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1. INTRODUCTION

In 1995, the Washington state legislature amended the Growth Management Act (GMA) to require that local governments include Best Available Science (BAS) in designating and protecting critical areas (RCW § 36.70A.172(1)). In 2000, the state's Office of Community Trade and Economic Development (CTED) adopted procedural criteria to implement these changes to the GMA and provided guidance for identifying BAS. The rule makers concluded that identifying and describing functions and values and estimating the types and likely magnitudes of adverse impacts were scientific activities. Thus, RCW 36.70A.172(1) and the implementing regulations require the substantive inclusion of BAS in developing critical area policies and regulations.

This document summarizes BAS for Whatcom County critical areas and provides recommendations for updating the County's critical areas ordinance (Chapter 16.16 of the Whatcom County Code [WCC]).

As directed by RCW 36.70A.050, this document addresses the following critical areas:

- Geologically hazardous areas;
- Frequently flooded areas;
- Critical aquifer recharge areas (CARAs);
- Wetlands (both freshwater and estuarine); and
- Fish and wildlife habitat conservation areas (HCAs).

In addition, this document addresses the habitat requirements and management needs of anadromous fish, and discusses habitat mitigation banking. Maps of the County's critical areas are provided in Appendix A.

1.1 REPORT BACKGROUND AND PURPOSE

The information contained within this document is a summary of scientific studies related to designating and protecting critical areas, including habitat for anadromous fish species, as defined by the GMA. The information provides a basis for recommended changes and additions to the Whatcom County critical areas ordinance¹. It is not intended to provide an exhaustive summary of all science available for all critical areas. The information reviewed is pertinent to Whatcom County, applicable to the types of critical areas present, and is believed to be the best available scientific information. BAS² means current scientific information derived from research, monitoring, inventory, survey, modeling, assessment, synthesis, and expert opinion that is:

- Logical and reasonable
- Based on quantitative analysis
- Peer reviewed
- Used in the appropriate context
- Based on accepted methods
- Well referenced.

¹ In some instances, the BAS review supports existing provisions of the County code and no changes are recommended.

² Washington Administrative Code (WAC) 365-195-900 through 925

Each chapter of the report is devoted to a specific critical area as designated in WCC 16.16. In many cases, the information presented for one critical area overlaps, complements, or is applicable to another type of critical area because these areas function as integrated components of the ecosystem. The chapters summarize the information and issues that the County is required to consider within its process for updating policies and regulations to protect the functions and values of critical areas (RCW §36.70A.172.1).

In some instances the GMA and its regulations constrain the choice of science that can be used to designate or protect a particular resource (e.g., local governments are required to use the definition of wetlands [RCW 36.70A.030.2]). In other cases, there may a range of options that are supported by science (e.g., wetland buffer widths necessary to protect functions).

The State legislature and the Growth Management Hearings Boards have defined critical area “protection” to mean preservation of critical area “structure, function, and value.” Local governments are not required to protect all functions and values of all critical areas, but are required to achieve “no net loss” of critical area functions and values across the jurisdictional landscape. Local governments are also required to develop regulations that reduce hazards associated with some types of critical areas including geologically hazardous areas and frequently flooded areas. The standard of protection is to prevent adverse impacts to critical areas, to mitigate adverse impacts, and/or reduce risks associated with hazard areas.

This report was prepared by qualified scientists acting as consultants for County staff. A Technical Advisory Committee (TAC) composed of experts from federal, state, tribal and local agencies (Appendix B) reviewed all of information presented here in draft form and provided comments. In many cases TAC members provided scientific studies and data to be included in the review. A second committee composed of local citizens representing various stakeholder groups (Citizens’ Advisory Committee or CAC) also reviewed the draft documents and provided comments (see Appendix B). These committees conducted their reviews during a series of workshops in the latter part of 2004. This revised draft was prepared in response to committee members’ input. The recommendations described will be submitted to the County Planning Commission and County Council following public review in early 2005.

1.2 RELATIONSHIP TO OTHER PLANNING EFFORTS

The recommendations derived from the BAS review will be used as the basis for revising the County’s development regulations and Comprehensive Plan elements that pertain to critical areas. The County is required to integrate critical areas protection into zoning regulations, clearing and grading provisions, stormwater management requirements, subdivisions regulations and other applicable plans and policies. The County is also required to integrate the CAO provisions with its Shoreline Master Program (SMP), which will be updated in 2005. To comply with House Bill 1933, SMP regulations pertaining to critical areas must be as protective or more protective of functions and values as the CAO regulations themselves.

1.3 COUNTY SETTING

Whatcom County encompasses 2,152 square miles stretching from the Georgia Strait to the Cascade Mountains in northwestern Washington. The County, which includes the cities of Bellingham, Blaine, Everson, Ferndale, Lynden, Nooksack, and Sumas, is bounded by Canada on the north, Okanogan County on the east, Skagit County on the south, and the Strait of Georgia and Bellingham Bay on the west. Federal lands of the Mount Baker National Forest and North Cascades National Park make up the eastern two-thirds of the County. Most of the County’s nearly 167,000 residents live in the western third of the County (including some 70,000 residents in the City of Bellingham). Reservation and trust lands

belonging to the Lummi Indian Nation and the Nooksack Tribe are also located within the County borders.

According to the County's Comprehensive Plan, approximately 74 percent of the County is used for forestry or agriculture. Agricultural uses are concentrated on the lowlands in the western half of the County; and forestry dominates the upland areas to the east, including the federal lands. Other land uses include residential development, mining, and commercial and industrial development.

Tectonic activity and glaciation have shaped the landforms that make up Whatcom County. During the ice ages, glacial advances including the Salmon Springs the Vashon glaciations eroded the underlying bedrock, creating steep mountainsides and depositing glacial sediments such as lake deposits, till, and outwash. The Sumas Glacier, which reached in maximum extent near the City of Sumas, deposited coarse outwash sediments along a gradient between Sumas and Ferndale. The Nooksack River cut through the outwash and carried fine sediments out to Lummi Bay. Organic materials such as peat were deposited in areas such as near Sumas, Blaine, and along portions of the South Fork Nooksack River. Within the County, there are 16 major lakes (including Lakes Whatcom, Samish, Terrell, Cain, Reed, and Wiser), dozens of smaller lakes, 3,012 miles of rivers and streams and their estuaries, over 37,000 acres of wetlands, aquifers containing an undetermined amount of groundwater, and 134 miles of marine shoreline. These waters provide for domestic consumption, stock watering, industrial and commercial use, agriculture, hydroelectric power production, mining, maintenance, fish and wildlife habitat, recreation, and aesthetic appreciation.

The majority of Whatcom County (about 88 percent or 1,239 square miles) is within Water Resource Inventory Area (WRIA) 1 (Nooksack). The WRIA 1 drainage area includes the Nooksack River, five coastal subbasins, and two Fraser River subbasins. Approximately 800 square miles in the eastern part of the County drain south and east to the Upper Skagit (WRIA 4) and Methow (WRIA 48) watersheds. Part of southwestern Whatcom County drains south to the Lower Skagit/Samish watershed (WRIA 3).

Whatcom County is located within Pacific Lowland Mixed Forest Province and the plant communities and habitats reflect relatively mild climate of this ecoregion. The wetlands, fields, streams, riparian areas, and uplands of Whatcom County support many species of fish and wildlife including several federally listed species (e.g., Chinook salmon [*Oncorhynchus tshawytscha*], bull trout [*Salvelinus confluentus*], and bald eagle [*Haliaeetus leucocephalus*]), several species of concern (e.g., pileated woodpecker and peregrine falcon [*Falco peregrinus anatum*]) and numerous state priority species (e.g., trumpeter swan [*Cygnus buccinator*], great blue heron [*Ardea herodias*], and geoduck [*Panopea abrupta*]). Coastal and nearshore habitats support forage fish species such as Pacific sand lance (*Ammodytes hexapterus*), surf smelt (*Hypomesus pretiosus*), and Pacific herring (*Clupea harengus*), shellfish beds for commercial and recreational use, and marine mammals (e.g., harbor seals and California sea lions). Native fish including all five species of Pacific salmon (coho [*Oncorhynchus kisutch*], cutthroat trout [*Oncorhynchus clarkii*], Chinook, chum [*Oncorhynchus keta*], and steelhead [*Oncorhynchus mykiss*]) occur in lakes, rivers, and streams along with bull trout and Dolly Varden. Ducks such as bufflehead and goldeneye winter in the County, and other bird species such as scoters, snow geese, trumpeter swans, canvasbacks, cormorants, grebes, loons, and other migrating waterfowl pass through every spring and fall as they travel between their breeding grounds in Alaska and Canada and their wintering grounds in California and Mexico.

2. GEOLOGICALLY HAZARDOUS AREAS

This chapter describes geologically hazardous areas in Whatcom County, and summarizes the scientific literature concerning various types of geologic hazards and how they can affect or be affected by land use and other human activities. The chapter also presents an overview of the management and protection tools for these areas. The purpose of this chapter is to establish a basis for recommending updates to the geologically hazardous areas provisions of Article III of the WCC Chapter 16.16.300.

Whatcom County is a geologically active area and some areas within the County are considered to be geologically hazardous. According to WAC 365-190-080 (4)(a), geologically hazardous areas include areas susceptible to erosion, landslides, earthquakes, volcanic eruptions, or other geological events. These areas pose a threat to the health and safety of citizens when incompatible commercial, residential, or industrial development is sited in areas of significant hazard. Some geological hazards can be reduced or mitigated by engineering, design, or modified construction or mining practices so that risks to health and safety are acceptable. The following explanation of geologically hazardous areas is excerpted from the WAC (Chapter 365-190-080 [4]):

(a) Areas that are susceptible to one or more of the following types of hazards shall be classified as a geologically hazardous area:

(i) Erosion hazard;

(ii) Landslide hazard;

(iii) Seismic hazard; or

(iv) Areas subject to other geological events such as coal mine hazards and volcanic hazards including: Mass wasting, debris flows, rockfalls, and differential settlement.

(b) Counties and cities should classify geologically hazardous area as either:

(i) Known or suspected risk;

(ii) No risk;

(iii) Risk unknown - data are not available to determine the presence or absence of a geological hazard.

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

(d) Landslide hazard areas shall include areas potentially subject to landslides based on a combination of geologic, topographic, and hydrologic factors. They include any areas susceptible because of any combination of bedrock, soil, slope (gradient), slope aspect, structure, hydrology, or other factors. Example of these may include, but are not limited to the following:

(i) Areas of historic failures, such as:

(A) Those areas delineated by the United States Department of Agriculture Soil Conservation Service as having a "severe" limitation for building site development;

(B) Those areas mapped as class u (unstable), uos (unstable old slides), and urs (unstable recent slides) in the department of ecology coastal zone atlas; or

(C) Areas designated as quaternary slumps, earthflows, mudflows, lahars, or landslides on maps published as the United States Geological Survey or department of natural resources division of geology and earth resources.

(ii) *Areas with all three of the following characteristics:*

(A) *Slopes steeper than fifteen percent; and (B) Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock; and (C) Springs or ground water seepage;*

(iii) *Areas that have shown movement during the Holocene epoch (from ten thousand years ago to the present) or which are underlain or covered by mass wastage debris of that epoch;*

(iv) *Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials;*

(v) *Slopes having gradients steeper than eighty percent subject to rockfall during seismic shaking;*

(vi) *Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action;*

(vii) *Areas that show evidence of, or are at risk from snow avalanches;*

(viii) *Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding;*

(ix) *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.*

(e) *Seismic hazard areas shall include areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting. One indicator of potential for future earthquake damage is a record of earthquake damage in the past. Ground shaking is the primary cause of earthquake damage in Washington. The strength of ground shaking is primarily affected by:*

(i) *The magnitude of an earthquake;*

(ii) *The distance from the source of an earthquake;*

(iii) *The type of thickness of geologic materials at the surface; and*

(iv) *The type of subsurface geologic structure.*

Settlement and soil liquefaction conditions occur in areas underlain by cohesionless soils of low density, typically in association with a shallow ground water table.

(f) *Other geological events:*

(i) *Volcanic hazard areas shall include areas subject to pyroclastic flows, lava flows, debris avalanche, inundation by debris flows, mudflows, or related flooding resulting from volcanic activity.*

(ii) *Mine hazard areas are those areas underlain by, adjacent to, or affected by mine workings such as adits, gangways, tunnels, drifts, or air shafts. Factors which should be considered include: Proximity to development, depth from ground surface to the mine working, and geologic material.*

Delineation and classification of these areas by estimated risk ensures that residential, commercial, municipal, and industrial developments are sited and constructed to avoid or reduce risk to the health and safety of citizens and to avoid or reduce risk to public resources.

2.1 EXISTING WHATCOM COUNTY POLICIES AND CODE PROVISIONS

County policies concerning geologically hazardous areas are spelled out in the Comprehensive Plan – Natural Hazards Section. The Plan highlights the responsibility local governments have for balancing private property rights and the need to provide a safe and healthy environment. The Plan also establishes specific policies aimed at:

- Minimizing public investments for infrastructure in known hazard areas,
- Using best available science to research and investigate hazards and educate the public,
- Informing the public of the potential effects of geological hazards,
- Establishing decision-making criteria for development in hazard areas based on established levels of risk,
- Uses that do not require human habitation when adverse impacts can be minimized or mitigated, and
- Prohibiting critical public facilities in known natural hazard areas unless the public benefits outweigh the risk.

Whatcom County manages and protects geologically hazardous areas primarily by implementing the standards contained in WCC 16.16.300. The stated purpose of the regulations is to minimize hazards to the public and to reduce the risk of property damage from development activities on or adjacent to geologically hazardous areas. The regulations also regulate land use so as to avoid the need for construction of flood control devices on alluvial fans and allow for natural hydrologic changes.

Specific designations for landslide hazards areas, seismic hazard areas, mine hazard areas, and alluvial fan hazards areas are contained in WCC sections 16.16.310 through 16.16.340. The existing regulations do not specifically address tsunamis, seiches, volcanic hazards, channel migration, or erosion hazards, although volcanic hazards are mentioned in the Comprehensive Plan.

The regulatory requirements of the existing code (WCC16.16.350) are noted below:

- A. No critical facilities shall be constructed or located in geologically hazard areas without fully mitigating the hazard.*
- B. Projects shall be assessed through the Critical Areas Assessment Process.*
- C. Projects shall be engineered and/or constructed to fully mitigate the hazard, and protect the building and occupants from the hazard.*
- D. Land divisions may be clustered where permitted by zoning and as appropriate to reduce disturbance to the area.*
- E. Projects in landslide hazard areas must cause no increase in surface water discharge or sedimentation to other properties and shall not decrease slope stability on or off-site.*
- F. All development in seismic hazard areas shall conform to the provisions of the Uniform Building Code, which contains structural safeguards to reduce impacts from seismic activity.*
- G. Projects within a mine hazard area where mine workings are less than 200 feet below ground level shall be engineered and/or constructed to fully mitigate the hazard, and protect the building and occupants from the hazard.*

H. All projects on an alluvial fan hazard area must be engineered and constructed to withstand alluvial fan hazards and/or flooding equivalent to the largest known event evident on the fan as determined by professional assessment.

I. Clearing within alluvial fan hazard areas is prohibited without adequately addressing the significance of tree retention in an Assessment Report.

2.2 OVERVIEW OF GEOLOGICALLY HAZARDOUS AREAS INVENTORY

Geologic hazard analysis requires a broad range of studies and site evaluations. Primary studies evaluate the surface and subsurface geology, watershed conditions, hydrology, stream flow records, topography, and landform features. Geologic mapping has been carried out in the Whatcom County area by a number of scientists since the 1960s. Armstrong et al. (1965) documented the late Pleistocene stratigraphy in southwestern British Columbia and northwestern Washington and Easterbrook (1976a, 1992) produced geologic maps of western Whatcom County, including examining the engineering geology characteristics of local geologic materials (Easterbrook 1976b). The geology of the Kendall and Deming quadrangles were compiled by Dragovich et al. (1997) and the geology of the Bellingham 1:100,000-scale quadrangle was compiled by Lapen (2000), which is the most current and comprehensive mapping of geology of the Whatcom County area, Tabor et al. (2003) mapped the Mount Baker quadrangle. Numerous other geologic studies related to the region and specific sites are also available through university libraries, and the USGS. The Washington State Division of Geology and Earth Resources keeps a bibliography of geologic references related to Washington State geology, which can be accessed at <http://www.wa.gov/dnr/htdocs/ger/washbib.htm>.

Mapping the geologic units, soils, slopes, faults, and other features is an important first step to identifying geologic hazards. Analysis and estimates of the rate and frequency of geologic processes is also important because change in the landscape is an inherent part of geologic processes and hazards. Geologic processes form, modify, and erode the land surface over time. Some of the main forces that drive geologic processes include gravity, the hydrologic cycle, and plate tectonics. They provide the energy source that is constantly and sometimes rapidly changing the earth surface we live on.

2.2.1 Types of Coastal Geologic Hazards

2.2.1.1 Coastal Bluffs

According to the 2004 Washington Coastal Zone Atlas maintained by the Department of Ecology, coastal landslide hazard areas occur along the marine bluffs of Whatcom County. Areas of unstable slopes include portions of the coastline at Birch Point, Point Whitehorn, Cherry Point, the west side of Lummi Island, north of Neptune Beach, and other scattered areas.

Overall, the bluff along the Whatcom County marine shoreline is composed of a relatively thin deposit of gravelly sand and silt at the surface. This surficial material consists of glaciomarine drift and reworked glaciomarine sediments that were eroded and deposited by waves as the land rebounded upwards following the melting of the glacial ice sheet at the end of the most recent glaciation. This unit is now referred to as emergence (beach) deposits, of the Everson Interstade (Pleistocene).

Glaciomarine drift composes the majority of the height of the bluffs in the County. This unit typically consists of pebbly, silty clay, but more homogeneous silt deposits are also found in the unit. This unit has been termed the “Bellingham Drift” (Easterbrook 1976b), and was deposited near the close of the last glacial period, approximately 10,000 years ago. At that time, sea level rose enough to float the remaining ice, and subsequently melt the ice and release the sediment it contained into the shallow marine

environment. Vertical rebound of these deposits and the long-term result of wave attack formed the bluff configuration we see today. Other units exposed in the coastal bluffs include Vashon till and Vashon advance outwash deposits.

2.2.1.2 Tsunamis

Tsunamis are a specific type of geologic hazard associated with earthquakes, although the WAC (365-190-080 [3]) identifies tsunami hazards as being associated with frequently flooded areas rather than geologically hazard areas (tsunamis are also discussed in Chapter 3, Frequently Flooded Areas). Tsunamis are long-wavelength, long-period water waves generated by abrupt movements of large volumes of water, often induced by submarine earthquakes and associated vertical movement of portions of the ocean floor. Large subduction earthquakes causing vertical displacement of the sea floor and having magnitudes greater than 7.5 are the most common cause of destructive tsunamis. In the open ocean, the distance between wave crests can be greater than 100 kilometers, and the wave periods can vary from 5 minutes to 1 hour. These tsunamis travel 600 to 800 kilometers per hour, depending on water depth. Large waves produced by an earthquake or a submarine landslide can overrun nearby coastal areas in a matter of minutes. The destructive potential of tsunamis is demonstrated by the recent event in the Indian Ocean, which devastated countless coastal areas and killed tens of thousands of people.

Tsunami wave heights at sea are usually less than one meter in deep water, and the waves are not often noticed by people in ships. As tsunami waves approach the shallow water of the coast, their amplitude increases and wave heights increase dramatically. Recent analysis of marsh sediments in the form of sand deposits overlying marsh plains and marine vegetation suggests that the most recent large tsunami hit the Washington coast about 300 years before present that was caused by a Cascadia subduction zone earthquake. An additional tsunami generated in central Puget Sound approximately 1,100 years before present reached south Whidbey Island (Atwater and Moore 1992). Other inferred tsunami deposits (four separate events) have been documented on the northwest shore of Whidbey Island (Williams and Hutchison 2000). The age of two of the four events appear to match up to dated Cascadia subduction zone earthquakes, but the other two events (around 2,000 years before present) do not match up to known Cascadia subduction zone earthquake dates, and could have been caused by faults in the eastern Strait of Juan de Fuca (Johnson et al. 2002; discussed below).

Walsh et al. (2004) recently mapped tsunami hazards associated with a major Cascadia subduction zone (located offshore of Washington State) earthquake in Whatcom County. These authors also present current velocity associated with a modeled tsunami. The earthquake event that was modeled had a moment magnitude of 9.1, which is reported to be similar in magnitude to the earthquake that occurred in the year 1700 (Satake et al. 2003), the last major Cascadia Subduction Zone earthquake. The recurrence interval for major earthquake events ranges from a few centuries to a millennium, and averages about 600 years (Atwater and Hemphill-Haley 1997). While this mapping does not take into account more local tsunami origins, it can be generally applied to known tsunami hazards for Whatcom County. The modeling (Walsh et al. 2004) showed initial waves of generally 1 to 3 meters high for Bellingham and Lummi Bay, with waves of up to just over 3.0 meters in northern Bellingham Bay. The arrival time was modeled at approximately 2.5 to 3 hours after the initial earthquake event. There would be a noticeable drop in water levels (up to 1 meters) over 1 hour before the first wave would reach Whatcom County, such that a warning system is feasible for a Cascadia Subduction Zone earthquake.

Modeling of a Cascadia subduction zone earthquake (Walsh et al. 2004) resulted in areas with potential inundation of 2 to 5 meters are confined to the Nooksack River Delta near Marietta and small portions of Hermosa Beach on the southern Lummi Peninsula, as well as uninhabited portions of the Portage, slightly further south. Inundation of 0.5 to 2 meters was modeled at all of Sandy Point, much of Neptune Beach,

the Lummi River Delta and Lower Nooksack River south of Tennant Lake, Gooseberry Point, western Eliza Island, and small portions of Lane Spit and Legoe Bay on Lummi Island. Inundation depths of less than 0.5 meter were predicted for the industrial fill areas surrounding the Georgia Pacific site and the Squalicum Marina area. The Semiahmoo spit and Birch Bay areas were not in the modeled area, but are also likely at risk of inundation and wave velocity.

The Cascadia Subduction Zone was the only source area modeled for potential earthquakes and tsunamis. As is other North Puget Sound areas, there are other potential source areas for earthquakes and locally generated tsunami waves. Other faults have recently been mapped in the northern Puget Lowland and eastern Strait of Juan de Fuca located south of Whatcom County. This presents additional risk of tsunamis reaching the low-elevation portions of the Whatcom County coast, but the faults and risks are not yet documented (Crider 2005 personal communication; Schermer 2005 personal communication). A major fault that runs east-west across northern-most Whidbey Island is the Devils Mountain Fault (Johnson et al. 2002). Two other recently recognized faults, the Strawberry Point Fault and the Utsalady Point Fault, are located a short distance further south (Johnson et al. 2002). The South Whidbey Fault Zone (Johnson and others 1996) is located further south in Admiralty Inlet.

The Devils Mountain fault and the Strawberry Point and Utsalady Point faults are thought to be active structures and represent potential earthquake sources (Johnson et al. 2002). These faults could potentially initiate tsunamis, though they are thought to be primarily strike-slip faults (lateral motion), vertical offset could occur in any significant event (that could generate tsunamis). These faults are generally not thought to represent nearly as large a risk as the Cascadia Subduction Zone, but they are not well understood yet. Faults within Whatcom County include the Vedder Mountain Fault and the newly named Sumas Fault, that extend down the Sumas Valley towards the southwest, and may extend into Lummi Bay or the Strait of Georgia. However, if a tsunami were to be generated at any of these relatively close locations, it would arrive in a much shorter time than would a Cascadia subduction zone-generated tsunami. The frequency of these local earthquakes and potential tsunamis is unknown but the intensity of any locally-generated tsunamis is expected to be significantly less than a subduction zone earthquake tsunami (Crider 2005 personal communication).

2.2.1.3 Seiches

A seiche is a standing wave in an enclosed or partly enclosed body of water that has often been compared to the sloshing of water that can occur when a bowl is tilted sideways. Earthquakes may cause seiches in lakes and bays. More commonly, wind-driven currents or tides cause seiches. Seiches generated by the 1949 Queen Charlotte Islands earthquake were reported on Lake Washington and Lake Union in the Seattle area and on Commencement Bay in Tacoma. So far, no significant damage has been reported from seismic seiches in Washington caused by local or distant earthquakes.

2.2.2 Types of Inland Geological Hazards

Inland geologic hazards in Whatcom County include channel migration and alluvial fan hazards, erosion, landslides, earthquakes, seismic-induced waves on lakes from delta or shore slumps, abandoned underground mines, and hazards associated with volcanic eruptions (e.g., ash fall, mud flows, lateral blast, and lahars). The County Geologic Hazards Map (Whatcom County 1997) shows many of the potential geologically hazardous areas including some landslide areas, seismic hazard areas, alluvial fans, and mine hazards, but the mapping needs to be updated and supplemented with new information.

Geologic hazards are present when there is the possibility of a geologic process affecting public safety or structures. Landslides can directly affect public safety and structures because they can happen faster than people can react or get out of the way. Alluvial fans pose a risk to people and structures in and around the depositional areas at the mouths of creeks and rivers. During floods, stream channels can quickly fill and shift to other portions of the alluvial fan. Earthquakes are a hazard because they cause landslides, seismic-induced waves, ground breaking, and/or liquefaction of surface soils. The dramatic beauty and abundant recreational opportunities provided by Mount Baker come with the threat of occasional volcanic eruptions and dangerous volcano-related floods and debris flows that can be much larger than floods generated by storm runoff.

2.2.2.1 Channel Migration Hazards

Rivers and creeks naturally migrate and jump across valley bottoms, depositing, storing, and eroding banks and valley bottom sediment (Collins and Sheikh 2003, 2004; Deardorff 1992; Abbe and Montgomery 2003). Channel migration builds the floodplain, terraces, and landforms along the valley bottoms. In Whatcom County, the areas with the greatest potential for channel migration are the major depositional areas at the Nooksack delta, various smaller deltas into the Puget Sound and lakes, river and creek valley bottoms. Because of the numerous mountains and hills in Whatcom County, alluvial and debris fans are common landforms that are also built by channel migration during storms and debris flows. Alluvial and debris fans are discussed separately in later sections.

Stream channels adjust over time to the watershed, valley bottom, and flood conditions. Creek and river channels in Whatcom County have annual floods that transport and shift sediment down channel and out across the floodplains. Channel banks erode and shift in response to these flood flows. Deposition and erosion along the streams and especially on alluvial fans and deltas can frequently adjust the stream flow and the whole river or creek channel can shift or jump (channel avulsion) across the channel migration zone. Areas subject to risk due to streambank destabilization, rapid stream incision, stream bank erosion, and shifts in location of stream channels are defined as a channel migration area (King County 1999). Channel changes are natural and ongoing processes for streams, and are a significant part of how important aquatic habitat forms and is constantly renewed. Channel migration can occur gradually over a period of years or rapidly during one flood. Some reaches of a creek or river channel are confined by natural terraces, bedrock, or substantial armored levees and generally show little recent channel migration, in unconfined reaches or on alluvial fans and deltas, however, streams can have considerable channel changes.

The floodplains of the lower Nooksack River and the South Fork are in broad, glacially modified valleys. The upper Nooksack and the upper parts of the North Fork, Middle Fork, and South Fork are relatively narrow and bounded by mountainsides (Collins and Sheikh 2004). The widths of the floodplains of the three forks are narrowed in two locations by two large Holocene landslides (in the North Fork at river mile [RM] 44 and the South Fork near the North Fork confluence), and bounded elsewhere by Holocene fluvial and Pleistocene glacio-fluvial terraces (North Fork and South Fork) and lahar terraces (Middle Fork) (Collins and Sheikh 2004). The lower Nooksack River (RM 6 to RM 20) has built a narrow meander belt several yards higher than the rest of the valley. The valley bottom of the historically anastomosing channel, and currently braided upper Nooksack channel (RM 24 to RM 37), has a “corrugated” cross-valley profile associated with multiple channels and sloughs (Collins and Sheikh 2004). Much of the South Fork Nooksack River channel combines characteristics of both the upper and lower Nooksack River.

Collins and Sheikh (2004) evaluated the historical channel positions for the Nooksack River from the river's mouth to RM 58 (the town of Glacier) on the North Fork, the Middle Fork to RM 5 (Heislars Creek above the Mosquito Lake Bridge) and the South Fork to RM 16 (downstream of the Skagit County line). Their analysis documents channel migration rates for the period of historic records that includes the influence of historic and existing infrastructure. Average annual migration rates are lowest in the delta (exclusive of several distributary channel avulsions) and the lower Nooksack (RM 6 to RM 20), which were characterized by small amounts of meander migration, averaging only about 3.3 ft/yr (1 m/yr) in the delta and lower part of the lower Nooksack (RM 6 to RM 15), and about 13 ft/yr (4 m/yr) in the upper part of the lower Nooksack (RM 15 to RM 20) (Collins and Sheikh 2004). Rates were also low in the South Fork, averaging 16.4 ft/yr (5 m/yr) in the segment downstream of the canyon (SF RM 0 to SF RM 13), and 9.8 ft/yr (3 m/yr) and 13 ft/yr (4 m/yr) since 1933 in the South Fork canyon (SF RM 13 to SF RM 16). Migration rates in the upper Nooksack (RM 24 to RM 37), and especially the lower part of the upper Nooksack (RM 24 to RM 31) were much higher, 56 ft/yr (17 m/yr) since 1933 (Collins and Sheikh 2004). Rates were also high in the lower North Fork (RM 37 to RM 40), averaging 59 ft/yr (18 m/yr) since 1933. The upper North Fork (RM 40 to RM 58) and the Middle Fork had rates of 26 ft/yr (8 m/yr) and 29.5 ft/yr (9 m/yr) since 1933.

2.2.2.2 Alluvial Fan Hazards

Alluvial fans are a landforms built by sediment deposition and channel migration. Alluvial fans are localized areas of increased sedimentation downstream of locations where laterally confined creeks or rivers expand (Collinson 2002). Confinement is usually within a narrow valley or ravine eroded into an area of high relief; expansion is usually where the stream hits the low gradient valley floor, lake, or coastal plain. The classic fan shape (often modified by local terraces or valley wall conditions) is built because of the typically rapid migration and avulsions (jumping) of the main and secondary channels, responding to large amounts of sediment and trees that deposit in the currently active channels.

Alluvial fans form when sediment delivery rates from eroding uplands exceed sediment transport rates on the fan. Flow expansion results in a reduction in depth and velocity of flood waters or debris flow sediment, resulting in loss of energy and deposition of sediment and large woody debris (LWD) transported from the more confined and higher-gradient reaches upstream (Collinson 2002). Alluvial fans are built of coarse sediment consisting of blocks (rocks >2ft), boulders, cobbles, and gravel; channel and debris flow deposits; gravel, sand, and fines deposited overbank; and, in forested regions LWD derived from bank and valley wall erosion and landslides during large floods and especially debris flows.

Fans formed by stream transport and deposition are called alluvial fans; those formed by debris flows, rockfall, or raveling are called debris fans. Often they form by a combination of these processes and are called alluvial/debris fans or more generally just alluvial fans, which is the term that will be used in this review. Most of the fans in Whatcom County are built at the mouth of mountain streams, and are formed by both river and debris flow events (Orme 1989).

Alluvial fans vary in size from small features a few yards in radius to large features several miles or more across. Alluvial and debris fan areas present a hazard to people and facilities because channel changes and sediment deposition can occur rapidly during moderate to large floods or debris flows. Floods and debris flows from mountain watersheds have high velocities and can transport large amounts of woody debris that can be very damaging as it moves across and deposits on the fan. Steep mountain valley walls, high-gradient mountain streams, forest roads, and logging can generate debris flows that scour the channel and send floods full of sediment and trees to the fans, destroying everything in their path.

Upland watershed conditions influence the deposition and channel changes of alluvial fans, but even fans formed by undisturbed watersheds continually change through channel shifting and sediment deposition. The frequency of floods from a watershed controls the growth of alluvial deposits on fans. Flood frequency is controlled primarily by the frequency, magnitude, and duration of precipitation, as well as the runoff characteristics of the watershed. Debris flows are motivated by these same precipitation conditions and by the conditions of the valley walls and stream channels. In January 1983, warm rains falling on snow in the forested Cascade foothills generated debris flows and floods leading to rapid deposition on 20 alluvial fans (Orme 1989).

The limited detailed alluvial fan studies in the region indicate debris flows and floods leading to net deposition and sudden creek migration have an average return interval of about 60 to 70 years (Orme 1989, 1990). Sediment cores from Lake Whatcom show 7 very large and 43 large events over the past 3,370 years, an average recurrence interval of 67 years; the 1917 and 1983 events caused considerable damage to roads, utilities, structures, and loss of life (Orme 1990).

Kerr, Wood, and Leidal (2003, 2004) evaluated data collected by Orme (1989, 1990), deLaChapelle (2000), and their own analyses of Jones Creek (2004) and Canyon Creek (2003), and found small debris flows (10,000 to 50,000 cubic yards) depositing on the Jones Creek fan. This equates to an average return interval of 20 to 100 years for a 5 percent to 1 percent chance of a small debris flow occurring in any given year. Kerr, Wood, and Leidal (2003, 2004) found larger events (over 100,000 cubic yards of deposition) to have an average return period of about 400 to 600 years, or 0.25 to 0.16 percent chance of occurring in any year.

During floods, sediment and LWD are deposited on the upper fan, shifting the main flood channel to either side or the center of the fan. In narrow high-gradient valleys, landslides or debris jams can temporarily dam the valley and then break, forming a dangerous flood and debris flow that surges downstream and across the alluvial fan. Deposits revealed by field investigations of scoured upstream channels and source areas of debris flows and excavations in alluvial fans suggest the danger posed by such events; when they occur we need to be out of their way (Orme 1987; Stoker 1983).

2.2.2.3 Landslide Hazards

Landslide hazard areas are those portions of the landscape that have existing landslides or are at risk of future failure. Mass movement or mass wasting is the more general classification that includes landslides. Mass wasting includes the downward and outward movement of slope-forming materials including rock, soils, artificial fills, and combinations of these materials (Gray and Sotir 1996). Mass wasting is a problem in coastal and inland areas of Whatcom County. Another type of mass wasting that is often associated with landslides is surface erosion, consisting of detachment and transport of individual particles, as discussed in Section 3.2.2.4. Landslides are also associated with earthquakes and volcanoes, and are discussed further in Section 3.2.2.6.

Landslides involve the sliding, toppling, falling, or spreading of relatively large and often fairly intact masses along a failure surface or combination of surfaces (Gray and Sotir 1996). Landslides are generally classified based on the type of movement and slide materials (Varnes 1978). The geologic processes and mechanics of landslides are well understood but the site-specific conditions of individual slides can be quite variable (Burroughs et al. 1976; Chatwin et al. 1991; Varnes 1978; Selby 1993; Montgomery et al. 1998).

Several mass wasting classification systems are available for detailed studies, but these can be simplified into shallow slides that occur fairly rapidly, and those that are deeper and typically occur over extended time periods (Washington Forest Practices Board 1997). The main landslide types occurring in Whatcom County include shallow rapid translational slides (also called translational slides), rockfalls and debris

flows that occur rapidly, and deep-seated rotational slides (also called slumps) that typically occur more slowly.

Shallow Rapid Translational Slides

Translational slides occur along relatively shallow, fairly planar failure surfaces. Because they occur rapidly they are also called shallow rapid translational slides. Shallow rapid translational slides are especially common in the Pacific Northwest because of steep topography, surface materials, and moisture conditions; they are easily formed by ground disturbance, concentrated runoff, logging, and roads. Alteration of slopes by development or roads intercepts surface and shallow groundwater; removing vegetation increases surface runoff and shallow groundwater; and diversion and concentration of increased water runoff down steep slopes reduces stability of the surface soils, causing slides and erosion (Montgomery et al. 2000; Bunn and Montgomery 2004; Church 2002; Gomi et al. 2002; Dunne and Leopold 1978; and others). The number, size, and frequency of shallow translational slides are increased by slope development such as road building, logging, clearing and grading, or other ground disturbing activities. Run-out of translational slides often extends far downslope until a low-gradient bench or valley bottom is encountered. Depending on site and moisture conditions, translational slides can form into debris flows. Consequently, the risks associated with the slide source areas and run-out paths can be hazardous and need to be evaluated in planning studies.

Rockfall

With rockfalls, the slide material travels mostly through the air and movement is very rapid. Movement includes freefall, tumbling, and rolling of fragments of rock or highly compact glacial soils (Norman et al. 1996; Chatwin et al. 1991). Rockfalls typically originate from steep cliffs or mine faces, and form a debris wedge or fan in the accumulation zone. Material strength, surface gradient, joint pattern and spacing, geologic contacts, groundwater, and faulting are some of the primary factors related to rockfall occurrence. Run-out from the source area can extend quite far on steep slopes. Typically, however, debris forms a wedge or debris fan at the toe of the source area, and is identified by landform shape, slope position, and a mix of angular, often well-drained fragments of various size. Over time the accumulation zone can become overly steep and prone to secondary ravel, and translational slides can occur. Rockfalls are common in the main mountain areas, along mountain highways and railroad lines, and along coastal bluffs in Whatcom County.

