A Department of Ecology Report

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Moses Lake Dunes Wastewater Treatment Plant, Class II Groundwater Inspection

Abstract

The Washington State Department of Ecology (Ecology) conducted a Class II groundwater inspection of the city of Moses Lake Dunes Wastewater Treatment Plant (WWTP) on April 27-29, 1998. The inspection consisted of:

1. An evaluation of the WWTP groundwater monitoring network,
2. An audit of the WWTP sampling procedures,
3. A comparison of Ecology and Moses Lake split sample results, and
4. An evaluation of Moses Lake's compliance with permitted effluent limits.

Four of the facility's five monitoring wells were sampled during the inspection for general and physical chemistry parameters and total metals. The fifth well was not sampled because it was dry.

The facility is complying with permitted effluent discharge limits for annual and monthly discharge volumes (Ecology, 1997a). However, facility wastewater has degraded groundwater quality to the extent that secondary drinking water standards for total dissolved solids, manganese, and iron are not met in the facility down-gradient wells. Significant down-gradient increases are also apparent in other constituents including nitrate, ammonia, total Kjeldahl nitrogen, sodium, fluoride, chloride and sulfate.

Groundwater metals analyses results were all less than applicable groundwater quality standards, although several parameters (barium, calcium, cobalt, magnesium, potassium, sodium, and strontium) were elevated in one or more of the down-gradient wells, relative to concentrations noted in the up-gradient well.

Differences between Ecology and Moses Lake split sample results were generally within acceptable limits.

by Kirk Sinclair

Waterbody No. WA-41-9280GW
Ecology Report #99-325
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The monitoring well network at the Dunes WWTP does not adequately characterize groundwater gradients or facility impacts to groundwater beneath and immediately down-gradient of the WWTP. Additional down-gradient and cross-gradient wells are needed to differentiate the facility wastewater effects from those originating on down-gradient property owned or managed by the Basic American Foods vegetable processing facility.

The groundwater sampling procedures employed at the Dunes WWTP (1) are not consistent with current industry protocols, and (2) do not meet the monitoring requirements specified in the facility discharge permit. The Dunes WWTP should develop a formal written monitoring plan in accordance with the implementation guidance for the groundwater quality standards (Kimsey, 1996).

Recommendations

- Moses Lake should develop and implement a formal *Sampling and Quality Assurance Plan* to address the groundwater sampling and water level measurement deficiencies identified during this inspection. The plan should incorporate the sampling procedures specified in the implementation guidance for the groundwater quality standards (Kimsey, 1996), as required in subsections S2b and S2c of the Dunes WWTP discharge permit.

- Moses Lake should install additional monitoring wells to enable better characterization of groundwater conditions at the Dunes WWTP. Two additional wells are needed along the western property boundary north of well MW-5 and west of wells MW-2 and MW-3. An additional well is needed east of well MW-5 along the southern facility boundary.

- The new wells should be constructed in accordance with Washington well construction standards (Chapter 173-160 WAC). Ecology review and approval of potential well locations and designs are necessary to ensure that the wells are appropriately located and designed to detect contaminants of interest.

- Two priority pollutant and other target volatile organic compounds and four BNAs were detected in the Moses Lake effluent. In all cases these constituents were below applicable groundwater quality standards, although the concentration of bis(2-ethylhexy)phthalate (2.1 ug/L) equaled approximately 35% of the groundwater quality criteria (Golding, 1999). Moses Lake should initiate organics monitoring of its wells to rule out groundwater contamination by these constituents.

- Well MW-4 should be properly abandoned at the time new wells are installed.

Introduction

The Washington State Department of Ecology (Ecology) conducted a Class II inspection of the city of Moses Lake Dunes Wastewater Treatment Plant (WWTP) between April 27 and April 29, 1998. The inspection was conducted at the request of Wayne Peterson, Ecology site manager for the Dunes WWTP. The inspection consisted of an engineering evaluation of the facility treatment process, evaluation of the facility groundwater monitoring network and sampling procedures, and determination of facility compliance with permitted discharge limits. This report presents the results of the groundwater inspection. Results of the facility treatment inspection are contained in a companion report (Golding, 1999).

The Ecology groundwater inspection was conducted by Kirk Sinclair of the Environmental Assessment Program. Bill Smigha, Dunes WWTP operator, coordinated sampling for Moses Lake.

Facility Description

The Dunes WWTP was constructed in 1984 to replace a trickling filter system that discharged directly to Moses Lake. The primary objective for installing the new treatment plant was to reduce nutrient loading to the lake which had contributed to prior algal blooms.

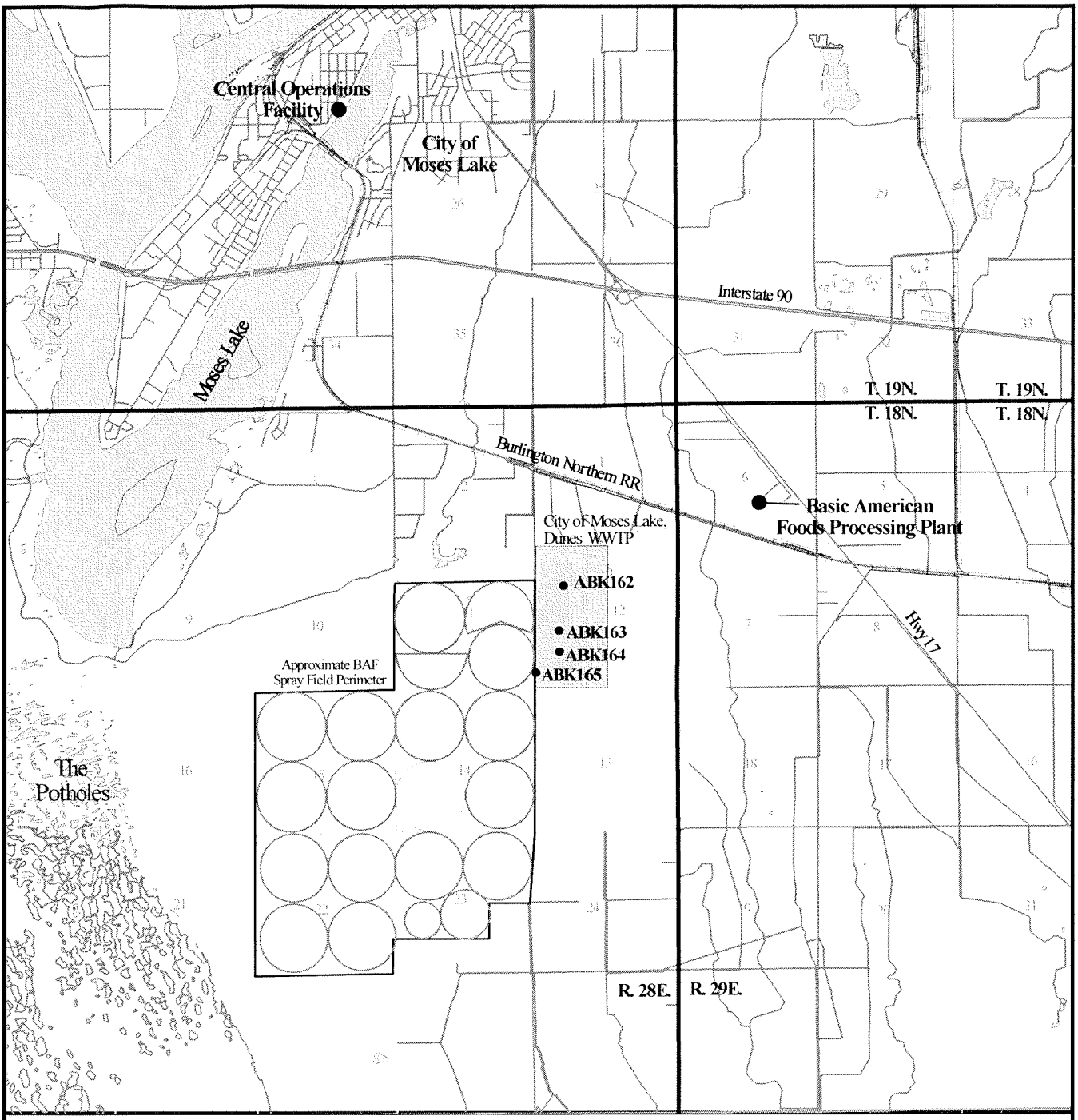
The sewage collection system for Moses Lake consists of gravity sewers and pump stations that convey wastewater to the Central Operations Facility located at the old treatment plant adjacent to Moses Lake. At the Central Operations Facility, wastewater is screened, degritted, and then pumped through approximately five miles of pressurized force main to the Dunes WWTP southeast of Moses Lake (Figure 1).

