Quality Assurance Project Plan

Groundwater Assessment Program Pilot Study Phase 2

by
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Approvals

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Table of Contents

Abstract

In response to concerns regarding the absence of a systematic, state-level approach to measuring and describing ambient groundwater conditions, a pilot test of a Washington Department of Ecology (Ecology)-based groundwater assessment program was recommended. The program design proposed for trial is intended to provide comparable procedures for the collection of *baseline* information about groundwater and hydrogeologic conditions at a basin or subbasin scale. Conducting a pilot study will allow evaluation and refinement of the technical methods and schedule, staff, and budget requirements of the proposed assessment approach. The lessons learned during the pilot study will be instrumental in the agency's decision whether to pursue and dedicate resources to a longer-term state program.

In October 2003, a Quality Assurance Project Plan (QA Project Plan) was published describing field activities being conducted during the pilot study under the terms of a U.S. Environmental Protection Agency (EPA) grant (Phase 1). This current plan was prepared to describe the field activities for the remaining portion of the pilot study (Phase 2).

Background

Ecology's Environmental Assessment (EA) Program recently completed an in-depth review of the program's groundwater assessment efforts. The goals of the review were two-fold: 1) evaluate the current state of affairs for the assessment and measurement of state ambient groundwater conditions and 2) outline recommendations for how the EA Program can best help the agency and the state meet current and future information needs for the groundwater resource. A final report summarizing the findings and recommendations of this review was published in May 2003 (Pitz, 2003a).

In response to concerns regarding the absence of a systematic, state-level approach to measuring and describing ambient groundwater conditions, a key suggestion of the recommendations report was to pilot test an EA Program-based state groundwater assessment program. The program design proposed for trial is intended to provide systematic, comparable procedures for the collection of *baseline* information about groundwater and hydrogeologic conditions at a basin or subbasin scale.

Conducting a pilot study will allow the EA Program to evaluate and refine the technical methods and schedule, staff, and budget requirements of the proposed assessment approach. The lessons learned during the pilot study will be instrumental in the agency's decision whether or not to pursue and dedicate resources to a longer-term state program. If successful, the approach could be progressively applied to study areas across the state where baseline groundwater data is lacking and is in high demand.

In October 2002, the EA Program received a Clean Water Act 104(b)(3) grant from the Region 10 office of the EPA. A primary purpose of the EPA grant was to support the early stages of a pilot study, as described above, in a high priority groundwater basin. The first of two QA Project Plans for the pilot study was issued in October 2003 (Pitz and Erickson, 2003). The Phase 1 plan specifically described the field activities of the pilot study that the EA Program is obligated to complete under the terms of the EPA grant (a dry season seepage evaluation, and the installation and sampling of a stream-based piezometer network). The current document describes the technical procedures proposed for the remaining pilot study tasks (Phase 2). A summary of the complete scope of work and schedule for the pilot study is also presented.

Project Goals and Objectives

The primary goal of the pilot study is to test the groundwater assessment approach outlined in the recommendations report. To help accomplish this goal, the EA Program identified a high priority study area that would benefit from baseline characterization and monitoring (Pitz, 2003b). The area selected for evaluation encompasses the unconsolidated sediments filling the central lowland valley located between Napavine and Grand Mound, Washington, along the Newaukum and Chehalis Rivers in Lewis County (Figures 1 and 2).

The main objectives for the pilot study include:

- Characterizing and describing the basic study area hydrogeologic setting through assembly of existing and new information.
- Monitoring and describing baseline groundwater water-level conditions.
- Monitoring and describing ambient groundwater water-quality conditions.
- Monitoring and describing baseline conditions for groundwater/surface water interactions, focused on the interactions between the uppermost portion of the study area aquifer system and the mainstem drainage.

Since many of the most pressing groundwater-related environmental or public drinking-water health issues occur or begin near-surface, pilot study monitoring and characterization efforts will focus on the uppermost principal aquifer of the study area. Sampling and measurement of current groundwater and hydrogeologic field conditions will be accomplished through the use of surface water seepage evaluations, installation, and monitoring of in-stream piezometers, monitoring of existing wells (*Tier 1* wells), and installation and monitoring of new, dedicated monitoring wells (*Tier 2* wells).

The pilot study will focus on *description* (vs. explanation) of current ambient conditions and setting. The study will not attempt to assign cause or origin to problems observed, and will not attempt to provide solutions for specific water-supply or water-quality concerns that may exist in the study area. The study's sampling and measurement efforts are intended to provide a description of basin-scale ambient conditions and will not be biased towards specific, known point sources or facilities. Standard tools such as geologic or hydrogeologic maps and cross-sections, geochemical diagrams, descriptive statistics, and comparison to promulgated standards will be employed to summarize the data collected during the project.

If the conceptual approach and technical methods used during this study are shown to provide reliable information on baseline hydrogeologic conditions in a cost effective manner, the procedures will be recommended for use in a longer-term state groundwater assessment program. If these procedures are not adequate for this purpose, modifications or alternatives to the approach will be recommended.

