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WEBB HILL BIOSOLIDS FACILITY HYDROGEOLOGIC INVESTIGATION - PHASE 2

Mason County, Washington

Prepared for: Mason County Department of Community Development, on behalf of WRIA 16 Planning Unit

Washington State Department of Ecology Grant No. G0800485

Project No. 070041-004 • June 30, 2008 Interim Report

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Aspect Consulting, LLC

Joseph S. Lubischer, PE
Project Engineer
jlubischer@aspectconsulting.com

Erick W. Miller, LHG
Senior Associate Hydrogeologist
emiller@aspectconsulting.com

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Acronyms

bgs	below ground surface
^{14}C	radioactive carbon isotope with atomic mass 14
CFC	chloroflurocarbon
DNR	Washington Department of Natural Resources
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
GWQC	Ground Water Quality Criteria
^{3}H	tritium, radioactive hydrogen isotope with atomic mass 3
^{3}He	non-radioactive helium isotope with atomic mass 3
HCDOP	Hood Canal Dissolved Oxygen Program
MCL	maximum contaminant level
mg/L	milligrams per liter
NTU	nephelometric unit
QAPP	Quality Assurance Project Plan
SF_6	sulphur hexaflouride
SMCL	secondary maximum contaminant level
TKN	total Kjeldah nitrogen
TOC	total organic carbon; top of casing
TP	total phosphorus
µS/cm	microSiemens per centimeter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WAC	Washington Administrative Code

Executive Summary

The BioRecycling Corporation's Webb Hill Facility is a state permitted biosolids treatment and land application facility on Webb Hill Road in Mason County, Washington. This report presents the findings of the Phase 2 hydrogeologic investigation of the facility.

The objectives of this investigation are to expand evaluation of impacted groundwater beneath the facility and to refine the groundwater flow (transport) directions and horizontal gradients on and off the site. Under the Phase 2 program, two additional groundwater monitoring wells (MW-6 and MW-7) were installed at the facility using rotary-sonic drilling method. This drilling method allowed collection of continuous soil core and identification of perched zones.

The new monitoring wells reinforce previous geologic interpretations of a thin layer of recessional soil over stratified glacial deposits, where the glacial deposits are highly variable, both laterally and vertically. The glacial soils are interpreted to have been deposited in a dynamic sub-glacial environment and include weakly cemented tills, sand and gravel fluvial layers, and some silt units.

Groundwater flow direction in the regional aquifer continued to be southwesterly throughout the last year of measurements (Table 3.1 and Figure 3.1). The groundwater gradient varies from 0.002 feet per foot (ft/ft) (about an 11-foot decline in groundwater level per mile) at the site to 0.007 ft/ft (37 feet per mile) southwest of the site. Additional water level monitoring locations would be useful for better definition of flow direction, particularly northeast of the site, as well as northwest and southeast of the currently defined groundwater contours.

Groundwater quality impacts beneath the facility are indicated by elevated nitrate concentrations, elevated specific conductance, and changes in major ion concentration and chemistry. Increases in specific conductance are well correlated with elevated nitrate concentrations.

Maximum nitrate concentration in groundwater is listed by the Washington Department of Ecology (Ecology) groundwater quality criteria (GWQC), Washington Administrative Code (WAC) 173-200, *Water Quality Standards for Ground Water of the State of Washington*). The allowable maximum contaminant level (MCL) of nitrate in drinking water is specified by Washington Department of Health, WAC 246-290-310, *Public Water Supplies*. In both cases, maximum nitrate concentration is 10 milligrams as nitrogen per liter (mg/L).

Exceedance of GWQC and MCL for nitrate was observed at monitoring well MW-6 (11.9 mg/L). Nitrate concentration at monitoring well MW-5 (4.0 mg/L) is elevated over background conditions. Nitrate at well MW-7 (0.7 mg/L) may be within background levels

The following recommendations are presented:

- Expand definition of off-site groundwater flow paths (1) northeast of the facility (2) northwest and southeast of the currently defined groundwater contours, and (3) further southwest toward Purdy Creek;
- Start quarterly on-site groundwater monitoring and assess temporal variation in nitrate concentration;
- Determine the extent of off-site water quality impacts and monitor nitrate concentrations at off-site water supply wells; and
- Perform an annual review of groundwater flow information, water quality data, and the monitoring and analytical testing scheme.

Specific items for implementation include:

- Quarterly sampling of on-site monitoring wells and semi-annual sampling of hydraulically down-gradient off-site supply wells;
- Identification and inclusion of additional off-site wells in the well network;
- Re-evaluation of groundwater flow paths; and
- Installation of additional monitoring wells to define extent of off-site impacts and to expand definition of groundwater flow paths in areas lacking supply wells . Locations for new monitoring wells include the area downgradient of impacted wells MW-4, MW-5, and MW-6 and the northeast corner of the site.

1 Introduction

Aspect Consulting, LLC is contracted to perform a hydrogeologic investigation of the Bio Recycling Corporation's biosolids recycling facility located on Webb Hill Road in Mason County, Washington (Figure 1.1). This work is being performed cooperatively with the Webb Hill Technical Committee, Mason County, U.S. Environmental Protection Agency (USEPA), and U.S. Geological Survey (USGS). The Bio Recycling Webb Hill facility is a biosolids treatment and land application facility permitted to accept Class B biosolids and untreated sewage sludge. The facility is designated as a Regional Septage Management Facility. Biosolids treated at the facility originate from private septic tanks and area sewage treatment facilities.

An initial investigation of the facility was performed by Aspect Consulting in April and May of 2007 that included the installation and sampling of four groundwater monitoring wells (Aspect Consulting, 2007). Results of the initial investigation indicated that the site was underlain by a regional unconfined aquifer within stratified glacial deposits. Groundwater flow direction was found to be southwesterly. Groundwater quality impacts were identified beneath the facility including nitrate concentrations of 13.3 mg/L in one monitoring well (MW-1) in excess of the maximum contaminant level (MCL) of 10 mg/L. The 2007 Aspect Consulting report also summarized site history and operations and previous investigations.

Pacific Groundwater Group (PGG) under contract to BioRecycling observed installation of one monitoring well (MW-5), two 50-foot boreholes (L-1 and L-2) equipped with soil moisture sensors and lysimeters, and nine additional boreholes in November and December 2007. Installation results were summarized in a draft technical memorandum (PGG, 2007). The PGG investigation also indicated a southwesterly groundwater flow direction.

In addition to these investigations, Mason County Public Health has sampled and analyzed two off-site wells for nitrate concentration.

