Critical Aquifer Recharge Area Susceptibility Index Methodology

Prepared for

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TABLE OF CONTENTS

ACRONYMS

CAO	Critical Areas Ordinance
CARA	Critical Aquifer Recharge Area
gpm	gallons per minute
WHPA	Wellhead Protection Area

1. CARA, WHAT IT MEANS, AND ELEMENTS TYPICALLY CONSIDERED TO DELINEATE.

This memorandum identifies the approach, methodology, and data utilized to establish aquifer susceptibility and vulnerability and delineation of critical aquifer recharge areas (CARA) in Cowlitz County.

From WAC 365-190-030(3)

"Critical aquifer recharge areas" are areas with a critical recharging effect on aquifers used for potable water, including areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water, or is susceptible to reduced recharge.

From Ecology CARA Guidance

Identifying “areas with a critical recharging effect on aquifers used for potable water,” depends on understanding aquifer recharge and what is meant by “a critical recharging effect.”

Aquifer recharge occurs where rainfall, snowmelt, infiltration from lakes, wetlands and streams, or irrigation water infiltrates into the ground and adds to the water underground that can supply a well.

On the other hand, **discharge areas** are where ground water is headed toward the ground surface and ultimately flows out from a spring, wetland, stream, lake, estuary, or ocean shore. Wells can also serve as discharge areas, especially larger volume wells, such as those used by municipalities.

Most of a watershed is typically a recharge area, with discharge areas occurring to a more limited extent in topographically lower areas. Recharge areas and discharge areas can be mapped using hydrogeologic techniques to determine where ground water is and where it is flowing.

Aquifers used for potable water are identified by looking at existing and future planned uses. Existing wells and their protection areas, sole source aquifers, and aquifers otherwise identified as important supplies, are examples of “aquifers used for potable water.”

Aquifer recharge areas shall be rated as having high, moderate, or low susceptibility based on **soil permeability, geologic matrix, infiltration, and depth to water** as determined by the criteria established by the state Department of Ecology (Ecology, 2000).

Ecology’s 2005 CARA Guidance refers to **susceptibility** as what the ground is like. It notes that when water can move readily through the ground, it can carry contaminants to groundwater more quickly. An example is that sandy, shallow aquifers are more susceptible than deep aquifers that are overlain by clay. The term **vulnerability** refers to the risk of contamination from chemical use combined with the risk from the susceptibility of aquifers. **Critical aquifer recharge area maps** are identified as delineations of where a community’s groundwater supply meets criteria such as susceptibility, potential for contamination, and priority.

Other CARA Elements to Consider

CARA have prevailing geologic conditions associated with infiltration rates that create a high potential for contamination of ground water resources or contribute significantly to the replenishment of ground water. These areas include the following:

- **Wellhead Protection Areas**. Wellhead protection areas shall be defined by the boundaries of the ten-year time of ground water travel, or boundaries established using alternate criteria approved by the Department of Health in those settings where ground water time of travel is not a reasonable delineation criterion, in accordance with WAC 246-290-135. Wellhead protection areas for Group A and B community water supply systems located in Cowlitz County are presented in Washington Department of Health water supply system database.
- **Sole Source Aquifers.** Sole source aquifers are areas that have been designated by the U.S. Environmental Protection Agency pursuant to the Federal Safe Drinking Water Act. No sole source aquifers have been identified in Cowlitz County. The Troutdale Aquifer Sole Source Aquifer area located in neighboring Clark County extends up to portions of the southern Cowlitz County line but does not extend into Cowlitz County.
- **Susceptible Ground Water Management Areas.** Susceptible ground water management areas are areas that have been designated as moderately or highly vulnerable or susceptible in an adopted ground water management program developed pursuant to Chapter 173-100 WAC. The presence of Susceptible Ground Water Management Areas in Cowlitz County has not been identified.
- **Special Protection Areas.** Special protection areas are those areas defined by WAC 173-200-090. The presence of Susceptible Protection Areas in Cowlitz County has not been identified.
- **Moderately or Highly Vulnerable Aquifer Recharge Areas.** Aquifer recharge areas that are moderately or highly vulnerable to degradation or depletion because of hydrogeologic characteristics are those areas delineated by a hydrogeologic study prepared in accordance with the state Department of Ecology guidelines. The presence of hydrogeologic studies that provide this information for Cowlitz County has not been identified. The aquifer vulnerability assessment conducted to establish CARA for Cowlitz County attempts to identify moderately or highly vulnerable recharge areas as described in this memo.
- **Moderately or Highly Susceptible Aquifer Recharge Areas**. Aquifer recharge areas moderately or highly susceptible to degradation or depletion because of hydrogeologic characteristics are those areas meeting the criteria established by the state Department of Ecology. A highly vulnerable aquifer recharge area is considered to be the same as a highly susceptible aquifer recharge area. As such, the aquifer vulnerability assessment being conducted to establish CARA for Cowlitz County also attempts to identify moderately or highly susceptible recharge areas.