Wastewater treatment at the Dunes facility includes aeration lagoons, settling basins, coarse rock filters, and eight two-acre rapid-infiltration basins (Figure 2). Treated effluent is routed to one infiltration basin at a time.

The Dunes WWTP is regulated under State Waste Discharge Permit Number ST-8012 which restricts land disposal of wastewater to an annual average of 2.5 million gallons per day (mgd). The plant wastewater contains appreciable biochemical oxygen demand (BOD_5), ammonia, phosphorous, and chloride (Table 1).

Groundwater Monitoring Network

Moses Lake installed five wells in 1983-1984 to monitor groundwater quality and water levels at the Dunes WWTP (Figure 1 and Table 2). Well ABK162 (MW-1) is upgradient of the WWTP and represents background water quality conditions. The other operable wells, ABK163, ABK164, and ABK165 (MW-2, MW-3, and MW-5 respectively), are completed within or down-gradient of the treatment plant. Well MW-4 has been dry since construction.



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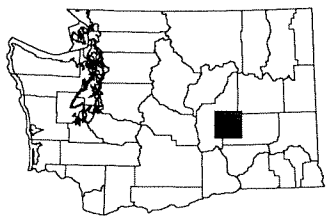

- Moses Lake Well Site
- Township Boundary
- Section Boundary
- Rail Lines
- Lakes and Ponds
- Major Roads
- Rivers and Irrigation Ditches

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Figure 1
City of Moses Lake, Dunes
Wastewater Treatment Plant

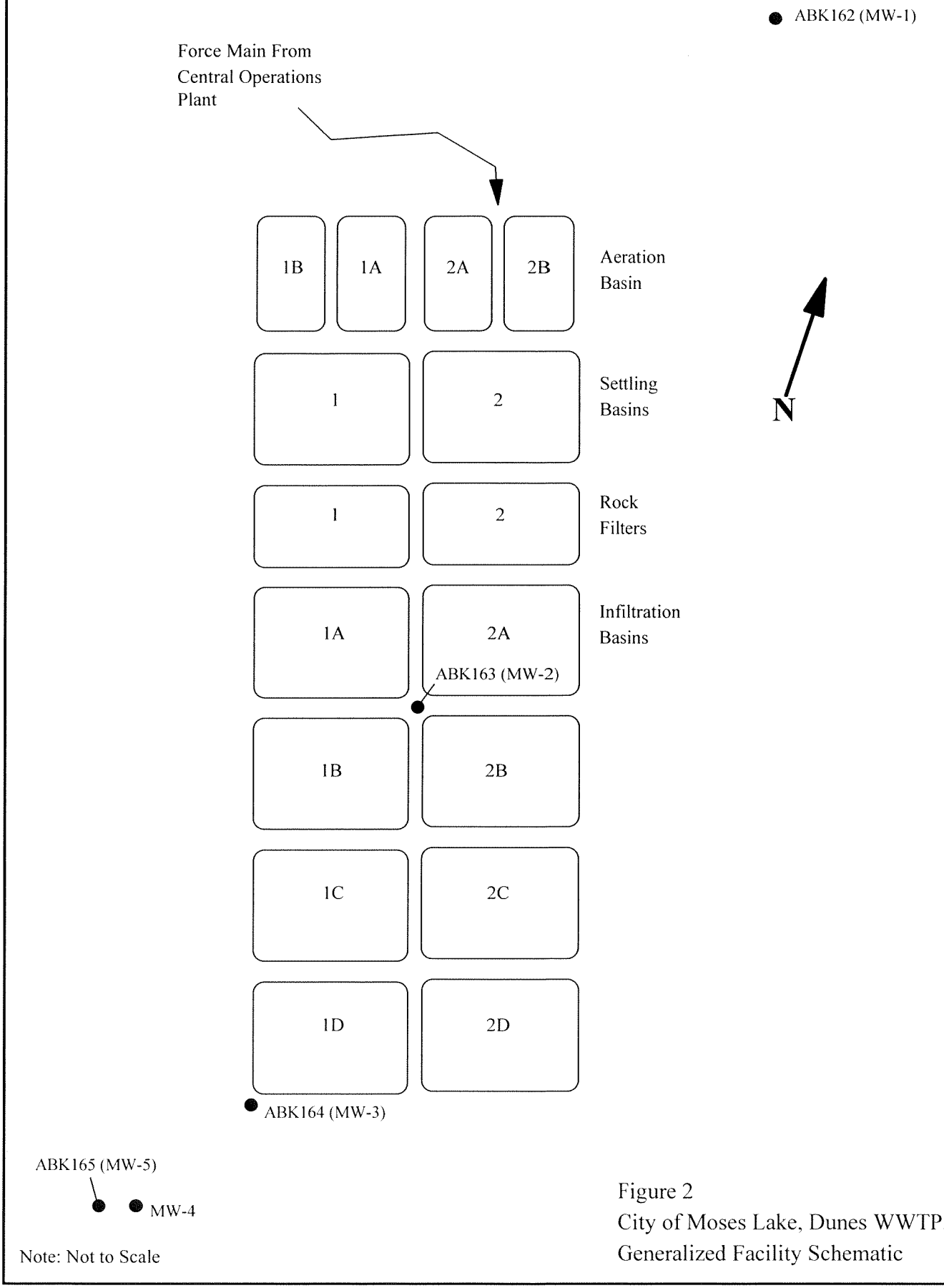


Figure 2
City of Moses Lake, Dunes WWTP,
Generalized Facility Schematic

Table 1. Average effluent concentration by parameter for Moses Lake Dunes WWTP for March 1, 1993 to March 1, 1996 (Ecology, 1997a).

Parameter	Average Value
BOD average, 5-day (20 C°) *	36 mg/L
BOD maximum, 5-day (20 C°)	47 mg/L
BOD average, 5-day (20 C°) *	548 lbs/day
BOD maximum, 5-day (20 C°)	725 lbs/day
Total Suspended Solids, average *	12 mg/L
Total Suspended Solids, maximum	17 mg/L
Total Suspended Solids, average *	188 lbs/day
Total Suspended Solids, maximum	266 lbs/day
Ammonia as N	12.03 mg/L
Nitrate as N	1.41 mg/L
Nitrite as N	0.25 mg/L
Ortho-Phosphate as P	3.18 mg/L
Chloride	92.8 mg/L

* Average of mean monthly values.

Table 2. Moses Lake Dunes WWTP monitoring well construction details.