The objective of this Phase 2 investigation is to further evaluate groundwater conditions at the facility and better define the groundwater flow (transport) direction at the site. To accomplish these objectives, the following work elements were performed:

- Development of Quality Assurance Project Plan (Aspect Consulting, 2008);
- Installation of two groundwater monitoring wells using rotary-sonic drilling methods;
- Preparation of detailed geologic logs and stratigraphic analysis;
- Well development;
- Sampling and analysis for major ions and nitrogen compounds at the two new wells, MW-6 and MW-7, and previously installed well MW-5;

- Groundwater sample collection and dating using Carbon 14 (^{14}C), tritium/helium 3 ratio ($^{3}H/^{3}He$), chloroflurocarbon ratios (CFC), and sulfur hexafluoride (SF_6);
- Performance of one round of water levels from the on-site wells;
- Development of groundwater elevation contours; and
- Survey of the two new monitoring wells and two off-site wells identified to us by Mason County Public Health.

Results of this investigation are presented in this technical memorandum. Groundwater dating results will not be available for several months and will be presented in a separate memorandum. The remainder of this memorandum is organized into the following sections:

- Section 2 presents a summary of field activities;
- Section 3 describes site geologic and hydrogeologic conditions;
- Section 4 discusses results of water quality sampling and testing;
- Section 5 details conclusions and recommendations of the investigation; and
- Appendices, wherein Appendix A presents a detailed description of field activities (well installation, surveying, and sampling); Appendix B has available boring and well logs; Appendix C contains laboratory analytical reports; and Appendix D contains the USGS groundwater dating and water quality results (USGS, 2008) for wells MW-1, MW-2, MW-3, and MW-4. The USGS dating results will be incorporated in a forthcoming memorandum on groundwater age, to be prepared upon completion of dating analyses for wells MW-5 through MW-7.

2 Investigative Methods

2.1 Drilling and Monitoring Well Installation

Two monitoring wells (MW-6 and MW-7) were installed at the facility using a rotary-sonic drilling method. Boart Longyear Company of Fife, Washington was contracted to complete this task. Geologic monitoring during drilling was performed by Aspect Consulting personnel. The rotary-sonic method produces near-continuous cores that allow detailed stratigraphic analysis. All drilling and related activities were performed in accordance with Quality Assurance Project Plan (Aspect Consulting, 2008) and Washington state regulations (Washington Administrative Code [WAC] 173-160, *Minimum Standards for Construction and Maintenance of Wells)*. Drilling, well installation, well development, and soil and water sampling are discussed in detail in Appendix A, Sections A.1 and A.2.

A reconnaissance site visit was held on April 28, 2008, with drilling contractors, Aspect Consulting, and Mason County Department of Community Development to observe site features, discuss monitoring well locations, and evaluate access to proposed locations. Options for well locations, including one off-site alternative, were staked at this time.

Monitoring well drilling, installation, and development was performed between May 20 and June 3, 2008. Monitoring wells were completed with 2-inch Schedule 40 PVC casing and machine slotted screen. Screens were 25-foot long with bottom of screen set about 30 feet below the water table at time of drilling. This construction followed criteria specified in the Quality Assurance Project Plan (QAPP) (Aspect Consulting, 2008). The first boring, MW-6a, was decommissioned after the PVC well casing separated during installation. MW-6 was successfully redrilled 50 feet to the east of MW-6a.

No perched groundwater was encountered during drilling.

Both MW-6 and MW-7 met the alignment test by passing a 1.66-inch by 4.2 foot long slug to the bottom of the wells.

Monitoring wells MW-5, MW-6, and MW-7 were developed by surging with a bailer and then pumping until the discharge was sand free and turbidity was less than 50 nephelometric units (NTUs). Development of MW-5 was performed by the driller, but not supervised by Aspect Consulting as the work was under contract with Pacific Groundwater Group, Inc.

Wells MW-6 and MW-7 were surveyed by a licensed surveyor, MacLearnsberry, Inc., to top-of-casing after well installations were completed (Appendix 3.1). Depth-to-water measurements were made with an electronic water-level indicator to the nearest 0.01 foot.

2.2 Groundwater Sampling

Monitoring wells MW-5, MW-6, and MW-7 were sampled on June 10 through June 12, 2008, using low-flow sampling protocol as specified in the QAPP (Aspect Consulting,

2008). Intake of the sample pump was placed 5, 15, and 12 feet below the water surface for MW-5, MW-6, and MW-7, respectively. Sampling procedures are detailed in Appendix A, Section A.3.3.

Field parameters of temperature, specific conductivity, dissolved oxygen, pH, Eh, and turbidity were measured during sampling. Laboratory-prepared sample containers for wet chemistry analyses were filled, cooled in an ice bath, stored in insulated coolers with cold packs to keep samples at less than 4°C, and submitted under chain-of-custody to a Washington-certified environmental laboratory (Columbia Analytical Services, Inc., Kelso, Washington) for the analysis of inorganic constituents, dissolved metals, total organic carbon (TOC), nitrate, nitrite, ammonia, total Kjeldahl nitrogen (TKN), and total phosphorous. Samples for metals analyses were field filtered. Analytical results and field measured parameters are discussed in Section 4.

Samples for groundwater dating by ^{14}C, $^{3}H/^{3}He$ ratio, CFC, and SF_6 techniques were taken in specified containers. For CFC and SF_6 samples, collection procedures recommended by the USGS Reston Chloroflurocarbon Laboratory and by the Department of Geology and Geophysics, University of Utah, were followed. Diffusion samplers for noble gas collection were installed immediately after groundwater sampling, June 10, 11, and 12, 2008, and removed on June 19, 2008. Additional details are provided in Appendix A, Section A.3.3.

2.3 Wellhead Surveys

Wellheads MW-6 and MW-7 were surveyed in June 2007 by MacLearnsbury, Inc. of Bainbridge Island, Washington. Monitoring wells were surveyed to top of PVC casings as marked and notched. Two off-site wells (Biser and Williams) were surveyed on June 19, 2008. Survey data is presented in Table 2.1. Data for MW-5, also surveyed by MacLearnsbury, Inc., was provided by Pacific Groundwater Group, Inc. The surveyor's reports for MW-6, MW-7, and off-site wells are presented in Appendix A 3.1 and Figure A-1.

3 Facility Hydrogeology

The Webb Hill facility is underlain by a complex sequence of glacial deposits. These deposits, and the occurrence and movement of water within them, have previously been described in the Phase 1 report (Aspect Consulting, 2007b). Since that report, two lysimeters and three additional monitoring wells have been installed at the site: L-1, L-2, and MW-5 by Pacific Groundwater Group, Inc. and MW-6 and MW-7 by Aspect Consulting, LLC.

