Chapter 4 Environmental Consequences – Effects on Ecosystems

What is addressed in this chapter?

This chapter describes the existing natural environment and how the alternatives may impact natural resources. This chapter specifically addresses the following elements:

- Earth
- Hazardous Materials
- Water
- Plants and Animals
- Climate Change

Several exhibits within this chapter identify the locations and/or conditions of natural resources. The mapping information used to create these exhibits came from a variety of sources, are intended only as general depictions, and may not be accurate to the parcel level. During the MPD process, natural resources will be analyzed parcel level detail will be analyzed accordingly.

Water

Surface Water Resources

1 What drainage basins and surface water bodies are present in the study area?

The Villages study area is located within the Duwamish-Green River Drainage Basin, also known as Water Resource Inventory Area 09 (WRIA 09). All surface water runoff within the study area drains to Rock Creek and Lake Sawyer, and then on to Covington Creek and Big Soos Creek. Big Soos Creek flows into the Green River. The Green River becomes known as the Duwamish River Waterway at River Mile 11 and flows into Elliot Bay and then Puget Sound in Seattle.

What is analyzed in the "Water" section?

- Surface Water: Streams, lakes
- Groundwater: Hydrology between water bodies, aquifers
- Stormwater: Water quality

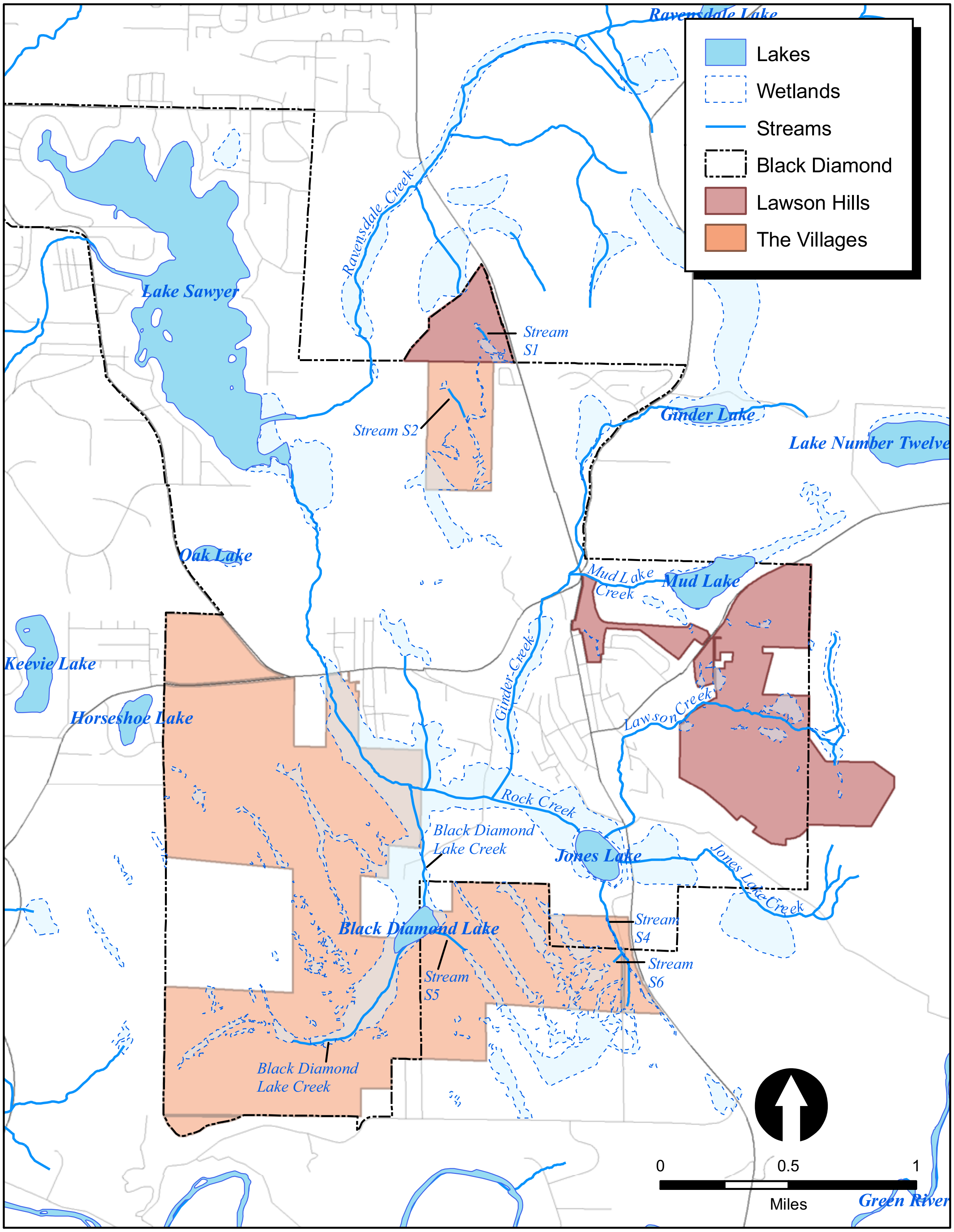
In the study area, there is a large concentration of natural features that affect ecological function and the health of the watershed. These features include Jones Lake, Mud Lake, Mud Lake Creek, Ginder Creek, Rock Creek, and a large wetland complex. They provide flood desynchronization, water storage, and a variety of nutrient control functions. These features also provide important fish and wildlife habitat areas. As shown in Exhibit 4-7, the study area has been divided into seven drainage subbasins: subbasins 1 through 6 are located on the Main Property, while subbasin 7 comprises the whole North Property.

What is flood desynchronization?
Flood desynchronization is the ability of wetlands to store flood waters and later discharge those water at a nonsimultaneous rate reducing the height and rate of flows that would otherwise be associated with flooding.

The Villages is underlain primarily by a mix of both Alderwood and Everett soil types. Alderwood soils are classified as till soils and have low water infiltration rates. Everett soils are classified as outwash soils and have high water infiltration rates. Lands within individual subbasins have common traits; stormwater runoff within each subbasin flows to the same water body, infiltrates into the soil in a similar manner, or shares both characteristics.

Exhibit 4-7

Surface Water



Exhibits in this EIS are intended to provide a general graphical depiction of built and natural environment conditions and may not be accurate to the parcel level.

