Best Available Science Issue Paper: Snoqualmie Watershed Near Term Action Agenda Implementation Project

March 2004

Prepared for the cities of:
Carnation, Duvall, North Bend and Snoqualmie
of the Snoqualmie Watershed, King County

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1.0 INTRODUCTION

1.1 Report Purpose

This paper provides an overview of the "best available science" (BAS) for managing critical areas and protecting salmonid habitat in the Snoqualmie River watershed. It summarizes some of the recent science-based assessments and latest technical reports for both the Snohomish Basin and the Snoqualmie Watershed, and it reviews applicable compilations of other best available science reviews that have been completed to date. This paper has been prepared so that local governments can use this information in efforts to coordinate regulatory review and develop watershed-based policies and regulations for critical areas, stormwater management, and water quality (Snoqualmie Watershed Forum, 2001).

Discussions of BAS in this paper are framed by two major considerations. First, this paper has been prepared to respond to state regulatory guidance requiring the consideration (BAS) in decision-making regarding the management of critical areas. "Critical areas" include the following areas and ecosystems: (a) wetlands; (b) areas with a critical recharging effect on aquifers used for potable water; (c) fish and wildlife habitat conservation areas; (d) frequently flooded areas; and (e) geologically hazardous areas. Second, this paper addresses guidance for salmonid protection and recovery provided by the Near Term Action Agenda (NTAA) for the Snohomish River basin. Topics addressed in this paper include floodplains and channel migration zones, streams and fish habitat, wetlands, buffers, wildlife habitat conservation areas, geologic hazard areas, and aquifer recharge areas. Stormwater and water quality are also discussed in the context of watershed management issues.

Following the Methodology and Scope section below, the remaining sections of this paper are organized around the various critical area topics identified in the WAC BAS regulations, and in the NTAA regulatory review. Each section briefly identifies major issues and discusses applicable best available science, identifying findings applicable to management on a watershed level across jurisdictions, and those that are more appropriately focused at the local level.

1.2 Overview of Growth Management Act Requirements and Near Term Action Agenda Development

In 1990, a new rule under Washington State's Growth Management Act (GMA) (RCW 36.70A.060) required counties and cities to adopt development regulations that protect the functions and values of critical areas. In 1995, the Washington State legislature added a new section to the GMA to ensure that counties and cities consider reliable scientific information when adopting policies and development regulations to designate and protect critical areas. The new section, RCW 36.70A.172, requires all cities and counties to include BAS to protect the functions and values of critical areas, and to give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries. In 2000, as a result of this legislation, the Growth Management Division of Washington's Office of Community Development (OCD) adopted as a rule procedural criteria to guide cities and counties in identifying and including

BAS in their critical area policies and regulations. Applicable sections of the regulations are cited throughout this paper to provide a framework for the discussion.

This paper also focuses on issues identified during the Near Term Action Agenda (NTAA) review and summarized in the *Snoqualmie Watershed NTAA Regulatory Review for King County* (Snoqualmie Watershed Forum, 2002). In response to the listing of chinook salmon as a threatened species under the federal Endangered Species Act (ESA), the *Snohomish River Basin Chinook Salmon NTAA* was originally prepared by the Snohomish Basin Salmon Recovery Forum (2001) to identify near-term actions that would contribute to the protection and recovery of chinook salmon in the watershed. Since then, salmon recovery planning efforts in the Snohomish River Basin have broadened to include all salmonid species (Snohomish Basin Salmonid Recovery Technical Committee, 2002). Through a review of their own regulations and policies, Snoqualmie Valley cities and King County have identified a number of issues from the NTAA that specifically pertain to their jurisdictions, and conceptual regulatory options for addressing these issues.

1.3 State and Federal Regulations

In addition to the BAS regulations, a number of state and federal agencies may have regulatory jurisdiction over land or natural elements within NTAA jurisdictions. Local development proposals most commonly trigger requirements for state or federal permits when they impact wetlands or streams; potentially affect fish and wildlife listed under the federal ESA ; result in over five acres of clearing and grading; or affect the floodplain or floodway of a waterbody. The state and federal regulations affecting critical areas include, but are not limited to:

- The Shoreline Management Act (SMA): The state's SMA is implemented through the development of local shoreline master programs (SMPs). Local SMPs establish a system to classify shoreline areas into specific "environment designations." The purpose of the shoreline environment system is to provide a uniform basis for applying policies and use regulations within distinctly different shoreline areas. Policies and regulations generally address allowable uses, protection of critical areas, and restoration of impacted areas. SMP regulations must provide a level of protection to critical areas at least equal to that provided the County or City's critical areas ordinance. Also note that wetlands located within the 100-year floodplain fall under SMA jurisdiction per WAC 173-22-040 (3)(c).
- Endangered Species Act (ESA): The federal ESA addresses the protection and recovery of federally listed species. The ESA is jointly administered by the National Oceanic and Atmospheric Administration (NOAA) Fisheries (formerly referred to as the National Marine Fisheries Service [NMFS]), and the United States Fish and Wildlife Service (USFWS).
- Clean Water Act (CWA): The federal CWA requires states to set standards for the protection of water quality for various parameters; it regulates excavation and dredging in waters of the U.S., including wetlands. Certain activities affecting wetlands in the shoreline jurisdiction or work in the adjacent rivers may require a permit from the U.S. Army Corps of Engineers and/or the Washington Department of Ecology (Ecology) under Section 404 and Section 401 of the CWA, respectively.

- Hydraulic Project Approval (HPA): The Washington Department of Fish and Wildlife (WDFW) regulates activities that use, divert, obstruct, or change the natural flow of the beds or banks of waters of the state and may affect fish habitat. Projects requiring construction below the ordinary high water mark of the rivers or tributary streams could require an HPA from WDFW. Projects creating new impervious surface that could substantially increase stormwater runoff to waters of the state may also require approval.
- National Pollutant Discharge and Elimination System (NPDES): Ecology regulates activities that result in wastewater discharges to surface water from industrial facilities or municipal wastewater treatment plants. NPDES permits are also required for stormwater discharges from industrial facilities, construction sites of five or more acres, and municipal stormwater systems that serve populations of 100,000 or more.

2.0 METHODOLOGY AND SCOPE

2.1 Scope of Review

This report is a focused evaluation of BAS applicable to local jurisdictions in the Snoqualmie Watershed. Rather than exclusively referencing individual sources of scientific information, this report also focuses on incorporating the extensive BAS review that has already been completed by other jurisdictions, such as King County. Preparation of this report did not include any new field inventory or evaluation; instead, the report relies on previously published maps and inventory information, and on the information already identified by local jurisdictions through their NTAA regulatory review.

2.2 Sources of Information

Major sources of information used to compile this report are listed below in reverse chronological order and include:

- *East King County Ground Water Management Plan Supplement 1 - Area Characterization (*East King County Ground Water Advisory Committee, 1998)
- *Snohomish River Basin Conditions and Issues Report (Pentec Environmental, 1999);*
- *Initial Snohomish River Basin Chinook Salmon Conservation/Recovery Technical Work Plan (Snohomish Basin Salmonid Recovery Technical Committee, 1999);*
- *Pierce County Endangered Species Act Response Plan: Evaluation of County Policies, Regulations, and Programs (URS Greiner Woodward Clyde et al., 2000); and*
- *Salmon Conservation in the Snoqualmie Watershed (Snoqualmie Watershed Forum, 2001);*
- *Snohomish River Basin Chinook Salmon Near Term Action Agenda (Snohomish River Basin Salmon Recovery Forum, 2001);*
- *Streamside Science and an Inventory of Significant Riparian and Wetland Resources (City of Portland, 2001).*

- *Snoqualmie Watershed NTAA Regulatory Review for King County (Snoqualmie Watershed Forum, 2002);*
- *NTAA Joint Regulatory Review – Top 28 Analysis (Snoqualmie Watershed Forum, 2002);*
- *Snoqualmie Watershed Aquatic Habitat Conditions Report: Summary of 1999-2001 Data (Solomon, Fran and Melissa Boles, 2002);*
- *Draft Overview of Best Available Science for Critical Areas Protection in King County (KCDNRP, 2002); and*
- *Biological Review Tri-County Model 4(d) Rule Response Proposal (Parametrix, 2002).*

The document *Freshwater Wetlands in Washington State: Volume 1 – A Synthesis of the Science* is due for publication by Ecology in July 2003, but was not yet available for this review. Other cited literature is provided in Section 11.0, References.

3.0 FLOODPLAINS AND CHANNEL MIGRATION ZONES

3.1 Definition

A floodplain is a generally flat, low-lying area adjacent to a river or stream that is periodically flooded by overbank flows during storm events (KCDNRP, 2002). Floodplains are typically delineated by the projected inundation of areas by a 100-year storm; these areas are mapped by the Federal Emergency Management Agency (FEMA). Channel migration is the process of a river channel moving, or migrating, laterally across its floodplain. Areas affected by channel migration are called channel migration zones (CMZs) (KCDNRP, 2002). Channel migration can occur gradually over time frames of decades or centuries, or may occur as an abrupt shift of the channel to a new location. This abrupt shift is called an avulsion, and may happen during a single flood event, such as when a logjam reroutes the river into a side channel during high flows.

The limits of CMZs are usually determined by examining the lateral extent of river channel movement in the last 100 years. The period of time used to define a CMZ is often 100 years because available information can be used to evaluate channel movement in this time frame. Also, it is believed that this time span is sufficient to grow mature trees that can provide functional large woody debris to most channels (KCDNRP, 2002). Also considered are the extent of the 100-year floodplain, and cut-off side channels or oxbows that have bed elevations at or below bankfull elevation, determined by drawing a line that connects the points of greatest variation measured from the top of bank along a given stretch of river.

3.1.1 WAC BAS Requirements

The WAC (365-190-080 (3)) identifies that floodplains and other areas subject to flooding, collectively referred to as “frequently flooded areas,” perform important hydrologic functions. These areas may also present a risk to human lives and property. According to the regulations, classifications of frequently flooded areas should include, at a minimum, the 100-year floodplain as designated by the Federal Emergency Management Agency (FEMA) through their Flood Insurance

Rate Maps. While channel migration zones are not specifically defined in the BAS regulations, the definition of geologic hazard areas includes new potentially unstable areas as a result of rapid stream incision, streambank erosion, and undercutting by wave action (WAC 365-190-080).

3.1.2 NTAA-identified Issues

The NTAA identified a number of floodplain-related issues and recommendations relevant to jurisdictions in the Snoqualmie Valley. The review found that the watershed has experienced a loss of channel area and complexity resulting from bank protection and diking of the river and major tributaries, disconnecting channels from their floodplains. The NTAA called for critical area ordinances and flood hazard reduction plans to strongly discourage new development in floodplains, and to incorporate restoration and enhancement where necessary. The review also recommended that new levees, dikes, and culverts be prohibited, and that large woody debris or other habitat enhancements be incorporated into flood control and bank stabilization measures. Where decommissioning flood control facilities is not feasible, setbacks and bioengineering should be used (Snoqualmie Watershed Forum, 2002).

3.2 Watershed-Wide Issues

3.2.1 Erosion and Accretion

At the watershed scale, floodplains and CMZs can play a major role in maintaining a variety of watershed processes. River channels are dynamic and can migrate horizontally as water currents erode banks, usually depositing the eroded water-borne sediment on the opposite bank. The flux of gravel and large woody debris to the river resulting from channel migration illustrates the connectivity between a river and its floodplain. Bank erosion from both gradual and abrupt channel migration recruits spawning gravel from alluvial riverbanks, along with nutrients. With bank erosion, trees often topple into the channel and become a source of large woody debris, which creates high quality, diverse habitat for salmon rearing, spawning, migration, and refuge (KCDNRP, 2002). The highest rates of channel migration typically occur in zones of rapid sediment deposition, such as when steep rivers flow out of foothills onto flatter floodplains (King County, 1996).

However, excessive bank erosion beyond natural erosion rates can degrade habitat conditions by contributing excessive fine sediment, aggrading the channel bed, or filling pools (Solomon and Boles, 2002). Bank erosion is accelerated by adjacent bank armoring such as riprap, and by altered hydrologic regimes, which can alter flows and increase velocities. As a result, erosion of unarmored banks may be caused by upstream bank armoring or by armoring on the opposite bank (Solomon and Boles, 2002).

3.2.2 Storage Capacity

The overall channel morphology within a floodplain or CMZ often includes accessible side channels and/or multiple channels, both of which increase channel complexity and benefit salmonid spawning and rearing habitat. Overbank flooding also provides connectivity between a river or stream and its riparian soils and vegetation. Floodplains provide storage of water during these storm events and, if appropriately protected or managed, can reduce downstream peak flood discharge and decrease flood velocity. In addition, natural floodplains provide highly productive habitat and functions for a wide variety of fish and wildlife (KCDNRP, 2002).

3.2.3 Modification by Levees and Dikes

Traditional flood control measures include channel widening or deepening, channel straightening, levee construction adjacent to the channel, streambank stabilization, and clearing of living and dead vegetation in and along the river (KCDNRP, 2002). Floodplain alterations such as bank hardening and channel confinement can result in an increase water velocity; reduce floodplain storage; and remove the natural connectivity between a river or stream and its riparian vegetation, side channels, and floodplain wetlands (KCDNRP, 2002). Channelized rivers tend to have (1) increased temperatures and greater fluctuations in water temperature, (2) reduced cover and diversity of habitat for fish, and (3) less organic matter input (KCDNRP, 2002). If meandering is prevented by channelization, there can be a loss in the benefits of flooding to help create side channel habitat and channel complexity, and in the interchange of organic material and nutrients in the form of leaf litter, wood, and invertebrates with the adjacent floodplain.

Channelization projects also have the potential to drain and dewater local aquifers/hyporheic zones adjacent to river systems (Bolton et al., 2001). The hyporheic zone is the area of substrate that lies below the substrate/water interface, and may range from a layer extending only inches beneath and laterally from the stream channel, to a very large subsurface environment. In small streams, the hyphorheic zone is generally not continuous, and likely limited to small floodplains, meadows, and stream segments where coarse sediments are deposited over bedrock. In mid-order channels with more extensive floodplains, the spatial connectivity of the hyporheic zone increases. In large order streams, the spatial extent of the hyporheic zone is usually greatest (e.g., up to two miles wide and thirty three feet deep on the Flathead River in Montana), but it tends to be highly discontinuous because of features associated with fluvial activities such as oxbow lakes and cutoff channels, and because of complex interactions of local, intermediate, and regional ground water systems (Naiman et al. 1994 *in* Federal Interagency Stream Restoration Group, 2002). Channelization causes the greatest decline in groundwater levels nearest the stream and diminishing declines with increased distance from the stream. The result is the permanent removal of potential saturated storage volume essential for aquatic organism habitat and riparian vegetation (Bolton et al., 2001). When the channel is confined, the cross-sectional area decreases. If a channel must still carry the same flow or discharge, then the flow velocity must increase, resulting in an increase of the energy in the flow, and an increase in erosion and transport of sediments (Bolton et al., 2001). Levees decrease flow capacity of the channel, and decreased flow capacity results in higher water velocity and depth, both of which may be harmful to fish. However, some studies have shown that over time, levees can locally function as bank stabilization but may have opposite bank or downstream erosion effects (Bolton et al., 2001).