Unique Well ID Tag No.	Facility Well No.	Land Surface Elevation (Feet above mean sea level)	Casing Height Above Land Surface (Feet)	Casing Diameter (Inches)	Grout Interval (Feet)	Screen Interval (Feet) Below Land Surface	Filter Pack Interval (Feet Below Land Surface)	Cased Well Depth (Feet)
ABK162	MW-1	1155.38	1.5	2	0-26.5	33-38	26.5-38.5	38.5
ABK163	MW-2	1150.74	1.7	2	0-18	23-28	18-28	29
ABK164	MW-3	1151.40	2.2	2	0-21	27-33	21-33	33
Not tagged	MW-4	1155.78	1.9	2	0-23.6	29-33.5	24.5-33.5	34
ABK165	MW-5	1155.13	2	2	0-39	41-46	39-46	46

Site Conditions

Hydrogeology

The Dunes WWTP lies within the interior of the Columbia River Plateau, an area that formed through repeated extrusions of flood basalt during the Tertiary period. The basalts and interbedded sediments were subsequently folded and warped into a broad structural basin/subbasin complex. During the Pleistocene epoch, glaciofluvial deposits of gravel, sand, silt, clay, and wind-borne deposits of sand and silt accumulated on the basalt. These deposits were later reworked and scoured during catastrophic outburst floods of the late Pleistocene epoch. Eolian deposits of sand and silt continue to accumulate within the basin (Bretz, 1959; Walters and Grolier, 1960).

Within the treatment plant area, this complex assortment of bedrock and sediments can be grouped into three hydrogeologic units: 1) *Columbia River basalts*, 2) *Ringold Formation*, and 3) *Glaciofluvial sand and gravel* (Cascade Earth Sciences, 1996).

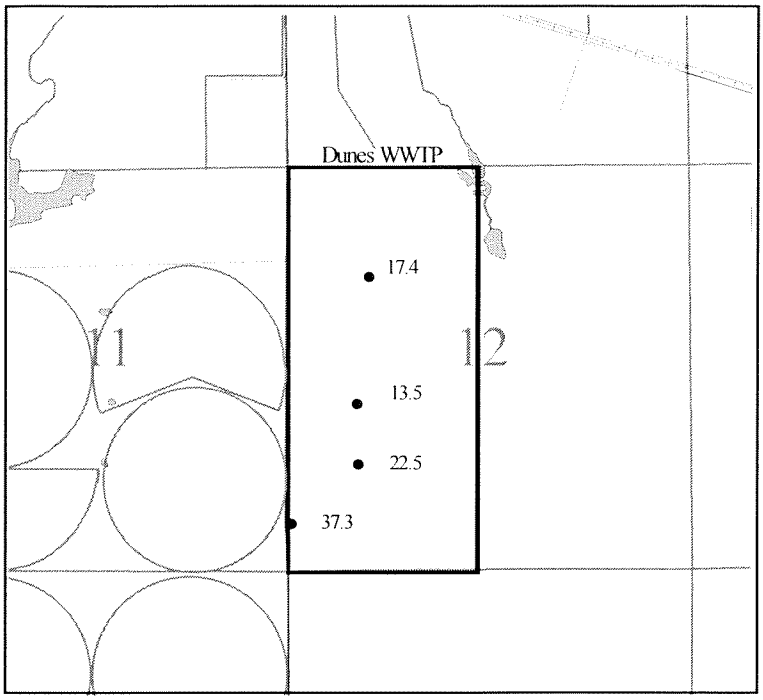
1. The *Columbia River Basalt group*, which comprises area bedrock, underlies the plant site at depth. This unit was not encountered during construction of the Moses Lake monitoring wells which range from 29 to 46 feet in depth. However, Columbia River Basalts were encountered at depths of 15 to 90 feet below ground surface to the west of the Dunes WWTP, underlying spray fields owned or managed by the Basic American Foods vegetable processing facility (Figure 1).

   The Columbia River Basalts consist of numerous layered lava flows ranging from a few feet to more than 100 feet thick. The lava is typically a dense, dark, fine-grained basalt that often exhibits prominent vertical jointing. The upper surface of individual flows is commonly porous and vesicular. Sedimentary interbeds of tuffaceous material, volcanic ash, sand, and clay separate individual basalt flows in some areas (Walters and Grolier, 1960).

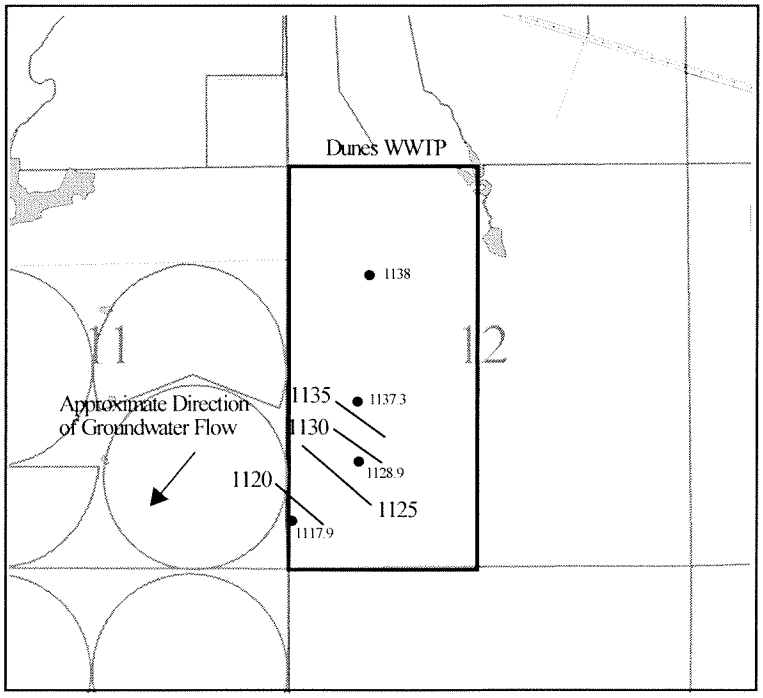
2. The *Ringold Formation* directly overlies the Columbia River Basalts in the vicinity of the Dunes plant. This unit is comprised of Pleistocene age deposits of fine sand, silt, clay, volcanic ash, and caliche. Locally, this formation may impede the downward movement of groundwater owing to its abundance of fine-grained sediments (Cascade Earth Sciences, 1996).

3. Where present, the Ringold Formation is overlain by permeable fine-to-coarse grained *glaciofluvial sand and gravel* and wind-blown dune sand. This is the uppermost unit at the Dunes site.

Based on water levels measured during this inspection, groundwater is approximately 15 to 40 feet below ground surface within the Dunes WWTP area. Depth to groundwater is generally shallowest in the northeastern portion of the site and increases toward the south and west (Figure 3). During this inspection groundwater beneath the WWTP was moving generally toward the south/southwest (Figure 3).



Depth to Groundwater (Ft below ground surface)



Water Table Elevation Contours (Ft above mean sea level)

2000 0 2000 Feet

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Figure 3
Depth to Groundwater and
Water Table Elevation Contours
for April 29, 1998

Soils

The Dunes WWTP is underlain by soils belonging to the Burbank and Quincy series. Burbank soils are characterized as very deep, excessively drained soils that formed on terraces from gravelly glacial outwash and eolian sand. These soils consist of variously colored fine sand and gravelly sand extending to depths of 60 inches or more. Below a depth of 36 inches, the gravel may be weakly cemented, but does not prevent root penetration (Nelson, 1997).

Quincy soils are also very deep and somewhat excessively drained. They are found on terraces and active dunes and formed in sand derived from mixed sources (Gentry, 1984). The Quincy and Burbank soils are highly permeable, generate little runoff, and have low available water capacity (Gentry, 1984).

Inspection Methods

Adequacy of the Moses Lake Monitoring Well Network

In evaluating the Moses Lake monitoring network, we considered the following factors which are summarized from Ecology's implementation guidance for the groundwater quality standards (Kimsey, 1996).

- Is the monitoring network capable of defining the background or up-gradient groundwater conditions over time? "Background" refers to groundwater conditions unaffected by WWTP waste disposal practices.

- Does the monitoring network adequately characterize the horizontal/vertical direction of groundwater movement and depth to groundwater over time?

- Are the individual wells properly placed and constructed to enable early detection of possible groundwater problems associated with WWTP waste disposal practices?