Debris Flows

Debris flows are common in upland creeks, swales, and slopes in Whatcom County. They can be triggered by valley wall translational slides, slumps, road fill failures, diversion of surface water, logging, and other ground disturbance on the valley walls or channels of steep hill or mountain areas. Debris flows occur rapidly and travel down the creek to low gradient reaches or the valley bottom where the debris comes to rest in debris deposits or alluvial fans. Active flows accumulate additional material by scouring the hillslope colluvium or valley bottom alluvium down to bedrock or dense glacial deposits, and by carrying along the trees in the debris path. Debris flows can be small, originating from a small drainage and moving a short distance down slope more often, debris flows are 100 to 200 feet wide and travel one-half to several miles down slopes or creek drainages. Very large debris flows may be caused by a glacial outburst flood or collapse of a volcanic cone, as occurred at Mt. St. Helens in 1980. Debris flows can stall partway down a confined channel or at channel junctions, forming a temporary dam that breaks and results in an even larger debris flow downstream. This was what occurred on the Mills Creek debris slide during the 1983 storms, causing several waves of destruction down valley. Slides along confined valleys can block the channel, forming a dam that can also start a debris flow.

Hillslope development can contribute to debris flows by intercepting surface or shallow groundwater and diverting it down swales or into the heads of small mountain creeks. The addition of water to these areas reduces soil strength by increasing saturation. In addition, hillslope development is often associated with removal of trees, which further reduces the soil strength through loss of root reinforcement.

Debris flows move rapidly, leaving little time to move out of the way; facilities in the valley bottom of the steep confined creeks and their associated alluvial fans are at risk. Huge debris flows and lahars are types of mass wasting associated with volcanoes, and will be discussed further in the Volcanic Hazards section (3.2.2.6).

Deep-Seated Rotational Slides

Another common type of landslide is rotational slides or slumps. Such slides are often deep-seated and have a bowl-shaped or broad curving failure surface with a steep headwall scarp and additional scarps in the slide mass. Rotational slumps can be small, covering only a few yards (as is common along road cuts), or they can be very large, covering many square miles, like the slides that partially block the three Nooksack forks. Slumps and deep-seated rotational slides are common in glacial tills and glacial lake deposits. Source areas are associated with over-steepened valley walls with thick glacial deposits, geologic contacts, and groundwater conditions. They often occur over many months or years. Thus, human actions that alter surface conditions have relatively minor effects compared to the forces involved with the slide formation or activity.

Larger deep-seated rotational slides are characterized by a constantly shifting surface layer. Such shifting poses hazards to buildings, roads, and other facilities. Remedial actions to slow the slide can be costly, and often the slide is so big that little can be done to mitigate its motion. Even small slumps can be difficult and costly to deal with. In some cases, deep-seated rotational slides can be initiated or reactivated by earthquakes or changes to water conditions related to logging road construction or other activity. Large deep-seated slides can block creeks and rivers, changing channel directions and short-term sediment supply. Smaller slumps in steeply cut slopes above buildings can be a hazard to people if buildings are damaged, generally, however, motion is slow and damage to facilities is the primary hazard.

Other types of mass movement that are common in Whatcom County are soil creep and raveling. These are ongoing gradual movements of slope materials; over many years, soil creep and raveling result in the accumulation of thicker soils at the lower portions of slopes. Motion is too slow to present a safety hazard but development that requires cutting into steep slopes need to plan for maintenance related to raveling and soil creep.

Many factors influence the occurrence and severity of landslides, including slope gradient, slope shape, surface and subsurface materials, precipitation, surface and subsurface water conditions, drainage area, elevation, slope aspect, vegetation history and condition, roads and other ground disturbance, earthquakes, and volcanic eruptions (Selby 1993; Montgomery et al. 1998). Extensive research and literature exists related to landslides, based on local, regional, and worldwide investigations (Benda and Cundy 1990; Benda and Dunne 1997; Chatwin et al. 1991; Coho and Burges 1994; Coppin and Richards 1990; Dietrich and Dunne 1978; Eisbacher and Clague 1984; Fiksdal and Brunengo 1981; Gray and Sotir 1996; Greenway 1987; Montgomery and Dietrich 1994; Montgomery et al. 1998; Selby 1993; Thorsen 1989; Tubbs 1974a, b; Varnes 1978, 1984; Wiczorek 1984; Wu et al. 1993; and numerous others).

Glaciers eroded steep bedrock valley walls and deposited compact lake-bottom clays, dense advance outwash sands, and tills throughout the County. These deposits are often eroded by creeks and rivers, forming steep slopes and valley walls. Steep slopes are one of the main factors leading to landslides, and

are often used as a first-level screening for identifying landslide hazard areas. Glacial materials typically grade from fine grained glacial lake and advance outwash deposits overlaying glacial tills and recessional outwash. Contacts between relatively permeable loose sandy slope materials and the denser less permeable lower layers, often lead to saturated contacts where slides can form (Tubbs 1974a). Some of the denser surface materials are stable when undisturbed, but can become unstable when excavated.

Loose recessional outwash and slope colluvium typically overlie rock or dense glacial clays or fine-grained advance outwash. Water builds up during wet periods, and shallow translational slides or small slumps form in the surface material. Water soaking into the ground from rainfall or snowmelt, shallow groundwater from upslope, deep groundwater from cracks in the rock or compact glacial materials, or water intercepted, diverted and concentrated by roads or other ground disturbing development reduce the internal soil strength beyond the forces pulling it down slope, and slides occur.

Vegetation cover plays an important part in controlling landslide formation. Vegetation reduces shallow groundwater by interception and evaporation; in addition, the complex web of roots reinforces the soil. Many surface soils on slopes over 22 degrees do not have enough strength between the individual soil grains and it is the additional strength provided by deep roots that holds the slope together. Consequently ground or vegetation disturbance on slopes can easily cause landslides depending on the slope, surface materials, water, and vegetation conditions.

Landslides and slope stability are analyzed using the infinite slope, circular arc, or other similar approaches (Selby 1993; Montgomery et. al 1998; Gray and Sotir 1996; and others). Reduction of landslide hazards has been an ongoing effort in the region, with numerous regional and local studies appearing since the 1970s (Artim 1973a,b; Booth 1989; Miller 1973; Thorsen 1989; Tubbs 1974a,b and many others).

Landslide hazard areas can be estimated using the criteria outlined in the WAC (see the Introduction to this chapter). Inland landslide hazard areas have been estimated in Whatcom County by identifying areas between 15 and 35 percent slope that have permeable sediments over impermeable sediments/bedrock. Other potential hazard areas include groundwater seepage or springs; slopes greater than 35 percent; and unstable slopes caused by stream incision, bank erosion, or wave action. These areas tend to be concentrated in the foothills and mountains as well as in scattered drainage ravines throughout the County.

2.2.2.4 Erosion Hazards

Undisturbed areas of the Pacific Northwest typically have dense vegetation, decomposed organic material, and loose surface soils. These features reduce water runoff and associated surface erosion and rilling. Runoff and erosion can occur when vegetation or surface soil layers is removed. If left unchecked, erosion areas can grow into problem areas delivering significant amounts of sediment to lakes, streams, and wetlands and possibly leading to landslides. Erosion is also related to channel migration, volcanic activity, coastal processes, agriculture, and clearing and grading. This section focuses mostly on erosion related to ground disturbance in inland areas of Whatcom County.

Vegetation, landform shape, slope gradient, slope length, soil type, rainfall intensity, drainage conditions, and other factors can be used to identify erosion-prone landtypes. Soil surveys are very useful in identifying the main erosion hazard areas. The Whatcom County soil survey (Goldin 1992) identifies soil units that have severe erosion potential. These include soils in the Gallup, Hartnit, Heisler, Hinker, Hovde, Klawatti, Oakes, Kulshan, and Fishtrap soil series.

Any type of soil can erode when disturbed, but not all erosion is transported to adjacent properties or surface waters. Consequently, the proximity of ground-disturbing activities to surface waters, in any soil type, will often determine the type or level of risk associated with erosion hazard areas. Soils that are impermeable or minimally permeable generate surface water runoff and begin to erode sooner than very porous soils. Vegetation, the organic duff layer, small depressions, and soil density all minimize runoff and erosion.

Many of the erosion-prone soils in Whatcom County are associated with steep slopes or loose silty soils. Because they often overlap, erosion and landslide hazard areas are sometimes grouped together for regulatory purposes. Whatcom County however, has many more areas with erosion hazards compared to landslide hazards. These include erosion hazards at construction sites, which are typically addressed through grading and building plans, and erosion hazards related to land or resource management, which can generate large amounts of eroded material.

In Whatcom County, erosion is regulated through a variety of WCC chapters and building standards. The main erosion control provisions are identified in the soil conservation agreement Code 1.42.010, where the Whatcom Soil Conservation District agrees to bring to the attention of the County any evidence of deterioration, erosion, or conditions not compatible with the principles of soil and water conservation and flood control on County-owned lands, roads, or other property. Erosion is also regulated through the Department of Ecology Phase II Storm Water regulations that require a General Construction NPDES Storm Water permit for all clearing activities greater than 1-acre.

2.2.2.5 Seismic Hazards

Ground shaking and ground failure are the major factors leading to loss of life and property damage during earthquakes (Rogers et al. 1998). Seismic hazard areas are subject to a severe risk of damage as a result of ground shaking, differential settlement, or soil liquefaction caused by earthquakes. The main seismic hazards in Whatcom County include ground shaking, ground breakage, coastal and inland landslides, liquefaction, coastal and inland lake tsunamis, seiches, and shoreline slumps. The damage caused by seismic activity is dependent upon the intensity of the earthquake, its proximity to developed areas and population centers, the slope, thickness, consolidation, and moisture conditions of the surface and subsurface materials, and many other factors.

In the past, the primary areas considered to be at the greatest risk of earthquake damage were areas where surface deposits of manmade fill or partially decomposed organic material average at least five feet in depth, filled wetlands, and areas of alluvial deposits subject to liquefaction. Regional and worldwide investigations over the past 60 years have shown that seismic risk is far more complex and extensive.

In the 1940s and 1950s, understanding of the need to include earthquake loadings into building designs slowly began to emerge in the west coast region (Kennedy 1996). There was resistance to adoption of building codes like the uniform building code because of political and economic fears and a lack of detailed evidence that earthquakes were a real risk in the region. More evidence of earthquake risks along the west coast motivated an approach where the region was segmented into seismic zones and additional analysis or earthquake loadings were added to the uniform building code through the 1960s. There was still considerable uncertainty and discussion on the zone boundaries.

Through the 1970s and 1980s, additional records and analysis of regional earthquakes and geologic mapping started to bring into focus the regional earthquake risks (Noson et al. 1988; Gower et al. 1985; Washington Geologic Newsletter 1987; and others). At the same time analysis of structural failures from earthquakes started to reveal a close relationship between seismic characteristics of a site and its response to seismic loading (Bourgeois and Johnson 2001; Kennedy 1996; Satake et al. 1996; SPNSN 2001;

Williams and Huthinson 2000; Yamaguchi et al. 1997). This makes a simple zone approach to building design less effective if specific features at the site are also an additional controlling factor.

There was resistance to additional seismic loading requirements from proponents of critical structures during the 1970s and 1980s because of the large costs involved, but local and regional evidence of seismic hazards became overwhelming, based on numerous local and regional faults and earthquake monitoring. Geologic understanding developed in the 1980s and 1990s, based on the now well documented plate tectonic theories, identified the sources and mechanics of west coast earthquakes (Gower et al. 1985; Hyndman 1995; Atwater 1986, 1997; Schuster et al. 1992; Jacoby et al. 1992, 1997; Heaton and Hartzell 1986; Adams 1990; Applied Technology Council 1994; Rogers et al. 1998 at <http://pubs.usgs.gov/prof/p1560/>; and numerous others).

Washington is situated on the collisional boundary between two tectonic plates. The offshore Juan de Fuca plate is pushing into and under the North American plate at a rate of about 3 to 4 centimeters per year. At the same time, the northward-moving Pacific plate is pushing the Juan de Fuca plate north, causing strain to accumulate (Riddihough 1984; Heaton and Hartzell 1986). Small to extremely large earthquakes are caused by the slipping and abrupt release of the accumulated strain related to the juncture of these three plates. The motions of these three plates can also build up strains on the crust underlying Whatcom County causing shallow breaking (faulting) and local earthquakes.

These regional seismic conditions combine with local site conditions to create earthquake hazards. Areas are at risk of damage from local shallow earthquakes, large regional great earthquakes. Even areas with stable site conditions are at risk of shaking damage from large earthquakes. Areas such as the marine shorelines, steep slopes, fill or loose saturated sediments, and areas closest to the main active local faults have a high probability of damage due to ground shaking, liquefaction, ground breakage, differential settling, or landslides (Noson et al. 1988; Heaton and Hartzell 1986; McCulloch 1966; McCulloch and Bonilla 1970; Foster and Karlstrom 1966; Hansen 1966; Plafker 1969; Wilson and Torum 1972; Schuster et al. 1992; Jacoby et al. 1992; Bucknam et al. 1992; Crozier 1992; Keefer 1983, 1984, 1994; Brown and Dragovich 2003).

Proximity to the fault that causes an earthquake is a major factor in determining how much seismic energy impacts the local area. Small earthquakes on faults in Whatcom County can cause ground shaking similar to larger earthquakes centered farther away. The entire County is tectonically active, as the mountains and valleys are being moved and uplifted by region-wide pressures created by the motion of the ocean crust into and under the continental crust (Atwater 1987, 1988). Moderate quakes on local Whatcom County faults, or larger ones farther away, can both be very damaging. Some of the main faults in Whatcom County such as the Vedder Mountain fault, Sumas fault, and dozens of others have been identified, but additional faults are likely present in this highly fractured and tectonically active region.

2.2.2.6 Volcanic Hazards

Mount Baker is a steaming, ice-mantled, andesitic stratovolcano that is the most conspicuous component of a multivert Quaternary volcanic field active almost continuously for the past 1.3 million years (Hildreth et al. 2003). Future activity is likely to create a variety of hazards for the region. Mount Baker is the most likely source of volcanic hazards in Whatcom County, but other nearby volcanoes such as Glacier Peak, Mount Rainer, Mount St. Helens, Mount Adams, or Mount Hood, could deposit ash in the area. Volcanoes like Mount Baker are capable of violent eruptions that deposit enormous amounts of material over the landscape (King County 2004). Worldwide, over 200,000 people have been killed by volcanic hazards in the past 500 years. This is far more than in previous centuries because of the increased numbers of people living near volcanoes (Tilling 1991).

Geologic hazards related to Mount Baker include debris flows (lahars), ash (tephra) fall, landslides or debris avalanches, pyroclastic flows and surges, ash clouds, ballistic debris, lava flows, and lateral blasts (Gardner et al. 1995; Hildreth et al. 2003; Swan 1980; Majors 1978). These and other similar hazards have occurred recently in western Washington (Mount St. Helens) and are clearly identified in the geologic record of Mount Baker and the other similar nearby active Cascade volcanoes such as Glacier Peak and Mount Rainer. Glacial ice has influenced eruptions and amplified erosion throughout the lifetime of the volcanic field (Hildreth et al. 2003). Existing information suggests lahars may be the greatest volcanic hazard in Whatcom County because of the distance they can travel down valleys and their frequent history at Mount Baker and nearby volcanoes (Hildreth et al. 2003). Lahars and ash fall are triggered by volcanic eruptions, but some types of debris flows and outburst floods can occur without apparent volcanic activity.

Debris Flows or Lahars

Debris flows are dense slurries of water-saturated debris (including rock, soils, and trees) that form when loose masses of material move downslope (Gardner et al. 1995). They are sometimes called lahars when derived from a volcano and can also form from a pyroclastic flow (discussed in the next section) (Gardner et al. 1995). They often occur during eruptive periods or from thick, steeply sloped deposits years after an eruption, but also occur without any apparent association to eruptive events.

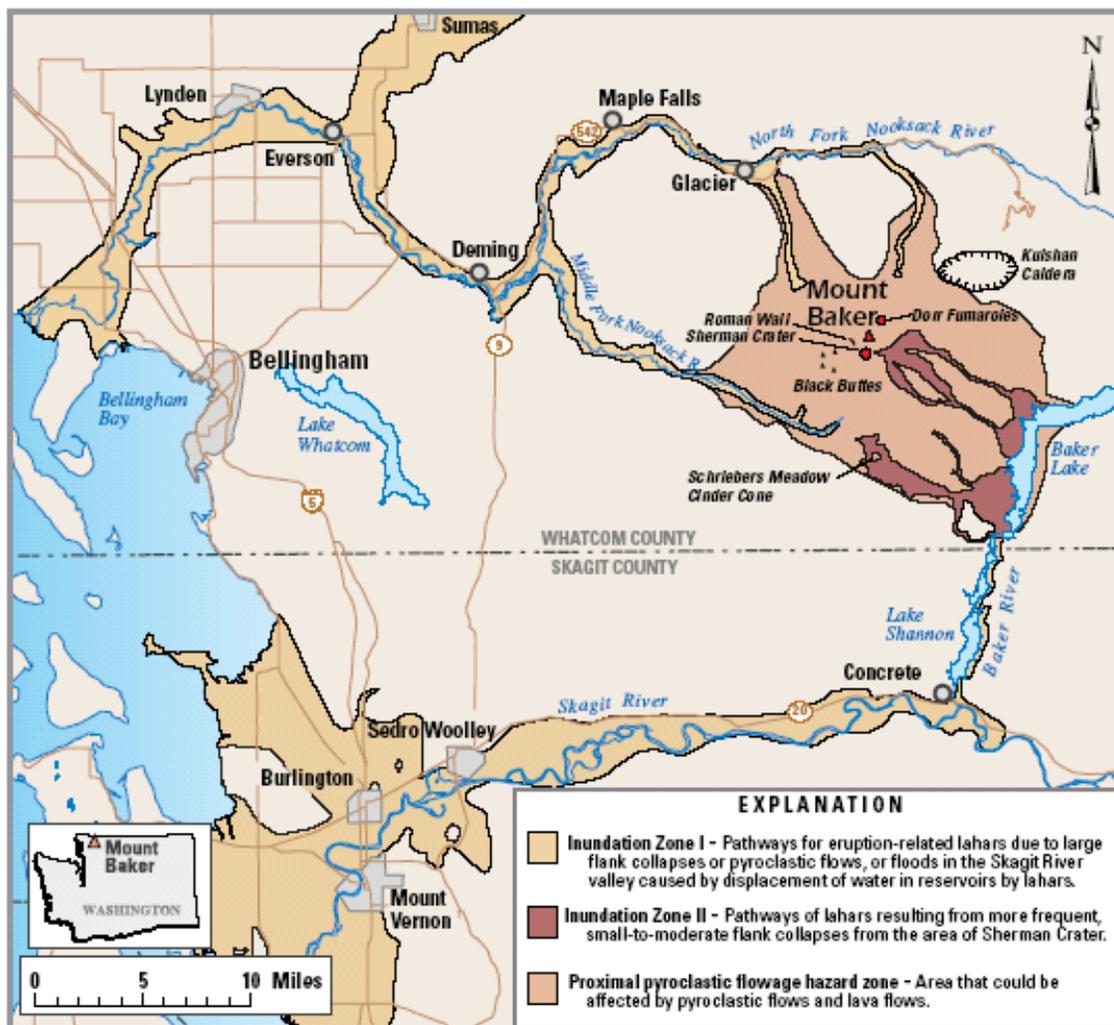
Stratovolcanoes like Mount Baker are composed of an accumulation of relatively weak rock and ash deposits that are altered by weathering and hot fluids. Such volcanoes are very steep because of glacial erosion, dome building, and landslides. This leaves them vulnerable to small and large debris flows that can move great distances down valleys at speeds of 6 to 90 miles per hour, with average speeds of 20 to 40 miles per hour. Debris flows grow larger as they move down valley, scouring the valley bottom and picking up additional water, sediment, and trees.

Debris flows from Mount Baker pose a risk to life and property from burial or impact. Debris flows follow existing drainages; the risk tends to decrease with distance downstream and with height above the river channel. They are a hazard in association with volcanic eruptions and for many years following major eruptions; as accumulated loose material is remobilized during wet periods. Debris flows have moved down all of the Mount Baker drainages (Gardner et al. 1995). Small debris flows (<0.002 cubic miles) travel up to a few miles from the source areas and are more often associated with wet periods and not directly related to eruptions. Since 1958, six debris flows have originated from Sherman Crater and moved 2 miles down valley. Moderate-size debris flows (0.002 – 0.02 cubic miles) on Mount Baker have occurred with and without eruptions and traveled 6 to 9 miles reaching just beyond the flanks of the mountain.

One large debris flow from Mount Baker, exceeding 0.02 cubic miles in volume, does not appear to be associated with an eruptive event. It traveled 7.5 miles down Sulphur Creek valley and more than 7.5 miles down the Middle Fork Nooksack. It was at least 325 feet thick in the Middle Fork, and deposits from this debris flow are mapped as far as Deming. Downstream of Deming the deposits are buried by more recent river deposits but analysis indicates they likely extended all the way to Puget Sound (Gardner et al. 1995). Debris flows of this size or much larger are possible from Mount Baker. Such flows would profoundly alter river locations and the valley bottoms.

Volcanic hazards are usually dealt with by establishing hazard zones around the mountain based on available knowledge. Much of the destruction related to the Mount St. Helens 1980 eruption could have been avoided if land use planning based on volcanic hazard zones had been used (Schuster 1981; Waldron 1989). Mount Baker volcanic hazard zones related to debris and pyroclastic flows were estimated by the

USGS in 1995 (Gardner et al. 1995) (Figure 2-1). The Proximal Pyroclastic Flowage and Inundation Zone II classifications are areas where development should be limited to temporary-use, day-use, or expendable facilities. Inundation Zone I includes areas where development of critical structures would typically be limited. Further detailed geologic mapping and dating of eruption deposits around Mount Baker may allow Inundation Zone I to be divided into several hazard zones, similar to results of additional studies around Mount Rainier (Crowley and Zimbelman 1997; Moran et al. 2000; Reid et al. 1999; Vallance and Scott 1997; Vallance et al. 2002).



Map showing hazard zones for lahars, pyroclastic flows and lava flows (for more detail see Plate 1 in US Geological Survey Open-File Report 95-498).

Figure 2-1. Mount Baker Volcanic Hazard Zones Related to Lahars or Pyroclastic Flows

The proximal pyroclastic flowage and Inundation Zone II are areas where development should be limited to temporary use, day use, or expendable facilities. Inundation Zone I includes areas where development of critical structures would be limited.

Pyroclastic Flows, Pyroclastic Surges, and Ash Clouds

Pyroclastic flows occur during explosive eruptions. Pyroclastic flows or surges are avalanches of hot (300° to 800° C), dry volcanic fragments and gasses that travel down the flanks of the volcano at speeds

up to 200 miles per hour. The mass, high temperature, and great mobility of pyroclastic flows makes them very destructive and dangerous, posing a lethal hazard by incineration, asphyxiation, burial, and impact. They are difficult to escape because of their high speed, so evacuation must begin before they occur. Prediction and cautious area closures are essential to hazard management in areas susceptible to pyroclastic flows.

Pyroclastic flows tend to follow existing valleys, and have enough energy to overtop ridges and hills. Pyroclastic surges are even more energetic events associated with pyroclastic flows, and are less restricted by topography. Debris flows can be generated when pyroclastic flows interact with snow or ice. Because of the extensive ice and snow on Mount Baker, pyroclastic flows from the upper slopes are likely to form debris flows; large ones would move downstream as debris flows or floods (Gardner et al. 1995).

One period of pyroclastic flows has been identified on Mount Baker in the Boulder Creek area. It includes 11 pyroclastic flows and related deposits forming a large fan on the shore of Baker Lake. Pyroclastic and debris flow hazard zones were estimated by the USGS for Mount Baker in 1995 (Gardner et al. 1995) (see Figure 2-1).

Landslides and Debris Avalanches

Landslides and debris avalanches can occur from volcanoes; like debris flows, such events may not necessarily be accompanied by an eruptive event. Landslides or debris avalanches from volcanoes can range from relatively small slides off of the steep, often glaciated slopes, to large slides similar to the one that led to the 1980 eruption of Mount St. Helens. The 1980 Mount St. Helens eruption started with swelling of the mountain that made the north side overly steep and unstable, leading to a massive landslide that led to the eruption (Schuster 1989). The north and northeast sides of most of the Cascade volcanoes are very steep because this is where alpine glaciers have been more active, as was the case with Mount St. Helens. When volcanoes swell, as new lava pushes up under the mountain, the steeper sides are more vulnerable to landslides. Over dozens to hundreds of years, dense lava typically pushes up, rebuilding the top of the mountain, often with a slightly different center, eventually setting the stage for another eruption. Smaller landslides are very hazardous only on the slopes and valleys around the volcano; large ones can travel many miles down the valleys, forming into debris flows (Scott et al. 2001).

Ash Falls or Tephra Plumes

Ash or tephra is ejected rapidly into the air during eruptions. The distance this material travels and the depth to which ash and larger rock fragments may cover the ground depends on distance from the mountain and the prevailing wind directions during the eruption (Wolfe and Pierson 1995; Gardner et al. 1995). The larger particles fall near the mountain and finer ash fall further downwind. Ash fall hazards can vary from life-threatening to a nuisance. Ash plumes are a hazard to aviation, causing damage to engines that can result in loss of power; in addition, ash particles can block visibility, sandblast windshields, and generate a lot of lightning (Casadevall 1994). High ash concentrations can make breathing difficult and collapse roofs, especially if wet. Wet ash four inches thick places a load of about 20 to 25 pounds per square foot (Wolfe and Pierson 1995). Even low concentrations of ash are damaging to car or other engines, can short out power lines, damage crops, and disrupt regional social and economic activity (Schuster 1989).

Upper elevation winds in Whatcom County come from the east only about 10 percent of the time, which means the eastern portions of the County face the greatest risk of ash fall, rather than the primary populated areas to the west. Winds blowing to the west are often strong, however, two of the six main 1980 ash eruptions at Mount St. Helens were spread to the west.

Ballistic Debris

Ballistic debris includes pebble- to boulder-size rock fragments blown from the volcano during steam explosions or eruptions. Rocks can be blasted up to about six miles into the sky. During active volcanic periods, high-speed impact by falling debris can pose a significant hazard.

Lava Flows

Lava flows are masses of hot, partially molten rock that flow from the volcano. They typically follow existing valleys. Lava from Cascade volcanoes is very stiff because of its mineral composition and consequently flows very slowly. Lava flows are usually not a safety risk because they flow slowly and their paths can be estimated once they start. Lava flows can generate debris flows if in contact with ice or snow. They can damage structures by burial or burning because they generally cannot be stopped, and also can start forest fires.

Lateral Blasts

Lateral blasts are an explosive eruption where much of the energy is directed horizontally away from the eruptive center instead of up. They vary by size and large ones are rare; the Mount St. Helens 1980 eruption is the classic example of a lateral blast. In that blast a 570° F mixture of rock, gas, and ash moved up to 650 miles per hour crossing over ridges as high as 2,500 feet above the valley floor and extending up to 15 miles from the source (Gardner et al. 1995). Most trees in this zone were knocked down and nearly everything perished. Lateral blasts are not well understood; the Mount St. Helens blast was the first time they were recognized. The lateral blast there was preceded by several months of deformation of the mountain, so the hazard zone may be predictable with further research and monitoring (Gardner et al. 1995) (Figure 2-2).

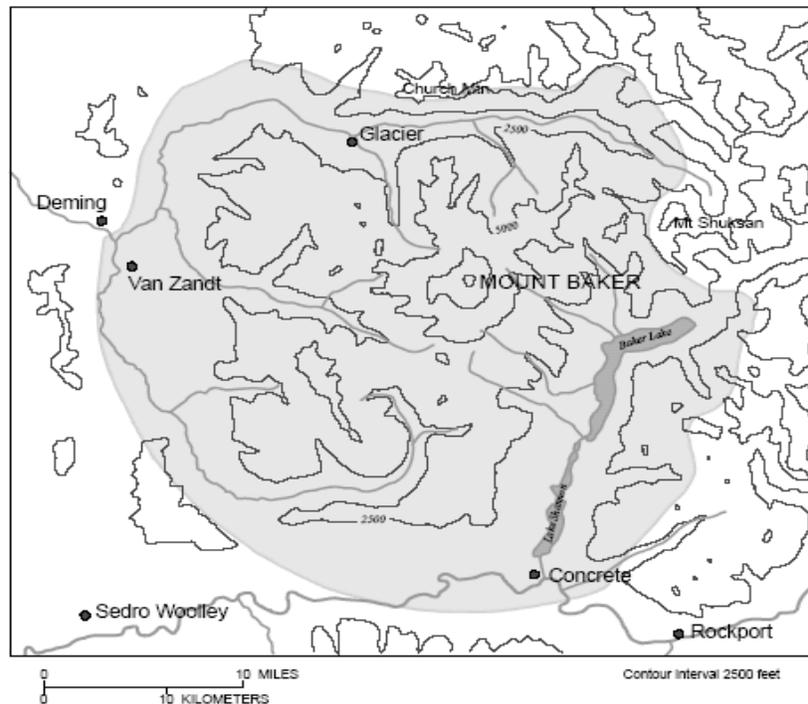


Figure 2-2. Area around Mount Baker that Could Be Affected By a Lateral Blast Similar in Size to the May 18, 1980 Mount St. Helens Blast.

The lateral blast would not affect this entire circumference, but only a 90- to 180-degree portion of this area (Gardner et al. 1995).

2.2.2.7 Mine Hazards

Mine hazards in Whatcom County mostly relate to coal mines that were active in the late 1800s and early 1900s. Mine hazard areas are underlain by abandoned mine shafts, secondary passages between shafts, tunnels, or air vents. Mine hazards include subsidence, which is the uneven downward movement of the ground surface caused by underground workings caving in; contamination to ground and surface water from tailings and underground workings; concentrations of lethal or noxious gases; and underground mine fires (WCC 16.16.330).

The Whatcom County Geologic Hazard Map (1997) shows mine hazard areas at abandoned underground mines and known mine areas. Typical hazards related to abandoned coal mines include local subsidence and entrance or air shaft collapse. Other less likely hazards include underground fire, air emissions, and water quality impacts. Evaluation of individual sites in known mine areas can be used to guide development in these areas or to support avoidance of the area. The shallow mine areas in Whatcom County appear to be fairly well known from historic reports.

2.3 HUMAN ACTIVITY AND GEOLOGICALLY HAZARDOUS AREAS

Natural geologic processes create hazardous areas that are easily recognized as dangerous. In many situations, however, the hazards are not so obvious and experienced scientists and engineers are needed to evaluate risks. Some geologic processes are easily influenced by land management actions, while others occur at a scale or magnitude over which we have limited control. Many types of landslides and surface erosion are easily caused or increased above natural levels by human activities along the coast, near streambanks, and on hillslopes. Larger slides generated by volcanic eruptions or earthquakes are not influenced by land use management, but recognizing their potential is still important for development planning and for safe response when they occur. Geologically hazardous areas can sometimes be identified based on present site conditions and how events have occurred in the past. Identifying the magnitude and frequency of past geologic events can help identify current geologic hazards; however, conditions can change over time and the influence of past and proposed management needs to be considered.

2.3.1 Coastal Geologic Hazard Areas

2.3.1.1 Bluff Stability and Drainage

The abundance of silt and clay in the bluffs, over-steepening by toe wave attack, and direction of lateral groundwater movement toward the coastline cause water to be directed to the exposed bluff face as seepage, which exacerbates mass wasting (landsliding) of the bluff.

Moderate to significant dispersed seepage occurs in many Whatcom County bluffs at a variety of elevations, especially 10 to 20 feet or more below the bluff crest. The highest volumes of groundwater observed seeping from the bluff face typically occur following prolonged heavy precipitation. Periods of high rainfall intensity and duration (especially during saturated soil conditions) are known to trigger landslides (Tubbs 1974a; Thorsen 1987; Shipman 2001), such as those observed locally in November 1995.

Surface water volumes can increase and become concentrated by development of housing and roads, which typically occurs near coastal bluffs. This is due to decreased infiltration of water and often occurs simultaneously with increased surface water flow. Concentrated surface water can locally over-saturate soils, which can increase “natural” slope stability problems at coastal bluffs and can often trigger landslides. Runoff running down a driveway and rapidly across a lawn as sheet flow to the bluff face is an example of this process. Failed septic systems also contribute to this problem. A broken drainage pipe on a bluff face is another example. Failed drainage pipes are often observed along Whatcom County bluffs, and likely contribute to initiating landslides. Upland drainage control could help decrease bluff seepage, as discussed in a later section of this chapter.

Undercutting of the toe of the bluff is the long-term “driver” of bluff recession. Bulkheads and other development can accelerate this on the beach. Winter windstorms that create significant wave attack at the bluff toe can also trigger some bluff failures. For example, significant northwest windstorms occurred at very high water levels in mid-December 2000 and mid-December 2001 (Williams and Hutchison 2000). These events caused toe erosion of the bluffs and likely triggered landslides both at the time of the storm and over subsequent wet-weather months. The January 2 to 3, 2003 southeast windstorm also coincided with very high water periods in Whatcom County.

Clearing trees and shrubs from portions of the uplands and bank face (sometimes repeatedly) decreases the soil-binding benefits of roots, decreases evapotranspiration rates (removal of soil water by vegetation), and increases surface water flow concentration (Gray and Sotir 1996), and can also trigger landslides (Menashe 1993; Shipman 2001).

2.3.2 Inland Geologic Hazard Areas

2.3.2.1 Channel Migration

Development affects channel migration in a number of ways by modifying watershed and channel condition, and encroachment into the channel migration zone places facilities in the way of stream changes. Along some portions of streams, channel migration occurs gradually over many years; in others it can occur rapidly during high flows or floods when residents are often on-guard from rising waters and flood warnings. Consequently, property damage and not public safety is the primary hazard from channel migrations. Channel migration is a natural and ongoing process that builds and constantly changes the channel and floodplain. Streams by their very nature are always changing in balance to water, sediment, LWD supply, and streambank and channel conditions. However, development patterns typically develop as if streams are static and do not change (Brooks 1988; Petts 1989). This has motivated extensive diking and armoring of creeks and rivers in part to stop channel migration and channel changes. When these control measures fail they can pose a risk to residents who may have assumed the structures were secure.

Construction of dikes, bank armor, constrictions like bridges and culverts, and river training works can reduce or stop channel migration. These protection works often lead to changes in bank erosion, sediment transport and storage, and channel migration up- and downstream of the modified areas, causing more land losses or requiring more protection measures. Protection projects often confine the channel and floods to a much smaller width, which can exacerbate channel changes such as deposition or incision.

The natural tendency of channels to change is also influenced by increased runoff and/or bedload sediment supply from clearing, logging, roads, agriculture, and other development actions. Increased stormflow runoff is concentrated in creeks and rivers, causing increased frequency, magnitude, and duration of flood flows. This in turn causes changes in the rate and amount of incision, deposition, increased bank erosion, and related channel migration.

Migration rates are often further increased by clearing of trees along stream banks and in the channel migration zone. Removal of streambank trees and channel dredging removes LWD and jams of trees that provide bank protection, store sediment in the channel, and provide important features for aquatic habitat. Dense streambank and overbank vegetation slows water velocity, leading to sediment deposition. When natural or managed vegetation cover is removed or modified, erosion often results (Bennett and Simon 2004). For example, one of the more effective ways to reduce bank erosion is to add log jams or rock points spaced along the eroding streambank. This diverts the main flow energy away from the bank similar to natural LWD jams or fallen trees, both of which depend on streambank and migration zone trees for supply of LWD. Removal of trees and dense vegetation from the channel migration zone reduces the stream's ability to recruit LWD, as well as other streambank and channel buffer functions. River processes and aquatic habitat conditions depend on the ability of the river to change and form on its own. These functions are hampered by increased stormwater runoff, channel confinement and bank armoring, dikes, or other projects designed to reduce channel migration.

2.3.2.2 Alluvial Fans

Natural watershed and channel processes, forest management, roads, utilities, agriculture, and residential development can all reduce stability of valley wall slopes and streams upstream of alluvial fans. This in turn increases the natural tendency of floods to deposit sediment and change channels on alluvial fans. Clearing and excavation on alluvial fans can also alter channel migration and flooding areas. The soil strength, changes to rainfall-runoff response, and drainage patterns influence the degree and extent of instability and the subsequent occurrence of valley wall landslides and erosion. Landslides and erosion increase sediment supply and channel migration along the channel and on the alluvial fan, resulting in increased probability and magnitude of debris flows, large floods, and sediment deposition on the fan. Even moderate sized floods from an undisturbed basin can shift the main or side channels across most or all of an alluvial fan; indeed, this is how they form.

