DATE: April 20th, 2012
TO: Bob Barwin, Stan Isley, Files G4-35536, G4-35541, G4-35542, G4-35543, G4-35544, G4-35545, G4-35546, G4-35547, and G4-35548.
FROM: Anna Hoselton
TITLE: Lower Swauk Basin Reference Report

Introduction

This report summarizes the results of Ecology’s technical investigation of the hydrogeology of the lower Swauk Creek drainage. All discussion presented here assumes that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule). The Rule withdraws from appropriation all groundwater in Upper Kittitas County with the exception of uses which are determined to be water budget neutral. Under the Rule, a new use of groundwater is considered to be water budget neutral when other water rights are placed into the State’s trust water right program that mitigate for the new consumptive use. The new use may be approved by the Department in areas where groundwater is available from the aquifer without detriment or injury to existing rights.

The specific area studied is defined by the topographic watershed boundary delineated for the “Likely Suitable” (Green area) of Ecology’s Draft Swauk Mitigation Suitability map (Ecology reference 28) developed for the Swauk Creek Basin in association with the Suncadia and Roan Trust Water Right Agreement and later adopted for the James and Jan Roan Trust Water Right Agreement (Figure 1). For simplicity, the project area will be referred to as the “Mitigation Suitability Area” or “MSA” in further discussion.

The study found that because of the area’s complex geology it was necessary to subdivide the MSA, based on geologic and hydrogeologic characteristics, into distinct groundwater units. Eight groundwater units were ultimately identified and described so that permitting issues such as water availability and impairment potential could be considered and discussed for each.

As this work progressed, groundwater application Number G4-35536 was filed by J. P. and Jan Roan. The application identified a portion of the Roan’s First Creek water right, Court Claim No. 00648, as the proposed mitigation for their request. The right had been earlier conveyed to Ecology’s Trust Water Right Program (Ecology reference 34) under CS4-00648(AA)sb-4b and CS4-00648(AA)sb40-c(A) to make it available for mitigation purposes in the Swauk Creek Basin in Kittitas County.

Application No. G4-35536 was later split into Application Nos. G4-35541, G4-35542, G4-35543, G4-35544, G4-35545, G4-35546, G4-35547, and G4-35548 to reflect the different groundwater sources identified during this investigation. The proposed total water use
information contained within the original application, G4-35536, was used to compare with probable precipitation inputs for the eight groundwater units and is presented with the study's findings, within the constraints of limited data and geologic complexity, for consideration during the permit decision process.

![Map of Swauk Basin MSA, Kittitas County, Washington](image)

*Figure 1: Lower Swauk Basin MSA, Kittitas County, Washington, adapted from Ecology's Draft Swauk Creek Basin Draft Mitigation Suitability map "Likely Suitable (Green) Area". MSA shown here in Green.*

**Study Location**

The lower Swauk Creek MSA is located just east of the Cascade Mountains crest in Kittitas County, Washington, approximately 80 miles east of Seattle and 25 miles west of Ellensburg. More locally, the MSA is situated just east of the Cle Elum and west of the small town of Thorp. As noted above, the project area is located within the topographic watershed boundary described by the “Likely Suitable” (Green area) of Ecology’s Draft Swauk Mitigation Suitability map (Ecology reference 28) developed for the Swauk Creek Basin in association with the Suncadia and Roan Trust Water Right Agreement and later adopted for the James and Jan Roan Trust Water Right Agreement (Figure 1). More specifically, the MSA is located within the following
metes and bounds: Sections 13, 14, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, and 35, Township 20 N., R. 17 E.W.M.; Sections 3, 4, 5, 6, 7, 8, 9, 10, 16, 17, 18, 19, and 20, Township 19 N., R. 17 E.W.M.; Sections 1, 2, 12, and 13, Township 19 N., R. 16 E.W.M.; Sections 19 and 30, Township 20 N., R. 18 E.W.M.; and within Section 36, Township 20 N., R. 16 E.W.M.; ALL within Kittitas County, Washington.

Purpose and Scope

The purpose of this study is to provide hydrogeologic input necessary for permitting purposes. Tasks performed during this effort generally consist of the following:

- Review of the area’s general geologic/hydrogeologic characteristics from field observations, geologic maps and reports, air photos, and well log data.

- Compilation, mapping, and interpretation of existing well logs that could be located to the parcel level. Consideration of existing well logs which could not be located to the parcel level but may add value in development of a general geologic/hydrogeologic conceptual understanding.

- Subdividing the MSA into specific groundwater units and recognizing that within the MSA, some units may represent only a small portion of larger groundwater units that extend outside of the MSA boundaries.

- Development of a conceptual understanding of groundwater unit recharge and discharge relationships and the effects that existing and future groundwater withdrawals may have on the groundwater/surface water system dynamics.

- Consideration of local water availability based on infiltration from precipitation, aquifer characteristics, and surface water-groundwater exchange with First and Swauk Creeks.

- Consideration of potential for impairment between water users.

The findings and observations resulting from the above efforts are presented in the sections below where the general area geology is briefly presented, the project area hydrogeology is explored in greater detail and discussion relative to the permitting issues of water availability and impairment is offered.

General Area Geology Discussion

The lower Swauk Creek drainage is contained within the larger Swauk watershed. The Swauk watershed is bounded to the north along the Kittitas-Chelan county border where the boundary follows the northwest-southeast trending ridge of the Wenatchee Mountains. Table Mountain forms the watershed’s eastern extent; Teanaway Ridge to the west; and the Yakima River to the south. Lilliquist (2001) notes that “Tabor et al. (1982) has summarized the key geologic units of
the watershed. The sedimentary Eocene Swauk Formation dominates the central portion of the watershed. Teanaway Basalt lava flows, pyroclastic flows, and ash flow tuffs overlie the Swauk Formation, especially along the western and southern boundaries of the upper basin. Scores of Teanaway basalt and diabase dikes intrude the Swauk Formation throughout the... area. The sedimentary late Eocene Roslyn Formation overlies the Teanaway dikes outcropping along the east side of the watershed and immediately east of Lauderdale Junction. Columbia River Basalts of Miocene age overlie the sedimentary Roslyn Formation in the eastern and southern portions of the watershed (Fig. 1). The Ellensburg Formation occurs as sedimentary beds between Columbia River Basalt flows along the west face of Table Mountain and in lower Swauk and Horse canyons. Pliocene alluvial Thorp Gravels outcrop in the southeastern portion of the study area, whereas Quaternary alluvium fills valley floors, and Quaternary till and lacustrine sediments comprise Swauk Prairie.” Lilliquist’s Figure 1 is presented here in Appendix A. For a more detailed description of the general area geology than what is given here for the purposes of this report, the reader is referred to the related works of Porter (1976), Lilliquist (2001), Waitt (1979), Cheney (2007), Tabor (1982 & 1984), Tolan, et al. (2009) and others listed in the reference section of this report.

Project Area Hydrogeology Discussion

In attempt to simplify complex geology and reasonably deal with artificial constraints imposed by the MSA delineated boundaries the following approach was used:

Within the MSA boundary, mapped surficial geologic outcrop areas were initially grouped into unconsolidated and consolidated units. Consolidated units include the Wenatchee (?) Formation, Roslyn Formation, Teanaway Formation, and the Grande Ronde Formation interbedded with the weakly consolidated sediments of the Ellensburg Formation. Unconsolidated units include glacial, alluvial and mass wasting sediments. It was assumed that groundwater in the unconsolidated units would be consistent with porous medium behavior and that groundwater within the consolidated units would generally simulate porous medium behavior and/or comply with fracture system flow dynamics similar to that described by Freeze and Cherry (1979) and Fetter, (1999).

Further assumptions were made regarding hydrogeologic boundaries. It was assumed that soft (may migrate) boundaries such as groundwater divides occurring in the unconsolidated units may migrate in response to climatic changes and groundwater pumping pressures. Hard (unlikely to migrate) boundaries were assumed to occur in the form of geologic structures, at unit margins or where units pinch out, and where significant contrasts in transmissivities between or within units may occur. It was recognized that some boundary conditions may be obscured by overlying sediments and may not be presently identified.
Consolidated and unconsolidated units were then grouped into Units (Table 1) that could reasonably be expected to function as a distinct groundwater Unit (Figure 2). Surficial unconsolidated sediments that were limited by small extent, high clay content, or were unlikely to have sufficient recharge or saturated thickness to support sustainable domestic wells were treated as non-significant overburden and ignored. Tabor’s (1982) Wenatchee (?) Formation was grouped with the Roslyn Formation because both are composed of sandstones and shales and because the two Formations are in direct contact. However, because of field observations and well log data, it was recognized that Tabor’s Wenatchee (?) Formation, where present, is an unlikely target for wells due to its limited thickness and high clay content.

