Appendix E

North Bend Gravel Operation Water and Environmental Health Technical Report

NORTH BEND GRAVEL OPERATION
WATER AND ENVIRONMENTAL HEALTH
TECHNICAL REPORT

For

KING COUNTY
URS JOB NO: 53-42279001.00
December 12, 2001

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1.0 INTRODUCTION

This technical report addresses the potential impacts on water and environmental health from the proposed development of gravel extraction and processing operations in North Bend, Washington (Figure 1). The report assesses potential impacts on surface water at the site and surrounding area, as well as groundwater beneath the site. Impacts potentially associated with the application of soil amendments during reclamation of the site are also assessed. Impacts are qualitatively assessed for four project alternatives.

1.1 ALTERNATIVES

Development of a gravel extraction and processing operation has been proposed on land east of North Bend, in unincorporated King County. The four alternatives defined for the land are the basis for the analyses presented in this technical report. They are as follows:

- Alternative 1 – No Action.
- Alternative 2 – Proposal: Lower and Upper Sites Mining – Exit 34; involves development of two separate areas of land, referred to as the Lower Site and the Upper Site, for gravel extraction and processing. Operations would include the excavation, washing, crushing, sorting, and stockpiling of sand and gravel. Construction of concrete and asphalt batch plants at the Lower Site is planned in later stages of site development. Extraction would initially occur in the Lower Site, with material hauled from the site via Exit 34. Material from the Upper Site would be moved to the Lower Site using a 36- to 42-inch-wide conveyor.
- Alternative 2A – Upper Site Mining and Limited Lower Site Mining. Cadman, Inc. has included this option to decrease the footprint of the Lower Site's gravel operations to keep the operations at least one-quarter mile from the nearest residence. The amount of gravel to be removed will be reduced accordingly.
- Alternative 3 – Lower and Upper Sites Mining - Exits 34 and Exit 38. Gravel extracted from the Lower Site would be transported from the site via Exit 34. After extraction has been completed at the Lower Site, the Upper Site would be developed, with material hauled out via Exit 38 and SE Grouse Ridge Road. Aggregate processing would take place on the Upper Site. The concrete and asphalt batch plants would be located at the Lower Site. This alternative does not include a conveyor line between the Lower and Upper Sites.
- Alternative 3A – Upper Site Mining and Limited Lower Site Mining – Exits 34 and 38. Cadman, Inc. has included this option to decrease the footprint of the Lower Site's gravel operations to keep the operations at least one-quarter mile from the nearest residence. The amount of gravel to be removed will be reduced accordingly.
- Alternative 4 – Upper Site Mining - Exit 38. Under this alternative, the Lower Site would not be developed. Extraction and aggregate processing would occur at the Upper Site, with processed materials hauled out via SE Grouse Ridge Road. Onsite concrete and asphalt batch plants are not included in this alternative.

1.2 STUDY AREA

The gravel mining operation is proposed on land east of North Bend, Washington, in unincorporated King County. The land is owned by Weyerhaeuser Company and leased to Cadman, Inc. Two separate sites are proposed for development. The Lower Site is north of I-90 and east of 468th Avenue SE. The Lower Site is about 115 acres. The Upper Site is north of I-90 on the Grouse Ridge plateau and is about 578 acres. The sites are approximately 1 mile apart. The Upper Site is approximately 900 feet higher than the Lower Site. The sites are between the Middle and South Forks of the Snoqualmie River (Figure 1). The Lower Site lies over the eastern edge of a regional aquifer that extends to the west and north beneath the Snoqualmie Valley.

The study area for the water and environmental health assessment includes the two leased sites (approximately 700 acres) and the conveyor line connecting the sites, as well as areas within approximately a 1-mile radius of the site (Figure 2). Areas beyond the site boundary were included so that the surface water and groundwater assessments could be performed in the context of a more regional understanding and potential impacts on regional resources, such as rivers and aquifers, could be evaluated. The water and environmental health impacts discussed within this technical report are limited to that study area.

1.3 METHODOLOGY

The methodology used to evaluate impacts on water and environmental health by the proposed development and its alternatives is derived from the Washington State Environmental Policy Act Rules, WAC Chapter 197-22. The primary sources of information used to establish the affected environment and to assess potential impacts included the following:

- Information provided by the applicant, Cadman Inc., and its consultant Hart Crowser in technical reports and memoranda, and during discussions.
- Available literature regarding the surface water and groundwater resources of the site vicinity.
- Available literature regarding impacts on surface water and groundwater resources at other gravel mining operations.
- Environmental Impact Statements for other gravel mining operations in western Washington.
- Discussions with key agency personnel.
- Data from one monitoring well installed at the Lower Site by Dames & Moore.
- Data from 9 monitoring wells installed at the Upper Site by Dames & Moore.
- Field reconnaissance and measurements.

2.0 AFFECTED ENVIRONMENT

This section describes the existing condition of the surface water and groundwater resources of the study area and the Lower and Upper Sites. Based on the existing conditions, a generalized water balance for each site is presented.

2.1 SURFACE WATER

2.1.1 Regional Surface Water

2.1.1.1 Drainage Basins

The Lower and Upper Sites lie within the drainage basins of the Middle and South Forks of the Snoqualmie River. The Lower Site is entirely within the drainage basin of the South Fork. The Upper Site is on the drainage divide between the two basins, with drainages on the north side flowing into the Middle Fork, and drainages on the south side flowing into the South Fork.

The Middle Fork of the Snoqualmie River has a drainage area of 154 square miles above the U.S. Geological Survey (USGS) gauging station number 12141300, which is approximately 3 miles northeast of the Lower Site (Figure 1). The Middle Fork drains an estimated additional 14 square miles between this gauging station and the Lower Site, for a total drainage area above the site of approximately 168 square miles.

The South Fork of the Snoqualmie River has a drainage area of approximately 42 square miles above the USGS gauging station number 12143400, which is approximately 4 miles east of the Upper Site (Figure 1). The South Fork drains an estimated additional 24 square miles between this gauging station and the Lower Site, for a total drainage area above the site of approximately 56 square miles.

The confluence of the two forks, approximately 5 miles northwest of the Lower Site, forms the Snoqualmie River. The Snoqualmie River is tributary to the Snohomish River, which drains into Puget Sound.

2.1.1.2 Climate

The closest regularly monitored National Oceanic and Atmospheric Administration (NOAA) precipitation data station to the site is at Cedar Lake (Station #451233), approximately 4 miles south/southwest of the Lower Site. The period of record for this measurement station is 1931 to present. Average temperatures for the period of record at the station range from a minimum of 30 degrees in January to a maximum of 72 degrees in July and August. The record low temperature for this period was –11 degrees in January 1935, and the record maximum was 101 degrees in September 1988. Over this period, the annual precipitation ranged from approximately 52 to 138 inches. The average annual precipitation at this location is approximately 101 inches over the period of record, with a standard deviation of approximately 18 inches. Monthly precipitation data for this station from January 1995 through March 2001 are summarized in Table 1. Over this period, precipitation ranged from approximately 80 inches in 2000 to 114 inches in 1997 with an average of 103 inches per year, which is slightly more than the average annual precipitation. Precipitation distribution is typical for the Puget Sound region, with the majority of precipitation (typically as rainfall), occurring between October and March. Snowfall has been recorded at the station during the months of November through March, with an average of 1 to 4 inches accumulated per month. Based on measurements on Grouse Ridge in 1995, annual precipitation near the site was estimated by Golder (1996) to be approximately 80% of the precipitation measured at Cedar Lake or about 81 inches per year (Table 1).

2.1.1.3 Surface Water Flow

Surface water flow in the Middle and South Forks of the Snoqualmie Rivers results from direct runoff of precipitation, groundwater discharge into rivers, and runoff from snow melt. In the South Fork, the average daily flow at USGS gauging station number 12143400 was approximately 300 cubic feet per second (cfs) between 1960 and 1996 (USGS, 1999). Over the last 5 years, monthly average flow rates have ranged from 26 cfs in September 1998 to 1,160 cfs in November 1995 (Table 2). In the Middle Fork, the average daily flow at USGS Station Number 12141300 was approximately 1,230 cubic feet per second (cfs) between 1960 and 1996 (USGS, 1999). Over the last 5 years, monthly average flow rates have ranged from 135 cfs in September 1998 to 4,534 cfs in November 1995 (Table 2). These flow rates correspond to below-average precipitation in August-September 1998 and above-average precipitation in October-November 1995 (Table 1). Generally, periods of high flow correlate to periods of high runoff due to precipitation in late fall and winter and snow melt in late spring. The periods of low flow that occur in summer and early fall are considered baseflow, which is sustained by late season snowmelt and groundwater discharge.

Minimum stream flow requirements were established by Ecology for the Snohomish/Snoqualmie river basin in 1979. An initial assessment of the basin in 1994 showed that the established flow requirements were not being met. The initial assessment indicated that, at the gauging station at Snoqualmie Falls, minimum instream flows were not being met an average of 114 days per year between 1979 and 1992 (Pacific Groundwater Group, 1995). The variations in stream flow were interpreted to be primarily a feature of climatic variability. A long-term review of stream flows was not completed to determine if instream flows have changed historically. According to the Department of Ecology (J. Jorg, personal communication 2001), the Snohomish/Snoqualmie River basin is not closed to new water rights. However, granting new water rights for additional consumptive use is not likely in the basin due to the existing minimum instream flow restrictions. Mitigation would likely be required as part of any approved water right, such as the transfer or relinquishment of existing water rights, or low-flow or seasonal restrictions.

2.1.1.4 Surface Water Quality and Use

The Snoqualmie River is classified as a Class A water source by Ecology. Class A water quality meets or exceeds the requirements for all or substantially all uses, including water supply; stock watering; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; recreation; and commerce and navigation. Water class is determined by chemical and biological limits such as fecal coliform, pH, turbidity, dissolved oxygen, temperature, and aesthetic qualities.

The Middle and South Forks of the Snoqualmie River are classified as Class AA water sources by Ecology. Class AA water quality "markedly and uniformly" exceeds the requirements for all or substantially all uses, including water supply; stock watering; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; recreation; and commerce and navigation.

Individual sampling locations on the Middle and South Forks of the Snoqualmie River are listed on Ecology's 303(d) list for water body segments that do not meet applicable water quality standards after implementation of technology-based controls. Exceedances of surface water quality criteria per

Ecology's 303(d) list appear to be either infrequent events or of a seasonal nature. Values outside the criterion at sampling points on the Middle and South Forks of the Snoqualmie River include temperature, dissolved oxygen, and pH. The closest periodic surface water quality monitoring to the study area occurs at the Snoqualmie River at Snoqualmie Falls, 6 miles northwest of the Lower Site and downstream of the confluence of the South and Middle Forks of the Snoqualmie River. The station has been operated by Ecology since 1959. Water quality parameters tested for include flow, temperature, conductivity, dissolved oxygen, pH, fecal coliform, suspended solids, total and ammonia nitrogen, total and dissolved phosphorus, turbidity, and nitrate/nitrite. The data show the water to be generally in conformance with Class A requirements, except for exceedances of turbidity, likely the result of stormwater runoff. Turbidity exceedances occur during periods of high flow, typically between October and March. Other reported analytes are within acceptable limits. Table 3 summarizes flow and selected water quality parameters from 1995 to 2001.

2.1.1.5 Usage per Water Rights

Within a 1-mile radius of the Lower and Upper Sites, there are approximately 37 surface water rights. These rights include 24 certificated rights and 13 water rights claims. Groundwater rights records in the site vicinity include 6 certificated rights, 29 water rights claims, plus 3 water rights applications or permits, which are not certificated rights. Ecology water rights printout is included as Appendix A.

Water use volumes in the vicinity of the Upper and Lower sites were estimated based on certificated rights and the number of reported, uncertificated wells. Surface water rights for approximately 1.4 cubic feet per second (628 gallons per minute) have been granted in the project vicinity. Groundwater rights for 982 gallons per minute have been granted in the project vicinity. In addition, there are approximately 31 groundwater wells, mostly listed for domestic usage. Assuming these wells are pumped at the Ecology-allowed maximum for domestic use of 5,000 gallons per day (3.24 gpm), total groundwater use in the Upper and Lower Site vicinity totals 1,092 gpm. These totals do not include water right claims or applications, or non-consumptive rights, such as hydroelectric power generation.

2.1.2 Site Surface Water

2.1.2.1 Lower Site

The Lower Site is in an outwash plain between the Middle and South Forks of the Snoqualmie River, on the west side of Grouse Ridge. The leased property consists of 115 acres and is the site of a previous gravel-mining operation. An intermittent stream that drains on the west slope of Grouse Ridge (Figure 2) flows into the northeast corner of the Lower Site. Based on the topography at the site, surface water flow is south toward the South Fork of the Snoqualmie River. However, the porous nature of the ground surface and reconnaissance observations suggest that most precipitation and stream flow received by the site infiltrates through underlying sands and gravels, rather than leaving the site as surface water runoff. In addition, with construction of I-90, the natural drainage to the south was blocked by the large embankment upon which the highway was constructed. Therefore, there is no significant runoff from the site onto adjacent property.

No other significant surface drainage features were observed during the reconnaissance conducted in February 1999. However, minor ponding of stormwater was observed in low spots, where fine-grained sediments have accumulated. These low spots were observed in the area of the previous gravel-mining operation in the central portion of the site and in the south-central portion of the site adjacent to I-90.

2.1.2.2 Upper Site

The Upper Site is on Grouse Ridge, a flat-top ridge, and encompasses approximately 578 acres. The upper portion of the ridge, which is relatively flat, and much of the northern slope of the ridge have been cleared of timber in recent years and contain a light grass vegetative cover. As with the Lower Site, most of the precipitation falling on the Upper Site infiltrates through permeable sands and gravels. No significant surface drainage features, such as streams or wetlands, were observed during the reconnaissance in February 1999 on the upper and relatively flat portion of the ridge. However, minor ponding of stormwater was observed in low spots, where fine-grained sediments have accumulated. There are no offsite drainage basins that contribute runoff to the Upper Site. Stormwater flows from the upland area to the east are intercepted at the Washington State Patrol Fire Training Academy and directed to a small stream that feeds into the South Fork of the Snoqualmie River.

On the northern and southern flanks of the ridge, small streams originate as springs at elevations of between approximately 1,500 and 1,390 feet above mean sea level (msl). Springs occur where groundwater intercepts the face of the ridge. The springs were identified during reconnaissances conducted by Hart Crowser in September 1998 and March 1999 (Hart Crowser, 1999a), and by Dames & Moore in February and March 1999. Dames & Moore established surface water gauging stations below selected springs in March 2000 to evaluate surface water discharge from the Upper Site.

Hart Crowser identified six springs (S-1 through S-4, S-6, and S-7) on the northern flank of the ridge during its reconnaissance of the site in September 1998 (Figure 3 and Table 4). These springs occur at approximately 1,440 to 1,460 feet above msl, according to survey and altimeter data. The springs were identified during probable low-flow conditions (September), and are assumed to be perennial. Dames & Moore located an additional spring (S-10) in a drainage west of Spring S-1 in February 1999. This spring occurs at an elevation of approximately 1,450 feet above msl, and may be intermittent as it was not previously identified during Hart Crowser's reconnaissance. The springs feed streams that flow north off the ridge and are tributary to the Middle Fork of the Snoqualmie River. The streams fed by Springs S-1 through S-4, S-6, and S-7 are considered Class 4 streams at elevations greater than 1,000 feet above msl. Class 4 streams may be perennial or intermittent, and are not habitat to significant numbers of fish, but are typically tributary to fish-bearing streams. At elevations less than 1,000 feet above msl, the streams are considered Class 3 streams, which have a moderate use to fish, wildlife, and humans. The stream fed by Spring S-10 appears to reinfiltrate into surficial soils at an elevation greater than 1,160 feet above msl. Surface flow was not observed in the drainage below Spring S-10 during March 1999, May 2000, or February 2001. Periodic, intermittent surficial flow may occur in this drainage after storm events or during periods of higher spring flows. This drainage does not regularly contribute to downstream flows by surface discharge and is considered a Class 5 stream.

Hart Crowser identified one spring (S-5) on the southern flank of the ridge during its reconnaissance of the site in September 1998, and a second spring (S-8) and series of seeps (S-9) during its March 1999 geotechnical evaluation of the Homestead Valley gravel mine (Hart Crowser, 1999b). Dames & Moore identified four springs (S-11 through S-14) during the February 2000 reconnaissance of the Upper Site.

The S-5 spring occurs at 1,388 feet above msl. Springs S-8 and S-9 occur at approximately 1,460 to 1,500 feet above msl, according to altimeter and topographic map data. Springs S-11 through S-14 occur at approximately 1,460 to 1,480 feet above msl, according to topographic map data (Table 4). Drainage from springs S-5 and S-8 appear to reinfiltrate into the subsurface are not tributary to surface water drainages. Springs S-11 and S-12 feed streams that flow south off the ridge and are tributary to the South Fork of the Snoqualmie River. At elevations less than 1,000 feet above msl, the stream is considered Class 3. The stream fed by Spring S-9 is considered Class 5 stream and does not appear to regularly contribute surface flow to either tributaries of the South Fork or directly to the South Fork. The streams fed by Springs S-13 and S-14 are considered Class 4 streams and appear to contribute surface flow to the South Fork via culverts along I-90. Photographs of the Springs are included in Appendix G.

URS established nine surface water measuring points (weirs) below selected springs or groups of springs in March 2000 (Table 4). The weirs were generally installed at elevations between 1,430 and 1,470 feet above msl where the streambeds below the springs where accessible and where a single stream channel was present. Streams were not gauged in drainages where they appeared to reinfiltrate (S-5 and S-8) or in areas that were inaccessible at the time of this study (S-9). The majority of the ungauged surface water appears to be on the south side of the Upper Site. Based on URS' field observations during the spring reconnaissance and selection of the gauged springs, and the conditions of weirs during installation and subsequent discharge measurements, it is estimated that the gauging locations account for over 50% of the spring discharge from the upper portion of Grouse Ridge.

Surface water discharge measurements collected during March 2000 totaled between 0.27 and 0.32 cfs flowing from the north side of the Upper Site, and between 0.21 and 0.29 cfs flowing from the south side of the Upper Site (Table 5). These flow rates are likely to be close to peak annual flow, based on historic groundwater level and climate data. Subsequent discharge measurements collected between April 2000 and March 2001 generally decreased, and reflected the general pattern of precipitation during the year.

Discharge measurements were collected at various drainage crossings below the springs and above the Middle Fork in May 2000 and February 2001 to assess whether the stream reaches were gaining or losing, and to assess the relative proportion of spring discharge contribution to the north side drainages. The measurements were collected during dry periods so that precipitation runoff was not a potential factor in measured discharge. Stream flow measured at crossings 1,700 linear feet and 3,000 linear feet downhill of Springs S-1 through S-4, which share a drainage, appeared to remain consistent, and gaining or losing reaches were not identified. A gauging point below Springs S-6 and S-7, which share a drainage, indicated that the stream was gaining 4 to 40 times the discharge measured at the springs in the same period. This increased inflow along this drainage appears to be in part due to surface water that originates in the vicinity of the State Patrol Fire Training Center and Mailbox Peak. Discharge from Spring S-10 reinfiltrated before reaching the first road crossing, approximately 1,000 linear feet below the spring. During the measurement events, discharge off a drainage below the Fire Training Center and Mailbox Peak was measured to be 2½ to 6 times that measured at the north side springs. Based on a discharge measurement collected at a stream crossing below the north side drainage at Lake Dorothy Road, discharge from the Upper Site springs may account for 10 percent of the surface water discharge from the drainage basin on the north side of the ridge.

2.2 GROUNDWATER

The Lower and Upper Sites are within the upper Snoqualmie Basin, a drainage basin covering approximately 375 square miles along the Snoqualmie River above Snoqualmie Falls. A series of groundwater and geologic resource investigations within this basin have been conducted during the 1980s and 1990s in response to the following: (1) Ecology designating portions of the basin, including the Lower Site, part of the East King County Groundwater Management Area; (2) the East King County Regional Water Association's (EKCRWA) evaluation of aquifers within the Snoqualmie Valley for use as a potential a regional water supply; and (3) Weyerhaeuser Company's and Cadman, Inc.'s assessment of the sand and gravel resources of the Lower and Upper Sites. The regional investigations were performed primarily by the U.S. Geological Survey (USGS, 1995) in cooperation with the Seattle-King County Department of Public Health, and by Golder Associates, Inc. (Golder, 1995, 1996, and 1998), on behalf of the EKCRWA. Associated Earth Sciences, Inc. (AESI, 1983), investigated the Upper Site on behalf of Weyerhaeuser, and Cadman, Inc., investigated conditions of the Lower and Upper Sites with the assistance of Hart Crowser (Hart Crowser, 1999a). Dames & Moore completed a supplementary drilling program at the Lower Site in May 1999 and at the Upper Site in January and February 2000. The following summarizes the findings of these regional and site-specific groundwater investigations and the results of recent work completed by Dames & Moore on behalf of King County.

2.2.1 Regional Groundwater

This section describes the regional geohydrologic units and the occurrence and movement of groundwater in the study area. Groundwater quality and usage are also described.

2.2.1.1 Groundwater Occurrence

The hydrogeologic setting of the Upper Snoqualmie Basin is complex because of the glacial, lacustrine, fluvial, and mass wasting origins of the materials deposited in the area. A majority of the glacial materials were deposited in response to continental glaciers originating from Canada that moved south into Puget Sound, and alpine glaciers originating in the Cascade Mountains (Golder, 1998). Glacial materials are underlain by bedrock, and along the existing streams, recent alluvium has cut into and filled the glacial materials. Mass wasting between and after glacial episodes has left areas of complex mixtures of soils and other materials. The alluvium and glacial sediments consist primarily of unconsolidated gravel, sand, silt, and clay. The occurrence of groundwater in materials that can supply wells is predominately in the glacial and fluvial deposits.

The USGS (1995) identified 10 geohydrologic units in the area. These units are listed below from youngest to oldest:

1. Alluvium (Qal)
2. Vashon recessional outwash (Qvr)
3. Vashon till (Qvt)
4. Vashon advance outwash (Qva)
5. Upper fine-grained unit (Q(A)f)
6. Upper coarse-grained unit (Q(A)c)
7. Lower fine-grained unit (Q(B)f)

8. Lower coarse-grained unit (Q(B)c)
9. Deepest unconsolidated and undifferentiated deposits (Q(C))
10. Bedrock (Br)

A summary of "typical" and estimated local thickness, and lithologic and hydrologic characteristics for each of these units is presented in Figure 4. These values are not intended to be site-specific. Based on the number of wells completed within each unit and the lithologic characteristics, the USGS identified the Qal, Qvr, Qva, and Q(A)c as the principal aquifers in the area. Qvt, Q(A)f, and Q(B)f generally act as confining beds, although usable quantities of water may be obtained from the more permeable facies of these units.

In the study area vicinity, Golder (1995) used geophysical methods to assess the depth of bedrock and to estimate the thickness of the alluvial and glacial materials. The estimated thickness of these materials ranged from less than 30 feet along the western edge of Grouse Ridge to more than 1,000 feet along the Middle Fork of the Snoqualmie River (Figure 5). Accumulations of glacial fluvial deposits more than 800 feet thick are also present in the Middle Fork and South Fork (Grouse Ridge) embankments, which rise approximately 1,000 feet above the surrounding valleys. Bedrock outcrops are evident east of the Washington State Patrol Fire Training Academy on the eastern portion of Grouse Ridge, along I-90 near Twin Falls State Park, north of the Middle Fork of the Snoqualmie River, and on the slopes of Grouse Mountain near the northern portion of Grouse Ridge (Figure 5).

Groundwater in the region occurs in a series of interconnected aquifers that are composed of glacial fluvial materials and bedrock. Aquifers in the vicinity are shown in cross-section on Figures 6 and 7. Golder (1998) has divided these aquifers into shallow unconfined aquifers and deep confined to semi-confined aquifers as follows:

SHALLOW UNCONFINED AQUIFERS

Shallow Valley Aquifer – An unconfined aquifer that is located throughout the main portion of the Snoqualmie River Valley from Snoqualmie Falls to the Middle and South Forks of the Snoqualmie River. The aquifer in the site vicinity is up to approximately 100 feet thick and occurs in the Qal near the Middle Fork of the Snoqualmie River and in the Qvr beneath the Sallal Prairie. The aquifer is used primarily for local potable supply (Golder, 1998).

Upland Aquifers – These shallow aquifers occur on uplands that commonly flank the valley floor and, in the site vicinity, include the Middle and South Fork Embankments. The aquifers occur in recessional outwash sand and gravels (Qvr) that were deposited in deltas and also have been referred to as deltaic deposits (Qvd) by Hart Crowser (1999a) and AESI (1983). The embankments are hydraulically linked to the valley aquifer (Golder, 1998).