Not all portions of an alluvial fan are equally active at any given time, and it is difficult to identify or predict which area of an alluvial fan may be active. Relatively recent activity on one portion of a fan is no guarantee that other portions are inactive. For this reason, development on alluvial fans can be problematic and protective dikes and channel dredging may be required in an attempt to protect roads, bridges, and other structures. These measures are typically aimed at keeping the floods and debris flows on one portion of the fan. Fixing the channel in one portion of the fan is often motivated by placement of a bridge, culvert, or other structures. Intermittent dredging following a moderate or large depositional event, or a number of smaller ones, does not guarantee adequate storage for the next floods and deposition events in the channel; a large flood can still overwhelm the room provided for sediment storage, ultimately sending the floodwaters or channel in alternate directions across the fan.

Developments in the channel migration zone are at risk of destruction and considerable planned or emergency shore armoring, dredging, diking, and other measures are required to control channel migration on developed alluvial fans. Critical structures like bridges can be built to survive most floods, but it is often economically and technically impractical to build houses and other facilities to those standards. Consequently avoidance, limitations of the types of development, and buffers on the channel migration zone, and not just the present channel location, can be used to reduce damage or losses in or near the channel migration zone of alluvial fans. Alluvial fans and adjacent areas are presently regulated in WCC 16.16.340. The purpose of these regulations is to minimize or avoid the need for construction of flood control devices on alluvial fans and to allow for natural hydrologic changes along rivers and streams.

2.3.2.3 Landslides and Erosion Hazards

People affect landslide erosion hazard areas by clearing vegetation, grading and excavating, modifying drainage, and developing on steep slopes. Clearing changes the overall stability of a slope and often increases runoff, erosion, or landslide hazards down-slope or down-stream. Clearing and grading reduce or remove the interception of precipitation provided by vegetation, the litter and loose surface soil layer, and on-site ponding that occurs during short periods of intense rainfall (Konrad 2000, 2003; Konrad and Burgess 2001; Booth 1990; Burgess et al. 1998). Removing vegetation, especially deep-rooted mature plants, reduces or removes the strength that roots provide to the soils on river banks and steep slopes (Bennett and Simon 2004; Gray and Barker 2004; Schiechl 1980; Schiechl and Stern 1996). Roads, ditches, and clearing or modifying the vegetation and litter layer increase runoff and often generate runoff where only infiltration previously occurred. Increased stormflow runoff is then concentrated by surface and subsurface drains, ditches, and roads, and directed down swales and into creeks. The combined cumulative impact of all of these management actions causes surface erosion and landslides if high risk areas are not avoided and adequate control measures are not provided and maintained.

Shoreline erosion is affected in a similar way by excavation and grading that removes some or all of the natural slope structure and strength. Clearing and grading along the shore and inland increase runoff that is directed across the shore zone; causing erosion and promoting landslides. Lake and coastal shorelines, river channels, and streambanks are naturally changing on at least an annual time scale, due to floods, storm waves, and tides; these natural processes of change combine with development modifications, causing even more rapid erosion and slides. Building structures, yards, roads and other development near these active areas creates the need to “fix“ the shore, which often can adversely impact nearby neighbors, wetlands, and aquatic habitat conditions.

Erosion and stormflow runoff damage are typically minimized by restricting, or conditioning development and agricultural management practices. The County soil survey and GIS data can help to identify the general slopes and materials that are most at risk of erosion. GIS analysis can identify the general erosion and landslide hazard areas, but site-specific data and analysis will still be needed to evaluate most ground-disturbing development actions.

2.3.2.4 Seismic Hazards

Human actions have no influence on the likelihood of occurrence, timing, or severity of a seismic event. As a result, avoidance of high-risk hazard areas like tsunami inundation zones or landslide hazard areas are among the few options for most structures. Evacuation coupled to a warning system is one option for tsunamis generated by distance earthquakes but the threat from locally generated flood waves is the greater risk in Whatcom County. With these, the warning time is limited to none.

Measures such as establishing high enough floor elevations and using properly engineered foundation designs need to be taken to avoid the type of coastal flooding and potential wave velocity and heights associated with tsunamis along the Whatcom County coastal and lakeshore areas. Building on fills that are not engineered, or on delta and loose alluvial deposits along the coast or around local lakes, puts structures and residents at great risk from large waves that are generated from submarine or shoreline slumps. Spills and earthquake- or tsunami-related damage to fuel storage tanks, pipelines, and hazardous materials storage areas are of particular concern in Whatcom County. Planning for safe failure of these facilities should be an important part of risk reduction.

Mass wasting or inundation damage from seismic events can be reduced by not building in high risk inundation areas, building or upgrading existing structures to better survive or safely fail when large waves hit, or evacuating if warning occurs soon enough. A warning network is used to reduce the coastal tsunami hazard along the Pacific coast including Whatcom County; however, warning for local seismic events and large wave hazards around inland lakes would not be fast enough to allow evacuation.

The Whatcom County building code standards are the main vehicle for reducing risks from seismic hazards. WCC (15.28) mentions seismic bracing for fuel tanks; emergency response for earthquakes is assigned in WCC (2.40) to the Emergency Management Director and County Sheriff's Department.

2.3.2.5 Volcanic Hazards

Human activities do not influence volcanic events, but volcanic hazards do greatly influence us (Schuster 1989). During an active period of a Cascade volcano there can be many small steam and ash explosions or dome building events that make the immediate area around the mountain dangerous. Larger eruptions or debris flows are not as common but do occur so that at least every few generations there is likely to be some type of relatively dramatic event. The most effective response to these risks is emergency planning and preparation to allow evacuation of high and moderate hazard areas and not locating critical structures in high hazard areas.

2.3.2.6 Mine Hazard Areas

Areas over mines can experience subsidence and slumping from collapse of mine tunnels, entrances, or air shafts. Without checking maps, property owners may not even know if mine workings underlie their land. Known mine entrances and vents should be properly stabilized and closed to minimize risks.

2.4 HAZARD MANAGEMENT AND PROTECTION TOOLS

One way to address geologic hazard risk management is to acknowledge that our knowledge and ability to predict some risks are often limited, and to use the best available information and apply a factor of safety. This is a common approach in engineering, where the factor of safety is greater for less well investigated problems or factors that are more difficult to predict. Safety factors vary with the development type, with more caution taken for critical structures where failure could be more serious. With geologic hazards the factor of safety often involves excluding some development types in some areas and defining buffers or areas where development is restricted or allowed pursuant to special engineering or other intensive and often more costly approaches.

Fundamental physical geologic processes need to be identified, and numerous secondary impacts may also need to be considered. Failure to consider the entire physical and social environment that relates to a project often results in significant public costs. For example, dikes or dredging may result in channel changes, and clearing or drainage from roads which could result in increased runoff, increasing the size and number of floods. Therefore, modern approaches for evaluating and regulating development tend to include comprehensive ways of assessing and mitigating land development risks.

Geologic hazard assessments can be used to rank the relative risk associated with different hazardous areas. Development limitations, building or other hazard constraints, and guidelines can be applied to the moderate and high risk areas. Not all geologic processes can be influenced or controlled by human action. However, some natural geologic processes such as erosion, landslides, and river channel migration can be exacerbated by land use practices such as shore defense works, dredging, drainage modifications, road

construction, vegetation clearing, and grading. Generally, designating and classifying the hazard areas are the first steps in managing the risks and protecting human life and property. The most successful and ultimately least costly protection from geologic hazards is often avoidance of known hazardous areas. This includes activities on adjacent areas that may result in an increased failure hazard that moves off site, down slope, or downstream. Other common regulatory approaches to managing hazardous areas include restrictions on the types of developments; requirements for building setbacks, buffers, and vegetation management; adherence to building codes; and development of monitoring and warning systems, evacuation plans, and recovery plans. The majority of these measures are included in the County's existing regulations as noted below.

2.4.1 Channel Migration Hazard Areas

Channel migration areas are identified through mapping of landforms and vegetation associated with channel migration, analysis of historic maps and photographs, and surface and subsurface geologic studies. Identification of these hazards helps with land use planning, minimizes exposure to risks, reduces the need for and maintenance of protection works, and reduces damage to channel conditions essential for aquatic habitat (Brice 1977; Collins and Sheikh 2003; Dunne and Dietrich 1978; Kerr Wood and Leidal 2003, 2004; Nanson and Hickin 1996; Perkins 1996, 1993; Rapp and Abbe 2003; Shannon & Wilson 1991).

Classification of channel migration hazards can depend on many factors (Rapp and Abbe 2003). The size of a river or creek, watershed conditions, valley bottom materials and conditions, river gradient, degree and type of encroachment, and many other factors cumulatively create the potential for some rivers or creeks to migrate or jump across the valley bottom. Most river and creek channels migrate to some degree. Small creeks can be subject to substantial floods and migration similar to large rivers.

Riverine flood damage is often the result of high water impacts, combined with erosion and deposition from channel migration or shifting. Facilities near the main river or creek channel are typically at greatest risk unless there is bedrock or substantial bank protection. Historic encroachment near or in a channel migration zone motivates bank armoring, dikes, channel dredging, and other measures aimed at forcing the river into a static condition in a narrow area. This approach is often costly, difficult to maintain, has up- and downstream impacts, and adversely affects aquatic habitat.

Natural or managed buffers along channels are often used to avoid damage to structures or agricultural fields, reduce erosion, provide for riparian and aquatic habitat biodiversity, and protect water quality. Buffers are often requested or required based on multiple objectives (Kondolf et al. 2003). Vegetated buffers provide shade, bank erosion protection, and water quality protection. Common vegetated buffer widths used for rivers and creeks vary from 50 feet to 100 feet. As channels move, the buffer can be reduced or lost completely, reducing or eliminating the benefits of establishing the buffer.

Channel migration zones often include a portion of the flood-prone area of a river or stream, but in many areas the channel migration zone can be a lot larger or smaller than the floodway. Geologic features such as glacial age terraces, or bedrock banks commonly serve as boundaries to the channel migration zone. Engineered and maintained levees are considered the channel migration boundary if they meet approved building standards, but poorly built, abandoned, and undocumented levees often are not substantial enough to limit channel migration or jumping.

Floodway and migration zone development that fails to acknowledge the dynamic nature of rivers has led to a cycle of continuous development and maintenance of protection projects. The most basic but least used approach to reducing problems related to stream channel migration is simply to allow adequate room

for stream processes. Although this approach conflicts with historic development and property ownership, long-term reduction of shoreline encroachment (over 30 to 100 years) will greatly reduce flood and channel migration damage costs and will allow for restoration of aquatic habitat, which is almost impossible to accomplish while the encroachment still exists. Long-term planning needs to account for and work with ongoing stream processes; this will reduce the danger from sudden channel changes, reduce flood and river management costs, and allow for aquatic habitat improvements from protection and maintenance projects.

An example of channel migration regulations developed for rivers similar to those in Whatcom County are the King County sensitive area rules and guidelines related to alterations within channel migration areas (King County Code Chapter 21A to 24). The King County channel migration regulations are based on estimating the extent of channel changes over the past 100 years or as far back as map or ground evidence can demonstrate. Some types of development are restricted and setback buffers are established based on flood heights and the documented channel changes. Maps that delineate high and moderate channel migration hazard areas have been prepared for portions of four rivers. Application of the King County rules depends on detailed studies of historic maps, aerial photographs, and field surface and subsurface investigations. In some areas the channel migration zone is fairly easy to define because of older terraces or bedrock, but in others the migration zone may not be well defined.

Delineation of the channel migration zone of the Nooksack River is ongoing but high, moderate, and low hazard zones have not been estimated. Studies are also needed to identify the boundaries of creek channel migration zones and estimate high risk areas. The same approaches used to estimate the migration hazard areas of rivers are used for creeks.

2.4.2 Alluvial Fan Hazard Areas

Development has been common on alluvial fans because they are outside the main river floodplains, are relatively flat compared to the steep valley walls, are well drained, have easily accessible water supplies, and generally have great views of the surrounding landscape. These qualities make alluvial fans attractive development sites along the valley edges of Whatcom County.

The hazards of building on alluvial fans may not always be apparent in humid regions because dense forest cover gives the false impression that the alluvial fans are inactive (Orme 1989). In addition, incision of the main channels, formation of apparent terraces, short-term channel stability, sediment routing, and the complex response of stream channels can be difficult to interpret even with extensive detailed investigations and analysis (Cazanacli et al. 2002; Whipple et al. 1998; Muto and Steel 2004). Past problems on alluvial and debris fans include sediment deposition, channel migration, the need for repeated channel dredging or diking, damage to bridges and structures, and loss of life. These all indicate that regulation of development on fans is needed to protect public safety and reduce hazards to public and private resources. It is clear, based on local, regional, and worldwide studies of alluvial fans, as well as local past experience, that many large or small alluvial fans can be very dangerous during storms depending on watershed, valley, and channel conditions. It takes detailed geologic and watershed studies to evaluate alluvial fan hazards.

Development (including road construction, logging, and even sparse residential development) in watersheds that feed alluvial fans increases the rainfall-runoff response of the watershed. This leads in turn to increased frequency, magnitude, and duration of flood peaks in the small valley wall swales and creeks, as well as the main valley-bottom creek. Vegetation clearing and addition of ditches can concentrate the increased storm runoff and intercept shallow groundwater runoff. Incision and bank slumps occur more often, making the valley walls and channel banks less stable and more prone to

increased bedload sediment transport and debris flows. Stormwater detention to reduce runoff is required for most urban and suburban development, but has rarely been used for logging, rural roads, or sparse residential development. Dense developments typically detain only a small part of the increased stormflow, so the hillslopes and channels still adjust to flow changes. Consequently, existing or proposed development is more at risk of flooding, increased deposition, and channel activity on downstream alluvial fans (Booth 1989; Booth et al. 1999; Burgess et al. 1998; Konrad 2000, 2003).

Analysis of watershed, valley bottom, channel, and alluvial fan conditions are all used to assess alluvial fan conditions. Some alluvial fans in Whatcom County have been mapped in a variety of studies, but no single study has comprehensively mapped and classified all of them. Identifying alluvial fans is just the first step in evaluating their potential hazards. Numerous alluvial fans are apparent on area topographic maps, and larger ones are identified on area geology and soils maps (Easterbrook 1976a,b, 1992; Dragovich et al. 1997; Lapen 2000; Goldin 1992). Fans that directly influence the Nooksack River channel were mapped in a recent channel migration study by Collins and Sheikh (2004).

Alluvial fans that are more prone to debris flows and dam break conditions can be distinguished from less active ones by analysis of valley confinement and slope models (Benda and Cundy 1990), but assessment of risks require more extensive studies (Kerr, Wood, and Leidal 2003, 2004). Based on topographic and watershed conditions, a first-level screening process could be used for a relative classification system to help identify higher risk fans in Whatcom County. Such a process would employ methods and concepts developed by Benda and Cundy (1990); Benda and Dunne (1997); Dietrich et al. (1995); and Montgomery et al. (2003). A comprehensive classification of alluvial fans is needed in Whatcom County, and those fans with the greatest risk to people should be studied in detail to develop approaches to reduce hazards. The recent Canyon Creek and Jones Creek alluvial fan studies (Kerr, Wood, and Leidal 2003, 2004) are examples of the types of alluvial fan assessments that are needed for areas identified as high-hazard alluvial fans. These studies provide a basic assessment of each alluvial fan and estimate of hazard levels on various portions.

Strategies for mitigating damage associated with alluvial fans include moving structures out of high-risk areas, avoiding construction in some areas, using pile filters to help remove logs and large rocks from floods or debris flows, and building dikes and dredging channels to fix the channel location. Dredging and dike construction can also be used to increase the channel's capacity to store flood sediment, minimize major channel shifting. Some problems related to safety on alluvial fans are difficult to mitigate because of costs; in addition, common mitigation solutions typically conflict with stream aquatic habitat conditions in many creeks. Whatcom County currently prohibits clearing within alluvial fan hazard areas unless tree retention issues are adequately addressed.

2.4.3 Landslide Hazard Areas

Factors that affect landsliding include precipitation, channel network shape, drainage area, elevation, relief, slope, aspect, geologic materials, vegetation history and condition, roads, and other ground disturbance (Selby 1993; Montgomery et al. 1998). Avoidance of existing and at-risk landslide areas is the primary management tool that responds to all of these risk factors. Land use and construction management can respond to the vegetation and ground disturbance factors. Areas at risk of landslides can be identified by mapping existing failure sites and classifying areas with similar conditions.

A common approach used in the past to identify landslide risk areas was to classify hazard based primarily on slope or the presence of existing slides. Areas with gentle slopes are often considered to have a lower risk of landslides. Slope gradients less than about 15 percent are typically classified as low hazard. Landslide risks in low-slope areas are typically related to deep-seated rotational slides or run-out

from slides generated in nearby steeper terrain. For example, one type of low-slope landslide hazard area in Whatcom County is on the nearly flat deltas, alluvial fans, and unconsolidated fill or alluvium along lakeshores or the coast.

Steeper areas have more landslides because of the greater slope, more active soil processes, and surface and subsurface water conditions (Baum et al. 1998; Chatwin et al. 1991; Dietrich et al. 1992; Gerstel and Brunengo 1994; Swanston 1997; Thorsen 1989). Slopes steeper than about 35 percent typically have more landslides and are classified as higher risk landslide hazard areas for clearing and grading. Slopes steeper than about 60 percent present an elevated slide risk with road building or tree cutting (Swanston 1970, 1978, 1980, 1981, 1989, 1997).

The County Geologic Hazards Map (Whatcom County 1997) shows areas with slopes of 15 percent or greater and slopes over 35 percent. Site-specific mapping and analysis of slide-prone sites at the time of development application is the current mechanism for identifying and mitigating landslide and erosion hazard areas in the Whatcom County. WCC 16.16.310 lists a few of the minimum conditions that can indicate landslide hazards, including soil or rock materials, slope, aspect, and water conditions. The County limits development in landslide hazard areas unless drainage, sedimentation, and slope stability are adequately addressed and there is no increase in hazard potential.

Recent research has shown that shallow landslide hazard models can improve estimates of landslide-prone areas by using multiple risk factors in addition to slope (Montgomery and Dietrich 1994; Montgomery et al. 1998). More reliable mapping of landslide risk areas can be achieved by using computer models that classify risk based on slope gradient, slope shape, surface and subsurface geology and soils, and valley and channel confinement and gradient. These models can be further improved by including site factors at existing slide areas. Site-specific analysis would still be needed for evaluation of land use proposals located in moderate and high risk slide areas identified with the area-wide models.

2.4.4 Erosion Hazard Areas

Determination of areas where erosion potential may present a hazard or deliver sediment to surface waters is based on evaluation of soil type, slope gradient, slope length, vegetation condition, precipitation zone, water conditions, slope position, and land use. The Whatcom County Soil Survey (Goldin 1992), and available topographic and hydrographic data in the County's GIS system, can be used to estimate areas of high, moderate, and low erosion potential.

Generally it is assumed that bare soils on construction sites and agriculture fields will erode, so temporary and permanent erosion control measures are employed to reduce soil loss and delivery to surface waters. Soil erosion and surface water drainage are commonly administered through drainage plans, grading plans, and erosion control plans that are a part of project design, construction, and maintenance. The County implements special erosion and water quality regulations in sensitive watersheds such as the Drayton Harbor, Lake Whatcom, and Lake Samish watersheds. The federal EPA Phase-2 Storm Water regulations, administered by Whatcom County, require that a Construction General Storm Water NPDES permit be obtained for clearing or land-disturbing activities greater than one acre. One of the main conditions of this permit is the development and implementation of a site-specific surface water pollution prevention plan.

2.4.5 Seismic Hazard Areas

Delineation of ground shaking and ground failure hazards by mapping and site-specific prediction analysis is an important step in the process of reducing the effects of earthquakes (Rogers et al. 1998). Ground-shaking and ground-failure hazard maps are valuable in land use policy development, sighting or

relocation of local government emergency facilities, and urban renewal decisions (Rogers et al. 1998). Seismic ground shaking and ground failure hazards are estimated based on analysis of regional historic earthquake records, location and physical properties of geologic deposits, topography and sediment thickness, basin geometry, water conditions, analysis of factors affecting the attenuation of ground motion, seismic and geologic mapping of active faults, and mapping and analysis of site-specific geologic conditions (Rogers et al. 1998). Preparation of seismic hazard maps based on this level of information is far from complete in the Pacific Northwest (Rogers et al. 1998). Currently and in the near future, decisions will need to be made based on applying a factor of safety to the best available information.

Building standards that are varied by building type and use are adopted to help reduce earthquake damage and injuries. Considerable engineering is applied to the design and review of seismic loading on critical structures. Extensive site mapping and analysis are needed to support foundation and structure design. Being prepared, avoiding high hazard site locations and conditions, and implementing building standards to minimize danger during and immediately following an earthquake, are the main approaches used to reducing seismic hazards. These approaches are currently employed by Whatcom County.

Structure design and layout can help to reduce danger during earthquakes. Locally generated tsunamis and seiches happen quite fast, so people near the water should be educated to evacuate from the lakeshore and coast following warnings or local earthquakes to reduce the safety risk from landslides or large waves.

2.4.6 Volcanic Hazard Areas

Geologic mapping around the Cascade volcanoes preceding and following the destruction from the 1980 Mount St. Helens eruption provided the wakeup call for more studies, monitoring, and preparation for these dangerous but relatively infrequent geologic hazards (Schuster 1989). Studies of Mount Baker, other volcanoes in the region, and worldwide, provide a much better indication of the early warning conditions of a volcano and the frequency with which these large events can occur (Gardner et al. 1995; Hyde and Crandell 1978). The Volcano Observatory web site (<http://vulcan.wr.usgs.gov/home.html>) summarizes some of the Mount Baker studies and provides a good overview of the possible types of hazards. The USGS Open File Report 95-49 (Gardner et al. 1995) open file report provides a preliminary estimate of the volcanic hazards around Mount Baker.

2.5 FINDINGS AND CODE RECOMMENDATIONS

In Whatcom County the basic regulatory framework for geologically hazardous areas is well developed. Some geological hazard areas have not been formally designated and some require expanded or updated designations. These include volcanic hazard areas, channel migration and alluvial fan hazards, seismic-related coastal and inland lake shoreline wave hazards, and seismic-related landslide hazard areas for hillslopes and shorelines. Land use and management practices can have a significant influence on some geologic hazards as well as public and private resources. Historic encroachment into previously unknown or unacknowledged geologic hazard areas needs to be addressed.

2.5.1 Coastal Geologically Hazardous Areas

Setbacks for development features should be established based on landslide hazard (Gerstel et al. 1997) and coastal erosion potential, instead of by the character and density of development in the adjacent area (existing shoreline designations).

Proposed development within those buffers or within the slide area should meet scientifically based design and construction standards such as the International Building Code. Because of the highly variable nature of areas that are subject to landsliding, site-specific studies should be required for design and construction of structures that are built in or adjacent to landslide hazard areas. The hazard area and proposed development should be evaluated by a geotechnical engineer or engineering geologist, including subsurface exploration, soil sampling, soil testing, and development of a detailed construction sequencing and monitoring plan.

Vegetation management for maintaining stability of slopes is an important element of an overall bluff management program (Chatwin 1991; Greenway 1987; Menashe 1993). Improved vegetation management on the bluff face and bluff crest can provide significant benefits to slope stability in the majority of the study area. This is particularly true in the developed and partially developed portions of Whatcom County bluffs. Retention of large conifer trees, especially Douglas-fir and western redcedar, is very important in maintaining widespread root strength in upper soils. Conifers can also provide significant benefits in terms of water balance in bluff soils through evapotranspiration, which continues through winter in conifers, although at lower levels. Retention of deciduous species such as big-leaf maple is also beneficial for slope stability. These trees have high erosion control and high root strength, which can prevent and retard landsliding (Menashe 1993), as compared to removal of trees from steep slopes, which can lead to an increase in landsliding (Bishop and Stevens 1964; Figure 12a). Other species with high root strength include ocean spray, Nootka rose, snowberry, and other native woody plants. These species should be retained where present and/ or replanted where slopes are not well vegetated.

Retaining or creating a vegetated buffer landward of the bank crest can also provide a significant slope stability benefit. This is through increased shallow and (relatively) deep root strength as well as the uptake of shallow subsurface water. A vegetated buffer also reduces surface water flow during rainfall events, which decreases the erosion potential. Minimum vegetated buffer widths are on the order of 20 to 30 feet (as measured from the bluff crest landward) with greater widths providing greater benefit. Appropriate native plants should be used within vegetative buffers, as discussed for bluff face, above.

Preparing for safe failure of fuel storage and hazardous materials facilities and pipelines is only briefly mentioned in the present code. Additional review and evaluation of current conditions is warranted given the large impacts to the economy and aquatic habitat that can occur from large petroleum or hazardous spills.

2.5.1.1 Avoidance of Tsunami Hazards

Building standards and restrictions can help reduce damage but for large waves we simply need to get out of the way. Tsunami hazards are minimized by building restrictions along the coast in known hazard areas. The existing tsunami hazard monitoring system should be supported and local warning methods refined. Existing critical structures like hazardous materials or petroleum storage facilities should be moved away from tsunami hazard areas and built for safe failure for seismic loadings.

Analysis and modeling of the most at-risk areas can be estimated based on seismic and wave model studies (Vanurato et al. 2004), however, these studies have only included Cascadia subduction zone earthquake-induced tsunamis. Additional research should be completed on local faults and tsunami hazards, and incorporated into hazard assessment and planning. Areas of high wave impact could be classified and the hazard listed on property titles, and warning signs and sirens should be placed in low-lying public areas.

2.5.2 Inland Geologically Hazardous Areas

2.5.2.1 Channel Migration Hazard Areas

Flood damage, degradation of stream channel and streambank habitat conditions, and development in the flood and channel migration zone are all closely related. Development in the floodway and channel migration zone creates the danger; such development is as risky as deliberately stepping into the path of a moving train, except a stream has considerably more energy. It is also now recognized that measures intended to protect structures that encroach into the channel migration zone and floodway have degraded and delayed the development of healthy aquatic habitat conditions. Precluding new development in areas that need bank armoring, dikes, and dredging to remain safe is a recommended approach for reducing the hazard. Such restrictions would also allow for stream resource values, reduce flood damage risks, and reduce costs. In a similar manner, reducing or eliminating historic encroachment removes the motivation for costly maintenance and rebuilding of protection facilities and associated on-site and downstream public and private resource damage.

Alluvial fans are recognized as a geologically hazardous area in Whatcom County (WCC 16.16) but channel migration zones on creeks and rivers presently are not. Collins and Sheikh (2004) evaluated the historical channel positions for the Nooksack River; this information can be used as the basis for planning and code development along the Nooksack River. Channel migrations also occur on tributary creeks but have been evaluated only at isolated sites. Generally, smaller creek areas with armored banks or dikes probably had channel migration as well as flooding concerns. Whatcom County should examine the King County code provisions to develop similar regulations for channel migration areas specific to the local conditions.

2.5.2.2 Alluvial Fan Hazard Areas

Alluvial fans are one type of particularly active and hazardous channel migration and debris flow run-out zone that was added to the Whatcom County code (WCC 16.16) because of a number of storms that caused extensive damage. Alluvial fan hazards, flood damage, degradation of stream channel and streambank habitat, and development in the flood, channel migration, and debris flow hazard zone, are all very much related. Dredging and dikes are common approaches for attempting to address flooding and limit bank erosion and channel migration on alluvial fans. Encroachment into the floodway and channel migration zone of the fan motivates channel and bank armoring of various types. Precluding development in areas that need extensive streambank armoring and channel dredging to remain safe is a recommended approach for reducing alluvial fan hazards. In a similar manner, reducing or eliminating historic encroachment removes the motivation for costly shore dredging, armoring, or diking on site, and minimizes downstream resource damage. In watersheds that deliver to alluvial fans, land management approaches—for example, the Washington State watershed analysis and prescriptions approach, or stormwater drainage control and landslide and debris flow hazard reduction studies—can reduce alluvial fan hazards.

More detailed mapping is required to fully address alluvial fan hazards in Whatcom County. Once such maps are available, a hazard rating system could be developed to identify the low, moderate, and higher hazard alluvial fans. Detailed studies of the developed high-hazard alluvial fans have been prepared for Jones and Canyon Creeks (Kerr, Wood, and Leidal 2003, 2004). These show the need to restrict new applications for new development and to seek approaches to reduce the hazard on developed fan areas. Additional detailed studies for new development on higher risk alluvial fans should be required at the time of application for building permits. However, identifying risk areas on alluvial fans depends on

detailed subsurface and surface geologic mapping and watershed studies; such studies may require more resources than are typically available to the average landowner.

A large flood often will fill an existing natural or dredged alluvial fan channel, overwhelming the available storage capacity and sending the flood in various directions across the fan. This is how channels migrate and form the classic fan shape. As a result, alluvial fan risk assessments must include evaluation of conditions assuming the channel has filled to natural levels and can spill the flood to other portions of the fan.

Clearing is one action that is restricted on alluvial fans (WCC 16.16 350 I). Other tools for risk management on alluvial fans include precluding or restricting some types of development, improving watershed conditions, channel excavations, dikes, and debris filters, monitoring, warning, and evacuation plans. Some of these actions are problematic because they directly conflict or influence public resources like water quality, wetland and aquatic habitat, and would need to be implemented in ways that avoid adverse impacts on these on-site and downstream resources.

2.5.2.3 Landslide Hazard Areas

Landslide hazards are addressed in Chapter 16.16.310. The general opening statement (16.16.310 A) and slope range in the WCC are inclusive of common landslide-prone areas in Whatcom County. WCC 16.16 lists the minimum conditions that may indicate landslide-prone areas. The current Whatcom County landslide hazard slope criteria identify two hazard classes based on slope (15 to 35 percent and >35 percent). This appears reasonable, and is in line with hillslope studies and code requirements in the region. The state's model code uses a similar steep slope criterion (40 percent). Using two classes and starting at the 15 percent slope gradient provide a better understanding of site conditions and include the full range of areas where slides are typically an issue. Some jurisdictions divide the slopes into 3 or more hazard levels with more restrictions and buffers applied to the higher-gradient slopes. Building setbacks, vegetated buffers, and drainage guidelines are commonly used to reduce hazards from landslides or in landslide run-out areas.

Other site-specific factors that increase landslide hazard are not specifically listed in the code. These include slope shape, seismic shaking, grading, and vegetation conversion. The code (WCC 16.16.310 A 3) designates streambank, lake, and marine shoreline areas with banks greater than 10 feet high but shorter banks can also slump and erode. Mass wasting in these areas is linked to normal shore wave, tide, and other shore processes, floods, channel migration, and seismic hazards in the region. Slopes less than 10 feet high should be considered a geologically hazardous area where slope conditions or forces acting on the slope increase the potential for mass wasting. One example of this type of hazard is the unconsolidated deposits around lakes, especially delta deposits. Many lakes in Whatcom County were formed by sub-glacial scour and consequently are quite deep. Deltas and slide deposits around their shores are made of loose, saturated materials that often have steep fronts. Shaking from small local or large regional earthquakes can cause slumps in these deposits, which can be dangerous to shore facilities. Displacement from such slumps generates waves that wash across the lake and back to shore, causing inundation and impact hazards (Foster and Karlstrom 1966; Hansen 1966; McCulloch 1966; McCulloch and Bonilla 1970; Plafker 1969; Wilson and Torum 1972). This can happen so rapidly that evacuation may not be effective. For example, detailed studies of Lake Washington showed that almost every bay around the lake is actually the head scarp of a large landslide, and numerous slides and buried forests are present (Karlin 2004). Similar studies are needed on populated Whatcom County lakes and coastal areas to identify areas at risk of inundation of wave impact.

Landslide and erosion hazard areas on some private and most state-owned forest lands in Whatcom County are also identified and conditioned through the Washington State Forest Practices Act, Watershed Analysis and prescriptions, and emergency rules. These are science-based rules that will, over the long term, reduce the risks of landslides, debris flows, and increased sediment loads from creeks that drain from state and private forest lands in Whatcom County.

Because small landslide areas and many erosion areas can be modified with structures and other construction methods, the code should remain adaptable. This places considerable responsibility on site-specific studies, design approaches, review processes, construction methods, and effective monitoring. The minimum reporting and performance standards for landslide analysis and erosion control should be quite specific, because these standards address a hazard that is not always that easy to assess. Reporting and performance standards also need to support compliance with State and Federal water quality standards.

Adding in more specifics to the code—similar to the state’s model code, but retaining the slope range from the current Whatcom County code—could make site evaluation expectations, reporting, and review easier and more consistent. A detailed surface geology map for the County, combined with topography, soils, land use and other data, would help in the first-level screening for hazard areas. A county-wide map would also provide a context for site-specific mapping conducted for development proposals. Site-specific mapping should be a part of every development permit.

2.5.2.4 Erosion Hazard Areas

Whatcom County erosion hazards are addressed to various degrees in a variety of code chapters and standards. Erosion is mentioned in the following County regulations:

- Chapter 16.16 CRITICAL AREAS, (protect the public from harm due to erosion);
- Chapter 12.48 ROADSIDE VEGETATION (backslopes and front slopes where vegetation is maintained to prevent erosion);
- Chapter 14.04 RIGHT TO PRACTICE FORESTRY (to control erosion and slope failure);
- Chapter 16.28 MANURE AND AGRICULTURAL NUTRIENT MANAGEMENT
- Chapter 17.04 GENERAL PROVISIONS (restricting or prohibiting uses which are dangerous to health, safety, and property due to water or erosion hazards, or which result in damaging increases in erosion);
- Chapter 20.34 RURAL RESIDENTIAL-ISLAND;
- Chapter 20.36 RURAL (R) DISTRICT (the development and performance standards of WCC 20.73.650 and 20.73.700. (6) All topsoil remains on site for use in subsequent reclamation. (7) No soil erosion or sedimentation will occur beyond the exterior property lines of the site, and (8));
- Chapter 20.40 AGRICULTURE (AG) DISTRICT ((9) No soil erosion or sedimentation will occur beyond the exterior property lines of the site. (10) Excavation activity will commence and conclude within four years);
- Chapter 20.42 RURAL FORESTRY (RF) DISTRICT;
- Chapter 20.43 COMMERCIAL FORESTRY (CF) DISTRICT;
- Chapter 20.72 POINT ROBERTS SPECIAL DISTRICT;
- Chapter 20.80 SUPPLEMENTARY REQUIREMENTS;

- Chapter 24.05 ON-SITE SEWAGE SYSTEM REGULATIONS; (small development activities are required to employ best management practices (BMPs), to control erosion and sediment during construction, to permanently stabilize soil exposed during construction, to protect adjacent properties and water bodies from stormwater effects caused by development).

With so many code references, erosion and erosion control are clearly important issues. In addition other authorities, such as the Washington Department of Ecology (Ecology) oversee drainage activities, BMP utilization, and water quality standards related to the Clean Water Act.

The County should consider developing one comprehensive set of building, drainage, and erosion guidelines and regulations that focus on protecting health, safety, and public resources, including water and aquatic habitat. Some counties develop separate erosion control regulations while others combine them with drainage, grading, building, or landslide portions of the code. The Whatcom County standards specify that source control BMPs be selected, designed and maintained according to the latest edition of the Ecology Manual.

The current Whatcom County standards for erosion and sediment control address most of Ecology's proposed requirements. Ecology's Construction Stormwater Pollution Prevention Plan (SWPPP) Element #12, Manage the Project, is not explicitly included in the current code. This element includes construction phasing requirements, seasonal work limitations, and inspection and monitoring requirements. Seasonal restrictions are often added to in-stream and near-stream projects. Frequently, however, the expense of extra erosion control measures is worthwhile for many wet-season construction projects. Ecology also proposes that a certified professional with training and experience in erosion and sediment control be involved in the erosion control plan design, and be on-site or on call at all times for performance inspections and modifications. The main association doing national registration for erosion control professionals is the International Erosion Control Association, in Steamboat Springs, Colorado.

Because most erosion concerns are so closely associated with drainage control, ground disturbing activities, and landslides; it is recommended that a single Erosion and Drainage Control section be developed for the code. The primary approach should be performance-oriented and included in the design, construction, and maintenance of development sites. Erosion control measures need to be included on project site plans and required in construction contracts. Inspection during project development is required to document performance, and failures need explicit responses.

Typical erosion regulations are oriented to new construction and may not adequately address erosion control for agriculture, roads, and hobby farms. The County shall consider keeping agricultural districts regulated with approaches similar to those provided by the USDA Natural Resources Conservation Service (NRCS) (formally USDS Soil Conservation Service). The County shall also apply these guidelines to hobby farms and consider adding erosion control guidelines specific to roads and road maintenance.