3.1 Geologic Investigation

Detailed geologic data was obtained during the drilling and logging boreholes using rotary-sonic drilling method and continuous sampling. Detailed geologic logs for all monitoring wells and the two lysimeters are presented in Appendix B. Also included is the Well Drilling Report for the off-site Biser well; no log has been located for the off-site Williams well.

The subsurface geology in the new borings fits the previous description of a thin layer of recessional soil over stratified glacial deposits, where the latter are highly variable both laterally and vertically. The glacial materials are interpreted to have been deposited in a dynamic sub-glacial environment and include weakly cemented tills, sand and gravel fluvial layers, and some silt units. Variation in soil types in the continuous sample core was frequently noted on a scale of less than half a foot. As at previous borings, the occurrence of fairly clean (low silt) sands and gravels increased with depth, but the elevation of transition varied.

Relatively thick upper till units and thin lower till units were identified during the drilling at MW-7. Relatively thick till was present starting at 20 feet below ground surface (bgs) with thinner till units and lenses present to about 140 feet bgs. The upper till consisted of 2.5 and 32.5 foot layers, while the 10 lower layers varied from 1 to 8 feet in thickness. This stratigraphic assemblage is similar to that identified in MW-2 where the upper till layer also starts at 20 feet bgs and at is relatively thick (15 feet) compared to the 11 lower layers, which were typically about 1 foot thick.

Soils at MW-6 were primarily characterized by the log for decommissioned boring MW-6a. Till in MW-6a was identified at a depth of 12.5 feet in two layers of 21.5 and 5 feet thick. Although separated by only 50 feet, lateral heterogeneity was observed between the borings MW-6a and MW-6.

No thick silt layers were noted in either MW-6 or MW-7, as opposed to the 1.5 to 10.5 foot silt layers (non-till) found in MW-4.

3.2 Groundwater Occurrence

No perched groundwater was identified during the drilling of MW-6a, MW-6, or MW-7.

The uppermost regional aquifer at the site is generally unconfined. Water level measurements over the past year, Table 3.1, show significant, which is estimated at 28 feet from May to December 2007 (Aspect Consulting, 2008). Monitoring wells MW-1 through MW-4 are dry seasonally as a result of the water level fluctuations. A large unrecovered decline in water levels was noted between spring 2007 and spring 2008. For example, at MW-1 water elevation varied from approximately 299 feet in May 2007 to 285 feet in May 2008. Contributing factors to differences in recharge may include variations in precipitation and changes in biosolids application. No significant changes in withdrawals are expected.

A full round of on-site water levels was taken on June 12, 2008. Groundwater contour elevations were developed with the Surfer™ program (Golden Software, 2002) using the Kriging technique and hand adjusted. Groundwater contours for June 12, 2008, are presented in Figure 3.1. All available nitrate results are also included.

The general flow direction continues to be southwesterly, generally in line with the northeast-southwest glacially formed ridges (drumlinoids) observable in the topographic base map in Figure 3.1. The coincidence of groundwater flow direction with the orientation of the drumlinoids supports the hypothesis that the depositional environment created lateral anisotropy within the aquifer

The contour gradient appears to have a fairly uniform gradient (evenly spaced contours) of 0.007 ft/ft in the region from MW-7 to the Williams well. Northeast of MW-2, the gradient is lower (a more horizontal water surface), about 0.002 ft/ft, over the main portion of the biosolids site The 0.002 ft/ft gradient at the site is the same as estimated during the Phase 1 investigation (Aspect Consulting, 2007b).

4 Groundwater Quality

This section provides a presentation and discussion of groundwater quality at the Webb Hill Biosolids Facility for sampling of MW-5, MW-6, and MW-7 performed June 10 through June 12, 2008. Table 4.1 summarizes the June 2008 groundwater analytical data. Sample results from May 2007 and January 2008 are also included in the table.

Data validation, performed by Aspect Consulting using criteria specified in the QAPP, is discussed in Appendix C.1 and the laboratory analytical reports are included in Appendix C.2.

Groundwater samples were analyzed for the following parameters using EPA or standard methods as specified below:

Field Parameters

Turbidity
Temperature
pH
Specific Conductance
Dissolved Oxygen
Eh

Dissolved Metals

Iron (EPA Method 200.7)
Manganese (EPA Method 200.7)

Nutrients

Ammonia as N (SM4500)
Nitrate as N (EPA 300.0)
Nitrite as N (subtraction of nitrate from nitrate+nitrite)
Nitrate+nitrite (EPA 353.2)
Total Kjeldahl Nitrogen (ASTM D 1426-93B)
Phosphorous (EPA 365.3)

Major Ions

Calcium (EPA 200.7)
Magnesium (EPA 200.7)
Potassium (EPA 200.7)
Sodium (EPA 200.7)
Chloride (EPA 300.0)
Sulfate (EPA 300.0)
Bicarbonate Alkalinity (SM 2320B)
Carbonate Alkalinity (SM 2320B)

Miscellaneous Conventional Chemistry Parameters

Bromide (EPA 300.0)
Fluoride (EPA 340.2)
Total Organic Carbon (EPA 415.1)

A discussion of the conventional groundwater chemistry and distribution of detected analytes is presented below (Section 4.1) followed by a comparison of analytes with Washington state groundwater quality criteria and drinking water standards (Section 4.2). Wells MW-1 through 4 were not resampled as part of the Phase 2 investigation. Therefore, the June 2008 water quality results for MW-5, MW-6 and MW-7 are compared with the May 2007 data for MW-1, MW-2, MW-3, MW-4, and WS-2 (Section 4.1).

4.1 Nitrate Occurrence and Conventional Chemistry

Nitrate and major ion data indicate water quality impacts are occurring at the facility boundary. A summary of groundwater quality data at the facility is presented on Table 4.1 and nitrate values are posted on Figure 3.1. Greatest water quality impacts at the site boundary were identified at monitoring wells MW-1, MW-4, MW-5, and MW-6 where nitrate (measured as nitrogen content, i.e., nitrate-N) was detected at concentrations of 13.3mg/L (May 2007), 9.8 mg/L (May 2007), 4.0 mg/L (June 2008) and 11.9 mg/L (June 2008), respectively. These wells are located hydraulically downgradient of biosolids application areas and have elevated major ion and nitrate data compared to previously collected data in upgradient monitoring well MW-3. Monitoring well MW-7 had a low nitrate detection (0.7 mg/L) similar to MW-2 (0.8 mg/L), but may prove to be within background conditions with continued monitoring[1]. Water quality test results for each new well (MW-5, MW-6, and MW-7) are discussed below.