DEEP CONFINED TO SEMI-CONFINED AQUIFERS

Deep Valley Aquifer – A confined to semi-confined aquifer is located throughout the main portion of the Snoqualmie River Valley from Snoqualmie Falls to the Middle and South Forks of the Snoqualmie River. The aquifer is tapped by City of Snoqualmie wells and may also be tapped by several wells in the Tanner area. In the study area, the aquifer occurs in the upper coarse-grained unit (Q(A)c), below glacial till (Qvt). The aquifer is considered highly productive and has been the focus of the investigations conducted by EKCRWA. This aquifer was encountered in the EKCRWA test well in 1993 (well MF-TW-1) and is approximately 140 feet thick in this location (Figure 6). The Sallal Water District No. 3 well also appears to be screened in the upper portion of this aquifer. According to Golder (1998), the aquifer is not well defined near North Bend, and there is some uncertainty regarding the continuity of deep aquifer throughout the valley. The transmissivity of the aquifer ranges from 5,000 to 46,000 square feet per day (ft^2/day), generally decreasing in permeability in a downstream direction (Golder, 1998).

Bedrock Aquifer – Wells in the upper basin obtain groundwater from bedrock reported as sandstone, shale, and basalt. The transmissivity of the bedrock is reported to range from 500 to 5,000 ft^2/day (Golder, 1998).

RECHARGE

Infiltration of precipitation is the primary source of water to these aquifers. Groundwater recharge in the Upper Snoqualmie Basin is relatively great because of high annual precipitation and coarse-grained surficial materials. Because of the coarse-grained nature of the soils, large areas have little or no surface runoff even after periods of extended precipitation. As described above, average annual rainfall is estimated to be 101 inches per year in the vicinity of Grouse Ridge (Table 1). The USGS (1995) estimates that in areas where annual precipitation exceeds 60 inches per year and the surficial soil is the sands and gravels of either Qvr or Qal that 69% of the precipitation recharges the underlying aquifers. In the site vicinity, this corresponds to 70 inches of recharge per year. In dry or wet years, recharge estimates based on a normal range of precipitation would be between 57 and 82 inches. Similarly, Golder (1996) estimated that recharge to the study area could be approximately 58 inches per year. In addition to recharge from precipitation, streams may recharge the Shallow Valley Aquifer during periods of high flow, producing bank storage.

2.2.1.2 Groundwater Flow

Groundwater within the Shallow and Deep Valley Aquifers is inferred to follow topography and flow from the margins of the valley toward the Middle and South Forks of the Snoqualmie Rivers, and then northwest toward Snoqualmie Falls. Figure 8 presents groundwater elevations for wells screened in the shallow and deep valley aquifers. Groundwater elevations are based on measured elevations in selected wells and estimated elevations based on well logs for other wells (Hart Crowser, 1999a). Although sufficient water-level data are not available to prepare detailed groundwater contour maps or accurately estimate the hydraulic gradient or potential for flow between the aquifers for the site vicinity, the available data support the inferred groundwater-flow pattern. In addition, this interpretation of regional groundwater movement is consistent with the interpretation presented by the USGS (1995).

An Upper Site perched groundwater occurrence is inferred at elevations of about 1,460 to 1,535 feet msl in the Upland Aquifer. These occurrences are characterized by a set of piezometers and are associated with seeps and springs at lower elevations around the perimeter of the ridge.

Groundwater in the study area discharges as seepage to springs and streams, transpiration by plants, groundwater outflow down valley, and withdrawals from wells. In the study area, groundwater discharges from aquifers into the Middle and South Forks of the Snoqualmie River.

In a stream-flow survey conducted on the Middle Fork of the Snoqualmie River in 1995 by the USGS (Golder, 1996), stream flow was measured at five stations between Tanner (approximately 1.5 miles west of the Lower Site) and Granite Creek (approximately 4 miles west-northwest of the Lower Site). Four sets of measurements were collected between July 25 and September 26 during a period when stream flow was less than 400 cfs. The results were variable with certain reaches losing water and others gaining depending on the date of the measurements. In general, changes in flow rate between stations were small relative to the total flow of the river and were within the range of uncertainty associated with these types of measurements.

2.2.1.3 Groundwater Quality and Use

To identify potential groundwater uses in the area surrounding the Lower and Upper Site, water well records and water rights within a 1 mile radius of the sites were obtained from Ecology. The previous work performed by Hart Crowser (1999a) identified some wells that were not in Ecology's records. The wells identified within a 1 mile radius and wells identified by Hart Crowser are shown on Figure 2. A summary of data for these wells and a well location number are included in Table 6. Logs for these wells are included in Appendix B. Thirty-nine wells were identified and include 29 domestic wells, six municipal water supply wells, two industrial wells, one irrigation well, and one test well. Most of the wells appear to be screened in Shallow Valley Aquifer.

The closest well to the Lower Site is the Sallal Water District Well (Sallal Well) No. 3, which is near the northwest corner of the site (Figure 9). This well pumps periodically on a daily basis at approximately 75 gallons per minute, with an annual production of approximately 15 million gallons (Pancoast, 1999). This well is screened below a 25-foot silty zone that appears to separate the Shallow and Deep Valley Aquifers. Recent water quality data for the Sallal Water District (Sallal) Well No. 3 indicate that groundwater quality parameters were either not detected or were well below state and federal criteria for target analyses. The water is of very good quality (Table 7). The wellhead protection area for this well extends onto the Lower Site (Compass Geographics, Inc., 1998) as shown on Figure 9.

The closest well to the Upper Site is the Washington State Patrol Fire Training Academy well (Well 28C on Figure 2) located east and considered upgradient of the Upper Site. Dames & Moore understands that this well was reconfigured in 1998 and currently provides water for use at the Fire Training Academy. The nearest wells considered to be downgradient of the Upper Site are south of the ridge in the Homestead Valley area (wells 29J to 29R on Figure 2).

Several wells are also located north of the ridge near the Middle Fork of the Snoqualmie River. These wells are used for domestic purposes.

A number of wells, such as Valley Camp and B. Olsen (Well 20D) are less than 50 feet deep and screened in aquifer materials that are interpreted to be either thin deposits of Vashon recessional outwash or alluvium (Figure 2). These wells receive recharge from precipitation and surface water infiltration in the vicinity. Deeper wells, such as the Middle Fork Well Association well (20B1) and Roloson (20B2) are up to 400 feet deep and completed in either pre-Vashon undifferentiated deposits or bedrock (Figure 2). The aquifers that the wells are screened in receive recharge from groundwater sources farther up the Middle Fork Valley and/or the deep aquifer beneath the Upper site. Groundwater flow in the Middle Fork Valley is expected to be parallel to the river, in a westerly direction.

In addition to the existing groundwater use, Ecology is currently considering a joint water right application filed by EKCRWA and the Seattle Water Department (now Seattle Public Utilities) on January 19, 1994, to withdraw 60 million gallons per day (MGD) (41,600 gallons per minute) from the Upper Snoqualmie Basin. If the water right were granted, the water would be used to meet the projected water needs for eastern King County. Currently, there is a large backlog of water rights application to water rights decisions in Washington State (Ecology, 2001). In 1998 (the last reported year), 1128 water rights applications were received, and 189 decisions were made by Ecology. A long, possibly multi-year, waiting period between the application and granting or rejection of a water right application can be expected.

2.2.2 Site Groundwater

This section summarizes and interprets the occurrence and movement of groundwater beneath the Lower and Upper Sites based on the data collected at the sites. Cadman, Inc., collected data regarding the occurrence of groundwater at the Lower and Upper Sites during the drilling of a series of borings in September 1995 and January 1998 (Hart Crowser, 1999a). Five of these borings were completed as monitoring wells: three at the Lower Site (GR95-R, GR98-1, and GR98-4) and two at the Upper Site (GR95-2 and GR95-4). In addition, one boring was completed at the Upper Site in 1983 by AESI (AESI, 1983) on behalf of Weyerhaeuser. URS understands that the primary purpose of these borings was to evaluate the sand and gravel resources beneath Grouse Ridge, rather than to evaluate the presence and occurrence of groundwater. Documentation regarding the methods and procedures used to sample and log the borings was not available. However, these borings were included in the subsurface analysis for their stratigraphic information and for the limited groundwater information they provided. To supplement the information provided by Cadman, Inc., URS installed one monitoring well on the Lower Site and 9 borings at the Upper Site to further assess the depth to groundwater and the groundwater flow direction. Boring and monitoring well locations are shown on Figure 10. Logs for these borings and wells and available survey data are included in Appendix C. Summary tables for borings and wells, and geotechnical data are included as Tables 8, 9 and 10. The methods and procedures used by URS to install the monitoring wells are included in Appendix D.

2.2.2.1 Lower Site

GROUNDWATER OCCURRENCE

The presence of groundwater beneath the Lower Site was evaluated by reviewing boring logs and water-level data for the monitoring wells and borings installed at the site and wells installed in the site vicinity. In 1995 and 1998, Cadman, Inc., completed six borings at the Lower Site. Three of these borings (GR95-12, GR98-1, and GR98-4) were completed as monitoring wells. Wells GR95-12 and GR98-1 are in the proposed excavation footprint, and well GR98-4 is on the ridge on the eastern portion of the Lower Site

(Figure 10). In addition, URS installed a monitoring well (GR99-1) at the Lower Site in May 1999 to further assess site water levels and subsurface conditions. Well log and water-level information from Sallal Well No. 3 was also reviewed. Water levels for these wells are summarized in Table 11.

Four of the regional geohydrologic units described by the USGS (1995) have been identified beneath the and in near-site borings and through geophysical methods. The four units are recessional outwash (Qvr), till (Qvt), the upper coarse-grained unit (Q(A)c), and bedrock (Qbr).

The shallow recessional material (coarse gravels and sands) and the till (silty sands and gravels) in the central portion of the Lower Site contained wet or saturated intervals in two borings (GR95-12 and GR98-7), but significant quantities of water indicative of an aquifer were not encountered. Groundwater was not encountered in borings GR98-3 and GR98-6. The recessional material at the Lower Site is underlain by a layer of silty material, which may be glacial till or a transitional zone and groundwater was not encountered at this interface. Therefore, the shallow valley aquifer does not appear to be present beneath the central and western portions of the Lower Site.

The lower portion of well GR95-12 was screened through this silty layer (Figure 11) beneath the recessional outwash. Well GR95-12 was initially dry when installed, but shortly following installation it consistently contained a small amount of water. Groundwater that has accumulated in well GR95-12 appears to be perched on or within this layer of silty sand that occurs at an elevation of approximately 593 to 613 feet above msl, at the base of the coarse recessional outwash. The water level in this well does not fluctuate significantly in response to seasonal precipitation patterns (Figure 12). Based on these findings, water levels in well GR95-12 do not appear to be representative of the local water table.

Wells GR98-1 and GR99-1 appear to penetrate the silty material and are interpreted to be completed in the top of the upper coarse-grained unit, referred to as the Deep Valley Aquifer. However, in this area, the Deep Valley Aquifer does not appear to be confined. The water-level elevation in well GR98-1 fluctuates between approximately 612 and 632 feet above msl in response to seasonal precipitation patterns (Figures 12 and 13). Well GR99-1 appears to respond in a similar manner. The period of record for water-level measurements in both wells is relatively short, and greater fluctuations than measured in the period of record may occur seasonally or during long-term climatic variations. Sallal Well No. 3, northeast of the Lower Site, is also assumed to be completed in this zone, and water levels in this well have been measured between 540 to 580 feet above msl, although these water levels may be affected by periodic pumping of the well.

Based on the presence of bedrock outcrops at the northeast corner of the Lower Site, and the shallow depth to bedrock determined by the geophysical survey of the area (Golder, 1995), shallow groundwater flow from the ridge to the east of the Lower Site may be controlled by the slope and elevation of the bedrock surface. Water levels in Well GR98-4 are approximately 100 feet above water levels in wells completed within the lower portion of the Lower Site and appear to represent this influence. Water levels in well GR98-4 fluctuate in response to seasonal precipitation patterns similar to wells GR98-1 and GR99-1 (Figure 12) suggesting that the aquifers monitored by these wells are hydraulically connected. The bedrock surface is assumed to slope steeply to the west, as interpreted from the geophysical survey (Figure 5).

CONCEPTUAL MODEL FOR GROUNDWATER FLOW

Groundwater beneath the Lower Site originates as precipitation that falls on areas upgradient of the site, infiltrates and flows beneath the site, and as precipitation that infiltrates on site. Based on the relationship of an estimated 69% of precipitation contributing to recharge developed by the USGS (1995) and the estimated annual precipitation near the ridge (101 inches), it is estimated that up to 70 inches of precipitation may recharge groundwater beneath the Lower Site annually. This quantity of recharge is consistent with the significant water-level fluctuations (up to 19 feet) that have been measured in wells GR98-1 and GR98-4 (Figure 9). Assuming that this response is due primarily to infiltration rather than lateral flow of groundwater and assuming a 30% porosity for the formation, a 19-foot fluctuation could correspond to up to 63 inches of recharge.

Groundwater at the Lower Site generally flows in a westerly direction, according to analysis of water-level elevations based on measurements from onsite monitoring wells. The water table is steeply sloped (approximately 15%) between well GR98-4, on the ridge on the eastern side of the Lower Site, and wells GR98-1 and GR99-1 (Figure 12). This steep hydraulic gradient is likely a result of the influence of shallow bedrock beneath the ridge. This gradient likely decreases to the west across the Deep Valley Aquifer, and away from the bedrock influence where highly permeable sands and gravels drain the groundwater.

The investigations completed at the site are insufficient to assess the hydrogeologic conditions or extent of the deeper confined or semi-confined aquifer beneath the central and western portions of the Lower Site. As described above, Wells GR98-1 and GR99-1 appear to penetrate the upper surface of this aquifer, but it appears that groundwater is under unconfined conditions. Well GR95-12 and boring GR98-7 encountered a silty zone inferred to overlie the Deep Aquifer in the central and western portion of the Lower site, but did not penetrate the silty zone into the Deep Aquifer. Additional deeper monitoring wells would be required to assess the groundwater flow direction beneath these portions of the site.

Sallal Well No. 3 also appears to penetrate the upper portion of this aquifer. Assuming that well GR98-1 and Sallal Well No. 3 are completed in the same aquifer, the gradient across the site between these two wells would be less than 3%. A test well (MFTW-1) installed approximately 1 mile northwest of the Lower Site by the EKCWA in 1993 was completed in this deeper aquifer, which is at least 140 feet thick at that location (Figure 6). This aquifer could have a hydraulic connection with the shallow valley and bedrock aquifers, and the Middle and South Forks of the Snoqualmie Rivers.

GROUNDWATER QUALITY AND USE

No groundwater production wells have been completed at the Lower Site. Sallal Well No. 3 is located approximately 100 feet northwest of the Lower Site property boundary. The northern portion of the Lower Site is within the wellhead protection area for Sallal Well No. 3 (Compass Geographics, 1998). The location of the wellhead protection area is presented in the Sallal Water Association's Wellhead Protection Plan (Compass Geographics Inc., 1998) and is shown on Figure 9. According to representative for the Sallal Water District (Pancoast, 1999), the Wellhead Protection Plan is considered final. The wellhead protection area assumes that groundwater flows west from Grouse Ridge toward Sallal Well

No. 3. The southern boundary of the wellhead protection area closely corresponds with the northern limits of the proposed gravel operation on the Lower Site. Because the groundwater flow direction in the wellhead protection area has not been confirmed through the installation of monitoring wells, the area should be considered an estimate. Estimated travel times for groundwater from beneath the Lower Site to reach Sallal Well No. 3 range from less than six months near the northwest corner of the site up to about 3 years for groundwater beneath the eastern site boundary (Figure 9).

Groundwater samples from onsite monitoring wells have not been collected and analyzed to assess groundwater quality beneath the Lower Site. Based on results of water sample testing (Table 7) for Sallal Well No. 3, groundwater quality beneath the site is expected to be very good.

2.2.2.2 Upper Site

GROUNDWATER OCCURRENCE

The potential presence of groundwater beneath Grouse Ridge was evaluated by reviewing boring logs and water-level data for the existing monitoring wells (GR95-2 and GR95-3) and borings installed on the ridge and the installation of nine additional monitoring wells during January and February, 2000. To assess the presence of groundwater in areas beneath the ridge where monitoring wells were not installed, boring logs were reviewed. However, the discussion below is based primarily on the observations and measurements collected from the recent drilling program, and water level measurements collected in all Upper Site monitoring wells.

The primary hydrologic unit identified beneath the Upper Site is recessional outwash (Qvr). This occurrence of groundwater within this unit is controlled primarily by the presence of silty layers which form the base of perched aquifers. The presence of groundwater is limited in extent and discontinuous in the upper 100 feet of the sand and gravel beneath the Upper Site (Figures 14, 15 and 16) due to a limited amount of silt. At a depth of approximately 100 to 120 feet (1,500 to 1,550 feet above msl), a zone of silty material was encountered beneath the ridge (Figure 17). This silty material (shallow perching layer) was approximately 5 to 40 feet in thickness, and in some areas it appeared to be interbedded with up to 10 feet of sandy materials. This layer was not encountered in borings and wells completed on the southwest end of the ridge (GR95-11, GR00-1) or locally along the south side of the ridge (GR95-9) (Figure 17). The shallow perching layer supports the first laterally extensive occurrence of perched groundwater beneath the Upper Site. However, groundwater was not observed within or above the shallow perching layer in borings GR00-2 or GR00-4. Where present, the shallow perching layer was underlain by generally sandy material.

A second laterally extensive silty perching layer was encountered at approximately 130 to 160 feet bgs (1,450 to 1,475 feet above msl) (Figure 18). This silty material (deeper perching layer) was approximately 3 to 25 feet in thickness, and was underlain by silty sand to gravelly material (Figures 14, 15 and 16). This layer appeared to be more laterally continuous throughout the ridge, although it was not encountered locally along the north edge of the ridge (GR00-8) (Figure 18). Groundwater was also discontinuously perched on this layer.

The fine-grained materials impede downward groundwater movement and allow perching conditions. Permeability ranges for selected geotechnical samples of these materials were consistent with silts and silty sands (Table 10). Significant perching layers and groundwater were not encountered below approximately 170 feet bgs, to the maximum depth of the borings, 270 feet (1376 feel msl).

Groundwater in these upland aquifers occurs under perched conditions. The perched nature of the groundwater in these wells is exhibited by the general absence of wet or saturated conditions in sandy material encountered below the saturated zone screened by wells GR00-1, GR00-2, GR00-4, GR00-9, and GR00-10. In addition, in many of the borings, wet or saturated zones were underlain by dry or moist zones. Water level data for two monitoring wells (GR95-2, GR95-3) indicated that groundwater occurs beneath the central portion of the ridge on the shallow perching layer throughout the year at elevations ranging from about 1,510 to 1,540 feet above msl (Figure 19 and Table 12). Water levels fluctuate in response to seasonal precipitation patterns. Water in four wells installed in January and February 2000 (GR00-5 through GR00-8) also appears to be perched on this shallow perching layer. Wells GR00-1, GR00-2, GR00-4, GR00-9, and GR00-10 are screened in water-bearing materials above the deeper perching layer. Water level data for these wells are summarized in Table 12 and hydrographs are shown on Figures 19 and 20. Water level contour maps for the perching zone in the Upper Site are shown on Figures 21 and 22.

A test well drilled at the Washington State Patrol Fire Training Academy (28C, Figure 2), to 757 feet bgs encountered groundwater at approximately 60, 164, 391, and 650 feet bgs (Hart Crowser, 2000). Bedrock was encountered at 734 feet bgs or an elevation of approximately 866 feet above msl. The deepest water-bearing zone, between 650 and 734 feet bgs, encountered directly above the bedrock surface and appears to be confined beneath fine-grained undifferentiated pre-Vashon deposits (Figure 6). The water level in this zone is approximately 600 feet bgs. This well was screened in this deep aquifer, and a pump test was performed at 40 gallons per minute for 24 hours. The test produced approximately 8 feet of drawdown in the well.

CONCEPTUAL MODEL FOR GROUNDWATER FLOW

Groundwater beneath the Upper Site originates as precipitation that falls on the ridge and infiltrates through the permeable surficial deposits. Based on the relationship between precipitation and recharge developed by the USGS (1995) and the estimated annual precipitation near the ridge (101 inches), it is estimated that up to 70 inches of precipitation may recharge groundwater beneath the Upper Site annually. This quantity of recharge is consistent with the significant changes in water levels that have been measured in well GR95-2. The water level in this well has fluctuated up to approximately 20 feet annually in response to infiltration of precipitation (Figure 19). Assuming 37% porosity for the formation (based on geotechnical data for sands and silty sands collected during the drilling program), a 20-foot fluctuation could correspond to up to 89 inches of recharge. These recharge estimates (70 to 89 inches per year) are within a reasonable range given annual climatic variability and uncertainties in estimating factors that control recharge.

As the water percolates downward through the sand and gravel in response to gravity, it would accumulate on the lower permeability layers of silt and silty sand. Low permeability layers are limited in extent in the upper 100 feet of the deposits beneath the ridge (Figures 14, 15 and 16). The water that encounters these discontinuous silty layers would perch on these layers either seasonally or throughout the year depending on the recharge rate, and the permeability and extent of the silty layer. Water perched on these silt layers migrates laterally through the sand and gravel overlying the silt, flows to the edge of the layers, and then continues a downward infiltration through the sand and gravel. A limited amount of water also may infiltrate directly through these relatively low permeability silty layers.

The shallow perching layer is present at elevations between 1,500 to 1,540 feet msl (Figures 14, 15, and 16). Below 1,525 feet msl, the gravel content of the deposit generally decreases and the silt and sand content increases (Figures 14, 15, and 16). Wet or saturated zones were identified at this depth interval in most of the borings and six of the monitoring wells are completed above this layer (GR95-2, GR95-3, GR00-5, GR00-6, GR00-7, GR00-8). The layer is continuous through the central portion of the site (Figure 17). Some of the water accumulating at this depth flows laterally to the north side of the ridge and discharges into Spring S-8, which was observed at an elevation of approximately 1,500 feet above msl on the north side of the ridge (Hart Crowser, 1999a). The absence of additional springs at this elevation suggests that the remainder of the water infiltrates vertically down around the perimeter of the discontinuous silty zones or through the silt, not making it to an outcrop on the ridge slope at this elevation.

The deep perching layer, corresponding to increased silt content, was present between approximately 1,460 to 1,475 feet above msl. Wells GR00-1, GR00-2, GR00-4, GR00-9, and GR00-10 are completed above this layer. The layer is continuous throughout the site, except at the west end of the ridge, and appears to have a slight northward slope (Figure 18). The deep perching layer appears to correspond to the elevation of Springs S-1, S-2, S-3, S-4, S-6, S-7, and S-10 on the north side of the ridge and Springs S-9 and S-11 through S-14 on the south side of the ridge. Water perched on this zone appears to flow to the north and southeast, intercept the face of the ridge, and discharge at these spring locations.

The one exception to the apparent presence of groundwater in one or more zones between elevations of about 1,525 and 1,460 feet above msl is boring GR95-11, which is on the western portion of the ridge (Figure 15). The log for this boring identifies one wet interval between about 1,580 and 1,550 feet above msl. Between elevations of about 1,500 and 1,460 feet above msl, the moisture content was reported as moist to dry. This suggests that perched groundwater may not be as extensive beneath the western portion of the ridge. The absence of any observed springs on the west side of the ridge near the proposed gravel operation tends to confirm this finding.

Below the deep perching layer, evidence of groundwater was observed in borings GR00-5, GR00-7 and GR95-10. However, the occurrence of water appears to be discontinuous and no laterally extensive aquifers were encountered between elevations of 1,460 to 1,426 feet above msl. Other evidence of groundwater at greater depth beneath the ridge includes the presence of Spring S-5 at an elevation of 1,388 feet above msl on the south side of the ridge (Figure 3). Groundwater that does not discharge into springs or streams along the flanks of the ridge would continue to infiltrate downward and may recharge an aquifer that exists at depth beneath the ridge, such as the aquifer encountered in the Washington State Patrol Fire Training Academy test well. This aquifer would most likely be underlain by either low permeability deposits such as silt and clay of pre-Vashon deposits or by the bedrock that underlies the ridge and is evident around the western, southern, and eastern margins of Grouse Ridge. Given the apparent bedrock high located along the western edge of Grouse Ridge and the absence of springs on the western portion of the ridge, water from this aquifer would be expected to flow north toward the Middle Fork of the Snoqualmie River and/or south toward the South Fork of the Snoqualmie River. Water that infiltrates to this depth also could recharge the bedrock aquifer.

GROUNDWATER QUALITY AND USE

Groundwater beneath Grouse Ridge is not currently developed. The quality of the groundwater has not been tested; however, given the nature of the geologic deposit, the high rate of recharge, and the limited land use development of the Upper Site, excellent water quality is expected.

2.3 WATER BALANCE

This section describes a generalized water budget for the Lower and Upper Sites, based on the conceptual models described above and the available data regarding groundwater recharge and discharge. The purpose of the water budget is to identify and quantify primary components of the water budget for each site, such as precipitation, evapotranspiration and recharge. Recharge is considered important because it is the component of the water budget that is most likely to be affected by the gravel operation. The water budgets for the Lower and Upper Sites focus only on areas that would be disturbed as part of the gravel operation. Components of the water budgets are summarized in Table 13.