Subbasins

Subbasins 1, 2, and 3 are located on the northwestern side of the Main Property and drain stormwater primarily through infiltration. These three basins are all in close proximity, and are tributary via groundwater flow to Horseshoe Lake, which has a history of flooding.

Subbasin 4 comprises the majority of the southwestern portion of the Main Property. Stormwater runoff from the northern portion of Subbasin 4 drains toward Black Diamond Lake, which in turn drains through a small tributary, Black Diamond Creek, to Rock Creek. Rock Creek in turn drains to Lake Sawyer, a phosphorous–sensitive water body. Runoff from the northwestern portion of the subbasin drains to wetlands and to Everett soils where infiltration occurs. The east side of the subbasin is underlain by Alderwood soils that drain offsite, to both the north and the south, where steep slopes are located.

What is nutrient control?
Wetlands play a very crucial role in storing and providing a source of nutrients to organisms in the surrounding environment. More information regarding nutrient control and water quality is available in the Water Quality Technical Report in Appendix M.

Subbasin 5 is underlain primarily by Alderwood soils. This subbasin drains to Rock Creek downstream of Ginder Creek, and to Black Diamond Creek, which is tributary to Rock Creek and eventually discharges to Lake Sawyer.

Subbasin 6 is located almost entirely upon Alderwood soils and is covered by several wetlands. The eastern portion of the subbasin drains to a small stream (Stream 4) that in turn drains north to Jones Lake. Jones Lake flows into Rock Creek, which ultimately discharges to Lake Sawyer.

Subbasin 7 consists of the North Property, which is underlain by Everett soils in the north and by Alderwood soils in the south. Runoff from the north drains over land to the north and to the northwest and through wetlands and streams to the northwest Everett soils where infiltration occurs. Additionally, flow from land to the east of the subbasin drains to the Alderwood soils within the subbasin, which in turn flows to the northwest area where it infiltrates. The southern Alderwood soils portion of Subbasin 7 drains to wetlands in the southwest corner. All flow entering Subbasin 7 ultimately drains to Lake Sawyer either through infiltration with eventual discharge to tributary surface water bodies or through flow to tributary wetlands.

Surface Water Bodies

Black Diamond Lake includes a bog wetland complex, and is partially located in Subbasin 4. The lake has an outlet that is tributary to Rock Creek called Black Diamond Creek. The lake's wetland complex has been identified by King County as a "sphagnum bog." Water quality samples taken in 2007 were consistent with healthy sphagnum bog conditions and were within the water quality standards for this type of environment.

What is a sphagnum bog?
Sphagnum bogs are oligotrophic (nutrient poor), acidic, anoxic (low oxygen), and have low temperatures, which result in the formation over time of peat and sphagnum. Sphagnum bogs typically have a central mat portion of sphagnum moss surrounded by a "moat" of open water. Bog vegetation is adapted to acidic, low mineral, and low nitrogen conditions and is susceptible to being out-competed by non-bog vegetation if bog conditions are changed.

Stream S4 flows from Subbasin 6 off-site to Jones Lake. The stream is influenced from runoff from SR 169, which it runs parallel to prior to draining into Jones Lake. Monitoring performed in the spring of 2008 showed that Stream S4 has poor water quality with regard to low dissolved oxygen and a somewhat elevated level of total petroleum hydrocarbons. The analysis attributed the low dissolved oxygen to recharge from groundwater, which can be low in dissolved oxygen, and the elevated hydrocarbons to untreated runoff from SR 169. All other water quality measures were within acceptable ranges.

Jones Lake is characterized by relatively high concentrations of naturally occurring acidic organic materials. The majority of the lake shoreline is undeveloped and surrounded by a mature coniferous forest. The majority of the land draining to Jones Lake is relatively undeveloped. Exceptions include historical mining activities, low-density residential development in lower Lawson Creek, and SR 169.

How do petroleum hydrocarbons affect water bodies?
Petroleum hydrocarbons include products like gasoline and motor oil and are often carried into water bodies by runoff from roadways. The presence of petroleum hydrocarbons in water bodies can result in degraded water quality and impacts to an area's ecosystem.

Jones Lake has moderate to high primary productivity with good to fair water quality, although temperatures reach as high as 25 degrees Celsius (77 degrees Fahrenheit) during summer. Despite relatively low direct use of the lake by fish species, it constitutes the headwaters of Rock Creek, a stream that provides valuable habitat for steelhead, cutthroat trout, and coho salmon. Consequently, the Jones Lake watershed provides process-intensive functions that are critical for fisheries downstream in Rock Creek and Lake Sawyer.

Rock Creek passes through a portion of Subbasin 5. Until 1992, a wastewater treatment plant discharged into Rock Creek, near its confluence with Lake Sawyer, which negatively affected water quality in that portion of Rock Creek. Since the discharges were terminated, total phosphorous levels in the creek have diminished considerably. High concentrations of phosphorous occur seasonally, however, as vegetation dies and low oxygen conditions facilitate the release of mineralized phosphorous from sediments into the water column.

What is primary productivity?
Primary productivity is the production of organic compounds from carbon dioxide in the atmosphere or in the water. This is primarily accomplished by photosynthesis by plants and some types of microorganisms.

In 2006 and 2007, monitoring of Rock Creek was performed upstream of the Auburn/Black Diamond Road crossing. Results for conductivity, hardness, alkalinity, dissolved oxygen, and ammonia indicated a wetland influence on Rock Creek. Additionally, fecal coliform measurements appeared to indicate wildlife use of the extensive wetland system associated with Rock Creek.

Ravensdale Creek drains all water from the North Property. Surface water runoff on the North Property discharges onto the outwash plain, where it infiltrates, and ultimately contributes to baseflows to Ravensdale Creek. With the exception of the SR 169 crossing, the lower portion of the basin is relatively undisturbed. Extensive wetlands (both forested and emergent) flank portions of Ravensdale Creek. Riparian canopy closure is good, and canopy closure appears to meet the 89 percent target required to maintain Class A water quality temperature standards.

How will a 303(d) listing affect the alternatives?
Section 303(d) of the CWA requires states to develop a list of waters not meeting water quality standards or not supporting their designated uses. Ravensdale Creek's 303(d) listing for temperature means that it has exceeded standards for temperature. Waters placed on the 303(d) list require preparation of a plan to limit pollutants. Because Ravensdale Creek is listed, it will likely receive more intense scrutiny for any activities that might result in further temperature exceedances.