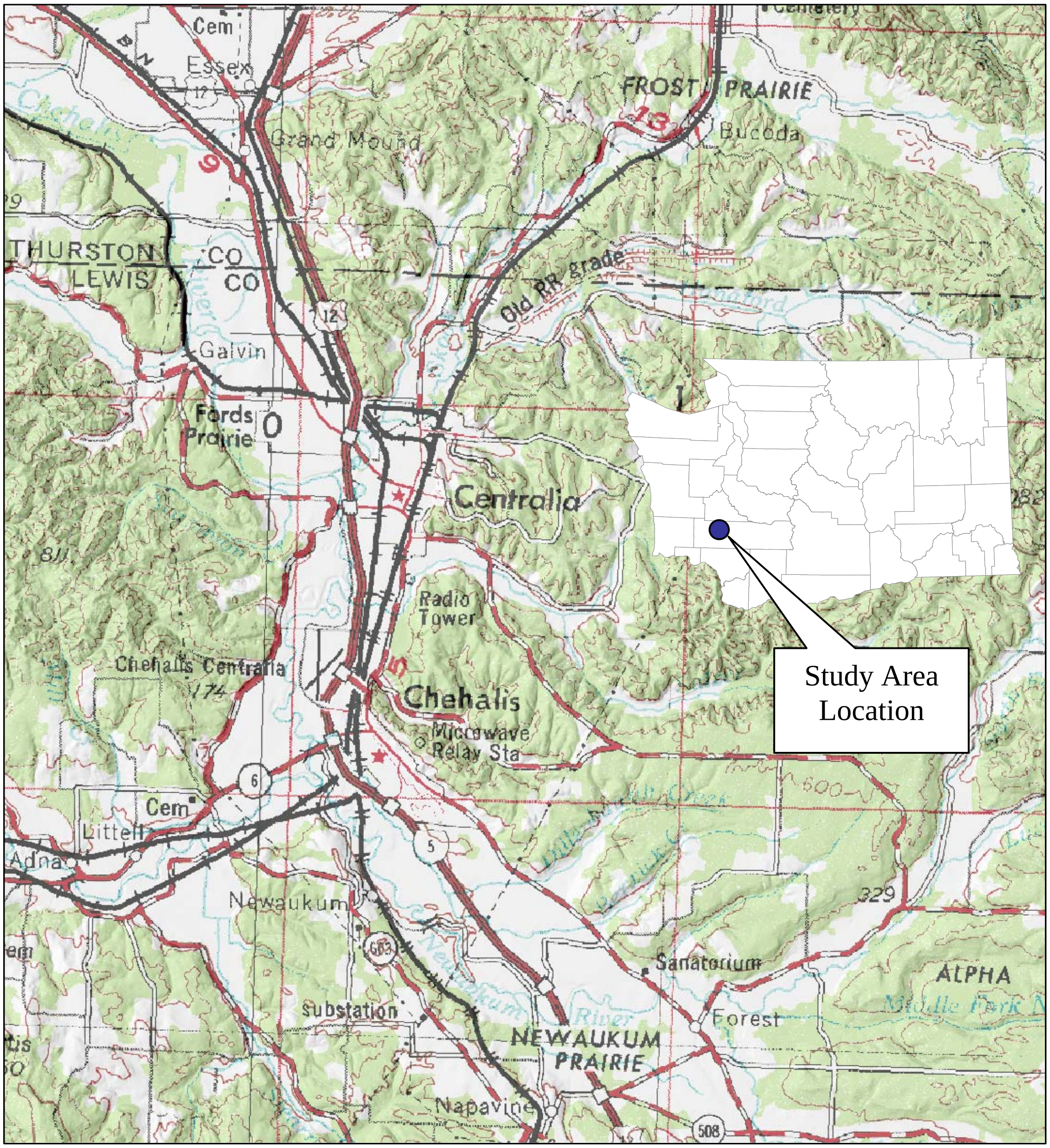

Figure 1
Pilot Study
Location Map

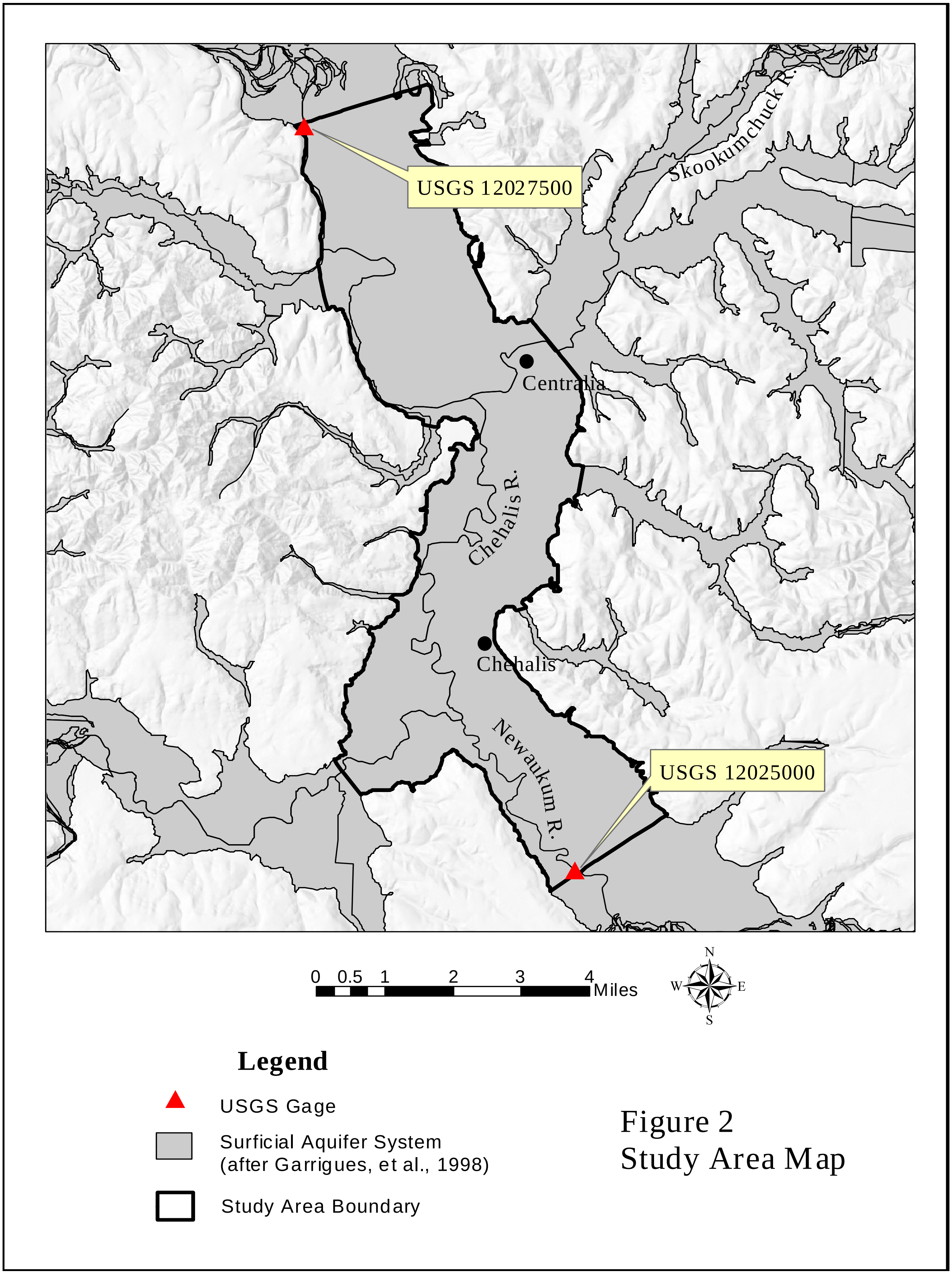

Figure 2
Study Area Map

Responsibilities

The following individuals will be involved in this project:

Kahle Jennings, SEA Program, SWRO. As the WRIA 23 watershed lead, Kahle will be instrumental in coordinating with local stakeholders, agencies, and the public. Kahle will assist in arranging access for measurement and sampling efforts conducted during the project (360-407-6310).

Denis Erickson, WQ Program, SWRO. As a regional hydrogeologist for the Water Quality Program, Denis will serve as a point of contact for technical issues that arise during the study (360-407-6368).

Charles Pitz, Watershed Ecology Section. He is the EA Program project manager for this study. Charles will also serve as a project hydrogeologist for the study (360-407-6775).

Kirk Sinclair, Watershed Ecology Section. He will serve as a project hydrogeologist for the study (360-407-6557).

Adam Oestreich, Watershed Ecology Section. He will serve as a project staff scientist and field technician for the study.

Will Kendra, Section Manager, Watershed Ecology Section. He is responsible for approving the QA Project Plan, project budget, and project reports (360-407-6698).

Darrel Anderson, Unit Supervisor, Watershed Ecology Section. He is responsible for internal review of the QA Project Plan and project reports (360-407-6453).

Stewart Lombard, EA Program Quality Assurance Coordinator. He will assist in providing technical guidance for QA/QC issues or problems that arise during the project and will review and approve the QA Project Plan (360-895-6148).

Manchester Environmental Laboratory (MEL). The lab will analyze all water samples collected during this study, other than for field-measured parameters. Pam Covey is responsible for coordinating requests for analysis and providing access to project data. Karin Feddersen is the primary contact for lab coordination on sample management and data quality issues. Phone numbers are MEL (360-871-8800), Pam (360-871-8827), and Karin (360-871-8829).

Study Area Description

The study area, which in total encompasses approximately 80 square miles, is focused on the surficial aquifer system lying between the U.S. Geological Survey (USGS) gauging station on the Newaukum River near Chehalis (12025000 – RM 4.1) and the USGS gauging station on the Chehalis River near Grand Mound (12027500 – RM 59.9) (Figure 2). The lateral boundaries of the surficial aquifer system that will be used for this study were previously defined by Garrigues et al., (1998).