<table>
<thead>
<tr>
<th>Unit #</th>
<th>Abbrev. Unit Name</th>
<th>Units Identified Within MSA Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCRB-West of Swk Crk</td>
<td>Marginal Columbia River Basalt-West of Swk Crk; Marginal Columbia River Basalt flows of the Mid-Miocene Grande Ronde Formation and the Miocene Ellensburg Formation sandstones/shales occurring west of Swauk Crk.</td>
</tr>
<tr>
<td>2</td>
<td>MCRB-East of Swk Crk</td>
<td>Marginal Columbia River Basalt-East of Swk Crk; Marginal Columbia River Basalt flows of the Mid-Miocene Grand Ronde Formation and the Miocene Ellensburg Formation sandstones/shales occurring east of Swauk Crk.</td>
</tr>
<tr>
<td>3</td>
<td>HC ALV</td>
<td>Horse Canyon Alluvium: Holocene alluvial fan deposits and Pleistocene alpine glacial drift, pre-Fraser, occurring within the Horse Canyon Area east of Swauk Crk.</td>
</tr>
<tr>
<td>4</td>
<td>Swk Creek ALV</td>
<td>Swauk Creek Alluvium: Quaternary alluvial sediments occurring along and adjacent to Swauk Creek below its confluence with First Crk.</td>
</tr>
<tr>
<td>5</td>
<td>W. Swk Creek Unc</td>
<td>West Swauk Creek Unconsolidated sediments: Holocene-Pleistocene mass wasting, Holocene alluvial fan deposits and Pleistocene alpine glacial till, pre-Fraser, occurring west of Swauk Crk and north of Unit1.</td>
</tr>
<tr>
<td>6</td>
<td>E. Swk Creek Unc</td>
<td>East Swauk Creek Unconsolidated sediments: Holocene-Pleistocene mass wasting and Quaternary alluvial sediments occurring east of Swauk Crk, north of Unit 1 and south of First Crk.</td>
</tr>
<tr>
<td>7</td>
<td>1W77/Roslyn</td>
<td>Tabor’s Wenatchee? Formation / Roslyn Formation: Eocene Roslyn Formation and Oligocene Wenatchee (?) Formation sandstone/shale outcrops.</td>
</tr>
<tr>
<td>8</td>
<td>Teanaway Formation</td>
<td>Teanaway Formation: Eocene Teanaway Formation basalt and mixed volcanics outcrops.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit #</th>
<th>Associated Units Occurring Outside MSA Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>N/A Mass wasting deposits of Holocene-Pleistocene age occurring around the southern, western, and northern margins of the Unit 1</td>
</tr>
<tr>
<td>10</td>
<td>N/A Mainstem Yakima River Valley Quaternary age alluvial sediments south of Units 1 and 2 and between approximately 1 mile downstream of the Yakima River’s confluence with the Teanaway River to just downstream of its confluence with Swauk Creek.</td>
</tr>
<tr>
<td>11</td>
<td>N/A Miocene Columbia River Basalt Group (CRBG) and Miocene Ellensburg Formation occurring east of Unit 2</td>
</tr>
<tr>
<td>12</td>
<td>N/A Groundwater bearing unconsolidated Quaternary alluvial and Pleistocene glacial sediments and Eocene bedrock of the Roslyn Formation comprising the west portion of Swauk Prairie but located within the Teanaway Drainage Basin, west of Unit 5</td>
</tr>
</tbody>
</table>
Eight distinct groundwater Units were identified within the MSA. Seven of the eight Units extend outside of and beyond the MSA boundary. Four more Units located adjacent to, but outside, the MSA were also identified because it was recognized that pumping effects originating within the MSA may propagate outside of the MSA boundaries. Description of the guiding assumptions, the grouped Units, their recharge/discharge relationships and likely effects propagated due to groundwater pumping follow:

**Assumptions:**

1. All discussion presented here assumes that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule).

2. Capture of groundwater from the Swauk Creek Alluvium (Unit 4) ultimately equates to capture of recharge to or discharge from Swauk Creek.

3. For the purposes of this report, the term “local” is used to mean within the MSA, while the term “regional” is used to mean outside of the MSA. Example: a local effect implies propagation of an effect inside the MSA; a regional effect implies propagation of an effect outside the MSA.

4. Anticipated regional effects are expected to occur in addition to the anticipated local effects.

5. In the case where groundwater withdrawals from a Unit were considered unlikely to result in the propagation of regional effects, then no regional effect discussion was offered for those Units or sub-Units. In cases where wells were drilled through a surficial Unit and completed into an underlying Unit, anticipated effects of groundwater pumping from the underlying unit is discussed in the section associated with the Unit from which groundwater is being withdrawn.

6. Hydrogeologic and/or structural complexities may result in conditions that allow capture of groundwater by one Unit from another Unit that may be adjacent to, overlying or underlying the Unit from which groundwater is being withdrawn. For example, the effects of pumping groundwater from a shallowly dipping sandstone unit may be to capture recharge from a saturated overlying unit in an up dip direction. Well proximity, depth and aquifer characteristics may also factor into whether a particular well may be more likely to capture water from a particular unit or from some other unit.

7. The wells and well logs discussed or referenced in this report are generally wells that could be located to the parcel level accuracy. Where no wells could be located to the parcel level, such as with Unit 6, wells that could be located by driller’s coordinates to the ¼ ¼ section were evaluated. In general, wells that could not be located to the parcel level were reviewed and considered but are not specifically included in the report discussion unless so stated.
8. Loss of groundwater discharge to evapotranspiration is recognized as a water quantity component but not specifically discussed in this report.

9. Efforts here may not reflect every possible recharge/discharge relationship and every possible groundwater pumping related effect.

Figure 2: Distribution of project area groundwater Units. Surface exposure of Units 1-8 inside MSA boundaries; Related Units 9-12 located outside of the MSA boundaries. Identification of boundaries for Units outside the MSA was not critical to analysis of the Units within the MSA and therefore not done.

UNIT 1

Marginal Columbia River Basalt West of Swauk Creek (MCRB-West of Swk Crk): Unit 1, as shown in Figure 3, occurs along the western margin of the Columbia River Plateau and is composed of basalt flows of the Grande Ronde Formation of the Columbia River Basalt Group
(CRBG). In this area, the marginal Grande Ronde flows are interbedded with volcaniclastic sedimentary rocks of the Ellensburg Formation and are overlain with relatively minor, discontinuous surface deposits of glacial drift, alluvium, and mass wasting debris. It is, however, the Ellensburg Formation sedimentary interbeds together with the marginal Grande Ronde Basalt flows into which domestic wells have been developed within this Unit.

The marginal Grande Ronde basalt flows of the MSA, unlike the more common sheet flows of the CRBG, are more likely to exhibit compound flow characteristics that include local discontinuities (Tolen, et al, 2009), invasive flows, and complex jointing (Tabor, et al., 1982) in addition to subaqueous deposited hyaloclastites/pillow complexes (Tolan, personal communication, 2011). Locally exposed Grande Ronde flows are generally of normal magnetic polarity, composed of fine to medium grained basalt that is commonly non-porphyritic to very sparsely porphyritic with plagioclase and clinopyroxene phenocrysts (Tabor, et al., 1982).
The Ellensburg Formation occurs as weakly lithified sedimentary layers, of andesitic to dacitic tuffaceous sandstones, siltstones, conglomerates, and lahars, derived from Cascade Arc volcanoes. Within the MSA, the sedimentary layers are interbedded with the marginal Grande Ronde basalt flows and are commonly composed of white to yellow clays, silts, sands, and gravels.

Because depositional characteristics of the marginal basalts result in features having higher permeabilities with greater connectivity than non-marginal basalts, the marginal basalts when considered together with the interbedded sedimentary layers, will generally display a common hydraulic head rather than isolated or distinct heads. As a result, they can be reasonably grouped together with the interbedded sedimentary deposits. It should be noted, however, that while marginal basalts may be relatively simple to identify, the interior point at which groundwater heads begin to separate into and between distinct groundwater units can be difficult to define.

Aquifer properties for Unit 1 are expected to trend from unconfined to confined, depending on depth and presence or absence of local confining layers. Because of the physical characteristics described above, good hydraulic communication between the basalt members and the sedimentary interbeds is anticipated. The few existing wells located within this Unit suggest dependency on local recharge. Hydraulic head generally conforms to surficial topography and a corresponding eastward structural attitude, except in landside areas. Drilling records document at least three unsuccessful wells but a majority of wells drilled were estimated to produce from between 0.75 to 50 gallons per minute (gpm), with most falling within 5 to 28 gpm. However, because no pump test data was found, no MSA data derived estimates of transmissivity were made. Experience from similar areas, however, suggest that a cautious and reasonable transmissivity range may fall between approximately 5,000 to 15,000 gallons per day per foot (gdpf) or about 670 to 2,000 square feet per day (ft²/day). Water column depths in existing well bores vary due to differing well depths and presumably somewhat differing pressure heads and range from approximately 60 to 460 feet with outlier water column depths of 29 ft and 862 feet. Recharge to Unit 1 is from direct precipitation generally above about 1800 ft mean sea level (msl). Below about 1,800 msl, Unit 1 may receive some recharge from the Yakima River Valley ALV (Unit 10) and from the underlying TW?/Roslyn (Unit 7). Discharge from Unit 1 is to wells, to springs, to the lower Swk Creek ALV (Unit 4), and to the MCRB-East of Swk Crk (Units 2a, 2b, 2c) and east-southeast to the CRBG (Unit 11) outside of the MSA below about 1,800 ft msl.

Anticipated local effects of groundwater pumping from wells completed in Unit 1 follows:
- Wells completed above about 1800 ft msl will capture groundwater that would otherwise discharge to springs and to the lower Swk Creek ALV (Unit 4).
- Wells completed below about 1,800 ft msl and above the underlying TW?/Roslyn (Unit 7) will capture groundwater that would otherwise discharge to the MCRB-East of Swk Crk (Units 2a, 2b, 2c), and possibly induce capture of groundwater from the lower Swk Creek ALV (Unit 4).
- Outside of the Unit 1 MSA outcrop boundaries (figure 3) where Unit 1 underlies the Swauk Creek Alluvium (Unit 4) or the West Swauk Unconsolidated sediments (Unit 5) and depending on head relationships, wells may capture additional recharge or discharge from the overlying Unit 4 or 5.