For all land disturbing activities that could deliver sediment off-site or to surface waters, or that are larger than one acre, Whatcom County should adopt Ecology standards or similar approaches for erosion control. The County should further require that erosion control plans be developed by professionals familiar with erosion control design, installation, and monitoring in the Puget Sound region. If the County lacks inspection and enforcement powers, the effectiveness of erosion control is left in the hands of project managers and contractors. Many project managers and contractors understand the importance of standard erosion control methods; some developers and many private builders, however, still require education. To address the resistance to effective erosion and drainage control measures, some regions have used one-day short courses for heavy equipment operators, explicit inclusion of erosion control

measures in permits and building contracts, requirements for secured performance bonds, or fines against escrow accounts.

Most guidelines and BMPs address erosion control of new construction. Erosion related to ongoing maintenance of roads or fields can be overlooked if standards are not attached to contracts. Differentiating erosion control guidelines among development types will allow for the big differences in erosion control measures for urban or residential areas compared to agricultural, commercial, and industrial areas.

2.5.2.5 Seismic Hazard Areas

Although some areas face a greater risk than others, all of Whatcom County is potentially at risk of significant earthquake damage. To respond to our changing understanding of the seismic risk in this region, the County should continue to link regulations to the International Building Code and relevant local U. S. Geological Survey (USGS) or other agency documents and studies; as codes and studies change, the County code should also change. The County should establish exemplary seismic retrofitting and new construction and development standards for this tectonically active area.

The state's model seismic hazard code is fairly limited, but provides a general approach that could be adapted for Whatcom County. For example, the state's list of allowed activities would likely require additional detail and categories for Whatcom County. Experienced geotechnical engineers, geologists, engineering geologists, and structural engineers should perform analyses of seismic conditions. Most construction is covered by standard building codes specifically dealing with seismic hazard reduction. Critical and specialized structures receive special analysis and design conditions that exceed standard code guidelines. This is particularly true for ports and industrial facilities in Whatcom County. Safe failure of these large facilities is important to the health and safety of workers and local residents, and to Puget Sound waters.

Three main approaches are often taken when hazardous forces (e.g., earthquakes) are inevitable: (1) a fail-safe approach, (2) a safe-failure approach, or (3) a combination approach. A fail-safe design is intended to survive shaking with little or no damage; this approach is often attempted with very critical structures. The safe-failure approach is where the design cannot practically be built to survive shaking or because the structure is less critical and can be allowed to fail. For the combination approach, fail-safe designs are attempted up to a practical design level, and safe-failure aspects are included to reduce the hazard when shaking exceeds design standards. Approaches 1 and 3 work for critical structures, and approach 2 is appropriate for homes and low-occupancy buildings. Existing structures can be at least partly retrofitted to meet many safe-failure standards. The greatest costs and engineering challenges are retrofitting existing critical facilities for safe failure. For example, many bridges or oil and gas storage and processing facilities were not originally built to survive damage caused by shaking or waves. Such facilities face greater challenges in preventing potential large spills or failures of high use routes. Consequently, new regulations should consider data collection and design codes for new construction, as well as guidelines and programs for retrofitting existing facilities.

Minimum regulations to help reduce injury and damage should be implemented countywide, and should not be limited to any one landtype. Sites with greater damage risk, such as shorelines, thick unconsolidated soils, or steep slopes, could be screened on a broad scale. This would only be a first-level screening, however, and would miss numerous isolated or poorly mapped areas, potentially under-representing risk. Basing design criteria on proximity to known active faults or unstable soils does not address the risk posed by unrecognized faults or fault activity, or deep subsurface conditions. Even in alluvial basins with known risks, the complex interactions of seismic reflections and basin materials make prediction difficult and risky, so safety factors on designs will always be needed. With existing soils and

geology maps, only general zones of higher risks can be classified. As detailed surface and subsurface geologic mapping and analysis become available in the future, it may be possible to differentiate hazard zones more precisely. This type of mapping is usually done only in small areas (e.g., for large critical structures). Widespread mapping is accomplished at a slower pace, as it is conducted by graduate students or through regional research by the USGS and others.

The Sumas and Nooksack valleys and Nooksack delta form a deep depositional basin containing unconsolidated saturated fluvial glacial and inter-glacial sediment that can amplify the ground-shaking energy and disturbance during an earthquake. Shallow, loose and saturated soils can easily deform or liquefy during ground shaking and are found in many areas throughout the County, such as the Nooksack floodplain or Sumas valley. These areas were identified based on the soil survey fieldwork completed for the County soils survey completed in 1982 (Goldin 1992).

Building standards for seismically active areas are generally based on region-wide tectonic and seismic studies from the past few decades. Estimates of the likely vertical and horizontal accelerations and displacement are calculated and used as the basis for static and dynamic design for various types of structures. In areas of high risk, upgrades and retrofits are common for the numerous structures built using older standards. Currently, the County has no process to screen for the structures that need retrofits, and no programs to motivate appropriate retrofits.

Estimates of seismically induced landslide and run-out hazard areas are based on slope gradient and shape, materials, probabilities of moisture conditions, and the presence of past slope failures. Seismic shaking is only one of many factors influencing landslide hazard; linking the seismic and landslide hazard regulations would be a reasonable approach. Seismically induced landslide hazards could be addressed in the landslide section of the code and simply mentioned in the seismic section, or vice-versa. In a similar way, tsunami and seiche hazard areas could be addressed in the seismic regulations and mentioned in the landslide code. Tsunami and seiche hazard areas may be identified in a separate geologically hazardous areas estimate based on Washington Department of Natural Resources modeling of seismic and shore hazards, or on future updates.

Because of the risk of great earthquakes, mapping and analysis for each development is needed to establish site-specific seismic loading design criteria. Specific seismic regulations may be needed for the highest risk zones such as the coastal zone, landslide-prone slopes and run-out areas, shoreline slump hazard areas, lakeshore seiches, areas with shallow loose saturated soils, and areas over deep unconsolidated sedimentary basins. Each development should be required to provide site-specific information to support the general classifications and selected design criteria.

Seismic hazard studies specific to Whatcom County and a detailed map of the surface and subsurface geology would help further identify liquefaction, landslide, and ground shaking hazard areas. This may or may not provide additional development latitude compared to less-specific regional information. No single factor (e.g., local fault locations or liquefaction potential) fully defines seismic risk. Many other factors influence seismic risk, for example, the shape of the consolidated bedrock below the Nooksack delta or deep thrust faults.

The County could be segmented into a few seismic hazard classes, but current studies should be updated before fully committing to that approach. Consequently, the most supportable approach for the present and near future may be to base using building standards on the type of building or development, and to apply the same standard countywide.

2.5.2.6 Volcanic Hazard Areas

The present approach for volcanic hazard mapping in Washington State and other regions has been to define hazard zones around volcanoes. These zones are based on historic and ancient occurrence of volcanic hazards, as described by geologic mapping around the volcano and in surrounding valleys, combined with debris flow run-out modeling. Hazard zones are estimated for the main risks, including blast zone, pyroclastic flows, debris flows (lahars), ash fall, and outburst floods. When monitoring indicates an elevated risk, the public and agencies are warned based on the best information at the time.

The state's model code, the Pierce County code, and proposed volcanic hazard codes for cities around Mount Rainier are based on USGS hazard zone estimates. All call for warning and evacuation plans, as well as restrictions on critical structures such as schools, large occupancy structures, and hazardous chemical tanks. Three different hazard zones were defined in the vicinity of Mount Rainier (Rogers et al. 1996). In that area, Case I debris flows (lahars) are estimated to have an average return interval between events of 500 and 1,000 years. Case II lahars are estimated to have an average return interval of 100 to 500 years. In the vicinity of Mount Rainier, therefore, the occurrence risk of Case II lahars approaches that of 100-year floods (one-percent chance in any given year). Each volcano has a unique combination of history and hazard conditions. Similar to Mount Rainier, Mount Baker requires further study to identify hazard areas and to provide more data to estimate the frequency of volcanic events.

The model code does not provide enough specifics for volcanic hazards, but does have language on reporting and performance standards. The Pierce County Volcanic Hazard Areas Title (18E.40.050) was updated based on a USGS report (Rogers et al. 1996), and is the basis for the volcanic hazard classes in the Pierce County code. A later USGS (Rogers et al. 1996) report substantially modified hazard zones, based on additional studies and findings. This will replace the 1995 report in Pierce County, and is proposed for adoption by other local cities. The Whatcom County code should be adaptable to the changes that will result from additional studies and analysis.

Lateral blasts, debris flows, pyroclastic flows, and surges can move so fast that warning and evacuation are effective only if accomplished well in advance of the actual event. Adequate monitoring and response is essential for public safety. Warning signs, warning systems, and evacuation plans in conjunction with monitoring have been developed for areas around Mount St. Helens and Mount Rainier. Monitoring of earthquakes and volcanoes for all the Cascade volcanoes including Mount Baker is provided by the Pacific Northwest Seismograph Network (PNSN). The PNSN uses a network of seismic sensors to locate earthquakes in Washington and Oregon (<http://www.geophy.washington.edu/SEIS/PNSN/>). If earthquakes are associated with Cascade volcanoes (as recently occurred with Mount St. Helens), the PNSN warns the appropriate agencies.

Response pre-planning has been established for Mount Baker with the Mount Baker-Glacier Peak Coordination Plan. The plan provides a framework for coordination between governmental agencies in the event of volcanic unrest at Mount Baker or Glacier Peak. The areas around Mount Baker and Glacier Peak are continuously monitored by the PNSN, which is jointly operated by the University of Washington and the USGS. When indications of volcanic unrest occur at Mount Baker or Glacier Peak, the plan calls for establishing a temporary volcano observatory and emergency operations center. The plan also calls for installing additional monitoring instruments to analyze conditions.

Identifying the extent and frequency of volcanic events is an ongoing and important part of dealing with the risks near the Cascade volcanoes. Measures that can be taken to reduce volcanic hazard risks include limitations on critical structures in volcanic hazard areas, monitoring for hazard conditions, early warning systems, and evacuation plans. Ongoing studies and monitoring should be expanded, and further detailed studies conducted to increase our knowledge and ability to evaluate the extent and frequency of volcanic hazards around Mount Baker. Although relatively rare, volcanic events can be pose a significant hazard to health and safety, and have significant impacts on public resources. Because the risk of a catastrophic

volcanic event in Whatcom County is significant, further study of the Mount Baker volcano is warranted. Other precautionary measures include the following:

- Upgrading Mount Baker monitoring, warning, and research facilities,
- Establishing evacuation plans, warning signs, and rehearsed evacuations,
- Attaching notification of volcanic hazards to property titles and building permits in high-hazard areas, and
- Restricting the types of structures that are built in high-risk volcanic hazard areas.

The consequences of lahars, debris flows, and outburst floods can be devastating. These events have occurred in the past in Whatcom County and will occur in the future. Therefore, a hazard classification approach and appropriate regulations should be adopted. There are many example and model codes and approaches for dealing with landslides, erosion, and flooding, but codes related to the volcanic hazards associated with Mount Baker are scarce. Modified for local conditions, the Pierce County ordinance (Title 18E.40.050) would be a good model to consider for Whatcom County. Additional examples of model volcano land use ordinances were requested on the worldwide Volcano ListServ by the USGS Cascades Volcano Observatory (Driedger 2003), but the Pierce County ordinance may be the only one not primarily related to actual lava inundation.

The Pierce County ordinance is only one page long and is included:

18E.40.050 Volcanic Hazard Areas.

A. General. Volcanic hazard areas are areas subject to pyroclastic flows, lava flows, and inundation by debris flows, mudflows, or related flooding resulting from geologic and volcanic events on Mount Rainier.

B. Classification.

- 1. Criteria. Volcanic hazard areas are those areas that have been historically inundated by a Case I, Case II, or Case III debris flow or are located in other drainages expected to be inundated by a future Case I, Case II, or Case III debris flow as identified in the report entitled, Sedimentology, Behavior, and Hazards of Debris Flows at Mount Rainier, Washington, U.S. Geological Survey Professional Paper 1547, 1995.*
- 2. Sources. The following sources were used to identify volcanic hazard areas that are depicted in the Critical Areas Atlas-Volcanic Hazard Areas Map (see Section 18E.10.060 B.):*
 - a. "Map Showing Debris Flows and Debris Avalanches at Mount Rainier, Washington--Historical and Potential Future Inundation Areas," Hydrogeologic Investigations Atlas HA-729, U.S. Dept. of Interior, Geologic Survey, 1995 as amended by Kevin Scott, USGS, on November 10, 1997, to be consistent with the reports listed as b. and c. below;*
 - b. Volcano Hazards from Mount Rainier, Washington by Hoblitt et al. (1998), U.S. Geological Survey Open File Report 98-428;*
 - c. Sedimentology, Behavior, and Hazards of Debris Flows at Mount Rainier, Washington, U.S. Geological Survey Professional Paper 1547, 1995; and*
 - d. Emergency Action Plan for Nisqually Hydroelectric Project, Federal Energy Regulatory Commission (FERC) Project No. 1862, December 13, 1996, City of Tacoma, Department of Public Utilities, Light Division.*

C. *Regulations for Location of Critical Facilities. No critical facilities shall be constructed or located in volcanic hazard areas. Critical facilities are those facilities listed below, as selected from the Uniform Building Code, 1994 Edition, Table No. 16-K, Occupancy Category:*

1. *Hospitals and other medical facilities having surgery and emergency treatment areas;*
2. *Structures or housing supporting or containing sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released;*
3. *Covered structures whose primary occupancy is public assembly, with a capacity of greater than 300 persons;*
4. *Buildings for schools through secondary or day-care centers, with a capacity of greater than 250 students;*
5. *Buildings for colleges or adult education schools, with a capacity of greater than 500 students;*
6. *Medical facilities with 50 or more resident incapacitated patients;*
7. *Jails and detention facilities; and*
8. *All structures with occupancy of greater than 5,000 people. (Ord. 97-84 § 8 (part), 1997)*

Critical structures are typically restricted from the higher-risk volcanic hazard zones. Whatcom County, as a minimum, should adopt some form of risk classification for the valleys around Mount Baker. The valley bottom of the Nooksack River generally defines the area at risk of eruption-related lahars. This area also includes the floodway and channel migration zone of the Nooksack River, so some of this area is already known to be geologically hazardous.

Public education (e.g., the Mount Baker web page), technical and administrative memory, monitoring, and warning systems are all important for informing the public and agencies of the risks and present status of the mountain. Detailed geologic mapping and analysis for Whatcom County for each of the main volcanic hazards (blast zone, pyroclastic flows, lahars, lava flows, ash fall, and outburst floods) can be used to establish hazard zones based on risk, and used to guide development regulations.

The definition and regulation of critical structures presented in part ‘C’ of the Pierce County example (above) is similar to those adopted and proposed by cities around Mount Rainer. Similar provisions are recommended for the volcanic hazard areas in Whatcom County.

Whatcom County should include volcanic hazards in the geologic hazard code similar to the Pierce County code. Identification of hazard areas should be based on the USGS Open File Report 95-49 (Gardner et al. 1995), and updated with information in Hildreth et al. (2003). The code should provide for updates based on more detailed studies; the County should encourage such studies. Additional detailed mapping of the lahar and eruption history of Mount Baker eventually can be used to classify downstream volcanic hazard zones with greater confidence and in greater detail. Existing mountain monitoring, emergency planning, and management should be supported and regularly updated.

2.5.3 Summary of Findings and Recommendations

The existing Whatcom County code is well developed and the geologically hazardous standards are generally founded in science. The following table summarizes some changes that should be made to strengthen the code.

Geologic Hazard Findings and Recommendations

Coastal Hazard Areas

<u>Finding #1</u>	Development on coastal bluffs should meet science-based standards for design and construction. Site-specific studies are needed to address wave, flooding, and landslide hazard potential on coastal and shoreline bluffs.
<u>Recommendation</u>	Require building standards to be consistent with the international building code. Define minimum study and reporting requirements to include subsurface exploration, site hazard analysis, soil sampling, and development of monitoring plans.
<u>Finding #2</u>	Vegetation management is essential for mitigating landslide hazard potential on coastal bluffs.
<u>Recommendation</u>	Include provisions for requiring setbacks from the top and toe of landslide-prone bluffs where necessary. Include provisions to require retention of native vegetation on steep slopes to improve stability.

Channel Migration Hazards

<u>Finding #3</u>	Failure to recognize the dynamic nature of river and stream systems can lead to flood damage to public and private facilities. Response to channel changes motivates costly dredging and bank armoring that degrades critical aquatic and riparian habitat.
<u>Recommendation</u>	Create a channel migration hazard map and consider linking riparian buffer requirements to the channel migration zone in high-risk channel migration areas.

Alluvial Fan Hazards

<u>Finding #4</u>	Assessing risk associated with active portions of alluvial fans is sometimes difficult; basing this assessment on recent deposition (past 20 to 100 years) may not provide adequate protection.
<u>Recommendation</u>	Consider all alluvial fan areas active unless analysis of fan topography, stratigraphy, and watersheds demonstrates otherwise. Tie building restrictions to hazard zones.
<u>Finding #5</u>	Building structures and roads on alluvial fans often creates a need to dike the channel and/or dredge portions of the channel.
<u>Recommendation</u>	Avoid construction of major structures/facilities on alluvial fans. Consider requiring road designs that allow the channel to migrate without extensive dredging or diking.
<u>Finding #6</u>	Catastrophic debris flows can be generated from steep confined channels and deposited on alluvial fans.
<u>Recommendation</u>	Identify hazard class for all alluvial fans based on assessment of channel, valley, and watershed conditions, and develop an appropriate regulatory program.

Seismic Hazards

<u>Finding #7</u>	Seismic hazards are present throughout the County, with higher risk areas associated with certain substrate materials, slope position near landslide-prone areas, and shorelines.
<u>Recommendation</u>	Continue to use uniform building code standards (or the International Building Code) but do not limit the hazard regulations to alluvial basins or areas with organic layers. Also, base the building standards on the classification of the structure (e.g., residence, barn, critical structure).
<u>Finding #8</u>	Seismic risk can be reduced building standards for new development and retrofits for existing structures
<u>Recommendation</u>	Continue updating building code standards based on best available science and engineering.
<u>Finding #9</u>	Seismically induced underwater or shoreline slumps in loose saturated shoreline deposits are a hazard in inland lakes.
<u>Recommendation</u>	Add a new category of landslide hazard and map the lakes to identify high, moderate, and low risk zones. Link it to the landslide and seismic hazard codes.
<u>Finding #10</u>	Seismically induced landslides are a hazard that should explicitly be addressed in the code.

Geologic Hazard Findings and Recommendations	
<u>Recommendation</u>	Add code language that identifies seismically generated landslide and run-out areas, and develop an approach to classify high, moderate, and low risk areas. Link the code to the landslide and seismic hazard codes.
Erosion Hazards	
<u>Finding #11</u>	Erosion risk areas are not specifically designated as geologically hazardous areas in Whatcom County code.
<u>Recommendation</u>	Add erosion hazard designation and regulations similar to the state's model code
Landslide Hazard Areas	
<u>Finding #12</u>	The basic landslide guidelines for percent slope are adequate, with the exception of the need to address seismically induced slides as discussed above.
<u>Recommendation</u>	Maintain existing regulations. Consider adding provisions to require buffers or setbacks from the toe and top of landslide-prone slopes and run-out zones where warranted.
<u>Finding #13</u>	Code does not provide guidance to review staff on minimum studies for steep slope landslide or erosion hazards, potentially making staff review difficult or inconsistent.
<u>Recommendation</u>	Develop minimum professional standards for analysis and reporting for slope stability studies.
Volcanic Hazard Areas	
<u>Finding #14</u>	Volcanic hazards are not presently addressed in the code.
<u>Recommendation</u>	Add volcanic hazard regulation similar to the Pierce County Code, based on USGS Open File Report 95-49 (Gardner et al. 1995), and updated with information in Hildreth et al. (2003).
<u>Finding #15</u>	Volcanic hazards in Whatcom County include areas near Mount Baker as well as the downstream valleys.
<u>Recommendation</u>	Attach warnings to building permits and titles disclosing the nature of the hazard.
<u>Finding #16</u>	Evacuation is one of the ways down-valley volcanic hazards are addressed.
<u>Recommendation</u>	Establish a monitoring and warning system and requirements for evacuation for predicted debris flow and lahar run-out areas. Continue to evaluate volcanic hazard areas around Mount Baker to better understand and define hazard areas.
All Hazard Areas	
<u>Finding #17</u>	Present code does not stipulate minimum criteria for hazard studies, potentially making staff review difficult or inconsistent.
<u>Recommendation</u>	Develop minimum professional standards for analysis and reporting for slope stability studies.
<u>Finding #18</u>	Costs of diking, dredging, and habitat damage resulting from channel migration, deposition on alluvial fans, landslides, and other geologic hazards are often partially or wholly borne by public funds, even though they are for a limited number of private facilities.
<u>Recommendation</u>	Include language with the building permits and attach to titles stipulations that protection of private property is the responsibility of the landowner. Require notice on title to disclose presence of a hazard area as part of the County's permit process. Require and facilitate maintenance districts to provide for funding and maintaining these facilities similar to what is done with major dikes.

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3. FREQUENTLY FLOODED AREAS

For regulatory purposes, frequently flooded areas are defined as “lands in the floodplain subject to a one percent or greater chance of flooding in any given year” (WAC 365-190-030 (7), Minimum Guidelines to Classify Agriculture, Forest, Mineral Lands, and Critical Areas). This is equivalent to the 100-year floodplain designation mapped by the Federal Emergency Management Agency (FEMA) on Flood Insurance Rate Maps (FIRMs). The FIRMs delineate the FEMA designated floodway (the area of the floodplain that should be reserved or kept free of obstructions) to allow floodwaters to move downstream and to prevent substantial increases in flood heights) and the flood fringe (the 100-year floodplain outside the designated floodway). The floodway is managed for conveyance of floodwaters, while the flood fringe is managed to provide storage, but not to provide significant conveyance. The 100-year flood is also termed the Base Flood, and the total area subject to flooding during the 100-year flood is the Area of Special Flood Hazard.

Development within a floodplain creates a risk to human health and property. Floodplain development also poses risks to aquatic habitats and species. This includes habitats for Chinook salmon and bull trout, listed as Threatened in the Puget Sound Evolutionarily Significant Unit (ESU); and coho salmon, listed as a Species of Concern in the Puget Sound ESU.

WAC 365-190-080 (3) states that counties and cities should consider the following when designating and classifying frequently flooded areas:

- Effects of flooding on human health and safety, and to public facilities and services;
- Available documentation including federal, state, and local laws, regulations, and programs, local studies and maps, and federal flood insurance programs;
- The future flow floodplain defined in the WAC as defined as the channel of the stream and that portion of the adjoining floodplain that is necessary to contain and discharge the base flood flow at build out without any measurable increase in flood heights;
- The potential effects of tsunamis, high tides with strong winds, sea level rise resulting from global climate change, and greater surface runoff caused by increasing impervious surfaces.

This chapter discusses frequently flooded areas chiefly from the perspective of flood effects on human health, safety, and property protection, and the effects of human activities on flooding. The authors recognize that the floodplain development has the potential to affect all other critical areas regulated by WCC Title 16.16. For the most part, the ecological issues associated with floodplain management will be addressed in the chapters for wetlands, and fish and wildlife habitat conservation areas. Floodplain management issues will also be addressed in the chapter for geologically hazardous areas and aquifer recharge areas. One important goal of these reviews will be to ensure that the connection between frequently flooded areas and the other critical areas regulated under WCC Title 16.16 is integrated so that ecological impacts associated with development within frequently flooded areas are adequately reviewed.

3.1 OVERVIEW OF INVENTORY

3.1.1 Existing Inventory

FEMA mapping of the 100-year floodplain provides the basis for designation, protection, and regulation of frequently flooded areas. The Whatcom County floodplain inventory uses FEMA’s mapping (WCC 16.16.140).

The January 16, 2004 FIRMs for Whatcom County are the official effective maps for Whatcom County, every city and town in the County, and the Lummi Nation and Nooksack Tribe. FEMA distributed the information to the County in digital format and it is available via Whatcom County Planning and Development Services GIS. Steele (2004 personal communication) indicates that the new maps meet FEMA's digitization standards in the Map Modernization Guidelines and Specifications (FEMA 2003a). FEMA published the maps in a new countywide format (instead of separate maps for individual jurisdictions, all maps are on the same map series). The primary purpose of the January 16, 2004 series is to place all existing data onto a single, countywide map series. The January 16, 2004 FIRMs include new information for Sandy Point³, Terrell Creek, Samish River, Squalicum Creek, Everson-Sumas overflow corridor, and many coastal areas.

3.1.2 Updates to Inventory

FEMA initiated a nationwide effort in 1997 to modernize the flood mapping program (FEMA 2001). The updated maps will use digital orthophotogrammetry to produce more accurate base maps, from which improved floodplain boundaries will be delineated. In conducting the Map Modernization Program, FEMA will consult with, receive information from, and enter into agreements or other arrangements with State, regional, and local agencies to identify floodplain areas. The intent of using local agencies is to provide more accurate representations of floodplain conditions (FEMA 2003a). As stated above, the January 16, 2004 Whatcom County FIRMs represent new technical information only for Sandy Point, which was developed according to FEMA's Map Modernization Program.

Although the FEMA maps are the official effective maps for Whatcom County, these maps are in need of revision. The floodplain information contained in the January 16, 2004 FIRMs was developed or updated in the late 1970s for incorporated cities and unincorporated Whatcom County (FEMA 2003b, 2004a). The exception is new data that was prepared for Sandy Point, which was incorporated into the January 16, 2004 FIRM update. The Lower Nooksack River Comprehensive Flood Hazard Management Plan (Whatcom County Department of Public Works 1997) notes that the FEMA maps fail to address the path and depth of floodwaters outside the floodway. For example, the November 10, 1990 flood (the largest flood on record) was estimated to be a 50-year event, yet in some areas the flood levels during that event exceeded the 100-year elevations shown on the FEMA maps. Additionally, the FEMA maps delineate floodway limits by determining a corridor outside of which flow can be blocked without raising flood levels more than 1 foot. While this approach is appropriate for rivers where the main channel is the dominant flow corridor, it is not suitable for the lower Nooksack River and the lower North and Middle Forks of the Nooksack River, where parallel side channels up to a half mile from the main channel are an important element of the floodway. There are currently no federal efforts to update the FIRMs, but as discussed in the Lower Nooksack River Comprehensive Flood Hazard Management Plan, local efforts at hydraulic modeling have been underway to improve delineations of frequently flooded areas. This modeling, when complete, would be used to update the FIRMs. However, after multiple floodplain modeling attempts, there is not sufficient confidence in the modeling for changes to be made to the FIRMs.

The Lower Nooksack River Comprehensive Flood Hazard Management Plan contains recommendations for floodplain management and flood control facilities; any implemented recommendations should be recorded on the updated FEMA maps.

³ The new data for Sandy Point was prepared by Philip Williams & Assoc. for Whatcom County.

A study by Collins and Sheikh (2004) delineated historical channel positions of the Nooksack River from the mouth to RM 56 on the North Fork, South Fork to South Fork RM 16, and Middle Fork to Middle Fork RM 5⁴. The Collins study delineates the geomorphic floodplain (the floodplain that is actively being formed by the stream or water body) and is not relevant to definition of frequently flooded areas. The Lower Nooksack River Comprehensive Flood Management Plan (Whatcom County Department of Public Works 1997) includes mapping of levees on the Lower Nooksack River completed through 1988. Substantial additional levee construction has been completed since 1988. Whatcom County is in the process of preparing digital mapping of floodplain modifications (revetments and levees). This mapping may be completed in late 2004, but is not a high priority project for the County.

Regarding tsunami hazards, Whatcom County does not have an official tsunami hazard map. Walsh et al. (2004) has mapped predicted tsunami hazard zones for Bellingham Bay and Lummi Bay; this map shows the two main risks associated with tsunamis – inundation depth and wave velocity. The map was produced using computer models of earthquake-generated tsunamis originating from the Cascadia subduction zone. The map shows that the greatest amount of tsunami flooding is expected to occur in the valleys of the Lummi and Nooksack Rivers up to their confluence near Ferndale. Beyond that point, flooding would be confined to the relatively narrow valley of the Nooksack River. Sandy Point is expected to be flooded to a depth of a few feet. Elsewhere, tsunami flooding is expected only in the immediate vicinity of the shoreline. The Walsh report does not include other populated areas with likely tsunami hazards, including Point Roberts, Marietta, Gooseberry Point, Birch Bay, and Semiahmoo. Tsunami inundation and water velocity hazards for these areas should also be mapped. Recommendations for tsunami hazards are discussed in Findings and Recommendations. Lahar hazards are discussed in Chapter 2.

3.2 FLOODPLAIN FUNCTIONS AND VALUES

Floodplains store flood waters, which reduces the height, areal extent, and velocity of floodwaters at the point where the floodplain storage exists, as well as upstream and downstream areas. If the areal extent of the floodplain is constricted, greater depths will occur for a given flood. Backwatering occurs as water amasses at a location, reducing the hydraulic gradient from upstream areas, in turn reducing flow velocity and flow rate. A greater area of floodplain storage at a given location will result in lower flood depths at that point, in turn reducing backwater effects and reducing upstream flood heights. Flood storage provided at any point in the stream also slows the movement of water downstream, reducing flood height and extent in downstream areas.

Floodplains also provide for reductions in flow velocity, reduced erosion, and enhanced settling of sediment. As water overflows from the main channel of a river or stream, it spreads over the land surface, resulting in a much wider flow path cross-section. Additionally, vegetation in the floodplain creates roughness. A wider cross-section and increased roughness result in lower flow velocity, which in turn, reduces the erosive power of flowing water. Reduced velocity and physical trapping in vegetation also allow for suspended sediment to settle in the floodplain. This provides a mutual benefit for the floodplain and stream, depositing fertile soil and nutrients in the floodplain, and reducing sedimentation in the stream channel. An added benefit of river flow over the floodplain (and the associated reduction in velocities in the main channel) is recruitment and retention of large woody debris (LWD) in the channel; LWD is a critical element of salmonid habitat.

⁴ All river miles refer to river miles marked on USGS 7.5-minute topographic maps.

Floodplains are an interface between groundwater and surface water, providing areas of groundwater discharge or recharge. These areas may vary spatially or seasonally. For example, some areas may always be a discharge or recharge point, based on relatively constant groundwater levels and flow patterns. Other areas may act as a recharge point during dry months when the water table is low, and a discharge point during the wet season when the water table rises. Groundwater recharge and discharge are critical to maintaining baseflows, which are in turn critical to maintaining aquatic habitat and water quality during dry months (by maintaining wetted channels and delivery of cool, oxygenated water).

Floodplains are also a setting for riparian ecosystems. Riparian ecosystems are found where high water tables, overbank flooding, or channel meandering occur. Riparian ecosystems are a highly variable environment, both spatially and temporally. They form a transition between terrestrial and aquatic ecosystems. They are saturated or flooded during most of the wet season, while the water table recedes below the root surface during the summer. Riparian ecosystems have a high flux of energy, water, and other material. As such, they generally have high plant and animal species diversity, high species and biomass density, and high productivity (Mitch and Gosselink 1993). The importance of riparian areas to fish and wildlife is discussed in the Chapters 6 and 7.

Caplow et al. (1992) identified 367 wetlands in the Nooksack River floodplain⁵, covering 6,406 acres, or approximately 18 percent of the floodplain. Table 3-1 shows the percent of identified wetlands that provided various ecological functions according to the rating categories developed for the study.

Table 3-1. Functions of Nooksack River Floodplain Wetlands (from Caplow et al. 1992)

Wildlife Habitat	74% ^a
Fish Habitat	76% ^b
Flood Storage	86% ^a
Base Flow Support	78% ^c
Water Quality	98% ^a
Groundwater Discharge	40% ^{c, d}
Groundwater Recharge	100% ^{c, d}
Cultural	68% ^a
Shoreline Stabilization	52% ^a
Heritage	58% ^a

^a Function/Value rated as Medium or High, on a scale of Low, Medium, and High. Remaining wetlands rated low for that function.

^b Function/Value rated as Possible or Known, on a scale of Unlikely, Possible, and Known. Remaining wetlands are rated unlikely to provide the function.

^c Function/Value rated as Possible or Probable, on a scale of Unlikely, Possible, and Probable. Remaining wetlands are rated unlikely to provide the function.

^d Caplow et al. (1992) state that the Nooksack River floodplain is underlain by an unconfined aquifer, thus all wetlands in the floodplain are considered likely to act as recharge wetlands. Caplow et al. state that the evaluation of groundwater discharge is speculative, and is based on indicators such as inundation, lack of inlets, springs, and peat. All wetlands in the floodplain are considered recharge wetlands, while only some of them may have indicators of discharge.

The functions and values listed above are also described in subsequent chapters pertaining to wetlands, fish and wildlife habitat, geologically hazardous areas, and aquifer recharge areas.

⁵ Within the FEMA 100-year flood boundary, from the mouth of the river to the limits of County jurisdiction, including the South, Middle, and North Forks.

3.3 HUMAN ACTIVITY AND FREQUENTLY FLOODED AREAS

The most common types of human disturbance to floodplains are filling, channelization, creation or alteration of barriers, and alteration of land cover. Each of these is described below.

Filling is typically performed to floodproof an area so that it may be developed. Without compensatory volume replacement, filling would reduce floodplain storage. FEMA model regulations require that the cumulative effect of a proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community. Additionally, fill in the floodway (where water is likely to be deepest and fastest) will potentially create constrictions that increase flood heights. FEMA model regulations require that proposed encroachments in the floodway not increase flood levels during the occurrence of the 100-year flood discharge (FEMA 2004b).

Filling, paving, soil compaction, and construction of impervious surfaces also increase runoff (increasing peak flows and durations of elevated flows) and reduce infiltration (reducing groundwater recharge and base flows). Surface erosion can also increase from filled sites and from agricultural fields if proper best management practices (BMPs) are not in place (e.g., buffers, relay crops, etc.).

Stream or river channelization can be described as the deliberate or unintended alteration of channel slope, width, depth, sediment roughness or size, or sediment load (Bolton and Shellberg 2001). Widening, deepening, dredging, removal of live or dead vegetation, bank armoring, straightening, and construction of levees or similar structures may alter these variables. The physical effects of channelization include higher flow velocities, increased sediment transport, bank instability, loss of channel capacity, increased flood heights in downstream areas, and draining of wetlands. These effects in turn result in damage to or loss of stream and wetland habitat (Bolton and Shellberg 2001). Channelization also results in loss of natural habitat-forming processes, and even intentional homogenization of the channel. As a result, channel complexity is reduced, and specific habitat types (pool-riffle sequences, logjam-formed pools, meander pools, etc.) are reduced or eliminated. Loss of specific habitat types (pools, eddies, and off-channel areas), increased flow velocity, and longer durations of elevated flows affect fish, invertebrates, and periphyton (an important source of food) by sweeping organisms downstream, and by scouring food or redds.

Filling and channelization also reduce the water quality maintenance function of floodplains, through loss of wetlands and floodplain vegetation that filter sediment, nutrients, and chemicals, and by reducing the volume of flood flow that interacts with the floodplain outside of the channel.

Barriers are features that restrict the movement of water, sediment, animals (fish), or other material such as LWD, either downstream or laterally within the floodplain. Barriers may also restrict channel migration. Barriers include levees, embankments, bridges and culverts, floodplain fill, bioengineering structures (cribwalls, rootwad/rock mixtures, etc.), and walls. Levees protect infrastructure from flooding. Levees also affect conveyance and storage of floodwaters in two ways: (1) levees isolate naturally occurring floodplain storage from the channel, and (2) levees constrict flows to a narrower channel, resulting in increased flow depth and velocity. This may cause increased scour, sedimentation, and transference of flooding problems to downstream areas (Hey 1994). Other types of barriers such as bridges, culverts, fill, and embankments may impede flow, causing greater flood heights. Levees also physically disconnect riparian areas, wetlands, and off-channel habitats from the main channel, which has adverse effects on natural ecological processes (Bolton and Shellberg 2001).

3.4 FLOODPLAIN MANAGEMENT AND PROTECTION TOOLS

There are several mechanisms for managing frequently flooded areas to mitigate flood hazards and protect humans and natural habitats. These are described below.

As a condition of participation in the National Flood Insurance Program (NFIP), communities are required to adopt and enforce a flood hazard reduction ordinance that meets the minimum requirements of the NFIP (44 CFR 60.3); however, Washington State law (RCW 86.16) contains some additional requirements that are more restrictive⁶. FEMA requires that communities meet State standards as well. FEMA and the State of Washington have a Washington Model Flood Damage Prevention Ordinance (FEMA 2004b) based on 44 CFR 60.3 and RCW 86.16. Although the Model Ordinance has recently been updated (FEMA 2004b), the new Model Ordinance is substantially the same as previous versions (the revisions are for consistency and clarity). The Model Ordinance has not been substantially updated because there has been no recent revision to the National Flood Insurance Program or State regulations (Steele 2004). Therefore, Whatcom County's floodplain ordinance remains consistent with the Model Code, and with State and Federal Requirements for flood control and protection.