The physiography of the study area consists of a broad, north-south trending, flat-lying valley surrounded by mature hills and uplands. Topographic relief ranges between 250 to 450 feet with uplands achieving elevations of 500 to 600 feet above sea level and floodplain elevations at 50 to 250 feet. The surface hydrology is dominated by the north-flowing Chehalis River and its major tributaries the Newaukum and Skookumchuck Rivers.

The geology, listed youngest to oldest, consists of floodplain alluvium, glaciofluvial deposits, and Paleogene- to Neogene-age sedimentary bedrock (Walsh et al., 1987; Weigle and Foxworthy, 1962). A simplified map of the study area surficial geology is shown in Figure 3. Area bedrock, which is composed of marine and near-shore sediments, underlies most of the southern study area at depth and is frequently exposed at the surface in the northern study area. The glaciofluvial deposits consist of outwash of both the Pre-Fraser glaciation and the Vashon Stade of the Fraser glaciation. The Pre-Fraser outwash deposits dominate the southern portion of the study area and the Vashon outwash deposits are exposed mostly in the northern half of the study area. Floodplain alluvium associated with the major rivers and tributaries blankets the flat-lying valley floors.

Water is transmitted through the bedrock along fractures and typically the bulk hydraulic conductivity of the bedrock is low. The glaciofluvial deposits consist of sand and gravel and represent the most significant water-supply aquifers (Weigel and Foxworthy, 1962; Robinson and Noble, Inc., 1997). The alluvium consists of heterogeneous mixtures of gravel, sand, silt, and clay and, as a result, the hydraulic conductivity of these sediments shows wide spatial variability. In general, the saturated glaciofluvial deposits and hydraulically connected alluvial deposits form the major surficial aquifer in the study area.

Precipitation across the study area ranges from 35 to 40 inches per year (WDNR, 1995). The surficial aquifer is recharged primarily by infiltrated precipitation, with additional subsurface inflow from adjacent and underlying bedrock.

Groundwater/surface water interaction with the Chehalis River was estimated to be significant especially in the area near where the Skookumchuck River flows into the Chehalis River and northward (Sinclair and Hirschey, 1992; Erickson, 1993).

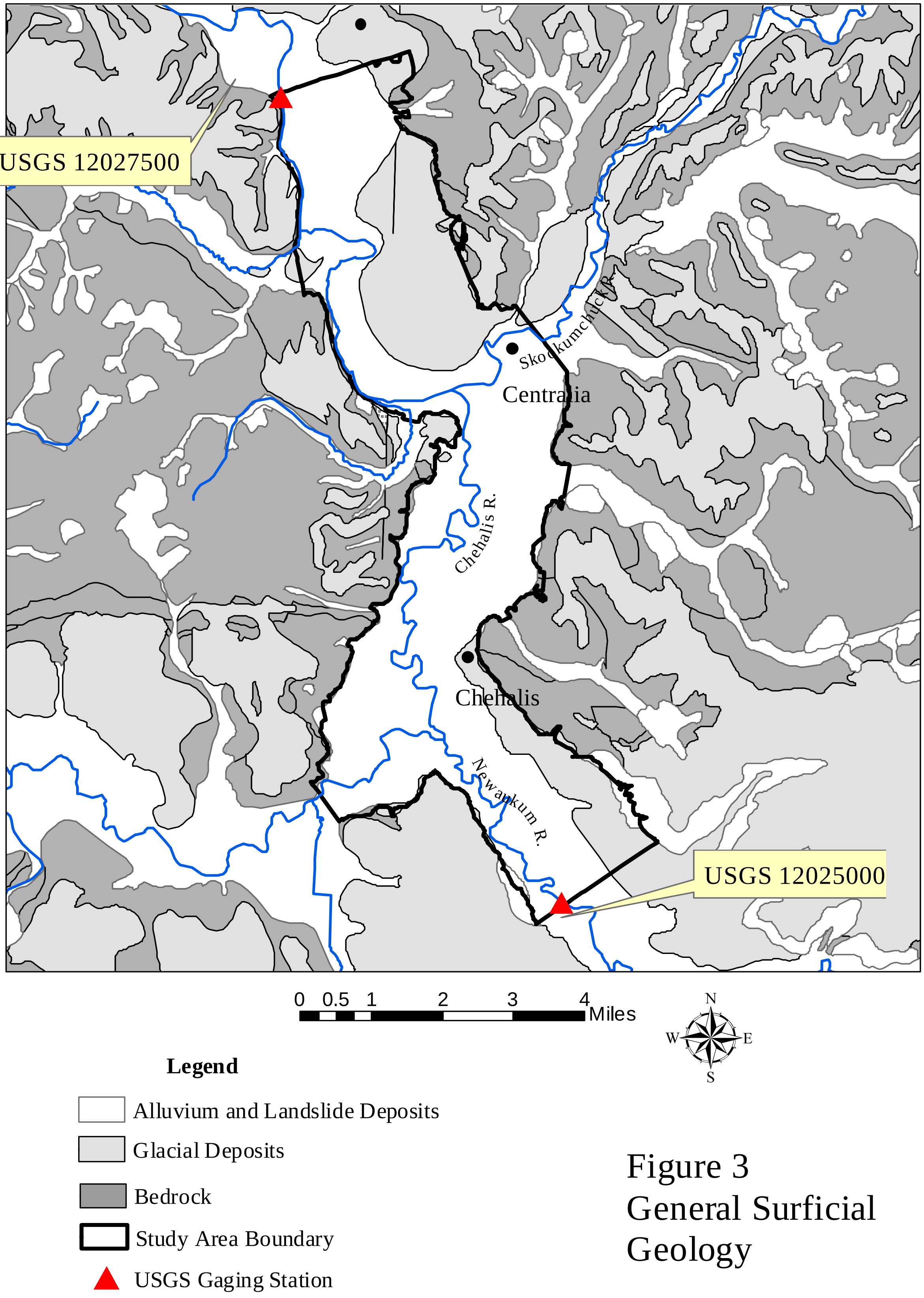

Figure 3
General Surficial Geology

Study Design

Phase 2 Project Tasks and Parameters of Interest

To help accomplish the objectives presented above, the following tasks will be undertaken for Phase 2 of this project:

1. Design a groundwater monitoring network of existing wells (Tier 1).
2. Design and install a groundwater monitoring network of dedicated monitoring wells (Tier 2).
3. Single-event sampling and analysis for a suite of common water-quality constituents (field alkalinity, dissolved organic carbon, arsenic, major ions, iron, manganese, and silica) for all Tier 1 and 2 wells to determine current ambient water-quality and geochemical conditions in the study area aquifer. Lead will also be tested in all Tier 1 and Tier 2 *monitoring* wells but will not be included in analyses from existing Tier 1 *water supply* wells due to concerns regarding possible bias from supply distribution lines.
4. Single-event sampling and analysis for volatile organic compounds (VOAs) (water-quality constituents of unique concern to the study basin) for all Tier 2 wells (Larson, 1994; Erickson, 2003; Balaraju, 2003). Upgradient monitoring wells incorporated into the Tier 1 monitoring network will also be sampled for VOAs during the single-event monitoring round.
5. To characterize seasonal changes in water quality, all Tier 1 wells will be sampled bi-annually (spring and fall) for a one-year period for a short-list of common indicator parameters (pH, temperature, specific conductance, dissolved oxygen, chloride, total dissolved solids, orthophosphate, and nitrate+nitrite as N) for all Tier 1 wells. Bi-monthly monitoring will be conducted for the same indicator parameters for all Tier 2 wells.
6. Where possible, bi-annual water-level monitoring of Tier 1 wells for a one-year period to characterize seasonal changes in aquifer water-level conditions.
7. Continuous groundwater water-level monitoring of Tier 2 wells for a one-year period.
8. Hydraulic property testing of Tier 2 wells to determine the hydraulic conductivity of the aquifer material adjacent to the well.