- Are individual wells constructed in a manner that precludes the inadvertent cross-contamination of aquifers or distinct groundwater zones penetrated during well construction?

- Are background and down-gradient wells screened over the same saturated zone? Is the screened zone appropriate for the site conditions and contaminants of interest?

- Are any of the wells down-gradient from other facilities or activities that are known or suspected to have affected groundwater conditions?

- Is the WWTP sampling methodology appropriate for the constituents of concern? Are the appropriate constituents being evaluated?

Groundwater Sampling Procedures

I observed Moses Lakes sampling procedures, as described below, during the collection of split samples.

1. Depth to groundwater was measured once with an electronic well probe just prior to purging the well. The Moses Lake well probe is graduated in one-foot increments. Measured water levels that fell between the one-foot gradations were estimated by Moses Lake sampling personnel based on "experience". Given the lack of rigor in performing the measurements, the water levels reported by Moses Lake should only be considered accurate to about 0.3 of a foot.

2. Each well was purged prior to sample collection using the wells dedicated piston pump. Approximately three casing volumes of water were purged before collecting samples for analysis. The purge rate and volume were measured using a one-gallon container and a wrist watch. The average purge rate for the four wells sampled was approximately one gallon per minute.

3. Split samples were collected by alternately filling Ecology and Moses Lake sample bottles. Ecology sample bottles were supplied by the Ecology/EPA Manchester Environmental Laboratory.

4. Ecology samples were labeled and stored on ice until delivery to the Manchester Environmental Laboratory for analysis. Samples were transported to the laboratory by the Ecology sampling team and the Manchester Laboratory courier service. Chain of custody procedures were maintained for all Ecology samples.

Analysis of Moses Lake sample splits for pH, TDS, and conductivity were performed on-site by WWTP staff. The remaining analyses were conducted by Cascade Analytical, an off-site laboratory.

Table 3 is a listing of target parameters, test methods, and quantitation limits for the Ecology samples.

Quality Assurance

The quality assurance methods and criteria employed during this inspection are discussed in Appendix A. With the exception of the total coliform bacteria results, the Ecology water quality data may be used without qualification. Ecology duplicate sample results for total coliform bacteria were 1 and 16 per 100 mL. This difference (177%) exceeds the maximum allowable 10% difference for sample pairs.

Table 3. Permit required parameters, test methods, practical quantitation limits and groundwater quality standards.

Parameter	Test Method	Quantitation Limit [A]	Groundwater Quality Std. [B]
General and Physical Chemistry			
*pH (Lab)	EPA150.1	0.1 std units	6.5-8.5 standard units
*Specific Conductance (Lab)	EPA120.1	1 µmhos/cm at 25 °C	---
*Total Dissolved Solids	EPA160.1	1 mg/L	500 mg/L
*Alkalinity, Carbonate	EPA310.2	10 mg/L	---
*Alkalinity, Bicarbonate	EPA310.2	1 mg/L	---
*Nitrate-Nitrite	EPA353.2	0.01 mg/L	10 mg/L (NO3 only)
*Ammonia	EPA350.1	0.01 mg/L	---
*Total Kjeldahl Nitrogen	EPA351.2M	0.5 mg/L	---
*Total Phosphorous	EPA365.3M	0.01 mg/L	---
*Chloride	EPA300.0	0.1 mg/L	250 mg/L
*Sulfate	EPA300.0	0.5 mg/L	250 mg/L
*Fluoride	EPA300.0	0.05 mg/L	4 mg/L
*Fecal Coliform, MF	SM16-909C	1/100 ml	---
*Total Coliform, MF	SM16-909B	1/100ml	1/100 ml
Total Metals			
Aluminum	EPA200.7	0.020 mg/L	---
Antimony	EPA200.7	0.030 mg/L	---
*Arsenic	EPA200.7	0.030 mg/L	0.05 mg/L
Barium	EPA200.7	0.001 mg/L	1.0 mg/L
Beryllium	EPA200.7	0.001 mg/L	---
*Cadmium	EPA200.7	0.004 mg/L	0.01 mg/L
*Calcium	EPA200.7	0.025 mg/L	---
*Chromium	EPA200.7	0.005 mg/L	0.05 mg/L
Cobalt	EPA200.7	0.005 mg/L	---
*Copper	EPA200.7	0.003 mg/L	1.0 mg/L
*Iron	EPA200.7	0.020 mg/L	0.30 mg/L
*Lead	EPA200.7	0.020 mg/L	0.05 mg/L
*Magnesium	EPA200.7	0.025 mg/L	---
*Manganese	EPA200.7	0.002 mg/L	0.05 mg/L
*Mercury	EPA200.7	0.00005 mg/L	0.002 mg/L
Molybdenum	EPA200.7	0.005 mg/L	---
Nickel	EPA200.7	0.010 mg/L	---
*Potassium	EPA200.7	0.40 mg/L	---
Selenium	EPA200.7	0.040 mg/L	0.01 mg/L
*Silver	EPA200.7	0.003 mg/L	0.05 mg/L
*Sodium	EPA200.7	0.025 mg/L	---
Strontium	EPA200.7	0.001 mg/L	---
Thallium	EPA200.7	0.050 mg/L	---
Titanium	EPA200.7	0.005 mg/L	---
Vanidium	EPA200.7	0.005 mg/L	---
*Zinc	EPA200.7	0.004 mg/L	5 mg/L

* Parameter specified for groundwater monitoring in Moses Lake, Dunes permit

A Ecology, 1994

B Washington State groundwater quality standard per Chapter 173-200 WAC

Results and Discussion

Results for the four primary elements of this inspection are described below.

1. Adequacy of the Moses Lake Groundwater Monitoring Network

The groundwater monitoring network at the Dunes WWTP does not reliably differentiate the effects on groundwater of the WWTP wastewater disposal from the effects of wastewater applied to down-gradient fields managed by the Basic American Foods (BAF) vegetable processing facility (Figure 1).

For example, TDS concentrations in BAF wells near the WWTP are generally higher than those in down-gradient BAF wells that are more distant from the WWTP (Sinclair, 1998). This implies that groundwater with high TDS is entering the BAF sprayfield from the WWTP. To enable better differentiation between the BAF and WWTP waste streams, Moses Lake should install at least three additional wells. Two wells are needed along the western property boundary north of well MW-5 and west of wells MW-2 and MW-3. An additional well should be installed east of well MW-5 along the southern WWTP boundary.

With the exception of well MW-4, Moses Lake monitoring wells are properly constructed and screened to detect constituents of interest. Due to its shallow depth, well MW-4 has been dry since construction and should be abandoned.

2. Moses Lake Groundwater Sampling Procedures

Many of Moses Lake groundwater sampling procedures are not consistent with accepted sampling protocols as described by Barcelona et al., 1985, and Kimsey, 1996. The following deficiencies were noted during this inspection.

Groundwater Level Measurement

Moses Lake's practice of estimating groundwater levels when measured water levels fall between the one-foot gradations of their well probe is not acceptable. This method is neither accurate nor reproducible between samplers and is inconsistent with the monitoring requirements of the WWTP discharge permit. Water level measurements should be taken using a well probe in combination with an engineers tape graduated in hundredths of a foot. Accurate and reproducible measurements are necessary for proper interpretation of long-term water level trends and groundwater gradients.

The well probe was not decontaminated between wells. The probe should be rinsed with de-ionized water before and after each measurement to help prevent cross contamination of wells.

Groundwater Sampling

Moses Lake presently purges three casing volumes of water from a well prior to collecting a sample. A more reliable and accepted procedure for determining when to sample is to monitor field parameters (temperature, pH, conductivity, and dissolved oxygen concentration) during well purging (Barcelona et al., 1985). Collecting samples only after field parameters have stabilized provides greater assurance that the samples are representative of groundwater in the formation. The preferred means of measuring these parameters is to use an above-ground flow-through cell, although grab-samples are also acceptable. Field parameters are considered stable when the measured variation between successive casing volumes is less than 5 percent for the above parameters (Kimsey, 1996).