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), anticipated regional effects of groundwater pumping from wells completed in Unit 1 follows:

- Wells completed below about 1,800 ft msl and above the underlying TW?/Roslyn (Unit 7) may capture groundwater from the CRBG (Unit 11) outside of the MSA.
- Wells may capture groundwater from the Unit 9 mass wasting sediments outside of the MSA along the south, west and northwest slopes of Unit 1.

UNIT 2

Marginal Columbia River Basalt East of Swk Crk (MCRB-East of Swk Crk): Unit 2 (Figure 4) is composed of marginal area basalt flows of the Grande Ronde Formation of the CRBG. Because the geologic setting of Unit 2 is similar to that of Unit 1, the reader is referred to the general description for Unit 1 above. Although geologically similar, the decision to treat the two areas separately is based on the observation that the exposed portions of Unit 1 and Unit 2 are separated by the narrow Swauk Creek canyon. The two Units are assumed to be connected and continuous below the canyon floor; however, well log data is lacking to demonstrate such. Because of the irregular surficial shape of Unit 2, it was further sub-divided into Sub-units 2a, 2b, 2c, and 2d for the purpose of more easily identifying a specific area in discussion (Figure 4).
Aquifer properties for Unit 2 are expected to trend, similar to that of Unit 1, from unconfined to confined depending on depth and presence or absence of local confining layers. Like Unit 1, good hydraulic communication between the basalt members and the sedimentary interbeds is anticipated. The few existing wells located within this Unit suggest dependency on local recharge with no currently discernable pattern to groundwater head elevations. Driller estimated well yields for Unit 2 range from between 1 to 75 gpm, with most falling within 10 to 55 gpm. However, because no pump test data was found, no MSA data derived estimates of transmissivity were made. Experience from similar areas, however, suggest that a cautious and reasonable transmissivity range may fall between approximately 5,000 to 20,000 gallons per day per foot (gdf) or about 670 to 2,675 square feet per day (ft²/day). Water column depths in existing well bores vary due to differing well depths and presumably somewhat differing pressure heads and range from approximately 30 to 234 feet.
The western outcrop exposure of Unit 2, where it is contact with the Swk. Creek ALV (Unit 4), varies in elevation from approximately 2,100 to 1,800 ft msl. Above these elevations, recharge to Unit 2 is from direct precipitation. Below 2,100 to 1800 ft msl, Unit 2 may also receive recharge from Swk. Creek ALV (Unit 4) along Unit 2’s western edge, from the E. Swk Creek Unc (Unit 6) along Unit 2’s northern edge and the overlying Horse Canyon ALV (Unit 3). Below about 1,800 ft msl the Unit may receive recharge from the MCRB-West of Swk Crk (Unit 1) and/or may receive recharge from the underlying TW?/Roslyn (Unit 7). Discharge from Unit 2 is to wells, to the Horse Canyon ALV (Unit 3) and east-southeast to the CRBG (Unit 11) outside the MSA. Groundwater within Unit 2 also discharges to Swk Creek ALV (Unit 4) via a seep/spring (about 1,900 feet msl) along the Unit’s western boundary (Sullivan, 2008; WDOE references # 30-33). Because, however, the structural attitude of Unit 2 along its western boundary results in a rather small recharge area for the seep/spring, it is speculated to be limited and possibly seasonal.

Anticipated local effects of groundwater pumping from wells completed in Unit 2 follows:

- Wells located in Unit 2a and 2b completed above about 1,850 ft msl may capture groundwater that would otherwise discharge as seeps/springs and as rejected recharge to the lower Swk Creek ALV (Unit 4).
- Wells located in Unit 2a completed below about 1,850 ft msl may capture groundwater from the Swk Creek ALV (Unit 4)
- Wells located in Unit 2b completed above about 2,300 feet msl (the approximate base of Unit 3) will capture groundwater that would otherwise discharge to springs or as rejected recharge to the Horse Cny ALV (Unit 3), which in turn, may reduce discharge to the lower Swk Creek ALV (Unit 4).
- Wells located in Unit 2b completed below about 2,300 feet msl may capture groundwater from the Swk Creek ALV (Unit 4).
- Wells located in Unit 2b completed below about 2,000 feet msl (the approximate elevation of the Swauk valley floor), may capture groundwater from the MCRB-West of Swk Crk (Unit 1).
- Wells located in Unit 2c completed above about 2,300 ft msl will likely capture groundwater that would otherwise discharge as rejected recharge to the Horse Cny ALV(Unit 3), which in turn, may reduce discharge to the lower Swk Creek ALV (Unit 4).
- Wells located in Unit 2c completed below about 2,300 ft msl may capture groundwater from Unit 2b which in turn may reduce discharge to the lower Swk Creek ALV (Unit 4).
- Wells located in Unit 2c completed below about 2,000 feet msl may capture groundwater from the lower Swk Creek ALV (Unit 4) and from the MCRB-West of Swk Crk (Unit 1).
- Wells located in Unit 2d will capture groundwater that would otherwise discharge as seeps/springs and rejected recharge to the E. Swk Creek Unc (Unit 6), which in turn may reduce discharge to Swk Creek ALV (Unit 4), to the TW?/Roslyn Formation (Unit 7) and to First and Swauk Creeks.

- Outside of the Unit 2 MSA outcrop boundaries (figure 4) where Unit 2 underlies the Swauk Creek Alluvium (Unit 4) or the East Swauk Unconsolidated sediments (Unit 6) and depending on head relationships, wells may capture additional recharge or discharge from the overlying Unit 4 or 6.

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), anticipated regional effects of groundwater pumping from wells completed in Unit 2 follows:

- Wells located in Units 2b and completed near or below about 2,300 feet msl and wells located in Unit 2c completed to any depth will capture groundwater from the CRBG (Unit 11) outside the MSA boundary and/or from the underlying TW?/Roslyn (Unit 7).

- Wells located in Unit 2d and Unit 2a will capture groundwater from the CRBG (Unit 11) outside the MSA boundary and/or from the underlying TW?/Roslyn (Unit 7).

**UNIT 3**

**Horse Canyon Alluvium (HC ALV):** Unit 3, as shown in Figure 5, includes sedimentary deposits consisting of poorly sorted boulders mixed with sand, silt and clay identified by Tabor, et al., (1982) as alluvial fan deposits. The alluvial fan deposits are likely derived by the erosion of the Grande Ronde Formation, Ellensburg Formation, and glacial sediments. Grouped with this Unit, for simplification, is a small remnant deposit of Lookout Mountain Ranch Drift (Tabor, et al., 1982) along the west wall of Horse Canyon composed of nonlithified, poorly sorted subangular, faceted and striated gravels of diverse rock types.

Unit 3 is not presently expected to be a generally viable groundwater source for domestic wells for the following reasons:

- The deposits are of limited extent
- The available recharge is likewise limited
- The deposits appear to have a relatively high clay content
- As suggested by sparse well log and soil data, the deposits may be no thicker than about 30 to100 ft with the saturated thickness being vulnerable to climatic conditions.
As a result, further discussion of aquifer characteristics for this Unit is not presented here. The few existing well logs reviewed appear to suggest that wells in this area are usually drilled through the sediments and are developed into the underlying MCRB-East of Swk Crk (Unit 2). Recharge to Unit 3 is from direct precipitation, spring discharge, and rejected recharge from Unit 2b and Unit 2c. Discharge from Unit 3 is to the underlying MCRB-East of Swk Crk (Unit 2) and to the lower Swk Creek ALV (Unit 4).

Anticipated local effects of groundwater pumping from wells that may be completed into Unit 3 would be to capture groundwater that would otherwise discharge to the underlying the MCRB-West of Swk Crk (Unit 2), to the Swk Creek ALV (Unit 4) and to the lower Swauk Creek.
Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), no regional effects of groundwater pumping from wells completed within Unit 3 are anticipated.

UNIT 4

Swauk Creek Alluvium (Swk Creek ALV): Review of well logs in combination with geologic maps and field observations suggest Unit 4 (Figure 6) is composed predominately of clay-rich glacial sediments with only minor amounts of sands and gravels particularly in the vicinity.

Figure 6: Unit 4, Swauk Creek Alluvium shown in light yellow with black outline.
downstream of Swauk Creek’s confluence with First Creek and continuing downstream to the southern extent of Hidden Valley. Along this stretch of Swauk Creek, unconsolidated sediment overlying bedrock ranges in thickness from approximately 40 feet at the north end of the valley, to possibly as much as 300 feet on the west side and widest region of Hidden Valley. Downstream as the valley narrows, constricted by bedrock, the sediment package again thins.

Fourteen wells were located to the parcel level along the reaches of Swauk Creek below the confluence of First Creek with the majority of those wells being within sections 22, 27, and 28 of T20N, R17E. Among the wells located within those sections, 7 of them appeared to be completed solely within the alluvial sediments of Unit 4. No yield estimate was given for 4 of the 7 wells. Of the remaining 3 wells, 1 was an artesian flowing well estimated to discharge at a rate of approximately 5 gpm, but when evaluated by air test, was estimated to be in the range of about 20 gpm. The remaining 2 wells were estimated at 5 and 35 gpm. Three of the wells were drilled to less than 100 feet in depth while the other 4 wells were all between about 200 to 355 feet in depth.