Table 1 summarizes the overall monitoring plan and analyte list for Phase 2 of the pilot study.

Table 1. Summary of Field Measurements, Laboratory Analytes, and Sampling Frequency – Phase 2

Parameter	Tier 1 Wells		Tier 2 Wells		
	Single Event	*Bi-Annual*	*Single Event*	*Bi-Monthly*	*Continuous*
Field Measurements					
Static Water Level (SWL)		•[a]		•[c]	•[d]
Hydrologic Property Test			•		
pH		•		•	
Temperature (Temp)		•		•	
Specific Conductance (SC)		•		•	
Dissolved Oxygen (DO)		•		•	
Alkalinity as CaCO3	•		•		
Laboratory Analytes					
Total Dissolved Solids (TDS)		•		•	
Chloride		•		•	
Fluoride	•		•		
Sulfate	•		•		
Orthophosphate as P (OP)		•		•	
Nitrate+Nitrite as N		•		•	
Iron	•		•		
Manganese	•		•		
Silica	•		•		
Calcium	•		•		
Magnesium	•		•		
Sodium	•		•		
Potassium	•		•		
Lead	•[b]		•		
Arsenic	•		•		
Dissolved Organic Carbon (DOC)	•		•		
Volatile Organic Analytes (VOAs)	•[b]		•		

[a] Where possible.
[b] Lead, and VOAs, will only be collected from existing upgradient monitoring wells incorporated into the Tier 1 network.
[c] Manual measurement.
[d] Transducer measurement.

Monitoring Network Design

Tier 1 Well Network

A network of approximately 40 existing wells is proposed for measurement and sampling during the study. Wells included in the Tier 1 well network will be selected from the well inventory database assembled at the beginning of the project. Wells selected for the Tier 1 network will be chosen based on a number of factors including:

- The need to provide a representative spatial distribution of water-quality (and, where possible, water-level) conditions in the study area's uppermost principal aquifer. Well selection will be guided by the preliminary conceptual model of the study area groundwater flow field.
- Permission is granted by the well owner to sample throughout the full monitoring schedule.
- A well log is available for the well, and the well depth and construction details are known.
- The well will preferably have an attached, unique Ecology well identification tag.
- The well draws water only from the aquifer of interest.
- Construction and sealing of the well are adequate to provide representative water-quality samples and water-level conditions for the aquifer of interest.
- Unbiased water-quality samples can be collected from the well (i.e. prior to any treatment system).
- The well will preferably allow access for water-level measurement.
- The well is not downgradient of a close-proximity, known point source of contamination or loading to the aquifer system.

Upgradient monitoring or observation wells located at known contaminated sites or commercial facilities permitted to discharge to ground may be incorporated into the Tier 1 well network if existing data show they are unaffected by past or present facility operations.

Owners of candidate wells will be contacted by telephone and by onsite visits to discuss their participation in the project, and to evaluate their well for suitability for monitoring. If not already tagged with a unique Ecology well tag, all Tier 1 wells will be tagged during the project if permission is granted by the well owner.

Tier 2 Well Network

A network of approximately six to eight monitoring wells will be installed in the uppermost principal aquifer as part of this project. Tier 2 monitoring wells will be used to augment the information collected from the Tier 1 network and, due to their specific design for monitoring, will provide higher quality data for water-quality, water-level, and hydrologic conditions.

Tier 2 monitoring well locations will be selected based on a number of factors including:

- Permission from the property owner to install and access a permanent monitoring well.
- Ability of the well location to fill in gaps in the spatial coverage of the Tier 1 well network.
- Data results from the pilot study's Phase 1 dry season seepage run (Pitz and Erickson, 2003) indicating areas of significant aquifer/surface water interaction.
- Ability of the well locations to collectively provide a representative spatial distribution along the longitudinal axis (N-S) of the study area groundwater flow path.

All Tier 2 monitoring wells will be tagged with a unique Ecology well identification tag and entered into both the project well inventory database and EIM.

Schedule

The anticipated schedule for Phase 2 of the pilot study is presented below.

Task	2003						2004												2005											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1 – Phase 2 QAPP					•	•																								
2 – Existing Well Network (Tier 1)																														
Well inventory	•	•	•	•	•	•	•	•																						
Develop well database	•	•	•	•	•	•	•	•																						
Well selection/network design		•	•	•	•	•	•	•																						
Field verification					•	•	•	•	•	•																				
Access arrangements					•	•	•	•	•	•																				
Monitoring											•					•														
Well owner result notification													•					•												
3 – Monitoring Well Network (Tier 2)																														
Network design					•	•	•	•	•	•																				
Permitting					•	•	•	•	•	•																				
Access arrangements					•	•	•	•	•	•																				
Contract development					•	•	•	•	•	•																				
Well installation										•																				
Well development										•																				
Transducer installation										•																				
Monitoring										•		•		•		•		•		•										
Hydraulic testing															•															
4 - EIM																														
Project development	•	•																												
LIMS data migration to EIM												•	•	•	•	•	•	•	•	•	•	•								
EIM project quality assurance and closeout																									•					
5 - Analysis and Reporting																														
Compile, evaluate, and summarize project data		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•									
Data quality assurance review												•		•		•		•		•		•								
Cross section and map development						•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•								
Prepare draft report																•	•	•	•	•	•	•								
Draft report review																						•	•							
Finalize report																						•	•	•						

Data Quality Objectives and Decision Criteria

Two important objectives of this project are to accurately measure the ambient water-level and water-quality conditions of the uppermost principal aquifer of the study area. To minimize bias (systematic error) and improve precision (random error), standardized field methods for the collection of groundwater data will be employed in a consistent manner throughout the project. Measurements of water-level and hydrologic data will be collected following guidelines outlined by Stallman (1983) and ASTM (1998). Similarly, standard water-quality sample collection procedures will be used that minimize potential changes to water chemistry during sampling. Standard protocols will be followed when measuring water-quality field parameters, and water-quality samples will be preserved, handled, and stored in a consistent manner using accepted procedures for maintaining sample integrity prior to analysis (e.g. Ecology, 1993; USGS, 1997; EPA, 2000).

The precision and bias routinely obtained by MEL for the target parameters of interest will be adequate for this project. The measurement quality objectives (maximum acceptable values) for this project are listed in Table 2. For this project, measurement quality objectives are identical to project data quality objectives.

