time Guidelines for Laboratory Analyses

Analyte	Minimum Volume[a]	Container Type[b]	Preservation[c]	Holding Time
Bromide	500 mL	Narrow-mouth poly or glass	Store at ≤6°C	28 days
Specific conductance	500 mL	Narrow-mouth poly	Store at ≤6°C	28 days

Note: This table only applies to laboratory analyses. Dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity are not listed because they are measured in the field.

a. Minimum volume provided is that volume required to run a sample with full quality control samples.

b. The term poly stands for U.S. Environmental Protection Agency clean polyethylene bottles.

c. For preservation identified as stored at ≤6°C, the sample should be protected against freezing unless it is known that freezing will not impact the sample integrity.

C3.4 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that equipment is functioning as expected, properly handled, and properly calibrated at required frequencies in accordance with methods governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved methods. Field screening instruments will be used, maintained, and calibrated in accordance with manufacturer specifications and other approved methods.

C3.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment should meet applicable standards (e.g., ASTM International, formerly the American Society for Testing and Materials) or should have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

Measurement and testing equipment used in the field or in the laboratory will be subject to preventive maintenance measures to ensure minimization of downtime. Laboratories must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included in the individual laboratory and onsite organization's QA plan or operating protocols, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with applicable Hanford Site requirements.

C3.6 Instrument/Equipment Calibration and Frequency

Field equipment calibration is discussed in the Chapter 2 of this report.. Analytical laboratory instruments are calibrated in accordance with the laboratory's QA plan and applicable Hanford Site requirements.

C3.7 Inspection/Acceptance of Supplies and Consumables

Consumables, supplies, and reagents will be reviewed in accordance with test methods in SW-846 and will be appropriate for their use. Supplies and consumables used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes. Responsibilities and interfaces necessary to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements must be in place. The procurement system ensures that purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

C3.8 Nondirect Measurements

Nondirect data refer to records of measurements and observations that were not collected directly under this tracer test project plan but may be used to provide a more complete understanding of site conditions (e.g., weather data, river stage data, historical monitoring data, and pump and treat system operating data). Data obtained from sources, such as computer databases, programs, literature files, and historical databases, will be technically reviewed to the same extent as data generated as part of any sampling and analysis QA/QC effort. Nondirect data used in evaluations will be identified by source.

C3.9 Data Management

The SMR organization, in coordination with the Project Delivery Manager for Groundwater Science, is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements governing data management methods.

Electronic data access, when appropriate, will be through a Hanford Site database (e.g., HEIS database). Where electronic data are not available, hardcopies will be provided in accordance with Section 9.6 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b).

Laboratory errors are reported to the SMR organization through an established process. For reported laboratory errors, a sample issue resolution form will be initiated in accordance with applicable methods. This process is used to document analytical errors and establish their resolution with the Project Delivery Manager for Groundwater Science. The sample issue resolution forms become a permanent part of the analytical data package for future reference and records management.

C4 Assessment and Oversight

Assessment and oversight activities address the effectiveness of project implementation and associated QA/QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

C4.1 Assessments and Response Actions

Random surveillances and assessments verify compliance with the requirements outlined in this plan, project field instructions, the QAPjP, methods, and regulatory requirements. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project line management chain coordinates the corrective actions/deficiencies resolutions in accordance with the QA program, corrective action management program, and associated methods implementing these programs. When appropriate, corrective actions will be taken by the S&GRP groundwater manager.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with laboratory QA plans. The SMR organization oversees offsite analytical laboratories and verifies that laboratories are qualified to perform Hanford Site analytical work.

C4.2 Reports to Management

Program and project management (as appropriate) will be made aware of deficiencies identified by self-assessments, corrective actions from ECOs, and findings from QA assessments and surveillances. Issues reported by the laboratories are communicated to the SMR organization, which then initiates a sample issue resolution form. This process is used to document analytical or sample issues and establish resolution with the Project Delivery Manager for Groundwater Science.

C5 Data Review and Usability

This chapter addresses QA activities that occur after data collection. Implementation of these activities determines whether the data conform to the specified criteria, thus satisfying the project objectives.

C5.1 Data Review and Verification

Data review and verification will be performed as measurement data are received to ensure that the collected data meet the data quality indicators (Table C-1) and are usable for the tracer study data reduction and evaluation in the 100-D and 100-K Areas. This includes confirmation that sampling and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations, reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times (if any) have been met, and reviewing QC data to determine whether analyses have met the data quality requirements specified in this plan.

The criteria for verification include, but are not limited to, review for contractual compliance (samples were analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors. Field QA/QC results also will be reviewed to ensure that they are usable.

The project scientist, assigned by the Project Delivery Manager for Groundwater Science, will perform a data review to help determine if observed changes reflect improved/degraded groundwater quality or potential data errors, which may result in submittal of a request for data review (RDR) on questionable data. The laboratory may be asked to check calculations or reanalyze the sample, or the well may be resampled. Results of the RDR process are used to flag the data appropriately in the HEIS database and/or to add comments.

C5.2 Data Validation

Third-party independent data validation will not be performed on the laboratory measurements reported for this study. No analysis of contaminants of concern are being performed, and the data will not be used in risk assessment or remedial action decisions.

C5.3 Reconciliation with User Requirements

The DQA process for this activity will incorporate the data review, verification, and validation activities described in Sections C5.1, C5.2, and C5.3. The DQA will compare completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the DQA is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet the project data quality needs. For groundwater monitoring performed for this tracer test plan, a summary DQA report will be prepared following the tracer study. In addition, the DQA is captured in the DQA appendix associated with the annual Hanford Site groundwater report, which evaluates field and laboratory QC and the usability of data on an annual basis.

Further DQAs will be performed at the discretion of the Project Delivery Manager for Groundwater Science and documented in a report overseen by the SMR organization.

C6 References

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