When the alluvial sediment wells are mapped and static water levels converted to elevations, the results suggest that groundwater levels are higher than creek surface elevations between approximately the confluence of First Creek to about 0.8 miles downstream (Schwartzman, 2002; Hoselton, 2008). Thereafter, groundwater levels appear to transition to lower than creek surface elevation, most likely due to a large increase in sediment thickness, particularly on the west side of the valley. The remaining wells located within Unit 4 appear to be completed into various depths of the underlying Unit 7. These wells range in depth from between 59 ft to approximately 245 feet. The distribution of wells completed into the underlying Unit 7 suggest a possible groundwater pattern of a higher head in the north valley area and lower heads in the south-southwest valley area and may be consistent with a regional geologic structure. Otherwise, no other patterns within this small area of Unit 4 are as yet apparent. Recharge to Unit 4 is from direct precipitation, by groundwater and spring discharge from adjacent Units and from Swauk Creek where/when groundwater levels are lower than Swauk Creek levels. Discharge from Unit 4 is to wells and to Swauk Creek where/when groundwater levels are higher than Swauk Creek levels. For greater surface water / groundwater characterization detail discussing recharge and discharge relationships, seepage loss results, and limited evidence of seasonal disconnection between the creek and groundwater in the area of Hidden Valley the reader is referred to Schwartzman (2002).

Anticipated local effects of groundwater pumping from wells completed within Unit 4 follows:

- Wells will capture groundwater that would otherwise discharge to Swauk Creek or will capture surface water from Swauk Creek.
Wells may capture groundwater from the W. Swk Creek Unc (Unit 5) or from the E. Swk Creek Unc (Unit 6).

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), no regional effects of groundwater pumping from wells completed within Unit 4 are anticipated. However, anticipated regional effects of groundwater pumping from wells completed to depths below Unit 4 are described in the corresponding relevant Unit(s).

UNIT 5

West Swauk Creek Unconsolidated sediments (W. Swk Creek Unc): Unit 5 (Figure 7) is comprised of mass wasting debris/talus slope deposits derived from the northeast flanks of Lookout Mountain, glacial sediments of the Kittitas Drift/Swauk Prairie subdrift, and minor alluvial fan deposits deposited along the southwest facing slopes of Teanaway Ridge. The mass wasting debris/talus slope deposits consists of basalt, sandstone and shale detritus resulting from slope failures and erosion of the Grande Ronde Formation and the Ellensburg Formation. Glacial sediments are composed of cobble to pebble sized material derived from the erosion of Teanaway Formation basalt and the Roslyn and Swauk sandstones (Porter, 1976), and light gray to blue-gray lacustrine clays and silts (Tabor et al., 1982). Alluvial fan sediments, being more recent deposits, overlie the glacial sediments to the south and small portions of the Teanaway Formation and Roslyn Formation along the northeast boundary of Unit 5. The alluvial fan sediments are comprised of poorly sorted boulders, cobbles, gravel, and gravelly sand derived predominately from the Teanaway Formation exposed along Teanaway Ridge.

Because Unit 5 includes mixed-rock-type mass wasting debris, an abundance of clay rich glacial drift, and minor surficial alluvial fan deposits, aquifer properties are expected to vary significantly both horizontally and vertically. Aquifer characteristics within the mass wasting debris appear to be generally unconfined and in some cases perched. Saturated thicknesses are expected to be sensitive to climatic variations in precipitation which will, in turn, affect the Unit’s transmissivity and consequently well yields. Where mass wasting debris tends to be coarse in size and poorly sorted, such as with basalt talus deposits, well yields will tend to be higher than wells drilled where the mass wasting sediments are finer, poorly sorted to unsorted, or occur as landslide blocks. Where well yields may be higher, sustainability, however, remains uncertain. Aquifer characteristics within the clay rich glacial sediments are expected to be generally unconfined to semi-confined and in some cases may also be perched. Transmissivities and well yields within the clay rich glacial sediments are expected to be generally low but with
occasional higher transmissivities displayed where small lenses of sands and gravels may be encountered. Because, however, the coarser sediments constitute only a small and irregularly distributed portion of the otherwise clay rich glacial sediments, sustainability of higher pumping rates for long periods is unlikely. Only two well logs offer any description of the alluvial fan sediments. One of the wells is located just west and outside the northwest corner of the MSA boundary while the other well is located just east and inside the northwest corner of the MSA boundary. The one MSA well, located near the upper mid-fan region, is 400 ft deep, cased.
through the fan sediments, and completed into the underlying TW?/Roslyn Formation (Unit 7). The well log description suggests the alluvial fan sediments, in this location, are about 55 feet thick, underlain by clay or poorly described Roslyn Formation from 55 to 110 feet, and clearly underlain by Roslyn Formation below 110 feet. Well log details from the well located just west and outside of the MSA describe alluvial sediments to only 25 feet bgs and Roslyn Formation thereafter. Consequently, it is appears likely the alluvial fan sediments may not be sufficiently thick or saturated to support wells. Since it is expected that the alluvial fan sediments will thin toward its southern distal end, they appear to be an unlikely target for wells.

A total of 38 wells were located to the parcel level within the boundaries of Unit 5. Of the 38 wells, 22 were located in Section 32, 13 were located within Section 28, 1 was located within Section 21 and no wells were located within Sections 20, 29 or 33 of T20N, R17E. The remaining 2 wells were located at the southern region of Unit 5 within the north ½ of Section 5, T19N, R17E. Of the 38 existing Unit 5 area wells, 10 had clearly encountered and were developed, in part or in whole, into underlying bedrock Units. It was uncertain whether 4 of the wells had or had not encountered underlying bedrock. The remaining 24 wells appeared to be completed within Unit 5 sediments. Among the Unit 5 wells located to the parcel level, wells not encountering bedrock ranged from the relatively shallow depth of 93 feet to about 340 feet. Wells located within Unit 5 boundaries but completed into bedrock tended to encounter the bottom of Unit 5 sediments around 250 to 380 feet bgs. Together, the logs suggest that Unit 5 sediment thickness is likely not greater than about 400 feet in any location. Driller estimated well yields for Unit 5 wells ranged from as little as 0.25 gpm to as much as 66 gpm but with most falling between 4 and 32 gpm. No yield estimates were given for 3 of the wells. Groundwater levels at Unit 5 wells appeared to generally conform to topography.

Understandably, no readily discernible groundwater level pattern emerged from wells appearing to be developed into both Unit 5 sediments and the underlying bedrock. However, the log of the deepest area well, identified and interpreted to be cased into the underlying Roslyn Formation (Unit 7), records an unverified but interestingly deep static water level (441 ft) that occurs below the 360 ft depth sediment/bedrock contact. By contrast, the rest of the wells all had static water levels occurring at levels within the overlying unconsolidated materials of Unit 5.

Recharge to Unit 5 is from direct precipitation, possibly by discharge from the MCRB-West of Swk Crk (Unit 1), and possibly by discharge from the underlying TW?/Roslyn (Unit 7). Discharge from the Unit 5 is to wells and to the Swk Creek ALV (Unit 4).

Anticipated local effects of groundwater pumping from wells completed in Unit 5 follows:
Wells will capture groundwater that would otherwise discharge to the Swauk Creek ALV (Unit 4).

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), anticipated regional effects of groundwater pumping from wells completed within Unit 5 follow:

- Wells may capture groundwater that would have otherwise discharged to the Teanaway Basin (Unit 12), particularly along the western boundary of Unit 5, by westward shifting of the ground water divide between the two basins in response to groundwater withdrawals. Location of the groundwater divide is poorly defined due to a lack of wells along the divide and consequently, until additional data is acquired, the groundwater divide will be assumed to correlate with the topographic divide between the two basins.

UNIT 6

East Swauk Creek Unconsolidated sediments (E. Swk Creek Unc): Unit 6 (Figure 8) includes mass wasting debris and talus slope deposits deposited along the north-northwest slopes

Figure 8: Unit 6, East Swauk Creek Unconsolidated sediments shown in yellow.
of MCRB-East of Swk Crk Unit 2d, and minor alluvial fan deposits located just north of head of Horse Canyon. Similar to Unit 5, the mass wasting deposits in Unit 6 consist of basalt and sandstone debris resulting from slope failures and erosion of the Grande Ronde Formation and the Ellensburg Formation. Unit 6 alluvial sediments are made up of poorly sorted boulders to gravelly sand predominately derived from erosion of the Grande Ronde Formation, the Ellensburg Formation and glacial period sediments (Tabor, 1982).

No wells were located to the parcel level within the Unit 6 area. As a result, wells that could be located to the ¼ ¼ section level within the Unit area were reviewed and considered. Of the 9 wells found within the area, 2 appear to be completed into the underlying bedrock. The remaining 7 wells that appear to be completed within Unit 6 range in depth from 56 to 380 feet; range in static water level from 10 to 100 ft bgs; and range in estimated yield from about 3 to 50 gpm. While no patterns and general characteristics can be confirmed because of poor well location, it can be reasonably assumed that aquifer characteristics will be similar to that of Unit 5 due to similarity of geologic environment and that groundwater flow will be generally unconfined and conform to topography.

Recharge to Unit 6 is from direct precipitation, possibly from spring or rejected recharge from the MCRB-East of Swk Crk (Unit 2d) and possibly from upward leakage from the underlying TW?/Roslyn (Unit 7). Discharge from Unit 6 is to wells, possibly to infiltration into down slope exposures of the TW?/Roslyn (Unit 7) located in the First Creek watershed east of Swauk Creek, to the Swk Creek ALV (Unit 4), and to the upper reach of First Creek.