MW-5

In general, water quality in this well indicates an impact above the upgradient conditions , observed at monitoring well MW-3. The nitrate concentration in MW-5 is greater than in wells along the northwest facility boundary (WS-2, MW-2 and MW-7), but less than concentrations in wells located in the center of or downgradient to the site (MW-1, MW-4, and MW-6).

Monitoring well MW-5 lies near the southwest corner of the facility and close to the south boundary (Figure 3.1). Well MW-5 was installed in December 2007 and initially sampled in January 2008. The well had a nitrate-N concentration of 6.9 mg/L in January 2008 (Table 4.1). In the June 2008 sampling, nitrate-N was detected at 4.0 mg/L. The seasonal variation in nitrates is consistent with a dilution effect, as nitrate concentration is inversely related to seasonal water level fluctuation where higher concentrations correspond to lower water levels. However, variable rates of nitrogen application could also affect groundwater nitrate measurements. Specific conductance (152 umohs/cm) and major ion concentrations (Table 4.1) are generally consistent with the nitrate concentrations and reflect a greater water quality impact than at upgradient well MW-3

[1] Background nitrate concentrations in western Washington can be very low, including non-detect levels such as observed in MW-3. However, additional sampling, both spatially and temporally, would be required to specify the local background nitrate concentrations and variation in the Webb Hill area.

and wells WS-2, MW-2 and MW-7 along the northwest facility boundary, but a lesser impact than observed at wells MW-1, MW-4 and MW-6.

The pH in wells MW-1 through MW-4 ranged from about 6 to 7.5 with lowest pH occurring in the more impacted wells. The pH measured in wells MW-5 through MW-7 ranged from 8.2 to 8.4, but showed the same pattern of lowest pH occurring in the more impacted wells. Field calibration records were reviewed for the pH meter and no anomalies were identified.

MW-6

Of the recently installed wells, MW-6 shows the greatest water quality impact. This well is located downgradient of Field 4 and portion of Field 3 at the south facility boundary. Nitrate concentrations in this well were measured at 11.9 mg/L. Similar to MW-1 and MW-4, major ions and specific conductance are elevated in this well relative to upgradient conditions measured at MW-3.

MW-7

Monitoring well MW-7 is located on the westerly boundary of the facility, approximately 1,300 feet due south of MW-2. MW-7 is downgradient of Field 10 and portions of Fields 1 and 2. Water quality in this well is similar to that identified in monitoring wells MW-2 and WS-2 in the May 2007 sample event. Specific conductance, major ions, iron, and manganese concentrations are similar between these wells.

4.2 Comparison with Regulatory Standards

Water quality standards for analytes are presented in Table 4.1. The Maximum Contaminant Level (MCL) is a health-based standard used to determine the maximum permissible level of a contaminant in water delivered to any user of a public water drinking system. The Secondary Maximum Contaminant Level (SMCL) is a guideline based on factors other than health effects. SMCLs control aesthetic qualities of water such as taste, odor, or staining characteristics. MCLs and SMCLs listed in Table 4.1 were obtained from drinking water standards listed by Department of Health (DOH) in WAC 246-290.

The State of Washington has developed water quality standards for groundwater of the state (Ground Water Quality Criteria or GWQC) (WAC 173-200). The goals of the water quality standards are "*to maintain the highest quality of the state's ground waters and protect existing and future beneficial uses of the ground water through reduction or elimination of the discharge of contaminants to the state's ground waters and protect existing and future beneficial uses of the ground water through reduction or elimination of the discharge of contaminants to the state's ground waters*". The implementing rule, WAC 173-200, establishes water quality criteria for protection of the environment, human health, and current and future beneficial uses of ground water. Under WAC 173-200, enforcement limits are defined on a site specific basis but are generally less than the numeric criteria.

In Table 4.1, GWQC exceedances are indicated with a shaded pattern and MCL or SMCL exceedances are indicated with a bold outline.

For the constituents analyzed, primary GWQCs and/or MCLs have been established for nitrate, nitrite, and fluoride. The GWQC and MCL for nitrate (10 mg/L) were exceeded in monitoring well MW-6 (11.9 mg/L) in the June 2008 sample event

For the analytes tested, secondary groundwater criteria and/or drinking water SMCLs have been established for pH, iron, manganese, chloride, sulfate, and fluoride. No secondary standards were exceeded in the June 2008 sample event.

5 Summary of Findings and Recommendations

5.1 Summary of Findings

1. Subsurface soils at the biosolids facility are generally characterized as a thin layer of recessional outwash underlain by laterally and vertically heterogeneous glacial deposits. The glacial deposits are interpreted to have formed predominantly in a dynamic subglacial environment. Till layers varying from less than 1-foot to over 30 feet were found interbedded with clean and debris rich sands and gravels.

2. The regional aquifer is present beneath the site under unconfined conditions at about elevation 300 feet. The aquifer is at least 55 feet thick. Groundwater flow within the unconfined regional aquifer is toward the southwest, in line with the drumlinoid surface features. Gradient at the site is low at 0.002 ft/ft, steepening to a gradient of 0.007 ft/ft between MW-7 and the Williams well.

3. No perched groundwater was identified in monitoring wells MW-6 or MW-7. Perched groundwater had been previously identified in monitoring well borings MW-1 through MW-4, although none of the perched zones were found to correlate between boreholes.

4. Water quality impacts are found in wells located downgradient of biosolids application areas. In the June 2008 sampling of wells MW-5, MW-6, and MW-7, nitrate concentrations above 1 mg/L as nitrogen occurred MW-5 (4.0 mg/L) and MW-6 (11.9 mg/L). Nitrate concentrations elevated above 1 mg/L were previously identified in MW-1 (13.3 mg/L) and MW-4 (9.8 mg/L) in the May 2007 sample event. The Ecology groundwater criteria (WAC 173-200) and the DOH MCL for nitrate in groundwater are 10 mg/L. Slightly elevated nitrate concentrations were identified at monitoring well MW-7 (0.7 mg/L) and previously at MW-2 (0.8 mg/L) and on-site supply well WS-2 (0.7 mg/L). These wells may prove to be within background conditions with additional sampling.

5.2 Recommendations

Because of the exceedance of the numeric criteria for nitrate concentrations under WAC 173-200 in groundwater at the Webb Hill biosolids recycling facility, needs remain for

- Expanded definition of groundwater flow paths beyond the currently defined groundwater contours: Northeast of the site, northwest and southeast from MW-5, and, southwest of the Biser well toward Purdy Creek;
- Continued nitrate analysis at on-site and off-site wells;
- Assessment of temporal variation in nitrate concentrations and extent of off-site water quality impacts; and
- Annual review of data.