2.3.1 Lower Site

The proposed area of disturbance for the Lower Site covers 43.8 acres or approximately 1,900,000 ft^2. Site reconnaissance has identified one small drainage that enters the Lower Site near the northwest corner of the site. There is no significant runoff from the site because the soil is very permeable and the water can infiltrate readily. In addition, all drainage and runoff from the site generally flows to low points within the former area of gravel mining or to a low point adjacent to the north side of I-90. Therefore, the water budget for the Lower Site can be simply summarized with the following equation:

$$P + RO - ET = R$$

Where:

P = annual precipitation

RO = annual surface water run-on

ET = annual evapotranspiration

R = annual groundwater recharge

Groundwater inflow and outflow are not considered in the water budget because there are no onsite groundwater discharge points or withdrawals, and thus the only change in quantity of groundwater beneath the Lower Site (excluding changes in storage) is due to recharge.

The quantity of precipitation over the Lower Site is estimated based on records for precipitation at Cedar Lake. Mean annual precipitation at Cedar Lake since 1931 is approximately 101.7 inches (Table 1). The historic range of precipitation at the site, based on Cedar Lake measurements, is 62 to 138 inches per year. Based on 1 year of monitoring at Grouse Ridge, Golder estimated that precipitation at Grouse Ridge is about 80% of the precipitation at Cedar Lake (Golder, 1996). Based on this relationship, the annual precipitation at Grouse Ridge would be 81.2 inches. However, reliable long-term precipitation data was not available for the vicinity of the Lower Site, so Cedar Lake precipitation data ranges were used for evaluation of climatic conditions at the Lower Site. Although the ridge would be expected to receive more rainfall than the Lower Site based on elevation alone, this estimate is consistent with the estimated precipitation presented in East King County annual precipitation maps (USGS, 1995). Over the 43.8-acre disturbed area, this corresponds to approximately 368 acre-feet or 16,030,000 cubic feet (ft^3) of water annually. A possible range of annual total recharge, based on historic records (1931 to 2000) is calculated to be 226 to 50 acre-feet per year.

Run-on has been observed near the northeast corner of the Lower Site and is associated with a small creek that drains approximately 32 acres of the northwestern portion of Grouse Ridge. This run-on appears to infiltrate in the area where the fresh water pond would be constructed. The quantity of runoff into this stream was estimated using the King County Runoff Time Series (KCRTS) Model (Appendix F). Based on this analysis, the average annual total volume of run-on is estimated to be about 25 acre-feet or 1,100,000 ft.

Using the USGS (1995) estimate that 69% of the precipitation recharges groundwater when annual precipitation exceeds 60 inches and surficial deposits are permeable, approximately 70 inches per year would infiltrate and recharge groundwater. On an annual basis, this corresponds to approximately 271 acre-feet or 11,800,000 ft^3. This includes recharge due to run-on and infiltration of precipitation. On a continuous flow rate basis, the annual rate of recharge to the aquifer beneath the disturbed portion of the Lower Site is estimated to be a minimum of 0.37 cfs. Review of the range of precipitation over the period of record (1931-2000) indicated that precipitation at the Lower Site could range from 228 to 505 acre-feet per year. Assuming 69% of the precipitation recharges the aquifer, aquifer recharge at the Lower site could range from approximately 170 to 365 acre-feet per year. In years of below average precipitation, recharge may decrease below 69% due to increased evapotranspiration. Conversely, in years with greater than normal precipitation, recharge may exceed 69% due to a decrease in evapotranspiration. These estimates are considered conservative, and actual recharge would likely be higher because the disturbed nature of the central portion of the site probably enhances recharge when compared to a forested area, as interception by vegetation is negligible. This water infiltrates downward through the permeable deposits and recharges the upper and/or lower valley aquifers.

Due to the absence of significant runoff at the Lower Site, the balance of precipitation and run-on (31%) would be considered evapotranspiration. Over the 43.8-acre disturbed area, this corresponds to an average of approximately 122 acre-feet or 5,300,000 ft^3 of water annually. This evapotranspiration estimate is higher than the estimate of 23 inches (84 acre-feet) for the Upper Snoqualmie Valley reported by Golder (1996).

Studies by the USGS (1997) in the Puget Sound Lowland have shown that evapotranspiration in a pasture is about 20 inches per year. Portions of the Lower Site that have been previously mined and are lightly vegetated may be considered similar to pasture. In the same study, the USGS estimated evapotranspiration for a mixed forest, similar to the forest on portions of the Lower Site, to range from about 26 to 28 inches per year. This study was conducted in areas that receive about 50% of the rainfall estimated at the Lower Site. These estimates are not considered directly applicable to the site because, evapotranspiration decreases proportionately with increasing cloud cover (USGS, 1995) and the cloud cover is assumed to be greater in areas with significantly greater annual precipitation. However, given the exposed gravel surface and pasture-like nature of portions of the Lower Site, actual evapotranspiration may be less than estimated. If this is the case, then actual aquifer recharge would be higher than estimated.

2.3.2 Upper Site

The proposed area of disturbance for the Upper Site covers 260 acres or approximately 11,300,000 ft^2. No evidence indicates that there is any significant surface water runoff from the area of the proposed gravel operation, and because the site is on a ridge, there is no potential for run-on. Therefore, the water budget for the disturbed portion of the Upper Site can be simply summarized with the following equation:

$$P - ET = R$$

Where:

P = annual precipitation
ET = annual evapotranspiration
R = annual groundwater recharge

There are no groundwater discharge points or withdrawals within the disturbed area, and thus the only change in quantity of groundwater beneath the Upper Site (excluding changes in storage) is due to recharge. However, spring discharge, which occurs outside of the disturbed area, is discussed below relative to the estimate of aquifer recharge. For the Upper Site, the quantity of recharge is also considered to be equal to the amount of groundwater that leaves the Upper Site. This is a reasonable assumption for the upper 200 feet of deposits beneath the ridge because the only opportunity for offsite groundwater inflow to occur onto the site is in the vicinity of the Washington State Patrol Fire Training Academy. The existing water well in this area is not currently operated (see Section 2.2.1). Groundwater in this area would be expected to migrate laterally out toward the edges of the ridge rather than along the axis of the ridge. Thus, the contribution of groundwater from this area to the upper deposits of the ridge are expected to be negligible.

The quantity of precipitation over the Upper Site was estimated using the same relationship described above for the Lower Site. Over the 260-acre proposed area of disturbance, the estimated annual precipitation of 101 inches corresponds to approximately 2,190 acre-feet or 95,400,000 ft^3 of water.

Using the USGS (1995) estimate that 69% of the precipitation recharges groundwater when annual precipitation exceeds 60 inches and surficial deposits are permeable, approximately 70 inches per year would infiltrate and recharge groundwater. Over the 260-acre disturbed area, this corresponds to approximately 1,512 acre-feet or 65,900,000 ft^3 of water annually. This estimate is considered conservative and actual recharge would probably be higher given that most of the Upper Site has been recently clear-cut and is more similar to a pasture than a forested area. This estimate is also greater than Golder's (1996) estimate of up to 58 inches of recharge per year for the Upper Snoqualmie

Embankments. On a continuous basis, the estimated average rate of recharge to the perched aquifers beneath the disturbed portion of the Upper Site is approximately 2.1 cfs.

Due to the absence of significant runoff at the Upper Site, the balance of precipitation, 31% or 31 inches, would be considered evapotranspiration. Over the 260-acre disturbed area, this corresponds to approximately 678 acre-feet or 29,500,000 ft^3 of water annually. This evapotranspiration estimate is higher than the estimate of 23 inches for the Upper Snoqualmie Valley reported by Golder (1996). As described for the Lower Site, actual evapotranspiration may be lower than estimated given that much of the Upper Site is similar to a pasture where the USGS (1997) estimates evapotranspiration to be about 20 inches per year.

Some of the groundwater that infiltrates downward through the permeable deposits, discharges as springs along the north and south flanks of the ridge between elevations of about 1,500 and 1,390 feet above msl. In March 2000, the average total discharge rate of the measured springs was approximately 0.5 cfs (Table 5). Not all springs were measured and the average annual spring discharge rate is expected to be lower than the rate measured in March. However, based on field observations it is estimated that over 50% of the spring discharge related to the shallow and deep perching layers was measured. These observations were based on weir placement and conditions, as wells as estimated flows of springs which were not accessible for gauging or were not selected as gauging points because their discharges reinfiltrated and did not contribute directly to surface water flow. Therefore, since the estimated average rate of recharge (2.1 cfs) is significantly greater than the measured rate of spring discharge (0.5 cfs), a significant quantity of water appears to infiltrate through and/or around the deep perching layer. Water that infiltrates deeper into the ridge may recharge other perched aquifers and/or deeper aquifers beneath the ridge. Water from these aquifers may discharge into streams along the flanks of the ridge or into the South and/or Middle Fork of the Snoqualmie River.

3.0 ENVIRONMENTAL IMPACTS

The potential environmental impacts of the four alternatives and the two Lower Site options are identified in this section. Operation, construction, and secondary and cumulative impacts are discussed. The potential impacts related to surface water, groundwater, the water supply for the project, and environmental health are evaluated. Specific issues related to water quality are described along with other surface water and groundwater issues. The environmental health impacts focus on the potential use of a biosolids compost product to reclaim the excavations. Following the identification of impacts, appropriate mitigation measures are identified.

3.1 CONSTRUCTION IMPACTS

Construction-related impacts associated with groundwater, water supply, and environmental health were not identified. Construction activities are considered to be either too short in duration to impact groundwater resources, or will be ongoing in relation with the excavation activities, and difficult to discern impacts separate from excavation. Therefore, most impacts are attributed to site operations. Biosolids compost products would not be used during construction and therefore there would be no impacts. Construction-related impacts for surface water are described below for each alternative.

3.1.1 Alternative 1 – No Action

No construction-related impacts are associated with this alternative.

3.1.2 Alternative 2 – Proposal

3.1.2.1 Runoff Volume

The volume of stormwater runoff from the Lower and Upper Site may be impacted during construction of the facility. When the volume of stormwater runoff is altered, impacts on the existing environment can occur. For example, an increase in runoff from the site can cause flooding of the downstream system, which may not have the capacity to accept an increase in flow. Likewise, a decrease in runoff from the site may deprive an environment that depends on this water source to survive.

As the Lower and Upper Sites are developed during construction and the natural ground cover is removed, stormwater falling on the site would run off at a higher rate. In addition, the exposed ground surface would be more susceptible to erosion and sedimentation. During ground preparation, mitigation measures such as hay bales, silt fences, and interceptor ditches would be installed to control sedimentation and erosion related to construction activities.

Construction of site access roads and the conveyor also would increase runoff from these graded areas, as well as erosion and sedimentation. Erosion and sedimentation would be minimized by incorporating stormwater controls such as roadside drainage ditches and bioswales into the road design and construction.

3.1.2.2 Floodplain

Construction activity is not proposed within or near the floodplain. No impacts on the 100-year flood elevation are expected.

3.1.2.3 Surface Water Quality

The greatest potential impact on surface water quality during construction is from sedimentation and erosion, which cause soil particles to become suspended in stormwater that flows over the exposed soil surfaces. During construction this could occur as a result of excavation and grading activities and vehicular traffic entering and leaving the site.

During construction, hay bales, silt fences, and hydroseeding of erosion-prone slopes would be used to minimize potential sediment loading of surface water. Stormwater runoff from access roads and the conveyor alignment would be managed similarly.

Vehicular traffic, including construction equipment, leaving the site could contribute sediment and debris to roadside drainage courses. Measures to address this impact include stabilized construction entrances and washing of vehicles in a wash down area prior to leaving the site.

The native topography and the proposed Drainage Plan would contain all runoff on the Upper and Lower Sites. With proper stormwater management controls and procedures, the impacts of construction activities are considered minimal.

ALTERNATIVE 2A – UPPER SITE MINING AND LIMITED LOWER SITE MINING

Construction impacts for this option would be similar to Alternative 2.

3.1.3 Alternative 3 – Lower and Upper Sites Mining (Exit 34 and Exit 38)

Impact on surface water drainage would be similar to Alternative 2 with site processing located on the Upper Site.

ALTERNATIVE 3A – UPPER SITE MINING AND LIMITED LOWER SITE MINING

Construction impacts for this option would be similar to Alternative 3.

3.1.4 Alternative 4 – Upper Site Mining (Exit 38)

Impacts on surface water drainage would be similar to Alternative 2 with site processing located on the Upper Site.

3.2 OPERATION IMPACTS

The impacts evaluated in this section include surface water, groundwater, and the water supply for the project. Potential sedimentation and erosion impacts on the surface water and groundwater quality are discussed along with other surface water and groundwater issues.

3.2.1 Alternative 1 – No Action

No operation impacts are associated with this alternative.

3.2.2 Alternative 2 – Proposal

3.2.2.1 Surface Water

The Proposal outlines a conceptual drainage plan for the Lower Site. At the Lower Site, stormwater runoff would be conveyed to an infiltration pond via drainage ditches and temporary piping. Water would then infiltrate into the underlying soil. The conceptual layout for the Lower Site shows the infiltration pond located at the west end of the processing facility. Offsite drainage would be controlled through perimeter ditches, which would route stormwater to existing drainage pathways. A 3.8-acre passive freshwater storage pond would be constructed at the Lower Site. Water would be drawn from this pond to replace process water lost during aggregate processing, concrete and asphalt production, and evaporation from process water recycling (settling ponds) storage in the Upper Site. A groundwater well and surface water runoff would provide water to the passive freshwater pond to maintain its water storage capacity.

At the Upper Site, process water from the Lower Site would be collected and stored in a settling pond, where it would be available for reuse in facility operations. Process water would be routed through settling ponds, where fines would settle out. Flocculents may be used, if necessary, to remove sediments from the process water. The conceptual layout shows the settling ponds located at the west end of the mining area. There are no other details for drainage-control facilities at the Upper Site.

RUNOFF VOLUME

As the gravel operation is developed and the natural ground cover is removed, stormwater falling on the site may run off at a higher rate in some locations. These locations include roadways or parking areas around the processing facility and other new impervious surfaces around the facility. Based on the proposed layout, the new impervious areas constitute a small percentage of the total site area and, therefore, the increase in stormwater runoff is expected to be minimal. Most precipitation falling on the site would infiltrate through the porous ground surface and would not become runoff.

At the Lower Site, all stormwater drainage would be contained on site. No direct runoff from the Lower Site into surface water drainages would occur. Approximately 40 acres would be excavated and the operations center would be built on the excavated floor, approximately 50 feet below the existing grade. Drainage from the proposed access roads would be collected in roadside ditches, which would flow to the infiltration pond. The proposed plan does not contribute surface water runoff to downstream watercourses. Drainage from the Lower Site access road would be collected and routed to the Lower Site stormwater facilities. Drainage measures for the access roads would generally consist of roadside ditches and culverts, as required. These facilities must be designed in accordance with the current King County Surface Water Design Manual, and shall be adequately sized to pass the 25-year storm, with the capacity to convey the 100-year event without overtopping.

Cadman, Inc.'s conceptual pond would have a depth of up to 30 feet, a surface area of about 3.8 acres, and a storage capacity of approximately 2 million cubic feet of water (15 million gallons). The pond would be lined to reduce losses to infiltration and serve as the main storage reservoir supplying water to the project. The quantity of surface water intercepted from an upgradient 80-acre basin was calculated by URS using rainfall data from a 10-year period (1987 – 1998) and the closed depression analysis method of the King County Runoff Time Series (KCRTS) Hydrologic Simulation Model. The average annual volume of surface water intercepted was estimated to be 1.1 million cubic feet (8.2 million gallons), or up to 13.5 percent of Cadman, Inc.'s estimated annual use of 61 million gallons of water for gravel processing. The average runoff contribution to the pond would be about 22,500 gallons per day.

The 15 million-gallon passive freshwater pond would act as the project's water supply for fire protection and process water. Process water demands are estimated to be 2.65 million gallons per day, with a loss of approximately 6 percent (167,000 gallons) of this water per day in the processing operations, evaporative losses, and use for dust control. The remainder of the process water is recycled to the pond each day. Replacement water (62 million gallons per year) is obtained from two sources: surface runoff interception (approximately 8.2 million gallons per year) and controlled addition of groundwater from a well.

Cadman, Inc., plans to actively manage the reservoir's water level to provide adequate water reserves and storage capacity to accommodating peak runoff events. Since consumptive use (167,000 gallons per day) is substantially larger than surface water input (22,500 gallons per day), the passive pond's water level would be controlled by groundwater addition from the well. If surface water were accumulating in the pond due to excessive stormwater flow, particularly during the winter, groundwater addition would be reduced or stopped until additional reserves were required. An emergency overflow structure and drainage path would be addressed during the design stage to handle excess stormwater accumulations in the pond during unusually wet years. Should excess water accumulate in the pond, an emergency overflow structure would divert water to the Lower Site's infiltration system.

All excavations on the Upper Site would be contained within a closed depression. No direct runoff from the Upper site into surface water drainages would occur. Stormwater collected in active mining areas would be contained within the active segment and allowed to infiltrate to groundwater. The storm runoff would be managed by direct infiltration to surface soil and diversion of excess runoff to infiltration ponds. Once constructed, these facilities would be maintained for the life of the mine and reclaimed as permanent synthetic riparian zones when mining is complete. Drainage at the slope faces would be controlled through the use of interceptor dikes or swales as necessary. Drainage from the access road for the conveyor alignment would drain back to the Lower Site. Drainage from SE Grouse Ridge Road flows through natural drainage features to streams and eventually to the South Fork of the Snoqualmie River.

Throughout the site, constructed drainage courses would be protected from excessive water velocities by the use of check dams. All disturbed areas would be drained to settling ponds where suspended solids would settle out.

Based on information provided, the Proposal would not effectively increase stormwater runoff contributed to the downstream system. The use of engineered stormwater control structures and implementation of procedures for erosion and sedimentation control are expected to result in minimal impacts during site operations.

SURFACE WATER QUALITY

There are no permanent surface water bodies on the Lower and Upper Sites and there would be no significant offsite stormwater runoff from the disturbed areas during site operations. The greatest potential impact to surface water quality is from sedimentation and erosion, which causes soil particles to become suspended in stormwater that flows over exposed soil surfaces. Other potential impacts include contamination of stormwater runoff by accidental chemical or petroleum product spills. Mining processes that would create leachate or mobilize metals, such as arsenic, are not expected at the site.

The Proposal would control sedimentation and erosion problems in several different ways. The onsite stormwater runoff that does not infiltrate directly into the soil would be collected and conveyed to infiltration ponds. Rock or vegetation-lined ditches and swales would be constructed to reduce sediment loading to the onsite infiltration ponds. Hay bales, silt fences, and hydroseeding of erosion-prone slopes would further minimize potential sediment loading of surface water. Stormwater runoff from the access roads would be managed in the same way.

A detailed stormwater drainage plan would be required for this project, to be prepared in accordance with the King County Surface Water Design Manual (SWDM). This plan must be submitted to King County for approval prior to the start of any construction activity on site. Because the project site would be developed in several phases, a phased drainage plan would be required, which must be approved by the County through the grading permit process.

In addition to the requirements of the drainage plan, the site must also comply with the NPDES permit issued by Ecology. The NPDES permit was recently revised, with the new requirements taking effect in August 1999. The NPDES permit and King County's standards mandate that stormwater control facilities be provided to manage the volume of water resulting from the 10-year, 24-hour storm event. Maintenance of all onsite stormwater facilities must comply with the SWDM, Section IV-4.10 Best Management Practice (BMP) S2.00.

The NPDES permit requires compliance with the Federal Clean Water Act of 1972 and the Water Quality Act of 1987. These regulations stipulate that a Spill Prevention and Emergency Response Plan and a Surface Water Pollution Prevention Plan (SWPPP) are to be prepared for the site. The Spill Control Plan provides procedures for the prevention, containment, control, and cleanup of spills or unplanned discharges of oil and petroleum products and other materials that may pollute waters of the state. The SWPPP provides documentation of the BMPs, location of structures and drainages, personnel training, and inspection procedures for the control of stormwater. An assessment of the SWPPP BMPs is required biannually, with one inspection occurring during the wet season and one during the dry season.

In addition to the measures listed above, surface water discharging to groundwater would be monitored for pH levels in accordance with the National Pollution Discharge Elimination System (NPDES) permit, and no visible oil sheen on any of the infiltration ponds would be allowed.

Another potential contaminant source is from flocculents, which would be used on site to promote settling of particles from the process water, collected in the settling ponds. The proposed product to be used (Nalco 7888) has a measurable toxicity to aquatic animals in its undiluted form. The active ingredients of the flocculent product is aluminum hydroxychloride. Based on other sites, Nalco 7888 is typically diluted into a wash-water stream to a working concentration of 15 parts per million (ppm). Nalco 7888 has a reported 96-hour no observable effect level (NOEL) of 37 mg/liter for rainbow trout, 119 mg/liter for fathead minnow, and 15 mg/liter for *Ceriodaphnia dubia* (7-day survival test). Once the treated water is discharged into the pond, the flocculent becomes bound to the sediment particles. In the settling ponds, the settled solids are biologically inert and would not infiltrate or impact groundwater.

Truck traffic leaving the site with aggregate products could also affect surface water quality. Sediment and debris could end up in roadside drainage courses. Measures proposed by the applicant to lessen this impact include paving the access roads and washing the vehicles in a contained truck wash facility prior to leaving the site. Wash water would be treated and recycled at the truck wash facility.

The proper implementation of surface water controls, policies, and procedures would result in minimal impacts during site operations.

FLOODPLAIN

The proposed action does not include mining within or near the floodplain. No impacts on the 100-year flood elevation are expected from implementation of the proposed action or final reclamation.

SPRINGS AND STREAMS ON GROUSE RIDGE

The water quality of springs and streams that originate on Grouse Ridge may be affected if groundwater that feeds the springs becomes impacted, and their flow could be affected if aquifer recharge is impacted.

Water Quality

There would be no direct runoff from the Upper Site into the springs and streams on Grouse Ridge due to the bowl-like excavation operation; therefore, impacts on water quality would be related to the transport of potential contaminants from groundwater to surface water.

The most likely contaminants are considered to be turbidity, as well as fuel and lubricants used in the equipment on the Upper Site. Interception and filtration of turbid water by the sandy and silty zones occurring within the ridge materials combined with low groundwater velocities, are expected to be sufficient to remove turbidity before groundwater is discharged to the springs, provided that active excavation does not extend into the perched zones that are in direct hydraulic connection with the springs. Additional analysis of groundwater quality impacts are discussed below.

Surface water runoff at the site can infiltrate through permeable surfaces. The primary impact on this water would be turbidity from fine-grained (typically clay to silt-sized) particles. In general, turbidity within groundwater has not been found to be a significant impact where gravel mining does not intercept the groundwater table (Thurston County, 1995). Turbidity is reduced or removed from water through gravitational settling and interstitial filtration through sediments. The transport of fines (silts and clays) from stormwater runoff through the infiltration ponds into the aquifer will be limited by the mechanical screening effect of the soils which will make up the bottom and sides of the ponds. Initially the finer clay particles will be able to move vertically into the aquifer; however, over time the accumulated silts in the base of the ponds will effectively stop the transport of clay particles. Over time the pond infiltration rates will decrease and the transport of fine particles to the aquifer will also decrease. Fine soil particles may be able to move vertically into the underlying soils due to the relatively high gradient and velocities. The same particles are not able to effectively move laterally through the same materials due to the very low water velocities (Thurston County, 1995).

At the Lower Site, the intent of the Proposal is to maintain an adequate buffer zone. The potential exists that some turbid water may infiltrate through the buffer zone; however, the silts and clays would settle out in the aquifer in a relatively short distance and would not likely be transported off-site. In portions of the Upper Site, where the buffer zone above perched aquifers may be absent seasonally, turbidity could locally impact groundwater quality immediately below the site when the groundwater table is above the floor of the mine. However, filtration of turbid water by the sandy and silty zones beneath the Upper Site and the low groundwater velocity is expected to be sufficient to remove turbidity before groundwater is discharged to springs, streams or wells.

Impacts on water quality due to accidental spills of petroleum products such as diesel fuel could occur at the Upper Site. These spills would be handled using procedures outlined in the Spill Prevention and Emergency Response Plan to minimize potential impacts on soil, surface water, and groundwater. Given the limited amount of equipment used on the Upper Site, releases are expected to be small and infrequent.

In the unlikely event of a significant groundwater impact, the potential exists that the springs and streams also could be affected; however, this potential is considered low for the following reasons: 1) the spill would be expected to be relatively small (less than 55 gallons) given the nature of activities at the Upper Site; 2) if the spill reached groundwater it would undergo natural attenuation before reaching the springs; and 3) the springs are located over 500 feet away from the edge of the proposed excavation.

Spring and Stream Flow

Aquifer recharge is expected to increase slightly as a result of to the proposed mining operation. The changes would occur gradually across the ridge over an estimated 25-year period. Springs that receive water from areas where mining is occurring or has recently occurred can be expected to receive greater quantities of water due to the increased recharge. Some of the increased recharge is likely to infiltrate deeper than the elevation of the springs and therefore, the increased outflow to the springs would likely be less than the total increased recharge. The travel time for infiltrating water to reach the springs would decrease due to the removal of about 100 feet of sand and gravel from the ridge. Based on existing groundwater level data at the site, an apparent lag time of approximately one month occurs between the period of maximum precipitation and highest water level elevations in the wells at the Upper Site (Figure 19). The removal of soils between the existing ground surface and perching layers that supply water to the springs would decrease this time lag. Water levels in wells screened at the perching layers would be expected to respond to large precipitation events in a period of days or weeks. Likewise the removal of soils would decrease the period between seasonal precipitation and maximum flow to the springs. Precipitation and spring flow data indicate there is a lag time of approximately two months between maximum seasonal precipitation and spring discharges. Based on the proposed volume of soil removal, the time lag could be expected to decrease by up to one-half.