Anticipated local effects of groundwater pumping from wells completed in Unit 6 follows:

- Wells will capture groundwater that would otherwise discharge to the Swauk Creek ALV (Unit 4), to the TW?/Roslyn (Unit 7) within the First Creek watershed, and to the upper reach of First Creek.

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), no regional effects of groundwater pumping from wells completed within Unit 6 are anticipated. However, anticipated regional effects of groundwater pumping from wells completed to depths below Unit 6 are described in the corresponding relevant Unit(s).

**UNIT 7**

**Tabor's Wenatchee? Formation / Roslyn Formation (TW?/Roslyn):** Unit 7 (Figure 9) includes both Tabor's (1982) tentatively identified Wenatchee (?) Formation and the Roslyn
Formation. Tabor's Wenatchee (?) Formation in the Swauk Creek and Teanaway River area is composed of volcanic ash-flow tuffs containing interbeds of tuffaceous feldspathic arkosic sandstones and red, purple, green, and tan colored clay rich shales. Steeply dipping beds in the Swauk Creek area, however, suggest considerable structural complexity that is not currently understood (Tabor, et al, 1982). The Wenatchee (?) Formation is thought to unconformably overlie the Roslyn Formation in this area (Tabor, et al, 1984). As observed in the field (Ekstrom & Hoselton, 2011) and described by well drillers, the Wenatchee (?) Formation appears to be largely composed of clay rich materials, is of limited thickness, may be absent in places, and as a result appears to be an unlikely water source for area wells. Consequently, the minor Wenatchee (?) Formation sedimentary unit is treated here collectively with the underlying Roslyn Formation in further review and discussion.

The Roslyn Formation was deposited in a fluvial environment and consists of white/grey thick-bedded feldspathic sandstone with minor conglomerate, carbonaceous shales and coal beds. The Formation, as described by Bressler (1951), was divided into three units generally based on variation in grain size and the presence of coal. The lower member contains interbedded rhyolitic flows and tuffs, tuffaceous to arkosic sandstones, conglomerate, siltstone, claystone and carbonaceous shales. Bressler's middle member is composed of mostly medium-grained, often poorly indurated sandstone, minor pebbly sandstone, siltstone, and carbonaceous shale and coal. The upper member consists mostly of medium grained sandstone with siltstone, shale,
carbonaceous shale and coal beds that were extensively mined during the 1900’s. Total thickness of the entire Roslyn Formation is estimated to be about 8,500 ft (Brownfield, M.E., 2008). Extent of the Roslyn Formation beyond the MSA, as identified by coal mining and gas exploration wells, reaches from just west of the southern end of Cle Elum Lake, eastward beyond the Columbia River at least as far north as the town of Quincy and southward to beyond Yakima (Walker, 1980; Wilson, et. al., 2008). Cheney (2007) argues the Chumsick Formation sandstones and shales that span from west of Leavenworth to east of Wenatchee within the boundaries of the Chiwaukum structural low should be reclassified as part of the Roslyn Formation. If this is correct, then the full extent of the Roslyn Formation is even larger than previously understood.

There are five outcrops of the TW?/Roslyn Formation (Unit 7) within the MSA all located north of the southern end of Hidden Valleys along Swauk Creek. Two are located west and three are located east of Swauk Creek (Figure 9). All together, the MSA Unit 7 outcrops constitute only about 650 acres where the few wells located to the parcel level were generally found to be drilled through Unit 7 and developed into the underlying Teanaway Formation. Unit 7, however, underlies the entire MSA and with the exception of the northern contact with the Teanaway Formation, extends well beyond the MSA to the west, east, and south. As a result, MSA wells which have been constructed through overlying Units and into the underlying Unit 7 were identified, reviewed, and included in this discussion.

Six wells, located to the parcel level, south of MSA’s northern boundary, outside of Unit 7 outcrop boundaries, and within the boundaries of Units 4 and 5, appear to be cased into the underlying Unit 7. The 6 wells are located within sections 22, 27 and 28, T20N, R17E. Two more wells identified in these section also appear to be cased into the underlying Unit 7, however, could only be located to the ¼ ¼ section. One of the 2 poorly located wells was excluded from further consideration because the well’s casing had been perforated above the sediment/bedrock contact, leaving 7 wells for further consideration. Of the 7 wells, 5 appeared to have encountered the top of Unit 7 at depths between about 40 to 235 ft bgs. Driller estimates of yield for these 5 wells ranged from 3.5 to 20 gpm, while completion depth ranged from 200 to 705 ft bgs. Static water level elevations at the 5 wells were estimated to range from approximately 2,120 to 2,180 ft msl.

At 2 of the 7 wells, the top of Unit 7 was clearly encountered at depths of only 9 to 13 ft bgs. Driller’s yield estimates for the 2 wells ranged from 40 to 60 gpm; completion depth was only 59 and 64 ft; the wells had 8 to 10 foot gravel packed screened intakes; and the wells were located only about 600-650 feet from Swauk Creek. Estimated static water level elevations in the 2 wells compared well with Swauk Creek’s surface elevation at approximately 2,147 and 2,148 ft msl. Because of their shallow depths, near-creek-surface elevation static water levels and higher
yields, the groundwater source for these 2 wells is interpreted to be more likely associated with capture of leakage from the Swauk Creek Alluvium (Unit 4) than with Unit 7. As such, the 2 shallow TW?/Roslyn Formation wells will be assigned to the Swauk Creek Alluvium of Unit 4.

Another 10 wells, located in section 32 of T20N, R17E, appear to have encountered Unit 7 below the overlying Unit 5. Of the 10 wells, 4 had perforations in the casing above the sediment/bedrock contact and were excluded from further consideration. Of the 6 remaining wells, if a basalt flow was recorded over the top of the first occurrence of sandstone, it was assumed the first sandstone was likely to be that of the Ellensburg Formation within the MCRB-West of Swk Crk (Unit 1). If no distinct basalt flow was present, then it was assumed the first sandstone was likely to be Unit 7. Once so sorted, the well locations were checked against geologic exposures. Of the 6 wells, 4 were considered to have likely encountered Unit 7 and 2 were considered to have likely encountered the Ellensburg Formation within the MCRB-West of Swk Crk (Unit 1) with a possibility of having encountered Unit 7 at depth (below Unit 1). Interpreted depth to the top of Unit 7, among the 4 identified Unit 7 wells in section 32, ranged from approximately 211 ft bgs to about 360 ft bgs with driller estimated yields ranging from 2 to 5 gpm. Static water level elevations among the 4 Unit 7 wells were estimated to range from about 1,939 to 2,217 ft msl.

In general, groundwater behavior within Unit 7 is expected to be influenced by the structural attitude of the Formation. Additionally, secondary permeabilities will encourage preferential flow through the more brittle shales that are commonly fractured during deformation. Where Unit 7 wells encounter only primary permeabilities, a well may be unsuccessful (dry hole) or yield as little as 2-3 gpm or less. Yields in the range of 5 gpm to 20 gpm for Unit 7 wells are less common and are likely related to secondary permeabilities resulting from fracturing of the Formation during folding and faulting.

Recharge to Unit 7 is from direct precipitation where the Unit outcrops at the land surface by diffuse infiltration, where precipitation may enter the Formation via fracture systems by focused infiltration and from infiltration of surface water where the Unit may be in contact with a surface water source. Recharge is also derived when/where groundwater levels in overlying, adjacent, and underlying Units (inside and outside of the MSA) are higher than groundwater levels in Unit 7. Discharge from Unit 7 is to wells, to overlying, adjacent, and underlying Units where/when the groundwater levels in those Units are lower than groundwater levels in Unit 7, and to the east-southeast regions of the Roslyn Formation.

Anticipated local effects of groundwater pumping from Unit 7 by wells completed in the outcrop area of Unit 7 follows:
Capture groundwater that would otherwise run off as rejected recharge to First Creek and possibly, because of structural attitudes of the Roslyn Formation, to the unnamed creek west of Swauk Creek and south of Teanaway Ridge. Both First Creek and the unnamed creek discharge to Swauk Creek.

Anticipated local effects of groundwater pumping from Unit 7 by wells completed within the MSA but outside of the Unit 7 outcrop area follows:

- Wells may, depending on location and head relationships, capture additional recharge or discharge from overlying Units 1, 2, 4, 5 or 6.

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), anticipated regional effects of groundwater pumping from wells completed within the Unit 7 outcrop area and elsewhere within the MSA boundaries follows:

- Wells may capture some component of groundwater that would otherwise discharge to the Roslyn Formation outside of the MSA.

UNIT 8

The Teanaway Formation: Unit 8 (Figure 10) outcrops along the northern boundary of the MSA and is thought to underlie most and possibly all of the MSA. The majority of the Teanaway Formation, however, extends to the west, the northwest and slightly south of the MSA (Figure 13) and is composed predominately of subaerial basalts that unconformably overlie the Swauk Formation and conformably underlie the Roslyn Formation. The Teanaway Formation is mostly basaltic, but ranges in composition to rhyolite and contains minor feldspatic sedimentary rocks, breccias, and rhyolitic ash-flow tuffs. Basalt flows of the Teanaway Formation are characteristically black in color, glassy to very fine grained, aphinitic with chalcedonic filled amygdules (Tabor, et al., 1982).