Specific recommendations are as follows:

5.2.1 Expand Lateral Definition of Groundwater Flow Paths and Seasonal Variation On and Off-site

- Continue monitoring water levels in wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, WS-2, and off-site wells on a monthly basis for one year and quarterly thereafter. Water level monitoring would be greatly facilitated by the installation of pressure transducers and dataloggers in the site monitoring wells.
- Continue monitoring water levels in off-site Biser and Williams wells. These wells provide good monitoring points about 3000 and 4500 feet, respectively, downgradient of the site.
- Define flow patterns in the northeast portion of the facility. This may be accomplished through an off-site supply well if a suitable well can be identified. If an off-site supply well is not available, we recommend a monitoring well be installed in the northeast corner of the facility.
- Define groundwater flow patterns in the downgradient direction. Expand the off-site domestic well network by adding wells (1) northwest of the Williams well and west of MW-5, (2) east of the Williams well and south of MW-6 and MW-4, and (3) southwest of the Biser well towards Purdy Creek. If flow patterns cannot be determined through the use of off-site wells, then additional monitoring wells should be considered.
- Criteria for inclusion of new off-site wells in the monitoring network include:
    - Completion in the uppermost regional aquifer;
    - Owner permission for quarterly measurement and, possibly, sampling and surveying; and
    - Well location and elevation information.

5.2.2 On-Site Water Quality Assessments

- Start water quality monitoring on a quarterly basis at wells MW-1, MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, and WS-2. Use of dedicated in-well sampling pumps is recommended. The water quality analytical testing scheme should be based on review of potential sources. Since metals may concentrate in biosolids, the analytical testing should include analysis for dissolved metals as a screening measure.
- Determine seasonal variation in nitrate concentrations.

5.2.3 Off-Site Water Supply Water Quality Assessments

- Install an off-site monitoring well downgradient of MW-6 to define the extent of off-site impacts. This information will be useful in evaluating water quality impacts to future domestic supply wells.
- As a precautionary measure, perform at least semi-annual sampling of potable water supply wells downgradient of the site for nitrate concentrations (see criteria in 5.2.1). Sampling should be done at seasonal high (late April to early May) and low water levels (December). The downgradient extent to which off-site wells are monitored for water quality should be determined based on identification of wells that indicate a return to background nitrate levels. The analytical testing scheme should be based on analytes detected in the facility monitoring wells and should include nitrate analysis as a minimum.
- Water level data should also be collected at these water supply wells to better define groundwater flow directions (Section 5.2.1).

5.2.4 Perform Annual Review

Annually review the water quality and the water level data for monitoring wells and off-site wells. Also review surface water quality data.

- Review water level data and update groundwater elevation contours and flow paths;
- Review groundwater and surface water quality data. Assess whether installation of additional monitoring wells, on-site or off-site, is necessary to determine extent of nitrate impacted groundwater.
- If analyte concentrations vary significantly between quarters, implement a monthly monitoring program for a 1-year period;
- Review the monitoring and analytical testing scheme and make appropriate recommendations for modification.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Mason County Department of Community Development, on behalf of WRIA 16 Planning Unit for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 2.1 - Monitoring Well Completion Summary

Webb Hill Hydrogeologic Investigation - Phase 2
Mason County, Washington

Well ID	Installation Date	Well Location Coordinates[1]		Ground Surface Elevation[2]	Monument Elevation[2]	Stickup	Top of Casing		Total Boring Depth	Well Depth[3]	Screen Length	Screen Interval Depth	Filter Pack Interval Depth
		Northing	Easting				Elevation[2,3]	Elevation Difference[4]					
		(feet)	(feet)	(feet)	(feet)	(feet)	(feet)	(feet)	(feet bgs)	(feet bgs)	(feet)	(feet bgs)	(feet bgs)
MW-1	4/26/07	730844	993069	402.51	406.35	3.06	405.57	0.01	125	124.8	19.5	105.0 to 124.5	102.5 to 125.0
MW-2	5/3/07	731148	991371	443.97	447.17	2.76	446.73	0.01	168	168.7	24.5	143.9 to 168.4	140.6 to 166.0
MW-3	4/24/07	732495	992946	465.84	469.14	2.71	468.55	0.01	187	185.3	24.5	160.5 to 185.0	154.9 to 187.0
MW-4	4/30/07	729408	994200	375.99	379.89	3.25	379.24	0.01	105	97.7	24.5	72.9 to 97.4	68.2 to 96.0
MW-5	12/4/07	728694	990367	411.54	-	1.64	413.18	0.25	165	161.0	20	140.7 to 160.7	137.0 to 161.0
MW-6	5/28/08	728588	992589	397.46	400.33	2.81	400.27	-	146	145.2	24.6	120.2 to 144.8	117.0 to 145.0
MW-7	5/30/08	729866	991229	418.55	421.58	2.78	421.33	-	170	170.6	24.6	145.4 to 170.0	141.7 to 170.6
WS-2[5]	4/18/00	731673	992697	444.85	-	1.9	446.75	0.03	197	197	6	191 to 197	None
Biser	10/10/94	725206	987893	-	-	-	332.28	-	110	110	10	100 to 105	None
Williams	-	726239	988343	-	-	-	337.20	-	-	-	-	-	-
Bench Mark	5/9/07	731757	992859	446.32	-	-	446.32	0.00	-	-	-	-	-

Notes

[1]Well location coordinates are in Washington State Plane South NAD83 (2007) coordinate system using U.S. feet.

[2]Elevations are NAVD88 (1996) using U.S. feet.

[3]Measuring points for both PVC and steel casings were marked and notched.

[4]Indicates elevation difference from previous surveys.

[5]Below grade information taken from state Water Well Report. The reported casing depth of 193.2 ft bgs may be inconsistent with the screen interval of 191 to 197 feet indicated on log.