2. WHAT AND WHERE ARE THE AQUIFERS THAT HAVE BEEN DELINEATED IN COWLITZ COUNTY?

Groundwater Presence

Delineation of water-bearing characteristics of the geologic units in Cowlitz County is based on the Myers (1970) report. The Myers report represents the most comprehensive report on groundwater presence in Cowlitz County. The extent of geologic mapping in Cowlitz County available during preparation of the Myers report was aerially limited and did not include the entire area of Cowlitz County; mostly the eastern half. Additional geologic mapping and mapping compilation has occurred since the Myers report that has further refined geologic units present primarily as presented in the

Phillips (1987) report. The geologic units identified in the Myers report and their water-bearing characteristics remain valid and were considered in the CARA development effort. Aquifers identified in the Myers report are also referenced in the Ebbert and Payne (1985) report on the quality of water in the principal aquifers of southwestern Washington.

The following are summary descriptions of the geologic units identified in the Myers report (in order of youngest to oldest) and their water-bearing characteristics:

- **Alluvium** – Sand, gravel, and silt underlying flood plains, valley floors, and low terraces. This unit is the major aquifer in the county. Yields ranging from up to 3,000 gallons per minute (gpm) may be obtained from a single well. The 1985 Ebbert report states alluvial deposits are the most productive sources of groundwater in Cowlitz County.
- **Landslide debris** – Debris of Quaternary and Tertiary rocks yielding minor amounts of water. The extent of these deposits is aerially limited.
- **Logan Hill Formation** – Highly weathered gravel and sand. This formation is located primarily in areas on the eastern side of Cowlitz River north of Silver Lake. This formation yields very little water but it is tapped by many domestic wells.
- **Troutdale Formation** – Unconsolidated sand and gravel. The formation is not extensive enough to yield large quantities of water, but can supply sufficient quantities for domestic use. This formation is found in areas above the alluvial deposits mostly north and east of Longview. The formation is fairly permeable and readily absorbs infiltrating water from precipitation.
- **Wilkes Formation** – Non-marine siltstone, sandstone, and conglomerate. Yields small to moderate quantities of water locally to wells tapping sandy beds. This formation appears to be primarily present to the north and east of Silver Lake. The 1985 Ebbert report notes that this formation is a source of groundwater to numerous domestic wells but generally has poor water-bearing characteristics.
- **Volcanic rocks** – These are mostly basalt and andesite volcanic rock not known to yield appreciable quantities of water to wells in the eastern area of Cowlitz County. However, yields as much as 120 gpm or more have been observed in several wells in the western area.
- **Sedimentary and Volcanic Rocks of Eocene Age** – Marine and non-marine sandstone with coal beds, shale, pyroclastic rocks and basalt flows. Wells tapping this unit are dependent on encountering joints/fractures for transmittal of water. Yields range from less than 10 gpm to more than 160 gpm in individual wells. The 1985 Ebbert report notes that this unit has poor water-bearing characteristics.

This information is considered in the delineation of water-bearing units, the location of water supply wells, and establishment of rating values used to determine aquifer susceptibility.

Groundwater Hydrology

The Myers report notes that groundwater is obtained mostly from unconsolidated alluvial materials and to a lesser extent from the older more cemented (indurated) sedimentary and volcanic rocks. In the alluvial deposits water is contained in pore spaces between individual grains. In the older sedimentary and volcanic rocks water occurs in small cracks and joints that generally become insignificant at depths greater than a few hundred feet.

Groundwater in Cowlitz County is recharged mainly by direct infiltration of water from precipitation. To a lesser extent, streams during high stage help recharge groundwater in aquifers adjacent to the stream. The path of movement of groundwater in rock deposits with cracks and joints is not known. Depth to water and yields can be notably different in wells located several hundred feet apart.

Groundwater in Cowlitz County discharges as spring flow, seepage to streams, well discharge, and evapotranspiration. Springs are common in Cowlitz County and are typically located at the contact of the present-day soil and the underlying, poorly permeable bedrock. Due to limited storage capacity in some of the weathered material, springs can dry up before the end of the dry season, or flow only during the wet period. It is assumed that most of the groundwater discharge in Cowlitz County occurs as seepage to the stream channels.