Whatcom County's ordinance, as based on the Model Ordinance, identifies flood hazard areas, provides procedures for development permits, review, and enforcement, and provides standards for floodproofing and flood control activities. These floodplain management tools are described below.

3.4.1 Restricted Uses

The restriction of development in the floodplain has a threefold purpose: (1) to reduce risk to human health, safety, and property, (2) to prevent development activities from adversely affecting the capacity of the floodplain or floodway to convey and store floodwaters, and (3) to preserve important ecological functions of floodplains.

Development is restricted by the following measures:

- The Model Ordinance (FEMA 2004b) contains language prohibiting development of critical facilities (e.g., schools, hospitals, emergency response facilities) anywhere within the 100-year floodplain. The Model Ordinance does not deem this language mandatory. The primary purpose of this prohibition is to protect the critical facilities, as opposed to protecting floodplain storage. WCC 16.16.430A requires that no critical facilities be constructed in frequently flooded areas without fully mitigating for flood hazards (by floodproofing). The River and Flood Division is in the process of revising WCC Title 17, Flood Damage Prevention, to include: Critical Facilities must be built outside the floodplain or elevated 3 feet above the base flood elevation.
- WCC 17.16.120A and the Model Ordinance prohibit encroachments within the floodway unless it can be demonstrated that the proposed encroachment would not result in any increase in flood levels during the 100-year flood. The purpose of this regulation is to protect floodplain storage and conveyance.
- Development within the floodplain is also indirectly discouraged by requiring flood insurance as a condition of Federal or federally backed financing, and by imposition of building standards that increase the cost of construction within the floodplain (see below).

⁶ RCW 86.16.041(2)(a) prohibits construction or reconstruction, repair, or replacement of residential structures within the floodway, except for repairs that do not increase the ground floor area, or the cost of which does not exceed fifty percent of the market value of the structure. Farmhouses and structures identified as historic places are exempt from this prohibition.

3.4.2 Floodproofing

WCC and the Model Ordinance require floodproofing of new development and substantial improvements to existing development within the floodplain, to reduce damage to structures during floods. Key floodproofing provisions include the following:

- Anchoring to prevent flotation, lateral movement, or collapse;
- Construction of utilities to prevent entry of water during flooding;
- Elevation of residential structures to or above the base flood elevation (BFE)⁷;
- Prohibition of enclosed areas below the lowest floor, or allowance for flow of floodwaters; and
- Elevation of non-residential structures above the BFE or floodproofing so that portions of the structure below the BFE are watertight and non-buoyant⁸.

Tsunami hazard protection and mitigation considerations are not included in the WCC or the Washington Model Ordinance. This is a significant item that should be included in the WCC, ideally addressed separately from frequently flooded areas. Although river flooding and tsunami hazards are similar because they involve inundation and flowing water, tsunamis are much less frequent, yet potentially much more destructive than river flooding (National Tsunami Hazard Mitigation Program 2001). The WCC should be updated to identify tsunami hazard zones, and to establish zoning, building standards, and requirements for protection and location of critical public facilities.

3.4.3 Restricted Alteration of Floodplains or Construction of Barriers

WCC requires that the cumulative effect of proposed development not increase the BFE by more than one foot (WCC 17.12.030A.3) at any point in within the Area of Special Flood Hazard. As noted in Section 2.4.1, WCC 17.16.120A and the Model Ordinance also prohibit encroachments within the floodway unless it can be demonstrated that the proposed encroachment would not result in any increase in flood levels during the 100-year flood.

3.4.4 Flood Hazard Management Planning and Projects

The Whatcom County River and Flood Division is responsible for preparing Comprehensive Flood Hazard Management Plans (CFHMPs) for specific flooding areas, including data collection, hydraulic modeling, alternatives analysis, floodplain mapping and channel migration zone identification, and coordination with the public and other agencies (Whatcom County 2004a). To date the Whatcom County River and Flood Division has completed one CFHMP for the Lower Nooksack River. Other ongoing or recent analyses that may provide information regarding flooding and related risks include the analyses of the South Fork Nooksack River, Swift Creek, Saar Creek, Johnson Creek, Canyon Creek, Jones Creek, Glacier and Gallup Creeks, Sandy Point, and Birch Bay. The major focus of staffing resources has been on the Lower Nooksack River between Deming and Bellingham Bay, including the Everson-Sumas overflow corridor (Note: Many of these were studies associated with geologically hazardous areas and are addressed in Chapter 3.

⁷ WCC requires elevation “to or above” the BFE, which meets the minimum standard in the Model Ordinance. However, elevation to one foot or more above the BFE increases safety and can reduce flood insurance premiums by as much as 30 percent (FEMA 2004b). Note: River and Flood is currently revising Title 17 to include “one foot or more above BFE”.

⁸ FEMA sets insurance premiums based on rates that are one foot below the floodproofed level (e.g., a building floodproofed to the BFE will be rated as one foot below) (FEMA 2004b).

Once a plan is adopted, identified projects are developed and implemented under the County's Flood Hazard Reduction Program (Whatcom County 2004b). The development of flood hazard reduction projects within the context of comprehensive flood hazard management planning ensures problems are not transferred to another location within the basin and that project implementation will result in a long-term reduction in flood damages and public expenditures throughout the basin. Comprehensive flood hazard management planning can also include other objectives, such as protection of floodplain ecological functions and values. The process of project implementation includes detailed analysis and design, permitting, and construction. Flood hazard reduction projects can be either structural or nonstructural in nature. Examples of structural measures considered for the Lower Nooksack River include the construction of setback levees and overflow spillways, and designation of overflow corridors in overbank areas. Nonstructural flood hazard reduction projects include acquisition, relocation, and elevation of flood-prone structures. The repetitive flood loss acquisition project is an example of this type of project.

3.4.5 Flood Response

In Whatcom County, the Public Works Department River and Flood Division works closely with the County's Division of Emergency Management to plan for and implement a coordinated response during flood events to ensure public safety and minimize flood damages (Whatcom County 2004c). Every October, the Department of Emergency Management hosts an annual flood meeting to bring all of the agencies involved in responding to flood events together to review response procedures. Agencies involved in emergency response include:

- US Army Corps of Engineers
- National Weather Service
- Red Cross
- Whatcom County Sheriff's Office
- Police departments within cities impacted by flooding
- Fire departments within cities impacted by flooding
- Fire departments within unincorporated Whatcom County impacted by flooding
- Whatcom County Maintenance and Operations Division
- Lummi Nation
- British Columbia Ministry of Environment
- Washington Department of Fish and Wildlife
- Washington Department of Transportation
- Local media

In addition to coordinating with external agencies, Whatcom County's flood response includes the mobilization of observers to evaluate flooding conditions in the field during floods. The Nooksack River basin is divided into sectors. During a flood, staff from the Engineering Division of Public Works travel throughout their assigned sectors and report back to River and Flood staff on actual flooding conditions in the field throughout the event. River and Flood staff work with DEM and Maintenance and Operations to prioritize problem areas and take appropriate measures to ensure public safety, minimize the loss of public and private property and inform the public of current and expected flood conditions. Once a

problem area is identified in the field, the situation is assessed to evaluate whether actions can be taken to minimize damages. When appropriate, sandbagging operations will be initiated.

3.5 FINDINGS AND CODE RECOMMENDATIONS

Inventory Findings and Recommendations

<u>Finding</u>	Although FEMA Flood Insurance Rate Maps (FIRMs) of the 100-year floodplain provide the basis for designation of frequently flooded areas, these maps are in need of revision. The use of FEMA maps is required for participation in the FEMA Flood Insurance Program. Whatcom County designates Frequently Flooded Areas as “areas subject to a one percent recurrence interval of flood water inundation or a 100-year base flood as mapped by the Federal Emergency Management Agency’s flood insurance rate maps (FIRM) as amended for Whatcom County FEMA’s mapping” (WCC 16.16.410). The January 16, 2004 FIRMs for Whatcom County are the official effective maps for Whatcom County and every city, town and tribe in the County. FEMA is in the process of partnering with local agencies to update the maps with more accurate mapping of floodway and flood fringe conditions. Hydraulic modeling has been started, but has not produced results suitable for map updates.
<u>Recommendation</u>	Revise the FIRM maps as recommended in the Lower Nooksack River Comprehensive Flood Management Plan. Complete hydraulic models using methods consistent with FEMA’s FIRM Modernization guidelines. Incorporate new floodplain mapping. Per WCC 16.16.140 and WCC 17.04.050, the FIRMs and any amendments are adopted into WCC by reference. Continue to use the FIRMs for designation of 100-year floodplain areas.

Functions and Values Findings and Recommendations

<u>Finding</u>	Whatcom County recognizes that natural floodplains, stream channels, and natural protective barriers help accommodate and convey floodwaters (WCC 17.04.030).
<u>Recommendation</u>	Maintain existing language in WCC 17.04.030

Functions and Values Findings and Recommendations

<u>Finding</u>	WCC 16.16.400 (CAO Article pertaining to Frequently Flooded Areas) states “It is the purpose of this article to reduce the risk to life and property damage that result from floods. (Ord. 97-056 § 1).” This statement does not recognize the value of frequently flooded areas for maintaining and providing fish and wildlife habitat.
<u>Recommendation</u>	Revise WCC 16.16.400 to state “It is the purpose of this article to reduce the risk to life, property damage, and public facilities that result from floods, and to protect fish and wildlife habitats that occur within frequently flooded areas. ” Also state the intention that that compliance with Title 17 shall be consistent with the provisions of WCC 16.16 that protect ecological functions and values of critical areas and minimize risks of geologic hazards.

Functions and Values Findings and Recommendations

<u>Finding</u>	WCC language does not establish the value of frequently flooded areas for providing an ecologically necessary flow regime and forming, maintaining, and providing access to a full range of functional salmonid habitats.
<u>Recommendation</u>	Add new language (i.e., a new Section 16.16.410) establishing that, in addition to reducing the risk to life and property damage, frequently flooded areas should also be managed to provide an ecologically necessary flow regime and to form, maintain, and provide access to a full range of functional salmonid habitats.

Flood Hazard Management Findings and Recommendations

<u>Finding</u>	Whatcom County Code (WCC 17.04) is substantially consistent with the latest version of the Washington Model Flood Damage Prevention Ordinance. WCC, as based on the Model Code, identifies flood hazard areas, provides procedures for development permits, review, and enforcement, and provides standards for floodproofing and flood control activities. Except: Whatcom County Code requires elevation “to or above” the base flood elevation (BFE) for residential and non-residential construction. The Model Ordinance advises jurisdictions to adopt a standard requiring elevation to one foot or more above the BFE, to increase safety and reduce flood insurance premiums (FEMA 2004b).
<u>Recommendation</u>	Continue to protect floodplain functions and values through regulating building and development, land clearing, and habitat protection. Revise WCC 17.16.080 and WCC 17.16.090 to require elevation of residential and non-residential structures one foot or more above the BFE (this would be consistent with the Lummi Nation's Flood Damage and Prevention Code (Title 15A of the Lummi Nation Code of Laws).

Flood Hazard Management Findings and Recommendations

<u>Finding</u>	WCC Title 16 (CAO) refers to Title 17 (Flood Damage Prevention), but Title 17 does not refer to Title 16. WCC 16.430B states “All development shall conform to the provisions of WCC Title 17, Flood Damage Prevention. (Ord. 97-056 § 1).”
<u>Recommendation</u>	A similar reference should be adopted within Title 17, stating that flood damage protection activities shall conform to Chapter 16.16.

Flood Hazard Management Findings and Recommendations

<u>Finding</u>	WCC does not include definition of tsunami hazard zones or provisions for protection of human health and property within tsunami hazard zones.
<u>Recommendation</u>	WCC should be updated to include definition of tsunami hazard zones, such as the mapping of Bellingham Bay by Walsh et al. (2004). The Walsh report does not address all tsunami hazard areas in Whatcom County; mapping of other populated tsunami hazard zones should also be undertaken. Title 17 should also be updated to include provisions for protection of human health and property within tsunami hazard zones. These provisions would include zoning, building standards, requirements for protection and location of critical public facilities, and capital facilities to mitigate tsunami hazards. Building standards should include elevation and engineering standards for buildings within tsunami hazard zones, similar to building standards in river flooding hazard areas. Construction of new critical facilities should be prohibited in tsunami hazard areas unless the need for the facility outweighs the consequences of its loss during a tsunami (e.g., a fire station in a remote, tsunami-prone area may be justified because it needs to be close to the population for routine emergencies). Coastal evacuation plans and routes for tsunami hazard areas should be established (including high bluff areas subject to wave erosion and secondary landslides).

3.6 FREQUENTLY FLOODED AREAS REFERENCES

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4. CRITICAL AQUIFER RECHARGE AREAS (CARAS)

Critical aquifer recharge areas (CARAs) are defined as areas that have a critical recharging effect on aquifers used as potable water (WAC 365-190-030). Examples include sole source aquifers designated pursuant to the federal Safe Drinking Water Act areas established for special protection pursuant to RCW 90.44, 90.48, and 90.54, and wellhead protection areas. Critical recharge areas function to protect human health from contaminated drinking water (anti-degradation of ground water), and to maintain stream flows and moderate temperatures for fish and wildlife habitat.

4.1 SUMMARY OF AQUIFERS IN WHATCOM COUNTY

Aquifers in Whatcom County generally occur in permeable glacial deposits and stream valleys in the western part of the County, and in fractured bedrock and localized narrow stream valleys in the mountainous eastern part of the County. The aquifers in the west are most productive and are part of the Puget Sound Aquifer System described by Vacarro et al. (1998). A portion of this aquifer system extends northward into Canada (Abbotsford-Sumas Aquifer International Task Force 1994). Locations of major aquifers in Whatcom County are shown on Figure 1.

Much detailed work has been done to characterize and map surficial aquifers in Whatcom County. Little is known about the size and water quality of confined aquifers in the region. Most of this work has occurred in the Nooksack River Basin, which covers the western half of the County. Aquifers have been explored and described in many basins in Whatcom County including Bertrand Creek, California Creek, Dakota Creek, and Lake Whatcom. Ground water resources have also been studied on the Lummi Indian Reservation and in the major cities and towns, such as Blaine, Lynden, Sumas, Everson, and Point Roberts. These studies have identified the horizontal and vertical extent of major aquifers and intervening aquitards (non-water bearing formations), the occurrence and movement of ground water in these aquifers (including areas of recharge, discharge, and interactions with surface water bodies), and aquifer yields.

The Abbotsford-Sumas aquifer is the principal aquifer of the region, covers an area of approximately 100 square miles, and has a thickness generally ranging from 40 to 80 feet, although the maximum thickness exceeds 240 feet in the vicinity of Abbotsford BC (Cox and Kahle 1999). Depths to groundwater are typically less than 10 feet near streams and rivers, and up to 50 feet in upland areas (Kahle 1990). Ground water in Whatcom County generally flows from recharge areas in the uplands towards the Nooksack and Sumas Rivers, which are regional discharge areas. Ground water contributes a significant volume of baseflow to streams, as discussed below. In coastal areas, ground water also discharges to the marine waters of Georgia Strait and the Puget Sound.

4.2 OVERVIEW OF AQUIFER FUNCTIONS AND VALUES

4.2.1 Drinking Water Supply

Advantages of ground water as a water supply source include natural filtration as precipitation percolates through unsaturated soils; protection from turbidity, algal blooms, and other surface water quality issues; generally constant cool temperature; and readily accessible with wells and pumps. Ground water provides more than 65 percent of drinking water for Washington State through private wells and public water systems (Ground Water Protection Council 2004).

The majority of Whatcom County's drinking water supply capacity is surface water from Lake Whatcom or the Nooksack River, which provides drinking water to approximately 65,000 people (nearly half the County population). However, over 95% of the 347 public water systems in the County rely on ground water, and approximately 20,000 homes obtain water from domestic (exempt) wells (Whatcom County Water Team 1999). The largest purveyors of ground water in the County are the cities of Blaine, Sumas, and Everson (Whatcom County Water Utility Coordinating Committee 1993). The agriculture and dairy industries in the County also rely heavily on ground water for irrigation and process water. Ground-water use in Whatcom County has been estimated at 45 million gallons per day (Utah State University 2002).

4.2.2 Base Flow to Streams

Ground water and surface water systems constantly interact with respect to recharge and discharge of ground water. One critical interaction is discharge of ground water into streams as base flow during parts of the year and the recharge of ground water from streams during other parts of the year. The magnitude and timing of ground water discharge and recharge depends upon the relative elevations of the stream bed and the water table, the flow gradient between the aquifer and the stream, the water-transmitting characteristics of the geologic strata the comprise the aquifer and the stream channel, the location and extent of pumping from ground water wells, drainage activity, climate, and other actions and conditions that affect aquifer recharge. Base flow from ground water also provides critical water volumes to support fish life cycles (including moderation of stream temperatures) and to maintain water supplies that obtain water from streams and rivers.

A number of past and current studies provide insights into base flow contributions from ground water, including Lindsay (1998), Gibbons and Culhane (1994), and Sinclair and Pitz (1999). These studies indicate that the shallow aquifers of Whatcom County are responsible for approximately 70 percent of stream base flow (Ground Water Protection Council 2004).

4.2.3 Discharge to and Recharge from Wetlands

Shallow aquifers can be recharged by wetlands and can also discharge to wetlands that support vegetation and wildlife. Wetlands provide beneficial water quality functions including particulate filtration and buffering of pollutants. The interrelationships of wetlands, aquifer recharge, discharge from shallow aquifers, and water quality occur on both a landscape and site-specific scale. Assessment of the potential impacts of changes in ground water conditions (such as water-table elevation, ground water recharge and discharge rates, and water quality) on wetlands requires field data to define wetland hydrology and function.

4.2.4 Storage of Infiltrated Precipitation

Aquifers can provide temporary storage of the portion of precipitation that infiltrates into the ground and moves downward past the root zone (i.e., is not lost to the system through evapotranspiration). This storage can function as a detention mechanism that reduce stormwater runoff and allow delayed discharge into streams and lakes well after the precipitation event. Stored ground water becomes a resource for water supply, base flow, and discharge to wetlands and other surface water bodies, such as lakes and the marine waters of Georgia Strait and Puget Sound.

4.3 OVERVIEW OF CRITICAL AQUIFER RECHARGE AREA ISSUES

4.3.1 Susceptible Aquifer Recharge Areas

Aquifer susceptibility is defined as the ease with which contaminants can move from source areas to the aquifer based solely on the characteristics of surface and subsurface geologic materials in the unsaturated zone above the aquifer (Cook 2000). For example, an aquifer with a ground water depth less than 20 feet and overlain by coarse sand and gravel would have high susceptibility to contamination, but a confined aquifer overlain by 50 feet of clay would have a relatively low susceptibility.

Susceptibility can be estimated in a number of ways ranging from evaluation matrices supported by the scientific literature and field data, to ground water computer models calibrated with data from field aquifer tests. Studies and mapping conducted to date in Whatcom County (such as Vaccaro et al. 1998; Cox and Kahle 1999; and Utah State University 2002) provide a strong base of information for identification of susceptible aquifer recharge areas.

4.3.2 Vulnerable Aquifer Recharge Areas

Aquifer vulnerability is defined as the combined effects of susceptibility and the presence of chemicals above the aquifer at specific locations (Cook 2000). The factors that contribute to vulnerability include the nature of the chemical threat (potential or confirmed release), the form of the chemicals (solid or liquid), the toxicity of the chemical, and the mobility of the chemicals in the subsurface.

Vulnerability can be approached from varying levels of detail. For example, non-point contamination sources such as agricultural chemicals may best be addressed on a regional scale, whereas point sources such as leaking underground storage tanks or registered hazardous waste disposal sites are best addressed on a site-specific basis. Completed and ongoing contamination studies in Whatcom County have identified a number of impacts to ground water, the largest of which are due to agricultural chemicals, fertilizers, and animal wastes (Erickson 1991, 1992, 1994, and 1998). Impacts to ground water from leaking underground storage tanks and landfills have also been documented (Wang and Peck 1989; Walker and Wyatt 1990). Databases and geographical information systems maintained by the Department of Ecology Toxics Cleanup Program (<http://www.ecy.wa.gov/programs/tcp/cleanup.html>) can provide an efficient means of updating potential or confirmed releases to ground water.

4.3.3 Wellhead Protection Areas

The 1986 amendments to the federal Safe Drinking Water Act mandated measures to protect ground water supplies through wellhead protection. The State of Washington adopted regulations (WAC 246-290-135, Source Water Protection) to address these requirements. Potable water-supply purveyors in Washington using ground water must develop and implement wellhead protection programs that include delineation of protection areas around each well, and inventory of contamination sources within wellhead protection areas, and development and implementation of water supply contingency and spill response plans to address contamination incidents that could cause loss of a well. The U.S. Environmental Protection Agency (1987, 1993) and Washington State Department of Health (1995) provide guidance for wellhead protection program development. A number of water purveyors in Whatcom County have delineated wellhead protection areas, including Blaine, Sumas, Everson, Deer Creek, and Pole Road (Whatcom County Water Team 1999). In addition, the Lummi Nation has a wellhead protection program and has delineated wellhead protection areas that extend north of the Reservation boundary into Whatcom County (LWRD 1997).

The State of Washington wellhead protection regulations exclude individual domestic wells and well systems that do not meet the definition of public water supplies. The well drilling regulations (WAC 173-160) include requirements to locate water wells minimum distances from potential contamination sources such as feedlots and landfills.

4.3.4 Sole Source Aquifers

The federal Safe Drinking Water Act also authorized the United States Environmental Protection Agency (USEPA) to designate aquifers that are the sole or principal source of drinking water for an area. To meet the criteria for designation, a sole source aquifer must supply at least 50 percent of the drinking water to persons living over the aquifer, and there can be no feasible alternate source of drinking water. Designated sole-source aquifers are subject to EPA review for proposed projects that are to receive federal funds and that have the potential to contaminate the aquifer. No sole source aquifers are designated in Whatcom County.

4.3.5 Susceptible Ground Water Management Areas and Special Protection Areas

WAC 173-100-010 provides guidelines, criteria, and procedures for the designation of ground water management areas, subareas, or zones and to set forth a process for the development of ground water management programs. The objectives of these designations are protection of ground water quality, assurance of ground water quantity, and efficient management of water resources for meeting future needs while recognizing existing water rights. WAC-173-200-090 addresses designation of special ground-water protection areas that require special consideration or increased protection. As of this writing, no susceptible ground water management areas or special protection areas have been designated in Whatcom County.

4.3.6 Ground Water Quantity

The quantity of ground water present in aquifers under natural conditions represents an equilibrium of recharge, storage, and discharge, and responds to changes in climate. Land-use activities that can affect ground water quantity by reducing recharge include impervious surfaces with drainage diversion, drainage ditches, ground water cutoff trenches, over-pumping from wells and springs. Increases in recharge also occur as a result of irrigation, leakage from irrigation canals, and septic system discharges in areas served by surface water supplies.

4.4 HUMAN ACTIVITY AND AQUIFER FUNCTIONS

4.4.1 Ground Water Quality

Use and disposal of chemicals is the principal cause of adverse impacts to ground water quality from human activities. Leaks and spills of chemical products and hazardous residues from manufacturing operations, storage tanks, shipping containers, and waste disposal areas are major point sources of contamination. On-site septic systems that are improperly installed or maintained are also potential point-sources of ground water contamination. Non-point sources of ground water contamination include runoff from agricultural areas, field application of fertilizers and manure at greater than agronomic rates, concentrated agricultural feeding operations, paved and unpaved areas used by vehicles or used for chemical storage, and areas where airborne dispersion of hazardous chemicals has contaminated soils. As noted previously in this section, adverse impacts on ground water quality from agricultural operations have already been documented in Whatcom County. Principal chemicals of concern are nitrates (from

fertilizer applications, animal feedlots, and animal waste lagoons) and fumigants used as pesticides (such as ethylene dibromide and dibromo chloropropane).

Recent studies indicate that on-site septic systems can be a significant contributor to ground water contamination, depending upon system density and hydrogeologic conditions. Generally, a maximum density of one system per one acre is sufficient to avoid ground water contamination (Cook 2000). However, varying soil types and depths may cause modification to this one system per one acre suggested density.

Intrusion of saltwater from marine water bodies into coastal aquifers can result from over-pumping of wells and reversal of ground water flow directions from seaward to landward. Areas of the Lummi Indian Reservation have been affected by saltwater intrusion (Whatcom County Water Team 1999).

4.4.2 Ground Water Quantity

Withdrawal of ground water at rates and/or volumes exceeding natural recharge causes depletion of ground-water storage in aquifers. If this situation persists for an extended period of time, significant declines in ground water levels and change of flow gradients and directions can occur, and damaging compaction of the aquifer matrix can result from extreme long-term water level declines. In principle, ground water withdrawals are regulated by the Department of Ecology through water rights, although ground water withdrawals that are less than 5,000 gallons per day (approximately 3.5 gallons per minute continuous pumpage) and for the certain purposes (stock watering, single or group domestic purposes, industrial purposes, or watering a lawn or non-commercial garden that is not larger than one-half acre) are exempt from the water-right permitting process.

Natural ground water recharge rates can be reduced by changes in land use. For example, agricultural drainage systems and drainage systems associated with roads and urban areas are specifically designed and constructed to intercept water that would, in an unaltered state, discharge from the site and recharge aquifers. Similarly, installation of impervious areas (such as pavement and buildings) and soil compaction from heavy equipment, and changes in vegetation type and quantities can affect recharge rates to ground water (Fair 2003). Techniques to mitigate some of these impacts are addressed by the Stormwater Manual for Western Washington (Ecology 2001) and section 20.97.187 (Impervious Surface) of the Whatcom County Code (2004).

Agricultural drainage systems, stormwater collection and conveyance systems in developed areas, and impervious surfaces have the effect of reducing the amount of ground water available to support baseflow in streams. Decreased recharge can lower ground water levels and cause reversal of ground water flow directions and gradients. The aquifer is then recharged by the stream (i.e., stream flow depletions are increased), rather than discharging to the stream to augment baseflow.

4.4.3 CARA Designation

4.4.3.1 Aquifer Susceptibility and Vulnerability to Contamination

Three factors generally dominate determination of aquifer susceptibility (Cook 2000):

- overall permeability of the unsaturated zone (soil and underlying geologic strata);
- thickness of the unsaturated zone (depth to ground water in unconfined aquifers); and
- amount of available recharge.

Rating systems with tables of representative values of geologic characteristics are available from guidance documents (Cook 2000) and technical references. These rating systems can be applied to specific aquifers to obtain a relative susceptibility score, which can then be used to support development of policies and protective measures.

Aquifer vulnerability is generally more difficult to address because of the significant amount of time required to obtain and organize information regarding the distribution of chemicals in areas underlain by aquifers. Organizations with effective geographic information system (GIS) resources and staff availability (such as Whatcom County) are best equipped to add a vulnerability component to CARA designation. Existing resources such as the pilot study of aquifer vulnerability in the Nooksack Basin (Morgan 1999), the contaminated sites mapped by the Department of Ecology, and the documented areas of nitrate and pesticide contamination are available to support this effort.

Data already compiled and described above for Whatcom County are sufficient to support determination of aquifer susceptibility and vulnerability. General recommendations regarding rating systems are provided below.

4.4.3.2 Wellhead Protection Areas

Wellhead protection areas (WHPAs) designated by water purveyors (as required by WAC 246-290-145) and wellhead protection areas delineated by the Lummi Nation (LWRD 1997) should be added to the County's CARA map. Zones corresponding to the 1-, 5-, and 10-year ground-water travel times to each well or well field should be shown, if available. Superposition of all designated WHPAs illustrates where aquifers are currently used for water supply. The mapping should be update periodically to allow for additions and deletions of specific water wells. WHPA delineation data for Whatcom County public water supply systems are available for transfer to a CARA map.

4.4.3.3 Areas of Ground Water Overdrafts and Water-Level Declines

The quantity aspect of CARAs is best addressed by identifying and mapping aquifer areas where withdrawals have caused depletion of storage and resulting declines in water levels (i.e., "ground water mining"). Other contributing factors to ground water level declines include agricultural drainage systems installed to lower ground water levels, stormwater collection and conveyance systems along roads, and impedance of ground water recharge by impervious surfaces. These phenomena may be evident on a local or regional basis. Ground water mining is a seasonal issue in Whatcom County, which is a concern in terms of instream flow, water quality (including saltwater intrusion), and well pumping. While current information is insufficient to determine if net depletions are occurring on an annual basis, the resulting seasonal changes in ground water levels can have significant impacts to ground water recharge, ground water discharge, ground water availability, and ground water quality.

4.4.4 Inventory of Known or Potential Ground Water Contamination Sources

The USEPA maintains records of Superfund site investigations and cleanups in Washington State. The Department of Ecology maintains records of confirmed and suspected chemical releases; locations of underground storage tanks; holders of permits for discharges to ground water; and holders of permits for hazardous waste treatment, storage, and disposal facilities. The Whatcom County Health Department issues permits for solid waste facilities and has records regarding the regulatory status of each facility. Database search firms are also available for custom searches in specific areas regarding chemical storage and releases to the environment. All of these data sources could interface with the Whatcom County GIS system to provide mapping of known and potential contamination sources.

4.4.5 Prohibited Activities

Aquifer protection regulations typically include lists of activities that are prohibited in highly susceptible CARAs or WHPAs. Such activities are usually associated with hazardous materials or wastes and can include landfills, injection wells, and commercial and industrial facilities that use highly toxic and mobile chemicals. The inclusion and selection of prohibited activities may depend upon a balance between aquifer susceptibility and mitigation of risks by means of stringent regulatory requirements and design requirements, through application of conditional permits. Clarification must be provided regarding prohibition of new activities and phasing out of existing activities, if considered.

4.4.6 Conditionally Permitted Activities

Land use activities posing risks to ground-water quality and quantity that can be mitigated are candidates for conditional permits. Many such activities in Whatcom County are already regulated by the Department of Ecology, with specific requirements for design and monitoring. Proposed actions that would involve pumping above the aquifer recharge rate would be addressed through water rights permitting, and associated engineering studies, and project mitigation to prevent aquifer depletion and unacceptable water level declines.

4.4.7 Exempt Activities

Certain activities present low potential impacts to ground water quality and quantity and may not be practical to regulate. One example is residential use of chemicals and fertilizers. An effective means of addressing such issues is community outreach and easily accessible guidance resources. Clarification of regulatory application to existing versus new land uses must also be addressed.

4.4.8 Site-Specific Hydrogeologic Reports

One of the most effective and documentable means of evaluating potential adverse impacts to CARAs and supporting conditional use permit applications is a site-specific evaluation of hydrogeologic conditions and project impacts to ground water. Cook (2000) provides a comprehensive listing of potential requirements for such investigations and reports. A site-specific investigation provides the opportunity to tie together potential impacts of the project to ground water quality, recharge, discharges to streams and wetlands, and water levels. Requirements for hydrogeologic reports can be adjusted according to aquifer susceptibility.

4.5 FINDINGS AND CODE RECOMMENDATIONS

Finding	Recommendation
General CARA Findings and Recommendations	
<u>Finding #1</u>	Existing data and reports, combined with the GIS capabilities of the County, provide an excellent information base to support development of CARA designations and aquifer protection measures by Whatcom County.
<u>Recommendation</u>	Use water quality, water quantity, and land use data to support creation of the CARA component of Article 5 of the County Code.
Characterization and Mapping of Aquifers in Whatcom County	
<u>Finding #2</u>	Existing data are sufficient to support mapping of major aquifers in Whatcom County.
<u>Recommendation</u>	Compile mapping data from County GIS and technical reports to map aquifers. Distinguish between unconfined and confined aquifers, to the extent feasible.

Finding	Recommendation
Determination of Aquifer Susceptibility and Vulnerability to Contamination	
<u>Finding #3</u>	Existing data are sufficient to determine aquifer susceptibility and to support vulnerability assessment.
<u>Recommendations</u>	<p>Use the guidance and data resources in Appendix Two of Cook (2000) as the basis for determining susceptibility of specific aquifers. Support with recent field data if available. Plot on the CARA map and apply color codes to map susceptibility of these aquifers.</p> <p>Compile all available wellhead protection area (WHPA) designations from public supply wells, using information from water purveyors, the Lummi Nation Natural Resources Department, the Whatcom County Health Department, and the state Department of Health as resources. Superimpose WHPAs on the CARA map.</p> <p>Evaluate the results of the contamination inventory (see below), to determine if or when to add a vulnerability analysis to the susceptibility determination. Consider the incremental resources and costs required to accomplish this step.</p> <p>Identify areas of ground-water level declines and potential overdraft, in coordination with the Department of Ecology. Plot on the CARA map.</p>
Inventory of Known or Potential Ground-Water Contamination Sources	
<u>Finding #4</u>	Resources are available to map point and some non-point contamination sources, including Ecology web site mapping tools and technical reports of past contamination incidents.
<u>Recommendations</u>	<p>Determine the desired scale and scope of contamination source mapping, including staff and GIS availability.</p> <p>Separate documented chemical release from potential releases and superimpose on CARA map.</p>
Petition for Formation of a Ground-Water Management Area	
<u>Finding #5</u>	In consideration of documented ground water quality problems from agricultural chemicals, commercial and organic fertilizers, and seasonal declines in ground water levels from excessive pumpage and drainage activity, consider a petition to forms a ground-water management area under WAC 173-200.
Develop Sections for Update of Chapter 16,16, Critical Areas, Article V, Critical Aquifer Recharge Areas, Sections 16.16.500 through 16.16.599 (as needed)	
<u>Finding #6</u>	The model code outline for CARAs in Washington State (Washington Office of Community Development (2002); attached as Appendix A) provides an appropriate basis for updating Article 5.
<u>Recommendations</u>	<p>Use sections of the Model Code as follows:</p> <p>X.30.010, CARA Designation: Insert "Highly and Moderately Susceptible Aquifer Recharge Areas" as the first item under designation. Susceptibility will be determined as described above in Section 4.5.1.1. Note that there are currently no sole-source aquifers, susceptible ground-water management areas, or special protections areas designated in Whatcom County. Delete the "Moderately or Highly Vulnerable Aquifer Recharge Areas" until vulnerability has been incorporated into the designation process.</p> <p>X.30.020: delete</p> <p>X.30.030: no change</p> <p>X.30.040: check for consistency with County stormwater and wastewater regulations</p> <p>X.30.050: Critical Area Report: no change; coordinate with general critical area report requirements that apply to all critical areas in Chapter 16.16.</p> <p>X.30.060 Performance Standards: no change</p> <p>X.30.070(A) Storage Tanks: Add references to compliance with existing Department of Ecology regulations pertaining to underground petroleum tanks (WAC 173-360) and hazardous materials tanks (WAC 173-303)</p>

Finding	Recommendation
<u>Finding #6 Recommendations (continued)</u>	X.070(E) Performance Standards – State and Federal Regulations: Include the “Animal Feeding Operations/Concentrated Animal Feeding Operations, WAC 90.64” in the table of “Statutes, Regulations, and Guidance Pertaining to Ground Water Impacting Activities”
	X.30.080 Uses Prohibited from Critical Aquifer Recharge Areas: add Dry Cleaning Facilities and other Facilities that use Perchloroethylene (PCE); add Facilities that use Fuels Containing Methyl Tertiary Butyl Ether (MTBE)
<u>Finding #7</u>	Article V does not address the ground water quantity issue with respect to impacts on critical aquifer recharge areas.
<u>Recommendation</u>	Add a new section to Article 5 regarding activities that may diminish groundwater recharge, deplete aquifer storage, reduce ground-water levels, or have other negative impacts on ground-water quantity and required mitigation measures.

4.6 CARA REFERENCES

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5. WETLANDS

Wetlands are generally defined as “areas that are inundated or saturated by surface 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 (WAC 173-22-030(19)). Wetlands generally include swamps, marshes, bogs and similar areas (Federal Register 1982, 1986).

Wetlands provide important biological and social functions. These functions include flood control, water quality improvement, base flow contribution, nutrient sequestration, fish and wildlife habitat, and education opportunities (Mitsch and Gosselink 2000; Hruby et al. 1999; Cooke Scientific Services 2000). This paper provides an overview of the best available science pertaining wetlands and wetland management⁹. The information focuses on research conducted in the Pacific Northwest and environments such as those found in Whatcom County. This Chapter also describes some of the challenges of managing wetland areas in rural and urban settings.