The net result of this is expected to be more rapid response in the spring flow rates to precipitation. Overall, the increase in recharge combined with the decreased travel time would tend to provide wider fluctuations in the average daily or monthly flow rates in the springs and streams. For example, the springs would be expected to: (1) increase discharge earlier in the season due to the decreased travel time for infiltrating precipitation; (2) flow more in the winter due to the overall increase in recharge; and (3) flow less in the spring and summer due to decreased groundwater storage due to the removal of perched layers and overburden. The spring discharge would also be affected by the locations of stormwater infiltration ponds on the Upper Site which would redistribute recharge. For example, only approximately 10 percent of surface water flow off the north side of the Upper Site is derived from spring discharge along the Upper Site. Increased flows from these springs would not be expected to cause additional flooding or erosional concerns, or significant changes to turbidity or water quality because the water discharged at the springs represents only a small percentage of the total streamflow along the flanks of the Upper Site.

Below the steeper faces of Grouse Ridge, the majority of the annual spring and surface water discharge is derived from capillary diversion and subsurface stormflow in the forested ridge side drainages. This component of discharge would not be affected by the proposed operations.

As the mining and reclamation progresses and changes to the landform increase, the potential exists that the areal distribution of recharge could change significantly. Fine-grained soils are proposed to be placed in areas that are reclaimed, and slopes would be introduced into areas that were previously flat. This combination would tend to increase runoff and could focus recharge in new or different areas. Runoff would be routed to stormwater infiltration ponds, which depending on their location could change the quantity of water flowing into springs and streams. Given the bowl shaped nature of the Upper Site following mining and the reintroduction of significant quantities of fine-grained material, the potential exists that ponding of water may also occur. Ponding may seasonally develop where the cut depth encounters the perched water table. Either condition could influence the water budget and the rate and movement of perched groundwater. These changes could affect springs and streams by reallocating the water between these features. Following reclamation, the quantity of water recharging the perched aquifers could potentially decrease to below the pre-mining levels if the use of fine-grained material to reclaim the Upper Site or the excavation depth contributes to significant ponding that would increase evaporation.

Overall, the impacts to the spring flow rates are expected to be low provided that: (1) the infiltration ponds and other drainage features constructed as part of reclamation are designed to minimize the ponding of water over large areas at the base of the excavation; and (2) the ponds are located with the intent of distributing recharge across the base of the excavation, in a manner similar to existing conditions, rather than focusing it in a few locations.

SOUTH AND MIDDLE FORKS OF THE SNOQUALMIE RIVER

Groundwater from beneath the Lower Site may discharge into the rivers. Groundwater beneath the Upper Site discharges into small streams that drain into the rivers, and groundwater beneath the Upper Site may discharge directly into the rivers. If the quantity or quality of groundwater beneath the site changes, this could affect the rivers.

Lower Site

Groundwater quality is susceptible to impacts at the Lower Site. Given the activities in this area, the most likely contaminant would be petroleum hydrocarbons (e.g., diesel fuel and lubricants), and the quantity of the contaminants released is not expected to exceed 55 gallons. These types of releases would locally contaminate soils and could degrade groundwater quality locally beneath the site. Implementation of the Spill Prevention and Emergency Response Plan should eliminate or minimize impacts on water quality from such spills. If impacts on groundwater occur, they should be detected through groundwater monitoring proposed for the project before the contaminants have had the opportunity to migrate off site. However, even without monitoring or corrective actions, natural attenuation is expected to reduce petroleum concentrations in groundwater to below applicable standards before it could migrate the one-half mile to the South or Middle Forks of the Snoqualmie River. Therefore, the potential for water quality impacts to the rivers is considered to be low.

The use of groundwater as the source of water for the proposal is expected to decrease the quantity of water in the aquifer beneath the Lower Site. On average, the quantity of groundwater moving beneath the site, is not expected to decrease by more than the average rate of water usage for the Proposal (0.16 cfs). Depending on the hydraulic connection between the aquifer that the water is pumped from and the Middle and South Forks of the Snoqualmie River, there could be a slight decrease over time in the groundwater contribution to the river. In the South Fork and Middle Fork, the average daily stream flows upstream of the site were 300 and 1,230 cfs, respectively.

Based on water level elevations collected at the Lower Site monitoring wells and historic water level information from Sallal Well No. 3, groundwater gradients were calculated between the Lower Site and the Middle and South forks of the Snoqualmie River. Based on the calculated gradients, Sallal Well No. 3 transmissivity, and estimated permeability of the aquifer sands, lag time between groundwater interception by a theoretical well at the Lower Site and the rivers is estimated to be between 1,000 days (South Fork) and 2,500 days (Middle Fork). This is the period of time a water molecule would take to travel from the location of the well to a potential discharge point in one of the rivers. These times are consistent with those calculated for the Sallal Well No. 3 WHPA area (Compass Geographics, Inc., 1998). Under pumping conditions, the gradient would be decreased, and the lag time increased, because the water table would be depressed by pumping. Even under steepest potential gradient conditions, pumping effects to potential groundwater discharge to surface water would not reach the surface water bodies for a minimum of 2.7 years. However, impacts to streamflow could occur more quickly because pressure changes within the aquifer could be transmitted more rapidly than the water molecules would flow from one point to another.

Upper Site

The use of chemical and petroleum hydrocarbons at the Upper Site would be significantly less than the Lower Site and therefore, the potential for water quality impacts would be decreased. However, if contaminants reach the perched groundwater, the potential for natural attenuation is somewhat less before the groundwater discharges into the springs and streams above the rivers because of the relatively short distance between the edge of the mining activity and the springs. If contaminants are discharged from the springs into the streams, the streams could quickly transport the contaminants to the rivers.

The enhanced recharge at the Upper Site would likely increase the quantity of water contributing to the rivers. The increase in contribution could result from increases in spring discharge which increases the flow in tributary streams or increased groundwater contribution to the rivers. The increases would be very small compared to ranges of flows in the river. These slight increases would however, on an annualized basis, tend to offset the potential small decrease in stream flow that could result from groundwater pumping at the Lower Site.

3.2.2.2 Groundwater

BUFFER ZONE

Due to the coarse nature of the soils and lack of fine-grained confining units, gravel mining often occurs in areas where groundwater is considered to be susceptible to surface impacts and in aquifer recharge areas (East King County, 1998a). The Lower site is located in an area characterized as an aquifer recharge area, and as an area of high susceptibility to surface impacts (East King County, 1998b). Gravel mining can also decrease the distance between the ground surface and aquifers, or in the cases of a 'wet' mine, occurs within the water table or river floodplain. Wet mining can allow direct effects of mining on the groundwater and aquifer, such as changes to turbidity and temperature (Thurston County, 1995). These actions can increase the risk to aquifer water quality.

Because of these concerns, the proposed excavation plan includes a buffer zone between ground surface and the top of the regional aquifer beneath the Lower Site to prevent direct contact of the groundwater surface with the base of the proposed excavation. The buffer zone is a term used to describe the vertical distance between the base of the proposed excavations at the Lower and Upper Sites and the seasonal high groundwater level in the underlying regional aquifer(s). Cadman, Inc. incorporated a buffer zone in to their mining plan at the Lower Site to provide protection of groundwater. The purpose of the buffer zone is to provide an adequate vertical separation so if there is a spill of chemicals, lubricants or fuels on site, the operator can respond to the spill in accordance with the Spill Prevention and Emergency Response Plan before the underlying groundwater becomes impacted. In addition, during reclamation, the buffer zone provides separation from the water table needed for the development of roots for trees that would be planted at the site. Without a sufficient buffer zone, groundwater quality could be easily impacted and reforestation during site reclamation would be more difficult.

Assessment of Buffer Zone Thickness – Lower Site

Evaluation of water-level data for wells at the Lower Site indicates that the buffer zone would exceed 20 feet over at least the western three-quarters of the Lower Site following excavation to the design depth, which ranges from approximately 630 to 650 feet above msl (Figure 10). In the central portion of the site, where the asphalt and concrete facilities would be located, water-level measurements indicate that the buffer zone would be a minimum of 30 to 40 feet. Additionally, boring data for Well GR95-12 and boring GR98-6 indicate that a silty zone of unknown thickness overlies the Deep Aquifer in the central and western portion of the Lower Site at an elevation of approximately 575 to 590 feet above msl (Figure 11).

In the eastern portion of the Lower Site where the gravel washing, crushing, and sorting would occur, the base elevation of the proposed excavation ranges from 640 to 650 feet above msl. Seasonal high water level elevations in the two wells in this area (GR98-1 and GR99-1) have been measured between 621 to 632 feet above msl (Figure 12). Higher groundwater levels would be expected beneath the easternmost portion of the excavation. In this area, the 20-foot buffer zone would not be maintained throughout the year under average rainfall and aquifer recharge conditions. In addition, the potential exists that the water table could be encountered during excavation if the excavation occurred during the period of high seasonal groundwater levels. This encounter would not constitute an aquifer breach, where inflow of groundwater into the excavation due to the release of groundwater under a confining layer would cause a volumetric decline in water quantities and groundwater levels in the aquifer. The proposed groundwater seepage interception trench should maintain a minimum 5-foot buffer zone beneath the easternmost portion of the Lower Site during ongoing site operations if it is properly designed and maintained.

Assessment of Buffer Zone Thickness – Upper Site

At the Upper Site, there are no data indicating that a regional aquifer is present within the upper 200 feet of the deposits beneath Grouse Ridge. Alternative 2 proposes to remove sand and gravel to an elevation of 1,535 feet above msl, which corresponds to removal of about 100 feet of gravel, or less (Figure 10).

Shallow perched aquifers exist beneath the Upper Site. Excavation to an elevation of 1,535 feet above msl would remove the shallow and discontinuous perched water-bearing zones within the excavation footprint. These discontinuous perched zones would be excavated, and the water would drain into the excavation, and infiltrate and migrate downward to the underlying perched zones that appear to be more laterally continuous. This could increase water levels in the deeper perched zones and/or result in increased spring discharge. Given the apparent limited extent of these zones, the relatively small quantity of water contained in the zones, and the lack of evidence that they contribute water directly to the springs on the flanks of the ridge, impacts associated with their removal are expected to be minimal.

The more laterally continuous water-bearing zones associated with the shallow and deep perching layers would not be breached; however, groundwater within the shallow perching zone locally rises above proposed excavation base. Specifically, the water level in well GR95-2 (Figure 19) has risen above the proposed base elevation for the Upper Site for a short period of time during 4 of the last 5 years. Based on these measured water levels, there would be no buffer zone with the perched aquifers on a seasonal basis in certain areas of the excavation. However, given that the water levels in only 1 of the 11 existing wells on the Upper Site was within 15 feet of the proposed excavation base during the winter and spring of 2000, the extent of the water table interception is expected to be limited and only likely to occur where the shallow perching layer is present.

Fuel Spill Migration Through the Buffer Zone

Numeric modeling was performed to simulate an accidental release of petroleum hydrocarbons to the pit ground surface. Dames & Moore selected the U.S. EPA Hydrocarbon Spill Screening Model (HSSM) to perform this simulation. The HSSM is intended for simulation of surface or subsurface releases of light nonaqueous phase liquids (LNAPLs) in homogeneous soils (EPA, 1997). The model consists of separate modules for LNAPL flow through the vadose zone, spreading in the capillary fringe, and dissolve transport of chemical constituents of the LNAPL in a water table aquifer. The modules are based on simplified conceptualizations of the flow and transport phenomena in the three media. Dissolved-phase transport in the water table aquifer was not evaluated due to the limitation of the available data.

Approach

The model was used to assess how rapidly a surface petroleum spill would migrate through the vadose zone. The developed model is based on the scenario that an equipment fuel tank develops a leak and the leak goes undetected for one day. The LNAPL resulting from this leak first pools on the ground surface then infiltrated to the subsurface. Recharge due to precipitation events was not evaluated; surface recharge would saturate the soil and reduce the migration rate of the LNAPL. Only transport of the LNAPL through the vadose zone was assessed; movement of the LNAPL associated with the capillary fringe or the water table was not examined. In addition, the partitioning of polyacrylic aromatic hydrocarbons (PAHs) into pore water was evaluated to assess potential impacts due to dissolved constituent movement. Naphthalene was selected for this evaluation because it has the highest solubility of PAH constituents in diesel fuel.

Model Assumptions

The following assumptions were used when developing the HSSM model:

- The petroleum hydrocarbon product (LNAPL) spilled is diesel fuel
- The first constituent to partition from the diesel fuel is naphthalene
- The spill goes undetected for a period of one day
- An unspecified volume of LNAPL is released; a "pond" of LNAPL one inch deep exists on the ground surface for one day
- Only vertical migration of the LNAPL through the vadose zone occurs
- The Brooks and Corey method is applicable for calculating the capillary pressure curve

Model Inputs

Table 14 summarizes the model input values. Calculations of specific model values and data supporting these calculations are presented in Appendix E. The Brooks and Cory capillary pressure curve model values were calculated using the program SOPROP, part of the HSSM package. The SOPROP program uses the porosity and the percent sand and clay of the soil to calculate the pore size distribution index (the Brooks and Corey lambda), residual water saturation, and the air entry head. The SOPROP inputs were calculated from laboratory and field measurements based on samples collected from well 99-1, which was installed by Dames & Moore in May 1999 on the Lower Site. The inputs were selected to provide a conservative estimate of diesel fuel migration by using the soil exhibiting the highest vertical permeability. In addition as described above, recharge due to precipitation events was not included as a model input because surface water infiltration would saturate the soil and reduce the migration rate of the water immiscible LNAPL. During periods of high water table conditions which occur in late winter or early spring, surface water infiltration would be expected and would inhibit the downward migration of LNAPL. Consequently, an arid condition represents a conservative assumption for LNAPL migration.

Results

Results of the model run (Appendix E) indicate that the LNAPL reaches a depth of 1.5 feet (0.43 meters) bgs 30 days from the spill (Figure 23). The results indicate that diesel fuel migration due to a spill would be relatively slow through the sands and gravels beneath the site, but could reach the water table if a sufficient buffer zone was not maintained and the spill was not cleaned up. The results are considered representative of migration that could occur under arid conditions through permeable sand and gravel. The boring log for well 99-1 (Figure 11 and Appendix C) indicates that at the proposed base of the excavation, there is a significant amount of silt. The increased silt in this area would further decrease the rate of diesel fuel migration.

The concentration of naphthalene in the soil pore water calculated by the model was 0.27 mg/L after 30 days. The naphthalene concentration was slightly below the Model Toxics Control Act (MTCA) Method B groundwater cleanup level (0.32 mg/L); however, the dissolved concentration of other PAHs may exceed MTCA cleanup levels. PAHs generally have low solubility in water, tend to adsorb to soil and are not major constituents of diesel fuel. The presence of naphthalene in the soil pore water indicates that within a relatively short period of time dissolved phase hydrocarbons have the potential to impact water in the vadose zone following a spill of diesel fuel. The dissolved phase constituents are expected to migrate through the vadose zone at a rate greater than the LNAPL due to the difference in viscosity of the carrier fluid. Dissolved phased migration also would tend to be enhanced by surface water infiltration.

Under this scenario, the LNAPL migration would be relatively slow and dissolved constituents would migrate more quickly. However, impacts on groundwater quality should be mitigated by implementation of the Spill Prevention and Emergency Response Plan in areas where an adequate buffer zone is maintained. In areas where the buffer zone is limited in this thickness or absent, impacts on groundwater. However, given the limited potential for a significant release of contaminants and the substantial buffer zone beneath most of the site, the potential for significant impacts on groundwater quality is considered low.

GROUNDWATER QUALITY

Groundwater quality at the Lower and Upper Sites and in the vicinity has the potential to be affected by two types of events. First, surface water discharge to groundwater would occur via infiltration through the pit floor or through the stormwater infiltration ponds. Secondly, the potential exists for releases of petroleum products and other chemicals stored on site to migrate through the soil down to the water table.

Turbidity

Surface water at the site can infiltrate through permeable surfaces not covered by paving or buildings. This surface water results from precipitation on the site, road-watering activities, and truck and gravel washing. The primary impact on this water would be turbidity from fine-grained (typically clay to silt-sized) particles. Turbidity is a groundwater quality concern in that it reduces the effectiveness of chlorine disinfection and may lead to sedimentation or clogging of well screens, pumps and fixtures. Turbidity also detracts from the aesthetics of drinking water.

In general, turbidity within groundwater has not been found to be a significant impact where gravel mining does not intercept the groundwater table (Thurston County, 1995). Turbidity is reduced or removed from water through gravitational settling and interstitial filtration through sediments. For silt-sized materials, the silt would likely settle out of standing water (as in a stormwater pond) in less than a day. Very fine clay-size materials may be as much as 40 times smaller than silt particles and may settle at the rate of less than one inch per day (Thurston County, 1995). In order to facilitate settlement of these very fine materials, the addition of flocculents to the onsite surface water basins may be required to cause the clay particles to flocculate and settle more quickly. Settling would be reduced in areas of flow which are sufficient to keep the fine-grained sediments in suspension. Maintenance, such as periodic removal of fine-grained sediments, would be necessary to optimize pond function.

. Where fine-grained sediments clog the interstices between coarse sediments, interstitial filtering may take place. The clogging takes place relatively near the surface of the ground or pond bed. The clogging layer may be established in less than a day, and typically the majority of clogging occurs within a foot of the pond bed (Thurston County, 1995). The deposition of clogging is controlled by gradient, and tends to accumulate on the bottom and down-gradient sides of ponds. The transport of fine soils (silts and clays) from storm water runoff through the infiltration pond into the aquifer will be limited by the mechanical screening effect of the soils which make up the bottom and sides of the pond which act as a filter. Based on the existing soil gradation information available from samples taken at the approximate depth and location of the infiltration pond, the screening will have an effective lower limit of large clay particles (approximate particle diameter of 0.0045 mm).

The estimated screening limit based on literature values (Sherard, et al, 1984) is a particle diameter to filter diameter ratio of 0.10, where the particle diameter is defined as the diameter at which 85% of the particles are smaller and the filter diameter as the diameter at which 15% of the particles are smaller. Taking a more conservative ratio of 0.20 and assuming a filter diameter of 0.0225 mm from the gradation curves, particles greater than 0.0045 mm in diameter should be retained at the interface. In addition, there is some indication that filters with this media particle size can achieve much better results than the assumed ratio of 0.20.

Initially, the finer clay particles that do not remain at the surface of the pond's liner would be able to move vertically through the underlying soil. However, over time the accumulated silts and larger clay particles will produce a filter cake at the water interface and effectively screen more of the smaller clay particles that could initially penetrate the interface. This process would result in a gradual decrease in the infiltration rates from the pond as the fine particles form less permeable layer under the pond.

The particles that do penetrate the interface will undergo physical-chemical filtration while traveling through the soil. Because the process is highly dependent on the soil and particle properties (e.g., electrostatic interaction, hydrodynamic forces), there are no established guidelines for estimating particle uptake in the filtration media. In some cases the particles travel through the soil without interaction and in other cases particles can become attached to the filtration media.

Fine soil particles move vertically into the underlying soils by remaining suspended in water due to relatively high gradient and velocities. The same particles are not able to effectively move laterally through the same materials due to the reduced gradient and velocities. These conditions increase the amount of time that the fine particles interact with each other and the soil. If the particles undergo physical-chemical filtration, the increased contact time may increase the soils capacity to remove suspended particles from the water. These conditions allow the fine materials to adhere to each other and to the surrounding soil particles. As a result the fine materials are not effectively transported into the aquifer.

At the Lower Site, the majority of surface water runoff is proposed to be collected in a stormwater pond on the west side of the site. Based on soil boring logs, the soils at the proposed base of the excavation are coarse sands and gravels in the vicinity of the stormwater pond. Infiltration rates and transport of fine-grained materials would be dependent on the permeability of these materials and the design of any filter material in the base of the pond.

In portions of the Upper Site, where the buffer zone above perched aquifers may be absent seasonally, turbidity could locally affect groundwater quality when the groundwater table is above the floor of the mine. Filtration of turbid water by the sandy and silty zones occurring within the ridge is expected to be sufficient to remove turbidity before groundwater is discharged to the springs

Petroleum Products

In the event of a spill at the ground surface of the pit floor, such as a petroleum release from a vehicle or storage tank, spilled liquid would infiltrate into the ground surface and could affect onsite groundwater quality if not detected and cleaned up. As part of the onsite Spill Prevention and Emergency Response Plan, procedures for the prevention, containment, control and cleanup of spills or unplanned discharges of oil and petroleum products and other materials would be provided. Prevention of groundwater impacts would be dependent upon rapid observation and response to any spill event, in order to initiate cleanup without compromising the established buffer zone. At the Lower Site, a minimum 5-foot buffer zone would be maintained. At the Upper Site, the buffer zone would be less than 5 feet in some isolated areas on a seasonal basis. Given the slow rate of petroleum hydrocarbon movement through the soil and provided that the spill is quickly identified and cleaned up, groundwater quality impacts should be avoided at the Lower Site and would only be a concern of the Upper Site on a localized and seasonal basis.

In the unlikely event of a significant chemical spill at the Upper Site where the buffer zone does not exist on a seasonal basis, then groundwater quality could be impacted. At the Upper Site, the impact would be on a shallow perched aquifer that is not developed. The shallow perched aquifer is about 600 feet above the screened interval in the nearest domestic wells and more than 2,000 feet away horizontally. Groundwater from the perched aquifer also discharges to springs on the north and south sides of the ridge, 500 to 1000 feet lateral from the base of the proposed excavation. Overall, the potential for significant groundwater impacts beneath the Upper Site is considered low.

AQUIFER RECHARGE

Surface conditions at the Lower and Upper Sites would be modified as part of this alternative, and this has the potential to impact groundwater recharge. Precipitation from paved areas and other areas where runoff occurs would be routed to stormwater infiltration ponds and vegetation would be removed, at least temporarily, from disturbed areas. The combined effect of these changes to the site would be to increase runoff, focus recharge into certain areas, and decrease evapotranspiration. Overall this would increase aquifer recharge on both the Lower and Upper Sites. At the Lower Site, the increase in recharge would be reduced by the construction of fresh water pond that would collect precipitation and surface water runoff. The construction of the settling ponds on the Upper Site would also reduce aquifer recharge.

The actual quantity of additional recharge that would be attributed to the gravel operation is dependent on the rate at which the Lower and Upper Sites would be developed and reclaimed. Recharge would increase as vegetation and topsoil are removed and would then decrease as reclamation and revegetation occurs.

Lower Site

Vegetation and topsoil would be stripped from approximately 40 acres of the Lower Site surrounding the processing area. This would increase infiltration rates and aquifer recharge by exposing permeable sands and gravels and would decrease evapotranspiration by removing vegetation. Although recharge in this portion of the disturbed area would increase, the increase is expected to be modest (less than 0.1 cfs) given that: (1) an estimated 69% or more of the precipitation (about 0.32 cfs) already recharges the aquifer in the area that would be disturbed by the gravel operation; Review of the range of precipitation over the period of record (1931-2000) indicated that precipitation recharging the aquifer at the Lower site could range from approximately 0.24 to 0.5 cfs; (2) approximately half of the 40-acre area that would be disturbed has been previously used as a gravel mine, which has already enhanced recharge; and (3) an estimated 35% or more of the disturbed portion of the Lower Site would be revegetated during the early phases of the gravel operation decreasing the area over which enhanced recharge would occur to about 25 acres, which corresponds to the processing area.

The fresh water pond (a lined reservoir) would provide storage to reduce the instantaneous rate at which groundwater pumping would be required to meet peak water use requirements. The freshwater pond on the Lower Site would intercept precipitation and would be designed to collect surface water runoff. The pond would cover an area of approximately 3.8 acres. The decrease in aquifer recharge attributable to the interception of precipitation (assuming 69% of the precipitation recharges the aquifer) would be about 965,000 ft^3 per year or 0.03 cfs. As discussed in Section 2.3, the quantity of water that is estimated to annually infiltrate in the vicinity of the fresh water pond due to run-on from the drainage adjacent to the east is approximately 1,100,000 cfs or 0.03 cfs. It is assumed that this water would be collected by the pond and would not recharge the aquifer. Therefore, the estimated average decrease in aquifer recharge due to construction of the fresh water pond would be about 2,100,000 ft^3. On an annualized basis, this is equivalent to a decrease in aquifer recharge of about 0.06 cfs.

Various engineering controls would be provided to control water storage and surface water elevations in the freshwater storage pond including emergency spillways, routing water to the infiltration pond at the Lower Site. Although the pond design would include a spillway, the operation of the pond is expected to minimize the potential for overflow. In the event that the pond were to overflow, some of this water would recharge the aquifer. Water stored in the pond would not be treated; therefore, there would be no impacts to groundwater quality due to overflow from the pond.

When considering the impacts of the pond and the limited potential for increased recharge in the processing area, the overall change in aquifer recharge at the Lower Site is expected to be negligible.

Surface water runoff at the Lower Site would be routed to a stormwater infiltration pond in the western portion of the excavation, and infiltration would be focused in this area. Depending on the amount of runoff, this could result in the local mounding of groundwater around the infiltration pond. Given the apparent high permeability of the sand and gravel deposits beneath the pond, the mounding is expected to be small.