Table 2. Project Measurement Quality Objectives

Parameter	Accuracy (Deviation from True Value)	Precision (%RSD)	Bias (%)	Required Reporting Limit (Concentration Units)
Field Measurements				
SWL[a]	±0.03 feet	N/A	N/A	N/A
pH[a]	±0.15 s.u.	N/A	N/A	N/A
Temp[a]	±0.2°C	N/A	N/A	N/A
SC[a]	±10 µmho/cm	N/A	N/A	1 µmho/cm
DO[a,b]	± 0.2 mg/L >2 mg/L ±0.05 mg/L < 2 mg/L ±20 µg/L @ 140-180 µg/L ±15 µg/L @ 5-140 µg/L	N/A	N/A	5 µg/L
Alkalinity[c]	±5%-20% [d]	N/A	N/A	10 mg/L
Laboratory Analyses	Accuracy (Precision * 2) + Bias)			
TDS	25	10	5	1 mg/L
Chloride, dissolved	25	8	8	0.1 mg/L
Fluoride, dissolved	20	7	5	0.1 mg/L
Sulfate, dissolved	20	7	5	0.5 mg/L
OP, dissolved	25	10	5	0.003 mg/L
Nitrate+Nitrite-N, dissolved	25	10	5	0.01 mg/L
Iron, dissolved	25	10	5	50 µg/L
Manganese, dissolved	25	10	5	10 µg/L
Silica, dissolved	20	7	5	50 µg/L
Calcium, dissolved	35	15	5	50 µg/L
Magnesium, dissolved	35	15	5	50 µg/L
Sodium, dissolved	35	15	5	50 µg/L
Potassium, dissolved	35	15	5	0.5 mg/L
Lead, dissolved	25	10	5	0.02 µg/L
Arsenic, dissolved	25	10	5	0.1 µg/L
DOC	30	10	10	1 mg/L
VOAs	25	10	5	1-5 µg/L

[a] Accuracy as units of measure.
[b] Field photometric or colorimetric test kit for confirmation of field meter values below 2 mg/L.
[c] Field test kit for alkalinity.
[d] Test kit accuracy for alkalinity varies with concentration, due to non-linear concentration reading scale on ampoules; greater accuracy (±5%) when reading low concentrations.

The focus of the water-quality monitoring program for Phase 2 of the pilot study is to describe the current ambient groundwater conditions in the study area. No regulatory, or programmatic, decision is pending the monitoring results of the study; therefore, no decision criteria are established in this plan other than determining if the data meet the acceptance criteria.

Field Procedures

Existing Well Network (Tier 1 Wells)

Water Level Measurements

Where owner permission is granted, and measurement is feasible, static water levels in each Tier 1 well will be measured using a commercial electric probe or steel tape following standard measurement techniques (Stallman, 1983). Measurements will be collected prior to well purge and will be recorded to the nearest 0.01 feet.

To prevent cross-contamination, the well probe or steel tape will be thoroughly cleaned prior to use in water supply wells by sequential rinses of 10% bleach water and de-ionized water, and field personnel will wear clean sampling gloves while handling measurement equipment. Measurements from water supply wells will be collected only from wells where the pump is temporarily shut off. To ensure the well is not undergoing pumping recovery, water levels will only be recorded if three consecutive measurements collected at one-minute intervals show a change of less than ±0.03 feet.

To estimate the water level elevation for private water supply wells, depth-to-water measurements will be compared to the interpreted land-surface elevation of the well head, as determined from 1:24,000 scale USGS topographic maps.

Water-depth measurements for Tier 1 monitoring wells will be benchmarked to a fixed reference position on the well casing or surface monument previously established by the well owner. Measurements will then be compared to existing well survey data to calculate water-level elevations. Measurements from monitoring wells will be collected only after the well cap has been removed and the well vented for approximately five minutes.

Contour maps of the potentiometric surface will be developed for the study area using both existing information and measurements collected during this study. Map accuracy and contour interval selection will be a function of a number of different factors including the density of data points, the lateral and vertical accuracy of the estimated land-surface elevation at each well, and the reported accuracy of historic measurements.

Water Quality Measurements and Sampling

Water Supply Wells

All water supply wells included in the Tier 1 well network will be purged prior to sampling using existing pumps and plumbing. Samples will be obtained from a tap as close to the wellhead as possible, and prior to holding or pressure tanks whenever possible. No samples will be collected downstream of filters, water softening units, hot water tanks, etc. that could modify the water chemistry of the sample.

Temperature, pH, specific conductance, and dissolved oxygen will be measured at five-minute intervals during well purging through the use of a metered, closed-atmosphere flow cell. During purging, water from the selected tap will be routed by a clean "Y" fitting directly to the flow cell using a short section of tubing. Discharge from the flow cell will be routed to a suitable location identified by the property owner. Supply wells that are not routinely pumped will be purged for a minimum of three casing volumes and until all field parameters have stabilized. Wells that are routinely in use will be purged until all field parameters stabilize. Table 3 presents the criteria for purge stabilization.

Table 3. Stabilization Criteria for Well Purging

Purge Parameter	Stabilization Criteria[a]
pH	±0.1 standard unit
Temp	±0.1 ^{o}C
SC	±10 µmhos/cm for values <1000 µmhos/cm ±20 µmhos/cm for values >1000 µmhos/cm
DO	±0.2 mg/L for values > 2 mg/L
OR	
All parameters	< ±10% change over 3 consecutive readings at 5 minute intervals

[a]Criteria as allowable variation between two consecutive measurements collected at 5-minute intervals.

Once end-of-purge parameter values have been recorded, water will be re-directed to the second outlet of the "Y" fitting for further analysis and sample collection. Those wells showing a field-meter DO concentration of less than 2.0 mg/L will be verified using field photometric or colorimetric test kits. Table 4 presents a summary of the methods that will be used for the measurement of field water-quality parameters.

Table 4. Summary of Field Water-Quality Parameter Measurement Methods

Parameter	Measurement Method	Expected Range of Results
pH	GeoTech WTW multi-meter	5.5-8.0 SU
Temperature	GeoTech WTW multi-meter	8-21 ºC
Specific Conductance	GeoTech WTW multi-meter	30-1500 µmhos/cm
Dissolved Oxygen	GeoTech WTW multi-meter >2 mg/L CHEMetrics™ Indigo Carmine Photometric <2 mg/L CHEMetrics™ Rhodazine-D Photometric <0.8 mg/L CHEMetrics™ Rhodazine-D Colorimetric <0.18 mg/L	0.1-18 mg/L
Alkalinity	CHEMetrics™ Hydrochloric titrant cells 10-100 mg/L CHEMetrics™ Hydrochloric titrant cells 50-500 mg/L	5-300 mg/L

After all field tests have been completed, water samples designated for laboratory analysis will be collected directly into the appropriate containers. Samples requiring filtration will be collected using a clean, dedicated, in-line 0.45 micron capsule filter, attached to the appropriate "Y" outlet using clean tubing and fittings. The first 200 ml of filtrate will be discarded prior to collecting samples. When appropriate, preservative acid will be added to the sample immediately after collection, or alternatively, samples will be added to pre-preserved bottles. Sample containers for Tier 1 wells will be filled in the following sequence: 1) unfiltered, unpreserved samples (TDS), 2) filtered, unpreserved samples (chloride, fluoride, sulfate, and OP), 3) filtered, preserved nitrogen samples (nitrate+nitrite-N), 4) filtered preserved inorganics (iron, manganese, silica, calcium, magnesium, sodium, potassium, and arsenic), and 5) filtered, preserved DOC. During one sampling round, a filtered sample will be tested for alkalinity using a field test kit immediately after laboratory samples have been collected.

Upon collection, samples will be labeled and immediately placed on ice in a cooler for delivery to the EA Program Operations Center walk-in, chain-of-custody cooler. All samples will be transferred from the chain-of-custody cooler to Ecology's Manchester Laboratory by the lab courier for analysis. Details regarding the sample container type, minimum required sample volume, field handling, preservation requirements, and holding times for the project laboratory parameters are summarized in Table 5.