Much of the watershed is part of the Lake Sawyer Regional Park, which was transferred to public ownership as part of the Black Diamond Area Open Space Agreement.

Water quality data indicates that Ravensdale Creek has excellent water quality with respect to moderately low hardness, low dissolved metals, and low total phosphorous concentrations. However, it is 303(d) listed for temperature. During all or portions of the year, Ravensdale Creek likely supports many of the fish species found in Lake Sawyer.

Horseshoe Lake is located in a depression with no surface outlet. The lake is recharged by flow from the groundwater aquifer, including flows from infiltration occurring in Subbasins 1 and 2 and a portion of Subbasin 3. The lake ultimately recharges the pre-Olympia aquifer which in turn recharges Crisp Creek near its confluence with the Green River. The lake generally has good water quality but is prone to seasonal flooding.

Lake Sawyer is approximately 280 acres in size. Historically, untreated sewage from septic tanks and drainfields drained to Lake Sawyer, partially contributing to existing elevated phosphorous concentrations in the lake. In 1992, all wastewater discharge from Black Diamond's lagoons to Lake Sawyer was terminated, although numerous septic drainfields still surround the lake. In 1993, the EPA set a maximum mean summer total phosphorous concentration limit of 16 µg/L (0.016 mg/L). Although the Department of Ecology has determined that some short term noncompliance with the total phosphorous concentration limit may exist, it has concluded that Lake Sawyer appears to be meeting the limit as a long term average. Existing elevated total phosphorous concentrations in the lake stem from several sources: release from sediments during seasonal turnovers (19 percent); flow from the Rock Creek basin (35 percent); flow from Ravensdale Creek basin (17 percent); the immediate Lake Sawyer subbasin (12 percent); septic tanks (8 percent); and input from aquatic plants, groundwater, and the air (9 percent).

What is mesoeutrophic?
Mesoeutrophic means that a water body is not in poor health but is also not functioning optimally. In the case of Lake Sawyer, this is largely a function of excess phosphorous.

King County completed the Lake Sawyer Management Plan in 2000 and concluded that the lake is currently mesoeutrophic. The Lake Sawyer Management Plan has a goal of maintaining the lake's mesoeutrophic state while accommodating future population growth through 2030.

2 What regulations apply to surface water quantity and quality?

Surface water quality is regulated at the federal, state, and local levels. From a regulatory standpoint, most water quality issues are regulated under the umbrella of the Clean Water Act (CWA). The National Pollutant Discharge Elimination System (NPDES) is a federally mandated program enacted in accordance with the CWA with the goal of regulating point source discharges. The NPDES program sets limits on the amount of pollutants that can be discharged into receiving water bodies.

What are point source discharges?
A point source discharge is a discrete location from which pollutants may be discharged. Examples include pipes and ditches.

The United States Environmental Protection Agency (EPA) is the federal agency charged with enforcing the CWA and the NPDES program. In the state of Washington, EPA has delegated the operation of the NPDES program to the Washington Department of Ecology (Ecology). The State of Washington has adopted rules based upon the CWA. These rules are largely covered under various chapters of Title 173 of the Washington Administrative Code (WAC).

North tip of Black Diamond Lake.

In the State of Washington, water quantity resources are governed primarily under the authority of the Water Resources Act (WRA) of 1970. Section 173-509 of the WAC regulates water quantity for WRIA 09, which encompasses The Villages site, including current and future water rights. Moreover, WAC 173-509-040 dictates limits on withdrawals from specific streams/water bodies in WRIA 09.

At the local level, the City of Black Diamond regulates surface water through stormwater management standards (see the Stormwater section in Chapter 3 of this Final EIS for more information on these local standards).

3 What regulations apply to development near streams or other water bodies?

The State Shoreline Management Act (SMA) of 1971 regulates development activities in Lake Sawyer, which is the sole water body in Black Diamond regulated as a shoreline of the state. The City's SAO regulates development and redevelopment activities that might impact water quality in streams, wetlands, and smaller lakes, through the use of buffer zones and specific development standards.

4 What stormwater regulations apply to runoff?

Stormwater runoff is regulated in accordance with the CWA and the NPDES program. In Washington, the Department of Ecology is responsible for stormwater regulations in accordance with Chapter 90.48 of the RCW.

Stormwater
There is additional information about stormwater provided in Chapter 3.

As a city with a population less than 100,000, all stormwater-related activities are regulated under the Black Diamond's Western Washington NPDES Phase II Permit (Phase II Permit). Among other requirements, the Phase II Permit requires the City to have programs that directly deal with operation and maintenance of existing stormwater collection, treatment, and discharge systems; pollution prevention from sites of development, redevelopment, commercial, industrial, residential, and municipal activities; and an Illicit Discharge Detection and Elimination (IDDE) program to identify, isolate, and terminate illicit discharges to the City's storm sewer.

Additionally, for site disturbances of more than 1 acre, or for sites smaller than 1 acre which are part of a larger common plan of development, a Construction Stormwater General Permit must be obtained from Ecology. The Construction Stormwater General Permit details specifically what the permittee must do to prevent and mitigate water quality impacts due to construction activities.

5 What are some considerations to be made for managing stormwater at The Villages site?

There are two components of a stormwater management program – flow management and water quality treatment. Flow management refers to limiting the frequency and duration of a development's stormwater discharges to the levels occurring prior to development. *Peak Standard* flow management seeks to maintain the volume of peak discharges at their predevelopment levels. *Duration Standard* flow management seeks to maintain the length of time that a variety of peak discharges occur.

In managing water quality, a variety of treatment facilities are used to remove pollutants from stormwater prior to the stormwater entering a water body. These pollutants include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (for example, nitrogen and phosphorous); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Floatable pollutants such as oil, debris, and scum are usually removed from the stormwater through the use of separator structures, devices which trap floatable pollutants and discharge clean water.

What is eutrophication?
Eutrophication is a term that refers to the addition of nutrients to a water body. Although eutrophication can be a natural process, water pollution can greatly exacerbate and speed up this process. Eutrophication can lead to massive algae blooms in lakes and fish kills.