3.2.4 Contemporary Flood Control Measures

Ecological processes of floodplain habitats along leveed rivers can be restored by constructing new levees more distant from the channel (setback levees). Setback levees permit controlled inundation of adjacent floodplains and allow the river to meander within an area prescribed by levee dimensions (Inter-Fluve, 2001). Where shorelines have been modified, incentives can be provided to encourage redevelopment activities to include improved salmon habitat through methods such as bioengineering and construction of setback dikes and levees (Integrated Streambank Design Guidelines, 2001). Table A-1 in Appendix A lists contemporary flood control measures that use alternative construction and design practices to mitigate impacts.

3.3 Local Conditions and Issues

The Snoqualmie River system is unique among major King County rivers in that its flows are not regulated by reservoirs (King County, 1996). As such, it experiences the largest peak flows of any King County rivers. Portions of the Cities of Duvall, Carnation, Snoqualmie, and North Bend are all located within the floodplain of the Snoqualmie River or its tributaries, and all are subject to frequent flooding. During moderate to large floods, flows from the South Fork, Middle Fork, and North Fork Snoqualmie River combine to inundate the Snoqualmie-North Bend area. Kimball Creek, within the City of Snoqualmie, receives overbank flooding from the mainstem Snoqualmie River. Silver Creek, Ribary Creek, and Gardiner Creek in the City of North Bend receive overbank flooding from the South and Middle Forks of the Snoqualmie River. Bank stabilization downstream of the Snoqualmie Falls is depicted on Figure A-1, while bank stabilization upstream of the Falls is depicted on Figure A-2 (Appendix A).

Downstream of the Snoqualmie Falls, partially within the City of Carnation, the Tolt River exhibits rapid and extensive lateral channel migration (KCNDRP, 2002). Upstream of the Snoqualmie Falls within the Cities of Snoqualmie and North Bend, the mainstem Snoqualmie and the South Fork Snoqualmie have an active CMZ (King County, 1996) (Figure A-2, Appendix A). Table 1 provides a summary of conditions by local jurisdiction.

Table 1. Mainstem Snoqualmie River conditions

CITY	BANK STABILIZATION	CHANNEL MIGRATION
Duvall Snoqualmie River	Left bank and right bank[1]: 0.6 mile of revetments including riprap [a]	Deep, stable, and uniform channel with little history of avulsion[a]
Cherry Creek, Coe-Clemens Creek, and Thayer Creek	Artificially channelized in places	Some meandering; some sloughing at Coe-Clemens Creek
Carnation Snoqualmie River	Left bank[1] - 0.1 mile of toe/upper bank riprap[a] Right bank[1] - 0.2 mile of toe riprap[a]	Uniform streambed, increased velocity and gradient[a]
Tolt River	Right bank[1] - 1 mile of revetment including toe riprap [a]; Left bank[1] - 1 mile of toe and upper bank riprap	Active channel migration[c]
Snoqualmie Snoqualmie River	None downstream of Snoqualmie Falls[a]; approximately 2 miles of levee/revetment upstream of Falls[b]	Moderate, localized channel migration[b]
Kimball Creek	Approximately 250 feet of levee/revetments at confluence with Snoqualmie River	Some meandering
North Bend South Fork Snoqualmie River	Left bank and Right bank[1] – approximately 2 miles of levee/revetments upstream of river mile (RM) 1.9[b]	Channel migration slow, localized at RM 0-1 and rapid, widespread from RM 1-1.9[b]
Silver Creek, Ribary Creek, and Gardiner Creek	Artificially channelized in places	Some meandering, Silver Creek is mapped avulsion hazard cmz

Key: [1] Left bank – the bank on the left side of the river when looking downstream; Right bank – the bank on the right side of the river when looking downstream

Source: [a] Solomon and Boles, 2002; [b] Perkins et al., 1996; [c] City of Carnation Comprehensive Plan, 1996.

4.0 STREAMS AND FISH HABITAT

4.1 Definition

For the purpose of implementing Critical Areas regulations, streams are typically defined as areas where surface waters produce a defined channel or bed. Streams need not contain water year-round, but they must have a defined channel or bed is an area that demonstrates clear evidence of the passage of water. Streams are currently managed by King County and the cities in the NTAA area under each jurisdiction's sensitive areas regulations. Although specific thresholds and regulations vary by jurisdiction, the County and the cities presently use a similar multi-level classification system to determine land use constraints and buffer widths in riparian corridors. Streams are typically rated according to their value to fish, wildlife, or human use.

The highest classification in all jurisdictions includes streams that have been determined as shorelines of statewide significance and subject to the SMA. Other classifications are determined by such factors as the presence of salmonid fish and perennial flow in the stream. More restrictive land uses, primarily in the form of larger stream buffers and setbacks, are typically required for higher-class streams because of their potential to provide higher levels of beneficial uses.

4.1.1 WAC BAS Requirements

The BAS regulations focus on managing streams as critical areas for the protection and conservation of salmonids, particularly anadromous ones. Specifically, conservation or protection measures necessary to preserve or enhance anadromous fisheries are defined in the BAS rule (RCW 36.70A.172). These measures protect habitat important for all life stages of anadromous fish including but are not limited to:

- Spawning and incubation;
- Juvenile rearing and adult residence;
- Juvenile migration downstream to the sea; and
- Adult migration upstream to spawning areas.

The rule states that special consideration should be given to habitat protection measures based on the BAS relevant to each of the following:

- Stream flows;
- Water quality and temperature;
- Spawning substrates;
- Instream structural diversity;
- Migratory access;
- Estuary and nearshore marine habitat quality; and
- The maintenance of salmon prey species.

4.1.2 NTAA-identified Issues

Specific to salmonid recovery in the Snohomish River Basin, nine high priority habitat problems were identified by the Snohomish Basin Salmonid Recovery Technical Committee (1999). The more recent *Snoqualmie Watershed Aquatic Habitat Conditions Report: Summary of 1999-2001 Data* (Solomon and Boles, 2002) indicated that four of these nine habitat problems were of primary concern in the mainstem Snoqualmie River, namely:

- Increased sediment inputs from unnaturally high rates of erosion;
- Low levels of in-channel large woody debris;
- Poor quality riparian forests; and
- Loss of channel area and complexity resulting from bank protection and diking of the river, disconnecting the channel from its floodplain.

4.2 Watershed-Wide Issues

4.2.1 Anadromous Salmonid Habitat Needs

Streams and rivers provide essential spawning and migration habitat for anadromous salmonids. Each salmonid species found in the Snoqualmie River and its tributaries has different and specific habitat needs that vary depending on the season and/or their stage of development. There are, however, many needs that are common to all anadromous salmonids, as well as to the overall health of many other aquatic organisms, including benthic macroinvertebrates that are an important food source for salmonids and other animals. These elements include clean and cold water, suitably-sized spawning gravels and other suitable substrate for use as habitat, food sources, rearing habitats in proximity to food, refuge from predators, refuge from high flows, and unconstrained migration routes. These elements have been extensively described in the literature, and are summarized in Tables B-1 and B-2 (Appendix B) (NOAA Fisheries, 1996; USFWS, 1998).

4.2.2 Priority NTAA Habitat Needs

As described in Section 3.0, reach-specific, structural elements, such as those essential to healthy salmonid habitat, should be sustained by larger watershed-scale processes. Four watershed processes have been identified as of primary concern in the NTAA (KCDNRP, 2002), and are discussed in more detail below.

Increased sediment inputs to rivers and streams

To balance the displacement of gravel resulting from natural redistribution or scour, streams and rivers must have a constant source of new material to provide suitable spawning substrate for salmonids. Under natural conditions, bank erosion and channel movement help to replace gravels by providing a constant source of gravel. All species of salmonids present in the Snoqualmie River and its tributary streams require clean gravel of various sizes for spawning, ranging from cobble (orange to golf ball-sized gravel substrates), to pea-sized gravels.

While gravel recruitment is a necessary element in sustaining healthy salmonid habitat, too much, or the wrong kind of, erosion and subsequent sedimentation (such as silts and fine particles) can have negative effects on aquatic organisms and salmon production. The deposition of sand, silt, and other fine sediments can fill spaces between gravels and reduce the amount of oxygen that reaches developing salmon eggs. In addition, fine material can embed gravels, effectively cementing streambeds. For example, studies have found that in streambed gravels containing more than 13 percent fine sediment (<0.85 mm), almost no steelhead or coho salmon eggs survive (McHenry et al., 1994). The NMFS (1996) and the USFWS (1998) define properly functioning conditions for sediment and turbidity as <12% fines (<0.85 mm) in gravel, and low turbidity. Turbidity caused by suspended sediment can also affect dissolved oxygen levels and feeding by juvenile salmon (Newcomb and MacDonald, 1991).

Delivery of large woody debris

Water flowing over and around large woody debris in streams and rivers in the Snoqualmie River watershed creates pools that provide habitat for rearing salmonids, while overhanging wood provides cover and protection from predators. Woody debris adds roughness to the stream channel, which slows water velocities and reduces the scour potential of floodwaters. Log jams and other in-channel large woody debris trap and store sediment, reducing downstream sediment transport and sedimentation. Recruitment of woody debris to the stream occurs when a tree falls into a stream, often as a result of the lateral movement of the channel and bank undercutting, from windthrow, or when a downed log is washed into a stream during a flood. Floods are also responsible for distributing downed wood within the stream channel. Riparian forests that retain high numbers of standing and downed coniferous logs provide a source of high quality woody debris. Coniferous logs generally provide more benefit as woody debris than deciduous species because they are slower to decompose. The NMFS has defined properly functioning conditions as "conditions that create and sustain natural habitat-affecting processes over the full range of environmental variation and that support productivity at a viable population level [of listed species]" (NMFS, 1996). Standards for properly functioning levels of large woody debris within western Washington streams are 80 pieces per mile or greater (Table B-1, Appendix B)(NMFS, 1996). In addition, for riparian areas to be properly functioning for this habitat element, streamside areas should be capable of sustaining these levels of woody debris over the long term through adequate recruitment of woody debris to the stream.

Poor quality riparian forests

Mature, overhanging trees, shrubs, and exposed roots in a gradually eroding bank help to create and maintain habitats. Loss of riparian vegetation can result in decreased riverbank stability, excessive erosion, and reduction of shading, which in turn can lead to higher water temperatures. Loss of mature trees in the riparian zone also decreases large woody debris recruitment to the river, reducing the structural and hydraulic complexity of instream habitat. All of these factors combine to adversely affect freshwater life history stages of salmonids and to reduce biological diversity (Solomon and Boles, 2002). A lack of riparian vegetation can also limit habitat for a wide variety of wildlife species and insects on which fish feed, and can reduce wildlife linkages between areas (see Section 8.0). Salmonids consume a wide range of food sources throughout their life cycles. Leaf litter provided by adjacent forested riparian areas can be a primary source of organic carbon and nutrients (May and Horner, 2000). In some Pacific Northwest streams during the summer, an estimated 50 percent of the diet of juvenile salmonids is comprised of terrestrial insects that fall into streams from overhanging vegetation (City of Portland, 2001).

Loss of channel area and complexity

Along with closely associated floodplain and upland areas, river ecosystems are formed and maintained by natural disturbances operating at a watershed scale (such as landslides, debris torrents, and flooding) that contribute resources (such as woody debris, spawning gravel, and nutrients) to riparian and instream habitat. Alteration or disruption of these processes can diminish habitat complexity and quality. The NMFS (1996) and the USFWS (1998) define properly functioning channel conditions and river dynamics as a width/depth ratio of less than 10:1, naturally stable river banks, and a prevalence of riparian and riverside wetlands hydrologically linked to the river system. This issue is also discussed under Section 3.0 Floodplains and Channel Migration Zones, above.

Disconnection of the channel from its floodplain can limit the formation of complex and healthy habitat. Off-channel wetlands and side channels in riparian areas, such as those found in the Snoqualmie Valley, provide foraging habitat, over-wintering habitat, and refuges for rearing fish (Swales and Levings, 1989; City of Portland, 2001). These areas, which include wetlands connected to stream channel and side channel habitats, also have high levels of productivity and provide areas for juvenile fish to forage and grow. However, when previously vegetated riparian corridors are developed with urban land uses and stream banks stabilized to protect development, adjacent wetland and side channel continuity can be lost, and there may be little gravel or woody debris allowed to move from these off-channel areas to the stream system (May et al., 1997).

4.2.3 Restoration\Enhancement

Assessing and accounting for the natural ecosystem processes that create instream habitat structure can help make salmonid conservation and recovery efforts in the Snoqualmie River watershed more effective. Focusing habitat protection, reconnection, and restoration projects on restoring processes can increase effectiveness rather than only addressing the symptoms of observed impaired habitat conditions. For example, instream habitat would benefit from forest retention in headwater areas of the Snoqualmie River watershed, and native plant revegetation of riparian zones. Historical data could be consulted on the composition of the mainstem riparian plant community to determine the most appropriate species of native vegetation to plant along streambanks. Healthy riparian buffers can provide large woody debris for the rivers and streams of the Snoqualmie River watershed, which can lead to more nutrient cycling and to more and better quality habitat for juvenile salmonid rearing and refuge, and adult salmonid holding prior to spawning. The shade provided by riparian vegetation can help moderate summer water temperatures (restore a more natural heat energy transfer regime). The roots of riparian vegetation can reduce the amount of unnatural bank erosion, thereby helping to restore natural sediment transport. Because natural ecosystem processes are interrelated, restoring one process can help restore others (Solomon and Boles, 2002).

Roni et al. (2002) suggest that in the context of a comprehensive, watershed-based restoration strategy, instream restoration can be an effective tool in restoring and enhancing salmonid habitat and populations. For example, barriers like culverts and stormwater control structures can inhibit fish migration and prohibit fish from accessing upstream habitats, or they may limit many natural processes necessary for salmonid fish production including the natural redistribution of substrate and woody debris (Roni, et al., 2002). Restoring fish passage can be an effective way to increase the quality and accessibility of habitat and can result in relatively large increases in potential fish production at a nominal cost (Roni, et al., 2002).

Some authors have suggested that, due to altered hydrology, water quality, and stream channel stability, stream rehabilitation in watersheds with high levels of impervious surface may be less feasible compared to watersheds with less impervious cover (Booth, et al., 2001). Instream restoration projects should be planned carefully in the context of basin-wide conditions. In one study of 15 streams in Oregon and Washington, more than half of instream restoration structures (including pieces of large woody debris) failed before the expected lifetime of 20 years (Frissell and Nawa *in* McClean, J., 2000). Roni, et al. (2002) reported highly variable results; some studies suggested that 85 percent of wood remains in place and contributes to habitat formation. Often in urban systems, more “engineered” methods of bed and bank stabilization may be necessary to address high hydraulic forces, space constraints, and infrastructure and property protection restrictions (Miller et al., 2001). Instream restoration projects appear to particularly benefit coho salmon because many restoration efforts have been targeted at smaller coho streams (Roni, et al., 2002).