Greater care should be taken during purging to ensure a minimum of sample disturbance – particularly when sampling for metals. This can be accomplished by using the low flow purge and sampling techniques of Plus and Powell (1992). Low purge rates (less than one liter per minute) minimize mixing within the well and allow water from the formation to move into the well, while overlying stagnant zones remain relatively undisturbed (Kimsey, 1996).

Moses Lake should develop a formal groundwater sampling and analysis plan which incorporates the monitoring and sampling procedures described in the implementation guidance for Washington groundwater quality standards (Kimsey, 1996).

3. Ecology and Moses Lake Split Sample Results

The water quality results for Ecology and Moses Lake split samples are summarized in Appendix C and Table 4. With few exceptions the variations between Ecology and Moses Lake analytical determinations were small. Only three sample splits – one each for total Kjeldahl nitrogen (TKN), total phosphorous, and total coliform – exceeded the 10 percent criterion for relative percent differences (RPD) between sample pairs.

4. Moses Lake Compliance with Permit Limits

The permit for the Dunes WWTP does not prescribe limitations for parameters other than discharge volume and maximum annual average loads for BOD_5 (7,785 lbs/day) and TSS (5,967 lbs/day). Monitoring data for March 1995 to March 1996 indicate that Moses Lake discharged an annual average of 1.78 mgd to the rapid infiltration basins at the Dunes WWTP (Ecology, 1997a). At the time of this inspection, Moses Lake was discharging approximately 2.0 mgd (Golding, 1999). This is below the maximum permitted discharge volume of 2.5 mgd.

The Moses Lake permit and associated documents call for development of a plan to upgrade the Dunes WWTP to AKART (all known, available, and reasonable treatment) standards. Once approved, the new facility plan will define a preferred treatment alternative and water quality-based enforcement limits that can be incorporated into subsequent permits (Ecology, 1997b).

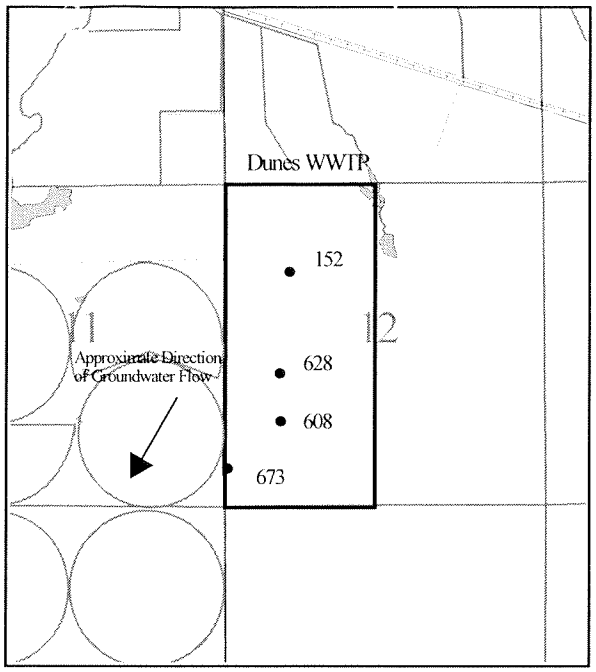
Table 4. Summary of relative percent differences between Ecology and Moses Lake split samples.

Conventional Parameters (mg/L)	Number of Duplicate Analyses	Approximate Range in RPD (%)	Number of Split Samples Exceeding 10% RPD	Mean RPD (%)	Median RPD (%)
Specific Conductance (µmhos/cm @ 25 C)	4	0.5-3.25	0	2.35	3.05
PH (standard units)	4	0.4-2.1	0	0.95	0.65
Ammonia as N	2*	5.4-7.7	0	6.55	----
Nitrate-Nitrite as N	2*	0.4-0.8	0	0.6	----
Total Kjeldahl Nitrogen as N	2*	7.8-24.9	1	16.35	----
Phosphorus, total as P	3*	1.8-52.9	1	20.0	5.3
Total Dissolved Solids	4	---	---	---	----
Fecal Coliform (#/100 mL)	0*	---	---	---	----
Total Coliform (#/100 mL)	1*	166.2	1	---	----

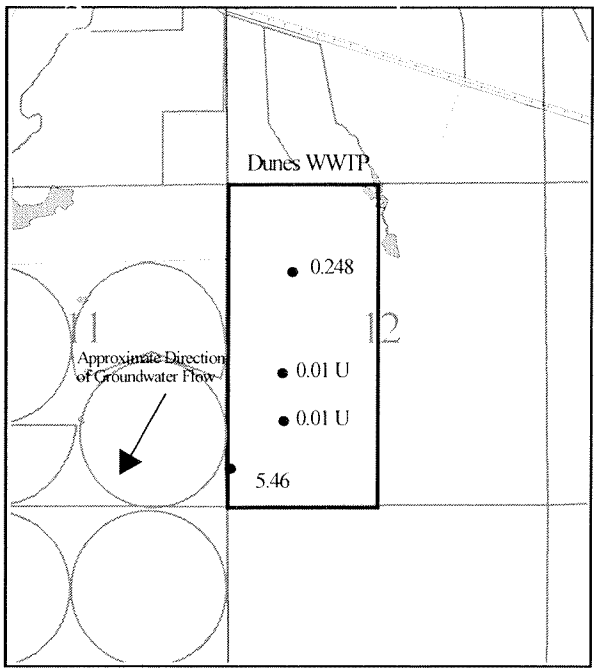
* Relative percent differences were not calculated when one or both laboratories failed to identify an analyte at concentrations that exceeded their respective method detection limit. The number of duplicate analyses refers only to those samples where both splits yielded a value in excess of the method detection limit.

In the interim, Moses Lake is obligated under Chapter 173-200 WAC to manage its wastewater in a manner that protects existing and future beneficial uses of groundwater. Comparison of the sample results from this inspection to Moses Lakes discharge monitoring reports (DMRs) indicates that the results obtained during this inspection are comparable to past results reported to Ecology. Several constituents are elevated in down-gradient wells relative to background conditions measured in up-gradient well ABK162 (MW-1) (Figures 4a and 4b). This pattern is consistent with previous findings and indicates that WWTP operations have degraded groundwater quality (Ecology 1997a). Three of four wells sampled exceeded the groundwater quality standard for total dissolved solids (500 mg/L). Two wells exceed the standard for iron and manganese. Other elevated constituents such as nitrate+nitrite, ammonia, TKN, chloride, sulfate, fluoride, and sodium did not exceed groundwater standards (Figures 4a and 4b).

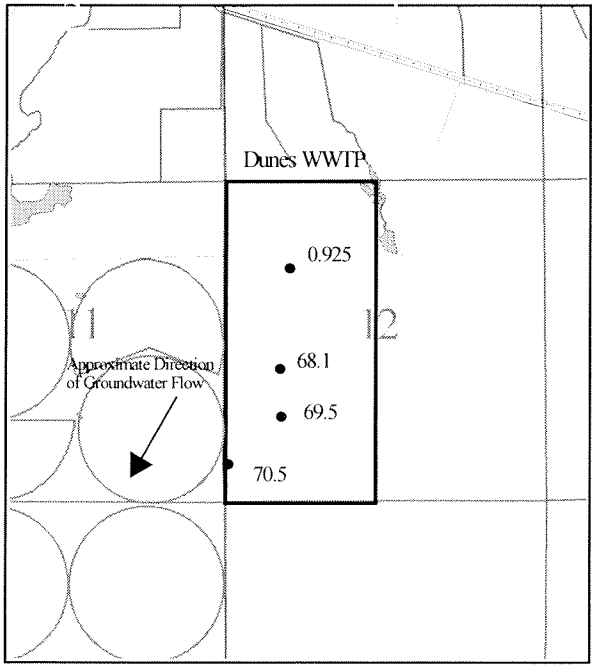
Groundwater metals analyses were all less than the groundwater quality standards, although several parameters including barium, calcium, cobalt, magnesium, potassium, sodium, and strontium were elevated, relative to up-gradient well ABK162, in one or more of the down-gradient monitoring wells.