In areas where the excavation reduces the ground surface elevation, the vertical distance traveled by infiltrating water before it encounters the water table would decrease. Recharge in these areas would reach the water table more rapidly; however, a comparison of monthly precipitation records and hydrographs for monitoring wells (Figure 12) indicates that recharge is already relatively rapid and this change is considered to have minimal impact with respect to recharge at the Lower Site.

Upper Site

The Upper Site recharge is expected to increase due to exposure of permeable sand and gravel and removal of vegetation. If a perched water table seasonally intercepts the excavation, this could provide additional opportunity for evaporation, but this would likely occur over a limited area during winter or early spring when evaporation rates are low. In addition, as the depth of the mine increases, the travel time for water infiltrating from the surface to the perched aquifers would decrease.

The Upper Site is proposed to be mined in 50-acre increments, with reclamation and revegetation occurring after operational area needs are met. As part of the gravel operation, precipitation would be intercepted in settling ponds for use in facility processes, which would affect aquifer recharge. The impact on groundwater recharge would be proportional to the area of the pond. This decrease in recharge would be offset, at least in part, by increases in recharge described above.

Overall, the increased rate of recharge is expected to be modest for the following reasons: (1) an estimated 69% or more of precipitation (about 1.7 cfs) already recharges the perched aquifer in the area that would be disturbed by the gravel operation; (2) the Upper Site would be developed in phases and would be revegetated as the gravel operation expands across the site and, therefore, only a fraction of the Upper Site would provide enhanced recharge at any time during the lifetime of the project; (3) most of the area was recently disturbed by logging, which enhances recharge by decreasing interception and uptake of water by vegetation; and (4) precipitation would be intercepted by the settling ponds, thus decreasing potential recharge. This increased recharge may locally increase water levels in the perched aquifer zones due to the limited nature of this aquifer system and the relatively low permeability of the silty material below the base of the excavation.

During site operations, stormwater runoff is expected to infiltrate readily through the exposed sand and gravel deposits which should minimize the redistribution of water recharging the perched aquifers. Runoff could occur in areas where silty layers are encountered. This runoff could result in recharge occurring in new or different areas.

The use of fine-grained soils to reclaim the Upper Site will affect stormwater runoff patterns. The Draft Reclamation Plan (Dunton, 2000) indicates that all stormwater would be captured and routed to ponds. The ponds would be designed to store and infiltrate the stormwater. The use of these ponds has the potential to redistribute the groundwater recharge to the perched aquifers. The recharged groundwater may locally mound in areas beneath these infiltration ponds. Depending on the number and location of ponds, this could impact the flow rate of springs and streams around the perimeter of the ridge. The quantity of water anticipated to be collected by the ponds, the number of ponds, and their locations are not identified in the Draft Reclamation Plan. Overall the impacts to the springs are expected to be low provided that: (1) the ponds and other drainage features constructed as part of reclamation minimize the long-term ponding of water over large areas at the base of the excavation; and (2) the number and location of ponds are designed with the intent of distributing recharge across the base of the excavation, in a manner similar to existing conditions, rather than focusing it in a few locations.

WATER SUPPLY WELLS

More than 30 domestic and municipal water supply wells have been identified within a 1-mile radius of the site. Wells that are most susceptible to water quality impacts are those located potentially downgradient of the Lower Site, because the Lower Site is located directly above a regional aquifer. Wells screened in the regional aquifer and located downgradient of the Lower Site include Sallal Well No. 3, an industrial well, and several domestic wells. These wells are more than 2,000 feet downgradient of the eastern portion of the excavation, which is the area considered most susceptible to groundwater impacts. Several domestic and community supply wells are present in the Middle and South Fork valleys. These wells are at least 1,500 feet downgradient of the Upper Site, and vertically separated from the existing ridgetop by up to 1,000 feet elevation difference. However, because no groundwater withdrawals are proposed at the Upper Site, and aquifer recharge at the site will be increased due to excavation activities, no adverse groundwater quantity impacts will occur in the Middle or South Fork valleys.

Given the activities in the eastern portion of the Lower Site, the most likely contaminant would be petroleum hydrocarbons (e.g., diesel fuel and lubricants) and the quantity of the contaminants released is not expected to exceed 55 gallons (the contents of an entire drum). A larger spill was determined to be unlikely and speculative based on the design plan for double-walled above-ground storage tanks (AST's) within concrete-bermed containment. This analysis represents a more probable event of drum or vehicle fuel tank spillage. These types of releases would impact soils and could impact groundwater locally beneath the site and then migrate farther downgradient. The northern portion of the Lower Site is within the wellhead protection zone for Sallal Well No. 3. Based on groundwater modeling results in the Sallal Water District's Wellhead Protection Plan (Compass Geographics, Inc., 1998), the eastern portion of the excavation appears to be just outside the southern edge of the capture zone for the well (Figure 9). However, the wellhead protection area is only an approximation, and it is possible that the well could draw water from beneath the processing area. The well proposed by Cadman, Inc. northwest of the excavation at the Lower Site would provide additional data regarding groundwater flow in the vicinity of Sallal Well No. 3 and would also be used to monitor groundwater. Potential travel times for groundwater from this portion of the site to the Sallal well would be about 1 to 2 years (i.e., 1,500 feet per year) based on the modeling results (Compass Geographics, Inc., 1998). The travel time to wells farther downgradient are expected to be greater. As a result of natural attenuation, contaminants would move more slowly on average than the groundwater, and their concentrations would generally decrease in a downgradient direction. Given the limited potential for a significant release of contaminants, and the substantial buffer zone beneath most of the site, the potential for offsite impacts on groundwater quality is considered low.

Groundwater monitoring is proposed by Cadman, Inc., to assess groundwater flow directions and detect potential impacts on groundwater quality. With properly selected well locations, a program of regular groundwater monitoring should detect any significant impacts before they migrate off site or enter the designated wellhead protection area.

3.2.2.3 Water Supply

The mining operations have been estimated by Cadman, Inc. to consume approximately 2,600,000 gallons of water per day. Most of this water would be recycled on site and reused. It is estimated that consumptive water usage would be approximately 150,000 gallons per day or 6% of the total daily water usage. The gravel operation is expected to operate 250 days per year and would consume an estimated 37,500,000 gallons (approximately 5,000,000 cubic feet) of water annually through evaporation. This corresponds to a continuous consumptive water usage of about 70 gallons per minute or 0.16 cfs which would be increased slightly by evaporation from the freshwater pond.

The proposed sources of the water to be used by the gravel mining operation are groundwater from a well on the Lower Site and surface water collected in the freshwater pond. A production well at the Lower Site, if completed in the deep valley aquifer, would be expected to have similar hydrogeologic properties to the Sallal Well No. 3 because of the proximity of Sallal Well No. 3 to the Lower Site. Sallal Well No. 3 currently yields about 75 gpm. Prior to use of the water, Ecology approval would be required to obtain the required groundwater and surface water rights.

Due to evaporation from the freshwater pond, interception of surface water runoff is expected to provide less than half the required water for the project. Therefore, groundwater would be the primary source of water. The extraction of groundwater has the potential to decrease water levels in the aquifers in the site vicinity. The average annual pumping rate for the well at the Lower Site is estimated to be 70 gpm or less. However, instantaneous discharge to provide make-up water seasonally may exceed the average discharge. At this rate, there is a potential for drawdown of the aquifer that could interfere with other wells. If the water supply well was screened in a different aquifer than the wells in the surrounding area, this potential interference could be minimized.

As described above, the rate of enhanced aquifer recharge at the Lower Site is expected to be negligible. The average groundwater withdrawal for the project is estimated to be up to 0.16 cfs. Therefore, there would be a net decrease in the amount of groundwater beneath the Lower Site. This decreased water beneath the Lower Site could lower the water level in nearby wells and could result in reduced stream flow. In years with below average precipitation, the impacts could be greater and during years with greater than average precipitation, impacts would be less.

A production well at the Lower Site, if completed in the Deep Aquifer, would be expected to have similar hydrogeologic properties to the Sallal well. Pumping test information for Sallal Well No. 3 is not available to determine aquifer transissivities for the Deep Aquifer in the vicinity of the Lower Site. However, an estimation of transmissivity may be based on the specific capacity, the amount of drawdown per unit rate of discharge. According to the well log, Sallal Well No. 3 was pumped at a rate of 91 gpm with approximately 12 feet of drawdown, or a specific capacity of 7.6 gpm/ft. Using a generalized relation of specific capacity to transmissivity for confined aquifers (Anderson, 1993) of:

$$\text{specific capacity} \times 270 = \text{transmissivity } (\text{ft}^2/\text{day})$$

yields:

$$7.6 \times 270 = 2{,}050 \text{ ft}^2/\text{day}$$
$$\cong 15{,}000 \text{ gpd/ft}$$

Potential drawdown due to pumping from a water supply can be estimated using the following relationship described by Viessman et al. (1977):

$$T = \frac{528(Q)\log(r_2/r_1)}{(h_2 - h_1)}$$

Where:

T = transmissivity (gpd/ft)
Q = discharge (gpm)
r_1 = radius of the pumping well (ft)
r_2 = a distance from the well (ft)
h_1 = drawdown at the pumping well (ft)
h_2 = drawdown at a distance from the well (ft)

Solving for drawdown at selected distance (r_2) from the pumping well, the equation may be presented as follows:

$$h_2 = \frac{528(Q)\log(r_2/r_1)}{T} + h_1$$

Assuming a pumping rate of 70 gpm at the proposed project well, drawdown in the pumping well (h_1) would be about 9 feet based on the specific capacity of 7.6 gpm/ft. Using the estimated aquifer transmissivity (T) of 15,000 gpd/ft and a radius for the pumping well (r_1) of 0.33 feet, drawdown at a distance (r_2) of 100 feet from the pumping well can be calculated as follows:

$$h_2 = \frac{528(70\text{ gpm})\log(100\text{ ft}/0.33\text{ ft})}{15{,}000\text{ gpd/ft}} - 9\text{ ft}$$

$$h_2 = 6.1\text{ ft} - 9\text{ ft}$$

$$h_2 = -2.9\text{ feet or } 2.9\text{ feet of drawdown}$$

At a distance (r_2) of 1,000 feet from the pumping well, the equation yields:

$$h_2 = \frac{528(70\text{ gpm})\log(1{,}000\text{ ft}/0.33\text{ ft})}{15{,}000\text{ gpd/ft}} - 9\text{ ft}$$

$$h_2 = 8.6\text{ ft} - 9\text{ ft}$$

$$h_2 = -0.4\text{ feet or } 0.4\text{ feet of drawdown}$$

Based on these assumptions and calculations, a pumping well at the Lower Site could have drawdown effects at nearby wells. Because of this, the proposed well should be located at a distance from neighboring wells, such as the Sallal Well No. 3, that would minimize or eliminate drawdown interference.

The proposed use of groundwater and surface water resources is considered a moderate impact because water resources in the drainage basin are currently insufficient, under certain conditions, to meet minimum instream flow requirements established by Ecology.

3.2.2.4 Environmental Health

The Memorandum of Understanding and the Conceptual Mining Plan (Appendix A) propose the use of "legally approved King County biosolids products" to reclaim and restore mined areas to productive forest cover. Biosolids are wastewater solids that are rich in nutrients and organic materials and have been treated to a level that allows beneficial recycling on land. They also have met the requirements of federal regulation 40 CFR Part 503 and the state biosolids rule Chapter 173-308 WAC. Biosolids have both soil conditioning and fertilizing value because they increase the organic matter content of the soil and add plant-essential nutrients such as nitrogen, phosphorus, sulfur, magnesium, and zinc. Most of the biosolids produced in the Pacific Northwest are beneficially recycled on agricultural crops, forests, or used in compost.

U.S. EPA has conducted environmental risk assessments concerning the use of biosolids and has set standards for allowable contaminants. The levels of these contaminants in King County biosolids are considered to pose relatively low risks when applied according to state and federal regulations (EPA, 1993). Because of various chemical bonding processes within biosolids organic matter, metals in the biosolids do not generally migrate from the biosolids and surface layers of the soil. From an environmental standpoint, the primary risk from use of biosolids is movement of nitrogen, which occurs with overapplication. If more biosolids nitrogen is applied than can be used by the crop or vegetation, then excess nitrogen may move down through the soil profile and contaminate groundwater.

The value of the soil-conditioning organic matter in biosolids can be as important as its value as a fertilizer (Henry, 1999). This is especially true for disturbed soils such as those that have been mined for topsoil or sand and gravel. Organic matter improves the soil's ability to store nutrients and water, immobilizes contaminants, improves soil structure, aeration and provides the basis for a healthy biological soil community. Short-term soil productivity is improved both by the additional nutrients and moisture-holding capacity. Long-term soil productivity is improved by the continual slow release of nutrients as the organic matter decomposes. A disturbed soil needs additions of organic matter and nutrients to bring it back to productive use. However, adding enough organic matter in the form of biosolids would provide too much nitrogen.

Because of this risk of nitrate leaching, the use of biosolids alone as a soil amendment is not recommended in mine reclamation. The preferred technique is carbon and nitrogen balancing, which combines a carbon-rich, nitrogen-deficient source of organic matter such as wood chips or sawdust with the nitrogen-rich biosolids (Cogger, 2000; Henry, 1999) Microbes naturally decomposing the carbon source use nitrogen from the biosolids. Other nitrogen is taken up by plants, leaving little available for leaching. A biosolids compost is rich in carbon and low in nitrogen. A biosolids compost provides the organic matter needed to build and restore a soil yet does not provide more nitrogen than the new cover crop can assimilate. A biosolids compost, or a similar mixture of Class A biosolids and carbon-rich materials, is the product that is proposed for reclamation of the Grouse Ridge sand and gravel mine.

The use of any biosolids product requires calculation of agronomic rates which match the amount of available nitrogen in the product to the nitrogen needs of the site and vegetation. Any application of soil amendment is also required to be in compliance with Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington. Washington State Department of Ecology, in cooperation with the University of Washington, Washington State University, Oregon State University and the University of Idaho, has published a manual to guide the development of agronomic application rates (Henry, 1999).

Because reclamation is proposed over the life of the mine, the King County biosolids products that will be available cannot be predicted with certainty. GroCo compost is presented here as representative of a product made with King County biosolids. GroCo or a Class A product similar to it may be available when soil amendments are needed. GroCo consists of approximately 1 part biosolids to 3 parts sawdust, mixed and allowed to compost at 55C for at least 60 days, then aged for at least 12 months. GroCo has been produced and marketed in the Puget Sound area since 1976. It is available to the general public and is used by commercial landscapers and home gardeners. Because it sustains high temperatures during the composting process, GroCo meets the federal pathogen reduction standards of a Class A biosolids product. Class A refers to a product that has been treated beyond the standard wastewater practices and has reached a level of "no-detectable" pathogenic organisms. Each batch of finished GroCo must pass Ecology's requirements for microbiological testing before it can be sold or distributed to customers.

All biosolids products contain some metallic elements. They come into the wastewater system from household products, food, water pipes, soil, and discharges from businesses. Some of the metals are also plant-essential nutrients, such as copper and zinc, but others like cadmium and lead are not nutrients but pollutants. EPA and WDOE have issued numerical quality standards to ensure the use of low-metal biosolids. Both King County biosolids and GroCo compost meet the "exceptional quality" standards for metals (see Table 15). The metals present in biosolids or compost remain tightly bound to the organic matter, do not move through the soil, and are not available for plant uptake. The amount added in land application is only a small percentage increase over the amounts of metals naturally present in all soils. Therefore metal content is not a factor that determines appropriate application rates. Biosolids composts are so effective at binding contaminants that they are now being used to revegetate and to immobilize metals in heavily polluted sites and brownfields (EPA, 1998).

The traces of organic chemicals in biosolids are present in such low concentrations that they are not regulated by the state or federal government and are not considered a risk or a significant factor in the land application of biosolids (EPA, 1995).

Ecology has recently updated its best management guidelines for the use of biosolids products (Cogger et al., 2000). These guidelines include suggested widths for buffer zones, which are areas within a site that receive no biosolids. Buffers control runoff from the amended area and protect surface waters from the addition of nutrients and organic matter. The minimum buffers suggested are 33 feet (10 meters) from surface waters and a vertical separation from ground water of at least 2 feet (0.6 meter). A further refinement of guidelines has been developed by the University of Washington specifically for the use of biosolids compost in the Mountains to Sound Greenway (Henry, 1996). This document proposes buffers for various types of slopes, berms and application methods

At the proposed Grouse Ridge mine site, there is little surface water impact expected, given that there are no permanent surface water bodies within the Lower and Upper Sites and there is no significant water flow off site. With proper application rates, impacts to groundwater beneath the Lower and Upper sites are also expected to be negligible.

The scientific literature contains many studies of the use of biosolids products in mine reclamation. Recent projects in British Columbia demonstrate reclamation of sand and gravel mines with biosolids products, even above sensitive and vulnerable aquifers (Van Ham, 2000). Near Aldergrove, B.C., a former gravel pit was converted to a public park by addition of organic amendments of biosolids, biosolids compost, and topsoil. Prior to adding the amendments, a lysimeter study was conducted to determine the most appropriate rates of application (lysimeters are devices which allow sampling of soil water directly underneath the amended soil). The entire area overlies the sensitive Abbotsford-Sumas aquifer. Post-application monitoring has shown an increase in soil nutrients, but no effects on ground waters or surface waters.

ALTERNATIVE 2A – UPPER SITE MINING AND LIMITED LOWER SITE MINING

This section describes the potential impacts associated with the Lower Site Option. Only impacts related to the Lower Site are considered. Impacts for the Upper Site would be the same as for Alternative 2.

SURFACE WATER

Runoff Volume

The impact on runoff volume would be slightly less than Alternative 2 because the disturbed area would be reduced on the Lower Site. Impacts are expected to be minimal.

Surface Water Quality

The onsite impacts on surface water quality would be similar to Alternative 2. Impacts are expected to be minimal.

Floodplain

The Lower Site Option does not include mining within or near the floodplain. No impacts on the 100-year flood elevation are expected from implementation of the Lower Site Option.

South and Middle Forks of the Snoqualmie River

Aquifer recharge would decrease slightly under this alternative when compared to Alternative 2 due to the decrease in the disturbed area. The potential impact on flow rates in the South and Middle Forks of the Snoqualmie River due to this small change is considered negligible when compared to Alternative 2. Potential impacts on water quality are similar to Alternative 2.

GROUNDWATER

Buffer Zone

Under this option, potential impacts due to the buffer zone are the same as Alternative 2 because the excavation extends to the same depth under both alternatives.

Groundwater Quality

Potential impacts on groundwater quality at the Lower Site would be the same as Alternative 2.

Aquifer Recharge

Under this option, aquifer recharge would decrease slightly when compared to Alternative 2 due to the decrease in the disturbed area on the Lower Site.

Water Supply Wells

Potential impacts on groundwater quality at the Lower Site would be the same as Alternative 2.

WATER SUPPLY

The Lower Site Option of Alternative 2 would require the same amount of water as Alternative 2. Due to the decrease in aquifer recharge, the impacts would increase slightly.

Environmental Health

Potential impacts due to the use of a biosolids compost product would be similar to Alternative 2 for the Lower Site because this option also requires reclamation.

3.2.3 Alternative 3 – Lower and Upper Sites Mining (Exit 34 and 38)

3.2.3.1 Surface Water

RUNOFF VOLUME

The impact on runoff volume would be similar to Alternative 2 with site processing located on the Upper Site.

SURFACE WATER QUALITY

The onsite impacts on surface water quality would be similar to Alternative 2 with site processing on the Upper Site. This alternative includes improvement to SE Grouse Ridge Road. Drainage from SE Grouse Ridge Road would be drained off site to the downstream drainage system. Because this is an existing roadway, impacts on drainage resulting from the proposed road improvements are expected to be minimal.

FLOODPLAIN

Alternative 3 does not include mining within or near the floodplain. No impacts on the 100-year flood elevation are expected from implementation of Alternative 3.

SPRINGS AND STREAMS ON GROUSE RIDGE

Potential impacts on the flow in springs and streams on Grouse Ridge under this alternative are slightly different than under Alternative 2 because the phasing of the project is different. Alternative 3 includes a semi-permanent processing area on the Upper Site that provides another area where enhanced recharge would occur throughout the 25-year project period. This is expected to slightly increase recharge to the shallow perched aquifer in the eastern portion of the Upper Site where the processing would occur. This increased recharge is expected to slightly increase discharge to springs and streams in this area.

SOUTH AND MIDDLE FORKS OF THE SNOQUALMIE RIVER

As a result of the small potential changes in groundwater recharge under this alternative, the potential impact on flow rates in the South and Middle Forks of the Snoqualmie River are considered negligible when compared to Alternative 2. Potential impacts on water quality are slightly higher under this alternative because springs and streams on Grouse Ridge are at slightly greater risk because of the increased activities on the Upper Site. However, the overall risk to water quality is still considered to be low.

3.2.3.2 Groundwater

BUFFER ZONE

Under this alternative, potential impacts due to the buffer zone are the same as Alternative 2 because the excavation extends to the same depth under both alternatives.

GROUNDWATER QUALITY

Lower Site

Potential impacts on groundwater quality at the Lower Site would be reduced under this alternative when compared to Alternative 2 because there would be no gravel processing activities at the Lower Site. By moving the gravel processing to the Upper Site and reducing the vehicular traffic and use of petroleum hydrocarbons at the Lower Site, the potential risk for impacts would be reduced.

Upper Site

Under this alternative, the gravel processing would be moved to the Upper Site and truck traffic at the Upper Site would increase significantly. This increases the potential for accidental releases of petroleum hydrocarbons and other chemicals that would be used or stored on the Upper Site, increasing the potential that groundwater would be affected. The apparent absence of groundwater above the shallow perching layer in this area suggests that an adequate buffer zone would be maintained. Therefore, implementation of the Spill Prevention and Emergency Response Plan should adequately mitigate potential water quality impacts.

AQUIFER RECHARGE

Potential impacts on aquifer recharge under this alternative would be slightly different than under Alternative 2 because the phasing of the project is different. Alternative 3 includes a semi permanent processing area on the Upper Site that provides another area where enhanced recharge would occur throughout the 25-year project period. This is expected to slightly increase recharge to the shallow perched aquifer in the eastern portion of the Upper Site where the processing would occur.

WATER SUPPLY WELLS

Lower Site

Potential impacts on groundwater quality at the Lower Site would be reduced under this alternative when compared to Alternative 2 because there would be no gravel processing activities at the Lower Site. Therefore, the risk of potential impacts on groundwater quality at offsite water supply wells would be reduced under this alternative when compared to Alternative 2.

Upper Site

Potential impacts on groundwater quality at the Upper Site would be increased under this alternative when compared to Alternative 2 because there would be gravel processing activities at the Upper Site which increases the potential for accidental releases of chemicals or petroleum hydrocarbons. Therefore, the risk of potential impacts on groundwater quality at offsite water supply wells downgradient of the Upper Site would increase under this alternative when compared to Alternative 2. However, the risk would still be considered low given the distance and topographic separation between the Upper Site and the nearest wells.

3.2.3.3 Water Supply

This alternative would require the same amount of water as Alternative 2. Therefore, potential impacts are the same as Alternative 2.

3.2.3.4 Environmental Health

Potential impacts due to the use of a biosolids compost product would be the same as Alternative 2 because this alternative also requires reclamation of both the Lower and Upper Sites.

ALTERNATIVE 3A – UPPER SITE MINING AND LIMITED LOWER SITE MINING

This section describes the potential impacts associated with the Lower Site Option for Alternative 3. Only impacts related to the Lower Site are considered. Impacts for the Upper Site would be the same as for Alternative 3.

Surface Water

Runoff Volume

The impact on runoff volume would be slightly less than Alternative 3 because the disturbed area would be reduced on the Lower Site. Impacts are expected to be minimal.

Surface Water Quality

The onsite impacts on surface water quality would be similar to Alternative 3. Impacts are expected to be minimal.

Floodplain

The Lower Site Option does not include mining within or near the floodplain. No impacts on the 100-year flood elevation are expected from implementation of the Lower Site Option.

South and Middle Forks of the Snoqualmie River

Aquifer recharge would decrease slightly under this alternative when compared to Alternative 3 due to the decrease in the disturbed area. The potential change to flow rates in the South and Middle Forks of the Snoqualmie River due to this small change is considered negligible when compared to Alternative 3. Potential impacts on water quality are similar to Alternative 3.

GROUNDWATER

Buffer Zone

Under this alternative, potential impacts due to the buffer zone are the same as Alternative 3 because the excavation extends to the same depth under both alternatives.

Groundwater Quality

Potential impacts on groundwater quality at the Lower Site would be the same as Alternative 3.

Aquifer Recharge

Under this option, aquifer recharge would decrease slightly when compared to Alternative 3 due to the decrease in the disturbed area on the Lower Site.

Water Supply Wells

Potential impacts on groundwater quality at the Lower Site would be the same as Alternative 3.

WATER SUPPLY

This alternative would require the same amount of water as Alternative 3, but due to the decrease in aquifer recharge the impacts would increase slightly.

ENVIRONMENTAL HEALTH

Potential impacts due to the use of a biosolids compost product would be similar to Alternative 3 for the Lower Site because this option also requires reclamation.