4.3 Local Conditions and Issues

The Snoqualmie River flows over a relatively unconfined, alluvial floodplain that is divided into two major segments by a bedrock protrusion at Snoqualmie Falls (Pentec, 1999). Snoqualmie Falls presents a natural barrier to anadromous upstream passage, creating two distinct sets of issues and conditions above and below the Falls.

Anadromous salmonids use the entire length of the Snoqualmie River below the Falls, as well as many of the River's tributaries. Mainstem Snoqualmie River spawning of chinook salmon (federally-listed as threatened under the ESA) occurs immediately downstream of the confluences with the Tolt and Raging Rivers and Tokul Creek and immediately below Snoqualmie Falls (Pentec, 1999), while most coho and steelhead spawning occurs in tributary rivers and streams. Chinook salmon are also documented in the Tolt and Raging Rivers. Coho salmon are documented in the Tolt and Raging Rivers and Tokul Creek as well as in the tributary streams near the cities of Duvall and Carnation.

Although upstream areas of the Snoqualmie River lie above a natural fish barrier, they still contribute significantly to the overall productivity of listed anadromous salmonid species occurring downstream. Furthermore, resident salmonid populations occur upstream of the Falls. Areas upstream of the Falls provide continuous sources of cold surface water and groundwater; filter pollutants via associated wetlands and vegetation; and contribute gravel, nutrients, and food sources for salmon downstream (Snohomish Basin Salmon Recovery Forum, 2001). According to the Washington Department of Fish and Wildlife's (WDFW's) streamnet data (2002), the South Fork Snoqualmie River contains cutthroat and rainbow trout, whitefish, and sculpin. Cutthroat trout are present in Ribary, Gardiner and Clough Creeks as well. As previously discussed, for purposes of implementing the federal ESA, the USFWS classifies the entire Snohomish Basin (WRIA 7) as presumed habitat for bull trout. However, none have been identified during surveys conducted by King County (King County, 2001). Major limiting factors by jurisdiction are summarized in Table 2 below.

Table 2. Documented Mainstem Snoqualmie River Habitat Conditions

CITY	FISH PRESENCE [a]	LIMITING FACTORS [b]
Duvall	Anadromous salmonids, resident salmonids, ESA-listed, other	Water quality: 303(d) list for temperature; Other water quality concerns – nutrients, fecal coliform, temperature, pH; Identified sources include animal access. Large woody debris lacking overall Natural low summer flows Dense native riparian vegetation (shrubs and deciduous trees) dominates, interspersed with non-dense non-native vegetation Lack of coniferous vegetation
Carnation	Anadromous salmonids, resident salmonids, ESA-listed, other	Water quality concerns: temperature, dissolved oxygen, fecal coliform Large woody debris lacking overall Natural low summer flows Non-dense non-native riparian vegetation (shrubs and deciduous trees) dominates lack of coniferous vegetation
Snoqualmie	Downstream of Falls: Anadromous salmonids, resident salmonids, ESA-listed, other Upstream of Falls: resident salmonids, other	Water quality concerns: temperature, dissolved oxygen, fecal coliform Large woody debris lacking overall Natural low summer flows Riparian vegetation not mapped
North Bend	South Fork Snoqualmie River: Resident salmonids, other	Water quality: 303(d) list for temperature, pH Large woody debris lacking overall Wide riparian band downstream of RM 1.9, narrow riparian band upstream of RM 1.9

Key: Anadromous salmonid = chinook, coho, pink, chum salmon; steelhead, sea-run cutthroat, Dolly Varden, bull trout; ESA-listed = bull trout, chinook; Resident salmonid = resident cutthroat, rainbow, brook, Dolly Varden, bull trout; whitefish; Other = Smallmouth bass, largemouth bass, bluegill, green sunfish, longnose dace, Olympic mudminnow

Source: Herrera Environmental Consultants, 2002; Northwest Hydraulic Consultants, 2001; 2002; Solomon and Boles, 2002

5.0 WETLANDS

5.1 Definition

Wetlands are formally defined by the Corps of Engineers (Corps) (Federal Register, 1982), the Environmental Protection Agency (EPA) (Federal Register, 1986), the Washington Shoreline Management Act (SMA) (1971), the Washington State Growth Management Act (GMA) (1992) and RCW 36.70A.030(22) as:

"… those areas that are inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas created to mitigate conversion of wetlands."

5.1.1 WAC BAS Requirements

The BAS regulations in WAC 365-190-080 (1) require, in designating wetlands for regulatory purposes, that counties and cities use the definition of wetlands contained in RCW 36.70A.030(22), above. Counties and cities are encouraged to make their actions consistent with the intent and goals of "protection of wetlands," as specified in federal Executive Orders 89-10 and 90-04. Additionally, counties and cities should consider wetlands protection guidance provided by the Washington State Department of Ecology. Specifically, when developing wetland rating systems, counties and cities should consider the following:

- The Washington state four-tier wetland rating system;
- Wetlands functions and values;
- Degree of sensitivity to disturbance;
- Rarity; and
- Ability to compensate for destruction or degradation.

5.1.2 NTAA-identified Issues

The NTAA recommended the protection of wetlands and their functions and values that support watershed processes needed for salmon habitat, and that provide other benefits such as flood hazard reduction. The NTAA review recommended that wetland mitigation sequencing be followed, including, in order of hierarchy, avoiding, minimizing, rectifying, reducing over time, and finally compensating for wetland impacts (Snohomish Watershed Forum, 2002).

5.2 Watershed-Wide Issues

5.2.1 Overview of Wetland Functions

Wetlands perform a number of different valuable functions. Generally recognized wetland functions include water quality improvement (biofiltration, sediment trapping, erosion control), aquifer recharge, flood storage and retention, stream base flow support, groundwater discharge/recharge, and wildlife habitat (amphibians, birds, fish, and mammals for all or portions of their life cycles) (KCDNRP, 2002).

Wetlands are often classified for the purposes of establishing regulations for their protection and for the mitigation of wetland impacts. According to Washington Administrative Code 365-190-080, counties and cities that do not now rate wetlands should "consider a wetlands rating system to reflect the relative function, value, and uniqueness of wetlands," including consideration of the Washington State four tier wetlands rating system. Local jurisdictions may choose to establish their own wetland rating system that does not use the four-tier wetlands rating system, but a rationale for this must be provided to the State. Ecology's Wetlands Rating System (1993) specifies four categories of wetlands: Category I, II, III, and IV.

According to Ecology’s rating system, Category I wetlands meet one or more of the following criteria:

1) Documented presence of a federal or state-listed endangered or threatened species;
2) Washington Natural Heritage program high quality native wetland;
3) Regionally significant waterfowl and shorebird concentration area;
4) Mature forest consisting of either at least 80 year old evergreen trees or at least 50 year old deciduous trees and less than 25 percent non-native cover;
5) Estuarine wetlands, bogs and fens, or eelgrass and kelp beds; or
6) Documented wetland of local significance.

Category II and III wetlands must meet criteria that are between Category I and Category IV wetlands (see below). In order to determine if a wetland is either a Category II or III wetland, the Wetland Rating System Data Form must be completed (Appendix C). To complete the Data Form, wetlands are assigned a score for each habitat feature, which includes size, number of wetland classes, plant species diversity, structural diversity, special habitat features, connections to streams and other habitats, and condition of buffers. If the wetland scores more than 22 points it is classified as a Category II wetland, otherwise it is classified as a Category III wetland. Larger wetlands that have more structure are vegetatively diverse, have undisturbed buffers, and are connected to other streams and habitats; these wetlands typically score the highest and meet the criteria for Category II wetlands.

Category IV wetlands meet one of the following characteristics:

1) Less than one acre, hydrologically isolated, and comprised of one vegetated class that is dominated by one species from Table 3 or Table 4 that are provided in the Wetland Rating System Manual (Ecology, 1993) (see Appendix WT-5); or

2) Less than two acres, hydrologically isolated, with one vegetated class and more than 90 percent aerial cover of any species in Table 3 (Ecology, 1993); or

3) Wetland excavated from upland and a pond smaller than one acre without a surface water connection to streams, lakes, rivers, or other wetland, and has less than 0.1 acre of vegetation.

5.2.2 Role of Wetlands in the Watershed

The functions that wetlands provide partially depend on the geographic context, or watershed position, within which a wetland is located. For example, riverine wetlands may provide important rearing and refuge areas for salmonids and other fish and wildlife species (KCDNRP, 2002). In general, large, permanently-flooded, depressional wetlands that are the headwaters of or connected to salmonid streams and are located in the upper one-third of the watershed have the best ability to provide salmonid habitat, as well as stream base flow and groundwater support (Brinson, 1993; Gwin et al., 1999; Cooke, 2000). Isolated wetlands, or those wetlands that are disconnected from the floodplain generally have a lower flood storage capacity, as do those where the outlet is unrestricted and floodwaters are not contained (Marble, 1992; Reinelt and Horner, 1991).

Wetlands can reduce and desynchronize peak flood crests and flow rates of floods by intercepting and retaining surface water runoff, and by slowly releasing it to adjacent water bodies and/or groundwater (Novitzki, 1979; Verry and Boelter, 1979 *in* Mitsch and Gosselink, 2000). Riverine wetlands along the Snoqualmie River and its tributaries that are vegetated with flood-tolerant tree and shrub species (such as black cottonwood, red alder, and various willow species) are able to create a high amount of frictional drag to slow floodwater. These wetlands also provide water quality functions. The fairly flat gradient of the four cities in the Snoqualmie Valley allows flood waters to spread out in adjacent wetlands, improving basin-wide water quality by allowing plants to take up nutrients, and allowing nutrients and pollutants from stormwater runoff to settle out (Mitsch and Gosselink, 2000; Cooke, 1995). Forested areas can store greater amounts of nutrients for longer periods, while emergent vegetation takes up nutrients and releases it seasonally.

The erosion control function is particularly effective in floodplain wetlands where velocities are slowed by vegetation that is dense and woody (Carter, 1986; Greeson et al., 1979; Sather and Smith, 1984; Brinson, 1993). Wetlands that have relatively undeveloped shorelines and contain dense woody vegetation extending over 200 to 600 feet from the ordinary high water mark (OHWM) of a lake or stream appear to provide the highest level of shoreline protection and erosion control (Hruby et al., 1999; Cooke, 2000).

Maintaining stream flow is an important function of wetlands to stream flow-sensitive salmonids in the Pacific Northwest particularly for summer low flow periods. Wetlands provide base flow during the region's typically dry summer season (City of Portland, 2001; Booth, 2000; May et al., 1997; Mitsch and Gosselink, 2000). Wetlands in the upper part of the watershed affect flows downstream, whereas those wetlands lower in the watershed affect less of the overall stream system.

Many species of waterfowl, amphibians, insects, and some species of fish and mammals (such as beaver) also depend on wetlands for foraging, breeding, and refuge.

5.3 Compensation for Wetland Impacts

Federal and state permitting processes use mitigation "sequencing" as the primary mechanism to ensure that wetland functions are protected or replaced. Ecology defines wetland mitigation as a sequential process used to address proposed wetland impacts to ensure that the total adverse impact of a project is reduced to an acceptable level (McMillan, 1998). When impacts to wetlands are permitted, the creation, restoration or enhancement of other wetlands is generally required. Ecology's mitigation process is applied in the following sequential order:

- Avoiding the impact by changing the location or the design of the project to eliminate wetland impacts.
- Minimizing the impact by changing the design of a project to reduce the extent of the impact.
- Rectifying the impact by restoring the impacted area after the development has taken place.
- Reducing the impact to the wetland over time, for example by using buffer areas and storm water treatment facilities.
- Compensating for the impact by replacing the impacted area and/or functions through wetland creation, restoration, enhancement, and/or preservation.
- Monitoring the impact over time and taking corrective measures to minimize additional impacts.

Typically, replacement of wetland area for wetland impacts is implemented at a ratio that covers a larger area than the wetland area adversely affected by a proposed project. Mitigation ratios are typically greater than 1:1 for several reasons. Higher ratios:

- Act as disincentives to fill wetlands;
- Provide an opportunity to achieve certain functions over a larger area, thus compensating for a temporal loss of function from the smaller but presumably more mature impact site; and
- Compensate for the inability to achieve full replacement of lost wetland functions (Washington Department of Ecology, 2000; Kusler and Kentula, 1990).

Several authors and agencies have recommended various replacement ratios (Castelle et al., 1992). Most ratios are based on known failures of compensatory mitigation and are designed to compensate for historic losses of wetlands. Studies of the success of mitigation projects suggest that replacement ratios based on mitigation success could be between 3:1 and 1.25:1. However, more information is needed to understand whether lost wetland functions and acreage can be entirely compensated for. Mitigation ratios for wetlands in most local jurisdictions in western Washington currently range between 1:1 and 4:1. The Washington Office of Community

Development recommended in its draft model critical areas ordinance ratios of up to 6:1 (OCD, 2002).

5.3.1 Restoration/Enhancement

Many wetland mitigation projects in the past have not been successful for various reasons and have resulted in lost acreage, wetland types, and wetland functions (Castelle et al., 1992b; Washington Department of Ecology, 2002; Mockler et al., 1998). Castelle et al., (1992b) reported that 50 percent or more of the mitigation projects studied did not meet permit requirements. Common problems included:

- Inadequate design;
- Failure to implement the design;
- Lack of proper maintenance
- Site infestation by exotic species;
- Grazing by geese or other animals;
- Destruction by floods, erosion, fires, or other catastrophic events;
- Failure to maintain water levels and failure to protect projects from on-site and off-site impacts such as sediment and pollutant loading; and
- Off-road vehicles.

Mitigation has been more successful for some wetland types, including emergent and open water wetlands (Castelle et al., 1992b). Other wetland types have been very difficult or impossible to replicate, such as mature forested or bog systems, or wetlands that contain habitat for sensitive wildlife species. Restoration of prior wetlands was often found to be easiest to achieve. The likelihood of success of restoration is greater than other types of mitigation because the site will benefit from restored hydrology, and seed sources from the original wetland may be present and viable. However, some authors suggest that mitigation projects in urban settings may not be able to recreate a historic wetland ecosystem due to changes in water regime and nutrient input (Ehrenfeld, 2000; Horner, 1997; Booth, 2000).

A predominant problem throughout wetland mitigation sites is the invasion of the site by non-native plant species. Studies have found that at least 50 percent of species in mitigation sites were non-native (Magee et al., 1999; Ecology, 2002). Mitigation areas that were not protected by an upland buffer had a larger percentage of non-natives species; long-term maintenance of sites resulted in lower percentages of non-natives. Gwin et al (1999) also found mitigation areas to be functionally different from replaced wetlands, resulting in net loss of function and, in some cases, net loss of wetland area. Enhancement of existing wetlands to replace lost wetlands does not actually create new wetlands but improves or modifies the functions of existing wetlands to compensate for those lost, therefore resulting in a "no net loss" of wetland acreage and possibly wetland functions (depending on how the enhancement was implemented) (Shaffer et al., 1999; Gwin et al., 1999; Ecology, 2002).