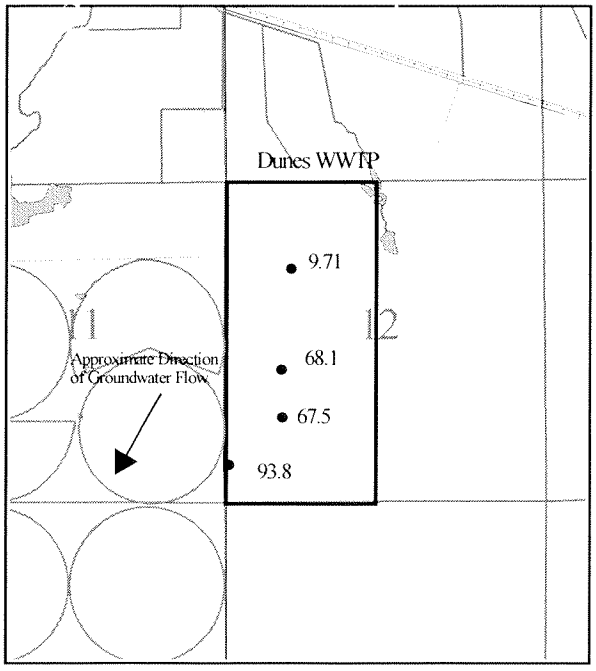
Total Dissolved Solids (mg/L)



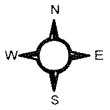
Nitrate + Nitrite as N (mg/L)



Chloride (mg/L)

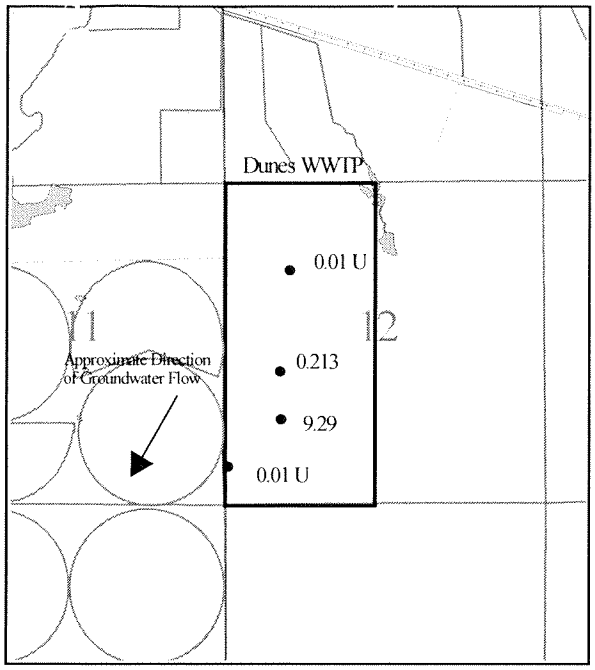


Sulfate (mg/L)

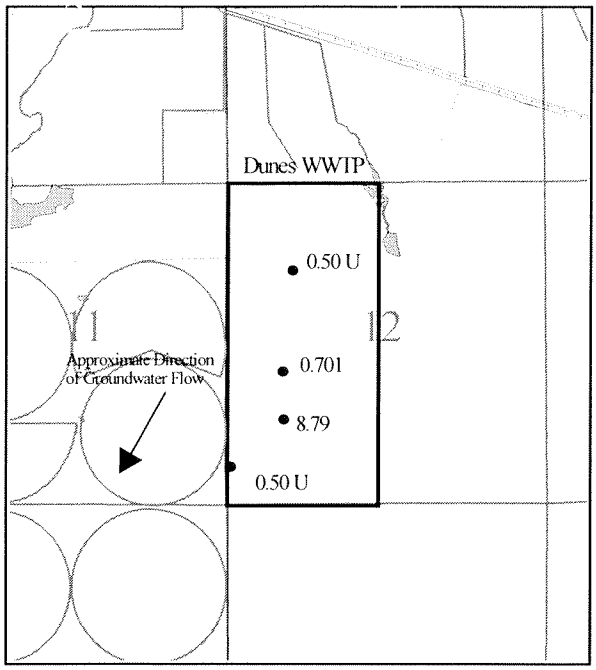


U - The analyte was not detected at or above the reported value.

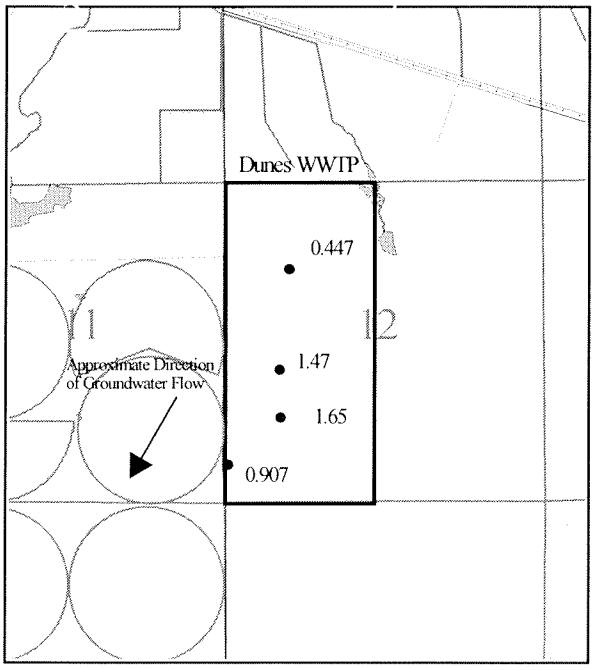
Figure 4a
Selected Water Quality Results by Parameter and Well



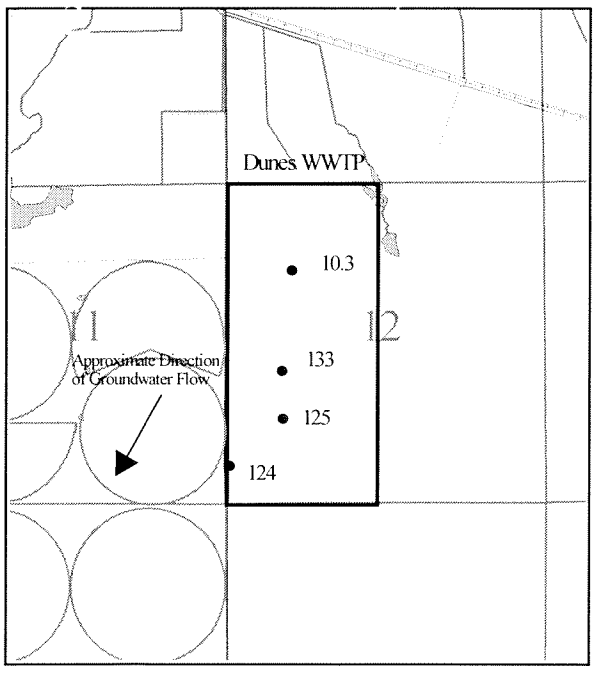
Ammonia (mg/L)



Total Kjeldahl Nitrogen (mg/L)



Fluoride (mg/L)



Sodium (mg/L)

2000 0 2000 Feet

N
W E
S

U - The analyte was not detected at or above the reported value.