Different types of facilities are required to address different water quality issues. The initial step in choosing a stormwater quality treatment approach is to determine the water quality requirements of the receiving water bodies. Receiving waters in the Lake Sawyer system require both "enhanced treatment" and "phosphorus treatment" because of the sensitivity of Lake Sawyer and other water bodies to nutrients and eutrophication (see the Stormwater section in Chapter 3 for more information on stormwater treatment facilities). Additionally, because the project site has soil types with very high permeability, infiltration of surface water flow as groundwater recharge in uncontrolled volumes has the potential to impact slope stability, increased ground water flooding, increase stream baseflow, and affect channel stability (see Appendix D).

6 How would the alternatives affect water resources?

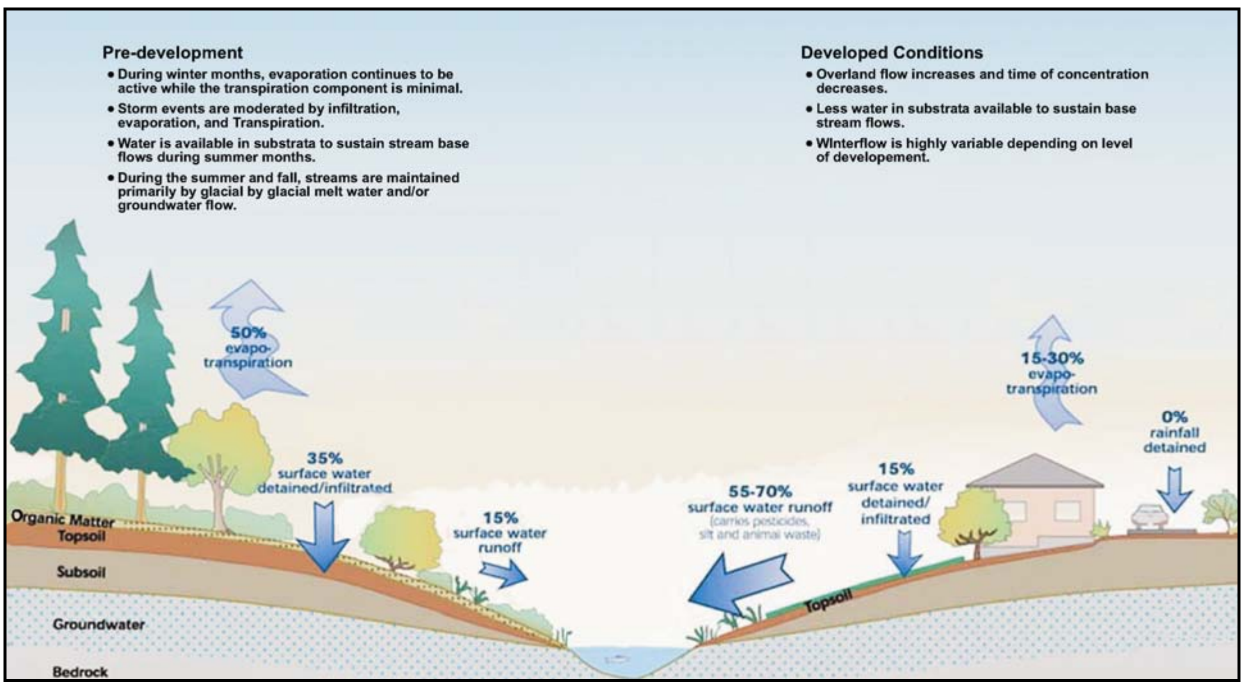
Background

How does development affect the hydrologic cycle?

All of the alternatives will result in replacement of natural vegetation with impervious surfaces and landscaping, which will change the natural patterns of water movement (known as the hydrologic cycle). Exhibit 4-8 presents a generalized overview of the hydrologic cycle. The exhibit displays how the replacement of natural vegetation with roads, parking lots, buildings, and turf and ornamental plants can result in dramatic increases in the amount of surface water runoff. Because the alternatives differ in amount and placement of development, the extent to which increased runoff impacts the hydrologic cycle under each alternative varies.

Exhibit 4-8

Overview of the Hydrologic Cycle in Predeveloped and Developed Conditions



How does development alter creeks and streams?
In general, the physical and biological health of creeks and streams declines as development increases within a watershed. Physical changes include flow and temperature alterations, channel incision, bank erosion, stream widening, and sedimentation, all of which can impact the ability of a creek or stream to support fish and wildlife. Studies have shown that there are two development thresholds that, once reached, usually result in noticeable impacts on the biological health of streams (Booth et al. 2002; Schueler 1994; Henshaw and Booth 2000):

- Approximately 10 percent of the subbasin is covered in impervious surface; or
- When the amount of forested cover drops below 65 percent.

Development can also result in reduced water volumes within these creeks and streams and increased water temperatures.

What does the term "2-year storm frequency" mean with regard to stormwater flow?
Storm events of a magnitude which are expected to be equaled or exceeded in a given time period are a commonly used component of designing stormwater facilities. A 2-year storm event has a 50 percent chance of being equaled or exceeded during any given year. Storms up to this magnitude are the dominant storms that determine the size and shape of receiving streams. Therefore, these types of storms are a commonly used component for designing stormwater facilities.

Displacement of Flows
When a system of pipes and detention facilities is used to manage stormwater in place of infiltration, stream sections above detention facilities tend to dry up while downstream sections experience increased water flows. In addition, alterations in hydrology from flow displacement can substantially affect wetlands. Because the majority of soils underlying The Villages site are amenable to infiltration, the utilization of pipes to displace flows is not likely to be a significant strategy used for stormwater flows on-site.

Peak Flows and Geomorphic Instability
Even when complying with the *Stormwater Management Manual's* peak and duration stormwater management standards, runoff is likely to increase, resulting in adverse impacts on receiving streams. This is because the total volume of runoff will increase when vegetation is replaced by development, and this larger volume of water cannot be stored as long as runoff was stored under predevelopment conditions. However, duration standards will be established in order to keep the increased stormwater volumes and decreased retention duration from negatively impacting creeks and streams. These

duration standards will be accomplished through the use of stormwater detention ponds and in accordance with the stormwater treatment methods outlined in the various alternatives in this EIS. Final design of storm ponds will have to consider flow duration as required by the 2005 Ecology *Stormwater Management Manual*. This is critical for streams with higher gradient sections where longer flow durations may result in increased bed movements.