Table 5. Container, Sample Volume, Filtration, Preservation, and Holding Time Requirements

Analyte	Container Type	Container Volume (ml)	Filtration	Preservation	Holding Time
TDS	w/m poly	1000	None	Cool to <4°C	7 days
Chloride	w/m poly	500[a]	Filter @ 0.45 micron	Cool to <4°C	28 days
Fluoride	w/m poly	500[a]	Filter @ 0.45 micron	Cool to <4°C	28 days
Sulfate	w/m poly	500[a]	Filter @ 0.45 micron	Cool to <4°C	28 days
OP	amber w/m poly	125	Filter @ 0.45 micron	Cool to <4°C	48 hrs
Nitrate+Nitrite-N	w/m clear Nalgene (pre-acidified)	125	Filter @ 0.45 micron	Adjust pH to <2 w/ H_2SO_4 and cool to <4°C	28 days
Iron	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Manganese	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Silica	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Calcium	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Magnesium	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Sodium	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Potassium	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Lead	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
Arsenic	HDPE	1000[b]	Filter @ 0.45 micron	Adjust pH <2 w/ HNO_3 and cool to <4°C	6 months
DOC	n/m poly (pre-acidified)	60	Filter @ 0.45 micron	Adjust pH to <2 w/ HCl and cool to <4°C	28 days
VOAs	Glass VOA vial w/ Teflon® septum	3 - 40ml[c]	None	Adjust pH <2 w/ HCl and cool to <4°C	14 days

[a] Water samples for chloride, fluoride, and sulfate analysis will be collected in a common 500ml bottle.
[b] Water samples for iron, manganese, silica, calcium, magnesium, sodium, potassium, lead, and arsenic analysis will be collected in a common 1-liter bottle.
[c] A total of six VOA vials will be submitted for the sample station that is additionally designated for matrix spike and matrix spike duplicate analysis.

Monitoring Wells

Water quality samples from monitoring wells incorporated into the Tier 1 well network will be collected using Ecology sampling pumps fitted with clean, dedicated polyethylene tubing. Samples collected for all single event sampling parameters will be obtained using a clean stainless steel Grundfos RediFlo-2™ submersible pump and flow controller. Samples collected for seasonal indicator parameters may be collected using a submersible pump, or a peristaltic pump. If a peristaltic pump is employed for sample collection, the length of the silicon tubing used at the pump head will be minimized to reduce possible bias introduced by sorption.

All monitoring wells will be purged and sampled using low-flow (<1 liter/min) techniques, until stabilization of purge parameters as described in Table 3. The pump, or pump tubing, will be positioned at the middle of the saturated portion of the well screen throughout the purge and sample process. Water levels in the well will be periodically monitored using a clean electric well probe to record drawdown during purging. Poorly producing wells that exhibit excess drawdown will alternatively be sampled, as time allows, after two cycles of well recovery. Monitoring wells will otherwise be purged, monitored, and sampled in a manner equivalent to that described above for supply wells. At the end of purging, the pumping flow rate will be reduced to <300 ml/min, and samples collected directly from the pump outlet. Samples requiring field filtration will be collected by attaching a clean, dedicated in-line filter directly to the pump outlet.

All Tier 1 monitoring wells will additionally be sampled during one round for VOAs and lead. Low-flow purge and sample techniques will be used to obtain VOA samples, and all VOA samples will be collected free of headspace directly from the pump outlet into designated containers. Samples for VOA analysis will be collected after TDS in the sampling sequence.

Monitoring Well Network (Tier 2 Wells)

Well Installation and Development

All monitoring wells installed for the Tier 2 network will be constructed by a licensed well driller under subcontract to Ecology. Wells will meet or exceed the requirements for resource protection wells (Minimum Standards for Construction and Maintenance of Wells - Chapter 173-160 WAC). A separate bid document will be prepared that describes the drilling activities.

The depth of installation for each well will be based at the time of construction on observed soil and aquifer conditions. To focus monitoring on the near-surface portion of the principal aquifer, wells will be constructed so that the well screen intersects the regional water table. Preliminary review of existing data indicates that most monitoring well borings will need to be drilled to a depth of approximately 20 to 40 feet below ground surface.

Wells will be constructed with two-inch diameter PVC, flush-threaded casing, and commercially fabricated screens. All wells will have a ten-foot PVC screen to allow measurement of temporal changes in water level. Clean, inert gravel/sand pack material will be placed around the screened interval to two feet above the top of the screen. Bentonite and cement/bentonite seals will be placed along the entire length of the annular space from the top of the gravel pack to the surface. A steel, six-inch diameter, outer protective casing will be installed over the PVC well. Depending on the preference of the land owner, the steel casing will either extend approximately three feet above ground surface (surrounded by steel or concrete posts for protection) or will be flush mounted with the ground surface.

Tier 2 monitoring wells will be developed by the subcontracted driller using a moderate surge method or equivalent until discharge from the well is sediment free.

If possible, the applicable measurement reference point elevation for all Tier 2 monitoring wells will be surveyed by a licensed surveyor or established through the use of a differential global positioning system. If an accurate elevation survey is not possible, Tier 2 well elevations will be determined as accurately as possible from 1:24,000 scale USGS topographic maps and matching digital orthophotography.

Water Level Measurements

Continuous water level measurements will be collected from all Tier 2 monitoring wells using dedicated, down-hole, In-Situ, Inc. miniTroll™ 30 psi (69-feet) absolute (non-vented) pressure transducers. Pressure transducers will be suspended by wire line into each well for a period of one year. Transducer recorded pressure measurements are accurate to ±0.1% over the full pressure and temperature range of the instrument. Transducers will be programmed to record on an hourly basis, and the data will be downloaded during the bimonthly well sampling events.

To compensate for the effect of barometric pressure changes on the recorded data, two additional In-Situ, Inc. BaroTroll™ barometric pressure transducers will be suspended by wire line above the water level in two of the Tier 2 wells (one in the northern portion of the study area, one in the southern portion) throughout the monitoring period. Barometric measurements will be collected hourly and programmed to correspond to the water-level measurement schedule. A correction software program will subsequently be used to remove the effect of barometric pressure on the recorded data.

During the bimonthly sampling events confirmatory static water-level measurements will be measured manually at the Tier 2 wells using a commercial electric well probe. Measurements will be taken prior to water-quality sampling, after the well has been properly vented. The well probe will be rinsed with de-ionized water prior to use to prevent cross-contamination of subsequent water-quality samples. Manual water level measurements will be recorded to 0.01 feet.

Water Quality Measurements and Sampling

Measurement and sampling of Tier 2 monitoring wells will occur no sooner than one week after well installation and development to ensure equilibration of aquifer conditions adjacent to the borehole. Water quality conditions in Tier 2 wells will be measured and sampled in the same manner as the Tier 1 network monitoring wells (see also Tables 1, 3, 4, and 5). During each sampling event, deployed pressure transducers will be removed from the well for data download prior to initiation of purging and returned to the well at the end of sampling.

All Tier 2 monitoring wells will be sampled during one round for VOAs. Low-flow purge and sample techniques will be used to obtain VOA samples, and all VOA samples will be collected free of headspace directly from the pump outlet into designated containers. Samples for VOA analysis will be collected after TDS in the sampling sequence.