A study by Ecology (2002) concluded that although better site selection, design, and performance standards will help to improve wetland mitigation, consistent follow-up, both to correct problems with current projects and to provide feedback for decision-making on future projects, will result in the greatest overall improvement. Most successful projects had long-term monitoring of at least five years and applied adaptive management strategies. Many other studies support long-term (at least five years) monitoring for mitigation projects (Kentula, 2002; Kusler and Kentula, 1990).

Less common but more comprehensive methods of wetland protection include regulating landscape and watershed-level activities (KCDNRP, 2002). Methods to protect wetland hydrology, water quality, and habitat in wetlands could be "regionally significant aquatic resource areas" (aiming to maintain 65 percent overall watershed basin vegetation). Such strategies, however, may be more feasible in unincorporated rural areas than in urban centers. More localized goals for urban-type areas could include minimizing vegetation removal to less than 35 percent of subdivisions (KCDNRP, 2002).

5.4 Local Conditions and Issues

Most wetlands in the four cities of the Snoqualmie Valley are riparian wetlands associated with the South Fork and mainstem Snoqualmie River, and its tributary streams (Table 3). Almost all wetlands within the cities of Duvall and Carnation are located along the tributary streams, whereas the cities of Snoqualmie and North Bend have a large number of wetlands within the floodplain of the South Fork and mainstem Snoqualmie River.

Table 3. Wetlands In Each Jurisdiction of the Snoqualmie Watershed

CITY	USFWS Classification	Hydrogeomorphic (HGM) Classification
Duvall	East bank Snoqualmie River – PSS/PEM (15.9 acres) Thayer Creek- PFO, PEM, PUB Cherry Creek PSS, Rasmussen Lake (PUB) Coe-Clemens – PEM, PEM, PSS	Riverine flow-through (associated with river channel), riverine impounded (associated with flood channel)
Carnation	Majority of City's wetlands are associated with Tolt River - PSS, R3 Single wetland adjacent to Snoqualmie River	Riverine flow-through (associated with river channel), riverine impounded (associated with flood channel)
Snoqualmie	Kimball Creek - PFO, PSS, PEM, R3, Both banks Snoqualmie River - Meadowbrook Slough, Sandy Cove Park, and Brockway Creek Wetland (PFO, PSS, PEM, R3)	Riverine flow-through (associated with river channel), riverine impounding (associated with flood channel)
North Bend	Riparian wetlands associated with Gardiner and Ribary Creeks. Forested, scrub-shrub, and emergent wetlands on the Tollgate Farm and Meadowbrook Farm sites and associated with South Fork Snoqualmie River	Riverine flow-through (associated with river channel), riverine impounded (associated with flood channel)

Key: PFO – Palustrine forested, PSS - Palustrine scrub-shrub, PEM - Palustrine emergent, PUB – Palustrine unconsolidated bottom; R3 – Riverine upper perennial [Source National Wetland Inventory (USFWS, 1989)]

Source: Herrera Environmental Consultants, 2002; City of Carnation Comprehensive Plan; Sheldon and Associates, 1991; RCA Huitt-Zollars & Meadowbrook Farm Preservation Association 501(c)(3).

6.0 WETLAND AND STREAM BUFFERS

6.1 Definition

Buffers are designated areas contiguous to streams, wetlands, wildlife habitat areas, steep slopes, or other critical areas intended to protect the critical area. This paper focuses on buffers that are upland areas immediately adjacent to the boundaries of wetlands and streams. Unlike some other critical areas discussed in this paper, buffers are a regulatory tool used to protect critical areas, most often comprised of a fixed-width conservation zone established around critical areas. Buffer widths can vary by jurisdiction, critical area type, or functions that they are intended to protect.

Buffers provide beneficial functions that enhance and protect the many functions and values of wetlands and streams described in previous sections of this paper. Buffers can also be particularly beneficial for some species of wildlife because many wildlife species require both wetland and terrestrial habitats for their survival. Because many of the functions associated with stream riparian areas also apply to wetland buffers, these buffers are discussed jointly below.

6.1.1 WAC BAS Requirements

Because they are regulatory tools rather than critical areas, buffers are not specifically addressed in the BAS regulations contained in WAC 365-195-900 through 365-195-925. However, the WAC 365-195-900 (b) does state that counties and cities must include the “best available science” when developing policies and development regulations to protect the functions and values of critical areas and give “special consideration” to conservation or protection measures necessary to preserve or enhance anadromous fisheries. Buffers are considered a primary tool in protecting critical area functions and values, and in conserving and protecting riparian habitat and functions necessary to support healthy anadromous fisheries.

6.1.2 NTAA-identified Issues

The NTAA recommended prohibiting clearing and development in riparian zones, and designating all streams and riparian zones as fish and wildlife conservation areas in local critical areas codes. In addition, the NTAA review recommended that all fish-bearing streams be protected by 150-foot minimum buffers (Snohomish Watershed Forum, 2002).

6.2 Watershed-Wide Issues

6.2.1 Buffer Functions

Buffers provide many functions for wetlands and streams, from providing large woody debris and wildlife habitat, to filtering sediments and maintaining benthic communities (Appendix F). Riparian forests and the large woody debris they contribute to streams play a key role in the creation and maintenance of salmon habitat, and provide benefits such as moderation of stream temperature, input of organic matter, and stabilization of streambanks (see Section 4.0, above).

Buffer areas can capture and retain sediments, nutrients, pesticides, pathogens, and other pollutants that may be present in stormwater runoff (Ecology, 1996). Stream buffers composed of forested and shrub vegetation also provide shade that in turn maintains water and wildlife habitat quality.

Buffers also provide important functions for wetlands. Reduction of sediment and pollutant discharge to wetlands can prevent alterations to plant and animal communities and degradation of water quality. As a result, buffers protect a wetland's ability to provide sediment and pollutant removal. Buffers around wetlands can also help to infiltrate floodwater, reducing water level fluctuations. Like streams, wetland buffers composed of forested and shrub vegetation also provide shade that in turn maintains water and wildlife habitat quality.

Wildlife species that use wetlands or streams for a portion of their life cycle also depend on terrestrial habitats for food, cover, nesting, and/or travel corridors. A variety of wildlife species utilize edge habitat between wetlands, streams, and upland habitat. Forested terrestrial habitat areas provide a source of large woody debris used by wildlife for foraging, nesting, and cover (O'Connell, 2000). Buffers also provide separation between wetland and stream habitats and human disturbance. This separation improves the quality of wildlife habitat by reducing the effects of noise, light, and human motion/activity on animal species sensitive to these disturbances.

6.2.2 Buffer quality vs. width

Stream and wetland buffer studies have been conducted in a wide variety of locations (e.g., Puget Sound lowlands, montane forests of the Cascades), and land use settings (primarily agricultural and forestry) using a variety of research methods. Moreover, studies have been conducted on a wide range of stream channel types (e.g., stream order, channel size, channel morphology) and site characteristics (e.g., slope, aspect, soil type, vegetative cover).

Several literature reviews summarize the effectiveness of various buffer widths (Castelle et al., 1992a; Castelle and Johnson, 2000; Desbonnet et al., 1994; FEMAT, 1993). McMillan (2000) provides the most recent literature review specific to buffers in western Washington (Appendix F). In general, buffer widths reported to be effective for a range of stream or wetland functions vary considerably; the literature is not definitive in identifying an ideal buffer width for each function studied. An overall conclusion of review of the scientific literature points to site-specific factors as determinants for buffer widths required to protect a given habitat function or group of functions (McMillan, 2000). These factors include the plant community (species, density, and age), aspect, slope, channel width, and soil type, and adjacent land use.

Buffer requirements for wildlife habitat support are typically larger, on the order of 100 to 600 feet (Knutson and Naef, 1997; FEMAT, 1993). In many of these studies, the relationship between buffer width and effectiveness is logarithmic, so that after a certain width an incremental increase in buffer width provides diminishing functional effectiveness. For example, one study indicates that 90 percent of sediment removal can be accomplished within the first 100 feet of a riparian buffer, but an additional 80 feet of buffer is needed to remove just five percent more sediment (Wong and McCuen, 1982).

However, given the variation in the various buffer widths evaluated in the literature and the factors influencing their effectiveness, a general relationship between buffer width and buffer effectiveness is apparent in research findings. Many studies indicate that buffers ranging from 100 to 150 feet wide provide most (on the order of 80 percent) of potential buffer functions in most situations (Castelle and Johnson, 2000; Knutson and Naef, 1997; Desbonnet et al., 1994; Castelle et al. 1994; FEMAT, 1993; Castelle et al, 1992a).

6.2.3 Buffer management techniques

Fixed buffer widths are the most common strategy used to protect streams and wetlands from disturbance and other detrimental impacts from immediately adjacent existing or expected land use (KCDNRP, 2002). Other buffer management techniques may include variable buffer widths based on site conditions, or establishment of “inner” and “outer” management zones along streams and wetlands. McMillan (2002) suggests an "advanced buffer determination method," that is more scientifically based and incorporates: 1) wetland type; 2) type of adjacent land use; and 3) buffer characteristics. The “advanced buffer determination method” would result in establishment of buffers that are more site-specific, scientifically supportable, and more flexible for the land developer than standard buffer methods (Appendix F) (McMillan, 2002).

The dynamic and variable state of nature, and the fact that change occurs over long periods of time and large areas, suggest that natural resource management must include a more comprehensive context of analysis for resource protections (KCDNRP, 2002). Current scientific literature emphasizes the principles of context, connectivity, and complexity to protect biological diversity, and healthy, functioning ecosystems (KCDNRP, 2002). In some areas, such as urban areas, simple prescriptive buffers may not be adequate to restore streams or wetlands because most of the functions of buffers have been compromised by past land use actions. For example, restoration of the natural woody debris recruitment function of stream buffers is difficult in areas that lack mature forested streamside vegetation (Larson, 2000). New watershed-based strategies may need to be implemented that address hydrology, water quality, and riparian functions together to successfully address management of buffer width and quality, land use controls, and stormwater management (Booth, 2000; Horner and May, 1999). When applied in the context of a basin-wide change, these strategies may most effectively address protection, enhancement, and restoration of stream and wetland systems.

6.3 Local Conditions and Issues

Each of the NTAA jurisdictions has established its own regulations for managing stream and wetland buffers. As discussed under local conditions for Streams and Fish Habitat, above, riparian areas along the mainstem Snoqualmie River in Duvall largely consist of dense native vegetation, while riparian areas in Carnation generally consist of non-dense, non-native vegetation. There has been little to no systematic documentation regarding buffer conditions in North Bend or Snoqualmie. Evaluations conducted to date, however, show that large woody debris is consistently lacking throughout the jurisdictions, suggesting that there may be opportunities to restore riparian areas to improve this function. A more systematic evaluation of buffer conditions could help to identify buffer restoration opportunities, particularly during redevelopment.

7.0 STORMWATER

7.1 Introduction

7.1.1 WAC BAS Requirements

Stormwater is not specifically addressed in the BAS regulations contained in WAC 365-195-900 through 365-195-925. However, stormwater is included in this paper as it relates to "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries (WAC 365-195-900 (b)).

7.1.2 NTAA-identified Issues

The NTAA provided two main recommendations that relate to stormwater management in each of the Snoqualmie Valley jurisdictions. First, the NTAA recommended the survey, prioritization, and upgrade of retention/detention facilities, and the adoption of a stormwater design manual equivalent to the Washington State Department of Ecology's 2001 *Surface Water Management Manual for Western Washington* (Snohomish Watershed Forum, 2002). The NTAA further recommended that new development and redevelopment use low-impact development techniques to reduce stormwater impacts to stream hydrology and water quality.

7.2 Watershed-Wide Issues

Excessively high peak stream flows can affect both stream morphology and habitat use by salmonids by destabilizing stream channels, causing rapid incision or other channel changes, disturbing eggs, and by eliminating refuge habitat for juvenile salmonids and other aquatic organisms. Excessive flows can also scour streambeds and banks and can disturb redds, killing eggs or fry.

Discharge regimes, including high and low flows, in streams can be substantially altered in urban or urbanizing watersheds, primarily due to runoff from impervious surfaces. The quantity of impervious surface in a basin (often termed Total Impervious Area, or TIA) has been associated with stream degradation (Booth, 2000; May et al., 1997; Horner and May, 2000). Studies in Puget Sound lowland streams show that alteration can occur in basins with as little as 10 percent total impervious surface. Dramatic effects can be seen relative to discharge in basins where impervious surface exceeds 40 percent (May et al., 1997). In many cases, stormwater is channelized into conveyance systems, completely bypassing riparian areas and changing the volume, rate, and timing of water delivery to streams (PHS, 2001). Peak flows can increase and become shorter in duration. Channelizing stormwater also reduces or eliminates the water quality function performed by riparian areas. Stormwater runoff and its impacts can be further exacerbated when streams are channelized and cannot meander or overflow into the floodplain to accommodate changing stormwater volumes. Changes in stream hydrology can impact the composition and establishment of streamside vegetation, resulting in increased erosion and channel incision, particularly in smaller, tributary streams.

Using low-impact development (LID) approaches for new development can help to achieve storm-water pollution reduction goals. LID emphasizes the protection and use of natural on-site features to manage stormwater as close to its origin as possible by reducing impervious surface and eliminating effective impervious area.

8.0 WILDLIFE HABITAT CONSERVATION AREAS

8.1 Definition

Wildlife conservation measures are defined in the BAS regulations (RCW 36.70.172). They include, but are not limited to, measures that protect habitat and movement corridors for wildlife. Wildlife habitat conservation is defined as land management that maintains species in suitable habitats in their natural geographic distribution so that isolated subpopulations are not created. This does not mean maintaining all individuals of all species at all times, but it does mean cooperative and coordinated land use planning is important among counties and cities in a region. In some cases, intergovernmental cooperation and coordination may help to assure that a local population of a species can be maintained in regions across the state.

8.1.1 WAC BAS Requirements

Fish and wildlife habitat conservation areas, as defined in WAC 365-190-080 (5) (a) include:

- Areas with which endangered, threatened, and sensitive species have a primary association;
- Habitats and species of local importance;
- Naturally occurring ponds under 20 acres;
- Waters of the state; and
- State natural area preserves and natural resource conservation areas.

Counties and cities may consider the following when classifying and designating these areas:

- Creating a system of fish and wildlife habitat with connections between larger habitat blocks and open spaces;
- Protecting riparian ecosystems;
- Evaluating land uses surrounding ponds and fish and wildlife habitat areas that may negatively impact these areas; and
- Establishing buffer zones around these areas to separate incompatible uses from habitat areas.

8.1.2 NTAA-identified Issues

Wildlife habitat conservation is cited in several places in the NTAA guidance document *Snoqualmie Watershed NTAA Regulatory Review for King County* (2002). Although wildlife habitat and conservation is not a specific section in the report, many of the topics listed under Land Use, Water Quality, Buffers, and other sections would benefit wildlife. Specifically, protection of wooded riparian areas provides wildlife travel corridors as well as structure, forage, and water for wildlife. The NTAA policies with direct effects on wildlife include:

- Retain forest in rural land use areas;
- Evaluate habitat impacts of roads when updating comprehensive plan changes;
- Protect and restore habitat in urban land use areas for all salmonid life stages;
- Locate new development away from riparian areas;
- Designate all streams and riparian zones as Fish and Wildlife Conservation Areas; and
- Protect and promote groundwater recharge.