A qualitative evaluation of existing stream conditions in the study area led to a conclusion that most of the stream sections appear stable. However, the methodology, modeling results, and qualitative assessment used in the evaluation did not analyze changes to duration of stream flow, only the rate (velocity) of those flows. Therefore, longer flow durations may result in increased bed movements, especially in higher gradient sections of streams. This will need to be considered when locating potential stormwater outfalls to streams.

Low Flows

Decreases in stormwater infiltration would likely lead to decreased summer water flows in local streams. Reduction in the magnitude of infiltration could result in adverse impacts to water levels in Horseshoe Lake or the overall hydrology and functioning of the Black Diamond Lake bog, which is especially sensitive to fluctuations in hydrology.

Reductions in infiltration may have adverse impacts on Jones Lake, especially when associated with temperature increases. The decrease in infiltration would likely lead to decreased summer low flows in local streams due to the decrease in infiltration and interflow.

Temperature

Development impacts on the hydrologic cycle may result in significant increases in the temperature of water discharged by streams in the summer, when receiving waters are most temperature sensitive. Pavement absorbs large amounts of solar radiation, particularly in the summer, and can be heated to temperatures in excess of 60 degrees Celsius (140 degrees

Fahrenheit). Removal of shade and decreased evapotranspiration due to reductions in vegetation contribute substantially towards elevated temperatures of roadways, sidewalks, and other surfaces. During a storm event, runoff flowing over heated pavement can absorb this heat, raising the temperatures of the receiving water bodies.

What is evapotranspiration?
Evapotranspiration is a term that refers to water loss from an area due to the cumulative effects of both evaporation and transpiration by plants. Transpiration is the loss of water by plants as water vapor as part of their natural metabolic processes.

Recent studies have confirmed that conventional stormwater detention ponds can significantly increase the temperature of receiving streams (due to solar heating) if stormwater is discharged directly into them, especially for streams at full capacity or those experiencing back-to-back storms (Kieser 2003). The use of open detention ponds with large surface areas presents the greatest risk of increased temperature, as water within these ponds can also gain heat from solar heating.

A study by A.C. Kindig and Company (see Appendix M) in Sammamish, Washington, showed that in the hottest months, July to September, the natural process of evaporation prevented stormwater discharges from occurring. Based on this study, the potential for high temperature discharges to receiving streams may be lower than in other regions given Western Washington's climate. However, the City or Applicant may want to perform limited temperature analyses post-construction if it is noted that stormwater discharges are occurring during periods of warm weather.

Stormwater detention ponds and discharge temperatures
Studies describing the effect stormwater detention ponds can have on the temperature of receiving water bodies can be found in Appendix M.

Water Quality

Transitioning from a natural hydrologic cycle to one dominated by urban runoff increases potential for bacterial and chemical pollutants entering water bodies. In natural environments, pollutant levels in stormwater are naturally filtered through vegetation and infiltration into soils. With urbanization, impervious surfaces replace vegetation, disrupting this natural filtration system and increasing bacterial and chemical pollutant concentrations in stormwater runoff.

The major sources of bacterial contamination are impervious surfaces and residential pets and wildlife that deposit feces on lawns, which is then washed into the stormwater system by storms. Fecal bacteria densities generally increase with greater housing density, increased impervious surfaces, and domestic animal density.

Chemicals of concern include heavy metals such as lead, zinc, and copper, which are largely deposited on road surfaces as a result of vehicle use. Lead is largely in the form of particulates and results from wear of moving vehicle parts. Copper results from wear from brakes, alternators, and radiators and is extremely toxic to aquatic life. Zinc results largely from tire wear. Lesser amounts of zinc originate from brake linings and exhaust emissions, as well as from galvanized metal in structures.

Oil and grease in urban stormwater are largely from automotive spills and leaks, including lubricants, antifreeze, and hydraulic fluids, and can leach out of asphalt road surfaces.

Nutrients of concern in stormwater consist largely of nitrogen and phosphorus and often originate from fertilizers used on lawn and landscaping, and from exterior use of detergents. Nitrogen and phosphorous can also enter waterbodies from erosion during construction and from bed movement in streams. Lake Sawyer currently has a 303(d) listing for phosphorus, and both it and Jones Lake are potential candidates for eutrophication based on increased nutrients resulting from development.

Urban versus “undeveloped” watersheds and phosphorous levels
Studies describing the effect development can have on phosphorous levels in water bodies can be found in Appendix M.

Potential impacts to Black Diamond Lake bear special consideration in the development of all of the alternatives. As a bog with low biological productivity, low nutrient availability, and low pH, it is especially sensitive to changes in hydrology and water quality. Alterations to site hydrology and the introduction of nutrients like phosphorous and nitrogen can disturb the delicate biochemical balance that is unique to sphagnum bogs.

The existing forested land cover in the Main Property and North Property is likely characterized by little or no discharge of pollutants. With regard to phosphorous in particular, grab sample measurements for total phosphorous were taken during storm and baseflow events between December 2006 and April 2007 and measured an average concentration of 0.021 mg/L (Appendix M, Table 2-8). To see what effects development may have on phosphorous concentrations in The Villages study area, this phosphorous measurement in an "undeveloped" state is compared in Exhibit 4-9 to some phosphorous measurements taken in urbanized areas.

The developed areas below were completed prior to Ecology's 2005 *Stormwater Management Manual.*

Exhibit 4-9

Comparison of Undeveloped Rock Creek Phosphorous Concentrations to Various Urban Watersheds

Watershed	Development Status	Total Phosphorous (mg/L)
Rock Creek	Undeveloped	0.021
Lakemont, Bellevue, WA	Urban	0.14
Lake Garrett, White Center, WA	Urban	0.13
Seattle Urban Watersheds	Urban	0.14–1.62
EPA – Various	Urban	0.3–300

Studies used to generate this exhibit can be found in Appendix M.

Based on the above examples, the increase in phosphorus in urban runoff may be several times greater than that of previously forested conditions. Specific to this site, quantified analysis indicates that total phosphorous discharge concentrations are forecasted to be higher in postdeveloped conditions (Appendix M, Table 3-13). Additionally, these measurements do not include phosphorus bound to sediments which may reenter the water column at a later date; this mechanism is especially pertinent in low oxygen environments such as Black Diamond Lake and Jones Lake. The combined impact of phosphorus in runoff and phosphorus bound to sediments may contribute substantially to the risk of eutrophication of receiving waters.