Hydrologic Testing

Short-term, constant-rate, single-well pumping tests will be conducted for each Tier 2 monitoring well to estimate the horizontal hydraulic conductivity of the aquifer materials adjacent to the well screen. Standard field procedures will be followed for all tests per ASTM (1998). Aquifer tests will consist of repeated measurement of the water-level response to pumping at a known rate, until drawdown has stabilized. Stabilization of water levels during pumping will be determined by repeated manual measurements using a commercial electric well probe. All wells will additionally be instrumented with a logging pressure transducer during the test procedure to record water-level drawdown and recovery data. Two to three aquifer tests will be conducted at each well at different discharge rates using a Grundfos RediFlo-2™ submersible pump. For each test, the pumping rate will be measured by timing flow into a volume-calibrated container and maintained at a constant rate throughout the test using a flow controller. Drawdown will be recorded to an accuracy of 0.01 feet.

Laboratory Procedures

Past studies have indicated that the accuracy error of the analytical methods selected is consistently smaller than the natural spatial heterogeneity and temporal variations in groundwater water-quality concentrations. No special reporting limits, analytical testing, or handling requirements will be needed for this project. The laboratory parameters, test methods, and expected ranges of results for the project are listed in Table 6.

Table 6. Summary of Project Laboratory Analysis Methods[a]

Parameter	Matrix	Test Method	Sample Preparation Method	Expected Range of Results
TDS	Water	EPA 160.1/SM 2540 C	N/A	30-1000 mg/L
Chloride	Water	EPA 300.0	Field filtered	2-75 mg/L
Fluoride	Water	EPA 300.0	Field filtered	<0.1 - 1 mg/L
Sulfate	Water	EPA 300.0	Field filtered	<0.5 - 50 mg/L
OP	Water	SM 4500-P G. Colormetric flow injection.	Field filtered	<0.003-2.5 mg/L
Nitrate+Nitrite-N	Water	SM 4500 NO3- I Colormetric flow injection.	Field filtered	<0.01-20 mg/L
Iron	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	<0.050-20 mg/L
Manganese	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	<0.010 - 1.5 mg/L
Silica	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	5 - 75 mg/L
Calcium	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	5 – 50 mg/L
Magnesium	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	1 - 50 mg/L
Sodium	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	2 - 250 mg/L
Potassium	Water	EPA 200.7 Inductively Coupled Plasma (ICP)	Field filtered	<0.5 - 10 mg/L
Lead	Water	EPA 200.8 Inductively Coupled Plasma-Mass Spectrometer (ICP-MS)	Field filtered	<1-5 µg/L
Arsenic	Water	EPA 200.8 Inductively Coupled Plasma-Mass Spectrometer (ICP-MS)	Field filtered	<1-10 µg/L
DOC	Water	EPA 415.1	Field filtered	<1-20 mg/L
VOAs	Water	EPA SW-846 Method 8260B	N/A	<1 -20 µg/L

[a]Reference: MEL, 2003

Estimated Laboratory Costs

Table 7 below summarizes the anticipated analytical costs for the water-quality samples collected from wells during Phase 2 of the pilot study.

Table 7. Estimated Phase 2 Laboratory Costs

	Assumed Number of Wells	Number of QA Samples	Number of Sampling Rounds	Analyte	Cost per Analysis (per Well)[k]	Cost per Round	Phase 2 Study Total
Tier 1 Wells - Single Event	40	5[a]	1	Fluoride	12	540	540
	34	5[a]	1	Inorganics[l]	138[m]	5382	5382
	6	0	1	Inorganics[n]	148[o]	888	888
	40	5[a]	1	Sulfate	12	540	540
	40	5[a]	1	DOC	29	1305	1305
	6	1[b]	1	VOAs	156	1092	1092
				Subtotals	$347-357	$9747	$9747
Tier 1 Wells - Periodic	40	4[c]	2	TDS	10	440	880
	40	6[d]	2	Cl	12	552	1104
	40	6[d]	2	NO2+NO3	12	552	1104
	40	6[d]	2	OP	12	552	1104
	40	5[e]	1	Fe	26[p]	1170	1170
				Subtotals	$72	$3266	$5362
Tier 2 Monitoring Wells - Single Event	8	2[f]	1	Fluoride	12	120	120
	8	2[f]	1	Inorganics[n]	148[o]	1480	1480
	8	2[f]	1	Sulfate	12	120	120
	8	2[f]	1	DOC	29	290	290
	8	4[g]	1	VOAs	156	1872	1872
				Subtotals	$357	$3882	$3882
Tier 2 Monitoring Wells - Periodic	8	1[h]	6	TDS	10	90	540
	8	3[i]	6	Cl	12	132	792
	8	3[i]	6	NO2+NO3	12	132	792
	8	3[i]	6	OP	12	132	792
	8	2[j]	5	Fe	26	260	1300
				Subtotals	$72	$746	$4216
					Phase 2 Total		$23,207

[a] Assumes 4 blind field duplicates and 1 equipment/filter blank.
[b] Assumes 1 blind field duplicate.
[c] Assumes 4 blind field duplicates per sampling round.
[d] Assumes 4 blind field duplicates, 1 equipment/filter blank, and 1 blind reference sample per sampling round.
[e] Assumes 4 blind field duplicates and 1 equipment/filter blank per sampling round.
[f] Assumes 1 blind field duplicate and 1 equipment/filter blank.
[g] Assumes 1 blind field duplicate, 1 matrix spike sample, 1 matrix spike duplicate sample, and 1 trip blank.
[h] Assumes 1 blind field duplicate per sampling round.
[i] Assumes 1 blind field duplicate, 1 equipment/filter blank, and 1 blind reference sample per sampling round.
[j] Assumes 1 blind field duplicate and 1 equipment/filter blank per sampling round.
[k] All analysis costs assume MEL "planned" price (50% discount).
[l] Includes iron, manganese, silica, calcium, magnesium, sodium, potassium, and arsenic.
[m] Analysis cost assumes unit price for 8 elements ($148) minus lab prep fee ($10) due to field filtration.
[n] Includes iron, manganese, silica, calcium, magnesium, sodium, potassium, lead, and arsenic.
[o] Analysis cost assumes unit price for 9 elements ($158) minus lab prep fee ($10) due to field filtration.
[p] Analysis cost assumes unit price for 1 element ($39) minus lab prep fee (($10) due to field filtration.

Quality Control Procedures

Field

Water Level Measurements

Quality control steps for the collection of water-level data from wells include accurate record keeping regarding measurement reference points, and evaluation and logging of the pumping status of the measured well. Steps will be taken in the field to avoid, whenever possible, measurement of water levels in wells that exhibit non-static conditions; duplicate field measurements will be used to verify changes in water level during the site visit. If possible, the same measuring device will be used for all wells; if different devices are used, they will be calibrated in a common well.

Water Quality Sampling

In addition to the standardized procedures described above, a variety of steps will be employed to maintain a high level of quality control during field sampling of groundwater water-quality conditions. These steps include:

- Accurate field notes will be maintained that describe field procedures, record values for measured field parameters, track sample identification, and note any variation from the planned procedure.
- Water-level measurement devices used prior to sampling will be thoroughly cleaned before use to prevent the introduction of contaminants to the well.
- Field meters will be calibrated (where applicable, to fresh commercial standards) in accordance with manufacturer's instructions on a twice-daily basis, at the beginning of the sampling day and at midday. For those parameters measured using field test kits, a duplicate test will be conducted for every ten stations tested.
- All field equipment that comes in contact with the water quality samples submitted to the laboratory for analysis will be thoroughly cleaned before use at each well to prevent cross-contamination of samples. Sampling equipment (fittings, non-dedicated tubing, and contact pumps) will be cleaned by sequential flushes or rinses with a mild solution (0.02%) of phosphate free detergent and de-ionized water.
- Pump, tubing, and fitting material type will be compatible with the parameters of interest to prevent bias in sample results.
- Sources of extraneous contamination (generator fumes, gasoline, sunscreen, lock lubricant, etc.) will be minimized during sampling. Sampling teams will employ a "clean hands/dirty hands" approach to sample collection.
- Equipment/filter field blanks will be submitted during each sampling round to determine if sampling equipment or filters are introducing bias into the sampling results. Blanks will be used to determine whether the pumps, sample tubing, filters, sample containers, preservatives, or transport methods represent a source of bias. If bias is recognized in blank samples early in the project, additional steps will be taken to isolate the source of error, and field procedures or equipment will be modified to eliminate the problem.