Identified Groundwater Occurrence Subareas

The Myers report identified the following five groundwater occurrence subareas:

- **Silver Lake** – Water supplies for most of the homes around Silver Lake and in the adjacent area are from wells tapping aquifers in the Wilkes Formation.
- **Coal Creek** – Occupies a fairly narrow valley about 7 miles northwest of Longview. Water mostly obtained from wells tapping water in carbonaceous Eocene sedimentary rock.
- **Rose Valley** – Area is about 4 miles south of Kelso and 2 miles east of I-5 in a small upland valley that drains the Coweeman and Columbia Rivers. The valley is floored by clayey alluvium underlain by Eocene sedimentary and volcanic rocks. Water is obtained from springs or wells. Most groundwater is derived from joints and cracks in the Eocene rock.
- **Woodland** – Located on the flay delta of the Lewis River. Groundwater is obtained from generally shallow wells (<50 feet) tapping alluvium.
- **Longview** – Located in reclaimed flood plain along the Columbia River and at the mouth of the Cowlitz River. Groundwater in the area has been used in large quantities for industrial purposes. Wells tapping the thick alluvium underling the flood plan have the highest reported productions in the Cowlitz County.

This information is carried forward with the consideration of water supply well density that is a parameter carried forward in the proposed aquifer susceptibility index.

Identified Cowlitz County Aquifer Regional Conditions

The Myers report suggests that water-bearing formations are present throughout Cowlitz County. Precipitation is identified as the main source of aquifer recharge. While the Myers report indicates low producing, bedrock type units appear to be generally present in the eastern portion of the County, this is also understood to be the area where the highest precipitation occurs and correspondingly a large percent of recharge occurs through both infiltration and surface water drainage. The alluvium deposits are identified in the Myers report as being the most productive aquifers in the County, but in lieu of well discharge, represent areas of aquifer discharge to the regional river drainage system. So it can be concluded that most of the County is potentially an aquifer recharge area. Given these conditions, the CARA delineation process for Cowlitz County needs to establish critical aquifer recharge areas with consideration of the CARA definition.

This type of information is also carried forward in the proposed aquifer susceptibility index with consideration of annual precipitation totals, water-bearing formation types, and specific soil characteristics.

3. SURFICIAL GEOLOGIC UNIT REFINEMENTS AND OBSERVATIONS

Geologic mapping to delineate water-bearing formation type used in the CARA effort was obtained from Washington State Geologic Information Portal. Selection of the 1:100,000 surface geology scale provides full coverage of Cowlitz County and is based on Phillips (1987) geologic map. The 54 geologic units identified as present in Cowlitz County were initially grouped in general accordance to the units identified in the Myers (1970) report. The results were examined and groupings were expanded to identify and delineate the distribution of geologic units that had aerial distributions greater than 1 percent of Cowlitz County. As indicated Table 1, this effort found that more than 58% (46.02% volcanic and 10.83% volcaniclastics) of mapped geologic material is considered to represent deposits associated with Goble Volcanics; deposits Myer mapped as Eocene sedimentary and volcanic rocks. Alluvial deposits represent the next largest geologic group at slightly more than 7 percent followed by Eocene sedimentary rocks associated with the Cowlitz Formation.

Table 1. Geologic Formation Types

Geology Group Abbreviation	Percent Area Represented
A (alluvium)	8.36
Cowlitz_S (sedimentary rock)	6.36
CRB (volcanic flows)	4.90
ESV (non-Goble formation Eocene deposits)	0.79
Goble_V (volcanics)	46.02
Goble_Vc (volcaniclastics)	10.83
Grays_V (volcanic deposits)	4.59
Helens_Vc (volcaniclastic deposits)	7.03
I (intrusive rock)	1.12
Sc (sedimentary continental rock)	0.82
Sm (sedimentary marine rock)	0.41
Till	3.26
V (non Goble volcanics)	0.71
Vc (non-Goble volcaniclastic deposits)	1.81
Wilkes_Sc (continental sedimentary rock)	2.97

See Figure 1 Geology Group, which shows the distribution of the geologic materials from Table 1.

4. WELL INFORMATION AND OBSERVATIONS

A total of 7,723 well log reports for wells reported to be located in Cowlitz County are contained in Ecology's well log record database. The approximate location of the wells were obtained and added to the geologic units map. The well locations are approximate and typically accurate only up to a quarter quarter section. This analysis found that 42% of wells in Cowlitz County are located in areas mapped as Goble Volcanics followed by alluvium where slightly less than 25% of the wells were located.