3.2.4 Alternative 4 – Upper Site Mining (Exit 38)

3.2.4.1 Surface Water

RUNOFF VOLUME

The impact on surface water drainage at the Upper Site would be similar to Alternatives 2 and 3. There would be no impacts at the Lower Site because it would not be mined as part of this alternative.

SURFACE WATER QUALITY

The impact on surface water drainage at the Upper Site would be similar to Alternative 3. There would be no impacts at the Lower Site because it would not be mined as part of this alternative.

FLOODPLAIN

Alternative 4 does not include mining within or near the floodplain. No impacts on the 100-year flood elevation are expected from Alternative 4.

SPRING AND STREAMS ON GROUSE RIDGE

Impacts on groundwater recharge at the Upper Site would be similar to Alternative 3. Potential impacts on water quality are considered slightly increased under this alternative because springs and streams on Grouse Ridge are at slightly greater risk due to the increased activities on the Upper Site when compared to Alternative 3. This increased risk would be on the eastern portion of the Upper Site where additional chemical storage and usage would occur. Impacts are expected to be minimal if appropriate controls, policies and procedures are implemented during site operations.

SOUTH AND MIDDLE FORKS OF THE SNOQUALMIE RIVER

Groundwater recharge at the Lower Site would not be affected under this alternative because the site would remain undeveloped. Therefore, potential impacts on rivers would only be related to activities at the Upper Site. Impacts on groundwater recharge at the Upper Site would be similar to Alternative 3. The potential impact on flow rates in the South and Middle Forks of the Snoqualmie River are considered negligible. Potential impacts on water quality are considered slightly increased under this alternative because springs and streams on Grouse Ridge are at slightly greater risk due to the increased activities on the Upper Site when compared to Alternative 3.

3.2.4.2 Groundwater

BUFFER ZONE

Under this alternative, the impacts due to the buffer zone are the same as Alternatives 2 and 3 for the Upper Site because the excavation would extend to the same depth under this alternative. However, there would be no mining at the Lower Site and therefore there would be no impacts related to the buffer zone at the Lower Site.

GROUNDWATER QUALITY

Lower Site

Potential impacts on groundwater quality at the Lower Site would be the same as for the No-Build Alternative (Alternative 1) because the Lower Site would not be developed.

Upper Site

Under this alternative, vehicle fueling and maintenance would be performed on the Upper Site, in addition to those activities included as part of Alternative 3. This increases the potential for accidental releases of petroleum hydrocarbons and other chemicals that would be used or stored on the Upper Site. Due to this increased activity, there is a greater potential that groundwater would be impacted when compared to Alternative 3.

AQUIFER RECHARGE

There would be no impact on groundwater recharge at the Lower Site because it would remain undeveloped. Potential impacts on aquifer recharge at the Upper Site under this alternative are the same as for Alternative 3.

WATER SUPPLY WELLS

Lower Site

The potential for direct impacts on groundwater quality at the Lower Site would be eliminated under this alternative because the Lower Site would not be developed and potential impacts on Upper Site groundwater are not likely to migrate to the Lower Site. Therefore, the risk of potential impacts on groundwater quality at offsite water supply wells near the Lower Site would be almost non-existent under this alternative when compared to Alternatives 2 and 3.

Upper Site

The potential for groundwater quality to be affected at the Upper Site would be increased under this alternative when compared to Alternatives 2 and 3 because gravel processing and vehicle fueling and maintenance activities at the Upper Site increase the potential for accidental releases of chemicals or petroleum hydrocarbons. Therefore, the risk of potential impacts on groundwater quality at offsite water supply wells downgradient of the Upper Site would be increased under this alternative when compared to Alternatives 2 and 3. However, the risk would still be considered low given the distance and topographic separation between the Upper Site and the nearest wells.

3.2.4.3 Water Supply

This alternative would require less water than Alternatives 2 and 3 because water for the concrete batch plant would not be required. Therefore, potential impacts on the water supply would be reduced.

3.2.4.4 Environmental Health

Potential impacts due to the use of biosolids would be limited to the Upper Site because the Lower Site would not be developed.

3.3 SECONDARY AND CUMULATIVE IMPACTS

3.3.1 Alternative 1 – No Action

No cumulative impacts are associated with this alternative.

3.3.2 Alternative 2 – Proposal

The cumulative surface drainage impacts on the surrounding drainage basin resulting from the Proposal are considered minimal. The Proposal would contain nearly all surface runoff, and discharges from the site would generally be to groundwater. Although the project would intercept some stormwater, and thereby prevent it from reaching groundwater, the volume removed is considered minimal and the net effect to groundwater flow rates should be negligible.

Surface water quality would be monitored over the life of the project in accordance with applicable Mining, Grading and discharge permits to ensure that discharge to groundwater is not affected. Because the threat would be identified at the surface, any contamination would be identified before it could affect the Middle or South Forks of the Snoqualmie River. If surface impacts were not identified, the groundwater monitoring program would be designed to identify both potential contaminants, and be sampled at a sufficient interval to identify potential impacts before they migrated off site.

Although there are no indications that a significant impact on the drainage basin would result from the Proposal, continual monitoring of drainage issues would prevent any unidentified adverse impacts from occurring.

Groundwater withdrawals in the Snoqualmie Valley can be expected to increase as development continues. Future groundwater uses may include residential, commercial, and municipal withdrawals.

The extraction of groundwater for the Proposal would contribute to this overall increase in groundwater usage. This would decrease the quantity of groundwater available for other development in the vicinity of the Lower Site. The use of groundwater at the Lower Site would be offset in part by enhanced recharge at the Upper Site; however, this recharge is in a different location than where the water would be extracted. Although recharge at the Upper Site, like the groundwater beneath the Lower Site, would be expected to ultimately discharge into the Middle and/or South Fork of the Snoqualmie River, the time required for the water to reach the rivers would likely change as a result of the proposal. The timing of this discharge may be important because groundwater provides baseflow to the streams and rivers in the area during the late summer and fall. The cumulative impact of groundwater withdrawal associated with the Proposal and other withdrawals in the basin, could reduce baseflows.

3.3.2.1 Alternative 2A – Upper Site Mining and Limited Lower Site Mining

The cumulative impacts for the Lower Site Option for Alternative 2 would be the same as for Alternative 2.

3.3.3 Alternative 3 – Lower and Upper Sites Mining (Exit 34 and Exit 38)

Under Alternative 3, the overall disturbed area would be less, and the natural drainage on the west face of Grouse Ridge would not be affected. The remaining cumulative impacts would be similar to Alternative 2.

3.3.3.1 Alternative 3A – Upper Site Mining and Limited Lower Site Mining

The cumulative impacts for the Lower Site Option for Alternative 3 would be the same as for Alternative 3.

3.3.4 Alternative 4 – Upper Site Mining (Exit 38)

Under Alternative 4, the overall disturbed area would be less. The Lower Site would remain undisturbed and the existing drainage at the Lower Site and the natural drainage on the west face of Grouse Ridge would not be affected. Cumulative impacts are not expected at the Lower Site. The cumulative Upper Site impacts would be similar to Alternative 3, although no concrete or asphalt plants would be located at the Upper Site.

3.4 SUMMARY OF MITIGATION MEASURES

3.4.1 Alternative 1 – No Action

No impacts requiring mitigation were identified for this alternative.

3.4.2 Alternative 2 – Proposal

3.4.2.1 Surface Water

The overall goal of surface water protection for this site is to minimize erosion, control sediment transport and deposition, and prevent impacts from chemicals and products used during site operations. The following actions are proposed to mitigate potential impacts:

- Temporary erosion and sediment controls should be inspected on a daily basis and continually adjusted to match current site conditions and operations.
- Permanent erosion and sediment controls should be inspected and maintained on a routine, scheduled basis in accordance with established operating policies and procedures.
- New employee training and periodic updates should emphasize the importance of surface water protection, operating policies and procedures, and proper chemical and product handling, storage, and disposal.
- Permanent drainage features and controls should be constructed as each phase of development occurs and maintained throughout the period of operation.
- Completed phases of gravel extraction and grading should be restored and revegetated in a timely manner.
- Long-term monitoring of surface water quality should be implemented during construction, operation, and post-closure.

3.4.2.2 Groundwater

AQUIFER RECHARGE

The construction of drainage features, the use of infiltration ponds, and reclamation have the potential to change the distribution of recharge across the Upper Site. If this recharge pattern is disturbed, it may impact the flow of water in upland streams and springs on the flanks of the ridge. The overall goal should be to manage stormwater runoff during site development and reclamation to maintain the natural pattern of recharge. The following actions are proposed to mitigate potential impacts:

- Infiltration ponds should be located over areas where the shallow and/or deep perching layers are present and in close proximity to the springs so that infiltrating water has the potential to discharge to the springs.
- Infiltration ponds should be located as close as possible to the area where the stormwater is collected. It is recommended that at a minimum, each 50-acre area that is mined should have its own infiltration pond.
- Maintenance, such as periodic removal of fine-grained sediments, should be performed as needed to optimize pond function. This maintenance should be included as part of the drainage design and Operations & Maintenance plan.

- To prevent surface water runoff from flowing out of each 50-acre area, berms should be maintained around the perimeter of each area.

GROUNDWATER QUALITY

The following action is proposed to mitigate potential groundwater quality impacts:

To maintain groundwater quality and minimize potential introduction of turbid water into groundwater beneath the Lower and Upper Sites, stormwater infiltration ponds should be designed in accordance with the King County SWDM to filter out suspended silt and clay.

BUFFER ZONE

Lower Site

To maintain an adequate buffer zone at the Lower Site the following mitigation measures are proposed:

- Excavation in the easternmost portion of the Lower Site should be limited to periods when it can be reasonably demonstrated based on the water levels in the existing wells that a buffer zone of at least 10 feet is present.
- Regular inspections and maintenance should be performed to ensure that the groundwater seepage interception trench is functioning properly.
- A shallow piezometer should be installed adjacent to the seepage interception trench and monitored periodically during the winter and early spring to confirm that the groundwater interception trench is maintaining a minimum 5-foot buffer zone. Based on the groundwater gradient across the site, this will provide a buffer zone of at least 10 feet in the eastern portion of the site, and over 20 feet in the central and western portion of the Lower Site.
- In the event that the trench does not maintain an adequate buffer zone, active dewatering (i.e., pumping) should be required. Groundwater removed by the interception trench and/or pumping would be transferred into the infiltration pond, where it would be returned to the groundwater system. If a 5-foot buffer zone cannot be maintained, operations should be removed from any portion of the mine pit without a sufficient buffer zone.

Upper Site

The Upper Site excavation plan includes excavation to a base elevation of 1,535 feet above msl. To maintain a buffer zone at the Upper Site and mitigate potential impacts to water quality, the following actions are proposed:

- Avoid excavation in areas where groundwater associated with the shallow and deep perching layers are within 5 feet of the base of the excavation. It is expected that this would seasonally restrict excavation in a relatively small portion of the Upper Site.
- Cease excavation in areas where perched groundwater is encountered above an elevation of 1,540 feet above mean sea level. Excavation could continue in these areas provided the water level declines sufficiently to maintain a 5-foot buffer zone and measures are taken, such as berming, to

prevent flow of water into other areas if the excavation and to prevent the introduction of contaminants into the seasonally exposed perched groundwater.

GROUNDWATER MONITORING

Lower Site

The following groundwater monitoring activities are proposed to confirm that the mitigation measures designed to protect groundwater quality are effective and to confirm assumptions regarding hydrogeologic conditions beneath the Lower Site:

- Water level data from the existing onsite wells, the well proposed in the area northwest of the processing area and Sallal Well No. 3 should be collected at regular intervals to confirm the direction of groundwater flow beneath the western portion of the Lower Site. If the water levels in the existing wells indicate that groundwater flow at the site changes seasonally or in response to pumping, an additional monitoring well or wells should be installed to confirm groundwater flow direction.
- Based on the groundwater flow direction confirmed through the measurements recommended above, an additional monitoring well or wells should be installed downgradient of the processing area in the event that the well proposed in the northwest portion of the site is not located downgradient.
- A groundwater quality monitoring plan should be implemented to assess potential impacts to groundwater quality. Minimum plan design should determine critical data elements, data collection techniques, frequency of monitoring, parameters for analysis, data reporting, location of monitoring stations, depth of monitoring well(s), independence of data gathering, interpretation of data, measurement and determination of direct impact to either buffer zone or to nearby wells from operations, required operator response to direct observable impact in either regard, and any other information or data necessary to comply with federal, state and local regulations and mitigation conditions necessary to prevent significant environmental impact. The program should include at a minimum baseline sampling and analysis, prior to construction, to provide data for comparison with future monitoring results. Following construction, the frequency of monitoring should consider the proximity of the nearest receptors (such as downgradient wells), the estimated groundwater velocity, and the anticipated response time for any corrective action that may be required in the event that groundwater quality is affected. Groundwater samples should be analyzed for chemicals (such as coagulants and flocculents) and petroleum products that would be used and stored on the site and are considered hazardous substances. Other analytes that should be considered include metals, turbidity, pH and any other parameters which are required by the Grading permit and other applicable permits.

Upper Site

To provide the data needed to maintain a buffer zone at the Upper Site, the following actions are proposed:

- Collect additional baseline water level data during the winter and spring using the existing monitoring wells on the Upper Site to further assess the potential areas where the groundwater perched on the shallow perching layer may intercept the base of the planned excavation.
- Maintain the wells installed above the shallow perching layer during the excavation and monitor the water levels in these wells.

If Cadman, Inc. is interested in excavating deeper than an elevation of 1,535 feet above msl, further evaluation of the hydrogeologic information collected at the Upper Site should be required. It is expected that excavating deeper could have a significant impact on the springs and upper reaches of the streams that originate on Grouse Ridge if the silty layers that appear to perch groundwater below an elevation of 1,535 feet above msl are breached. This option to excavate beyond an elevation of 1535, if selected by Cadman, Inc., would require a Supplemental EIS, including appropriate mitigation for groundwater and surface water impacts that could arise from excavating to a greater depth. This assessment could be performed in conjunction with King County's 5-year project review.

SPRING AND SURFACE WATER MONITORING

To provide baseline data and assess potential impacts to springs and surface water on the Upper Site, the following actions are proposed:

- Collect additional periodic data regarding flow rates in the springs and streams around the perimeter of Grouse Ridge before excavation begins on the Upper Site to provide a baseline against which post-excavation stream gauging data can be compared.
- Baseline water quality data from a limited number of springs on the north and south sides of the ridge should be collected to document existing conditions. The analytes should include turbidity, as well as those required by the Sand & Gravel General Permit, Grading permit and other applicable permits.
- Once the gravel operation is active on the Upper Site, regular observations and measurements of stream flow should be performed to confirm that impacts are not significant. Water quality testing should not be necessary unless the impacts to the water are visually evident (for example, the water appears turbid) or as required by the Grading permit and other applicable permits.

3.4.2.3 Water Supply

The following actions are proposed to mitigate the potential impacts associated with the use of groundwater at the Lower Site:

- The water supply well should be located in an area of the property and screened at a depth where it can be shown that there would be no significant interference with the water levels in nearby water supply wells due to the pumping of groundwater at the Lower Site.

- If pumping impacts are predicted or observed based on the test pumping of the proposed well, Ecology has the jurisdiction to either deny the right, or to approve the right with limitations or mitigation requirements. However, because no groundwater withdrawals are proposed at the Upper Site, and aquifer recharge at the site will be increased due to excavation activities, no adverse groundwater quantity impacts will occur in the Middle or South Fork valleys. In the event that Ecology does not grant a water right, the site should be operated as a 'pit run' only operation. Dry screening and vibratory wheel washing could be used as alternatives to water for the washing process.
- A contingency water supply plan should be prepared to provide a high-quality water supply to the Sallal Water Association (e.g., a new well or water treatment). The plan could then be implemented if impacts from the mining operation were detected at that well.

3.4.2.4 Environmental Health

The following actions are proposed to mitigate the potential impacts associated with the use of GroCo and to confirm that the mitigation measures are effective in protecting groundwater quality:

- A site-specific agronomic application rate for GroCo should be developed if this soil amendment is used during site reclamation.
- A land application plan for the use of GroCo should be developed for the Lower and Upper Sites prior to reclamation if GroCo would be applied in greater than agronomic rates. The plan should be prepared in accordance with the requirements of WAC 173-308-310(6)(iii) because there is a public benefit to ensuring that groundwater resources in the vicinity are not impacted.
- If GroCo or other fertilizers are used for reclamation, groundwater beneath the Lower and Upper Sites should be sampled and analyzed for nitrates to detect potential impacts. If impacts are detected, corrective action should be taken to restore groundwater quality.

3.4.2.5 Alternative 2A – Upper Site Mining and Limited Lower Site Mining

Mitigation measures for the Lower Site Option for Alternative 2 would be the same as for Alternative 2.

3.4.3 Alternative 3 – Lower and Upper Sites Mining (Exit 34 and Exit 38)

3.4.3.1 Surface Water, Water Supply, and Environmental Health

The mitigation measures for surface water, water supply, and environmental health described under Alternative 2 would also apply to Alternative 3.

3.4.3.2 Groundwater

The mitigation measures for groundwater described under Alternative 2 would also apply to Alternative 3. In addition, the following mitigation measures are proposed:

- A more detailed groundwater investigation should be performed on the portion of the Upper Site that would be used for sand and gravel processing, because this is a permanent facility and seasonal high groundwater cannot be easily avoided by working in other areas.

- A buffer zone of 10 feet above the seasonal high water table should be maintained in this area to account for potential water table fluctuation. If an interception trench were installed, the buffer zone could be decreased to 5 feet.

3.4.3.3 Alternative 3A – Upper Site and Limited Lower Site Mining

Mitigation measures for the Lower Site Option for Alternative 3 would be the same as for Alternative 3.

3.4.4 Alternative 4 – Upper Site Mining (Exit 38)

3.4.4.1 Surface Water and Water Supply

The mitigation measures for surface water and water supply described under Alternative 2 would also apply to Alternative 4.

3.4.4.2 Groundwater

No mitigation would be required for the Lower Site under this alternative because it would not be mined. The mitigation measures for groundwater at the Upper Site described under Alternative 3 would also apply to Alternative 4.

ENVIRONMENTAL HEALTH

No mitigation measures would be required for the Lower Site under this alternative because it would not be mined. The mitigation measures for environmental health for the Upper Site described under Alternative 2 would also apply to Alternative 4.

3.4.5 Significant Unavoidable Adverse Impacts

The project is unlikely to have significant and unavoidable adverse impacts on water or environmental health if the proposed mitigation measures described above are applied.

Table 1
Monthly Precipitation Data (Inches) for Cedar Lake and Grouse Ridge 1995-2001
North Bend Gravel Operation

Month	1995		1996		1997		1998		1999		2000		2001		Average[1]	
	Cedar Lake[2]	Grouse Ridge[3]	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge	Cedar Lake	Grouse Ridge
January	8.97	7.2	12.32	9.9	13.36	10.7	16.02	12.8	14.54	11.6	6.71	5.4	7	5.6	13.34	10.7
February	11.56	9.2	16.02	12.8	9.66	7.7	7.32	5.9	13.41	10.7	8.85	7.1	4.18	3.3	10.37	8.3
March	9.3	7.4	4.74	3.8	17.4	13.9	10.07	8.1	6.93	5.5	8.84	7.1	11.42	9.1	10.36	8.3
April	6.26	5.0	14.3	11.4	11.36	9.1	3.84	3.1	3.0	2.4	9.84	7.9	NA	NA	8.14	6.5
May	4.12	3.3	9.38	7.5	6.71	5.4	6.35	5.1	8.27	6.6	9.07	7.3	NA	NA	6.07	4.9
June	6.21	5.0	1.49	1.2	7.99	6.4	3.94	3.2	6.56	5.2	6.31	5.0	NA	NA	5.35	4.3
July	2.68	2.1	2.28	1.8	5.26	4.2	0.8	0.6	4.62	3.7	1.23	1.0	NA	NA	2.52	2.0
August	4.24	3.4	2.67	2.1	2.48	2.0	1.09	0.9	2.91	2.3	1.55	1.2	NA	NA	2.69	2.2
September	3.03	2.4	6.76	5.4	6.59	5.3	1.43	1.1	1.55	1.2	5.71	4.6	NA	NA	5.21	4.2
October	13.04	10.4	13.78	11.0	14.12	11.3	8.81	7.0	8.82	7.1	7.99	6.4	NA	NA	9.36	7.5
November	21.4	17.1	15.01	12.0	9.0	7.2	22.63	18.1	22.65	18.1	7.46	6.0	NA	NA	14.06	11.2
December	12.04	9.6	14.89	11.9	10.13	8.1	22.49	18.0	11.88	9.5	6.22	5.0	NA	NA	14.21	11.4
Total	102.85	82.3	113.64	90.9	114.06	91.2	104.79	83.8	105.14	84.1	79.78	63.8	NA	NA	101.68	81.3

Notes:
[1] Based on period of record (1/1931 to 7/2000)
[2] Precipitation data from NOAA station #451233, Cedar Lake, Washington
[3] Grouse Ridge precipitation calculated as 80% of Cedar Lake precipitation, based on Golder, 1996
NA - Not Available

Table 2
Monthly Surface Water Flow Data for the Middle and South Forks of the Snoqualmie River 1995-2000
North Bend Gravel Operation

Date	Monthly Average Flow, cfs	
	South Fork[1]	Middle Fork[2]
January 1995	249	1120
February 1995	648	2440
March 1995	277	995
April 1995	261	825
May 1995	471	1440
June 1995	235	1003
July 1995	97	536
August 1995	78	464
September 1995	46	235
October 1995	404	1640
November 1995	1160	4534
December 1995	427	1623
January 1996	549	2057
February 1996	744	2807
March 1996	231	725
April 1996	446	1442
May 1996	415	1392
June 1996	242	947
July 1996	86	514
August 1996	56	369
September 1996	87	449
October 1996	292	1425
November 1996	386	1759
December 1996	208	1237
January 1997	452	2142
February 1997	449	1681
March 1997	536	2014
April 1997	511	1764
May 1997	857	2770
June 1997	657	2452
July 1997	396	1741
August 1997	89	429
September 1997	134	776
October 1997	419	1794
November 1997	281	1085
December 1997	248	1072
January 1998	292	1307
February 1998	226	820
March 1998	296	1130
April 1998	310	939
May 1998	548	1793
June 1998	323	1347
July 1998	93	537
August 1998	35	193
September 1998	26	135
October 1998	95	548
November 1998	572	2408
December 1998	581	2498
January 1999	472	1805
February 1999	223	989
March 1999	214	884
April 1999	284	936
May 1999	556	1762
June 1999	777	2656
July 1999	473	1919
August 1999	127	727
September 1999	47	271
October 1999	153	827
November 1999	626	2648
December 1999	670*	2589
January 2000	175*	733
February 2000	165	739
March 2000	207	749
April 2000	486	1695
May 2000	562	1975
June 2000	508	2250
July 2000	143	776
August 2000	47	302
September 2000	145	754
October 2000	196	980
November 2000	100	550
December 2000	80	624
January 2001	157	802
February 2001	121	563
March 2001	251	1001

Notes:
[1] USGS Gage 12143400
[2] USGS Gage 12141300
* incomplete data
cfs = cubic feet per second

Table 3
Water Quality Data, Snoqualmie River at Snoqualmie Falls - 1995-2000
Washington Department of Ecology Station No. 07D130 (Snoqualmie Falls)
North Bend Gravel Operation