Figure 4b
Selected Water Quality Results by Parameter and Well

Conclusions

- The monitoring well network at the Moses Lake Dunes WWTP does not adequately characterize groundwater gradients or WWTP impacts to groundwater. The monitoring network could benefit from the installation of additional down-gradient and cross-gradient wells to help refine our understanding of groundwater gradients, groundwater flow directions, and water quality conditions beneath the facility.

- With the exception of well MW-4, Moses Lake wells are properly constructed and screened to detect contaminants of concern. Well MW-4 is screened above the water table and has been dry since construction. It should be properly abandoned.

- Moses Lakes groundwater sampling procedures are not consistent with current industry protocols, nor they do not meet the monitoring requirements of Ecology implementation guidance for the groundwater quality standards as specified in sections S2b and S2c of the WWTP discharge permit. A formal sampling and analysis plan should be developed to implement the requirements specified in the discharge permit.

- At the time of the inspection, Moses Lake was complying with discharge limits for annual and monthly discharge volume.

- Wastewater disposal at the WWTP has degraded water quality to the extent that groundwater fails to meet secondary drinking water standards for TDS, manganese, and iron. Increases in other constituents including nitrate, ammonia, TKN, sodium, fluoride, chloride, and sulfate are apparent in groundwater beneath the WWTP.

- Differences between Ecology and Moses Lake split sample results were small and within acceptable limits. While significant differences between Ecology and Moses Lake analyses for total phosphorous, TKN, and total coliform were identified, there does not appear to be a consistent pattern or obvious cause for the discrepancies.

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Appendix A. Sampling Procedures and Quality Assurance for Ecology Samples

We followed standard quality control procedures during the collection, transport, and analysis of Ecology split samples as specified in Barcelona et al. (1985). Samples were collected in pre-cleaned bottles supplied by the Manchester Environmental Laboratory (MEL). Samples for ammonia as N, nitrate + nitrite as N, and TKN were collected in pre-acidified bottles. Samples for metals analysis were acidified in the field with ultra-pure concentrated nitric acid. Filled sample bottles were labeled and stored on ice prior to being delivered to the laboratory. Chain of custody procedures were followed throughout sample collection and handling (Ecology, 1994). All samples arrived at the laboratory in good condition and were analyzed within established holding times.

Internal quality control checks performed by laboratory staff included verification standards for instrument calibration, procedural blanks, laboratory control samples, and spiked/duplicate samples. All internal laboratory quality control procedures were within acceptable limits.

Field quality control checks consisted of a metals transfer blank and blind duplicate samples collected from well ABK164 (MW-3). The duplicate samples were collected at the same time and submitted to the laboratory under different sample numbers. The metals transfer blank was prepared using reagent grade water supplied by the MEL. The reagent grade water was poured from the laboratory-supplied container into an empty metals container at the sampling site, and then acidified in the same manner as other metals samples.

The data quality for this project met all established quality-control/quality-assurance criteria. The following comments were included in the laboratory data submittal:

- Sodium was found in the metals transfer blank at a concentration of 0.110 mg/L. The sodium level in samples are greater than 10 times that of the blank, so the data may be used without qualification.

- Zinc was found in the metals transfer blank at a concentration of 0.012 mg/L. All samples, with the exception of the field duplicate sample for well ABK164 (MW-3), had zinc concentrations less than the practical quantitation limit for the analytical method. The field duplicate sample for well ABK164 had a zinc concentration of 0.0046 mg/L. This value is not significantly higher than the method detection limit of 0.004 mg/L. No other constituents were detected in the transfer blank.

Laboratory and field duplicate analyses were compared by determining the relative percent difference (RPD) between sample pairs. RPD is the numeric difference between sample pairs divided by their mean, expressed as a percentage. The RPD values for duplicate samples were less than 10% for all samples, with the exception of one field duplicate for total coliform bacteria (176 %) (Table A-2).

Appendix A-1. Laboratory Duplicate Analyses and Relative Percent Difference (RPD) for Ecology Samples

Analyte	ABK162 (Well MW-1) 04/29/1998	Laboratory Duplicate	RPD	ABK163 (Well MW-2) 04/29/1998	Laboratory Duplicate	RPD
Laboratory Analyses						
pH (standard units)	---	---	---	7.6	7.6	0
Specific Conductance (µmhos/cm @ 25 °C)	---	---	---	---	---	---
Conventionals (mg/L)						
Total Dissolved Solids	---	---	---	628	637	1.4
Carbonate Alkalinity	10 U	10 U	---	---	---	---
Bicarbonate Alkalinity	85.1	85.0	0.1	---	---	---
Nitrate+Nitrite as N	0.248	0.240	3.3	---	---	---
Ammonia as N	0.010 U	0.010 U	---	---	---	---
Total Kjeldahl Nitrogen as N	0.50 U	0.50 U	---	---	---	---
Phosphorous, total as P	0.030	0.033	9.5	---	---	---
Chloride	0.925	0.948	2.4	---	---	---
Sulfate	9.71	9.74	0.3	---	---	---
Fluoride	0.447	0.466	4.2	---	---	---
Total Coliform (#/100 mL)	---	---	---	---	---	---

Analyte	ABK164 (Well MW-3) 04/29/1998	Laboratory Duplicate	RPD	ABK165 (Well MW-5) 04/29/1998	Laboratory Duplicate	RPD
Laboratory Analyses						
pH (standard units)	---	---	---	---	---	---
Specific Conductance (µmhos/cm @ 25 °C)	999	999	0A	---	---	---
Conventionals (mg/L)						
Total Dissolved Solids	615	612	0.49A	673	665	1.2
Carbonate Alkalinity	---	---	---	---	---	---
Bicarbonate Alkalinity	---	---	---	---	---	---
Nitrate+Nitrite as N	---	---	---	---	---	---
Ammonia as N	---	---	---	---	---	---
Total Kjeldahl Nitrogen as N	---	---	---	---	---	---
Phosphorous, total as P	---	---	---	---	---	---
Chloride	69.5	69.4	0.14	---	---	---
Sulfate	67.5	68.1	0.88	---	---	---
Fluoride	---	---	---	---	---	---
Total Coliform (#/100 mL)	1	2 U	---A	---	---	---

U - Analyte was not detected at or above the reported value.
A - Laboratory duplicate analysis was conducted on the field duplicate sample for well ABK164.
RPD - Relative percent difference between Ecology duplicate sample results (in percent).

Appendix A-2. Field Duplicate Analyses and Relative Percent Difference (RPD) for Ecology Samples

Analyte	ABK164 (Well MW-3) 04/29/1998	(Well MW-3) Field Duplicate	RPD
Laboratory Analyses			
pH (standard units)	7.5	7.5	0
Specific Conductance (µmhos/cm @ 25 °C)	998	999	0.1
Conventionals (mg/L)			
Total Dissolved Solids	608	615	1.1
Carbonate Alkalinity	10 U	10 U	---
Bicarbonate Alkalinity	378	379	0.3
Nitrate+Nitrite as N	0.01 U	0.01 U	---
Ammonia as N	9.29	8.97	3.5
Total Kjeldahl Nitrogen as N	8.79	8.67	1.4
Phosphorous, total as P	2.15	2.07	3.8
Chloride	69.5	68.8	1.0
Sulfate	67.5	66.8	1.0
Fluoride	1.65	1.636	0.9
Fecal Coliform (#/100 mL)	1 U	2	---
Total Coliform (#/100 mL)	16	1	177
Total Metals (mg/L)			
Aluminum	0.020 U	0.020 U	---
Antimony	0.030 U	0.030 U	---
Arsenic	0.030 U	0.030 U	---
Barium	0.114	0.113	8.8
Beryllium	0.001 U	0.001 U	---
Cadmium	0.004 U	0.004 U	---
Calcium	56.6	56.1	0.9
Chromium	0.005 U	0.005 U	---
Cobalt	0.011	0.010	9.5
Copper	0.003 U	0.003 U	---
Iron	1.62	1.58	2.5
Lead	0.020 U	0.020 U	---
Magnesium	17.6	17.5	0.6
Manganese	2.4	2.4	0
Mercury	0.00005 U	0.00005 U	---
Molybdenum	0.005 U	0.005 U	---
Nickel	0.010 U	0.010 U	---
Potassium	15.3	15.1	1.3
Selenium	0.040 U	0.040 U	---
Silver	0.003 U	0.003 U	---
Sodium	125	124	0.8
Strontium	0.241	0.238	1.3
Thallium	0.050 U	0.050 U	---
Titanium	0.005 U	0.005 U	---
Vanidium	0.005 U	0.005 U	---
Zinc	0.004 U	0.0046	---

U – Analyte was not detected at or above the reported value.
RPD - Relative percent difference between Ecology duplicate sample results (in percent).