Alternative 1

Development under Alternative 1 is assumed to occur in conformance with the *Stormwater Management Manual*, and would meet detention and water quality treatment requirements. It would not have a specific requirement for open space or retention of native vegetation and therefore would be less beneficial in maintaining natural hydrologic cycle processes dominated by evaporation, evapotranspiration, and infiltration. The City's SAO would preserve wetlands and streams.

The replacement of native forest with lawn and ornamental vegetation would reduce evaporation, evapotranspiration, and infiltration. With slightly more impervious surface, less water would be available for groundwater recharge.

The development of multiple smaller detention/treatment facilities in Alternative 1 may result in less displacement of flows since there would be multiple points of discharge to surface water. Stream scouring and erosion from greater duration of flows and water quality impacts likely would be similar to Alternative 2.

Alternative 2

Alternative 2 relies heavily on infiltration methodologies for stormwater due to the presence of permeable soils on a large portion of The Villages site. Other Alternative 2 differences from Alternative 1 are:

- Greater areas utilized for commercial development in the North Property and Main Property.
- Higher density residential development.
- Mixed use development.
- Low Impact Development

The preservation of open space under Alternative 2 would tend to preserve the natural hydrologic cycle where portions of the site remain native forest. While all of the alternatives retain approximately 478 acres of native vegetation in the form of sensitive areas and their buffers, Alternative 2 provides an

What is a hydroperiod?
Hydroperiod refers to the length of time that the soil surface in a wetland is covered with water.

additional 29 acres of open space. Some of this open space will likely be forested and may add additional hydrological benefits.

The greatest potential impact Alternative 2 may have on water resources is through its development of the North Property, where the majority of the site would be developed in commercial use with a high proportion of impervious surface. Depending on the type and location of stormwater facilities placed at the North Property, area hydrology could be affected in multiple ways.

- If discharge of stormwater is routed through Wetland B4 on the southerly portion of the North Property without flow control, it would cause a substantial change in the wetland's hydroperiod.
- Conversely, if all stormwater is routed to the northwest corner for infiltration this would greatly diminish recharge to Wetland B4.
- The Applicant is currently proposing to divide the North Property into two stormwater management zones. The northerly zone is proposed to infiltrate stormwater to a detention/infiltration facility located in outwash soils in the northwest corner. In the southerly zone, stormwater would be conveyed to two stormwater facilities there. The wetlands in both zones are proposed to be recharged by rooftop runoff to mimic the existing hydrological inputs to these wetlands. The Applicant's stormwater strategy for the North Property could ameliorate potential impacts to hydrology in this area if implemented properly.

Another potential impact related to the Alternative 2 is the proposal to use a large wet pond for flows in Subbasin 6 that discharge directly to Jones Lake. The potential for higher temperature discharges due to a large wet pond discharging to Jones Lake in the summer months could further degrade this system, which already has high summer water temperatures. Increased water temperatures in Jones Lake could adversely affect the downstream Rock Creek stream/wetland system, and possibly Lake Sawyer, depending on the cumulative effects of urban runoff from other sources. Monitoring could be performed post-construction in order to better understand this potential impact.

Alternative 3

Since Alternative 3 represents a mitigated version of Alternative 2, it will have impacts to the same areas as Alternative 2. However, these impacts will be proportionally less. Potential impacts to Ravensdale Creek would be less in Alternative 3 given that there will be 36 less acres of commercial/office use. Additionally, overall impacts from new impervious surface would be less for Alternative 3 because it would create 276 acres of impervious surface versus 356 acres in Alternative 2.

Alternative 3 also will include 598 acres of total open space giving more opportunities than the other alternatives for mitigating some of the hydrological changes resulting from development of the project area. Also, the utilization of LID techniques such as reduced road widths, native vegetation in landscaping, and porous pavements give both Alternatives 2 and 3 fewer impacts.

7 What measures may reduce the effects of the proposal on surface water resources?

There are several general strategies available to reduce or mitigate the effects of urbanization on surface water resources:

- Preserving natural hydrologic functions to the extent possible;
- Providing facilities that mimic or enhance natural hydrologic functions of evapotranspiration and infiltration; and
- Providing for stormwater detention and treatment.

All of these strategies can be applied to stormwater management and are often known collectively as Low Impact Development (LID) or are outcomes of using LID best management practices.

Preserving Natural Hydrologic Functions

Preserving native forest vegetation and soils intact is the most effective means of preserving natural hydrologic functions. In general, surface hydrologic functions continue to operate well when 65 percent of native vegetation and soils are retained. However, the affects of development on hydrologic function will vary by soil type, underlying geology, topography, and placement in the watershed.

The proposal for preserving 50 percent open space in Alternatives 2 and 3 does not meet this 65 percent threshold, particularly since much of the open space can be altered for use as parks, stormwater facilities, and other infrastructure. In Alternative 2, most of the preserved native vegetation would be concentrated in Subbasins 4, 5, and 6. In order to most effectively preserve native open space for hydrologic functions, the areas preserved should:

- Be located on soils and topography best suited to infiltration;
- Be characterized by dense native vegetation; and
- Be located in the headwaters of streams or in conjunction with other natural features such as wetlands that provide year-round water sources to streams.

The most beneficial areas for vegetation retention are the moderately sloped areas with Alderwood soils in Subbasins 3 and 4 and the relatively flat area underlain by Alderwood soils in Subbasins 1 and 2. Under Alternatives 2 and 3, these areas are partially in proposed open space and are partially designated for intensive mixed-use and residential development. Other beneficial areas for vegetation retention are the existing forested areas around the wetland complexes in Subbasins 3, 4, 5, 6, and 7.

The most effective means of preserving native vegetation would be to more tightly cluster development to provide the same number of units in a smaller area or construct less dwelling units, thereby creating a smaller footprint of developed area. In addition, native vegetation can be preserved by fitting infrastructure and buildings to the site through methods such as stepping building foundations and foregoing the creation of flat yard areas on sloping sites. In residential areas, reducing driveway lengths through shallow lot frontages and reducing road widths and turnaround areas can also help preserve vegetation and soils.

Mimicking or Enhancing Natural Hydrologic Functions

Facilities that mimic or enhance natural hydrologic functions of evapotranspiration and infiltration are collectively included in LID techniques. There are several options for mimicking or enhancing natural hydrologic functions. One method is to increase the retention time of water in soils resulting in greater potential for infiltration. This can be accomplished by amending soils with compost in lawns, parks, greenbelts, and parking strips. This decreases runoff by increasing the potential for on-site infiltration and evapotranspiration.