Only 1 well was located within the outcrop boundaries of Unit 8 to the parcel level. However, both Unit 8 and the Roslyn Formation (Unit 7) outcrop on the associated parcel. Additionally, the well log tends to suggest the well may have been drilled through Unit 8 and into the underlying Swauk Formation which is presently outside the scope of this report. As a result and similar to Unit 7 above, wells drilled within the boundaries of MSA Units to the south were reviewed to identify whether Unit 8 may have been encountered below overlying Units.
Only 3 wells, located within the boundaries of Unit 7, were found to be clearly developed into Unit 8. Completion depths of the 3 wells were reported to be 500, 300, and 147 feet deep with static water levels of 190 bg's, not reported, and 90 feet bg's, respectively. Driller estimated yields for the wells was given to be 1 ½ gpm with a slow recovery noted for the deepest well, 3 gpm for the 300 ft well and 2 ½ gpm for the 147 ft well. Well log data and lithological descriptions of the Teanaway Formation suggest that Unit 8 is more likely to display fracture flow characteristics than porous medium properties. Sustainability of well yield and other hydrogeologic characteristics of Unit 8 are largely uncertain due to lack of wells in the Teanaway Formation both inside and outside the MSA. Recharge to Unit 8 is from direct precipitation where the Unit outcrops at the land surface and from infiltration by surface water where the Unit is in contact with a surface water source. Recharge to Unit 8 may also be derived from overlying, adjacent and underlying Units where/when groundwater levels in the overlying, adjacent or underlying Units are higher than groundwater levels in Unit 8. Discharge from the Unit 8 is to wells, to overlying, adjacent and underlying Units where/when the groundwater levels in those Units are lower than groundwater levels in Unit 8, and to portions of the Unit outside of the MSA.

Anticipated local effects for wells completed in Unit 8 follows:
Wells will capture groundwater that would otherwise run off as rejected recharge to First Creek east of Swauk Creek and to an unnamed Creek south of Teanaway Ridge and west of Swauk Creek, both being tributaries of Swauk Creek.

Anticipated local effects of groundwater pumping from Unit 8 by wells completed within the MSA but outside of the Unit 8 outcrop area follows:

- Wells may reduce discharge to or increase recharge from overlying (Units 1, 2, 4, 5, 6 or 7), adjacent and underlying Units within the MSA depending on groundwater head relationships.
- Wells may capture groundwater that would otherwise discharge to the south-southeast regions of the Teanaway Formation within the MSA.

Assuming that new water uses are mitigated in accordance with the Upper Kittitas Groundwater Rule - Washington Administrative Code (WAC) 173-539A (Rule), anticipated regional effects for wells completed in Unit 8 follows:

- Wells may reduce discharge to or increase recharge from overlying, adjacent and underlying Units outside the MSA depending on groundwater head relationships.
- Wells may capture some component of groundwater that would otherwise have discharged to the Teanaway Formation outside the MSA.

Related Units adjacent to but outside the MSA (Figure 11):

**Unit 9:** Mass wasting deposits occurring around the southern, western, and northern margins of the MCRB-West of Swk Crk (Unit 1) outside of the MSA boundary.

Unit 9 is composed of mass wasting debris and talus slope deposits derived from the south, west and north flanks of Look Out Mountain. The mass wasting deposits consist of rotational blocks and detritus of basalt and sandstone resulting from slope failures and erosion of the Grande Ronde Formation, the Ellensburg Formation, and possibly some remnant glacial sediments.

**Unit 10:** Mainstem Yakima River Valley alluvium south of the MCRB-West of Swk Crk (Unit 1) outside of the MSA boundary.

Unit 10 is limited generally to the sediments comprising the Yakima River’s mainstem valley from approximately river mile 175, downstream to river mile 170.5, or from approximately 1
mile downstream of the Teanaway River's confluence with the Yakima River to just downstream of Swauk Creek's confluence with the Yakima River.

**Unit 11:** Columbia River Basalt Group (CRBG) and the Ellensburg Formation occurring east of the MCRB-East of Swk Crk (Unit 2).

The Miocene age CRBG forms a large scale regional aquifer system composed of flood-type basalt flows which generally consist of a vesicular flow top, entablature, dense column or colonnade, and a vesicular base which may or may not include a pillowed zone. Within the basalt flow sequence, sedimentary units, referred to as interbeds may be present. Interbeds represent non-eruptive periods during which sediments were deposited over widespread areas of an existing basalt surface and later were covered over by new basalt flows when an eruptive phase resumed.
Where a vesicular flow top and subsequent flow bottom are found in contact, they are referred to as interflow zones. It is within the interflow zones that most of the groundwater flow occurs. Groundwater flow can also occur within interbed units; however, depending on the composition of the interbed, it may function as an aquitard and inhibit groundwater flow. While the basalt flow’s dense interiors initially have very low horizontal and vertical conductivities that inhibit groundwater flow, in regions where the flow interior has been fractured by folding and faulting, secondary permeabilities are created, conductivities are increased and groundwater flow between individual flows may occur. Conversely, folding and faulting of the basalt aquifer system may also result in barriers to groundwater flow which include but are not limited to the formation of fault gouge and clays along the fault plane or by the offsetting of flow zones against unfractured dense interiors or other zones of low permeability. The reader is referred to Tolan, Lindsey and Porcello (2009) for additional information regarding CRBG hydrogeology.

**Unit 12:** Unit 12 includes groundwater bearing unconsolidated sediments and bedrock units comprising the western portion of Swauk Prairie but located within the Teanaway Drainage Basin, immediately west of the W. Swk Creek Unc (Unit 5).

**Discussion Summary**

The above discussion has identified the project location, explained the methodology and assumptions used to identify and group geologic units into MSA groundwater Units. Once so identified and grouped, geologic and hydrogeologic characteristics provided the framework from which groundwater recharge and discharge relationships between MSA Units, Swauk Creek and with groundwater units immediately outside of the MSA were investigated. Once recharge and discharge relationships had been characterized, it was then possible to conceptualize probable local and regional effects of groundwater pumping within the MSA. Building on the above findings, physical water availability and potential for impairment between groundwater users will be discussed in the following Water Availability section.

**Water Availability Discussion (Units 1 through 6)**

WAC 173-539A-040(1) states that “all public groundwaters within the upper Kittitas County are withdrawn from appropriation.” WAC 173-539A-050 further states that “persons proposing a new use of groundwater shall apply to ecology for a permit to appropriate public groundwater” and identify in their application “one or more water rights that would be placed into the trust water right program to offset the consumptive use...associated with the proposed new use of groundwater”.

James and Jan Roan have conveyed a portion of their First Creek water rights (Court Claim No. 00648) to Ecology's Trust Water Right Program (Ecology reference 34) to make it available for
mitigation purposes in the Swauk Creek Basin in Kittitas County. This trust water right will primarily be used to serve as mitigation for up to eight ground water applications to serve up to 145 residences within the green zone of the Roan (Swauk Bain) DRAFT Mitigation Suitability Map which can be viewed at http://www.ecy.wa.gov/programs/wr/cro/slwb.html (March, 2012). This portion of Court Claim No. 00648 may also be used as a source of mitigation for some permit-exempt ground water uses that are independent of the up to eight permits. This right will vary in its effectiveness to serve as mitigation for new ground water users, depending primarily on where the proposed new use is located, as shown on the map.” Associated with this action, is the James and Jan Roan Trust Water Right Agreement which states: “The purpose of this Agreement and the primary reason Roan is willing to place the Water into the Trust is to provide a senior water right as off-setting mitigation that will allow Roan or third parties to apply for and receive new ground water withdrawal or surface water diversionary permits or water budget neutral determinations within the Yakima River basin, within Kittitas County. These new water rights will be mitigated by way of a permanent designation of such portion of Roan’s beneficial interest in the Water in Trust as reasonably required to ensure no impairment to TWSA or other water rights; provided that any portion of such mitigation may also be provided by other means.” (Ecology reference #37).

Although the actions described above are designed to remedy impacts to Swauk Creek and presumably result in water budget neutrality for the request associated with Application G4-35536, they do not address the question of local groundwater availability at or near the point of withdrawal. Consequently, and as in earlier mitigated permitting efforts under WAC 173-539A (Ecology Reference #36) prior to the completion of the ongoing USGS study, average annual precipitation will be used to roughly estimate an average annual infiltration volume that will then be treated as a reasonable estimate for an average annual recharge to the MSA groundwater Units 1-8 described earlier.

Assuming the estimated average annual recharge can offer a practical approximation of local water availability for permitting purposes, the following process was followed:

- The outcrop area of each individual MSA Unit was calculated.
- The average annual precipitation input was then calculated from the intersection of each Unit’s boundaries with the PRISM (Parameter-elevation Regressions on Independent Slopes Model) 1971-2000 dataset for average annual precipitation.
- Derived values of average annual precipitation were converted to an average annual acre feet of precipitation input for each Unit.
- It was then assumed that some percentage of the average annual precipitation distributed over the area of a Unit could reasonably represent an estimated average annual infiltration volume and subsequently recharge input for Units 1 through 6 based on each
Unit’s characteristics. Differing characteristics require that Units 7 and 8 be evaluated and discussed separately.