8.2 Watershed-Wide Issues

Wildlife habitat can be identified by the types and associations of vegetation present in an area. Johnson and O'Neil (2001) describe a number of wildlife habitat types that are found in the Pacific Northwest west of the Cascade Crest (referred to as "westside"), including the Snoqualmie Valley. Habitat types present in the NTAA jurisdictions include:

- Westside riparian wetlands;
- Westside lowland conifer/hardwood forest;
- Herbaceous wetlands and open water; and
- Agriculture and urban environs (agriculture, pasture, and mixed environs; and urban and mixed environs).

In addition to these vegetated landscape elements, the NTAA jurisdictions include areas that are urban in character, comprised primarily of residential development, both single-family and multi-family, and secondarily of commercial development. Within this matrix, habitat linkages between habitat blocks are predominantly comprised of westside riparian habitat. Open water and herbaceous wetland habitats in the NTAA jurisdictions are mostly associated river floodplains and agriculture (e.g., stock ponds).

In general, wildlife species require adequate forage, water, structure, and space for breeding/nesting, roosting, and for cover (Johnson and O'Neil, 2001; Link, 1999). In addition to the streams and fish habitat discussed earlier in this report, riparian areas also provide wildlife habitat that incorporates:

- Structural and plant diversity;
- Edge habitat where two or more habitat types adjoin;

- Varied forage; and
- A predictable water source (Kauffman, et al., 2001; O'Connell et al., 2000).

Lowland forest, when it includes large trees and dead tree snags, provides important foraging and breeding habitat for several special status species, most notably for bald eagle, pileated woodpecker, and Vaux's swift (Appendix D). In the NTAA jurisdictions, this habitat also provides important winter range for large animal species (e.g. black-tailed deer and Rocky Mountain elk), which use it to forage in winter when adjacent high elevation habitat is snow-covered (Pentec, 1999). In addition, native forest provides habitat for more than 130 other non-special status bird, mammal, amphibian, and reptile species (Johnson and O'Neil, 2001). Several key features in forests are important for wildlife and include large trees, the species composition of trees and shrubs, multi-stored canopies, dead wood, and forest litter layers.

Wildlife habitat linkages are linear strips of habitat that link larger habitat areas. These areas provide enough food, structure, and water for some wildlife species to live in the linkage area, while others use these areas to move from one habitat area to another. In urban areas where habitats are fragmented and isolated by development and roads, linkages that connect larger tracts of more diverse habitat are especially important (Adams, 1994; Adams and Dove, 1989; MacClintock et al., 1977). Linkages provide habitat for species moving between foraging areas, breeding areas, and seasonal ranges, and they can provide habitat for the dispersal of young animals (Knutson and Naef, 1997; O'Connell et al., 2000; Spence, 1996).

The Snoqualmie Valley contains large areas of agricultural land, including grazed pastures, cropped areas, and berry farms. Agricultural habitats are largely occupied by generalist species that are adapted to use a variety of habitats for foraging and breeding (Ferguson et al., 2001; Hunn, 1982; City of Bellevue, 1988). In general, agricultural habitats generally do not contain the required structure, forage, and space needed for specialist species, including special status species. Of the special status species that occupy the project area, only the red-tailed hawk is closely associated with agriculture, pasture, and mixed/urban environs due to the preference of this species to forage in open fields (Johnson and O'Neil, 2001; WDFW, undated; Terres, 1995). Special status species known to be present in each jurisdiction are discussed below.

8.3 Local Conditions and Issues

The NTAA jurisdictions support numerous species of fish, birds (waterfowl, songbirds, raptors, and others), amphibians, reptiles, insects and other invertebrates (Appendix D). Twenty seven sensitive species are identified as possibly present in the NTAA jurisdictions (Table 4).

Duvall and Carnation, which have more agricultural land and smaller blocks of forestland, are less likely to have large forest species such as elk and black bear, although these species may occur occasionally. North Bend and Snoqualmie, which contain more forested land in close proximity to commercial timber land (Snoqualmie Tree Farm), the Mount Si Natural Resources Conservation Area, and the Middle Fork Snoqualmie Natural Area, provide more suitable habitat for species that require large tracts of forest (e.g. Rocky Mountain elk and merlin). Table 4 discusses species presence and habitat linkages in each jurisdiction.

Table 4. Priority Species Presence in NTAA Jurisdictions

CITY	FEDERALLY-LISTED	SPECIAL STATUS SPECIES	WILDLIFE LINKAGES
Duvall[b]	bald eagle[1], chinook salmon[1], bull trout[2]	osprey, wood duck, hooded merganser, pileated woodpecker, great blue heron, green heron, Vaux's swift	Corridors mainly limited to river riparian areas
Carnation[a]	bald eagle[1], chinook salmon[1], bull trout[2]	osprey[1], wood duck[1], great blue heron[1], hooded merganser[1]	
Snoqualmie[c]	bald eagle[1], bull trout[2] , marbled murrelet[2], northern spotted owl[2]	peregrine falcon, Vaux's swift, pileated woodpecker[2], olive-sided flycatcher[2], willow flycatcher[2], Townsend's big-eared bat[2], long-eared myotis[2], long legged myotis[2], Oregon spotted frog[2], red-legged frog[2], western toad[2]	Low-elevation corridor between Rattlesnake Ridge, Three Forks, North Fork Corridor, Corridor extending from Three Forks Park to Middle Fork
North Bend[d]	bald eagle[1], bull trout[2]	wood duck[1], hooded merganser[1], pileated woodpecker[1], great blue heron[1], band-tailed pigeon[1], osprey[1], peregrine falcon[1], black-tailed deer[1], Rocky Mountain elk[1;] Beller's ground beetle[2] California wolverine[2], Pacific fisher[2], Cascade frog[2], Hatch's click beetle[2], long-eared myotis[2], long-legged myotis[2], northwestern pond turtle[2], olive-sided flycatcher[2], northern goshawk[2], Pacific lamprey[2], river lamprey[2], western toad[2], valley silver-spot[2], and white-top aster[2].	

Key: [1] Documented presence, [2] Potential presence

Source: [a] City of Carnation Comprehensive Plan (1996); [b] City of Duvall Comprehensive Plan; [c] Snoqualmie Falls Hydroelectric Project DEIS (2002); [d] Meadowbrook Farm Master Site Plan (RCA Huitt-Zollars & Meadowbrook Farm Preservation Association 501(c)(3))

9.0 AQUIFER RECHARGE AREAS

9.1 Definition

Critical aquifer recharge areas (CARA) are defined as those areas that significantly contribute to the recharge of aquifers used for potable water (WAC 365-190-030(2)). These areas have prevailing geologic conditions associated with infiltration rates that create a high potential for contamination of groundwater resources, or conditions that contribute significantly to the replenishment of groundwater.

9.1.1 WAC BAS Requirements

The quality of groundwater in an aquifer is inextricably linked to its recharge area. Local soil and surficial geologic conditions determine where recharge areas occur. The WAC requires that counties and cities classify recharge areas for aquifers according to the vulnerability of the aquifer (WAC 365-190-080 (2)). Vulnerability is the combined effects of hydrogeological susceptibility to contamination and the contamination loading potential.

To characterize hydrogeologic susceptibility of the recharge area to contamination, counties and cities may consider the following physical characteristics:

- Depth to groundwater;
- Aquifer properties such as hydraulic conductivity and gradients;
- Soil (texture, permeability, and contaminant attenuation properties);
- Characteristics of the vadose zone including permeability and attenuation properties; and
- Other relevant factors.

The following factors may be considered to evaluate the contaminant loading potential:

- General land use;
- Waste disposal sites;
- Agriculture activities;
- Well logs and water quality test results; and
- Other information about the potential for contamination.

9.1.2 NTAA-identified Issues

The NTAA recommended the protection and promotion of groundwater recharge and natural storage by minimizing impervious surfaces and using best management practices. However, the NTAA did not directly address vulnerability and contaminant loading potential.

9.2 Watershed-Wide Issues

9.2.1 Identification of recharge areas

Glacial and inter-glacial deposits under the Snoqualmie Valley form the largest aquifer system in the Snohomish River basin (Pentec, 1999). Aquifers in the Snoqualmie Valley discharge water naturally through springs and seeps, streams, lakes, and wetlands. Man-made wells create additional discharge points that influence ground-water flow patterns. As aquifers discharge, they in turn are recharged. Recharge occurs primarily as a result of the infiltration of rainfall, and secondly by the movement of water from adjacent aquifers or water bodies. The rate and quantity of water entering the ground depends on several factors. Natural factors include the amount of precipitation, soil types and conditions, vegetation, and topography. Man-made factors include impervious surfaces associated with development, the channeling of runoff, changes in soil condition such as compaction, and removal of vegetation.

The soils and surficial geology in the Snoqualmie Valley reflect the flooding and glacial history that deposited materials over the floodplain. These deposits vary from coarse-textured sands and gravels to silty and clayey floodplain deposits. Sands and gravels are permeable and permit the movement of groundwater, whereas silty and clayey materials are not as permeable and do not drain readily, retarding groundwater movement.

There are three general types of aquifers in the Snoqualmie Valley: perched groundwater areas located within the overburden, a regional groundwater aquifer in shallow alluvium along major river channels, and a deeper regional aquifer within the bedrock (FERC, 1996). Within these three main units, other studies have identified up to 8 sub units of aquifers and aquitards (Pentec, 1999). Perched groundwater areas are generally present throughout the NTAA jurisdictions and are both shallow and localized. Recharge is from direct precipitation. The alluvial groundwater system is the most productive and reliable water source in the area. The alluvial system is present in the upper Snoqualmie Valley from the City of Snoqualmie to approximately five miles east of the City of North Bend. This aquifer is recharged from adjacent uplands and from rivers and streams. The deep bedrock regional aquifer has the greatest areal extent of the aquifers in the region. Yields from the bedrock aquifer are variable. Recharge is from precipitation and from overlying alluvium and glacial deposits.

In 1998, King County adopted the *East King County Groundwater Management Plan* characterizing groundwater resources and aquifer recharge areas in the NTAA area. In general, recharge is lowest downstream (mapped from 10 to 30 inches per year in Duvall) and highest upstream (mapped from 41 to 60 inches per year in North Bend). Groundwater levels in the area are controlled by the relationship between recharge from precipitation, discharge to the rivers and bank storage. In general, groundwater levels rise during periods of precipitation and when discharge to the rivers is slowed or reversed by a rise in river levels. Groundwater levels respond to changes in river levels faster in relatively permeable soils and slower in less permeable soils. The effect of river levels on groundwater also decreases with distance from the rivers.

9.2.2 Contaminant loading potential

Aquifers can also be affected by contamination. A hazardous waste spill can have severe adverse impacts on an aquifer, possibly making the water unusable for years (City of Carnation, 1996).

There are three primary types of contaminants found in groundwater that threaten public health: microbial pathogens, inorganic chemicals, and organic chemicals. Microbial pathogens include bacteria, viruses and other disease-causing organisms. Improperly maintained sewage disposal systems, poorly constructed wells, leaking sewers, and animal wastes are common groundwater sources of microbial pathogens. Inorganic chemicals include sodium, chloride, nitrate and heavy metals. Nitrate occurs naturally, and from human activities such as septic systems, fertilizer use, and contaminated stormwater runoff. Nitrate is an important indication of groundwater quality, because it is associated with other pollutants.

Metals also may be naturally occurring, or from human activities such as commercial and industrial land uses and from stormwater runoff from streets and parking lots. Many metals, including copper, zinc, lead, arsenic, and cadmium, are harmful to health. Iron and manganese are common in groundwater in King County, but they do not pose a health threat; rather they primarily affect the taste and staining properties of water.

Improper use, storage or disposal of organic chemicals such as fuels, solvents, pesticides and herbicides can contribute to a variety of illnesses, and may persist in groundwater for decades if allowed to infiltrate the ground. These contaminants can come from such sources as hazardous materials, leaking underground storage tanks, on-site sewage disposal systems, pesticides and fertilizers, sewer pipes, landfills, mining activities, biosolids, and sewage effluents (City of Carnation, 1996).

The *East King County Groundwater Management Plan* reported that groundwater quality is generally good throughout the area surveyed, which included the entire NTAA project area. Others have reported groundwater quality to be "typical" for western Washington. Higher nitrate concentrations have been reported in shallow wells, with possible sources being septic tanks, pastures, and lawn fertilizers (Pentec, 1999).

9.3 Local Conditions and Issues

BAS available science guidance is limited for critical aquifer recharge areas, and is concentrated around mapping of local conditions. The *East King County Groundwater Management Plan* (1998) identifies the City of Duvall as an area with low susceptibility to groundwater contamination.

Much of the area around Carnation is highly susceptible to contamination. The primary water supply for Carnation is groundwater that flows from a series of springs located about 2.5 miles southeast of the City. A second source of supply is a well located near the intersection of Entwistle Street and Milwaukee Avenue. Because the City relies on groundwater as its source of potable water, protection of the aquifer is particularly important (City of Carnation, 1996). Upland areas located west and east of the City have higher groundwater elevations and serve as recharge areas throughout the year. Additionally, the Snoqualmie and Tolt Rivers may seasonally recharge the shallow aquifer system (City of Carnation, 1996). A viable and productive aquifer was identified at the mouth of the Tolt River (*East King County Groundwater Management Plan, 1998).*

Eastern, lower elevation portions of the City of Snoqualmie are highly susceptible to contamination, while higher elevations to the west are considered to be of low susceptibility to contamination.

North Bend is considered a high aquifer recharge area sensitive to contamination. North Bend contributes as much as 60 inches of recharge annually to underlying aquifer systems (Table 5). Groundwater in the shallow valley aquifer beneath North Bend occurs at depths ranging from 10 to 40 feet, primarily at a depth of 20 feet (HWA GeoSciences, 2001). The productive zone of this aquifer extends to a depth of approximately 250 to 300 feet. Most groundwater from this aquifer discharges to the Snoqualmie River at an estimated annual rate of 50 to 70 cubic feet per second (HWA GeoSciences, 2001). A portion of the groundwater discharges vertically downward into the deep aquifer system, and a minor percentage is withdrawn by water supply wells (HWA GeoSciences, 2001). The deep aquifer system reaches a depth of 550 feet north of North Bend in Snoqualmie, and 700 feet east of North Bend, approximately a mile and a half northeast of the North Bend airstrip.