Appendix B. Groundwater Level Measurements

Unique Well ID Tag No.	Facility Well No.	Measurement Date	Measurement Time	Water Level Below Measuring Point (Feet)	WL Altitude (Feet Above Mean Sea Level)
ABK 162	MW-1	04/29/1998	09:07	18.9	1138
ABK 163	MW-2	04/29/1998	09:52	15.2	1137.3
ABK 164	MW-3	04/29/1998	10:16	24.7	1128.9
ABK 165	MW-5	04/29/1998	11:09	39.3	1117.9

Appendix C. Ecology and Moses Lake Split Sample Water Quality Results

Analyte	ABK162(Well MW-1) 04/29/1998	Moses Lake	RPD	ABK163 (Well MW-2) 04/29/1998	Moses Lake	RPD
Field Measurements						
pH (standard units)	---	---	---	---	---	---
Temperature (°C)	---	---	---	---	---	---
Specific Conductance*	---	---	---	---	---	---
Laboratory Analyses						
pH (standard units)	7.9	8.07	2.1	7.6	7.55	0.7
Specific Conductance*	185	186	0.5	975	1005	3.0
Conventionals (mg/L)						
Total Dissolved Solids	152	124	20.3	628	602	4.2
Carbonate Alkalinity	10U	---	---	10 U	---	---
Bicarbonate Alkalinity	85.1	---	---	379	---	---
Nitrate+Nitrite as N	0.248	0.25	0.8	0.01 U	0.07 U	---
Ammonia as N	0.01 U	0.07 U	---	0.213	0.23	7.7
Total Kjeldahl Nitrogen as N	0.5 U	0.4	---	0.701	0.9	24.9
Phosphorous, total as P	0.03	0.07 U	---	1.14	1.12	1.8
Chloride	0.925	---	---	68.1	---	---
Sulfate	9.71	---	---	68.1	---	---
Fluoride	0.447	---	---	1.47	---	---
Fecal Coliform (#/100 mL)	1 U	0	---	1 U	0	---
Total Coliform (#/100 mL)	1 U	1.1 U	---	39	3.6	166.2
Total Metals (mg/L)						
Aluminum	0.020 U	---	---	0.020 U	---	---
Antimony	0.030 U	---	---	0.030 U	---	---
Arsenic	0.030 U	---	---	0.030 U	---	---
Barium	0.041	---	---	0.119	---	---
Beryllium	0.001 U	---	---	0.001 U	---	---
Cadmium	0.004 U	---	---	0.004 U	---	---
Calcium	13.4	---	---	60.4	---	---
Chromium	0.005 U	---	---	0.005 U	---	---
Cobalt	0.005 U	---	---	0.0074	---	---
Copper	0.003 U	---	---	0.003 U	---	---
Iron	0.020 U	---	---	0.876	---	---
Lead	0.020 U	---	---	0.020 U	---	---
Magnesium	9.04	---	---	17.5	---	---
Manganese	0.002 U	---	---	1.03	---	---
Mercury	0.00005 U	---	---	0.00005 U	---	---
Molybdenum	0.005 U	---	---	0.0059	---	---
Nickel	0.010 U	---	---	0.010 U	---	---
Potassium	2.6	---	---	14.3	---	---
Selenium	0.040 U	---	---	0.040 U	---	---
Silver	0.003 U	---	---	0.003 U	---	---
Sodium	10.3	---	---	133	---	---
Strontium	0.153	---	---	0.327	---	---
Thallium	0.050 U	---	---	0.050 U	---	---
Titanium	0.005 U	---	---	0.005 U	---	---
Vanidium	0.058	---	---	0.005 U	---	---
Zinc	0.004 U	---	---	0.004 U	---	---

* – µmhos/cm @ 25 °C U – Analyte was not detected at or above the reported value.
RPD – Relative percent difference between Ecology and Moses Lake sample split results (in percent).

Appendix C (cont'd).

Analyte	ABK164(Well MW-3) 04/29/1998	Moses Lake	RPD	ABK165(Well MW-5) 04/29/1998	Moses Lake	RPD
Field Measurements						
pH (standard units)	---	---	---	---	---	---
Temperature (°C)	---	---	---	---	---	---
Specific Conductance*	---	---	---	---	---	---
Laboratory Analyses						
pH (standard units)	7.5	7.47	0.4	7.9	7.95	0.6
Specific Conductance*	998	1031	3.25	1010	1042	3.1
Conventionals (mg/L)						
Total Dissolved Solids	608	587	3.5	673	649	3.6
Carbonate Alkalinity	10 U	---	---	10 U	---	---
Bicarbonate Alkalinity	378	---	---	341	---	---
Nitrate+Nitrite as N	0.01 U	0.07 U	---	5.46	5.44	0.4
Ammonia as N	9.29	8.8	5.4	0.01 U	0.07 U	---
Total Kjeldahl Nitrogen as N	8.79	9.5		7.8	0.5 U	1.0
Phosphorous, total as P	2.15	2.04	5.3	0.172	0.10	52.9
Chloride	69.5	---	---	70.5	---	---
Sulfate	67.5	---	---	93.8	---	---
Fluoride	1.65	---	---	0.907	---	---
Fecal Coliform (#/100 mL)	1 U	0	---	1 U	0	---
Total Coliform (#/100 mL)	16	1.1 U	---	1 U	1.1 U	---
Total Metals (mg/L)						
Aluminum	0.020 U	---	---	0.021	---	---
Antimony	0.030 U	---	---	0.030 U	---	---
Arsenic	0.030 U	---	---	0.030 U	---	---
Barium	0.114	---	---	0.119	---	---
Beryllium	0.001 U	---	---	0.001 U	---	---
Cadmium	0.004 U	---	---	0.004 U	---	---
Calcium	56.6	---	---	60.5	---	---
Chromium	0.005 U	---	---	0.005 U	---	---
Cobalt	0.011	---	---	0.005 U	---	---
Copper	0.003 U	---	---	0.0039	---	---
Iron	1.62	---	---	0.020 U	---	---
Lead	0.020 U	---	---	0.020 U	---	---
Magnesium	17.6	---	---	28.8	---	---
Manganese	2.4	---	---	0.002 U	---	---
Mercury	0.00005 U	---	---	0.00005 U	---	---
Molybdenum	0.005 U	---	---	0.0055	---	---
Nickel	0.010 U	---	---	0.010 U	---	---
Potassium	15.3	---	---	7.83	---	---
Selenium	0.040 U	---	---	0.040 U	---	---
Silver	0.003 U	---	---	0.003 U	---	---
Sodium	125	---	---	124	---	---
Strontium	0.241	---	---	0.52	---	---
Thallium	0.050 U	---	---	0.050 U	---	---
Titanium	0.005 U	---	---	0.005 U	---	---
Vanidium	0.005 U	---	---	0.046	---	---
Zinc	0.004 U	---	---	0.004	---	---

* - µmhos/cm @ 25 °C U - Analyte was not detected at or above the reported value.
RPD - Relative percent difference between Ecology and Moses Lake sample split results (in percent).