Date	Flow (cfs)	Temperature (Celsius)	Conductivity (umohs/cm)	pH	Suspended Solids (mg/l)	Turbidity (NTU)	Fecal Coliform (#/100ml)	Total Nitrate + Nitrite (mg/l)	Total Phosphorus (mg/l)
1/16/95	2,380	4.7	32	7.1	4	3.3	3	0.28	0.02
2/20/95	16,900	4.7	19	7.0	109	35	32	0.17	0.08
3/20/95	3,640	5.9	25	7.1	6	5.9	2	0.20	0.01
4/17/95	2,140	6.5	35	7.5	3	2.2	5	0.22	0.19
5/15/95	3,720	9.4	23	7.7	7	3.4	36	0.08	0.01
6/19/95	2,280	10.0	28	7.5	4	1.5	23	0.09	0.01
7/17/95	947	16.0	44	7.9	3	1.0	28	0.14	0.01
8/21/95	947	13.7	43	7.5	2	0.9	14	0.13	0.01
9/18/95	412	14.0	60	7.3	3	0.9	69	0.19	0.01
10/16/95	2,520	10.1	33	7.2	5	2.5	17	0.21	0.01
11/19/95	4,210	6.9	27	7.4	11	5.5	7	0.18	0.01
12/17/95	3,620	5.4	33	7.2	14	6.5	7	0.26	0.01
1/22/96	2,780	130.0	36	7.3	11	9.1	19	0.28	0.02
2/19/96	7,760	5.1	21	7.1	49	37	6	0.16	0.04
3/18/96	1,950	5.5	35	7.2	6	5.7	1	0.19	0.01
4/22/96	2,130	7.6	32	7.5	6	4.0	4	0.17	0.01
5/20/96	4,100	7.4	23	7.6	17	11	11	0.11	0.01
6/17/96	1,710	10.3	32	7.4	6	3.3	10	0.11	0.01
7/22/96	947	14.0	43	7.4	5	3.7	33	0.13	0.01
8/19/96	554	12.8	49	7.2	4	1.8	44	0.19	0.02
9/16/96	1,680	10.6	30	7.5	20	13	NA	0.21	0.02
10/21/96	2,195	5.6	30	7.5	5	4.3	11	0.32	0.01
11/18/96	2,760	3.7	31	7.8	8	7.2	4	0.27	0.01
12/15/96	2,040	4.5	37	7.1	5	4.3	1	0.33	0.02
1/20/97	5,630	3.7	23	6.7	24	17	5	0.19	0.02
2/17/97	5,550	3.9	23	7.0	16	9.7	1U	0.25	0.05
3/17/97	3,600	4.0	30	7.3	26	29	5	0.32	0.04
4/21/97	8,340	3.9	20	7.5	36	18	9	0.14	0.07
5/19/97	5,420	5.8	19	7.5	10	5.9	4	0.03	0.04
6/16/97	4,880	8.5	17	7.5	11	6.6	13	0.05U	0.04
7/21/97	2,930	12.7	25	7.1	4	2.7	20	0.09	0.02
8/18/97	739	13.7	45	7.1	2	0.9	16	0.15	0.02
9/21/97	1,750	11.5	30	7.5	3	2.9	38	0.22	0.04
10/20/97	1,430	7.1	33	7.5	1	2.5	3	0.20	0.02
11/17/97	1,140	5.6	44	7.4	3	2.1	11	0.25	0.02
12/15/97	1,030	4.2	44	7.5	5	5.0	2	0.26	0.01
1/19/98	4,380	3.8	30	7.2	21	20	7	0.27	0.02
2/17/98	1,880	4.3	37	7.0	4	3.1	1	0.27	0.02
3/16/98	3,200	4.7	29	7.5	8	5.3	17	0.22	0.02
4/20/98	1,710	6.2	33	7.6	2	1.9	3	0.19	0.03
5/18/98	4,680	5.8	18	7.5	26	22	49	0.13	0.04
6/22/98	2,390	11.3	27	7.5	4	0.9	28	0.07	0.01
7/20/98	835	13.3	35	7.3	4U	1.0	28J	0.14	0.02
8/17/98	490	12.6	60	7.4	4U	1.5	77	0.17	0.01
9/21/98	308	12.0	55	7.0	2	1.3	23	0.25	0.01
10/19/98	1740	5.6	28	7.5	2	1.4	14	0.27	0.01
11/16/98	7330	5.9	21	NA	34	20	6	0.30	0.02
12/14/98	7880	3.8	25	7.3	34	17	4	0.29	0.03
1/18/99	5750	3.6	23	7.4	17	11	15	0.29	0.02
2/15/99	1520	3.2	48	6.9	3	2.1	2	0.39	0.01
3/22/99	3360	4.0	18	7.0	8	4.2	1U	0.20	0.02
4/19/99	3550	4.2	26	7.0	NA	NA	NA	NA	NA
5/24/99	8320	5.1	15	7.0	73	29.0	8	0.11	0.04
6/21/99	4210	6.5	20	7.6	11	7.1	45	0.08	0.02
7/19/99	3330	9.1	19	7.1	6	3.2	11	0.07	0.01
8/15/99	1290	11.8	28	7.3	2	1.3	31	0.11	0.01
9/19/99	600	10.9	44	7.2	3	0.9	38	0.17	0.01
10/18/99	NA	5.7	51	7.1	3	1.3	9	0.21	0.02
11/1/99	NA	4.2	26	7.4	6	4.4	9	0.25	0.02
12/6/99	NA	4.1	31	7.1	12	7.4	8	0.27	0.02
1/17/00	NA	4.5	41	7.2	3	3.5	3	0.33	0.01
2/13/00	NA	2.0	39	7.6	2	2.4	3	0.26	0.01
3/20/00	NA	2.6	34	7.9	5	4.8	1U	0.248	0.012
4/17/00	NA	3.8	24	7.7	15	5.3	2	0.178	0.01U
5/15/00	NA	5.8	24	7.5	9	3.2	22	0.135	0.01
6/19/00	NA	6.3	21	7.2	6	3.5	13	0.111	0.01U
7/17/00	NA	11.2	34	7.1	3	1.3	10	0.108	0.01U
8/21/00	NA	12.8	50	7.1	NA	1.2	27	0.18	0.01U
9/18/00	NA	13.5	46	7.11	11	1.3	38	0.183	0.013
10/16/00	NA	8.1	41	7.31	1	1	14	0.194	0.01U
11/13/00	NA	3.2	41	7.39	1	0.8	1J	0.243	0.01
12/4/00	NA	3.6	35	7.39	2	1.5	1UJ	0.291	0.014
1/22/01	NA	3.6	32	7.58	NA	NA	NA	NA	NA
Data range for period of record		2.0-14	15-60	6.7-7.9	1-109	0.6-37	1-69	0.03-0.33	0.01-0.19
Water Quality Standards		18 [1]	NA	6.5-8.5 [1]	NA	5 [1]	100 [1]	10 [2]	NA

Notes:

[1] Surface Water Standards per WAC 173-201A (1997) for Class A surface waters
[2] EPA Drinking Water Standards (1975)
cfs = cubic feet per second
umohs/cm = micromohs per centimeter
mg/l = milligrams per liter

NTU = nephelometric turbidity units
ml = milliliters
NA = Data Not Available
U - not detected at reported limit
J - Estimated result

Table 4
Spring Locations and Elevations
North Bend Gravel Operation

Spring Identification	Northing (feet)	Easting (feet)	Spring Elevation (feet above MSL) [1]	Snoqualmie River Drainage Basin	Weir I.D.	Weir Elevation (feet above MSL)
S-1	12528	7895	1446.1	Middle Fork	W-1/2/3	1421.5
S-2	12542	7917	1445.0	Middle Fork		
S-3	12550	7828	1447.6	Middle Fork		
S-4	12600	8064	1443.3	Middle Fork	W-4	1348.5
S-5	10025	10127	1388.0	South Fork	NA	NA
S-6	-	-	~1470	Middle Fork	W-6	1464.1
S-7	-	-	~1460	Middle Fork	W-7	1437.7
S-8	-	-	~1500	South Fork	NA	NA
S-9	-	-	~1460	South Fork	NA	NA
S-10	-	-	~ 1450	Middle Fork	W-10	1445.5
S-11	-	-	~ 1460	South Fork	W-11	1430.6
S-12	-	-	~ 1470	South Fork	W-12	1467.7
S-13	-		~ 1480	South Fork	W-13	1452.7
S-14	-	-	~ 1480	South Fork	W-14	1448.7

Notes:
[1] Elevations for Springs S-1 through S-5 were surveyed relative to mean sea level.
Elevations for S-6 through S-14 were approximated in the field using altimeter or topographic map data.
NA - No weir established at this spring

Table 5
Spring Discharge Measurements
North Bend Gravel Operation

Basin	Spring/Drainage Discharge (cfs)									North side total (cfs)	South side total (cfs)
	Middle Fork Snoqualmie					South Fork Snoqualmie					
Spring	S-1/S-2/S-3	S-4	S-6	S-7	S-10	S-11	S-12	S-13	S-14		
Weir	W-1/2/3	W-4	W-6	W-7	W-10	W-11	W-12	W-13	W-14		
Date											
03/02-03/2000	0.06	0.15	0.03	0.04	NA	0.09	0.06	0.05	0.09	NA	0.29
3/6/00	0.05	0.14	0.02	0.03	0.07	0.07	0.05	0.04	0.07	0.32	0.24
3/13/00	0.04	0.12	0.02	0.02	0.07	0.05	0.05	0.04	0.07	0.27	0.21
3/21/00	0.06	0.13	0.02	0.03	0.07	0.06	0.05	0.04	0.08	0.32	0.22
4/7/00	0.06	0.14	0.02	0.03	0.07	0.06	0.05	0.04	0.07	0.33	0.21
4/26/00	0.05	0.12	0.02	0.03	0.08	0.05	0.04	0.04	0.08	0.30	0.21
5/26/00	0.04	0.12	0.04	0.06	0.05	0.06	0.04	0.04	0.07	0.32	0.21
06/27-28/00	0.05	0.11	0.01	0.02	0.04	0.03	0.04	0.03	0.06	0.23	0.15
7/27/00	0.03	0.07	0.01	0.01	0.03	0.02	0.03	0.02	0.06	0.15	0.13
8/30/00	0.02	0.04	0.01	0.02	0.02	0.01	0.03	0.02	0.05	0.11	0.11
9/28/00	0.02	0.02	0.00	0.01	0.02	0.00	0.02	0.01	0.05	0.06	0.09
10/28/00	0.01	0.01	0.01	0.02	0.02	0.01	0.03	0.01	0.05	0.07	0.10
11/30/00	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.04	0.07	0.09
12/28/00	0.04	0.04	0.02	0.01	0.01	0.00	0.02	0.01	0.04	0.12	0.08
1/31/01	0.03	0.04	0.01	0.01	0.04	0.01	0.02	0.01	0.05	0.12	0.09
2/28/01	0.04	0.04	0	0.01	0.05	0	0.03	0.01	0.04	0.14	0.08
3/27/01	0.03	0.02	0.01	0.01	0.04	0	0.03	0.02	0.04	0.11	0.09

Notes:
cfs = cubic feet per second (1 cfs = approximately 449 gallons per minute)

Table 6
Water Supply Wells within a 1-mile radius of the site
North Bend Gravel Operation

Well Location [1]	Owner[2]	Use	Approximate Surface Elevation[3]	Well Depth	Water Level[4]	Screened Interval	Aquifer Screened[5]	Information Source[6]
			feet above MSL	feet bgs	feet bgs	feet bgs		
T23N/R08E								
12R	Hamilton, M.	domestic	570	99	57	no screen	S	a
13Q	Everson, T.	domestic	650	300	124	240-300	B	a
13N	Highline School Dist. #401	test well	580	199	77	179-194	D	a
13R1	Anderson, G.	domestic	700	63	660	no screen	-	b
13R2	Forrester, S.	domestic	710	237	520	no screen	-	b
14G	Alyea, M.	domestic	528	96	30	no screen	S	a
23A	Riverbend Assoc.	municipal	520	60	22	35-60	S	a
23B	Riverbend Assoc.	municipal	500	62	4	52-62	S	a
24A	Rogers, K.	Industrial	650	207	143	197-207	D	a
24B	Schoenbaum, F.	domestic	630	97	25	no screen	S	a
24H	Wonsley, D.	domestic	610	119	74	no screen	S	a
24K	Douglass, D.	irrigation	600	25	4	no screen	S	a
24R	Shea, D.	domestic	610	60	34	no screen	S	a
25A1	Anderson, B.	domestic	590	26	6	no screen	S	a
25A2	Bogden, M.	domestic	590	45	20	no screen	S	a
25K	Wallsh, S.	domestic	670	109	44.8	no screen	B	a
25R	Meyers, E.	domestic	800	315	199	no screen	S	a
T23N/R09E								
17F	Peck, J.	municipal	730	48	0	no screen	S	a
18A	Anger, R.	domestic	920	180	158	no screen	S	a
18F	Strode, J.	domestic	800	88	57	81-88	S	a
18P	Sallal Water District	municipal	785	255	200	238-248	D	a,c
19D	Sallal Water District	domestic	700	273	183	258-273	D	a,c
19N	Cloud, D.	domestic	580	54	4	49-54	S	a
20A	Community Well	domestic	800	-	-	-	-	b
20B1	Middle Fork Well Association (Ferris, B.)	domestic multiple	780	272	70	no screen	D	a, b
20B2	Roloson, J.	domestic	820	400	48	no screen	B	a
20B3	Kasperski	domestic	810	-	-	-	-	b
20D	Olson, B.	domestic	800	48	32	no screen	S	a,c
20H	Valley Camp	domestic	800	35	26	-	S	b
28C	Dept. of Corrections	Industrial	1600	738	596	697-712	U	a
29A	Saemmer, J.	domestic	1100	40	26.5	no screen	S	a
29J1	Saemmer, J.	domestic	1090	29	9	no screen	S	a
29J2	Barkdale, E	domestic	1120	31	15	no screen	S	a
29N	Castagno, K.	domestic	1100	45	8	no screen	S	a
29Q	Brandalise, J.	domestic	1300	100	28	no screen	B	a
29R	Bianchi, L	domestic	1250	40	9.5	no screen	S	a
30C1	South Fork Water Supply	municipal	600	52	21	no screen	S	a
30C2	Oberlander, J.	domestic	620	33	14	no screen	S	a

Notes

[1] Letters designate 1/4, 1/4 Section based on USGS nomenclature system. Individual locations are based on well log or field inventory information. Locations for wells not field verified were estimated based on available information including 1/4,1/4 sections, address and owner.

[2] Owner identified on water well report. Current owners may be different than those indicated in table.

[3] Elevations are relative to Mean Sea Level (MSL) and were estimated from topographic maps.

[4] Water level is based on water levels reported on the original well log.

(-) Indicates no data available or unknown

[5]Aquifer Screened
S=Shallow Valley Aquifer
D=Deep Valley Aquifer
B=Bedrock
U=Upland Aquifer

[6]Information Sources
a= Washington State Water Well Reports
b= Department of Ecology Water Rights Database
c= Dames & Moore, Hart Crowser, or Golder field verified

Table 7
Water Quality Data, Sallal Water District Well No. 3
North Bend Gravel Operation

Analyte	Unit	Results		MCL
		November-96	August-99	
Antimony	mg/l	<0.005	<0.005	0.005
Arsenic	mg/l	<0.01	<0.01	0.05
Barium	mg/l	<0.1	<0.1	2
Beryllium	mg/l	<0.002	<0.002	0.004
Cadmium	mg/l	<0.002	<0.002	0.005
Chromium	mg/l	<0.01	<0.01	0.1
Copper	mg/l	<0.02	<0.2	1.3
Iron	mg/l	<0.05	<0.05	0.3
Lead	mg/l	<0.002	<0.002	0.015
Manganese	mg/l	<0.010	<0.010	0.05
Mercury	mg/l	<0.0005	<0.0005	0.002
Nickel	mg/l	<0.04	<0.04	0.1
Selenium	mg/l	<0.005	<0.005	0.05
Silver	mg/l	<0.01	<0.01	0.05
Sodium	mg/l	3.4	<5	20
Thallium	mg/l	<0.001	<0.001	0.002
Zinc	mg/l	<0.050	<0.2	5
Hardness	mg/l	72	66.1	NA
Conductivity	umohs/cm	130	146	700
Turbidity	NTU	<0.1	0.3	1
Color	color units	<5	<5	15
Chloride	mg/l	<20	<20	250
Cyanide	mg/l	<0.1	<0.1	0.2
Fluoride	mg/l	<0.5	<0.5	2
Nitrate	mg/l	0.52	0.5	10
Nitrite	mg/l	<0.5	<0.5	1
Sulfate	mg/l	<10	<10	250
Aluminum	mg/l	<5	NA	NA
pH	standard units	7.1	NA	6.5-8.5

Notes:
MCL= maximum contaminant level (Federal Drinking Water Standard)
mg/l= milligrams per liter
umohs/cm= micromohs per centimeter
NTU= nephelometric turbidity units
NA= not available

Table 8
Lower Site Monitoring Well and Boring Data
North Bend Gravel Operation

Boring/Well Identification	Drilling Date	Boring Depth (feet)	Ground Surface Elevation (feet above MSL)	Boring Base Elevation (feet above MSL)	Depth to Screened Interval (feet bgs)	Elevation of Screened Interval (feet above MSL)
Inside Proposed Excavation Footprint						
GR95-12	Sep-95	100	678	578	65-90	613-588
GR98-1	Jan-98	89	697	608	78-88	619-629
GR98-7	Jan-98	80	677	597	NA	NA
GR99-1	May-99	130	722	592	110-130	612-591
Outside Proposed Excavation Footprint						
GR98-3	Jan-98	100	680	580	NA	NA
GR98-4	Jan-98	125	835	710	99-109	736-746
GR98-6	Jan-98	130	693	563	NA	NA

Notes:
MSL = Mean Sea Level
bgs = below ground surface
NA = not applicable (boring not completed as a well)

Table 9
Upper Site Monitoring Well and Boring Data
North Bend Gravel Operation

Boring/Well Identification	Drilling Date	Boring Depth (feet)	Ground Surface Elevation (feet above MSL)	Boring Base Elevation (feet above MSL)	Depth to Screened Interval (feet bgs)	Elevation of Screened Interval (feet above MSL)	Screened Perching Zone
Inside Proposed Excavation Footprint							
GR-1[1]	Aug-83	220	1640	1420	NA	NA	NA
GR95-1	Sep-95	90	1607	1517	NA	NA	NA
GR95-2	Sep-95	200	1641	1441	120-140	1521-1501	Shallow
GR95-3	Sep-95	180	1654	1474	143-153	1511-1501	Shallow
GR95-4	Sep-95	125	1636	1511	NA	NA	NA
GR95-5	Sep-95	100	1635	1535	NA	NA	NA
GR95-6	Sep-95	116	1655	1539	NA	NA	NA
GR95-7	Sep-95	170	1635	1465	NA	NA	NA
GR95-8	Sep-95	140	1628	1488	NA	NA	NA
GR95-9	Sep-95	130	1607	1477	NA	NA	NA
GR95-10	Sep-95	270	1646	1376	NA	NA	NA
GR95-11	Sep-95	220	1633	1413	NA	NA	NA
GR00-1	Feb-00	240	1631	1391	150-160	1481-1471	Deep
GR00-2	Jan-00	240	1640	1400	144-154	1496-1486	Deep
GR00-4	Jan-00	220	1636	1416	150-160	1486-1476	Deep
GR00-5	Jan-00	220	1630	1410	115-125	1515-1505	Shallow
GR00-6	Jan-00	230	1635	1405	121-131	1514-1504	Shallow
GR00-7	Feb-00	210	1645	1435	120-135	1524-1509	Shallow
GR00-8	Feb-00	230	1613	1383	96-106	1517-1507	Shallow
GR00-9	Jan-00	210	1614	1404	145-155	1469-1459	Deep
GR00-10	Jan-00	210	1600	1390	125-135	1475-1465	Deep
Outside Proposed Excavation Footprint							
GR98-2	Jan-98	70	937	867	NA	NA	NA
GR98-5	Jan-98	70	1061	991	NA	NA	NA
GR98-8	Jan-98	50	1078	1028	NA	NA	NA
GR98-9	Jan-98	50	1331	1281	NA	NA	NA
GR98-10	Jan-98	70	1214	1144	NA	NA	NA

Notes:
MSL = Mean Sea Level
bgs = below ground surface
NA = not applicable (boring not completed as well)
The boring designated GR00-3 was not drilled.

Table 10
Geotechnical Data
North Bend Gravel Operation

Analysis	GR99-1	GR00-1	GR00-2		GR00-4				GR00-5		
Depth (feet bgs)	120	150	55	180	60	75	130	160	130	200	220
Wet Density (PCF)	120.4	125.6	NA	NA	NA	NA	131.1	119.9	NA	NA	121.2
Field Moisture Content (%)	15.2	18.8	NA	12.1	NA	NA	11.1	24.9	3	22.2	16.4
USCS Soil Classification	SP	SP-SM	GP	ML	SC-SM	SM	SM	ML	SP	SM	SM
Laboratory Soil Description	Medium-Coarse Sand, Dark Gray	Poorly-Graded Sand with Silt, Gray	Poorly-Graded Gravel with Sand, Gray	Gravelly Silt, Med. Brown	Clayey Silt with Sand, Dark Gray	Silty Sand, Gray	Silty Sand, Gray	Silt, Gray	Poorly-Graded Sand, Black	Silty Sand, Gray	Silty Sand, Dark Brown
Porosity (%)	NA	29.4	NA	NA	NA	NA	29.7	42.8	NA	NA	36.8
Permeability (ft/day)	1.4E-04	NA	NA	NA	NA	NA	1.4E+00	5.0E-03	NA	NA	NA

Analysis	GR00-6		GR00-7			GR00-8		GR00-9		GR00-10		
Depth (feet bgs)	125	175	125	150	175	50	100	100	150	75	100	125
Wet Density (PCF)	128.4	104.1	126	122.5	126.9	NA	125.3	NA	130	104.7	99.6	NA
Field Moisture Content (%)	19.3	6.3	19.6	28.8	29.8	5.4	27	52.2	18	2.4	2.8	19.9
USCS Soil Classification	SP-SM	SP	SM	SP	ML	SP	ML	CL	SM/ML	SP	SW-SM	SP-SM
Laboratory Soil Description	Poorly Graded Sand with Silt, Dark Brown	Poorly-Graded Sand, Dark Brown	130	Poorly-Graded Sand, Dark Brown	Clayey Silt with Sand, Med. Brown	Poorly-Graded Sand, Gray	Silt, Gray	Clay with Sand, Gray	Sandy Silt, Gray	Poorly-Graded Sand with Silt, Dark Gray	Well-Graded Sand with Silt, Dark Gray	Poorly-Graded Sand with Silt, Gray
Porosity (%)	35.4	41.0	39.9	44.1	40.4	NA	39.4	NA	NA	39.2	43.4	NA
Permeability (ft/day)	NA	NA	NA	NA	3.0E-04	NA	NA	NA	3.7E-02	4.2E+01	2.0E+00	NA

Notes:
bgs = below ground surface
PCF = Pounds per cubic foot
ft/day = feet per day
USCS = Unified Soil Classification System

Table 11
Groundwater Level Measurements for Lower Site Monitoring Wells
North Bend Gravel Operation

Well	GR95-12			GR98-1			GR98-4			GR99-1		
	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation
Date	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL
10/13/95	87.79	85.29	592.41	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/29/95	87.58	85.08	592.62	NA	NA	NA	NA	NA	NA	NA	NA	NA
3/7/96	86.58	84.08	593.62	NA	NA	NA	NA	NA	NA	NA	NA	NA
6/7/96	86.92	84.42	593.28	NA	NA	NA	NA	NA	NA	NA	NA	NA
8/23/96	87.25	84.75	592.95	NA	NA	NA	NA	NA	NA	NA	NA	NA
2/20/97	85.17	82.67	595.03	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/16/97	87.21	84.71	592.99	NA	NA	NA	NA	NA	NA	NA	NA	NA
1/22/98	84.96	82.46	595.24	NA	NA	NA	NA	NA	NA	NA	NA	NA
2/26/98	89.29	86.79	590.91	73.13	71.83	625.17	89.63	87.33	747.37	NA	NA	NA
5/19/98	87.13	84.63	593.07	78.38	77.08	619.92	92.17	89.87	744.83	NA	NA	NA
7/10/98	87.27	130	547.7	81.67	80.37	616.63	96.02	93.72	740.98	NA	NA	NA
9/9/98	87.5	85	592.7	84.42	83.12	613.88	99.71	97.41	737.29	NA	NA	NA
10/23/98	87.67	85.17	592.53	85.54	84.24	612.76	101	98.7	736	NA	NA	NA
12/17/98	85.58	83.08	594.62	79.71	78.41	618.59	97.17	94.87	739.83	NA	NA	NA
1/18/99	83.67	81.17	596.53	69.25	67.95	629.05	86.54	84.24	750.46	NA	NA	NA
3/16/99	86.67	84.17	593.53	65.81	64.51	632.49	82.71	80.41	754.29	NA	NA	NA
5/3/99	87.06	84.56	593.14	74.19	72.89	624.11	89.21	86.91	747.79	NA	NA	NA
5/18/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	102.5	100.17	621.63
5/20/99	NA	NA	NA	NA	NA	NA	NA	NA	NA	102.67	100.34	621.46
6/6/99	87.08	84.58	593.12	77.83	76.53	620.47	92.92	90.62	744.08	104.17	101.84	619.96
7/15/99	87.08	84.58	593.12	80.04	78.74	618.26	95.35	93.05	741.65	106.5	104.17	617.63
9/3/99	87.29	84.79	592.91	82.63	81.33	615.67	97.73	95.43	739.27	110.1	107.77	614.03
10/1/99	87.42	84.92	592.78	83.98	82.68	614.32	99.02	96.72	737.98	111.96	109.63	612.17
11/5/99	87.52	85.02	592.68	84.88	83.58	613.42	100.38	98.08	736.62	113.48	111.15	610.65
11/30/99	84.69	82.19	595.51	79.13	77.83	619.17	97.54	95.24	739.46	105.0	102.67	619.13
1/19/00	86.64	84.14	593.56	68.63	67.33	629.67	84.94	82.64	752.06	94.65	92.32	629.48
1/28/00	87.58	85.08	592.62	69.71	68.41	628.59	85.45	83.15	751.55	96.63	94.3	627.5
2/4/00	86.79	84.29	593.41	70.39	69.09	627.91	86.05	83.75	750.95	96.6	94.25	627.55
2/17/00	86.83	84.33	593.37	71.45	70.15	626.85	87.10	84.80	749.90	97.62	95.29	626.51
3/3/00	86.70	84.2	593.5	73.16	71.86	625.14	88.28	85.98	748.72	99.40	97.07	624.73
3/21/00	86.65	84.15	593.55	74.44	73.14	623.86	89.55	87.25	747.45	100.70	98.37	623.43
4/7/00	86.70	84.2	593.5	79.42	78.12	618.88	90.47	88.17	746.53	101.68	99.35	622.45
4/26/00	86.71	84.21	593.49	76.57	75.27	621.73	91.52	89.22	745.48	102.82	100.49	621.31
5/26/00	86.86	84.36	593.34	78.08	76.78	620.22	93.15	90.85	743.85	104.35	102.02	619.78
6/26/00	87.02	84.52	593.18	79.53	78.23	618.77	94.57	92.27	742.43	105.95	103.62	618.18
7/27/00	87.24	84.74	592.96	81.18	79.88	617.12	96.10	93.80	740.90	108.15	105.82	615.98
9/28/00	87.47	84.97	592.73	84.2	82.9	614.1	99.3	97.00	737.70	112.34	110.01	611.79
10/28/00	87.40	84.9	592.8	84.7	83.4	613.6	100.4	98.10	736.60	113.3	110.97	610.83
11/30/00	87.53	85.03	592.67	85.19	83.89	613.11	101.33	99.03	735.67	114.4	112.07	609.73
12/28/00	87.31	84.81	592.89	85.19	83.89	613.11	101.93	99.63	735.07	114.74	112.41	609.39
1/31/01	87.30	84.8	592.9	85.15	83.85	613.15	101.9	99.60	735.10	114.53	112.2	609.6
2/28/01	87.32	84.82	592.88	85.11	83.81	613.19	101.84	99.54	735.16	113.8	111.47	610.33
3/27/01	87.43	84.93	592.77	85.74	84.44	612.56	102.05	99.75	734.95	115.54	113.21	608.59