Abbreviations

bgs = below ground surface

Table 3.1 - Groundwater Levels

Webb Hill Hydrogeologic Investigation - Phase 2
Mason County, Washington

Well Name		MW-1		MW-2		MW-3		MW-4		MW-5		MW-6		MW-7		Water Supply- 2		Biser		Williams	
Ground Surface Elevation (ft MSL)		402.51		443.97		465.84		375.99		411.54		397.46		418.55		444.85		-		-	
Casing Stickup above Ground Surface (ft)		3.06		2.76		2.71		3.25		1.64		2.81		2.78		1.9		-		-	
Casing Elevation (ft)		405.57		446.73		468.55		379.24		413.18		400.27		421.33		446.75		332.28		337.20	
Top of Screen Elevation (ft MSL)		297.51		300.07		305.34		303.09		270.84		277.26		273.15		253.85		-		-	
Bottom of Screen Elevation (ft MSL)		278.01		275.57		280.84		278.59		250.84		252.66		248.55		247.85		-		-	
Date	Entity	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)	Depth (ft bTOC)	Elevation (ft, MSL)
5/23/2007	Aspect	106.92	298.65	149.98	296.75	168	300.55	80.37	298.87	-	-	-	-	-	-	147.49	299.26	-	-	-	-
5/30/2007	Aspect	-	-	150.55	296.18	168.56	299.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/31/2007	Aspect	107.64	297.93	150.68	296.05	168.66	299.89	81.18	298.06	-	-	-	-	-	-	148.14	298.61	-	-	-	-
6/27/2007	MCPH	110.37	295.2	154.09	292.64	171.56	296.99	83.895	295.345	-	-	-	-	-	-	-	-	-	-	-	-
9/26/2007	MCPH	122.6	282.97	166.575	280.155	184.02	284.53	94.735	284.505	-	-	-	-	-	-	-	-	-	-	-	-
11/21/2007	PGG	Dry	< 278.01	Dry	< 275.57	Dry	< 280.84	Dry	< 278.59	-	-	-	-	-	-	-	-	-	-	-	-
12/3/2007	PGG	-	-	-	-	-	-	-	-	154.89	258.29	-	-	-	-	-	-	-	-	-	-
1/22/2008	PGG	Dry	< 278.01	Dry	< 275.57	Dry	< 280.84	95.82	283.42	152.68	260.5	-	-	-	-	-	-	-	-	-	-
1/23/2008	PGG	-	-	-	-	-	-	95.04	284.2	152.04	261.14	-	-	-	-	172.5	274.25	-	-	-	-
3/13/2008	PGG	120.44	285.13	163.73	283	182.4	286.15	91.55	287.69	141.54	271.64	-	-	-	-	-	-	-	-	-	-
4/21/2008	PGG	119.03	286.54	-	-	180.09	288.46	91.16	288.08	-	-	-	-	-	-	-	-	-	-	-	-
4/22/2008	PGG	119.14	286.43	161.62	285.11	-	-	-	-	140.53	272.65	-	-	-	-	160.71	286.04	80.22	252.06	83.85	253.35
5/21/2008	PGG	120.05	285.52	162.73	284	-	-	92.46	286.78	141.28	271.9	-	-	-	-	161.88	284.87	81.80	250.48	85.20	252.00
6/12/2008	Aspect	121.43	284.14	164.27	282.46	182.44	286.11	94.02	285.22	143.33	269.85	119	281.27	143.61	277.72	162.08	284.67	83.43	248.85	86.83	250.37

Notes
Shaded groundwater levels for the Biser and Williams domestic wells were calculated based on an average groundwater level change for MW-1, MW-2, MW-4 and MW-5 between the May 21st and June 12th 2008 measurements.
Depth to groundwater was measured from the top of casing.
The elevation datum is NAVD88 (1996).