Table 5. Critical Aquifer Recharge Areas in the NTAA Jurisdictions

CITY	Recharge (inches per year) [1]	Contamination Susceptibility [2]
Duvall	10-20 close to Snoqualmie River 21-30 further away from River	Low
Carnation	21-30 close to Snoqualmie River 31-40 east of Highway 203	High
Snoqualmie	41-50 close to Snoqualmie River 21-30 further away to the south	High in eastern portions near the Snoqualmie River Low in western portions away from the Snoqualmie River
North Bend	41-50 upstream of downtown 51-60 downtown and upstream	High

Source: [1] Figure 6.6 - *East King County Groundwater Management Plan* (1998) (See Appendix E)

[2] Figure 4.7 - *East King County Groundwater Management Plan* (1998) (See Appendix E)

10.0 GEOLOGICALLY HAZARDOUS AREAS

10.1 Definition

Geologically hazardous areas are generally defined as areas that are susceptible to erosion, landsliding, earthquakes, or other geological events. As a result, these areas may not be suited to certain types of development. The following sections discuss general geologic conditions associated with geologic hazards and potential management techniques.

10.1.1 WAC BAS Requirements

In accordance with WAC 365-190-080 (4), landslide hazard areas include areas potentially subject to landslides based on a combination of geologic, topographic, and hydrologic factors. They include areas susceptible because of any combination of bedrock, soil, slope (gradient), aspect, structure, hydrology, or other factors including, but not limited to the following:

- Areas of historic failures;
- Areas with all three of the following characteristics:
  - Slopes steeper than fifteen percent;
  - Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock; and
  - Springs or groundwater seepage.
- Areas that have shown movement during the Holocene epoch (from 10,000 years ago to the present) or that are underlain or covered by mass wastage debris of that epoch;
- Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials;
- Slopes having gradients steeper than 80 percent subject to rockfall during seismic shaking;

- Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action;
- Areas that show evidence of, or are at risk from snow avalanches;
- Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding;
- Any area with a slope of forty percent or steeper and with a vertical relief of ten or more feet except areas composed of consolidated rock. A slope is delineated by establishing its toe and top and measured by averaging the inclination over at least ten feet of vertical relief.

Seismic hazard areas include areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting.

Erosion hazard areas are, at a minimum, those areas identified by the United States Department of Agriculture Soil Conservation Service as having a "severe" rill and inter-rill erosion hazard.

10.1.2 NTAA-identified Issues

The NTAA focuses only on landslide hazards and recommends prohibiting road building and clearing and grading in landslide hazard areas, and the use of geotechnical analysis. When human-induced landslides occur, the NTAA recommends the use of bioengineering approaches.

10.2 Watershed Wide Issues

Unlike some critical areas for which there is substantial “science” regarding their management, little such science exists for geologic hazard areas. Instead, management strategies typically focus on building code compliance and engineering techniques. In general, geologic hazards pose a threat to the health and safety of citizens when development is inappropriately sited in areas of significant hazard. Some hazards can be reduced or mitigated by engineering, design, or by modified construction practices. When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided (WAC 365-190).

10.2.1 Landslide Hazards

Landslide hazard areas are areas that exhibit movements of sliding soil and rocks, and are distinguished from the underlying stationary part of the slope by a plane of separation. In general terms, a landslide is movement downslope of a mass of soil, rock or both, along with water. The downslope movement may be very swift or slow, depending on the type of material involved, volume of water, slope gradient, and several other variables. The mass of material may be shallow or surficial in nature and small, or it may extend very deep underground and be large in size. Sliding can include slow, long-term, and plastic deformation of slopes and usually occurs not along one distinct failure surface, but within a system of sliding planes. This movement is often referred to as creep (KCDNRP, 2002).

Landslides in King County occur in sloping areas that are underlain by interbedded sediments that vary in grain size. Landslides can be triggered when there is a loss of lateral support at the bottom, or toe, of a slope due to the action of water, as in a stream or river. As the toe is eaten away, support for the overlying soil mass deteriorates and eventually gravity causes the slope to collapse. This type of slope failure is usually quite rapid once initiated and for that reason can be very hazardous to life and property (KCDNRP, 2002). Landslides can also occur when stabilizing vegetation is removed and/or hillsides disturbed by road building or other activities.

Steep slopes may serve several other functions and possess other values for the NTAA jurisdictions and their residents. Forested areas are often located in steep slope areas, providing habitat for a variety of wildlife species, including several “special status” species, and providing important linkages between habitat areas. These steep slope areas may also act as conduits for groundwater, which drains from hillsides to provide a water source for wetlands and stream systems.

In many jurisdictions in western Washington, setbacks or buffer distances for steep slopes are established between the tops and toes of steep or unstable slopes. Although not universally based on findings of specific studies, 50 feet is a very common and reasonable distance based on land use practices in the region. Setbacks may typically be decreased based on recommendations from a geotechnical engineer or geologist, but in few cases are they less than 10 feet. Setbacks can also conversely be increased for site-specific conditions where geotechnical investigations recommend larger setbacks.

10.2.2 Erosion Hazards

Erosion hazards have been mapped by the federal Natural Resources Conservation Service and in King County based on the grain size of the various soil units, and on slope. Many other variables influence erosion hazard areas including rainfall frequency and intensity, surface composition, permeability, and land cover (KCDNRP, 2002). Erosion is usually managed through best management practices (BMPs) that limit erosion and sedimentation during construction. This includes covering of bare ground with straw or plastic sheeting, using silt fences, and planting denuded areas following construction.

10.2.3 Seismic Hazards

Seismic hazard areas are created by several factors including distance from an earthquake epicenter, magnitude and duration of the earthquake, nature and thickness of surface and subsurface geologic materials, and subsurface geologic structures. Seismic hazard areas include soils that are induced into settlement or liquefaction including loose, water saturated soils. Seismic activity in these soils can result in ground surface failure and structural damage. Liquefaction also occurs in areas underlain by loose and saturated soil with small grain size, such as those present in floodplains. Seismic hazard areas are generally found in floodplain areas of the Snoqualmie Valley, and in sloping areas and bluffs adjacent to floodplains.

Management of development activities in seismic hazard areas is important for the protection of public health and safety, and to minimize potential property damage during seismic events. Management also limits risk of liability for each city and for private property owners.

In the current version of the Uniform Building Code (UBC, 1997) adopted for use in Washington State, seismic design of structures is based on a 10 percent probability that ground motions of a certain magnitude will be exceeded in a 50 year-period, or about a 475-year return period. In contrast, seismic design in the International Building Code (2000), which has recently been adopted by Washington State, is based on ground motions with a 2 percent probability of occurrence in 50 years, or about a 2,500-year return period.

10.3 Local Conditions and Issues

BAS available science guidance for geologic hazard area protection is largely limited to mapping of local conditions. Most of the Snoqualmie Valley cities lie primarily in the flat, alluvial plains of the Snoqualmie River. The cities of Duvall and Carnation are relatively flat and have few geological hazard areas. The only area with slopes over 15 percent is west of Carnation (City of Carnation, 1996). Erosion hazard areas and seismic hazard areas in Carnation are both mapped along the length of the Tolt River (Table 6).

In the City of Snoqulamie, steep slopes of greater than 40 percent are mapped to the east and west of Snoqualmie Falls, along Snoqualmie Ridge, and along Rattlesnake Ridge (City of Snoqualmie, 1994). Most of the floor of the upper Snoqualmie Valley has been identified as a seismic hazard area in the King County Sensitive Areas Map Folio (King County, 1990).

Most landslide areas in North Bend involve a relatively few feet of soil on slopes underlain by denser and less permeable till or bedrock. Landslide areas are confined to a small area near the base of Rattlesnake Ridge, and erosion hazard areas are small. Most of the City lies on the valley bottom and as such is considered a seismic hazard area (Table 6).

Table 6. Geologic Hazard Areas in the NTAA

CITY	Seismic Hazard	Landslide Hazard	Erosion Hazard
Duvall	Concentrated adjacent to the Snoqualmie River and other areas around town	Concentrated along Coe-Clemens Creek	Concentrated along Cherry Creek and Coe-Clemens Creek
Carnation	Concentrated adjacent to the Tolt River	Very few, along outskirts of City limits, north of Tolt River Road	Three small areas along the Tolt River
Snoqualmie	Throughout the valley floor	Northern portions of the City	Northern portions of the City; in the vicinity of Snoqualmie Falls, Snoqualmie Ridge
North Bend	Throughout the valley floor	Small area at the base of Rattlesnake Ridge in south of I-90	Small areas north of I-90

Source: City of Carnation Comprehensive Plan (1996); City of Duvall Comprehensive Plan (1996); City of Snoqualmie Comprehensive Plan (1994); City of North Bend Comprehensive Plan (1996)

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APPENDIX A: FLOODPLAINS AND CHANNEL MIGRATION ZONES

Table A-1. Contemporary Flood Control Measures Summarized by Bolton et al. (2000)

Minimization of Impacts during Design and Construction

emulate nature
revegetate or maintain vegetation
minimal channel alteration
use riprap judiciously
random placement of rocks
two-stage channel for flood control

Preservation of Channel Morphologic Features

preserve original meander bends
preserve small channel features, such as pools and riffles
reconstruct only one half of a channel and leave the other side untouched
alternate reconstruction segments on opposite sides of the channel

Vegetation Incorporation Into Levees, Revetments and Other Embankments

use a variety of vegetation to create habitat complexity
create a vegetated berm for two-stage channel morphology
set back the levee from the active low-level channel to allow natural revegetation

Integrated Stream Bank Protection

engineered large woody debris

Active Restoration and Rehabilitation Techniques

complete levee and revetment removal
habitat restoration

Partial Restoration, Channel Geometry and Habitat Features

partial meander restoration
restore to more natural cross-section morphology
restore to two-stage channel morphology
restore pool-riffle sequence

Holistic Riparian Corridor Management

changes in public attitude
zoning
delineation and mapping of 200+ year floodplains
conservation easements
land purchases

APPENDIX B: STREAMS AND FISH HABITAT

Table B-1. Matrix of Pathways and Indicators

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Water Quality:	Temperature	50-56°F[1]	57-60° (spawning) 57-64° (migration & rearing)[2]	>60° (spawning) >64° (migration & rearing)[2]
	Sediment/Turbidity	<12% fines (<0.85 mm diameter) in gravel, turbidity low	12-17% (westside)[3] 12-20% (eastside)[2] turbidity moderate	>17% (westside)[3] >20% (eastside)[2] fines at surface or depth in spawning habitat[2], turbidity high
	Chemical Contamination/Nutrients	Low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches[5]	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach[5]	high levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach[5]
Habitat Access:	Physical Barriers	Any man-made barriers present in watershed allow upstream and downstream fish passage at all flows	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows
Habit Elements:	Substrate	Dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%[3]	Gravel and cobble is subdominant, or if dominant, embeddedness 20-30%[3]	Bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant embeddedness >30%[2]
	Large Woody Debris	>80 pieces/mile and >24" diameter >50 ft. length[4]; >20 pieces/mile and >12" diameter >35 ft. length[2]; and adequate sources of woody debris recruitment in riparian areas	Currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	Does not meet standards for properly functioning and lacks potential large woody debris recruitment

Table B-1. Matrix of Pathways and Indicators (cont.)

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Habit Elements (cont.):	Pool Frequency <u>Channel width</u> <u># pools/mile</u>[6] 5 feet 184 10 feet 96 15 feet 70 20 feet 56 25 feet 47 50 feet 26 75 feet 23 100 feet 18	Meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)	Meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	Does not meet pool frequency standards
	Pool Quality	Pools >1 meter deep (holding pools) with good cover and cool water[3], minor reduction of pool volume by fine sediment	Few deeper pools (>1 meter) present or inadequate cover/temperature[3], moderate reduction of pool volume by fine sediment	No deep pools (>1 meter) and inadequate cover/temperature[3], major reduction of pool volume by fine sediment
	Off-channel Habitat	Backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)[3]	Some backwaters and high energy side channels[3]	Few or no backwaters, no off-channel ponds[3]
	Refugia (important remnant habitat for sensitive aquatic species)	Habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	Habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations[7]	Adequate habitat refugia do not exist[7]
Channel Condition & Dynamics:	Width/Depth Ratio	<10[2,4]	10-12	>12 (we are unaware of any criteria to reference

Table B-1. Matrix of Pathways and Indicators (cont.)

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Channel Condition & Dynamics (cont.):	Streambank Condition	>90% stable; i.e. on average, less than 10% of banks are actively eroding[2]	80-90% stable, i.e. on average, 10-20% of banks are actively eroding	<80% stable, i.e. on average, >20% of banks are actively eroding
	Floodplain Connectivity	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly
Flow/Hydrology:	Change in Peak/Base Flows	Watershed hydrograph indicates peak flow, base flow and how timing characteristics are comparable to any undisturbed watershed of similar size, geology and geography	Some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	Zero or minimum increases in drainage network density due to roads [8,9]	Moderate increases in drainage network density due to roads (e.g., ~5%)[8,9]	Significant increases in drainage network density due to roads (e.g., ~20-25%)[8,9]

Table B-1. Matrix of Pathways and Indicators (cont.)

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Watershed Conditions:	Road Density & Location	<2 ml/ml[2,11], no valley bottom roads	2-3 ml/ml[2], some valley bottom roads	>3 ml/ml2, many valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥15% retention of LSOG in watershed[10]	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), ≥15% retention of LSOG in watershed[10]	<15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; does not meet NWFP standard for LSOG retention
	Riparian Reserves	The riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition >50%[12]	Moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (~70-80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition 25-50% or better[12]	Riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition <25%[12]

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Table B-2. Effects of Ecosystem Alterations on Salmonids and their Ecosystems

Ecosystem Feature	Altered Component	Effects on Salmonid Fishes and Their Ecosystems
Water Quality	Increased Temperature	Altered adult migration patterns, accelerated development of eggs and alevins, earlier fry emergence, increased metabolism, behavioral avoidance at high temperatures, increased primary and secondary production, increased susceptibility of both juveniles and adults to certain parasites and diseases, altered competitive interactions between species, mortality at sustained temperatures of >73-84° F, reduced biodiversity.
	Decreased Temperature	Cessation of spawning, increased egg mortalities, susceptibility to disease.
	Dissolved Oxygen	Reduced survival of eggs and alevins, smaller size at emergence, increased physiological stress, reduced growth.
	Gas Supersaturation	Increased mortality of migrating salmon.
	Nutrient Loading	Increased primary and secondary production, possible oxygen depletion during extreme algal blooms, lower survival and productivity, increased eutrophication rate of standing waters, certain nutrients (e.g., nonionized ammonia, some metals) possibly toxic to eggs and juveniles at high concentrations.
Sediment/Substrate	Surface Erosion	Reduced survival of eggs and alevins, reduced primary and secondary productivity, interference with feedings, behavioral avoidance and breakdown of social organization, pool filling.
	Mass Failures and Landslides	Reduced survival of eggs and alevins, reduced primary and secondary productivity, behavioral avoidance, formation of upstream migration barriers, pool filling, addition of new large structure to channels.
Habitat Access	Physical Barriers	Loss of spawning habitat for adults; inability of juveniles to reach overwintering sites or thermal refugia, loss of summer rearing habitat, increased vulnerability to predation.
Channel Structure	Floodplains	Loss of overwintering habitat, loss of refuge from high flows, loss of inputs of organic matter and large wood, loss of sediment removal capacity.
	Side-Channels	Loss of overwintering habitat, loss of refuge from high flows.
Channel Structure (contd.):	Pools and Riffles	Shift in the balance of species, loss of deep water cover and adult holding areas, reduced rearing sites for yearling and older juveniles.
	Large Wood	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates, formation of new migration barriers, reduced capacity to trap salmon carcasses.
	Substrate	Reduced survival of eggs and alevins, loss of inter-gravel spaces used for refuge by fry, reduced macroinvertebrate production, reduced biodiversity.
	Hyporheic Zone (biologically active groundwater area)	Reduced exchange of nutrients between surface and subsurface waters and between aquatic and terrestrial ecosystems, reduced potential for recolonizing disturbed substrates.