Several recent publications have synthesized much of the available scientific information on wetlands in the Pacific Northwest, and are referenced throughout this paper. They include:

- Freshwater Wetlands in Washington, Volume 1: A Synthesis of the Science. Sheldon et al., (2003);
- Critical Areas Assistance Handbook. Washington State Department of Community, Trade, and Economic Development;
- Whatcom County Wetlands GIS Mapping by Hydrogeomorphic Classification. Gersib, R. (2000);
- Wetland Buffers: An Annotated Bibliography. Publ. 92-11. Castelle et al. (1992a);
- Wetland Mitigation Replacement Ratios: Defining Equivalency. Castelle et al. (1992b).

5.1 OVERVIEW OF WETLAND INVENTORY

Whatcom County currently contains an estimated 82,000 acres of wetlands ranging in type from forested swamps in freshwater settings to estuarine marshes along the coast (Gersib 2000). Past glacial deposits and scouring created the landforms and landscape conditions that sustain the numerous types of wetlands in Whatcom County. Peat deposits cover approximately 10 percent of the County, a greater acreage than any other county in Washington State (WCPD 1992a,b). Most of the large wetland systems are associated with the floodplains of major rivers and streams, or with large lakes. Whatcom County encompasses approximately 3,012 miles of rivers and streams and their estuaries, 16 major lakes and dozens of smaller ones, and 134 miles of marine shoreline (WCPD 2003). The greatest wetland acreage is located in the west portion of the County from sea level to 600 feet in elevation in flat to rolling terrain. Most of the County’s wetlands are located on lands in agricultural use.

Whatcom County contains two main physiographic regions: the Cascade Range and the Whatcom Basin (Goldin 1992). Elevations in the Whatcom Basin range from sea level to 600 feet. Glacial landform processes have formed the relatively flat Whatcom Basin (Goldin 1992; WCPD 1992a). Bellingham drift, a relatively impermeable glacial deposit consisting primarily of clay and silt, covers a large area of western Whatcom County. Wetlands are common on Bellingham drift deposits (WCPD 2003). The Cascade Range in the east portion of the County is rugged and mountainous, rising steeply up from the lower elevations of the Whatcom Basin in west of Sumas, Nooksack, and Cedarville.

⁹ This review is based upon a review of existing information; no fieldwork was performed for this study.

Portions of three major river drainages, the Nooksack (Water Resource Inventory Area No. 1 [WRIA 1]), Upper Skagit (WRIA 4), and Lower Skagit/Samish (WRIA 3) are found in Whatcom County. These river systems and associated tributaries shape the landscape and contribute to the formation of wetlands and their functions. Most of Whatcom County, not including federal lands, is located within WRIA 1, which is comprised of the Nooksack River watershed and certain adjacent streams including the Sumas River, other tributaries to the Fraser River, and a number of coastal stream systems including the Lake Whatcom watershed. The Nooksack River system alone contains approximately 1,300 miles of streams and tributaries (Goldin 1992). Mount Baker-Snoqualmie National Forest in Whatcom County is positioned within the Nooksack and the Upper Skagit (WRIA 4) areas. South of Bellingham, a small portion of the Lower Skagit/Samish (WRIA 3) extends into Whatcom County to encompass Lake Samish.

The National Wetland Inventory identified wetlands in Whatcom County based on the USFWS wetland classification system (Cowardin et al. 1979). The USFWS wetland classification system or Cowardin system characterizes wetlands according to water sources (i.e., freshwater or brackish) and type of vegetation (i.e., forested, scrub-shrub, etc.). According to the National Wetland Inventory the following classes of wetlands are common in Whatcom County: palustrine, riverine, open water, and estuarine. Vegetation types in palustrine and riverine wetlands include forested, scrub-shrub, and emergent.

In 1991, Whatcom County prepared a Critical Area Inventory Report to describe 15 Category 1 Wetlands deemed as having exceptionally high quality and important local significance. This inventory covered mainly the lowland areas of the County (WCPD 1992a). Two of the Category 1 wetlands described are estuarine and the remainder are associated with lakes and ponds. Information provided for each of the 15 wetlands includes a general description of wetland hydrology, soils, vegetation, ecology and wildlife habitat, and recommendations for protection (WCPD 1992a).

In 2000, the Washington State Department of Ecology (Ecology) identified potential wetlands in the Nooksack basin of Whatcom County using the hydrogeomorphic (HGM) wetland classification system (Gersib 2000) (Figure 2, to be provided at the Committee Meeting). The HGM wetland classification system, developed by the US Army Corps of Engineers (Brinson 1993), characterizes wetlands according to hydrologic and geologic features of the landscape within which the wetland has formed rather than vegetation or habitat types. To complete the Nooksack wetland inventory, each square mile in the basin was investigated using 1:12,000 scale stereo-paired black and white aerial photographs, existing hydric soils data, geologic maps, and existing wetland inventories (Gersib 2004 personal communication). Gersib (2000) identified expansive estuarine fringe wetlands associated with major bays and harbors, large areas of depressional flow-through wetlands in the east portion of the County, and extensive riverine wetlands associated with the main river and stream systems, most along the Nooksack River forks and mainstem. Many of the riverine wetlands are identified as being impounded. Other hydrogeomorphic wetland classes identified by Gersib (2000) in Whatcom County include depressional closed, lacustrine fringe, river channel, flats, and slope flow-through.

Gersib also developed a detailed GIS database linked to the HGM wetland inventory for evaluating wetland functions and values in the Nooksack basin (Gersib 2000). Wetland functions were divided into 17 specific functions covering important water quality parameters, flood water support, groundwater and base flow support, biological support and habitat, and human values. Existing information from scientific literature and from field studies in Whatcom County (mostly geology and hydrology) was used to develop a model for evaluating these functions in Nooksack basin wetlands. The resulting GIS data were used to identify wetlands with the greatest potential for providing each of the 17 different wetland functions, and wetlands with the greatest restoration potential for these functions. This database was designed to be queried for information regarding potential wetland functions and values in the Nooksack basin. The main

purpose for developing this database was to enable resource agencies to select appropriate restoration sites for providing specific functions (Gersib 2004 personal communication).

NRCS has also conducted a number of wetland delineations in Whatcom County. These wetland delineations are found on USDA Farm Service Agency Maps and are currently in the process of being digitized.

According to the existing inventories and GIS information, wetlands identified in Whatcom County encompass a substantial percent of the entire County area (Figure 5-1). The majority of the wetland area found in the County is located within the Birch Bay area, Drayton Harbor, and the Sumas River watersheds (Gersib 2000). However, the area of potential wetland in each drainage basin changes substantially if hydric soils are used as an indicator of potential wetlands, particularly in the Sumas and Lynden North drainage basins. Both Lynden North and Sumas have considerably more wetland area if areas with hydric soils are mapped and are assumed to have been wetlands prior to hydromodifications such as agricultural and roadside drainage.

Comparison of Wetland Area by Watershed Using Different Mapping Sources

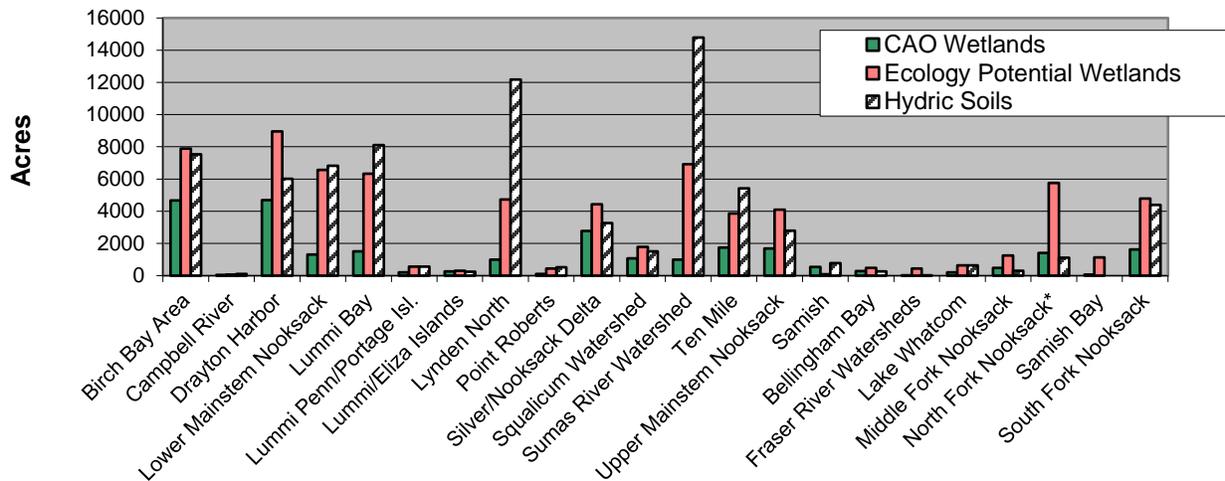


Figure 5-1. Comparison of Potential Wetland Areas by Watershed¹⁰

Considering all wetlands mapped through the Whatcom County inventory, by Ecology (Gersib 2000), and areas of hydric soils (NRCS 2002), the basins with the highest percentages of potential wetlands are Sumas (13%), Lynden North (11%), Drayton Harbor (10%), Birch Bay (9%), and Lummi Bay (8%) (Figure 5-2). These mapping methods surely have significant overlap. Although Lummi Bay, Lummi Peninsula, and Portage Island wetlands are included in this inventory, these areas are portions of the Lummi Reservation and are not subject to the Critical Area Ordinance and other County regulations.

¹⁰ The Potential Wetlands mapping effort focused on the area west of the National Forest Boundary. Tidelands are not included in the acreage estimates. Acreage estimates are for Whatcom County only, not watersheds extending in Canada or Skagit County. For more information about wetland maps see Combined Wetlands Map.

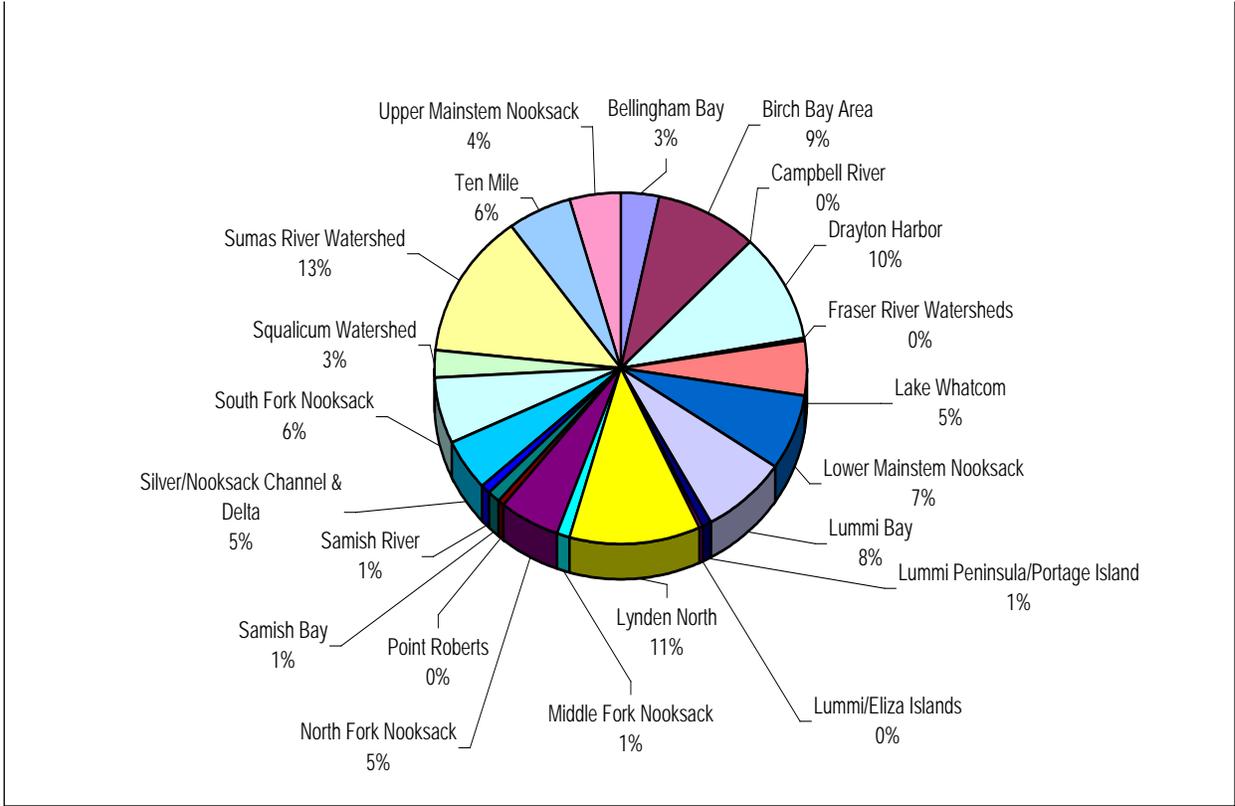


Figure 5-2. Percent of All Potential Wetlands in Whatcom County by Watershed Management Area

Land use pressures have affected wetlands throughout Whatcom County. Forestry and agricultural land uses cover almost 74 percent of unincorporated Whatcom County while residential development constitutes 11 percent of this land area (WCPD 2003). Commercial, industrial, and other uses make up the remaining areas.

Agriculture, forestry, and urban development have modified vast wetland areas in the Whatcom Basin. During the past century many previously forested wetlands had the timber harvested and then were drained for agriculture purposes, as evidenced by the extensive tile drainage used in many agriculture areas (Goldin 1992). Approximately 60 percent of the acreage (60,000 acres) used for crops and pasture in Whatcom County requires drainage of excess surface and subsurface water. This drained agricultural land is recorded as being prior converted cropland by NRCS (Gillies 2004 personal communication). Under federal law, under certain conditions prior converted cropland can continue to be drained and cropped in accordance with the 1985 Food Security Act. However, many of these prior converted croplands meet the definition of wetland under the State's 1997 wetland delineation manual and the GMA.

Wetland areas in the Cascade Range portion of Whatcom County are generally associated with the Nooksack River system including numerous steep-sided tributaries. Forestry is the main land use in the Cascade Range and forestry along with agricultural land use have dramatically altered wetland systems in this portion of the County. This analysis focuses on wetlands in the Whatcom Basin because this is primarily where the County regulations apply.

5.2 OVERVIEW OF WETLAND FUNCTIONS AND VALUES

As integral parts of the natural landscape, wetlands provide important functions and values for both the human and biological environment. Ecological functions are the combination of physical, biological, and chemical processes that characterize an ecosystem (NRC 1995; WAC 173-26; Brinson and Rheinhardt 1996). The types of functions performed by wetlands and the degree to which these functions are performed depend on several elements including wetland size and location within a basin, vegetation diversity, and the level of disturbance. While each wetland provides various beneficial functions, not all wetlands perform all functions, nor do they perform all functions equally well (Novitzski et al. 1995). Some of these functions provide goods and services that are beneficial to humans and society therefore places value on these functions (NRC 1995; Leschine et al. 1997).

The functions provided by wetlands and their human-assigned values have been identified and evaluated in several studies (Null et al. 2000; Adamus et al. 1987; Mitsch and Gosselink 2000; Hruby et al. 1995; Reppert et al. 1979; Cooke Scientific Services 1995). These include:

- Flood water attenuation and flood peak desynchronization;
- Stream base flow maintenance and groundwater support;
- Water quality improvement;
- Shoreline protection;
- Biological support and fish and wildlife habitat; and
- Recreation, education, and open space.

The following sections describe how freshwater and estuarine wetlands in Whatcom County perform these functions.

5.2.1 Freshwater Wetlands

5.2.1.1 Flood Water Attenuation and Flood Peak Desynchronization

Wetlands control stormwater flow by attenuating surface water runoff during and after storms and slowly releasing it to groundwater and/or to adjacent water bodies. Research has shown that this function can reduce and desynchronize peak flood crests and flow rates of floods (Novitzki 1979 and Verry and Boelter 1979 *in* Mitsch and Gosselink 2000). The efficiency of a particular wetland system in controlling runoff is based on factors such as its location on the landscape, the storage capacity and outlet discharge capacity of the wetland relative to the magnitude of stormwater inflow (Marble 1992; Reinelt and Horner 1991). The effectiveness of a wetland in reducing downstream flooding increases with:

- An increase in wetland area;
- The size of the flood;
- The proximity to an upstream wetland;
- The wetland's proximity to the flooded area; and
- The lack of other storage areas (Mitsch and Gosselink 2000; Erwin 1990).

Depressional flow-through wetlands located in the floodplain of the Nooksack River and other stream floodplains, and in headwater areas in Whatcom County are highly valuable for flood flow control due to their position in the landscape. Large floodplain wetlands such as Tennant Lake located in the Nooksack floodplain receive flood waters on a regular basis and have the capacity to store excess water even during the wet winter season, when soils are already saturated to the surface (WCPD 1992a). The lower Silver Creek drainage includes wetlands with high value for flood attenuation (WCPD 1992b). Wetlands positioned higher in the watershed, such wetlands along Kendall Creek (WCPD 1992b), generally provide greater flood flow attenuation because they help to prevent flooding along a longer area of river or stream reach than those wetlands located lower in the watershed, which only provide more localized flood water attenuation. Most wetlands in Whatcom County provide some level of flood flow support, with closed depressional wetland providing the highest levels.

5.2.1.2 Stream Baseflow Maintenance and Ground Water Support

Wetlands contribute to stream baseflow and groundwater recharge by retaining large quantities of water and slowly releasing it to streams or groundwater (Mitsch and Gosselink 2000; Erwin 1990). While the contribution of wetlands to near-surface (surficial) aquifers has been documented, relevant studies on deep aquifer recharge by wetlands are lacking. Generally, available studies indicate that some wetland types provide greater recharge to groundwater systems than others (Carter et al. 1979; Novitzki 1979; Carter and Novitzki 1988). Weller (1981) suggested that substantial recharge occurs around the edges of small depressional wetland systems and that seepage into the ground is highest where the edge is large relative to the water volume.

Wetlands can provide a continuous flow of water to streams because of their ability to store and slowly release water. This function is particularly important to stream flow-sensitive salmonids in the Pacific Northwest, because wetlands provide baseflow during the region's dry season (City of Portland 2001; Booth 2000; May et al. 1997; Mitsch and Gosselink 2000). Generally, large (10 acres or greater), permanently flooded, depressional wetlands that are connected to salmonid streams and are located in the upper one-third of the watershed have the best ability to provide stream baseflow and groundwater support (Brinson 1993; Gwin et al. 1999; Cooke Scientific Services 2000). Wetlands in the upper part of

the watershed affect flows in many downstream segments, whereas wetlands lower in the watershed have less of an effect on the overall stream system.

In Whatcom County, wetlands located in stream and river headwater areas likely provide the greatest stream baseflow maintenance as they are typically fed by springs and distribute surface water to streams all year long. These wetlands may be classified using the HGM method as depressional flow-through or slope wetlands. Pangborn Lake and the H-system (Dakota, South, Bertrand, and Canadian ponds) wetlands are good examples of headwater wetlands that provide surface water recharge for major fish bearing streams including Johnson Creek, Dakota Creek, and Bertrand Creek (WCPD 1992a). Surface water in the Bertrand Creek area is known to be hydraulically connected with the shallow Outwash Aquifer (Ecology 1990).

Most wetlands in Whatcom County with no surface water connection to streams or lakes have formed above relatively impermeable glacial deposits (WCPD 1992a), typified by a high seasonal water table, and are not likely to provide groundwater support due to their underlying geology. The impermeable layers beneath these wetlands limit groundwater support beyond a seasonal level near the surface.

5.2.1.3 Water Quality Improvement

Wetlands also improve water quality in surface waters through the removal of sediment and pollutants from storm water through “biofiltration” (Mitsch and Gosselink 2000; Cooke Scientific Services 1995). The vegetative structure of wetlands slows the flow of water, causing sediments, nutrients (primarily nitrogen and phosphorous), petroleum products, heavy metals, pesticides, and herbicides to settle out of the water column (Sipple 2002). Anaerobic and aerobic processes in wetlands promote denitrification, chemical precipitation, and other chemical and biological reactions that help to remove pollutants from water (Brettar and Hoefle 2002; Mitsch and Gosselink 2000; Sheldon et al. 2003). Nutrients, such as nitrogen and phosphorous, are taken up by vegetation; as vegetation dies, some of these nutrients are stored in wetland sediments, where decomposers further convert nutrients to biological use and contribute to the breakdown of some petroleum products. Some nutrients are exported from wetlands to adjacent water bodies after seasonal die-off of emergent plants. Wetlands can remove chemicals, such as some petroleum products, heavy metals, and some pesticides that are not converted to biological uses and permanently store them in wetland sediments (Gambrel and Trace 1994). Disruption of wetland soils and increased water fluctuations in the wetland may resuspend sediments and export buried pollutants.

The ability of a wetland to perform biofiltration can depend on a wetland’s physical configuration, size, location within the basin, vegetation community structure, and productivity (Ecology 1996; Marble 1992). Wetlands remove particulates through settling, which is controlled by water velocity, particle size, residence time of water in the wetland, and physical filtration through vegetation and substrate (Ecology 1996; Sather and Smith 1984). Wetlands can have pronounced effects on water quality if they:

- Are located downstream from sources of pollutants (agriculture, urban development);
- Contain 80 percent or more vegetative cover;
- Experience low velocity stormwater flows;
- Have a restricted outlet; and
- Attenuate 50 percent or more of overland flow (Mitsch and Gosselink 2000; Cooke Scientific Services 2000; Ecology 1996).

In addition, wetlands that are most effective at biofiltration, particularly nutrient and toxics removal, are those that (Sheldon et al. 2003):

- Contain diverse and dense, persistent vegetative classes;
- Contain organic or clay soils (Brettar and Hoefle 2002);
- Are in the depressional class; and
- Have seasonally ponded areas.

A combination of these characteristics, organic or clay soils, persistent vegetation, depressional characteristics, and seasonally ponded areas provide the greatest overall potential for water quality improvement in Western Washington (Sheldon et al. 2003). Organic and clay soils are more likely than mineral soils to bind with metals and synthetic organic toxicants (Gambrell and Trace 1994); though high organic matter has been shown to increase the survival of fecal coliform (Tate 1978 in Gersib 2000). Wetlands with diverse vegetation are most effective at nutrient cycling; dense emergent vegetation is particularly effective because it takes up nutrients rapidly and slows water flow allowing sediments and pollutants adsorbed to sediments to settle. Forested areas store greater amounts of nutrients for longer periods but generally offer less frictional resistance to water flow (Ecology 1996).

Once a wetland has been filled with sediment and is no longer able to provide storage, sediments and chemicals, such as heavy metals and phosphorous, will be transported out of the wetland. The filling/sedimentation reduces the water residence time, which means that soils and vegetation have less time to interact with nutrients and pollutants. The loading rate of the incoming water may exceed the wetlands' capacity to assimilate sediments, nutrients, and pollutants, so they get passed downstream (Mitsch and Gosselink 2000; Ecology 1996).

Many wetlands in Whatcom County contain the characteristics needed for water quality functions. A large percentage of the wetlands in Whatcom County are classed as depressional (Gersib 2000). Wetland soils in Whatcom County are commonly organic due to the high percentage of peat deposits, involving 10 percent of the total area of the County (WCPD 1992a). Clay soils are also common in lacustrine and estuarine wetlands (Goldin 1992). The low topographic relief of these glacially formed wetlands has resulted in the formation of large expanses of dense emergent wetland areas (WCPD 1992a). Many wetlands exhibit zonation where open water is surrounded by a ring of emergent, scrub-shrub, and forested habitats in a step-wise fashion of progressively taller vegetation at slightly higher elevations. Examples of wetlands that have potential to provide a high level of water quality functions include the Lake Terrell Creek and H-System wetlands (WCPD 1992a). Most of the Category 1 wetlands described in WCPD (1992a) provide high water quality functions due to their organic soils, depressional areas, dense vegetation, and large size, and most have the opportunity to provide this function given surrounding agricultural, industrial, and residential land uses.

5.2.1.4 Erosion / Shoreline Protection

Wetlands located adjacent to or upstream of water bodies or erosive areas can provide erosion / shoreline protection by decreasing the velocity of surface water flows (Sheldon et al. 2003). The ability of wetlands to perform this function depends on the presence of woody vegetation, the configuration of the wetland (channel constrictions can slow the flow of water), and the substrate type (Carter 1986; Greeson et al. 1979; Sather and Smith 1984; Brinson 1993; Sheldon et al. 2003). The erosion control function is particularly effective in depressional and riverine wetlands where flow velocities are slow, the wetland is wide relative to channel width allowing flooding to occur, and vegetation is dense and woody (Hruby et

al. 1999; Sheldon et al., 2003). Wetlands in basins that have relatively undeveloped shorelines and banks that contain dense woody vegetation along the ordinary high water mark (OHWM) of a lake or stream and extend more than 200 to 600 feet from the OHWM provide the highest level of shoreline protection and erosion control (Hruby et al. 1999; Cooke Scientific Services 2000). Wetlands that extend less than 200 feet provide less protection.

Many depression, riverine, and lacustrine wetlands located adjacent to or upstream of rivers, streams, and lakes in Whatcom County provide erosion/shoreline protection to these water bodies. Wetland vegetation along the shorelines of these water bodies stabilizes river and lake banks during high-water periods. Adjacent and upstream wetlands provide areas for flooding, decreasing the erosion potential of floodwaters. Wetlands providing this function include various floodplain wetlands along the Nooksack River, Tenant Lake, Lake Terrell, Terrell Creek, Whatcom Lake, Beaver Lake, the H-Street wetlands, and many others (WCPD 1992a).

5.2.1.5 Biological Support and Fish and Wildlife Habitat

Wetlands provide opportunities for wildlife grazing on living plants, and for organisms that depend on detritus and/or organic debris for a food source (Sheldon et al. 2003; Sipple 2002). Vegetated wetlands and upland forest habitats are highly productive systems (Hruby et al. 1999). Streamside vegetation can contribute up to 90 percent of the energy in aquatic food webs of headwater streams (Budd et al. 1987). These food sources are especially important for fish that feed on both terrestrial and aquatic insects, which in turn feed on organic matter exported from adjacent riparian areas including wetlands (Cummins 1974 and Gregory et al. 1991 in City of Portland 2001; Higgs et al. 1995).

Wetland habitats generally provide greater structural and plant diversity, more edge habitat where two or more habitat types adjoin, more varied forage, and a more predictable water source that increases wildlife species abundance and diversity compared to upland habitats (Kauffman et al. 2001; O'Connell et al. 2000). Many species of waterfowl, amphibians, insects, fish, and some species of mammals (such as muskrat) depend on wetlands for foraging, breeding, and refuge. Wildlife species richness increases when wetlands are surrounded by natural undisturbed upland habitat (WDFW 1992; Richter and Azous 2001; Azous and Horner 2001; Hruby et al. 1999). Wetlands and surrounding upland buffers provide specialized habitat and linkages for many species of wildlife including special status species (e.g., endangered, threatened, proposed, candidate, sensitive, monitor and species of local importance) (Mitsch and Gosselink 2000; Hruby et al. 1999).

Wetlands in Whatcom County provide food, cover, and breeding sites for a diversity of organisms. Relatively undisturbed or protected wetlands such as those associated with Lake Terrell, Pangborn Lake, Beaver Creek, Dailey Prairie, and the H-Street wetlands provide excellent wildlife habitat as they contain a variety of vegetation types, open water, and forest structure for breeding, cover, and forage (WCPD 1992a; WCG et al. 2002). These wetlands provide habitat for numerous animals including waterfowl, birds of prey, songbirds, elk, beaver, muskrat, frogs, salamanders, snakes, and freshwater fish. Some wetlands associated with the Nooksack River and other stream and lake systems provide pools for rearing juvenile fish.

State priority wildlife areas documented in Whatcom County wetlands include habitat for waterfowl and shorebird concentrations, trumpeter swan, cavity nesting duck, band-tailed pigeon, bald eagle, sandhill crane, great blue heron, and wood duck, among others (WDFW 2004; WCG et al. 2002). Some of these areas are used seasonally and others are used year round. Wintering bald eagles concentrate along the Nooksack River where they feed on thousands of migrating salmon, steelhead, and cutthroat trout (Goldin

1992). Other special status species that are associated with wetland habitats in Whatcom County include Puget Sound Chinook salmon, bull trout, coho salmon, pileated woodpecker, osprey, and merlin.

5.2.1.6 Recreation, Education, Cultural Resources, and Open Space

Because wetlands and their associated uplands are unique habitats, they provide natural areas for recreational and educational opportunities. Wetlands are economically important as recreation areas. In Whatcom County some wetlands provide habitat for large numbers of migratory waterfowl and for fish that attract sport hunters and fishers (WCPD 1992a). Other recreational activities popular in wetland areas include hiking, wildlife viewing, and boating.

Wetlands are important for scientific research, education, and the preservation of cultural resources. Whatcom County encompasses several unique wetland types including some relatively pristine bogs like Pangborn Lake, and fens like the Dailey Prairie Fen (WCPD 1992a). Cultural resources are often found in highly productive systems such as wetlands (Olivier 2001). The anaerobic conditions of wetlands, especially of bogs and fens, act to preserve cultural resources that would degrade in drier conditions (Davidson 2001).

Wetlands are also highly valued as open space within urban communities such as Bellingham. In urbanizing areas, aquatic resources and adjacent uplands may provide the foundation for greenways and open space. Property values in neighborhoods surrounding wetlands tend to be higher than those in areas with no natural open spaces (Todd 2000).

In Whatcom County, as noted in the Whatcom County Comprehensive Plan, wetlands and adjacent uplands provide important resources for wildlife viewing and other forms of passive recreation (such as photography) and education about natural wetland-upland ecosystems. These areas can also be important for commercial purposes because they attract tourists and local visitors such as hunters.

5.2.2 Estuarine Wetlands

For the purposes of this report, estuarine wetlands include vegetated and unvegetated areas that experience periodic effects of marine saltwaters. These areas lie above the Extreme Low Water of Spring tides (Cowardin et al. 1979)¹¹; subtidal areas below this level are not considered estuarine wetlands. Kneib (2000) considers tidal channels whose connection with open estuary are not interrupted at high tide to be part of the marsh “ecoscape”. These include low order tidal channels and small “rivulets” that cross “creekbank boundaries between subtidal channels and the vegetated intertidal”. In the Cowardin classification, the Extreme High Water of Spring tides¹² is considered the landward extreme of an estuarine wetland, however we consider tidal effects to include not only inundation by tidal waters but also deposition of materials by tidal storms and surges and infiltration of tidal waters. Consequently, especially in large estuaries or estuaries exposed to marine storms, the upland boundary of an estuarine wetland may be slightly higher than the Extreme High Water of Spring tides. Estuarine buffer areas may be affected by the marine climate but are not directly affected by marine waters. Buffer areas are considered transitional areas, ecotones, where high tide aquatic habitat merges into terrestrial habitat (Jamieson and Levings 2001)¹³.

¹¹ Extreme lower low water (ELLW) in the Pacific Northwest.

¹² Extreme higher high water (EHHW)

¹³ **Note**, in the hydrogeomorphic terminology, estuarine wetlands are considered a subclass of “fringe” wetlands and are defined as “wetlands occurring at the margin of topographic depressions in which the depth of permanent surface water is greater than two meters deep” (Gersib 1997). Only vegetated areas are considered wetlands (Shafer and

Like freshwater wetlands, estuarine wetlands provide many of the functions discussed in the previous sections. In some important ways, however, the physical processes of estuarine wetlands, and consequently the functions they perform and their vulnerability to human alterations, differ significantly from those in freshwater wetlands. The fluctuations of marine tidal waters affect processes of sediment deposition and erosion, the location and timing of salinity and suspended sediment conditions, the balance of hydraulic pressures, exchange of organic and inorganic inputs between the marine and terrestrial components, and the distribution of all the plants and animals that are adapted to the dynamic stresses of estuarine areas. The fact that estuarine wetlands are always the most downstream wetlands in a watershed makes estuarine wetlands vulnerable to effects from upstream habitat changes and pollutant loads as well as from local and marine-side conditions. The following discussion highlights the ways that estuarine wetlands may function differently than freshwater wetlands. However, the information provided above concerning freshwater wetland functions is also pertinent.

5.2.2.1 Tidal Flood Water Attenuation

Estuarine wetlands contribute to flood water attenuation by containing flood waters within tidal channel volumes, providing marsh surface area over which flood waters can spread (sheet flow), and by slowing water as it encounters vegetation and woody debris. Over longer time frames, the slope and elevation range of an estuarine wetland and the length, depth, and sinuosity of its tidal channels express an equilibrium between sediment deposition (that occurs when waters spread and slow) and erosion created by tidal and freshwater currents and flushing flows (Pethick 1984; Collins et al. 1987; Callaway 2000). The mid-tide sections of a channel, when a channel is half full, contain the fastest flowing waters and water velocities slow as they rise during the flood tide and spread over the marsh surface (Pethick 1984). Velocity differences during flooding and ebbing tides cause finer sediments to be laid down closer to shore and upper portions of estuarine channels are usually net sediment traps. Mudflats and marshes that lie above mid-tide are analogous to the floodplain of a river (Pethick 1984). Consequently, when landscape processes are intact, the slope and height of an estuarine wetland will naturally protect upland areas from most high water conditions. The same volumes and surfaces that contain marine tidal flow can contain and slow freshwater floods. When freshwater flood volumes increase, they will displace marine waters and occupy the same areas that marine waters otherwise would (Pethick 1984).

The shape of the shoreline, including aspect with respect to marine storms and surges, slope, the existence of protective spits, the existence of anthropogenic shore defense works along the shoreline, and the existing vegetation affect the ways that marine and freshwaters interact. In a situation of combined marine storms and high freshwater flows, a protected shoreline can reduce the strength of marine velocities and flows so that freshwater floods meet less resistance at the mouth and can spread more over the surface of the bay or mix with marine waters. A curving or irregular shoreline can provide more edge area to receive and absorb marine flows and more surface area for spreading of marine and freshwater flows. The slope, shape, and softness of adjacent upland areas also contribute to attenuation by providing area for unusual storm events to be absorbed. The adjacent uplands aid in flood control by reducing the velocity of runoff and encouraging the infiltration of precipitation and runoff (Rhode Island Coastal Zone Buffer Program 1994).

Depending on how estuarine wetlands are defined, the shorelines of Whatcom County include between 1,052 (2004 Whatcom County GIS database estimate of NWI acres) and 14,311 (2004 Whatcom County GIS database estimate from Gersib [2000]) acres of estuarine and estuarine fringe wetlands. The NWI

Yozzo 1998). Surface water in fringe wetlands has bidirectional horizontal and vertical components – in estuarine fringe wetlands this is due to forcing from tidal action. We include both unvegetated areas and areas with surface water less than two meters as long as they experience bidirectional flow of either surface or groundwater due to tidal forcing.

does not include unvegetated marsh areas while the Gersib inventory includes large intertidal fringing flats at the mouths of rivers in large bays such as Drayton Harbor, Birch Bay, Lummi Bay, and Bellingham Bay. Both vegetated and unvegetated areas provide surface area and channel volumes for floodwater attenuation. In addition, all of the major bays, especially Drayton Harbor, are relatively protected from marine storms; by virtue of their broad, curved shorelines, protective spits, and extensive fringing flats (visual assessment of maps produced by Whatcom County GIS). Buffer cliffs such as those near Chuckanut Bay provide less attenuation of marine floods, but Chuckanut Bay itself is protected. A smaller, Class 1, estuarine wetland south of Cherry Point likely contributes to local protection from freshwater flooding along with freshwater wetlands in the area but may provide more protection to the shoreline from tidal surges than from freshwater floods (Whatcom County GIS map).

5.2.2.2 Stream Baseflow Maintenance and Ground Water Support

As part of the shoreline system of hydraulic connections between marine waters and the surface and groundwaters of rivers and freshwater wetlands, estuarine wetlands participate in stream base-flow maintenance and groundwater support in lower portions of a watershed. The lower watershed connections between groundwater, surface water, hyporheic areas¹⁴, marsh pore water, and marine tidal waters are balanced via hydraulic pressures mediated by estuarine geology and sediment interstitial spaces. According to Stasavich and Brinson (1995) "The central hypothesis of the Virginia Coast Reserve LTER is that ecosystem, landscape, and successional patterns are controlled by the relative vertical positions of the land, sea, and fresh-water table, also known as "free surfaces". At these free surfaces, there is a zone of diffusion where the two waters meet. Geologic conditions affect the hydrologic continuity between surface, ground, and marine waters (Walters 1971). In order for saltwater intrusion of fresh groundwater to occur in coastal areas or on islands, an aquifer must be in hydraulic connection with marine water and the hydraulic head of the groundwater must be lower than sea level (Dion and Sumioka 1984). In undisturbed watersheds, the height of the water table (the potentiometric surface) is higher than sea level and decreases toward the coast so that freshwater movement is seaward. When the gradient is decreased or reversed, seaward flow of freshwater is reversed and saline water can move upslope (Dion and Sumioka 1984). Freshwater pumping is the main means of lowering the elevation of the potentiometric surface and reducing the gradient.