Abbreviations
bTOC = Below Top of Casing
MSL = Mean Sea Level

Table 4.1 - Groundwater Quality Summary

Webb Hill Hydrogeologic Investigation - Phase 2
Mason County, Washington

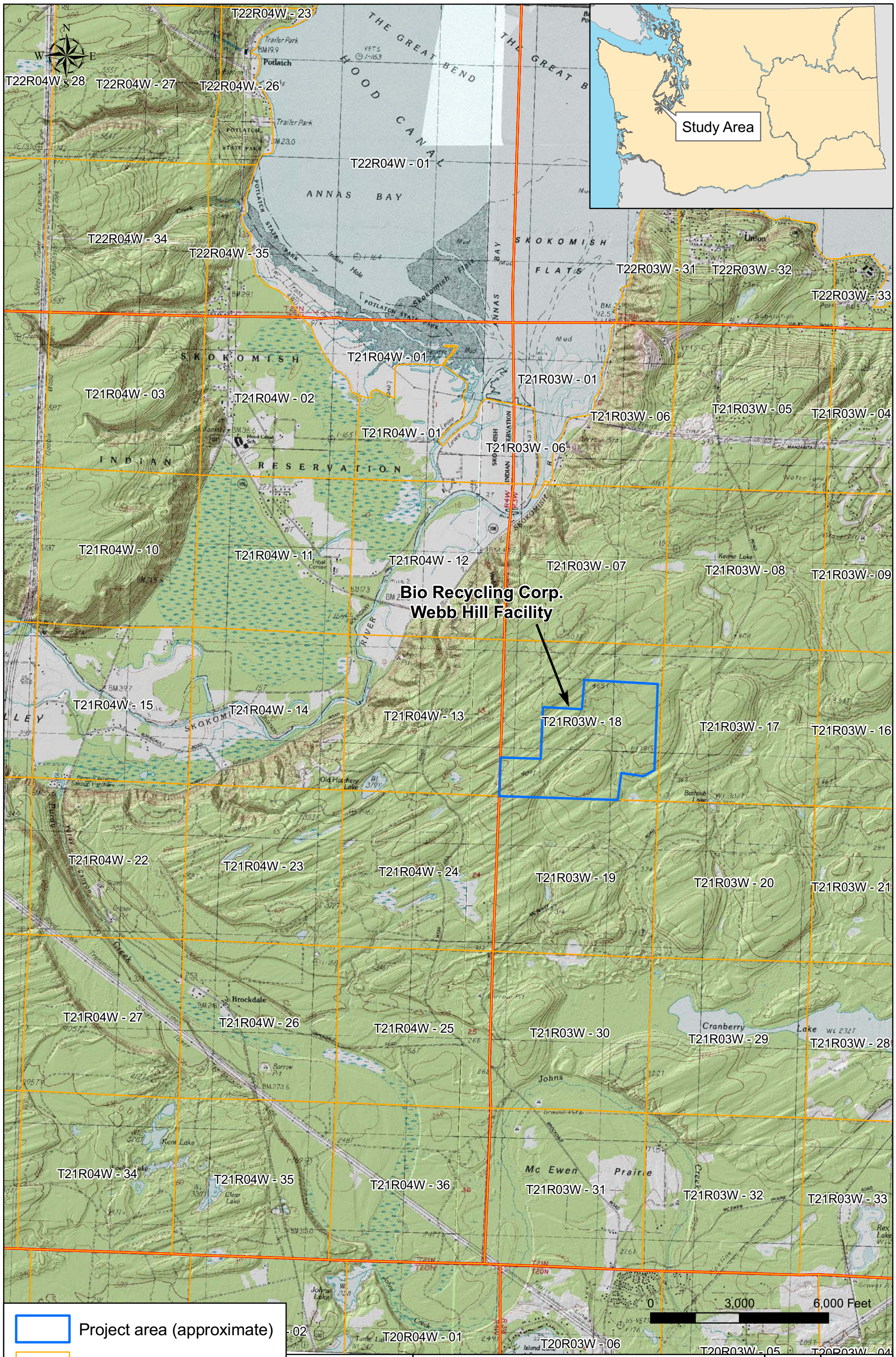
Parameter or Chemical	Units	DOE Groundwater Quality Criteria[1] Primary	DOE Groundwater Quality Criteria[1] Secondary	DOH Drinking Water Standard[2] MCL	DOH Drinking Water Standard[2] SMCL	May 2007 Sampling Event[8,9] MW-1 5/31/07	MW-1 (Blind Dup.) 5/31/07	MW-2 5/30/07	MW-3 5/30/07	MW-4 5/31/07	WS-2 5/31/07	January 2008 Sampling Event[8,9,10] L-1 1/23/08	L-2 1/23/08	MW-5 1/23/08	June 2008 Sampling Event[8,9] MW-5 6/10/08	MW-6 6/12/08	MW-7 6/11/08
Field Parameters																	
Temperature	°C	-	-	-	-	14.08	-	13.58	15.44	15.37	10.58	-	-	-	10.16	9.98	10.59
pH	pH	-	6.5 to 8.5	-	-	6.66	-	7.11	7.28	6.55	7.49	-	-	-	8.39	8.18	8.44
Specific Conductance	µS/cm	-	-	-	-	374	-	95	82	299	101	-	-	-	152	253	98
Dissolved Oxygen	mg/L	-	-	-	-	8.85	-	8.81	9.71	8.65	10.83	-	-	-	9.37	9.43	9.55
Eh	mV	-	-	-	-	140.1	-	118.7	91.6	148	122.1	-	-	-	83.7	135.2	150.7
Turbidity	NTU	-	-	-	-	1.51	-	2.99	33.80	1.46	1.19	-	-	-	0.46	0.76	1.05
Dissolved Metals																	
Calcium	mg/L	-	-	-	-	40.4	40.2	10.1	9.15	31.6	10.7	-	-	-	15.5	24.4	10.1
Iron	mg/L		0.3	-	0.3	0.150 U	0.150 U	0.150 U	0.150 U	0.150 U	0.150 U	-	-	-	0.010 U	0.005 J	0.010 U
Magnesium	mg/L	-	-	-	-	17.8	17.8	4.86	3.99	13.3	5.39	-	-	-	7.45	11.7	4.95
Manganese	mg/L	-	0.05	-	0.05	0.0100 U	0.0100 U	0.0100 U	**0.0798**	0.0100 U	0.0100 U	-	-	-	0.0011 J	0.0056	0.0138
Potassium	mg/L	-	-	-	-	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	-	-	-	1.00 U	0.41 J	1.00 U
Sodium	mg/L	-	-	20[3]	-	6.25	6.22	3.40	3.29	6.02	3.36	-	-	-	3.86	4.63	3.11
Conventional Chemistry Parameters																	
Bicarbonate Alkalinity	mg/L as $CaCO_3$	-	-	-	-	69.6	70.4	39.8	41.4	50.8	44.6	-	-	-	48	50	29
Carbonate Alkalinity	mg/L as $CaCO_3$	-	-	-	-	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	-	-	-	1.00 U	1.00 U	1.00 U
Hydroxide Alkalinity[4]	mg/L as $CaCO_3$	-	-	-	-	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	5.00 U	-	-	-	-	-	-
Chloride	mg/L	-	250	-	250	15.5	15.6	2.22	1.71	15.8	2.22	88.8	38.8	11	6.9	15.7	3.8
Sulfate	mg/L	-	250	-	250	17.5	17.5	1.95	0.870	13.7	1.66	**274.0**	110	4.8	2.0	6.7	0.9
Bromide	mg/L	-	-	-	-	0.400 U	0.400 U	0.400 U	0.400 U	0.400 U	0.400 U	-	-	-	0.012 J	0.012 U	0.012 J
Ammonia as Nitrogen	mg/L as N	-	-	-	-	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.256	0.050	0.327	0.080	0.120	0.020 J
Nitrate as Nitrogen[5]	mg/L as N	10	-	10	-	**13.3**	**14.1**	0.785	0.0100 U	**9.78**	0.713	0.403	**27.8**	**6.9**	**4.0**	**11.9**	0.7
Nitrite as Nitrogen[6]	mg/L as N	-	-	1	-	0.0100 U	0.0100 U	0.0100 U	0.0100 U	0.0100 U	0.0100 U	0.04	0.13	0.32	0.09	0.10	0.13
Nitrate-Nitrite	mg/L as N	-	-	-	-	13.3	14.1	0.785	0.0100 U	9.78	0.713	0.44	27.90	7.22	4.09	12.00	0.83
Total Kjeldahl Nitrogen[7]	mg/L as N	-	-	-	-	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	1.00 U	0.65 J	0.60 R	1.27 J	0.80	2.00	1.00
Phosphorus	mg/L	-	-	-	-	0.0620	0.0430	0.155	0.0880	0.0310	0.0800	-	-	-	0.0100	0.0100	0.0200
Fluoride	mg/L	4	-	4	2	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U	-	-	-	0.011 J	0.010 U	0.021 J
Total Organic Carbon	mg/L	-	-	-	-	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	2.00 U	9.14	3.72	1.50 U	1.00	1.00	0.70

Notes

[1]From Table 1 - Groundwater Quality Criteria in WAC 173-200.
[2]MCLs (Maximum Contaminant Levels) and SMCLs (Secondary Maximum Contaminant Levels) from WAC 246-290-310.
[3]20 mg/L is listed as a "level of concern" and is not an MCL.
[4]During the June 2008 sampling event, Hydroxide Alkalinity was not analyzed.
[5]Values greater than 1 mg/L are in bold.
[6]For the June 2008 sampling event, Nitrite was calculated as the difference between the laboratory reported results for Nitrate + Nitrite and Nitrate.
[7]For the January 2008 sampling event, Total Kjeldahl Nitrogen results (with dot pattern) were suspected of being inaccurate, as a quality control spike showed significant matrix interference. Reporting limit = 0.6 mg/L. (Pacific Groundwater Group and Bennett-Cumming, 2008).
[8]Concentrations in shaded cells exceed Groundwater Quality Criteria in WAC 173-200.
[9]Concentrations located within thick borders exceed Drinking Water Standard MCLs or SMCLs.
[10]Pacific Groundwater Group (2008).