Table B-2. Effects of Ecosystem Alterations on Salmonids and their Ecosystems (cont.)

Ecosystem Feature	Altered Component	Effects on Salmonid Fishes and Their Ecosystems
Hydrology	Discharge	Altered timing of discharge related life cycle cue (e.g., migrations), changes in availability of food organisms related to timing of emergence and recovery after disturbance, altered transport of sediment and fine particulate organic matter, reduced prey diversity.
	Peak Flows	Scour-related mortality of eggs and alevins, reduced primary and secondary productivity, long-term depletion of large wood and organic matter, involuntary downstream movement of juveniles during high water flows, accelerated erosion of streambanks.
	Low Flows	Crowding and increased competition for foraging sites, reduced primary and secondary productivity, increased vulnerability to predation, increased fine sediment deposition.
	Rapid Fluctuations	Altered timing of discharge-related life cycle events (e.g., migrations), stranding, redd dewatering, intermittent connections between mainstream and floodplain rearing habitats, reduced primary and secondary productivity.
Riparian Forest	Production of Large Wood	Loss of cover from predators and high flows, reduced sediment and organic matter storage, reduced pool-forming structures, reduced organic substrate for macroinvertebrates.
	Production of Food Organisms and Organic Matter	Reduced production and abundance of certain macroinvertebrates, reduced surface-drifting food items, reduced growth in some seasons.
	Shading	Increased water temperature, increased primary and secondary production, reduced overhead cover, altered foraging efficiency.
	Vegetative Rooting Systems and Streambank Integrity	Loss of cover along channel margins, decreased channel stability, increased streambank erosion, increased landslides.
	Nutrient Modification	Altered nutrient inputs from terrestrial ecosystems, altered primary and secondary production.
Exogenous Material	Chemicals	Reduced survival of eggs and alevins, toxicity to juveniles and adults, increased physiological stress, altered primary and secondary production, reduced biodiversity.
	Exotic Organisms/Plants	Increased mortality through predation, increased interspecific competition, introduction of diseases, habitat structure alteration.

Source: Pacific States Marine Fisheries Commission *Description and Identification of Essential Fish Habitat, Adverse Impacts and Recommended Conservation Measures for Salmon* http://www.psmfc.org/efh/Jan99-sec3-2.htm (excerpted from Gregory and Bisson (1997) with minor adaptions).

APPENDIX C: WASHINGTON STATE WETLAND RATING FORM

Wetlands Rating Field Data Form

Background Information:

Name of Rater: ____________________ Affiliation: ____________________ Date: ____________

Name of wetland (if known): ____

Government Jurisdiction of wetland: ____

Location: 1/4 Section: ______ of 1/4 S: ______ Section: ______ Township: ______ Range: ______

Sources of Information: (Check all sources that apply)

Site visit: ____ USGS Topo Map: ____ NWI map: ____ Aerial Photo: ____ Soils survey: ____

Other: ___ Describe: ____

When The Field Data form is complete enter Category here: [ ]

Q.1. High Quality Natural Wetland	Circle Answers
Answer this question if you have adequate information or experience to do so. If not find someone with the expertise to answer the questions. Then, if the answer to questions 1a, 1b and 1c are all NO, contact the Natural Heritage program of DNR.	
1a. Human caused disturbances.	
Is there significant evidence of human-caused changes to topography or hydrology of the wetland as indicated by any of the following conditions? Consider only changes that may have taken place in the last 5 decades. The impacts of changes done earlier have probably been stabilized and the wetland ecosystem will be close to reaching some new equilibrium that may represent a high quality wetland.	
1a1. Upstream watershed > 12% impervious.	Yes: go to Q.2
1a2. Wetland is ditched and water flow is not obstructed.	Yes: go to Q.2
1a3. Wetland has been graded, filled, logged.	Yes: go to Q.2
1a4. Water in wetland is controlled by dikes, weirs, etc.	Yes: go to Q.2
1a5. Wetland is grazed.	Yes: go to Q.2
1a6. Other indicators of disturbance (list below)	Yes: go to Q.2
____	No: go to 1b.
____	
____	
____	

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1b Are there populations of non-native plants which are currently present, cover more than 10% of the wetland, and appear to be invading native populations? Briefly describe any non-native plant populations and Information source(s):__________	YES: go to Q.2 No: go to 1c.
1c. Is there evidence of human-caused disturbances which have visibly degraded water quality. Evidence of the degradation of water quality include: direct (untreated) runoff from roads or parking lots; presence, or historic evidence, of waste dumps; oily sheens; the smell of organic chemicals; or lifestock use. Briefly describe:__________	YES: go to Q.2 NO: Possible Cat. I contact DNR
Q.2. Irreplaceable Ecological Functions: Does the wetland: ⊖ have at least 1/4 acre of organic soils deeper than 16 inches and the wetland is relatively undisturbed; OR [IIf the answer is NO because the wetland is disturbed briefly describe: Indicators of disturbance may include: - Wetland has been graded, filled, logged; - Organic soils on the surface are dried-out for more than half of the year; - Wetland receives direct stormwater runoff from urban or agricultural areas.]; OR	(NO to all: go to Q.3) YES go to 2a
⊖ have a forested class greater than 1 acre; OR	YES: Go to 2b
⊖ have characteristics of an estuarine system; OR	YES: Go to 2c
⊖ have eel grass, floating or non-floating kelp beds?	YES: Go to 2d
2a. Bogs and Fens Are any of the three following conditions met for the area of organic soil?	
2a.1. Are Sphagnum mosses a common ground cover (>30%) and the cover of invasive species (see Table 3) is less than 10%?	
Is the area of sphagnum mosses and deep organic soils > 1/2 acre?	YES: Category I
Is the area of sphagnum mosses and deep organic soils 1/4-1/2 acre?	YES: Category II
	NO: Go to 2a.3
2a.2. Is there an area of organic soil which has an emergent class with at least one species from Table 2, and cover of invasive species is < 10% (see Table 3)?	
Is the area of herbaceous plants and deep organic soils > 1/2 acre?	YES: Category I
Is the area of herbaceous plants and deep organic soils 1/4-1/2 acre?	YES: Category II
	NO: Go to 2a.3

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2a.3. Is the vegetation a mixture of only herbaceous plants and Sphagnum mosses with no scrub/shrub or forested classes? Is the area of herbaceous plants, Sphagnum, and deep organic soils > 1/2 acre? Is the area of herbaceous plants, Sphagnum, and deep organic soils 1/4-1/2 acre?	YES: Category I YES: Category II NO: Go to Q.3.
Q.2b. Mature forested wetland. 2b.1. Does 50% of the cover of upper forest canopy consist of evergreen trees older than 80 years or deciduous trees older than 50 years? *Note:* The size of trees is often not a measure of age, and size cannot be used as a surrogate for age (see guidance).	YES: Category I NO: Go to 2b.2
2b.2. Does 50% of the cover of forest canopy consist of evergreen trees older than 50 years, AND is the structural diversity of the forest high as characterized by an additional layer of trees 20'-49' tall, shrubs 6' - 20', tall, and a herbaceous groundcover?	YES: Go to 2b.3 NO: Go to Q.3
2b.3. Does < 25% of the areal cover in the herbaceous/groundcover or the shrub layer consist of invasive/exotic plant species from the list on p. 19?	YES: Category I NO: Go to Q.3
Q.2c. Estuarine wetlands. 2c1. Is the wetland listed as National Wildlife Refuge, National Park, National Estuary Reserve, Natural Area Preserve, State Park, or Educational, Environmental or Scientific Reserves designated under WAC 332-30-151?	YES: Category I NO: Go to 2c.2
2c.2. Is the wetland > 5 acres; . . . . *Note:* If an area contains patches of salt tolerant vegetation that are 1) less than 600 feet apart and that are separated by mudflats that go dry on a Mean Low Tide, or 2) separated by tidal channels that are less than 100 feet wide; all the vegetated areas are to be considered together in calculating the wetland area.	YES: Category I
or is the wetland 1-5 acres;	YES: Go to 2c.3
or is the wetland < 1 acre?.	YES: Go to 2c.4

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2c.3. Does the wetland meet at least 3 of the following 4 criteria: . . . . - minimum existing evidence of human related disturbance such as diking, ditching, filling, cultivation, grazing or the presence of non-native plant species (see guidance for definition); - surface water connection with tidal saltwater or tidal freshwater; - at least 75% of the wetland has a 100' buffer of ungrazed pasture, open water, shrub or forest; - has at least 3 of the following features: low marsh; high marsh; tidal channels; lagoon(s);woody debris; or contiguous freshwater wetland.	YES: Category I NO: Category II
2c.4. Does the wetland meet all of the four criteria under 2c3. (above)?. .	YES: Category II NO: Category III
Q.2d. Eel Grass and Kelp Beds. 2d.1. Are eel grass beds present?.	YES: Category I NO: go to 2d.2
2d.2. Are there floating or non-floating kelp bed(s) present with greater than 50% macro algal cover in the month of August or September?	YES: Category I NO: Category II
Q.3. Category IV wetlands. 3a. Is the wetland: less than 1 acre <u>and</u>, hydrologically isolated <u>and</u>, comprised of one vegetated class that is dominated (> 80% areal cover) by one species from Table 3 (page 19) or Table 4 (page 20)	YES: Category IV NO: go to 3b
3b. Is the wetland: less than two acres and, hydrologically isolated, with one vegetated class, and > 90% of areal cover is any combination of species from Table 3 (page 19)	YES: Category IV NO: go to 3c
3c. Is the wetland excavated from upland <u>and</u> a pond smaller than 1 acre without a surface water connection to streams, lakes, rivers, or other wetland, and has < 0.1 acre of vegetation.	YES: Category IV NO: go to Q.4

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Q.4. Significant habitat value.	
Answer all questions and enter data requested. 4a. Total wetland area Estimate area, select from choices in the near-right column, and score in the far column: Enter acreage of wetland here:_____acres, and source:___________	**Circle scores that qualify** acres — points > 200 — 6 40- 200 — 5 10 - 40 — 4 5 - 10 — 3 1 - 5 — 2 0.1 - 1 — 1 < 0.1 — 0
4b. Wetland classes: Circle the wetland classes below that qualify: Open Water: if the area of open water is > 1/4 acre Aquatic Beds: if the area of aquatic beds > 1/4 acre, Emergent: if the area of emergent class is > 1/4 acre, Scrub-Shrub: if the area of scrub-shrub class is > 1/4 acre, Forested: if area of forested class is > 1/4 acre, Add the number of wetland classes, above, that qualify, and then score according to the columns at right. e.g. If there are 4 classes (aquatic beds, open water, emergent & scrub- shrub), you would circle 8 points in the far right column.	# of classes — Points 1.......0 2.......3 3.......6 4.......8 5.......10

4c. Plant species diversity.	Class	# species in class	Points
For each wetland class (at right) that qualifies in 4b above, count the number of different plant species you can find that cover more than 5% of the ground. You do not have to name them.	Aquatic Bed	1	0
		2	1
		3	2
Score in column at far right:		> 3	3
e.g. If a wetland has an aquatic bed class with 3 species, an emergent class with 4 species and a scrub-shrub class with 2 species you would circle 2, 2, and 1 in the far column.	Emergent	1	0
		2-3	1
		4-5	2
		> 5	3
Note: Any plant species with a cover of > 5% qualifies for points within a class, even those that are not of that class.	Scrub-Shrub	1	0
		2	1
		3-4	2
		> 4	3
	Forested	1	0
		2	1
		3-4	2
		> 4	3

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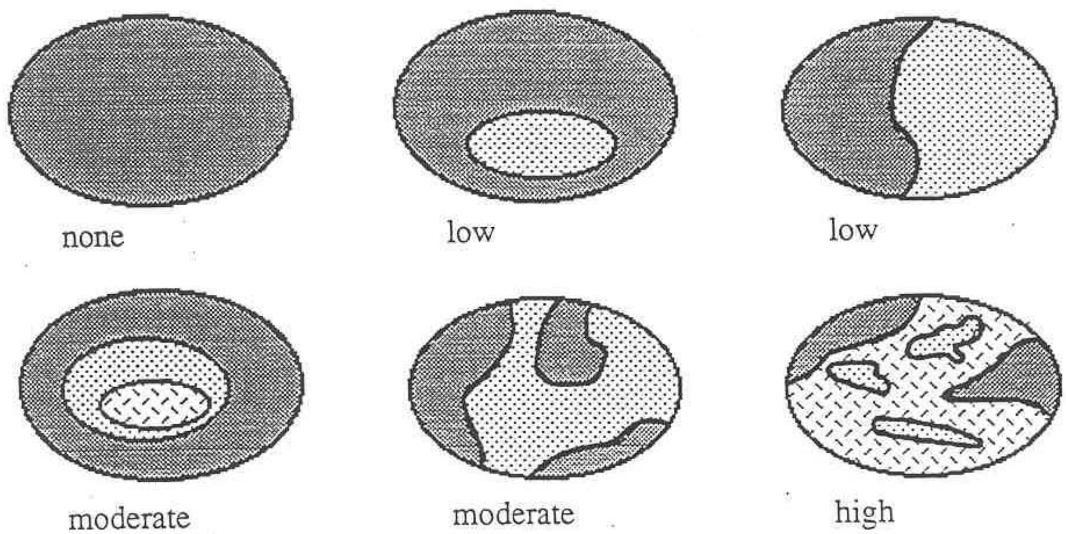
4d. Structural diversity. If the wetland has a forested class, add 1 point if each of the following classes is present within the forested class and is <u>larger than 1/4 acre</u>: -trees > 50' tall . . . . -trees 20'- 49' tall . . . . -shrubs. . . . . -herbaceous ground cover. . . . . Also add 1 point if there is any "open water" or "aquatic bed" class immediately next to the forested area (ie. there is no scrub/shrub or emergent vegetation between them).	YES - 1 YES - 1 YES - 1 YES - 1 YES - 1
4e. Decide from the diagrams below whether interspersion between wetland classes is high, moderate, low or none? If you think the amount of interspersion falls in between the diagrams score accordingly (i.e. a moderately high amount of insterspersion would score a 4, while a moderately low amount would score a 2)	High - 5 Moderate - 3 Low - 1 None - 0



4f. Habitat features. Answer questions below, circle features that apply, and score to right:	
Is there evidence that the open or standing water was caused by beavers	YES = 2
Is a heron rookery located within 300'?	YES = 1
Are raptor nest/s located within 300'?	YES = 1
Are there at least 3 standing dead trees (snags) per acre greater than 10" in diameter at "breast height" (DBH)?.	YES = 1
Are there at least 3 downed logs per acre with a diameter > 6" for at least 10' in length?	YES = 1
Are there areas (vegetated or unvegetated) within the wetland that are ponded for at least 4 months out of the year, and the wetland has not qualified as having an open water class in Question 4b. ?	YES = 2