- A conservative range of 5, 10, and 15 percent of the gross annual precipitation volume was calculated to represent an estimated average annual infiltration volume for each Unit 1 through 6.
- Based on Unit characteristics a ‘most likely’ percentage for infiltration was identified for each of the Units 1 through 6.
- Existing groundwater rights were correlated to the appropriate Unit and annual use volumes were estimated and summed for each Unit.
- Existing domestic exempt wells were correlated to the appropriate Unit and subtotaled for each Unit. Existing wells identified in Application G4-35536 were subtracted from the subtotals to avoid duplication in the use estimate. Annual use volumes for the remaining existing domestic exempt wells were estimated by multiplying the totals for each Unit by 1/4 acre foot per year.
- The total volume of groundwater use associated with existing groundwater right documents and domestic exempt well uses were subtracted from the infiltration range for each Unit to derive a net remaining infiltration volume for each Unit.
- The Total Water Use identified in Application G4-35536, derived from Ecology’s Consumptive Water Use Calculator and defined as the quantity of water required for the project was then compared to the remaining net infiltration volume for each Unit by converting the Total Water Use volume to a percent of the infiltration estimate for each Unit. This allowed a worst case scenario by assuming the entire use identified in Application G4-35536 (59.987 acre feet) could be taken from a single Unit and offers insight on what such an action may represent when compared to the Unit’s estimated average annual infiltration.

The results of the above described process are shown below in Tables 2 through 7 below where the “most likely” percentage infiltration selected, based on Unit characteristics, for each Unit is identified by dark green highlight:

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<tr>
<th>% infiltration</th>
<th>GROSS AF infiltration</th>
<th>less estimated AF of existing gw rights</th>
<th>less estimated existing exempt wells at 0.5 AF ea</th>
<th>NET remaining AF infiltration</th>
<th>61.86 af = approx what % of infiltration estimate ?</th>
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Table 2: Unit 1 (MCRB-West of Swk Crk)
Table 3: Unit 2 (MCRB-East of Swk Crk)

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<th>less estimated existing gw rights</th>
<th>less estimated existing exempt wells at 0.5 AF ea</th>
<th>NET remaining AF infiltration</th>
<th>61.86 af = approx what % of infiltration estimate?</th>
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Table 4: Unit 3 (HC ALV)

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<th>less estimated existing exempt wells at 0.5 AF ea</th>
<th>NET remaining AF infiltration</th>
<th>61.86 af = approx what % of infiltration estimate?</th>
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Table 5: Unit 4 (Swk Creek ALV)

<table>
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<th>% infiltration</th>
<th>GROSS AF infiltration</th>
<th>less estimated existing gw rights</th>
<th>less estimated existing exempt wells at 0.5 AF ea</th>
<th>NET remaining AF infiltration</th>
<th>61.86 af = approx what % of infiltration estimate?</th>
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<td>6</td>
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<td>156</td>
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<tr>
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<td>214</td>
<td>61.33</td>
<td>6</td>
<td>146</td>
<td>42</td>
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<tr>
<td>15%</td>
<td>321</td>
<td>61.33</td>
<td>6</td>
<td>253</td>
<td>24</td>
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<tr>
<td></td>
<td>Gross</td>
<td>AF Infiltration</td>
<td>less</td>
<td>estimated</td>
<td>existing</td>
</tr>
<tr>
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<td>-------</td>
<td>-----------------</td>
<td>------</td>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td>Unit 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Infiltration</td>
<td></td>
<td>AF infiltration</td>
<td></td>
<td>less</td>
<td>less</td>
</tr>
<tr>
<td>10%</td>
<td>257</td>
<td>12.1</td>
<td>12</td>
<td>233</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 6: Unit 5 (W. Swk Creek Unc)

|          | Gross | AF Infiltration | less | estimated | existing | exempt Wells | NET | Infiltration | remaining AF Infiltration |
|----------|-------|-----------------|------|-----------|----------|-------------|------|--------------| approx what % of infiltration estimate ? |
| Unit 6   |       |                 |      |           |          |             |      |              |                              |
| % Infiltration |       | AF infiltration |      | less      | less     | less        |      | less         | NET                          |
| 5%       | 202   | 0.5             | 3    | 198       | 31       | 601         | 10%  | 61.86 af      | 10                          |
| 10%      | 403   | 0.5             | 3    | 400       | 15       |             |      |              |                              |
| 15%      | 605   | 0.5             | 3    | 601       | 10       |             |      |              |                              |

Table 7: Unit 6 (E. Swk Creek Unc)

Results for Units 1, 2, 5, and 6 suggest average annual recharge from infiltration could reasonably satisfy the current request given that unknowns discussed below are considered. Unit 3, because of its small surface area and resulting small precipitation input, appears to be more limited. Unit 4, because of its small surface area and resulting small precipitation input, demand by existing groundwater rights and exempt wells appears to be the most limited of Units 1-6. Interestingly, during the summer of 2011, USGS measured 10 of the MSA wells identified in this study (Appendix B). USGS measured wells were distributed among Units 1, 2, 4, 5, and 7. Two of the MSA wells that were originally recorded to be flowing were found by the USGS to still be flowing, however, it is not known if head pressures have reduced, remained the same or increased over time. The remaining eight non-flowing MSA wells measured were all found to have static water levels that were higher than their original static water levels measured by the drillers at the completion of well construction.

Given the above discussion, groundwater is physically available; legal availability, however, is ultimately a permitting/management decision that is, in part, based on the above information.
Risks / Cautions / Unknowns:

Estimated volumes presented here should not be treated as absolute amounts of groundwater available, but more as a reference to be considered with existing authorizations and eventually with data from long term groundwater level monitoring. Further, while this effort provides consideration of the groundwater recharge by infiltration, it does not determine the quantity of water available for appropriation from the aquifer. The quantity of water available for appropriation from the aquifer is a management determination. This effort recognizes that unknowns and decisions risks still include and may not be limited to:

- Water budget component unknowns
- Time required for aquifer water levels to stabilize at a reduced level in response to adding new groundwater uses (via capture of discharge or recharge).
- Specifically, the time lag between infiltration and discharge along any part of the groundwater flow path is not known.
- Similarly, the rate for the groundwater system to reach equilibrium in response to added wells is unknown.
- Effects of boundary conditions
- Future demand and climate variation unknowns
- Magnitude and nature of acceptable impacts to the system caused by new withdrawals such as reduced discharge to springs, tributaries, etc., long-term change in water table elevation that may necessitate deepening of some wells etc).
- Permanent changes to groundwater levels may cause impacts to springs, water levels in local domestic wells, etc., and should be considered as part of the risks to new appropriations.

**Water Availability Discussion (Units 7 and 8)**

**Unit 7:** Roslyn Formation outcrops, identified within the MSA, represent less than five percent of the entire MSA (Figure 9). The Formation, however, is known to be present below the entire MSA and extends for considerable distances in all directions outside of the MSA (Appendix C). Additionally, Cheney (2007) presents thoughtful argument for re-classifying the Chumstick Formation, north of the Wenatchee Mountain Range, as part of the Roslyn Formation which would further add to the unit’s known extent. Because the majority of the Roslyn Formation occurs outside the MSA (Figure 12 and Appendix B), evaluating infiltration over the small portion of the Formation that outcrops inside the MSA is unlikely to yield any meaningful insight regarding local water availability for Unit 7. What is known regarding the water resource potential of the Roslyn Formation comes from area and out of area wells that range from
domestic exempt wells (Ecology references 29 and 36) to gas exploration wells (Wilson, et al., 2008) and from Packard’s (1981) evaluation for water resource potential of the abandoned coal mines near Roslyn and Cle Elum. Such sources suggest the Roslyn Formation has the capacity to produce generally low yield water wells in the range of less than 1 gpm up to about 2-3 gpm where only primary permeabilities are encountered. Secondary permeabilities resulting from folding and faulting of the Formation may facilitate higher yields perhaps in the range of 5 to 20 gpm, however, sustainability of higher yields is questionable (Ecology reference 36).

Within the MSA, only one short form claim (G4-138203CL) was identified as likely relying on a Roslyn Formation source. The claim was estimated to potentially represent 2.8 acre feet annually based on uses identified. Existing MSA domestic wells identified as likely relying on a Roslyn Formation source numbered only 16 with combined use from the wells estimated to total 8 a/f/yr. Outside of the MSA, water use from the entirety of the Roslyn Formation is not known although two limited area estimates associated with water right applications (Ecology reference 36) have been processed west of the MSA. Additional complication in assessing water resource potential of the Formation results from structural unknowns (Appendix A) which may or may not
compartmentalize the Formation. As a result, water use from Unit 7 within the MSA should be monitored and the current characterization reviewed and updated if necessary.

**Unit 8**: Previous efforts by Ekstrom (personal communication, 2011) and current efforts by the author (2011-2012) have identified only 3 well logs describing wells that are clearly developed into the Teanaway Formation inside the MSA and only 1 outside the MSA. This is in part because much of the Formation occurs at depth below more easily accessed water bearing units and in part because much of the land where the Formation crops out is publically owned (Figure 13).