Walters (1971) stated that many aquifers of economic importance on the Washington coast have at least moderate permeability where wells are located but may be sufficiently sealed geologically the seaward edge so that salt water intrusion does not occur. In some cases, however, an aquifer that is either above sea level or currently disconnected from marine waters can have elevated salinity due to remaining or relict seawater that has not been flushed with freshwater since it was left during previous geologic times. This relict seawater can cause elevated salinity in groundwater if it is tapped directly or if pumping levels are high enough that freshwater quantities are reduced and relict salt water that has been pushed to the extreme ends of an aquifer is drawn to mix with freshwater in the main portion of the aquifer.

Where connections between marine and terrestrial water exist, the balance of hydraulic pressures along free surfaces is affected by the size and slope of the watershed, the amount of freshwater flow and groundwater pressure relative to marine flow and pressure (related to both tidal range and volume or tidal prism) and local and watershed geology and soils. These attributes determine estuary conditions such as the upstream extent of salinity in the riverine water column and groundwater, percolation of freshwater onto mudflats and marsh surfaces (Tobias et al. 2001a), and the movement of organic and inorganic materials through terrestrial and marine surface waters and interstitial spaces (Tobias et al. 2001b,c). As part of this system of connections, estuarine wetlands play a large role in transferring energy between the

¹⁴ The hyporheic zone is the biologically active interface between groundwater and stream bed.

marine and terrestrial systems. Groundwater withdrawals, changes in surface freshwater flow, and subsidence and compaction of estuarine wetlands can all change the balance of pressures and, consequently, the location of the salt-fresh water interface both in surface waters and in ground waters.

All of Whatcom County's estuarine wetlands provide a protective function for groundwater and, simply by their size, help to maintain the location of the estuarine salinity gradient within the estuarine landscape. Walters (1971) found that many wells in Whatcom County produced water with slightly to very high salt concentrations. He felt that many of these concentrations were more likely produced by relict seawater than by salt water intrusion. However, in nearshore mainland wells, he found a relationship between well depth and salinity that could indicate intrusion. Nine of ten wells with depths greater than 100 feet had salt concentrations greater than 50 mg/l (Freshwater has a concentration of less than 10 mg/L, EPA drinking water concentration threshold is 250 mg/l USGS reports - e.g., Dion and Sumioka [1984]) - consider concentrations greater than 100 mg/l indicators of saltwater intrusion or relict seawater). He found no evidence of saltwater intrusion on the Lummi Peninsula or along the southeast coast, except in a few places. On the Lummi Indian Reservation, he found that even shallow wells that did not extend below sea level had elevated chloride concentrations and so attributed the concentrations to relict seawater. He felt that salinity concentrations in at least one well at Point Whitehorn were likely due to salt water intrusion, however other wells likely contained relict seawater. He found evidence of saltwater intrusion on the northeast shoreline of Lummi Island between the northern most point and Lummi Island (community) and near Village Point. Along Point Roberts, he found seawater intrusion in a small area along the west shore, south of the community of Point Roberts. This intrusion may be due to aggregate pumpage in the area during the summer season.

By 1978, Dion and Sumioka found that increased over 1968 concentrations on the western shore of the Lummi Peninsula near Gooseberry Point (noted also by Cline in 1974). They reported that several wells on Lummi Island had been abandoned or destroyed because of excessive salinity.

Shorelines where hydric soils indicate that groundwater supplies are close to shore and near the surface are especially vulnerable to salt water intrusion. Especially in these areas, it is important to preserve estuarine wetlands at the interface between upland and aquatic systems and limit freshwater pumping to buffer groundwater from salt water intrusion.

5.2.2.3 Water Quality Improvement

The sediments of estuarine wetlands perform similar filtering functions as the sediments in freshwater wetlands and constitute a significant component of the water exchange pathways between terrestrial and marine environments (Liu et al. 2001). Estuarine sediments filter and recycle nutrients and particulates and store stable toxic compounds so that they are removed from the water column. Water quality and sediment quality in estuarine wetlands are important for the protection of native shellfish resources and aquaculture (<http://whatcomshellfish.wsu.edu/>; <http://www.psat.wa.gov/Programs/Shellfish.htm>), to maintain habitat and food quality for invertebrates and juvenile salmon feeding and rearing (Attrill and Power 2000; Thom and Borde 1998; Giles and Cordell 1998), to protect non-migratory fish, especially bottom-feeding fish (West and O'Neill 1998), and to protect birds, predatory fish, marine mammals, and humans that feed on estuarine plants and animals (Simmonds et al. 1998).

Temperature, dissolved oxygen, and salinity affect the presence, growth, and survival of native shellfish and aquaculture species. Within a normal range, variation in temperature and salinity over time and space in an estuary can increase species diversity (Hackney et al. 1976). However, extremely low dissolved oxygen or high water temperatures create physical stress on resident and transient species, which can

affect their access to habitats or have negative effects on their growth and survival (Hackney et al. 1976; Kneib 2000; Craig and Crowder 2000).

Estuarine wetlands can improve water quality in shoreline areas by trapping pollutants and recycling nitrogen and organic matter within the sediments. Though marshes tend to be nitrogen limited, experiments have indicated increased loading of nitrogen can, to a point, be taken up by vascular plants and microbes (Teal and Howes 2000). Surface water, and, to some extent, interstitial water, is oxygenated by the flushing actions that occur during tidal exchange as water moves through marsh channels and vegetation and percolates through sediments. During high tide, cooler water replaces warmer, deoxygenated water in channels and marsh pools. Tidal exchange dilutes contamination, transports carbon and nitrogen offshore, and provides a means for clearing interstitial spaces that allow for nutrient exchanges between terrestrial and marine components.

Water quality is an important component of habitat. Even when recreational and habitat open spaces are preserved in an estuary, water quality can continue to limit the use of those areas by humans, animals, and plants. For example, even if large areas of estuarine marsh are preserved, nutrient enrichment, fecal coliforms, or contaminants can be transported in runoff to the marsh surface and eventually to nearshore waters. Though the marsh can absorb some of these substances, what it cannot absorb can lead to excessive growth of green algae (and subsequent decomposition and consumption of dissolved oxygen) at the marsh edge, reduction in eelgrass production, and to the concentration of disease organisms or other pollutants in plants and animals. Stressful abiotic conditions (e.g., high temperatures, low dissolved oxygen) can reduce the productivity of fish or shellfish and contamination can make them unfit to eat.

Most of Whatcom County shorelines and river mouths support significant populations of intertidal bivalves and mollusks, shorebirds, waterfowl, fish, and marine mammals (<http://whatcom-mrc.wsu.edu/MRC/projects/data/dataindex.htm>). They also provide areas for recreational water use by humans and human consumption of fish and shellfish. Given the importance of these areas for people and wildlife, preserving the quality of estuarine waters and sediments is critical in Whatcom County.

5.2.2.4 Erosion/Shoreline Protection

Due to their position in the landscape, estuarine wetlands provide unique erosion and shoreline protection functions. Both vegetated and unvegetated shorelines absorb and reflect wave energy via gradual slopes and irregularities and inundations in the shoreline. Upper intertidal and storm height deposits of large woody debris, cobbles, and boulders), and vegetation (including above- and below- ground vegetative structures are important stabilizing elements in estuaries. As described above, broad estuarine flats attenuate or desynchronize marine tidal flows and storm flows as well as river floodwaters. Maximum velocity waters are contained within estuarine channels at mid-tide level while maximum tidal levels are associated with slow volumes and sediment deposition in upland areas (Pethick 1984). Significant sediment deposition can occur at higher levels in a marsh during storm events (Callaway 2000; Stumpf 1983), which then makes these areas less prone to tidal inundation.

The elevation and slope of an estuarine wetland and the sinuosity of its channels are in equilibrium with hydrologic and sediment dynamics of the system (Pethick 1984; Hood 2002a,b; Garofalo 1980; Callaway 2000). Patterns of sediment deposition and channel slumping combined with cohesive sediment properties create stable channel locations and morphology (Collins et al. 1987; Gabet 1998; Garofalo 1980). Vegetation and other relief (e.g., LWD) on marsh surfaces also slow rising water, increase sediment deposition, and stabilize sediments and channel morphology (Garofalo 1980). Fine sediments that are laid down in higher elevations of marsh surfaces tend to be cohesive and extremely difficult to re-suspend or erode once they have settled (Pethick 1984).

Thom (1992) found that accretion rates in Pacific Northwest marshes were adequate to maintain their elevations, even in the face of sea level rise, given current sediment supplies. The equilibrium height of a marsh, the non-erosive quality of finer sediments deposited in more upland areas, and the tendency of marsh height to increase and larger vegetation to survive as water heights (and sediment deposition) increase provides natural and responsive protection from erosive waves and floodwaters. In more developed areas with significant boat traffic, the expanse and height of an estuarine wetland also provides protection from erosion caused by boat wakes.

Much of Whatcom County's residential shoreline, residential shorelines of the Lummi Indian Reservation, and important wildlife areas that lie within the major bays (Drayton Harbor, Birch Bay, Lummi Bay, northern and northwestern Bellingham Bay, along the eastern portion of the Lummi Reservation, and along the northern shores of Portage Island) are protected by broad intertidal areas and lesser extents of estuarine marsh (WCPD 2004a). Other sections of the shoreline, especially from Point Whitehorn to Cherry Point, a section of shoreline south of Cherry Point, the southwestern shore of Lummi Peninsula, the northwestern shore of Lummi Island, and some areas within Chuckanut Bay are protected by narrower bands of estuarine wetlands and fringing flats (WCPD 2004a). Cliffs and sand or cobble beaches protect other sections of the shoreline in the vicinity of Cherry Point, along southern portions of Portage Island, around Lummi Island, and along the eastern shores of Bellingham Bay (WCPD 2004a).

5.2.2.5 Biological Support and Fish and Wildlife Habitat

Estuarine wetlands provide important habitats for aquatic and terrestrial organisms. Tidal cycles temporally vary the sizes and types of habitats available to marine and terrestrial species. Tidal cycles create visible zones on the intertidal shore and invisible zones in the estuarine water column where physical factors such as salinity, desiccation, nutrients and organic matter, and availability of space establish biological patterns of competition and predation. Hourly, daily, seasonal, and inter-annual tidal cycles create a dynamic physical system that creates biological and ecological opportunities for feeding, refuge from predators, life history complexity, and terrestrial-marine exchanges. Some animals find refuge from predators when the tide is out (e.g., chitons and limpets that escape starfish, clams that escape siphon nipping by fish, epibionts on eelgrass and algae that escape feeding by fish), others find refuge when the tide is in (worms that escape predation from birds, juvenile salmon using marsh surfaces and buffer edges). When the tide is in, marine animals (especially, whales, seals, sea lions, crab, fish) have access to intertidal environments (e.g., gray whales feed on sand and mud shrimp in mudflats (Dunham and Duffus 2001; Calambokidis et al. 1994), seals and sea lions rest on sandy or rocky haul-out areas, crab and fish feed in tidal channels and on marsh surfaces. When the tide is out, terrestrial animals (e.g., heron, eagles, raccoon, deer, fox, even bear) have access to algae, worms, clams, and fish in intertidal and submerged areas. In the water column, the timing, duration, location, and degree of mixing within the estuarine salinity gradient has a profound effect on habitat. These factors determine where specific fish and invertebrate species are found, where nutrients are concentrated within the water column, and where organic matter will be deposited and made available for processing (by bacteria, other microbes, and invertebrates) and later consumption by higher trophic levels (e.g., fish, marine mammals, humans).

The feeding opportunities in estuarine wetlands are plentiful, due to high rates of primary production and the recycling of nutrients and by macroinvertebrates and microbes. Although exact production and exchange rates of carbon, nitrogen, phosphorus, and other materials are difficult to estimate, the high productivity of estuarine systems, the exchanges they support between marine and terrestrial systems, and the production and feeding opportunities they provide to a wide range of organism types are well documented (Simenstad et al. 1979; Odum 1984; Ewing 1986; Kwak and Zedler 1997; Zedler 2001; Rice et al. 2004; Teal and Howes 2000; Valiela et al. 2000; Childers et al. 2000).

Although fewer data are available about fish use of estuarine wetlands in the Pacific Northwest compared to estuarine wetlands on the east coast, at least twenty-seven species typify fish assemblages in estuaries of the PNW (Simenstad et al. 2000). Two thirds of these species occur as larvae or juveniles and 41 percent of the species occupy tidal marshes for significant portions of their life history (Simenstad et al. 2000). Salmonids and smelts dominate the assemblages. These groups use the entire estuarine landscape at different periods of their life cycle. Juvenile salmonids move between fresher and more brackish portions of an estuary, adjusting the time spent in each area as needed (Simenstad et al. 2000; Wissmar and Simenstad 1998; Bottom et al. 1998). Some stocks of chum salmon spawn in estuarine areas or just upstream of estuaries. Some marine species, such as English sole use estuarine areas as nursery areas (Gunderson et al. 1990 cited *in* Simenstad et al. 2000), and variability in estuarine conditions has been shown to affect their growth and mortality rates (Shi et al. 1995, 1997, cited *in* Simenstad et al. 2000).

Life history complexity is an important evolutionary strategy for species persistence and resilience in the face of environmental change and it is becoming increasingly clear that estuarine wetlands support life history complexity for many species, especially salmonids. While all species of salmon use estuarine wetland areas to some extent, juvenile ocean-type Chinook and chum tend to use estuarine areas for extended periods (Allen and Hassler 1986; Rice et al. 2004) to acclimate to marine conditions, feed, and rear away from marine predators until they reach adequate size to out-migrate, or move from fresh to salt waters. Estuaries provide salmon the possibility for great flexibility in the timing and duration of their out-migrations and in the time they spend rearing in estuarine areas (Burke and Jones 2001; Rice et al. 2004; Simenstad et al. 2000). This flexibility provides species-level resilience over short-term and evolutionary time scales.

Intertidal estuarine areas also support complex life history strategies for baitfish that spawn on intertidal vegetation and beaches. Herring spawn on intertidal vegetation and will also spawn on intertidal substrates when spawning densities are high. Sand lance and surf smelt spawn on upper intertidal beaches. Some baitfish species may return to the same areas each year to spawn while others may choose new areas. This kind of within-species life history variability is important for species persistence.

The landscape ecological characteristics of estuarine wetlands, including aspects of marsh edge, channel length, and channel sinuosity have an effect on the size and types of habitats available, the species that will be found in the estuary, and the life history possibilities available to them (Kneib 2003; Hood 2002b; Simenstad et al. 2000). It is currently believed that the particular proportional relationships among all the physical components of an estuary direct and regulate the biological and ecological possibilities (Simenstad et al. 2000; Hood 2002b; Kneib 2000). Research in larger rivers like the Columbia River has shown that the size, shape, and location of the salt wedge and mixing zones (all determined by the landscape characteristics of the estuary) have a profound effect on the presence and production of water column and benthic invertebrates (Morgan et al. 1997; Simenstad et al. 1994; Small and Morgan 1994). It is likely that the survival and production of species of flatfish, nektonic fish, and shrimp that rear in marsh channels and on marsh surfaces are highly affected by the landscape ecology of a marsh (Shenker and Dean 1979; Kneib 1984; Weinstein 1979; Weisbert and Lotrich 1982; Talbot and Able 1984). The balance of edge vs. interior, the width and depth of channels, and the amount of intertidal area also affects all higher level predators such as shorebirds, heron, eagles, and adult salmon and flatfish that use estuarine areas. Simenstad and Cordell (2000) suggested that salmonid use of estuarine areas be considered in terms of opportunity (or access), capacity (or habitat quality), and resulting performance (or realized function). These elements of biological support and wildlife habitat creation, which could be measured for any estuarine species, are affected by all the physical attributes of an estuary and are modified by estuarine modification, climate variability, flow regulation, and watershed modifications (Simenstad 2001).

As part of their efforts towards salmon recovery in Whatcom County and throughout the Pacific Northwest, the NOAA Fisheries has specified that viable populations must have adequate abundance, population growth rates, spatial structure, and genetic and life history diversity (McElhaney et al. 2000). Estuarine wetlands contribute to all these qualities by providing habitat and feeding opportunities to increase abundance and population growth rates and a diversity of life history opportunities that promote genetic diversity in a species or stock. Along a shoreline, estuarine wetlands promote spatial structure in a population by providing habitat opportunities across space.

Whatcom County estuaries and nearshore areas provide habitat for fish, dabbling ducks, shorebirds, bald eagles, trumpeter swans, and numerous other species (WCPD 1994). The habitat functions provided by estuarine wetlands and their adjacent uplands in Whatcom County, especially the habitats for designated species such as eagles, heron, osprey, salmonids, baitfish, and shellfish, are described in the wildlife habitat conservation areas white paper. It should be reiterated, however, that estuarine wetlands perform their habitat functions at multiple landscape scales – within a watershed, between watersheds, and along coastlines. Each of the estuarine systems in Whatcom County has its own unique components and, in fact, has been designated an important Wildlife Area by the County (WCPD 1994). These areas are physically connected and provide opportunities for broad-ranging species to meet their rearing, feeding, and reproductive needs – to have spatial and life history diversity. For example, larval transport over large areas may be important for maintaining genetic diversity for fish and shellfish; salmonids, baitfish, marine mammals; migratory birds migrate long distances and use very different habitats during different times of their life cycles; eagles, heron, kingfisher and other birds rely on local conditions as well as the ability to move to other areas to maintain their populations.

5.2.2.6 Recreation, Education, Cultural Resources, and Open Space

Marine and estuarine areas provide important functions for humans as they do for plants and animals. Estuarine areas have always provided important opportunities for fishing and hunting, harvesting plants (for example, grasses, sedges, and rushes for weaving), community and cultural activities (e.g., potlaches, family gatherings), recreation and education (boating, walking, bird watching), access to fishing and harvesting in marine waters, and transportation of goods.

Whatcom County shorelines are heavily used by humans for commerce, recreation, community gatherings, and as areas to enjoy open space. On a drive through Birch Bay, one can see people shellfishing, boating, engaged in family meals, meeting friends, walking, birdwatching. In other less densely populated areas such as the Cherry Point area and the Lummi Peninsula of the Lummi Indian Reservation, smaller groups of people still use intertidal areas for meeting, fishing, birdwatching, walking, and other recreational, cultural, and spiritual activities.

5.3 HUMAN ACTIVITIES AND WETLAND FUNCTIONS

Human activities have both positive and negative effects on wetland functions and values. Human activities that may have negative effects on wetland functions and values include forestry, agriculture, construction of utilities, in-water structures (dams, levees, and bank armoring and others), mining, road building, and urban development (Azous and Horner 2001; Mitsch and Gosselink 2000; Castelle et al. 1992a; May et al. 1997; Booth 2000; City of Portland 2001; Sheldon et al. 2003). Some human activities have greater impacts than others and different activities affect wetland functions in different ways. For example, urban development can result in the complete loss of wetland functions if wetlands are filled, whereas forest management might only change how wetlands function (e.g., what types of habitat they provide). Human activities with beneficial effects on wetlands include restoration, enhancement, dam removal, reconnection of wetlands to historic floodplains and control of invasive species. In the following section we describe how wetland functions are likely to change with different levels of and kinds of

human activity in Whatcom County. Human disturbances are generally described in order of ascending level of effect, beginning with agriculture and forestry and ending with urban development.

5.3.1 Freshwater Wetlands

In the Whatcom Basin expansive areas of wetlands and upland forest habitats were converted to agricultural lands more than a century ago as indicated by habitat type mapping of the upper and lower Nooksack River floodplain in 1880 versus 1998 (Nooksack Indian Tribe 2004). Vegetation was cleared, and extensive diking and draining created conditions suitable for crops, grazing, and hay production (Goldin 1992).

Forestry and mining, other economically important activities in Whatcom County, have also changed or eliminated wetland habitats. Forestry changes the vegetation structure of wetlands and it can change the hydrologic dynamics of wetlands by removing vegetation and compacting soils.

According to the Whatcom County Comprehensive Plan the population of Whatcom County is projected to increase by approximately 65,000 people between 2000 and 2022, with the majority of this growth expected to occur in lowland urban or urban growth areas (WCPD 2003). Wetlands are located in these urban growth areas. For example, 500 acres of wetlands are located within Ferndale's proposed urban growth area (WCPD 2003). Urbanization results in wetland loss and in the loss of or alteration of wetland functions. Even limited urban development, with its attendant increases in impervious surfaces, covering less than 10 percent of a contributing area, can increase surface water runoff to wetlands during rainfall events, altering wetland hydroperiods (Reinelt and Horner 1991; Schueler 1994; May et al. 1997; Sheldon et al. 2003).

5.3.1.1 Flood Water Attenuation and Flood Peak Desynchronization

Human activities related to agriculture and navigation such as diking and draining can separate wetlands from the floodplain limiting their ability to store and desynchronize flood water (Mitsch and Gooselink 2000). Commercial forest practices have affected this function to a lesser extent by compacting soils and altering wetland vegetation (Sheldon et al. 2003).

Urban development can also reduce the flood water support function of wetlands and upland habitats. The loss of wetlands in urban areas affects the ability of the remaining wetland systems to attenuate stormwater runoff, resulting in increased flood frequency and higher peak flood flows in drainage basins (Reinelt and Horner 1991; Schueler 1994; May et al. 1997; Mitsch and Gosselink 2000; Booth 2000). Reduced flood storage capacity can be partially replaced through wetland restoration and effective use of stormwater control facilities. However, even in basins where flood storage has been maintained, discharge volumes from detention facilities in areas with moderate to high levels of impervious surface are still substantially higher than in less-urbanized or natural environments because of reduced rainfall infiltration into pervious soils (Booth 2000).

The loss of flood water attenuation and flood peak desynchronization in urban basins has other consequences. Increased discharge to wetlands can alter the hydrodynamics and hydroperiod (the pattern of fluctuating water levels) in a wetland, resulting in substantial modifications to plant and animal communities adapted to stable hydrologic conditions (Taylor 1993; Booth and Reinelt 1993). This can reduce plant and animal diversity and decrease native plant cover in wetlands. In addition, increasingly higher storm flows in urbanized basins can result in sediment loading, introduction of contaminants (e.g., metals, pesticides, fertilizers), and increased bank erosion in streams and destruction of habitat for fish and other aquatic organisms (Richter 2001; Ludwa and Richter 2001; Richter and Azous 2001; Azous and Horner 2001).

Since the turn of the century, expansive wetland areas in the Whatcom Basin have been altered for agricultural uses by diking, ditching, and draining. Depressional flow-through wetlands have been drained for agriculture by tile drainage systems and drainage ditches (Goldin 1992). Riverine wetlands have been separated from river and stream floodplains by dikes, levees, and impoundments (Gersib 2000; Nooksack Indian Tribe 2004). Most wetlands in the lower mainstem of the Nooksack River were diked and ditched by the beginning of the 20th century (Nooksack Indian Tribe 2004). Wetland loss in urban areas in Whatcom County has further reduced flood support functions in these areas.

5.3.1.2 Stream Base-Flow Maintenance and Groundwater Support

Many studies have found that wetland loss, reduction, and vegetation alteration reduce the capacity of wetlands to provide baseflow support to streams (Booth 2000; Schueler 2000; City of Portland 2001; Mitsch and Gosselink 2000; Brinson 1993). Many wetland types support stream base flows, particularly riverine and headwater wetlands (Booth 2000; City of Portland 2001; Mitsch and Gosselink 2000; Brinson 1993). Urbanization may affect the base flow function of wetlands when wetlands are filled or their drainage patterns are altered by adjacent land uses and by storm drainage systems. In urban areas the loss and alteration of wetlands may reduce base flow and ground water support in areas where the base flow and ground water support functions of upland areas have been eliminated due to increased impervious surface. Impervious surfaces limit infiltration of surface waters (Booth 2000). Surface water flowing from wetlands in urban areas is sometimes intercepted by catch basins and diverted to storm drainage systems rather than to natural streams. This along with other wetland hydroperiod changes in urban areas may reduce base flows, but definitive studies on this topic are not available (Sheldon et al. 2003).

Base flow and groundwater support functions have been reduced in wetlands lost or altered by human activities in Whatcom County. Past and ongoing wetland alterations from agriculture (draining) reduce water storage capacity and increase the rate of surface water flow to downstream areas during the wet winter season, likely reducing base flows during the dry summer season. For example, extensive groundwater pumping and the draining action of agricultural ditches in the Sumas outwash plain lower the regional groundwater aquifer during the late summer months. This reduces the groundwater discharging to flow-through wetlands that support stream base flows and help to moderate stream temperatures (Gersib 2000).

Tributaries in the lower Nooksack Basin in particular experience low stream flows in the summer months, in part due to loss and conversion of wetlands to agricultural and other uses (Nooksack Indian Tribe 2004). The maintenance of instream flows may be the most significant management challenge in WRIA 1 because there is no mechanism at this time to ensure that instream flow needs can be met (WCPU 2004). Low flows in streams during summer can be detrimental to fish and other aquatic biota (AFS 2004). Base flow is particularly important for smaller salmonid-bearing streams that have low flows during the dry season, such as Silver, Wisner Lake, Tenmile, Deer, Fishtrap, Bertrand, Kamm, Smith, and Anderson Creeks (Nooksack Indian Tribe 2004).

5.3.1.3 Water Quality Improvement

The ability of a wetland to improve water quality is affected by the loss of wetland area or persistent vegetation and changes in hydroperiod (including bypass of surface water runoff into wetlands due to ditching and drainage). Physical changes to wetlands can eliminate or reduce their ability to biofilter sediment, nutrients, and chemicals. Agriculture, forestry, mining, and road building activities change the physical properties of wetlands. Ditching and draining, compacting surface soils, and clearing vegetation affect hydrologic regimes and the ability of in wetlands to act as natural filters (Sheldon et al. 2003).

Urbanization also may affect a wetland's ability to improve water quality and it can degrade the quality of surface and ground water in a manner similar to forestry, road building, mining, and agriculture. In addition, impervious surfaces created in urban areas can cause severe water fluctuations in wetlands. Higher and more rapid water level fluctuations can result in either an increase in sedimentation rates by causing erosion/sedimentation or a decrease in downstream sedimentation rates if more sediment is retained in wetland areas. Large and intermittent water level fluctuations also affect the survival of amphibian eggs within wetlands. Denitrification processes and phosphorous retention can also be affected (Ecology 1996).

There are few studies that directly address the impacts of urban runoff on water quality in wetlands; most studies have focused on a wetland's ability to treat runoff. However, Azous and Horner (2001) address direct impacts to wetland water quality by studying the effects of urbanization on 28 wetlands in the Puget Sound lowlands. Generally, pollutant concentrations in wetlands located in urbanized watersheds were somewhat higher than those in undeveloped watersheds, but no concentrations exceeded state water quality standards in any of the wetlands. Dissolved oxygen (DO) levels in urban wetlands, however, were significantly lower than in undeveloped watersheds (Horner et al. 1996).

Low DO and high turbidity and pollutant levels can negatively affect plants and animals inhabiting wetlands, particularly amphibians and fish (Adamus et al. 2001). Many studies document the negative effects of sedimentation, low DO, and pollutants on invertebrates, amphibians, and fish, particularly salmonids, in riparian wetlands, urban streams, and lakes (City of Portland 2001; Booth 2000; May et al. 1997; Mitsch and Gosselink 2000; Schueler 1994). Biofiltration in wetlands, along with infiltration of runoff in upland areas, can reduce negative impacts to flora and fauna in adjacent streams and lakes. However, there is a limit to the amount of sediments, nutrients and toxicants wetlands can assimilate.

The majority of the remaining wetlands in the Whatcom Basin have the opportunity to provide water quality functions; however, there are limits on the level of treatment that they can provide given the amount of pollutants in the landscape. Water quality conditions are currently degraded in the lower Nooksack River and its tributaries by high temperatures; low DO; elevated levels of nitrogen, phosphorus, metals, toxins, and fecal coliform; and high turbidity and suspended solids (WCPU 2004). Many of Whatcom County's wetlands are depressional flow-through and riverine. These wetlands do not retain substantial amounts of the sediments, or the nutrients, and pollutants that enter in the water column or in sediments because they are flow-through systems. Degraded wetlands may be used for stormwater discharge according to WCC 16.16.660 as long as the use of upland sites is not feasible and the wetland functions are enhanced by the discharge.

5.3.1.4 Erosion / Shoreline Protection

Human alterations to wetlands can also affect erosion and shoreline protection functions. Higher velocity surface water flows from altered wetlands and uplands can increase erosion of shoreline and increased sedimentation in wetlands and streams (Sheldon et al. 2003). In riverine or lacustrine wetlands the elimination of shoreline vegetation and soil compaction can directly affect a wetland's ability to protect shoreline areas from excessive erosion. Hard protection such as concrete bank armoring is often used to prevent shoreline erosion. This can exacerbate the problem by further increasing the velocity of flows downstream.

The shoreline and erosion protection functions of wetlands are important in urban watersheds that experience higher peak flood levels and flow velocities, as well as more frequent flooding. As little as 10 percent impervious surface area in a watershed can result in stream channel instability (Booth 1991 and Booth and Reinelt 1993 in Schueler 1994). Increasingly higher storm flows can result in sediment loading

of the stream and destruction of habitat for fish and other aquatic organisms. Wetlands assist in moderating storm flows and preventing erosion; therefore protection of forested or scrub-shrub wetlands along streams and lakes can provide important erosion control functions even in low to moderately-urbanized areas.

Historically, agricultural activities such as tilling, diking, draining have altered the erosion / shoreline protection functions of wetlands in Whatcom County. These activities have disturbed wetland soils and vegetation and modified drainage increasing surface water flow velocities and removing vegetation from shoreline areas (Goldin 1992; The Nooksack Tribe 2004). However, some riverine and lacustrine wetlands in Whatcom County still provide important erosion and shoreline protection functions if shoreline areas are stable and well vegetated (WCPD 1992a). Well-vegetated wetlands not directly connected to streams, rivers, and lakes may also indirectly contribute to this function by slowing stormwater flows to erosive shoreline areas. The functions that wetlands provide for erosion and shoreline protection are especially important amidst the ongoing agricultural, urban, and other developments that act to increase storm water flows, soil disturbances, and other agents of erosion.

5.3.1.5 Biological Support and Fish and Wildlife Habitat

Human activities such as forestry operations, agricultural use, mining, road construction, and urbanization can cause the loss of or the alteration of biological support and wildlife habitat functions in individual wetlands and in the landscape. All of these human activities fragment existing biological support systems including wetland habitats creating habitat islands for some species (Johnson and O'Neil 2001). Human activities also cause food web interruptions, vegetation changes, water quality degradation, and hydrologic modifications that affect wildlife habitat and biological support functions.

The loss of wetlands interrupts the food web for numerous fish and wildlife species (Sipple 2002). The food web for native species is also negatively affected by vegetation removal and by other changes to wetlands from human activities. For example, bald eagles and great blue herons depend upon fish for food. Relatively undisturbed off-channel habitats and wetlands are required for fish spawning areas. Fish in turn depend upon invertebrates for food. Invertebrates are also dependent upon wetland habitats for aquatic food plants and detritus and on wetland substrates. Therefore, disruption to food web processes affects both prey and predators alike.

Vegetation clearing changes wetland habitat type at least temporarily, from shrub and forest types to emergent vegetation. Vegetation removal and alteration in wetlands cause the loss of or degradation of habitat for many native fish and wildlife species including special status species in Washington State (Sheldon et al. 2003). Invasive plant species dominate in many disturbed wetland areas, lowering vegetation diversity.

Many human activities, especially agriculture, mining, and urbanization, are the source of pollutants that flow via surface water and suspended sediments to wetlands (Sheldon et al. 2003). Pollutants and excess sediments and nutrients from human activities can affect wetlands biologic support and habitat functions. Increased sedimentation in wetlands has been linked to a loss of vegetation diversity and microtopography (Dittmar and Neely 1999). Sediment loading and erosion along streams can block access to side-channel wetlands, which provide rearing and refuge habitat for fish (Swales and Levings 1989). Excess sediments have been linked to the burial and mortality of invertebrates; the destruction of fish spawning areas, eggs, and larva; clogging the gills of fish; and inhibiting fish feeding and growth (Sheldon et al. 2003).

Impacts to habitat and biologic support are intensified in urban areas. As discussed above, as little as 10 percent impervious surface in a watershed can increase stormwater runoff rates and flood peaks, substantially affecting vegetation and wildlife communities in wetlands (Richter 2001; Ludwa and Richter 2001; Richter and Azous 2001; Azous and Horner 2001). High fluctuations in wetland hydrology caused by urbanization and to a lesser extent by other human activities can contribute to an increase in the dominance of invasive plant species such as reed canarygrass that thrive in these altered environments (Galatowitsch et al. 1999). Hydrologic changes can cause excess flooding or drying of wetlands affecting species that depend on certain water regimes. Alterations in hydroperiod can be harmful or lethal to amphibian egg and larval development if egg masses attached to wetland vegetation are exposed and desiccated (Richter et al. 1991).

Historically, forest clearing for agriculture in Whatcom County has converted large areas of forested and scrub-shrub wetlands to grazed pasture, hay fields, or cropland. This conversion is evident in the Nooksack floodplain by GIS mapping of land uses and vegetation cover in approximately 1880 (archival sources) and 1998 (aerial photography) (The Nooksack Tribe 2004). Forestry practices have generally caused a decline in overall habitat diversity and integrity, and an increase in habitat fragmentation. Forestry has also changed the hydrological regime of the Nooksack River and other streams with higher peak flows especially during rain-on-snow events (The Nooksack Tribe 2004). Though not well documented for Whatcom County specifically, urban development and county road maintenance has resulted in wetland loss, changes in wetland hydrologic regimes, and water quality degradation. In summary, the result of these cumulative impacts to wetlands is fragmented wetland habitats and degraded conditions for wetland organisms.

5.3.1.6 Recreation, Education, Cultural Resources, and Open Space

Human activities can directly affect opportunities for recreation, education, and the preservation of cultural resources and open space in wetlands. These opportunities may be lost when wetlands are filled, drained, or altered in other ways by human activities. Even small wetlands surrounded by development can provide green spaces that are important for the human experience. In the Whatcom County Comprehensive Plan open spaces, even small corridors between buildings in a small town, are considered to be essential components to the health and wellbeing of individuals and communities (WCPD 2003). Property values, also linked to green space and wetland habitats (Todd 2000), could also be reduced with losses or alterations in wetland habitats.

The recreational value of wetlands can be lowered by human activities, especially if fish and wildlife populations are reduced. Most recreational activities in wetlands in Whatcom County such as in Terrell Lake are related to wildlife use of the site whether it be hunting, fishing, or viewing. Without proper management, recreational activities themselves can also have negative effects on wetlands in terms of vegetation trampling, wildlife disturbances, and mortality (Josselyn et al. 1989).

Many wetlands in Whatcom County are likely to be important culturally. Threats to the integrity of these wetlands could degrade or eliminate important archeological materials. For instance if the chemistry or hydrologic regime of relatively pristine bogs and fens like Pangborn Lake and Dailey Prairie Fen are affected by human activities, valuable cultural resources may no longer be preserved as they usually are in these anaerobic systems. In addition, certain wetland plants and animals are considered culturally important to indigenous people. For example, salmonberry is used as a food source by the Lummi Tribe and western red cedar is used in a variety of ceremonies, including use as a medicinal (Gunther 1988).

5.3.2 Estuarine Wetlands

5.3.2.1 Flood Water Attenuation, Flood Peak Desynchronization, and Tidal Flood Water Attenuation

Diking estuarine wetlands and dredging or filling their surfaces or channels changes the surface area and channel volume available for flood attenuation. Diking, tide gates, and upstream flow alterations can change the amount or pattern of water flow through tidal channels. These actions can also change the sediment supply patterns, which can affect the balance of physical factors that maintain marsh height at a level that provides consistent and resilient protection against fresh and tidal flood waters.

Changes in marsh height lead to changes in vegetation. Vegetation slows flood waters as they spread over the marsh surface. Diking and reductions in the supply of large woody debris can reduce the deposition of organic matter on marsh surfaces that slow flood waters and provide substrate for recruitment of other plant species (Hood 2002c).

Diking and tide gates frequently accompany the conversion of estuarine wetlands to agriculture or other non-wetland land uses. Elevations behind diked marshes often subside during the period that the area is diked due to loss of sediment supply, decomposition of organic matter, and compaction of sediments from settling and/or grazing animals (Anisfeld et al. 1999). Preserving estuarine wetlands will help to protect upland areas from flood waters. When development has been allowed within the tidal and flood plain of an estuary, dikes or other artificial means of protecting the development will be required. Where dikes have been built to protect such development, a seaward dike can sometimes be replaced by a more landward dike so that the area seaward of the new dike can be allowed to regain elevation and provide additional space for attenuation of floodwaters. Also, preserving the size and location of estuarine wetlands and natural processes such as the upstream freshwater flow regime and the supply of sediment and large woody debris will help to maintain the size and height of estuarine marsh features that provide the maximum attenuation and desynchronization of flood waters.