Notes:
TOC = top of well casing
bgs = below ground suface
MSL = Mean Sea Level
NA - Not available (prior to well installation or not measured)

Table 12
Groundwater Level Measurements for Upper Site Monitoring Wells
North Bend Gravel Operation

Well	GR95-2			GR95-3			GR00-1			GR00-2			GR00-4			GR00-5			GR00-6			GR00-7			GR00-8*			GR00-9			GR00-10		
	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation	Depth to Water		Water Level Elevation
Date	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL	feet below TOC	feet bgs	feet above MSL
9/12/95	131.33	128.83	1511.67	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9/22/95	124.83	122.33	1518.17	142	139.42	1514.48	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/13/95	125.79	123.29	1517.21	142.25	139.67	1514.23	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/29/95	126.08	123.58	1516.92	142.25	139.67	1514.23	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3/7/96	107.13	104.63	1535.87	139.88	137.3	1516.6	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6/7/96	110.5	108	1532.5	139.75	137.17	1516.73	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8/23/96	115	112.5	1528	140.92	138.34	1515.56	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2/20/97	107	104.5	1536	139.83	137.25	1516.65	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/16/97	115.92	113.42	1527.08	141.13	138.55	1515.35	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1/22/98	109.58	107.08	1533.42	139	136.42	1517.48	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2/26/98	109.38	106.88	1533.62	139.58	137	1516.9	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5/19/98	111.17	108.67	1531.83	140.04	137.46	1516.44	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7/10/98	104.38	101.88	1538.62	140.67	138.09	1515.81	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9/9/98	119.33	116.83	1523.67	141.54	138.96	1514.94	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/23/98	122.29	119.79	1520.71	142	139.42	1514.48	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12/17/98	109.92	107.42	1533.08	139.21	136.63	1517.27	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1/18/99	107.42	104.92	1535.58	138.96	136.38	1517.52	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3/16/99	106.94	104.44	1536.06	138.92	136.34	1517.56	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5/3/99	110.23	107.73	1532.77	139.81	137.23	1516.67	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6/6/99	112.27	109.77	1530.73	140.27	137.69	1516.21	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7/15/99	114.25	111.75	1528.75	140.52	137.94	1515.96	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9/3/99	116.96	114.46	1526.04	140.88	138.3	1515.6	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10/1/99	119.19	116.69	1523.81	141.31	138.73	1515.17	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11/5/99	121.54	119.04	1521.46	141.75	139.17	1514.73	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11/30/99	111.92	109.42	1531.08	139.71	137.13	1516.77	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1/19/00	108.41	105.91	1534.59	139.24	136.66	1517.24	NA	NA	NA	N A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1/28/00	108.8	106.3	1534.2	139.32	136.74	1517.16	NA	NA	NA	149.28	147.28	1492.86	144.06	142.06	1494.26	112.95	110.95	1519.13	119.95	117.95	1517.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	123.25	121.25	1479.03
2/4/00	109.02	106.52	1533.98	139.40	136.82	1517.08	152.65	150.65	1480.73	148.35	146.35	1493.79	144.15	142.15	1494.17	113.15	111.15	1518.93	119.97	117.97	1517.49	130.32	128.32	1516.38	100.30	98.30	1514.96	150.60	148.60	1465.56	122.40	120.40	1479.88
2/17/00	109.00	106.50	1534.00	139.41	136.83	1517.07	150.02	148.02	1483.36	148.40	146.4	1493.74	144.32	142.32	1494.00	113.06	111.06	1519.02	119.91	117.91	1517.55	130.26	128.26	1516.44	98.80	96.80	1516.46	151.54	149.54	1464.62	122.16	120.16	1480.12
3/3/00	109.55	107.05	1533.45	139.51	136.93	1516.97	149.96	147.96	1483.42	148.38	146.38	1493.76	142.25	140.25	1496.07	113.31	111.31	1518.77	120.17	118.17	1517.29	130.10	128.1	1516.6	102.18	100.27	1512.99	150.38	148.38	1465.78	121.90	119.90	1480.38
3/21/00	109.96	107.46	1533.04	139.66	137.08	1516.82	150.00	148	1483.38	148.38	146.38	1493.76	144.40	142.4	1493.92	113.47	111.47	1518.61	120.35	118.35	1517.11	130.08	128.08	1516.62	102.28	100.37	1512.89	Dry	Dry	Dry	121.90	119.90	1480.38
4/7/00	110.07	107.57	1532.93	139.68	137.1	1516.8	149.94	147.94	1483.44	148.42	146.42	1493.72	144.45	142.45	1493.87	113.52	111.52	1518.56	120.38	118.38	1517.08	129.98	127.98	1516.72	102.31	100.40	1512.86	150.20	148.20	1465.96	121.79	119.79	1480.49
4/26/00	110.45	107.95	1532.55	139.82	137.24	1516.66	150.02	148.02	1483.36	148.43	146.43	1493.71	144.52	142.52	1493.80	113.68	111.68	1518.4	120.55	118.55	1516.91	129.99	127.99	1516.71	102.19	100.28	1512.98	150.50	148.50	1465.66	121.76	119.76	1480.52
5/26/00	110.84	108.34	1532.16	139.92	137.34	1516.56	150.11	148.11	1483.27	148.75	146.75	1493.39	144.76	142.76	1493.56	113.77	111.77	1518.31	120.94	118.94	1516.52	130.08	128.08	1516.62	102.17	100.26	1513	150.27	148.27	1465.89	121.75	119.75	1480.53
6/27/00	111.61	109.11	1531.39	140.05	137.47	1516.43	150.11	148.11	1483.27	148.50	146.5	1493.64	144.88	142.88	1493.44	113.85	111.85	1518.23	120.76	118.76	1516.7	131.15	129.15	1515.55	102.26	100.35	1512.91	Dry	Dry	Dry	121.74	119.74	1480.54
7/27/00	113.20	110.70	1529.80	140.31	137.73	1516.17	150.22	148.22	1483.16	148.58	146.58	1493.56	144.98	142.98	1493.34	114.21	112.21	1517.87	121.15	119.15	1516.31	130.35	128.35	1516.35	102.35	100.44	1512.82	Dry	Dry	Dry	121.82	119.82	1480.46
8/30/00	116.25	113.75	1526.75	140.81	138.23	1515.67	Dry	Dry	Dry	148.61	146.61	1493.53	145.17	143.17	1493.15	Dry	Dry	Dry	121.71	119.71	1515.75	130.53	128.53	1516.17	102.69	100.78	1512.48	Dry	Dry	Dry	121.83	119.83	1480.45
9/28/00	119.00	116.50	1524.00	141.37	138.79	1515.11	150.86	148.86	1482.52	148.76	146.76	1493.38	145.45	143.45	1492.87	115.30	113.3	1516.78	122.23	120.23	1515.23	130.82	128.82	1515.88	103.00	101.09	1512.17	Dry	Dry	Dry	121.90	119.90	1480.38
10/28/00	120.20	117.70	1522.80	141.60	139.02	1514.88	151.10	149.1	1482.28	148.70	146.7	1493.44	145.60	143.6	1492.72	115.60	113.6	1516.48	122.50	120.5	1514.96	131.00	129	1515.7	103.00	101.09	1512.17	Dry	Dry	Dry	121.90	119.90	1480.38
11/30/00	120.61	118.11	1522.39	141.81	139.23	1514.67	151.43	149.43	1481.95	148.76	146.76	1493.38	145.83	143.83	1492.49	115.72	113.72	1516.36	122.62	120.62	1514.84	131.40	129.4	1515.3	103.38	101.47	1511.79	Dry	Dry	Dry	122.02	120.02	1480.26
12/28/00	119.69	117.19	1523.31	141.69	139.11	1514.79	151.43	149.43	1481.95	148.77	146.77	1493.37	145.9	143.9	1492.42	115.57	113.57	1516.51	122.48	120.48	1514.98	131.68	129.68	1515.02	103.23	101.32	1511.94	Dry	Dry	Dry	122	120.00	1480.28
1/31/01	114.1	111.60	1528.90	102.13	99.55	1554.35	150.43	148.43	1482.95	149.5	147.5	1492.64	145.7	143.7	1492.62	115	113	1517.08	121.83	119.83	1515.63	134.43	132.43	1512.27	102.5	100.59	1512.67	Dry	Dry	Dry	120.3	118.30	1481.98
2/28/01	116.95	114.45	1643.00	141.28	138.7	1514.35	149.2	147.2	1484.18	148.26	146.26	1493.88	145.2	143.2	1493.12	117.8	115.8	1514.28	121.62	119.62	1515.84	131.97	129.97	1514.73	103.01	101.10	1512.16	Dry	Dry	Dry	121.91	119.91	1480.37
3/27/01	117.5	115.00	1643.00	142.29	139.71	1514.35	148.89	146.89	1484.49	148.63	146.63	1493.51	145.37	143.37	1492.95	118.2	116.2	1513.88	121.75	119.75	1515.71	131.75	129.75	1514.95	102.1	100.19	1513.07	158.35	Dry	Dry	122	120.00	1480.28

Notes:
* GR00-8 replaced 2/21/00, stickup 1.91 feet
TOC = top of well casing
bgs = below ground suface
MSL = Mean Sea Level
NA = Not available (prior to well installation)
Dry = well was dry at time of measurement
The boring designated GR00-3 was not drilled.

Table 13
Average Water Budgets - Upper and Lower Sites
North Bend Gravel Operation

Lower Site - Cedar Lake Average (43.8 Acre Disturbed Area)		
Water Sources	Quantity (acre-feet/year)	Percent
Precipitation [1]	371	90%
Run-on [2]	42	10%
Subtotal	413	100%
Water Losses		
Run-off [3]	0	0%
Evapotranspiration [4]	115	31%
Infiltration/Recharge [5]	256	69%
Subtotal	371	100%

Upper Site -Cedar Lake Average (260 Acre Disturbed Area)		
Water Sources	Quantity (acre-feet/year)	Percent
Precipitation [1]	2,200	100%
Run-on [2]	0	0%
Subtotal	2,200	100%
Water Losses		
Run-off [3]	0	0%
Evapotranspiration [4]	682	31%
Infiltration/Recharge [5]	1518	69%
Subtotal	2,200	100%

Lower Site - Golder Average (43.8 Acre Disturbed Area)		
Water Sources	Quantity (acre-feet/year)	Percent
Precipitation [1]	296	88%
Run-on [2]	42	12%
Subtotal	338	100%
Water Losses		
Run-off [3]	0	0%
Evapotranspiration [4]	92	27%
Infiltration/Recharge [5]	246	73%
Subtotal	338	100%

Upper Site - Golder Average (260 Acre Disturbed Area)		
Water Sources	Quantity (acre-feet/year)	Percent
Precipitation [1]	1,760	100%
Run-on [2]	0	0%
Subtotal	1,760	100%
Water Losses		
Run-off [3]	0	0%
Evapotranspiration [4]	550	31%
Infiltration/Recharge [5]	1,210	69%
Subtotal	1,760	100%

Notes:

[1] Precipitation estimated as 80% of Cedar Lake precipitation (Golder, 1996)

[2] Run-on calculated using KCRTS (King County Department of Natural Resources, 1999)

[3] Based on field observations

[4] Assumed to be 31% of precipitation (USGS, 1995)

[5] Assumed to be 69% of precipitation (USGS, 1995)

Table 14

HSSM Model Input Parameters

North Bend Gravel Operation

PARAMETER	VALUE	SOURCE
Hydrologic Properties		
Water dynamic viscosity	1.0 cp	Standard value
Water density	1.0 g/cm^3	Standard value
Water surface tension	65 dyne/cm	Assumed based on pure water
Maximum k_{rw} during infiltration	0.5	Typical value (Brakensiek *et al*, 1981)
Recharge		
Saturation	0.22	Calculated from laboratory measurements
Capillary Pressure Curve Model		
Pore size distribution index	0.559	Calculated based on laboratory measurements of onsite soil
Residual water saturation	0.1964	Calculated based on laboratory measurements of onsite soil
Air entry head	0.2873 m	Calculated based on laboratory measurements of onsite soil
Porous Media Properties		
Saturated vertical hydraulic conductivity	0.124 m/d	Calculated from laboratory measurements of onsite soil
Porosity	0.27	Calculated from laboratory measurements of onsite soil
Bulk density	1.92 g/cm^3	Calculated from laboratory measurements of onsite soil
Total Organic Carbon	566 mg/kg	Calculated from laboratory analysis of onsite soil
Hydrocarbon Phase Properties		
NAPL density	0.827 g/cm^3	Typical value
NAPL dynamic viscosity	2.70 cp	Typical value
Vadose zone residual NAPL saturation	0.1	Typical value (Mercer and Cohen, 1990)
NAPL surface tension	28 dyne/cm	Typical value
Dissolved Constituent Properties		
Initial constituent concentration in NAPL	4,962 mg/L	Calculated from typical values
NAPL/water partition coefficient	18,500	Assumed based on typical values
Soil/water partition coefficient (K_D)	0.74 L/kg	Calculated from typical/laboratory values
Constituent solubility	31.7 mg/L	Typical value
Hydrocarbon Release		
Beginning time	0 d	Based on approach
Ending time	1 d	Based on approach
Ponding depth	0.0254 m	Calculated based on approach

Table 15
Range of Detected Metals Concentrations in Biosolids Used to Make GroCo in 1998
North Bend Gravel Operation

	Minimum (mg/kg)	Maximum (mg/kg)	Pollutant Concentration Limit[1] (mg/kg)
Arsenic	1.2	27	41
Cadmium	<1.2	8.8	39
Copper	370	1,200	1,500
Lead	<11	174	300
Mercury	0.3	6.3	17
Nickel	12	55.4	420
Selenium	2.4	10.1	100
Zinc	555	1,400	2,800

Notes:
[1] WAC 173-308-160 (3) Table 3
mg/kg = milligram per kilogram
Metals concentrations in GroCo are approximately four times less than those detected in biosolids because GroCo is a mixture of 1 part biosolids and 3 parts sawdust. Data were provided by GroCo, Inc., of Seattle, Washington.

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APPENDIX A

WATER RIGHTS SUMMARY

The information contained in this Appendix is on file with King County.

APPENDIX B
REGIONAL WELL LOGS

The information contained in this Appendix is on file with King County.

APPENDIX C

BORING LOGS, GEOTECHNICAL DATA, AND SURVEY DATA

The information contained in this Appendix is on file with King County.

APPENDIX D

METHODS AND PROCEDURES FOR MONITORING WELL INSTALLATION

APPENDIX D

METHODS AND PROCEDURES FOR MONITORING WELL INSTALLATION

D.1.0 INTRODUCTION

The purpose of the monitoring well installation was to investigate the subsurface soil and hydrogeological conditions at the Lower and Upper Sites of the proposed mining operation. The selected well locations were intended to provide additional information regarding the geologic materials, extent of the aquifers and groundwater levels beneath the proposed gravel mining operations. Field methods implemented were in general conformance with Washington State Department of Ecology (Ecology) (1988) requirements and standard methods of the American Society for Testing and Materials (ASTM) (1996a,b,c).

D.2.0 DRILLING PROCEDURES

Dames & Moore subcontracted Layne Christensen (Layne) of Tacoma, Washington, a Washington-licensed drilling contractor to drill and install monitoring well GR99-1 at the Lower Site in May 1999, Cadman, Inc. subcontracted Layne to drill and install monitoring wells GR00-1, GR00-2, and GR00-4 through GR00-10 at the Upper Site in January and February 2000. Dames & Moore provided oversight and direction of the drilling program.

The monitoring wells were drilled and installed using Layne's AP-1000 dual wall reverse percussion hammer drilling rig (ASTM D5781-95). This drilling method prevents erosion of the soils on the borehole wall and allows a monitoring well to be constructed through the drill stem as it is removed. The dual wall drill stem consists of a 9-inch-diameter steel threaded casing that forms the outer wall around a 6-inch-diameter inner drill pipe. An air compressor on the drill rig supplies air through the annulus between the inner and outer drill pipe walls. While drilling, a percussion hammer drives the casing into the soils. The pounding action of the hammer bit excavates the soils as the drill stem is advanced. The forced air circulates back to the surface up the inner drill pipe and transports a continuous discharge of soil cuttings. The cuttings generated from the drilling are routed through a hose connecting the drill pipe into a cyclone. By comparing drilling rates and soil recovery, an accurate log of the depth of changes in the soils encountered can be made.

D.2.1 GEOLOGIC LOGGING

The Dames & Moore field geologist prepared a detailed log of the soil materials encountered and pertinent sampling and drilling details in the field. Soils retrieved as cuttings and discrete samples were visually examined and classified in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487-93). Soil samples for chemical analysis and/or physical testing were collected, and handled per the procedures for soil sampling, discussed below. A geologic log was prepared that included the boring/monitoring well identification number, drilling contractor and method, field geologist's observations, description of soils encountered, USCS classification of soils, sample collection depths, and sample identification numbers. In addition, notes regarding the drilling operation including site conditions, drilling rate, blow counts required to drive samples, assessment of drilling cuttings, depth to groundwater and other pertinent subsurface conditions were recorded on the geologic log. Well construction information was also summarized on the geologic log.

D.3.0 SOIL SAMPLING COLLECTION PROCEDURES

Soil samples were collected for visual examination and classification, chemical analysis, and physical testing.

D.3.1 SOIL SAMPLING METHODS

Disturbed soil samples were collected by retrieving grab samples from the cyclone discharge. Grab samples from discretes depths were collected as the casing was halted and cleared prior to the addition of more casing. Grab samples were collected in reclosable plastic bags.

Undisturbed soil samples collected during rotary drilling were collected with a Dames & Moore U-Type split-barrel sampler equipped with three 3-inch-long, clean stainless steel sample rings. These samplers are designed to retrieve undisturbed samples of unconsolidated or semi-consolidated soils. The sampler was attached to the sampling rod, lowered through the drill pipe to the bottom of the borehole, and driven using a hammer with 30-inch drop. The approximately 1½-foot long sampler was driven until it penetrated 18 inches or a minimum of 50 blows had been applied. The well drilled in May 1999 was sampled using a 300-pound hammer. Wells drilled in January and February 2000 were sampled using a 140-pound hammer. Upon retrieval of the sample, the sample barrel was split open and the two rings with undisturbed or least disturbed soil were removed, immediately capped with Teflon sheets and tight fitting plastic end caps, and labeled. The third ring and soils contained in the sampler bit and waste barrel were used for visual examination.

D.3.2 SELECTION OF SOIL SAMPLING DEPTHS

In general, disturbed soil samples were collected from the borehole at 10-foot depth intervals. Undisturbed soil samples in boring GR99-1 were collected at 5-foot intervals between 70 feet below ground surface (bgs) and the water table at 100 feet bgs at the lower Site. Undisturbed soil samples were collected at 10-foot intervals below the water table to the total depth of the boring (130 feet bgs). Undisturbed soil samples in the January and February 2000 borings were collected at approximately 25-foot intervals below 75 feet to the total depth of the borings at the Upper Site.

D.3.3 SELECTION OF SOIL SAMPLES FOR PHYSICAL AND CHEMICAL TESTING

Soil samples were selected for physical testing from various depths to assess vertical variability in the characteristics of the representative soil types encountered. Soil samples were selected based on field observations of the subsurface soils during drilling and sampling and the proposed mining operation final base elevations. Physical tests were performed on selected soil samples to measure the representative physical characteristics of the geologic materials encountered and provide numerical values which could be used to evaluate the potential for chemical constituent movement through the soil. Samples were selected for physical testing including: grain size distribution, density, moisture content, and vertical hydraulic conductivity. In addition, chemical analyses for total organic carbon content was conducted on selected samples. These soil parameters affects the mobility of organic constituents and were used as contaminant transport model parameters.

Undisturbed samples for physical testing collected at the Lower Site were selected from depths equivalent to the base of the proposed excavation (70 feet bgs), within the buffer zone above the water table (75, 80, and 85 feet bgs), and within the water table (120 feet bgs). In addition, chemical analyses for total organic carbon content was conducted on the 70-, 75-, and 120-foot samples.

Undisturbed samples for physical testing collected at the Upper Site were selected from selected depths equivalent to the base of the proposed excavation, within fine-grained perching layers, and within the perched water tables. The selected depths of these samples varied in the 9 borings based on variances in geologic materials and recovery of samples. In addition, chemical analyses for total organic carbon content was conducted on the 60-, 120-, and 160-foot samples collected from boring GR00-10, which was located in the area of the proposed Upper Site processing area (Alternatives 3 and 4).

D.3.4 SOIL SAMPLE PHYSICAL TESTING METHODS

Physical tests were conducted by Dames & Moore's geotechnical laboratory. Total organic carbon analysis was conducted by Dames & Moore's contract laboratory North Creek Analytical, an Ecology accredited analytical laboratory. Selected soil samples were tested using appropriate ASTM or EPA standard methods.

D.4 MONITORING WELL INSTALLATION

Monitoring well GR99-1 was completed below the proposed base elevation of the lower mining operation. Borings GR00-1, GR00-2, and GR00-4 through GR00-10 were to at least 20 feet below the maximum proposed depth of excavation (elevation 1,440 feet above MSL) at the Upper Site. The depths of the borings ranged from 210 to 240 feet bgs. Monitoring wells were completed in each of the nine borings at elevations where the apparent primary water-bearing zone was encountered. The monitoring wells were constructed in accordance with Ecology's "Minimum Standard for Construction and Maintenance of Wells" (Chapter 173-160 WAC).

D.4.1 MONITORING WELL DESIGN AND CONSTRUCTION

The monitoring wells were constructed under the supervision of Dames & Moore field personnel by Layne with 2-inch-diameter, flush-threaded, blank and screened PVC well casing. The wells have a bottom, flush-threaded cap, and 10 to 20 feet of screened well casing, with blank well casing completing the wells to ground surface. The monitoring wells were constructed with 0.020-inch slotted screen and 10 to 12 grade sand filter pack. The monitoring wells were constructed so the screened section would intercept groundwater during the anticipated seasonal low groundwater level fluctuation.

The monitoring wells were constructed by lowering the well casing through the drill casing to the bottom of the borehole. The filter-pack sand was placed around the well casing from the bottom of the borehole to a depth of approximately 2 to 4 feet above the top of the well screen. As the sand was being placed, the drill casing was retracted with hydraulic pipe pullers. A 2 to 4 ½-foot-thick seal of bentonite was placed above the filter pack and hydrated using tap water. The wells were grouted to approximately 3 feet below ground surface with hydrated bentonite chips and bentonite grout. Concrete was used to seal the uppermost 3 feet of annular space and construct the surface seal. The sealing materials were tremied or poured slowly from the ground surface. After the well was installed, an aboveground locking steel monument casing was set in concrete around the well casing.

D.4.2 WATER LEVEL MEASUREMENT COLLECTION AND SURVEY

The top of casing/riser elevation and the horizontal coordinates for all additional monitoring wells were surveyed by a professional licensed surveyor so that accurate water elevation data can be obtained and the relative positions can be accurately identified. The surveyor measured the horizontal coordinates of the well relative to the existing on site monitoring wells. The horizontal coordinates were measured to the nearest 0.1 foot. The elevations were surveyed to the nearest 0.01 foot and were referenced to the National Geodetic Vertical Datum of 1929.

Dames & Moore collected water level measurements at the time of well drilling and completion. Cadman and Dames & Moore field personnel collected water level measurements as part of periodic water level measurements to establish seasonal groundwater flow direction and gradients.

D.5 REFERENCES

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APPENDIX E

BUFFER ZONE MODELING RESULTS

The information contained in this Appendix is on file with King County.

APPENDIX F

RUNOFF CALCULATIONS FOR WATER BUDGET

The information contained in this Appendix is on file with King County.

APPENDIX G

SPRING PHOTOGRAPHS

The information contained in this Appendix is on file with King County.