![Figure 13: Teanaway Formation outcrops shown in black hatch; Public lands shown in green mask; MSA boundary shown in red hatch; Where the green mask underlies the black hatch illustrates how much of the Teanaway Formation outcrops on public lands or, as in the central region of the figure above (shown in grey shaded relief) is overlain by other geologic units.](image)

Because the majority of the Teanaway Formation occurs outside the MSA, evaluating infiltration over the small portion of the Formation that outcrops inside the MSA is unlikely to yield any meaningful insight regarding local water availability for Unit 8. The few wells constructed into Unit 8 suggest only that the Unit is likely to behave as a low yield bedrock source. Geologic characteristics suggest a fracture flow system is more likely than a porous medium flow system. Sustainability of a fracture flow system in the upland and boundary regions of the Formation would likely be sensitive and responsive to climatic variations. Where the Teanaway Formation is otherwise overlain by the Roslyn Formation and various unconsolidated sediments, the groundwater flow system may be more constant in character because of potential for groundwater exchange with other units.
No existing groundwater rights were identified within the MSA boundaries for Unit 8 and only 3 existing domestic wells have been clearly associated with Unit 8. One existing adjudicated surface water right for with a diversion point within the boundaries of Unit 8 was identified. The existing right is for timber management with a maximum instantaneous rate of 0.58 cfs and an annual maximum volume of 1.840 acre feet. Unfortunately, the lack of hydrogeologic data for the Teanaway Formation precludes characterization of groundwater availability for Unit 8. Consequently, groundwater development in this Unit should be carefully monitored and the current characterization of the Unit reviewed and updated if necessary.

**Impairment Discussion**

**Impairment, Qualifying Works and Well Interference:** There are three concepts that are important when considering whether a withdrawal of water from a well would impair another existing water right. The concepts are defined as follows:

Impairment is an adverse impact on the physical availability of water for a beneficial use that is entitled to protection.

Qualifying groundwater withdrawal facilities are defined as those wells which in the opinion of the Department are adequately constructed. An adequately constructed well is one that (a) is constructed in compliance with well construction requirements; (b) fully penetrates the saturated thickness of an aquifer or withdraws water from a reasonable and feasible pumping lift (WAC 173-150); (c) has withdrawal facilities capable of accommodating a reasonable variation in seasonal pumping water levels; and (d) the withdrawal facilities and pumping facilities are properly sized to match the ability of the aquifer to produce water.

Well interference is the overlap of the cones of depression for two or more wells. Well interference reduces the water available to the individual wells and may occur when several wells penetrate and withdraw groundwater from the same aquifer. Each pumping well creates a drawdown cone. When several wells pump from the same aquifer, well density, aquifer characteristics, and pumping demand may result in individual drawdown cones that intersect and form a composite drawdown cone.

The concepts discussed above come together when potential for impairment is being considered. For example, to claim impairment, a groundwater right holder must have a qualifying groundwater withdrawal facility and be able to demonstrate that withdrawals by another groundwater user is resulting in an inability to satisfy a valid right which is entitled to protection. Consequently when a proposed withdrawal is evaluated, consideration is given to how the withdrawal may affect other existing groundwater users.
For MSA Units 1 and 2 impairing conditions between wells are generally not anticipated. Current aquifer conditions and infiltration estimates suggest these Units can presently tolerate the entire consumptive and non-consumptive request being considered (Table 2 and 3) in addition to existing groundwater rights and existing exempt wells. Because, these Units are marginal in nature, it is recommended that wells be located as far from the Unit’s western outer boundaries as possible and a minimum 100 foot spacing from existing wells observed.

For MSA Unit 3, because of the Unit’s small size, thin saturated thickness and limited recharge, the possibility of impairing conditions between wells appears to be moderate to high (Table 4). While no groundwater rights were found associated with Unit 3, at least two adjudicated surface water rights (S4-83888-J and S4-83935-J) for existing springs would likely require protection from future groundwater withdrawals; the two right s total 59.25 af/yr.

New groundwater users within the boundaries of Unit 3 are consequently encouraged to explore underlying Unit 2 as a more reliable and preferred groundwater source. Wells drilled through Unit 3 and into Unit 2 shall be required, at minimum, to have a solid casing through Unit 3. If, however, Unit 3 is to be further developed by water users, then a maximum upper limit of acre feet needs to be established for the Unit.

For MSA Unit 4, because of the Unit’s large number of existing groundwater rights, small size and generally thin (West Hidden Valley area is an exception) sediment package, the possibility of impairing conditions between wells and possibly surface water appears to be high (Table 5). Surface water / groundwater exchange may mitigate effects of Unit 4 wells nearby Swauk creek, however, areas of observed and likely seasonal disconnection between the groundwater and the creek have been documented (Schwartzman, 2002).

Similar to Unit 3, new groundwater users within the boundaries of Unit 4 are consequently encouraged to explore Units (1, 2, and 7 depending on location) underlying Unit 4 as more reliable and preferred water sources. Wells drilled through Unit 4 and into an underlying Unit shall be required, at minimum, to have a solid casing through Unit 4. If, however, Unit 4 is to be further developed by groundwater users, then a maximum upper limit of acre feet needs to be established for the Unit and a minimum 100 foot spacing from existing wells observed.

For MSA Units 5 and 6 impairing conditions between wells are generally not anticipated as current aquifer conditions and infiltration estimates suggest these Units should presently be able to tolerate the entire consumptive and non-consumptive request being considered (Table 6 and 7) in addition to existing groundwater rights and existing exempt wells.

Unit 5, however, does have regions where wells will encounter significant clays and likely result in low yield and slow recovery wells. Additionally, Unit 5 has areas of perched and thin
saturated thicknesses. As a result, it is recommended a minimum 100 foot spacing from existing wells be observed.

If new water users are not able to successfully develop into Unit 5, they may instead consider drilling into an underlying Unit, which depending on location may be Unit 7 (central and north), Unit 1 or 2 (south and southeast) or Unit 8 (north). Such wells shall be required to have a solid casing through Unit 5.

For MSA Unit 7, aquifer characteristics are expected to generally produce narrow and steep drawdown cones and low yielding wells which are likely to be more self-limiting than adversely affected by neighboring wells. Impairment is unlikely due to a low level of groundwater development from this unit versus the large extent of the Formation. Further, an unknown amount of recharge to Unit 7 is derived from sources outside the MSA.

Note: Because of the unit’s complex stratification, structure, and thickness, demonstrating impairing conditions between wells is likely to be extremely difficult.

For MSA Unit 8, Formation characteristics are presently expected to produce more self-limiting issues than adverse affects between neighboring wells. The current low level of groundwater development from this unit and its greater depth underlying more easily accessed Units to the South make it an unlikely target for groundwater development. Additionally, an unknown amount of recharge to Unit 8 is derived from sources outside the MSA.

Note: Believed to predominately function as a fracture flow system, demonstrating impairing conditions between wells is likely to be extremely difficult.
Report Limitations

This report has been prepared in reference to that portion of the lower Swauk Creek Basin described by the “Likely Suitable” (Green area) of Ecology’s Draft Swauk Mitigation Suitability map (Ecology reference 28) developed for the Swauk Creek Basin in association with the Roan Trust Water Right Agreement, Kittitas County, Washington, as illustrated in Figure 1. This report is not intended for use for projects or applications in any other geologic unit or units and the information contained herein is not applicable to other geologic unit or units. A number of unique, application or project specific factors were considered when preparing this report. This report should not be applied to any purpose or project besides the application or project for which it was prepared.

Because each hydrogeologic study is unique, each hydrogeologic report is unique and is based on conditions that existed at the time the application or project investigation was performed. The findings and conclusions of this report may, however, be affected by the passage of time as a result of either manmade events or natural events.

The geosciences practices (geology, geological engineering or hydrogeology) are far less exact than other engineering and natural science disciplines. Interpretations of subsurface conditions presented in this report are based on available data and field observations. Professional judgment was applied to form an opinion about subsurface conditions throughout the area of interest. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. This report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.
References


5. Ekstrom, I. & Hoselton, A., 2011, Field notes and photos investigating characteristics of selected outcrops of Ellensburg Formation, the Roslyn Formation and the Wenatchee (?) Formation in Kittitas County.


24. Tolan, Terry; Lindsey, Kevin; and Porcello, John (2009), A Summary of Columbia River Basalt Group Geology and its Influence on the Hydrogeology of the Columbia River Basalt Aquifer System: Columbia Basin Ground Water Management Area Of Adams, Franklin, Grant, and Lincoln Counties; Prepared by the Columbia Basin Ground Water Management Area, Othello, WA 99344. [www.cbgwma.org](http://www.cbgwma.org)


34. Washington Dept of Ecology, web page

35. Washington Dept of Ecology, web page


37. Washington Dept of Ecology, web page

38. Washington Department of Natural Resources (WDNR) Digital 1:100,000 Geologic Maps
http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/gis_data.aspx

Fig. 1. Swauk watershed, central Washington state. Stipled area represents the extent of Columbia River Basalts in the study area.

## Appendix B

Table 1: Comparison of Original Static Water Levels from ten MSA wells and one non-MSA well to static water levels taken by the USGS during the spring/summer of 2011 at the same wells. Non-flowing static water levels in all MSA wells appear to have increased. It should be noted, however, that the 2010 – 2011 water year was exceptionally above average with spring flooding occurring in the Upper and Lower Kittitas valley region.

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Appendix C

Figure 1: Section lines adapted from Chapter 4, Figure 4 of Evaluation of Well Test Results and the Potential for Basin-Center Gas in the Columbia Basin, Central Washington to show geographical region outside of the MSA, over which the Roslyn Formation is present below the Columbia River Basalt Group as illustrated in Figure 2 below.

Figure 2: Cross Sections from Chapter 4, Figures 3, 5 and 6 of Evaluation of Well Test Results and the Potential for Basin-Center Gas in the Columbia Basin, Central Washington to show geographical region over which the Roslyn Formation is present below the Columbia River Basalt Group and structural complexities and possible compartmentalization due to faulting.