Another option is utilizing roof runoff as a source of flow. Roof runoff has lower concentrations of pollutants and can be diverted to adjacent native vegetation or amended soils in both residential and commercial developments, thereby reducing the size of stormwater detention ponds and treatment facilities.

Various facilities are available to provide concentration of runoff in areas with deep soils, or connections to suitable soils for infiltration, or to store water during rainy periods to allow evaporation during warm periods. Typical facilities include bio-retention swales along streets and in parking areas and small rain gardens on or adjacent to residential lots. Though bio-retention facilities are of limited effectiveness in late winter when all soils are saturated, they can be very beneficial for summer and autumn discharge and can be used to address temperature concerns related to stormwater runoff.

Vegetated roofs (green roofs) are another option that fulfills the function of retaining water and increasing loss by evaporation and evapotranspiration. They do not, however, facilitate infiltration and are among the most costly options.

What is Adaptive Stormwater Management?
Adaptive stormwater management involves monitoring stormwater facilities over time, and adjusting the facilities and/or their management as needed, to ensure they continue to meet their design goals.

Finally, storage of runoff in small tanks on parcels can be used for irrigation in warm weather and larger detention facilities can be designed to provide metered release to infiltration facilities, as well as to streams and other water bodies.

Stormwater Detention and Treatment

Stormwater detention and treatment is an essential element in dense urban developments where the natural hydrologic cycle cannot be maintained. The key to well functioning detention and treatment systems are appropriate design goals and effective management, including adaptive management. As it pertains to the *Stormwater Management Manual*, the design goal is matching pre-existing forested conditions to the extent possible. Methods that can help detention facilities achieve this goal include:

- ***Design to accommodate large storm events:*** In addition to managing the duration of flow generated by the average storm event, detention facilities can be designed to accommodate storms that substantially exceed average conditions.
- ***Dispersed or multiple discharges:*** This may better mimic natural conditions by discharging stormwater into numerous headwaters versus a large point discharge at an outfall. This approach may require multiple detention facilities that generally have a higher development and maintenance cost.
- ***Groundwater recharge:*** Stormwater discharged into a groundwater system can provide benefits, such as reductions in stormwater temperature, before the water enters surface water bodies.

The initial step in designing a water quality treatment approach is determining the requirements of the receiving waters. Equally important is to select a treatment system based on meeting the requirements over a long period, and if necessary, one that is susceptible to retrofitting if monitoring shows the treatment methods are not meeting standards. Though important, adaptive management is difficult because the land area and monetary resources needed to modify facilities often are not available until years in the future after development is completed.

Design concepts that can reduce specific impacts of the alternatives are described below:

- Displacement of Flows;
- Peak Flows and Geomorphic Instability;
- Low Flows;
- Temperature; and
- Water Quality.

Displacement of Flows

Routing drainage through a piped system to a large downstream detention facility bypasses, and therefore dries up, streams and wetlands above those systems. This problem can be addressed by building multiple smaller systems with several discharges that more closely mimic natural hydrologic conditions. This strategy can be implemented in conjunction with LID measures that emphasize infiltration and groundwater input prior to detention, as well as infiltration from the detention facilities. Much of the stormwater detention and treatment proposed in Alternative 2 utilizes infiltration as the primary means of stormwater discharge. Other LID measures are also proposed as part of Alternative 2 Stormwater Management. This strategy combined with LID techniques as proposed for Alternative 3 will aid in mitigating the alteration of the area’s existing hydrology.

Peak Flows and Geomorphic Instability

The impacts of high volume and long duration stormwater events on receiving streams can be minimized by piping peak runoff to receiving waters that are less sensitive. Ideally, such a strategy would be implemented with dispersed facilities designed to discharge low flows into a variety of infiltration systems and streams.

Low Flows

Infiltration systems used in place of detention facilities, as well as detention facilities that allow for infiltration, limit the tendency of development to reduce summertime stream flows.

Temperature

A variety of methods can be used to reduce the temperature of stormwater runoff, including landscaping and shading of parking areas and streets, employment of infiltration faculties ranging from pervious pavement to biofiltration swales, providing smaller detention ponds with tree shading, providing detention vaults for areas of extensive pavement, and infiltrating runoff both before and after detention. These techniques should especially be considered for stormwater facilities if it is found that stormwater discharges with elevated water temperatures are occurring at the project site postconstruction.

Water Quality

Water quality impacts of nutrients can be most effectively addressed by using native plant species in landscaping and/or limiting the use of fertilizers and other chemicals that can become concentrated in runoff. LID practices that infiltrate nutrients into soil encourage uptake of these nutrients by plants and can result in reduction through natural soil processes. For water treatment facilities, proper design and maintenance are essential, as well as adaptive management, to ensure that water quality deficiencies can be identified and corrected (see Section 3.2.4.6 of Appendix M for a description of maintenance procedures which are derived from the 2005 Ecology *Stormwater Management Manual*). These methods bear special consideration for stormwater discharges to existing eutrophied water bodies like Jones Lake and sensitive water bodies like Black Diamond Lake.

Groundwater Resources

1 What groundwater resources are present in the study area?

Two major groundwater systems underlie The Villages Main Property. The first system is a shallow aquifer contained within recessional outwash, ice-contact deposits, and wetland/river/creek deposits. The shallow aquifer system is generally present near the ground surface and is directly recharged by rain, lakes and streams, and runoff from till upland surfaces. The other is the pre-Olympia aquifer, which is contained within coarse-grained glacial and nonglacial deposits. The pre-Olympia aquifer is a deeper aquifer that underlies most of the Main Property and is generally separated from the shallow aquifer by a layer of till. In some areas, gaps in the till layer exist that allow recharge of the pre-Olympia aquifer from the above-lying shallow aquifer. Five minor aquifer systems, including one interflow system, are also present in the Main Property. These are generally disconnected from the major aquifer systems.

Groundwater Analysis
More detailed information on Groundwater Resources can be found in the AESI (2008) report in Technical Appendix D.

What is an aquifer?
An aquifer is an underground layer of rock with characteristics that allow it to hold water.

The North Property of The Villages is generally underlain by bedrock. A shallow aquifer exists beneath the northwest lowland portion of the property in outwash materials. The large wetland in the southwest portion of the property recharges this shallow aquifer. Additionally, an interflow system is present on the till-covered portion of the North Property.