Abbreviations

U - The compound was analyzed for, but was not detected ("Non-detect") at or above the Minimum Reporting Limit (MRL) or Minimum Detection Limit (MDL).
J - The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.
R - The laboratory-reported result for L-2 was non-detect at 0.6 mg/L. Result was rejected by Pacific Groundwater Group due to 0% matrix spike recovery. (Pacfic Groundwater Group and Bennett-Cumming, 2008).
DOE - Washington Department of Ecology
DOH - Washington Department of Health



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Project Vicinity Map

Webb Hill Hydrogeologic Investigation
Mason County, Washington

DATE: June 2008	PROJECT NO. 070041
DESIGNED BY: EWM	
DRAWN BY: ACM	FIGURE NO. 1.1
REVISED BY: SCC	

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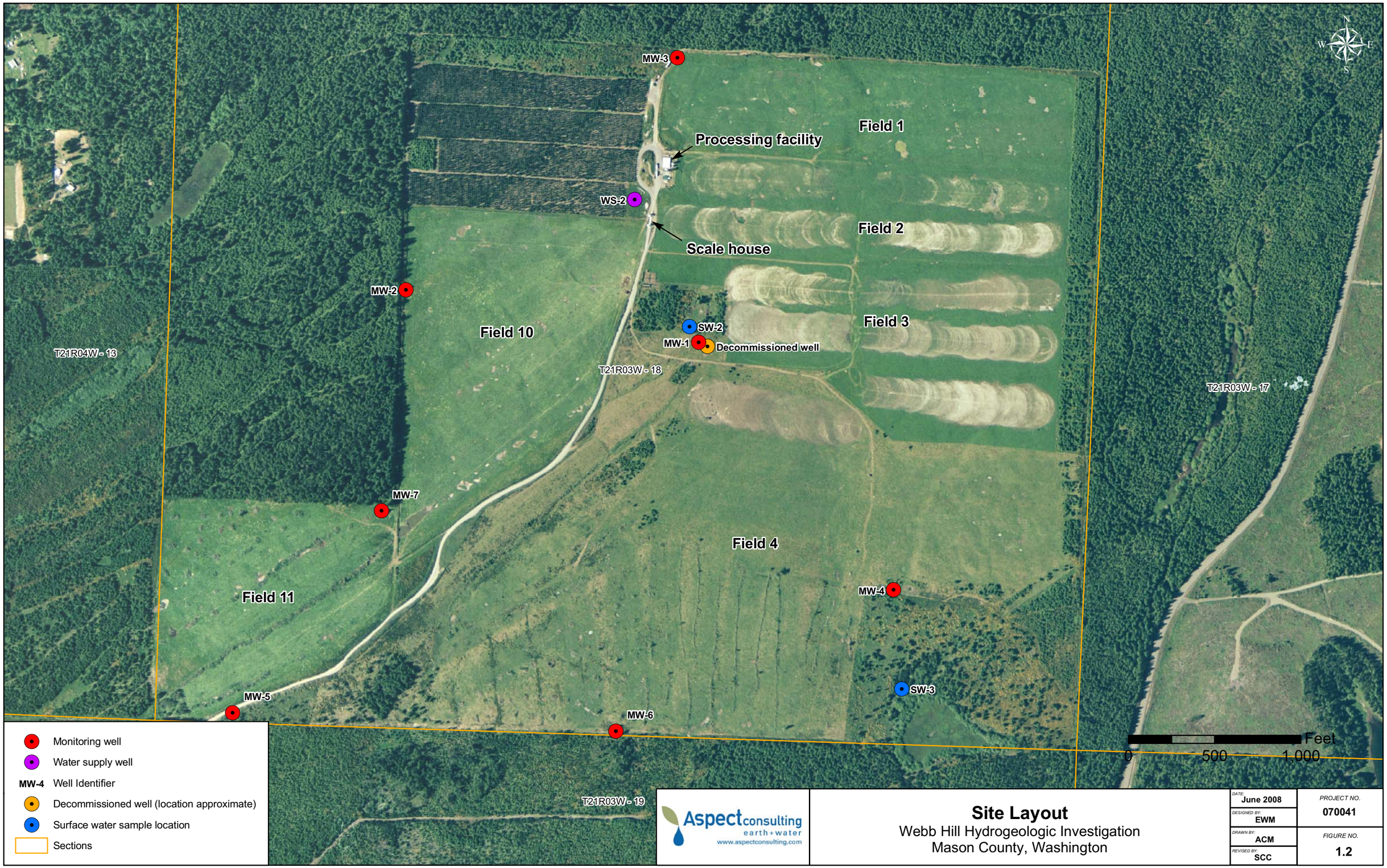

- Monitoring well
- Water supply well
- **MW-4** Well Identifier
- Decommissioned well (location approximate)
- Surface water sample location
- Sections

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Site Layout

Webb Hill Hydrogeologic Investigation
Mason County, Washington

DATE: June 2008	PROJECT NO. 070041
DESIGNED BY: EWM	
DRAWN BY: ACM	FIGURE NO. 1.2
REVISED BY: SCC	

T:\projects_8\mason_county\SiteLayout_06-2008

T21R04W - 09
T21R04W - 10
T21R04W - 11
T21R04W - 12
T21R03W - 07
T21R03W - 08
T21R04W - 16
T21R04W - 15
T21R04W - 14
T21R04W - 13
T21R03W - 18
T21R03W - 17
T21R04W - 23
T21R04W - 24
T21R03W - 19
T21R03W - 20
T21R04W - 26

MW-3
286.11
< 0.1
5/30/07

WS-2
284.67
0.71
5/31/07

MW-2
282.46
0.79
5/30/07

MW-1
284.14
13.3
5/31/07

MW-7
277.72
0.7
6/11/08

MW-5
269.85
4.0
6/10/08

MW-4
285.22
9.8
5/31/07

MW-6
281.27
11.9
6/12/08

Williams
250.37
< 1.0
11/19/07

Biser
248.85
< 1.0
11/19/07

Groundwater flow direction

Groundwater Elevation Contour

Monitoring well

Water supply well

MW-4 Well Identifier

284.14 Groundwater Elevation in Feet
13.3 Nitrate, mg/L
5/31/07 Nitrate Sample Date

Project area

Sections

Notes
- Groundwater elevation contours were prepared from monitoring well data by Kriging using Surfer 8 (Golden Software, 2002).
- Data from supply well WS-2 was not used in contouring.
- Groundwater elevations in Biser and Williams wells are based on measurements taken May 21, 2008.

0 2,000 4,000 Feet

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Groundwater Elevation Contours - June 12, 2008

Webb Hill Hydrogeologic Investigation
Mason County, Washington

DATE: June 2008	PROJECT NO. 070041
DESIGNED BY: EWM	
DRAWN BY: ACM	FIGURE NO. 3.1
REVISED BY: SCC	

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