Well depth information is listed in Ecology's well log report database if available. Well depths were categorized as follows: shallow (<50 feet deep); medium (50 to <150 feet); deep (150 to <300 feet); very deep (>300 feet), and unknown depth. Examination of well depth information indicates that most wells located in areas mapped as Goble Volcanics are very deep and deep. In contrast, well depths for wells located in areas mapped alluvium are mostly shallow or medium depth.

Examination of well density per square mile found that highest well densities occurred along the I-5 corridor and along the southern County area north of the Columbia River and north of the Lewis River drainage. Smaller well area densities occur in the area of Silver Lake and Wolf Point.

See Figure 2 Water Well Log Density. This map shows well depths and water well log density per square mile.

5. SOIL INFORMATION, USE, AND OBSERVATIONS

A total of 263 soil types are identified to be present in Cowlitz County. These soil types have been grouped in different ways as presented in the USDA's soil survey for Cowlitz County. One grouping method is based on unique natural landscape. This method results in 20 general soil groups that are found in 4 defined areas such as flood plains and terraces. These 20 general soil groups have also been generally grouped according to parent material (e.g., flow rocks such as basalt or sedimentary rock).

A more applicable grouping is contained in Table 19 of the USDA's report where the 263 soil types have been grouped into 4 hydrologic (hydric) soil groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. Table 19 well groupings were mapped. Examination of the hydric soil grouping map indicates that 64 percent is mapped as Group B followed by Group C at slightly less than 20 percent. Group B and C hydric soil groups are located in upland areas where older volcanic and sedimentary rocks are present. High infiltration Group A soils are located mostly in river drainage floodplains. Low infiltration soils and mixed soil groups (e.g., C/D) are also located in or slightly above river drainage floodplains which suggest that there are low permeability zones present in some of these low lying area soils.

See Figure 3 Hydric Soils, which shows the distribution of the 4 hydrologic soil groups and the 3 mixed groups.

Table 20 of the USDA's report identifies restrictive layer information. A restrictive layer is defined in the report as a nearly continuous layer that has one or more physical properties that significantly impede the movement of water and air through the soil or that restrict roots. Examination of Table 20 indicates all of the identified restrictive layers when called out are identified as bedrock.

Mapping of restrictive layer information contained in Table 20 indicates that restrictions associated with induration associated with a lithic bedrock or moderate cementation associated with paralithic bedrock represents the two groups with the greatest coverage area. The areas where these two types of

restrictive layers types occur in the upland areas of eastern and northwest Cowlitz County. Soils identified as having a noncemented abrupt textural change typically occur as discontinuous area present primarily along and above the Cowlitz River drainage. Noncemented strongly contrasting textural stratified soils are shown to be present in drainages in a number of the smaller drainages.

See Figure 4 Restrictive Layer Information, which shows the distribution of the various layer types identified in Table 20.

Soil permeability data was also obtained from NCRS's soil database for Cowlitz County. Mapping of this data indicates the most of the soil has a saturated permeability in the range of 4 to 14 inches per hour. Higher permeability soils (>42 inches per hour) are shown to be located in the Cowlitz, Toutle, and Coweeman River drainages. High permeability soils (14 to 42 inches per hour) are shown to be located in the eastern area of the County and upland areas in the County's northwest area.

See Figure 5 Permeability, which shows the distribution of various ranges of soil permeability.

6. ANNUAL PRECIPITATION

Annual precipitation data representing a ten year period was obtained from Washington Department of Transportation (WSDOT) website. This website contains several precipitation datasets. The mean annual precipitation dataset based on data from 1961 to 1990 was selected. The dataset is from a project sponsored by WSDOT and performed by MSG Engineering Consultants and Oregon Climate Service.

Mapping of this data indicates that highest precipitation totals occur in the eastern area of the County; particularly the topographic high areas in the southeast corner of the County. Progressively lower annual precipitation amounts occur toward the Columbia River and Cowlitz River drainages. A small slightly higher precipitation area is also present in the northwest corner of the County.

Annual precipitation map coupled with physiography information provides information of where some of the greatest amount of potential groundwater recharge occurs in the County which then drains to the west.

See Figure 6 Precipitation, which shows the distribution of the annual precipitation data obtained.