2 What policies and regulations apply to groundwater quantity or quality?

What is interflow?
Interflow is groundwater that is found above an aquifer and below the soil layer.

At the Federal level, groundwater quality is protected by the Safe Drinking Water Act (SDWA). In the State of Washington, groundwater quality standards have been promulgated from the SDWA and are codified in Chapter 173-200 WAC. The groundwater quality standards set maximum contaminant levels (MCLs) for primary and secondary contaminants for a wide-range of organic, synthetic, mineral, metallic, and radionuclide compounds.

Water rights for the State of Washington are covered under Chapter 173-152 WAC. Rules regarding protection of withdrawal facilities associated with groundwater rights are codified in Chapter 173-150 WAC. Water Conservancy Boards have been established in Washington to deal with water rights issues. These Boards are operated in accordance with Chapter 173-153 WAC. Rules for protection of groundwater in upper aquifer zones, which are primarily used for domestic water sources and light agricultural uses, are found in Chapter 173-154 WAC. Finally, requirements for measuring and reporting the amount of water used in conjunction with allotted water rights are found in Chapter 173-173 WAC.

3 How would groundwater resources be affected by the alternatives?

Any increases in impermeable surfaces (for example, roads, sidewalks, and buildings) will increase runoff from the area and cause a decrease in infiltration and groundwater recharge. All four alternatives involve a level of development in The Villages study area which, unless mitigated, will increase net surface runoff and decrease groundwater recharge.

How are groundwater impacts related to the hydrologic cycle?
Groundwater and surface water are connected via the hydrologic cycle. Impacts to surface water sources could ultimately impact groundwater sources and vice versa. For more information on effects of the alternatives to surface water sources, see Surface Water Resources, Question 6. For more information regarding project impacts to the hydrologic cycle, see Question 7.

Alternative 1

Alternative 1 assumes development of approximately 718 acres. Because development would occur on individual properties over time, it is not known what the ultimate composition of the buildable land would look like with regard to impervious surfaces created. Therefore, a quantitative calculation of impacts to groundwater recharge is not possible. However, it is possible to make a qualitative assumption regarding groundwater resource impacts.

Alternative 1 assumes 3,150 new dwelling units on 683 acres and commercial/office development on 35 acres. Given that most of The Villages study area is currently undeveloped, the development of the Main and North Property represents a large increase in impervious surface creation and will impact recharge of groundwater resources. As discussed in the Stormwater section in Chapter 3, calculations based on land use show that Alternative 1 would create 30 more impervious surface acres than Alternative 2. Since Alternative 1 does not include an open space provision, build out of the study area in accordance with this alternative would likely have greater impacts to the existing hydrological cycle and groundwater flows.

With regard to potential water quality impacts from residential use, the use of fertilizer, pesticides, herbicides, and vehicle parking have the potential to negatively impact groundwater. These impacts can be reduced through on-site stormwater facilities and homeowner best management practices.

Alternative 2

Alternative 2 includes a mix of residential, retail, office, educational, recreational, and open space uses, representing a combined development of 689 acres.

The greatest potential for impacts to groundwater recharge in The Villages for Alternative 2 includes:

- Impacts to Horseshoe Lake;
- Impacts to underlying aquifers and groundwater resource availability; and
- Impacts to springs and wetlands.

Analysis indicates Alternative 2 would result in a loss of groundwater recharge to the aquifers underlying the Main Property, with the shallow aquifer receiving the most significant impacts if mitigation was not implemented. Stormwater in Subbasins 1, 2, and 3 infiltrates to this aquifer, which in turn recharges Horseshoe Lake and the deeper pre-Olympia aquifer. In Subbasin 4, a portion of the basin infiltrates to the shallow aquifer, which flows westerly, eventually to the Green River, or infiltrates down to the pre-Olympia aquifer. The Applicant proposes to mitigate for impacts to the two aquifers by infiltrating stormwater to the shallow aquifer in volumes that mimic the existing rates of infiltration. Excess stormwater will be discharged to either the deeper outwash aquifer or to surface water.

Without mitigation, the proposed development of the North Property will result in a net groundwater recharge loss. Subbasin 7 infiltrates to the shallow aquifer and to Wetland B4, all of which eventually recharge Ravensdale Creek and eventually flow to Lake Sawyer. For the North Property, the Applicant is currently proposing to divide it into two stormwater management zones. The upper zone is proposed to infiltrate stormwater to a detention/infiltration facility located in outwash soils in the northwest corner. In the lower zone, stormwater would be conveyed to two stormwater facilities there. The wetlands in both zones are proposed to be recharged by rooftop runoff to mimic the existing hydrological inputs to these wetlands.

Alternative 3

Alternative 3 should result in fewer impacts than either Alternatives 1 or 2. Alternative 3 represents a combined development of 598 acres, nearly 100 less acres than Alternative 2. Alternative 3 will present more opportunities to preserve existing hydrological functions in areas that remain forested resulting in less impact on groundwater than either Alternatives 1 or 2.

4 What measures may reduce the effects of the proposal on groundwater resources?

Measures to reduce the effects of the proposal on groundwater resources are very similar to those presented in the Surface Water section. A combination of LID technologies provides a good strategy for minimizing and mitigating the effects of development in the area. Techniques specific for groundwater are summarized below.

Preserving Natural Hydrologic Functions

The LID discussion in the Surface Water section for preserving natural hydrologic functions is entirely applicable to groundwater. Please see that section for details.

Mimicking or Enhancing Natural Hydrologic Functions

Facilities that mimic or enhance natural hydrologic functions of evapotranspiration and infiltration are collectively included in LID techniques. Many of the options discussed in the Surface Water section are applicable for groundwater, including:

- Amending soils with compost in lawns, parks, greenbelts, and parking strips.
- Utilizing roof runoff as a source of infiltration.
- Creating bio-retention swales along streets, in parking areas, or as small rain gardens.
- Storing runoff in small tanks for use as irrigation in warm weather.
- Designing detention facilities to provide for infiltration over time.

Stormwater Detention and Treatment

Measures discussed in the Surface Water section applicable to minimizing impacts to groundwater include:

- Using infiltration systems in place of detention facilities as well as designing detention facilities that allow for infiltration.
- Using native species in landscaping and/or managing fertilizer and other chemical use to minimize pollutants in runoff.