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4g. Connection to streams. (Score one answer only.) 4g.1. Does the wetland provide habitat for fish at any time of the year AND does it have a perennial surface water connection to a fish bearing stream.	YES = 6
4g.2 Does the wetland provide fish habitat seasonally AND does it have a seasonal surface water connection to a fish bearing stream.	YES = 4
4g.3 Does the wetland function to export organic matter through a surface water connection at all times of the year to a perennial stream.	YES = 4
4g.4 Does the wetland function to export organic matter through a surface water connection to a stream on a seasonal basis?	YES = 2
4h. Buffers. Score the existing buffers on a scale of 1-5 based on the following four descriptions. If the condition of the buffers do not exactly match the description, score either a point higher or lower depending on whether the buffers are less or more degraded.	
Forest, scrub, native grassland or open water buffers are present for more than 100' around 95% of the circumference.	Score = 5
Forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/2 of the wetland circumference, or a forest, scrub, grasslands, or open water buffers for more than 50' around 95% of the circumference.	Score = 3
Forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/4 of the wetland circumference, or a forest, scrub, native grassland, or open water buffers wider than 50' for more than 1/2 of the wetland circumference.	Score = 2
No roads, buildings or paved areas within 100' of the wetland for more than 95% of the wetland circumference.	Score = 2
No roads, buildings or paved areas within 25' of the wetland for more than 95% of the circumference, or No roads buildings or paved areas within 50' of the wetland for more than 1/2 of the wetland circumference.	Score = 1
Paved areas, industrial areas or residential construction (with less than 50' between houses) are less than 25 feet from the wetland for more than 95% of the circumference of the wetland.	Score = 0

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4i. Connection to other habitat areas: Select the description which best matches the site being evaluated.	
-Is the wetland connected to, or part of, a riparian corridor at least 100' wide connecting two or more wetlands; or, is there an upland connection present >100' wide with good forest or shrub cover (>25% cover) connecting it with a Significant Habitat Area?	YES = 5
- Is the wetland connected to any other Habitat Area with either 1) a forested/shrub corridor < 100' wide, or 2) a a corridor that is > 100'wide, but has a low vegetative cover less than 6 feet in height?	YES = 3
-Is the wetland connected to, or a part of, a riparian corridor between 50 - 100' wide with scrub/shrub or forest cover connection to other wetlands?	YES = 3
- Is the wetland connected to any other Habitat Area with narrow corridor (<100') of low vegetation (< 6' in height)?	YES = 1
- Is the wetland and its buffer (if the buffer is less than 50' wide) completely isolated by development (urban, residential with a density greater than 2/acre, or industrial)?	YES = 0
Now add the scores circled (for Q.5a - Q.5i above) to get a total. **Is the Total greater than or equal to 22 points?**	**YES = Category II** **NO = Category III**

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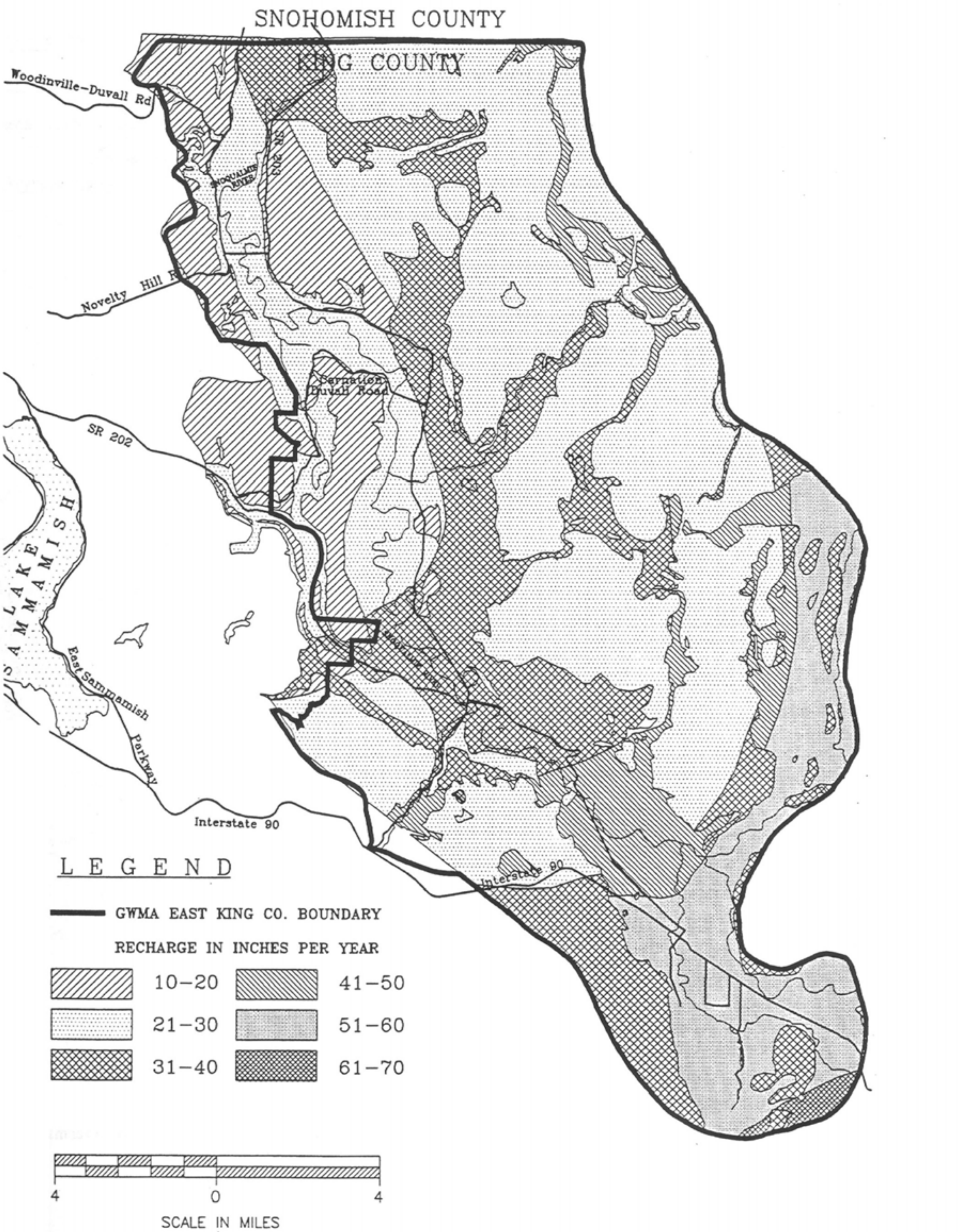
APPENDIX D: WILDLIFE HABITAT CONSERVATION AREAS

INSERT TABLE D-1 [SEPARATE PDF FILE]

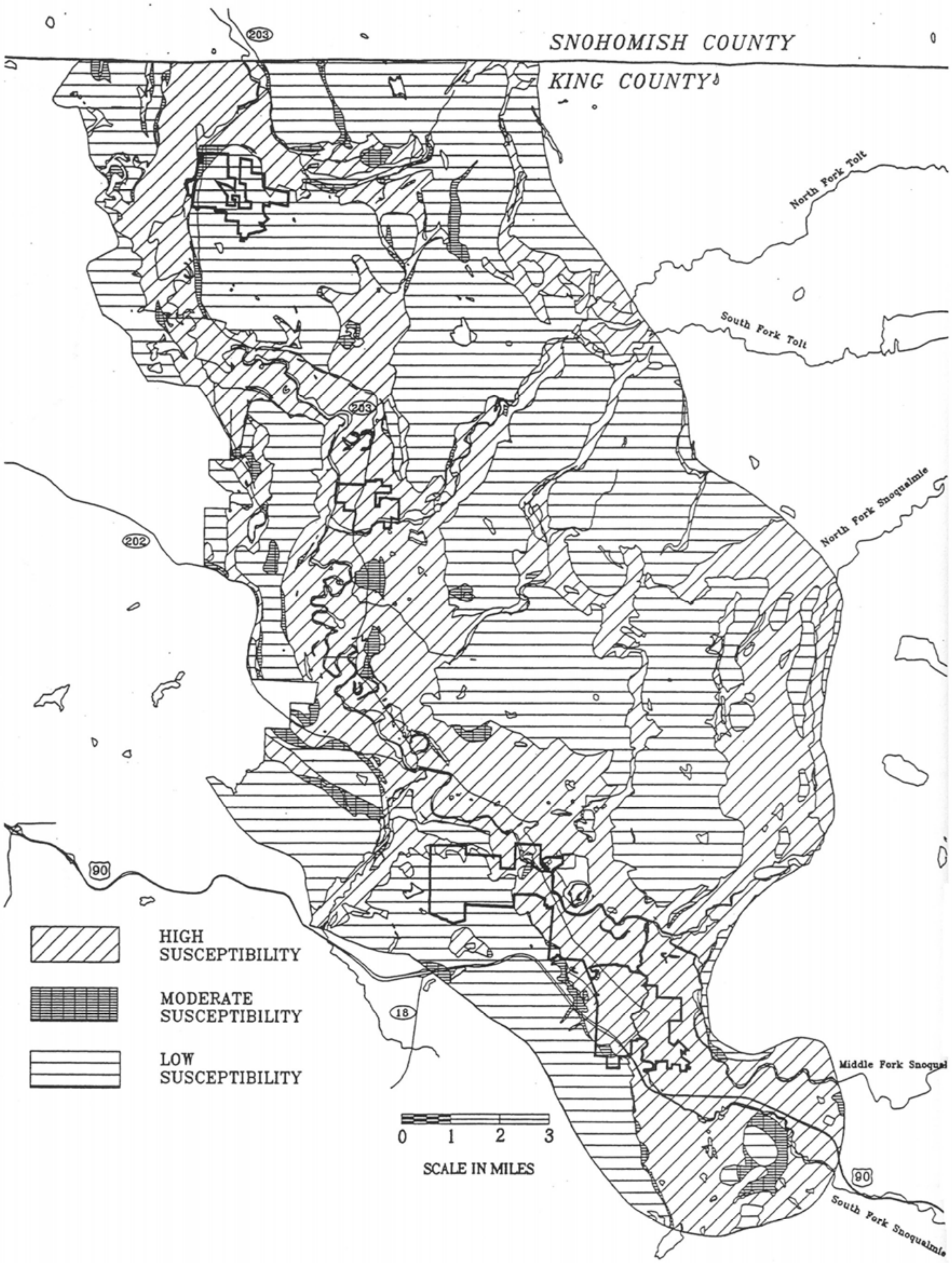
APPENDIX E: AQUIFER RECHARGE AREAS



File name: 23029_recharge.ai
Original graphic by: ACT
Edits by:
Date: 06/30/03

Source: East King County Ground Water Management Plan, 1998.

FIGURE E-1.
QUANTITY AND AERIAL DISTRIBUTION OF RECHARGE
SNOQUALMIE WATERSHED
NTAA IMPLEMENTATION PROJECT
KING COUNTY, WASHINGTON



ADOLFSON	NORTH File name: 23029_contamination.ai Original graphic by: ACT Edits by: Date: 06/30/03 Source: East King County Ground Water Management Plan, 1998.	**FIGURE E-2.** AREA SUSCEPTIBLE TO GROUND WATER CONTAMINATION SNOQUALMIE WATERSHED NTAA IMPLEMENTATION PROJECT KING COUNTY, WASHINGTON

APPENDIX F: LITERATURE FINDINGS ON BUFFERS

Table F-1. Riparian Buffer Functions and Appropriate Widths Identified by May (2000)

Function	Range of Effective Buffer Widths	Minimum Recommended	Notes On Function
Sediment Removal/Erosion Control	26 - 600 ft (8 – 183 m)	98 ft (30 m)	For 80% sediment removal
Pollutant Removal	13 - 860 ft (4 - 262 m)	98 ft (30 m)	For 80% nutrient removal
Large Woody Debris	33-328 ft (10 – 100 m)	262 ft (80 m)	1 SPTH based on long-term natural levels
Water Temperature	36 - 141 ft (11 – 43 m)	98 ft (30 m)	Based on adequate shade
Wildlife Habitat	33 - 656 ft (10 – 200 m)	328 ft (100 m)	Coverage not inclusive
Microclimate[2]	148 - 656 ft (45 – 200 m)	328 ft (100 m)	Optimum long-term support

Table F-2. Riparian Functions and Appropriate Widths Identified from Knutson and Naef (1997)

Function	Range Of Effective Buffer Widths (Ft)
Water Temperature	35 - 151
Pollutant Removal	13 - 600
Large Woody Debris	100 - 200
Erosion Control	100 - 125
Wildlife Habitat	25 - 984
Sediment filtration	26 - 300
Microclimate	200 - 525

Table F-3. Riparian Functions and Appropriate Widths Identified from FEMAT (1993)

Function	Number of SPTH	Equivalent (Ft) Based on SPTH of 200 Ft.
Shade	0.75	150
Microclimate	up to 3	up to 600
Large Woody Debris	1.0	200
Organic Litter	0.5	100
Sediment Control	1.0	200
Bank Stabilization	0.5	100
Wildlife Habitat	-----	98 – 600

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Table F-4. Riparian Habitat Area Buffer Recommendations: Washington Department of Fish and Wildlife

Stream Type	Recommended Riparian Width
Type 1 & 2, shorelines of statewide significance	250 feet
Type 3 or other perennial or fish bearing streams, 5-20 feet wide	200 feet
Type 3 or other perennial or fish bearing streams, less than 5 feet wide	150 feet
Type 4 and 5 (low mass wasting potential)	150 feet
Type 4 and 5 (high mass wasting potential)	225 feet

Source: OCD, 2002 (For definitions of the stream types see the Washington Administrative Code Sections 222-16-030 and 031.)

Table F –5. Draft OCD Model Critical Areas Ordinance Buffer Recommendations[1]

Wetland Classification (Highest to lowest)	**Type of Land Use**	**Buffer Recommendation (Feet)**
Class I	High Intensity[a]	300 feet
	Moderate Intensity[b]	250 feet
	Low Intensity[c]	200 feet
Class II	High Intensity[a]	200 feet
	Moderate Intensity[b]	150 feet
	Low Intensity[c]	100 feet
Class III	High Intensity[a]	100 feet
	Moderate Intensity[b]	75 feet
	Low Intensity[c]	50 feet
Class IV	High Intensity[a]	50 feet
	Moderate Intensity[b]	35 feet
	Low Intensity[c]	25 feet

[a] High intensity includes medium and high density residential (>1 home per 5 acres), multifamily residential, and commercial and industrial land uses.

[b] Moderate intensity includes, but not limited to, low density residential ($\leq$ 1 home per 5 acres), active recreation, and agricultural land uses.

[c] Low intensity includes, but not limited to, passive recreation, open space, or forest management land uses

[1] Note: As of July 2003, Model Code recommendations were undergoing revision, and revised buffer recommendations were not available.