7. IDENTIFIED DATA LIMITATIONS

A primary data limitation associated with development of an aquifer susceptibility and vulnerability assessment for Cowlitz County is depth to groundwater. This information is not readily available. Some depth to groundwater level data is presented in Table 6 of the Myers (1970) report. The NCRS soil report provides depth to water in Table 19, however, this data is specific to soil horizon, represents high water table condition, and typically indicates a depth greater than 6 feet. Depth to groundwater level data can also been found buried in a USGS online data set for State of Washington. However, it is difficult to extract this data and link it with the associated mapped well location.

Plate 2 of the Myers (1970) report shows well locations listed in Table 6 of the report. Groundwater levels are only contoured for the Woodland subarea. As noted in the Myers report, depth to groundwater can vary notably from location to location particularly where wells are tapping formations where water-bearing zones occur in cracks and joints. Due to these data limitations and issues, depth to groundwater has been considered by utilizing reported well depth information obtained from Ecology's online well log report database.

8. AQUIFER SUSCEPTIBILITY INDEX METHODOLOGY

The following parameters have been considered in the development of an aquifer susceptibility index: water-bearing formation type, soil infiltration, soil restrictive layer presence, soil permeability, annual precipitation, and water supply well density. The various units associated with these six parameters, as described in the preceding sections, have a rating value applied. The lowest rating is a zero (0) which indicates the unit of a given parameter considered to be the most critical with respect to aquifer susceptibility. For example, alluvial water-bearing formation deposits are assigned a 0 as they have been identified as the most productive aquifers in Cowlitz County and well log information indicates most wells completed in the unit are predominantly shallow (less than 50 feet). Progressively higher ratings have been applied to other water-bearing units that represent material (such as intrusive igneous rock) where productive water zones tend to be limited and data shows there is limited presence of water supply wells. A similar rating strategy is applied to the other six parameters. Table 2 (attached) shows the parameters and how their associated units have been rated. Rating rationale is provided for each parameter.

This rating information was then compiled to formulate a total score that was then mapped. Scoring is applied to areas that represent presence of the various 263 soil types. Total scores ranges from 6 to 48. The resulting total scores were then aggregated into three susceptibility groups; severe, moderate, and slight. The groups were aggregated by dividing the score range into three equal bins of 14 numbers each. As shown on the Susceptibility Index map total scores below 21 are considered to have **severe susceptibility**. Total scores between 21 and 34 are considered to have **moderate susceptibility,** and total scores above 34 are considered to have **slight susceptibility**.

Examining the resulting Figure 7 Susceptibility Index indicates that severe susceptibility areas occur in areas of the Cowlitz River valley, in portions of the Toutle River and Kalama River drainages, in areas of Longview, Woodland, Rose Valley, and near Coal Creek. Slight susceptibility areas generally occur in the upland areas located in the northwest, north, and central sections of the Cowlitz County. The majority of the area in the County is shown to have a moderate susceptibility.

Figure 7 represents full coverage of the County jurisdiction, similar to the current Critical Areas Ordinance (CAO) CARAs regulatory approach. A further step to incorporate the sensitivity of areas surrounding Group A and B wells more directly addresses the purpose of CARA regulation: protection of aquifers used for potable water.

Figure 8 Susceptibility Index shows the location of wellhead protection area buffers (WHPA) for Group A and B community water supply wells overlaid on the Figure 7 Susceptibility Index. Locations of Group A and B supply wells and associated WHPAs were obtained from Washington Department of Health database.

Similar to Clark County, Walla Walla County, Watcom County, and Greys Harbor County, Cowlitz County will utilize this data to apply CARAs to the slight, moderate and severe areas within the WHPAs. No areas outside of the WHPAs would be regulated as CARAs under the CAO, as shown on Figure 9. This approach focuses protection on the most critical areas, where public drinking water supplies are accessing groundwater.

9. REFERENCES AND DATA

References

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Myers, D. A., 1970. Availability of Ground Water in Western Cowlitz County, Washington. Washington Department of Ecology Water-Supply Bulletin No. 35. 1970.

Phillips, William, M., 1987. Geologic Map of the Mount St. Helens Quadrangle, Washington and Oregon. Washington Division of geology and Earth Resources Open File Report 87-4, Revised November 1987.

Data

SSURGO Soils – Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey

Surface Geology – Washington Department of Natural Resources

Annual Precipitation – Washington Department of Transportation, MSG Engineering Consultants, Oregon Climate Service

Well Logs – Washington Department of Ecology - Dave Nazy, Office of the Columbia River

Wellhead Protection Areas – Washington State Department of Health, Office of Drinking Water