- Field duplicate samples will be collected at a minimum ratio of one duplicate set for every ten sample stations. Duplicate samples will be submitted to the laboratory as blind samples.
- Reference solutions for chloride, orthophosphate, and nitrate+nitrite will be obtained from Ecology's Quality Assurance Unit for use in preparing blind reference samples. Blind reference samples will be submitted to the laboratory for each applicable sampling round. The measured concentrations will be compared to the known concentrations of the reference samples to provide an estimate of the overall accuracy of the analytical results for these parameters.
- Ionic charge balance errors will be calculated for each station to determine the charge neutrality for the monitoring results. Any error value <10% will be considered an indication of an acceptable charge balance for low ionic strength water. A charge balance error of <15% will be considered acceptable for high ionic strength water.
- Chain-of-custody procedures for all samples will be followed throughout the period between sample collection and delivery to the laboratory.

Table 8 presents a summary of the field quality assurance samples that will be collected in support of this project.

Table 8. Summary of Field Quality Assurance Samples Proposed for Phase 2

Parameter	QA Sample Type				
	Equipment/Filter Blank	Field Duplicate	Reference Sample	Matrix Spike/Matrix Spike Duplicate Set	Trip Blank
pH	NA	1/day	NA	NA	NA
Temperature	NA	1/day	NA	NA	NA
Specific Conductance	NA	1/day	NA	NA	NA
Dissolved Oxygen	NA	1/10 samples	NA	NA	NA
Alkalinity	NA	1/10 samples	NA	NA	NA
TDS	NA	1/10 samples	NA	NA	NA
Chloride	1/Batch	1/10 samples	1/Batch	NA	NA
Fluoride	1/Batch	1/10 samples	NA	NA	NA
Sulfate	1/Batch	1/10 samples	NA	NA	NA
OP	1/Batch	1/10 samples	1/Batch	NA	NA
Nitrate+Nitrite-N	1/Batch	1/10 samples	1/Batch	NA	NA
Iron	1/Batch	1/10 samples	NA	NA	NA
Manganese	1/Batch	1/10 samples	NA	NA	NA
Silica	1/Batch	1/10 samples	NA	NA	NA
Calcium	1/Batch	1/10 samples	NA	NA	NA
Magnesium	1/Batch	1/10 samples	NA	NA	NA
Sodium	1/Batch	1/10 samples	NA	NA	NA
Potassium	1/Batch	1/10 samples	NA	NA	NA
Lead	1/Batch	1/10 samples	NA	NA	NA
Arsenic	1/Batch	1/10 samples	NA	NA	NA
DOC	1/Batch	1/10 samples	NA	NA	NA
VOAs	NA	1/10 samples	NA	1/Batch	1/Batch

Laboratory

In addition to the submittal of blind reference samples, routine laboratory quality control procedures will be adequate to estimate laboratory precision and accuracy for this project. Laboratory quality control samples consist of blanks, duplicates, matrix spikes, and check standards (laboratory control samples) (Manchester Environmental Laboratory, 2002).

Duplicates, matrix spikes, duplicate matrix spikes, and surrogate recoveries will be used to estimate overall bias due to the combination of the analytical procedure and matrix interferences.[1] Check standards will be used to verify analytical precision and provide an estimate of bias due to calibration.[2] Laboratory blanks will be used to measure the response of the analytical system at a theoretical concentration of zero. Manchester Laboratory's quality control samples and procedures are discussed in detail in the Quality Assurance Manual, Manchester Environmental Laboratory (MEL, 2001).

Data Reduction and Management Procedures

Field data will be recorded at the time of measurement or sampling in a field notebook and, if appropriate, input into the Environmental Information Management (EIM) system. Data to be entered into field notebooks includes dates and times of measurement or sampling, names of field personnel, station identification, appropriate field measurement values and units of measure, laboratory sample numbers, and field comments on any deviations from described procedures.

Data generated by MEL will be managed by the Laboratory Information Management System (LIMS) and sent to the project lead in both electronic and printed format. After evaluation of the analytical data against the project data quality objectives, the reported results will be input into (or where appropriate withheld from) the EIM system. The data input into EIM will be flagged as provisional until final review by the project staff.

Data Review and Validation

Data Review

Prior to distribution to the project lead, all laboratory data will undergo a quality assurance review by Manchester Laboratory staff to verify that quality control samples met acceptance criteria as specified in the standard operating procedure for that method. Appropriate qualifiers will be attached to results that did not meet requirements. An explanation for the data qualification will be described in a quality assurance memorandum (case narrative) attached with the data package.

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[1] For VOAs, laboratory surrogate recovery control limits will range between 80-120%.
[2] For VOAs, laboratory control sample (LCS or "check standards") control limits will range between 60-140%.

Data Validation

Upon receipt of the verified data from MEL, the project lead will determine if the results have met the measurement quality objectives for bias, precision, and accuracy for that sampling episode.

Precision will be estimated by calculating the relative percent standard deviation (%RSD) between results for duplicate pairs. These values provide an indication of the degree of random variability introduced by sampling and analytical procedures. These values will be compared to the mean duplicate concentration (over the entire concentration range reported during the project) to assess the ability of the data to meet the project measurement quality objectives. The %RSD for duplicate pairs at, or near, the reporting limit are typically higher than the allowed error described by the measurement quality objectives but are small in absolute terms and will not automatically disqualify data from use.

Analytical bias is assumed to be within acceptable limits if laboratory quality control limits are met for blanks, matrix spikes, and check standards. Sampling bias will be assured by verifying that the correct sampling and handling procedures were used, and review of analytical results for blank samples. Overall accuracy will be estimated by comparing the measured result with the true value of the blind reference sample. Goals for completeness will then be evaluated and, if needed, replacement samples would be obtained and adjustments in subsequent sampling events will be made.

Data Quality Assessment

The purpose of the water quality data is to determine ambient groundwater quality conditions for the target aquifers; no specific agency decision will be forthcoming based on the results. If measurement quality objectives have been met for all sampling episodes, the data will be considered acceptable for use except as qualified during the data review and validation process, and no additional data quality assessment will be needed.

Reporting

Well-owner notification letters summarizing the water-quality sampling results will be delivered to the well owner after laboratory results have been received from MEL, and reviewed and validated by project staff. Notification letters will compare the sampling results to applicable drinking water standards. In any case where the well results exceed a standard, a recommendation will be included in the notification letter suggesting confirmation sampling and contact with the local health department. Sampling results for private wells sampled during the study will be published in the final technical report but names and addresses of well owners will remain permanently confidential.

It is anticipated that a draft report summarizing the technical results of the groundwater study will be completed by April 2005. The draft report will also present recommendations regarding the success or shortcomings of the study design for use for a longer-term state program. Publication of a final version of the report after review and response to comments is scheduled for June 2005.

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