Removing dikes and tidegates from estuarine wetlands is considered one of the least expensive restoration activities for restoring large estuarine areas to tidal inundation. It has been used in the Snohomish (Tanner et al. 2002; Cordell et al. 1999), Skagit (<http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=waterres&pagename=skagitsamish>, <http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/deepwater.pdf>, <http://www.wileyslough.org/ConceptualDesign/Dikes>), Dosewallups (<http://www.washingtontrout.org/>), and Bear (Tear 2004 personal communication) Rivers in Washington, the Salmon River in Oregon (Gray et al. 2002), the South Slough National Estuarine Reserve (Cornu and Sadro 2002), and many other rivers in the Pacific Northwest (<http://www.fs.fed.us/largewatershedprojects/annualreports/2001%20Annual%20Reports/Pac%20coast%2031%20pager.pdf>).

When sedimentation rates are high, breaching dikes can help restore marsh elevations and vegetation (Anisfeld et al. 1999; Callaway 2000). After a dike is removed, several years may be required before marsh heights begin to rebuild and salt tolerant vegetation replaces freshwater vegetation, but within two years, clear changes in sedimentation rates and vegetation have been observed (Frankel and Morlan 1991; Simenstad and Thom 1992; Zedler 1996). For example, in Whatcom County, it would be possible to determine whether diking and tidegates at the mouth of the Lummi River continue to serve their original purposes. If they do not, their removal could greatly expand the area currently available to attenuate floodwaters (and increase habitat for juvenile salmon and marine birds). The Lummi nation is actively studying this option (G. Boggs TAC comments).

5.3.2.2 Stream Base-Flow Maintenance and Groundwater Support

Changing the size of an estuarine wetland, the composition of the sediments, and the supply of freshwater or sediments affects the hydraulic and sediment balances of the wetland, the location of isohaline zones (Jassby et al. 1995), and the ability of saltwater to migrate into freshwater aquifers.

Diking wetlands tends to lead to compaction and subsidence of the marsh surface behind the dike. Compaction of interstitial spaces changes the ability of groundwater to percolate through the sediments and replenish fresh groundwater. This can change the balance of hydraulic pressures through an area and can lead to sheet flow along the interfaces of different sediment types if interstitial pathways are reduced.

According to Palmer et al. (2000), “even if peak flows and baseflows are within acceptable ranges from an ecological standpoint, if groundwater residence times are too short and/or the exchange of water between the hyporheic zone and the groundwater environment is greatly reduced, nutrients may reach unacceptable levels in river channels and estuaries and biodiversity may be significantly reduced.”

Reduced freshwater-flow or increased groundwater withdrawals can reduce the elevation of groundwater and increase the risk of saltwater intrusion into groundwater near the coast (Dion and Sumioka 1984; Monterey Bay National Marine Sanctuary web site/2004; US Global Change Research Program 1999). Reducing freshwater pressure and freshwater supply to interstices and groundwater aquifers increases the likelihood that brackish waters can migrate into these areas. Reducing base-flow moves the estuarine salinity gradient upstream as tidal waters meet reduced surface freshwater volume (Jassby et al. 1995). Shifting the salinity gradient upstream moves the risk of saltwater intrusion into groundwater further upstream.

Most Whatcom County rivers experience reduced summer base-flows that are exacerbated by irrigation withdrawals and groundwater pumping. Some coastal areas of the county may be experiencing salinity intrusions into groundwater due to excess removal of groundwater as the population in these areas increases. For example, on Lummi Island, along Point Whitehorn and on the western shore of the Lummi Indian Reservation, groundwater removals may be altering the balance of hydraulic pressures along the shoreline and contributing to saltwater intrusion into groundwater (Dion and Sumioka 1984; USGS website/2004).

5.3.2.3 Water Quality Improvement

Estuarine wetlands are located at the lowest downstream portion of a river system, therefore inputs at any point in the river, upstream in the watershed or local to the wetland, have a potential to affect the health and quality of the estuary. Estuaries are equally vulnerable to contamination from marine sources. Inputs from terrestrial point and non-point sources of pollution as well as from marine oil spills and vessel releases of sewage all contribute to water quality problems in estuarine wetlands.

Although vascular plants, macro and micro algae, and microbes seem to be able to respond to certain amounts of increased nitrogen supply (Teal and Howes 2000), it has been found that eelgrass production decreases with very small increases in land-based nitrogen (Valiela et al. 2000). Negative effects of increase nitrogen may be due to shading from increased production of phytoplankton and macroalgae or from direct nitrogen toxicity. For a given sized watershed, these effects seem to decrease with increases in the area of fringing saltmarsh indicating that salt marshes reduce the export of nitrogen to surrounding waters (Valiela et al. 2000).

Either excessive inputs or decreased flushing rates will have negative effects on water quality, sediment quality, and the use of intertidal and estuarine areas by all species. Increased loading of most

contaminants (including sediments, nutrients, toxics, fecal contamination, biological oxygen demand, temperature), generally comes from upland sources. Changes in flushing rates can occur when shorelines are modified or freshwater flow regimes are altered. Increased sediment supply can negatively affect spawning areas and sedentary invertebrates. Increased nutrients have been found to change the competitive interactions among plant species (Bertness and Pennings 2000) and decrease abundance of eelgrass (Valiela et al. 2000). Many estuarine organisms are filter feeders and can directly ingest contaminants or bacterial contamination dissolved in the water column or adhered to sediment particles. Many species are vulnerable to toxic contamination through their skin or through the food they ingest. Effects of toxics and bacterial contamination can be translated to higher trophic levels in the food web. Many fish and shellfish species have been found with tumors, lesions, and deformities that result from effects of organic and inorganic contamination from estuarine wetlands (Turgeon and Robertson 1995).

Drayton Harbor and Birch Bay are zoned City, Urban Residential, and Commercial (<http://whatcom-mrc.wsu.edu/MRC/projects/data/shorezones/county.htm>). The Cherry Point area is zoned Urban residential and Industrial. Water and sediment quality of estuarine wetlands in these areas may be affected by both point and non-point sources of pollution, including toxics and Biological Oxygen Demand (BOD-any materials whose decomposition or degradation consumes dissolved oxygen) from permitted outfalls and stormwater runoff, leakages from the sewage treatment system, and non-point agricultural and household sources. Of these bays, Drayton Harbor, which may not be well flushed due to protective spits and drift cells that tend to recirculate water (<http://www.whatcom-mrc.wsu.edu/MRC/projects/data/bathymetry/county.htm>), may be particularly vulnerable to pollutant loads. Lummi Bay, the western half of Bellingham Bay, and the southern half of Chuckanut Bay are zoned Rural residential and Resources and may be vulnerable to non-point sources of pollution such as fecal coliforms from septic systems, nutrient, pesticide, and herbicide runoff from lawns, and minor spills of hydrocarbons and other toxics from households. All areas are vulnerable to low dissolved oxygen and high temperatures if stream base flows are reduced and nitrogen or sediment supplies are increased.

Many shellfish beds in Puget Sound have been closed due to microbial contamination caused by development of different types (Glascoe and Christy 2004). Both Drayton Harbor and Portage Bay on the Lummi Indian Reservation have been designated as Shellfish Protection areas due in part to fecal coliform bacteria and other water quality problems (http://whatcomshellfish.wsu.edu/Drayton/reports/DH_sanitary_survey_05_04.pdf, <http://whatcomshellfish.wsu.edu/Portage/reports.htm>).

5.3.2.4 Erosion / Shoreline Protection

As mentioned in other sections, the elevation and vegetation of intertidal estuarine wetlands are in equilibrium with the sediment deposition and erosion created by interactions between tidal and freshwater flows. The dynamic processes created by these forces create a natural barrier to erosion of upland areas. As estuarine and intertidal areas are diked, armored, filled, or dredged, the system seeks a new equilibrium and erosion and deposition begin to occur at different rates and in different places than they previously did. As upstream or up-drift cell sediment supplies are cut off, the supply of sediments to intertidal areas is reduced, their elevation decreases, and upland areas become more vulnerable to erosion from tidal forces. Erosion can be moved closer to shore and deposition can be moved offshore into subtidal areas where it does not help protect upland areas (Jay and Simenstad 1996).

Reducing the shoreline modifications that inhibit longshore and cross shore movement of sediments and minimizing alterations in sediment supply and freshwater flow from upstream areas will provide the County with the landscape-scale sediment and water supply resources needed to protect the dynamics of natural sedimentation and erosion processes that will maintain the maximum protection of upland areas.

5.3.2.5 Biological Support and Wildlife Habitat

In estuarine areas, the interactions of freshwater flows and marine tides and storm surges create terrestrial, aquatic, and submerged habitats across a salinity gradient. The size, location (position), and timing (when during the annual, seasonal, biweekly, and daily tidal cycles) of different habitats along the estuarine salinity gradient are unique to each estuary and the flora and fauna of each estuary respond to these factors. When freshwater flow or sediments supply is modified or estuarine habitat is dredged, diked, or filled, all the qualities of estuarine wetlands to which biota are adapted change. Man-made alterations tend to decrease habitat quality and quantity, change landscape and biotic interactions, and make systems more prone to invasive species. For example, the size of the tidal prism (the volume of water that is drawn into a bay from the ocean through the inlet during flood tide) and the location, size, and timing of different isohaline zones are affected by the amount of freshwater flow into an estuary and the volume of the estuary. The volume of the estuary can be affected by shoreline armoring and diking that reduce the amount of land over which tidal waters can spread. Reductions in the tidal prism usually also results in changes in the location, size, and timing of isohaline zones which affect the distribution of estuarine invertebrates that provide food for many juvenile salmon (Jassby et al. 1995) the amount of time and space available to non-native pelagic invertebrates to “invade” an estuary (Cordell and Morrison 1996), and the volume of habitat available for juvenile salmon to acclimate to marine conditions and gain adequate size before they enter the ocean environment. In the short term (years), reductions in tidal prism reduce access to marsh habitats and the feeding opportunities they provide. In the long term (generations) reductions in tidal prism reduce possibilities for life history plasticity and diversity in salmonid populations – especially for Chinook and coho that tend to utilize estuarine areas. Changing the size and location of the tidal prism can also change the location and types of vegetation in marshes or buffers. Changing the types of vegetation can affect locations and rates of erosion, location and timing of shading, the recruitment of nutrients and organic matter, and access to marsh areas by fish and wildlife species that forage and rear in estuarine areas. Reductions in shading can lead to increases in water temperature. Alterations in freshwater flow have been shown to reduce species diversity and alter trophic interactions in estuarine wetlands (Livingston 1997) and can also reduce the size of the tidal prism. Simenstad (2001) presents conceptual models for how salmon access to estuarine habitats, the quality of those habitats, and the production of salmon by those habitats are affected by estuarine modification, flow regulation, and watershed modifications. Diking and filling also affect where large woody debris will be deposited and recruitment of vegetation to marsh surfaces (Hood 2002c).

In Whatcom County, freshwater flow has been lowered during summer months, residences, industry, roads, and railroads encroach into estuarine buffers, riparian vegetation has been reduced, dikes limit areas that are open to tidal action, and water pollution, boat activity, and human use of the shoreline affect the habitat qualities of estuarine areas. Nevertheless there are abundant opportunities to reverse many of these conditions and increase buffer areas, remove dikes and restore tidal flows, protect water quality from upstream and marine sources of pollution, and maintain freshwater flows to these important areas.

5.3.2.6 Recreation, Education, Cultural Resources, and Open Space

Threats to the recreational, educational, and cultural values provided by estuarine wetlands are similar to those experienced by freshwater wetlands. Additional stress is created in estuarine areas because of their location near bays and other prime commercial and industrial lands and their desirability as areas to live and vacation (U.S. Commission on Ocean Policy 2004). Nearshore areas provide economic opportunities for transportation, boating, and resource extraction that are not as prevalent in freshwater wetlands. As Whatcom County continues to develop, the pressures exhibited on estuarine wetlands will continue to grow. The County will be challenged to accommodate the many important uses these area provide while still maintaining the full range of wetland ecological functions.

5.3.3 Restoration Activities

Restoration efforts along the Nooksack River are currently underway in several areas, resulting in the restoration of wetland functions including flood support, biological support and wildlife habitat, water quality, and base flow support. Managers can use the GIS database developed by Gersib (2000) as a tool to select appropriate wetland restoration sites for performing certain functions in locations where these functions are needed. This database is being used for this purpose by Whatcom County governmental agencies. The U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) has an active wetland reserve program in Whatcom County that provides incentives for agricultural producers to take prior converted cropland and restore these areas to higher functioning wetland. One example of a large-scale wetland restoration project is in the Marietta area along the Lower Nooksack River. Land for this restoration project was initially purchased by WDFW and it is being restored in coordination with Ducks Unlimited, the Lummi Natural Resources Department, and other sponsors. It encompasses 500 acres and 18,000 feet along the river (Gillies 2004 personal communication). The Federal Conservation Reserve Enhancement Program is also active in Whatcom County with approximately 1,000 acres designated for riparian restoration (Gillies 2004 personal communication).

5.4 WETLAND MANAGEMENT AND PROTECTION TOOLS

Wetlands in Whatcom County are regulated at the federal, state, and county levels. The U.S. Army Corps of Engineers regulates discharges of dredged or fill materials into waters of the United States, including wetlands under Section 404 of the Clean Water Act. Section 401 of the Federal Clean Water Act is administered by the Environmental Protection Agency, which is authorized by Congress to delegate the administration of this section of the Clean Water Act to state and tribal governments. If a state or tribe applies for and is delegated authority to administer Section 401, the state and/or tribal government must certify that proposed activities will not adversely affect water quality or violate applicable aquatic protection laws. Washington State's Growth Management Act (GMA) (RCW 36.70A.060) requires counties and cities to adopt development regulations that protect the functions and values of critical areas, including wetlands. Whatcom County regulates certain activities in wetlands and has standard buffer and mitigation requirements for protecting regulated wetlands. This section provides a review of current wetland rating systems, buffer functions and recommended protective widths, and other wetland management and protection tools that are or can be used to regulate activities in and near wetlands. USDA regulates wetlands for all farm program participants as per attached table.

5.4.1 Designation, Rating and Classification

Designating, rating, and classifying wetlands are important wetland management tools. Local jurisdictions are required to designate wetlands in accordance with the state definition (see p. 1). These definitions specifically indicate that "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 artificially created wetlands intentionally created from non-wetland areas to mitigate the conversion of wetlands". This same definition of wetland is used in the Washington State Wetlands Identification and Delineation Manual (Ecology 1997).

Wetland classification and rating systems are used to classify and rank wetlands based upon their functions and values in order to prioritize protection measures. For example, higher functioning wetlands or large high quality wetlands are considered a high priority for protection than lower quality smaller wetlands with lesser functions. Local governments generally attempt to prioritize or rank wetlands based

on function and value to develop regulatory standards and protective measures that are tailored to the relative importance of different wetlands.

The Washington State Department of Ecology has developed a wetland rating system for ranking wetlands according to their relative importance in terms of functions and special characteristics. This rating system is described in the Washington State Wetland Rating System for Western Washington (Ecology 1993). Wetlands in the rating system are rated into four distinct categories, from Category I wetlands of highest function and value to Category IV wetlands of lowest function and value. This rating system has been recently revised by Ecology in its Publication No. 04-06-025 (Ecology 2004a). The revised rating system contains a semi-quantitative rating form used to evaluate wetlands based the functions they provide. Ecology recommends using this rating system for developing standards for regulating activities in wetlands and wetland buffer areas. However, they do not recommend that it replace a full wetland functional assessment needed for compensatory mitigation projects.

Washington State Department of Community, Trade and Economic Development recommends that counties use a wetland rating system to identify the relative function, value, and uniqueness of wetlands in their jurisdiction. They advise using the following tools to develop a rating system:

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

If a jurisdiction selects not to use the four-tiered state rating system, CTED requires that the rationale for that decision be included in the legal record.

The Whatcom County Code (WCC) does not use a particular rating or classification system to rank wetlands for the purpose of regulating and protecting wetlands. Rather all wetlands meeting the standard definition of wetlands as outlined by Ecology's 1997 wetland delineation manual are considered to be regulated wetlands with the exception of "isolated wetlands" less than 1/3 acre in size and "isolated wetlands" dominated by invasive species or pasture grasses with the dominant functions limited to storm water storage/flood attenuation (WCC 16.16 610). Whatcom County defines "isolated wetlands" as wetlands that are outside of and not contiguous to any 100-year floodplain or, under natural conditions, have no contiguous connection to a stream, river, pond, lake, or marine water (WCDC, 1997 – WCC 16.16.800). Even if wetlands are not regulated by Whatcom County, activities in wetlands may still be regulated by the Army Corps of Engineers and/or the EPA or Ecology as part of their administration of the Clean Water Act.

5.4.2 Buffers

Wetland buffers are vegetated upland areas immediately adjacent to wetlands. These areas provide beneficial functions that enhance and protect the many functions and values of wetlands described above. Terrestrial habitats surrounding wetlands provide a buffer to help mitigate the impacts of various human activities.

A scientific literature review indicates that buffer widths to protect a given habitat function or group of functions depend on numerous site-specific factors. These factors include the plant community (species, density, and age), aspect, slope, and soil type, as well as adjacent land use. The body of science indicates

that the appropriate buffer width for a given wetland is specific to the environmental setting and functions to be achieved by that buffer (Castelle et al. 1992a; Castelle and Johnson 2000; Desbonnet et al. 1994; FEMAT 1993). Several literature reviews have been published summarizing the effectiveness of various buffer widths, mainly for riparian areas, but also for wetlands (Castelle et al. 1992a; Castelle and Johnson 2000; Desbonnet et al. 1994; FEMAT 1993). Freshwater Wetlands in Washington State Volume 1: A Synthesis of the Science (Sheldon et al. 2003) provides the most recent literature review specific to wetland buffers in western Washington.

The Washington State Department of Ecology recently published guidelines for the use of appropriate wetland buffer widths based on wetland functions and characteristics and adjacent land uses (Ecology 2004b). Larger buffer widths are recommended for higher intensity land use such as commercial and residential development. Studies of buffers in forest practices and agriculture indicate that buffers ranging from 25 to 100 feet may be adequate to preserve many of the beneficial functions of wetlands excluding wildlife habitat and microclimate control (Castelle et al. 1992a; Sheldon et al. 2003). However, urban wetlands have many different variables affecting wetland functions and applying these buffer ranges may or may not be adequate to protect the wetland systems. Due to the type and degree of cumulative impacts to urban wetlands (and streams) that have already occurred as a result of high levels of total impervious area and past disturbance to wetlands, it may be necessary to develop new strategies to successfully address the issue of adequate buffers in the context of basin-wide change (Booth 2000; Azous and Horner 2001; Booth and Reinelt 1993).

Whatcom County requires that wetland buffer areas be established to protect wetland functions (WCDC, 1997). Regulated wetlands are protected by a standard 100-foot buffer, while wetlands determined to be “isolated” and not characterized as mature forested, fen, sphagnum bog, or estuary are protected by a standard 50-foot buffer (WCC 16.16.640). Isolated wet meadows are exempt from buffer requirements if wetland functions are restricted mostly to storm water storage or attenuation (WCC 16.16.640.C.2). Buffer width averaging or buffer width reduction is allowed as long as an applicant can demonstrate adequate wetland protection with a modified buffer (WCC 16.16.650.A). In some cases increased buffer widths may be applied (WCC 16.16.650.B).

Several studies indicate that buffers ranging from 100 to 150 feet wide provide most (on the order of 80 percent) of potential functions in most situations (Castelle et al. 1992a; Desbonnet et al. 1994). In some 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. 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, studies show that wildlife responses to human disturbance are varied and a buffer of 50 to 150 feet may not provide enough separation or protection (Knutson and Naef 1997; Cooke Scientific Services 1992). Rather, wildlife use of wetland and riparian buffers is highly dependent upon the species in question and site-specific characteristics (i.e., type of wetland, geographic setting, etc.). Buffers of 200 to 600 feet or more from the aquatic resource has been documented in the scientific literature as more appropriate for some wildlife species (i.e., amphibians, elk) with large dispersal requirements (Sheldon et al. 2003; Richter and Azous 2001).

Information concerning the specific buffer requirements of estuarine wetlands in the Pacific Northwest is scarce relative to information for freshwater wetlands; however recommendations provided by Desbonnet et al. (1994) were developed for wetlands in the coastal zone. As with freshwater wetlands, buffers maintain the health of estuaries by:

- Filtering sediment (excess sediment adversely affects spawning of most fish, filter and detrital feeding of bivalves and other invertebrates, and algae and vascular plants)
- Stabilizing of upper beach habitat
- Regulating temperature of substrate and water column
- Absorbing wave energy
- Filtering and mineralizing nonpoint organic pollutants
- Providing habitat and food production
- Maintaining Shoreline structure
- Ensuring long term stability and ecosystem integrity.

Jamieson and Levings (2001) note that the marine riparian area¹⁵ (including the vegetated and unvegetated areas along the marine shoreline) is an important transitional area (ecotone) where high tide aquatic habitat merges into terrestrial habitat. These areas have their own set of spatially and temporally defined processes and are used by numerous fish and invertebrate species for spawning and rearing (the authors cite Pentilla 1997 and 2000; Humphreys and Hourston 1978; Levy 1985; Peppar 1965; Marliave 1981; Healy 1979; Healy 1991; Grout et al. 1998; Levings et al. 1991; Whitehouse et al. 1993; Levings et al. 1995; Volk et al 1984).

There are limited data on which to base recommendations for buffer widths for estuarine wetlands, although data concerning freshwater wetland buffer widths provides some guidance (see below). Rhode Island has developed buffer standards for coastal and estuarine wetlands in accordance with that State's Coastal Resources Management Council's legislative mandate. The Rhode Island buffer standards range from 25 to 200 feet depending on the lot size and wetland type (Rhode Island Coastal Resources Management Council 1994). Other investigators (Jamieson and Levings 2001) suggest that, in the absence of developing a regional buffer standard for estuaries, individual buffer determinations should take into account:

- All habitat functions including upland and buffer wildlife functions.
- Actions needed to maintain soil integrity to protect against tree blowdown.
- Site stability, activities in the adjacent upland area, and exposure to marine waves to avoid sediment sloughing from terrestrial habitats onto rearing or spawning habitat.

The following sections describe the role that buffers play in protecting freshwater and estuarine wetlands.

¹⁵ Defined as the area seaward of the mean higher high tide level to the limit of salt marsh or brackish marsh vegetation or to the tidal elevation which is submerged < 10% of the time OR the area landward of mean higher high water to the limit of salt spray, dune vegetation, and/or ½ potential tree height or 30 m linear distance whichever is greater.

Flood water attenuation and food peak desynchronization. Buffers infiltrate flood water, reducing the effect of water level fluctuations within wetlands. Wetland buffers, of widths between 50 to 300 feet, play a role in moderating water level fluctuations within wetlands by slowing and detaining surface runoff and slowly releasing it to the wetland, as well as providing floodwater storage and control for the basin overall (Wong and McCuen 1982). However, the effects of buffers in moderating hydroperiods in wetland can be negated by high levels (> 15 %) of impervious surface within watersheds (Azous and Horner 2001; McMillan 2000). In high-density urban watersheds, buffers have a minimal or even insignificant effect on moderating water level fluctuations within wetlands; minimizing or reducing the amount of impervious surface would be more effective at controlling storm flows (Booth 2000; McMillan 2000).

Estuarine buffers provide additional space and elevation to accommodate extreme high freshwater and marine tidal flood and storm conditions.

Stream baseflow maintenance and groundwater support. In cases where wetlands provide this function, wetland buffers may add to a wetlands ability to provide stream baseflow maintenance and groundwater support by infiltrating, retaining, and slowly releasing storm water flows to wetlands. Buffers located in aquifer recharge areas offer additional support for this function.

Estuarine buffer areas contribute to the protection of upland groundwater from saltwater intrusion and provide pathways for the infiltration of fresh groundwater into estuarine tidal channels and onto marsh and mudflat surfaces. The width, slope, stability, sediment structure, and vegetative composition of a buffer area will have a profound effect on the speed and volume of exchange between marine and fresh groundwater.

Water quality improvement. Buffer areas retain sediments, nutrients, pesticides, pathogens, and other pollutants that may be present in runoff (Ecology 1996). Reduction of sediment and pollutant discharge to wetlands prevents alterations to plant and animal communities and degradation of water quality in wetlands.

Forested and shrub buffers provide shade which in turn helps to maintain water and wildlife habitat quality. For example, shading can reduce water temperature in wetlands that provide rearing habitat for amphibians and fish. The most effective buffer widths for water quality factors, including sediment or pollutant removal and temperature regulation, range from 15 to 125 feet in width, with the width greater on steep slopes (Castelle et al. 1992a; Knutson and Naef 1997). Specific studies have concluded that buffers of 100 feet can achieve sediment removal efficiencies of 75 to 100 percent, while depending on site-specific conditions and buffer type, buffers of 100 feet or less may provide substantial pollutant removal benefits. Several authors (Schultz et al. 1995; Lowrance 1992; Welsch 1991) advocate the use of a 3-zone buffer system (60 to 150 feet wide in total) to provide maximum water quality function. These zones are: Zone 1: a grassy filter strip at the outer edge of the buffer designed to maximize sheet flow; Zone 2: a managed forested area designed to provide maximal surface roughness and serve as a transition zone to the next zone; and Zone 3: a natural forested area adjacent to the aquatic resource.

Estuarine buffers help preserve the water and sediment quality of estuarine wetlands by providing additional sediments for filtering stormwater runoff from residential and industrial areas. Where buffers include trees, shrubs, and cliffs, buffers can also shade coastal areas, help keep the temperatures of nearshore waters or exposed intertidal substrates cooler, and take up nutrients and contaminants. The effectiveness of buffers for non-point pollution control is related to width, soil type, and slope (Rhode Island Coastal Zone Buffer Program 1994).

Erosion/shoreline protection. Upland buffers can augment a wetland's erosion /shoreline control function by allowing infiltration and slowing sheet flow. Buffers that contain plant species with fine and very fine roots are most effective at binding the soil and preventing erosion (Karr and Schlosser 1977 *in* McMillan 2000). Wetlands and buffers that extend 200 to 600 feet from lake shorelines and stream banks provide the most effective erosion control for these aquatic resources (Cooke Scientific Services 2000).

Estuarine buffers provide protection against erosion due to extreme high freshwater floods and marine tidal waves and storms. They are an important component of the dynamic maintenance of marsh and buffer elevations that are affected by sediment supply from freshwater and marine sources and sediment loss due to erosive forces from tidal currents and storms.

Biological support and wildlife habitat. Wetland buffers provide important biological support and habitat for a variety of fish and wetland-dependent wildlife species.

Most studies regarding biotic inputs of buffers focus on inputs to streams for fish; however, the studies also apply to wetlands, particularly open water wetlands. Since wetlands contain vegetation, import of nutrients and organic matter from adjacent buffers may not play as important a role in wetlands as in streams. Several stream studies demonstrate that buffers of 100 feet are necessary to maintain healthy benthic communities (Roby et al. 1977; Newbold et al. 1980; Castelle and Johnson 2000).

Wildlife species that use wetlands for a portion of their life cycle also depend on terrestrial habitats for food, cover, nesting, and/or travel corridors (Johnson and O'Neil 2001). A variety of wildlife species utilize the edge habitat between wetlands and uplands habitat. Terrestrial habitat areas provide a source of large woody debris used by wildlife for foraging, nesting, and cover (O'Connell et al. 2000).

Terrestrial habitats surrounding wetlands provide a buffer to help mitigate the impacts of human activities. Buffers provide separation between wetland habitat and human disturbance. This distance improves the quality of wildlife habitat by lessening the effects of noise, light, and human motion/activity upon animal species sensitive to these disturbances (Sheldon et al. 2003).

Appropriate buffers to maintain wildlife habitat functions of all but the most degraded wetlands range from 100 to 300 feet, if they contain a diversity of native trees and shrubs (Sheldon et al. 2003). However, certain animal groups may require larger buffers. For example, amphibians (that are highly affected by urbanization and fragmented forests) require upland forested buffer widths ranging from 50 to 1,000 feet (Richter and Azous 2001). For most bird species that use wetlands, a forested and/or shrub buffer width of 50 to 300 feet provides adequate foraging, roosting, nesting, and cover for birds (McMillan 2000). Mammals use wetland buffers ranging from 100 feet (beavers [WDFW 1992]) to 600 feet (mink [Allen 1982 *in* McMillan 2000]). Buffers of less than 50 feet are generally ineffective at screening out human disturbance to wetlands (Cooke Scientific Services 1992).

Estuarine wetland buffers protect these wetlands from upland disturbances such as noise and water quality pollution. They also provide transition habitat for animal species that can move between freshwater and terrestrial systems (e.g., raccoon, rodents, fox, deer, bear, eagle, osprey) and permanent habitat for species that feed in the estuary (e.g., heron, kingfisher). Buffer areas are occupied by plant species that can tolerate the somewhat harsh conditions of periodic salt spray or even brackish or alkaline conditions (e.g., willow, bigleaf maple, alder) and therefore are unique. Many fish species have been found to use upper elevation buffer areas during high tide (summarized in Jamieson and Levings 2001).

As buffer areas are changed, not only are the habitats they provide changed, but also the adjacent marine and terrestrial components and the flux between them that maintains estuarine areas. Terrestrial animals have less opportunity (space) to hide and wait for feeding opportunities in the intertidal zone. Organic

material and shading from riparian vegetation are reduced. Noise pollution and disturbances to shorebirds and waterfowl also can increase.

Recreation, education, cultural resources, and open space. Wetland buffers can directly increase opportunities for recreation, education, cultural resource protection, and open space by expanding the area available for these pursuits. Buffers also benefit these open space activities by supporting and maintaining other wetland functions such as fish and wildlife habitat, water quality, and shoreline protection. Buffer areas around estuarine wetlands contribute to the sense of place by containing the wetland space and providing visual and aural separation from more urban or developed areas.

5.5 WETLAND MITIGATION

Federal and state guidelines governing wetland mitigation generally require that mitigation sequencing be used to address impacts to wetland areas. Mitigation sequencing may be achieved by first avoiding, and then minimizing, rectifying, reducing, and/or compensating for impacts to wetlands and their functions. Where loss of wetland acreage and/or functions is necessary or unavoidable, compensatory mitigation must be provided. The majority of local jurisdictions in Washington implement these guidelines through local critical area regulations. Most local jurisdictions require compensatory mitigation for impacts to wetlands and/or their buffers resulting from development or associated activities. Jurisdictions generally allow four types of compensatory mitigation: creation, rehabilitation, enhancement, and preservation (Gwin et al. 1999; Sheldon et al. 2003). The different types of compensatory mitigation are generally considered to be in-kind (replacement of same functions as the affected wetland) and are typically constructed on the development site where the wetland impact occurred or at least within the same basin. Off-site or out-of-kind mitigation may also be allowed if in-kind and onsite mitigation opportunities are limited.

Whatcom County requires mitigation for activities in regulated wetlands with certain exceptions (WCC 16.16.225; WCC 16.16.245). Whatcom County requires that applicants use Ecology's Guidelines for Developing Freshwater Wetland Mitigation Plans and Proposals (Ecology 1994) as a guideline for preparing a mitigation plan (WCC 16.16.245.F). This guidance document has been revised and expanded to reflect knowledge gained from wetland mitigation successes and failures in the state during the past 10 years (Ecology 2004c).

Rice et al. (2004) list dike or levy breach or removal as the most prevalent method for restoring estuarine wetland restoration with excavation, substrate addition, transplantation, fertilization, hydrologic control (tidegates, etc.), grazer control, competitor control, large woody debris placement, wastewater and sediment discharge control, and chemical contaminant removal or containment as other methods. In most cases, mitigation of estuarine wetlands involves restoration of function in existing wetlands and not creation of entirely new wetlands. However, some cases of wetland creation exist. For example, the Oregon Department of Transportation Barview Wayside Mitigation site in Charleston, Oregon (Tear 2004 personal communication) and the famous Gog-Li-Hi-Te restoration in the Puyallup River (Simenstad and Thom 1996) were created by excavating areas on the shoreline of Charleston Harbor and the Puyallup River, respectively. At Barview Wayside, soils and seed bank were imported from another wetland.

5.5.1 Compensatory Mitigation Success and Failure

Most compensatory wetland mitigation projects in Washington have not been successful, both in regulatory compliance and in functional replacement for various reasons and have resulted in lost acreage, wetland types, and wetland functions (Castelle et al. 1992b; Ecology 2001; Mockler et al. 1998). An

initial study by Ecology (Castelle et al. 1992b) reported that 50 percent or more of the compensatory 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.

A predominant problem throughout freshwater 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 2001). Mitigation areas that were not protected by upland buffer had a larger percentage of non-native species, while long-term maintenance of sites resulted in lower percentages of non-native species. 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. The use of wetland exchange and 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 “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 2001).

Twenty-four freshwater wetland compensatory mitigation sites in Washington were analyzed by Ecology (2001) and found that although mitigation success has improved in the last 10 years, there is still much room for improvement. The Ecology study had the following findings:

- 29 percent of the projects were achieving all of their specified measures;
- 84 percent of the total acreage of mitigation was actually established;
- 65 percent of the total acreage of lost wetlands was replaced with new wetlands;
- 54 percent of the projects were found to be minimally successful or not successful;
- Wetland enhancement as a type of mitigation performed poorly, compared to creation (50 percent of enhancement sites provided minimal or no contribution to overall wetland functions; 75 percent of sites provided minimal or no contribution to general habitat function). Over half of the wetland creation sites provided at least moderate functions for water quality, quality, and wildlife habitat.
- Publicly funded mitigation projects tended to fail at a higher rate than privately funded mitigation (71 percent of private projects were deemed moderately or highly successful compared with 35 percent of public projects); and
- 60 percent of created wetlands were moderately or fully successful and provided significant contribution to water quality and quantity functions.

Compensatory 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 systems¹⁶, 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 et al. 1996; Booth 2000).

Ecology (2001) concluded that although better site selection, design and performance standards will help to improve compensatory wetland mitigation, consistent follow-up (adaptive management), 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. Other studies support long-term (at least five years) monitoring for mitigation projects (Kentula 2002; Kusler and Kentula 1990). The literature indicates that on-site, mitigation is desirable and can be most successful at replacing lost wetland functions, but success is dependent on site constraints, particularly hydrologic conditions. The literature is conflicting on whether on-site mitigation or off-site mitigation can adequately compensate for loss of wetlands and their functions (Erwin 1990; Castelle et al. 1992a; Kusler 1992). However, Kusler (1992) suggests that in cases where there are many small isolated wetlands and compensatory mitigation has been determined to be necessary (after evaluating mitigation sequencing), large-scale off-site mitigation may be more successful at replacing lost wetland acreage and functions, because replacement of these small wetlands is difficult to achieve. Greater functional benefit may be reached through a larger mitigation project that is established within the context of landscape level assessment where optimum location to meet the "needs" of the hydrologic and ecological system can be determined (Kusler 1992; Ecology 2001; Bedford 1996).

Buffer mitigation projects generally are affected by the same factors as wetland mitigation. Success of plant growth in the buffer depends on water, nutrient and soil requirements for plants, and controlling the invasion of non-native species (Gwin et al. 1999; Magee et al. 1999).

Success of buffer mitigation projects also depends on human disturbance in the buffer. Buffers in some urban environments, due to close proximity to development, have been altered through dumping of debris, clearing, conversions to residential lawns, and other human disturbances (Desbonnet et al. 1994; Cooke Scientific Services 1992; Castelle et al. 1992a). However, impacts to buffer areas were less likely in areas where residents had been educated about the value of buffers (Gwin et al. 1999; Kentula 2002).

The success of estuarine rehabilitation or creation, depends, to large degree, on the extent to which landscape processes are intact or can be restored (Simenstad 2000; Simenstad et al. 2000). For estuarine wetlands, restoring hydrologic processes involves restoring riverine inputs of freshwater, sediments, nutrients, and large woody debris, including the seasonal flux in these inputs. Likewise, daily and seasonal marine processes of sedimentation and erosion, currents and flushing, tides and storms form the landscape properties of an estuarine wetland to which the biota are adapted (Simenstad et al. 2000; Hood 2002a,b). In addition, changes in marsh structure created by restoration actions can increase the potential that invasive plants or animals will colonize a site. For example, the changes in salinity that occur over a diked marsh after a dike has been breached usually create open mudflats for a period of time as freshwater plants die and salt tolerant plants colonize. These open areas or open areas created when a site is excavated or graded, can be colonized by invasive plant species. It is particularly challenging to restore functions of estuarine wetlands in urban areas where restoration sites tend to be small, limited in number,

¹⁶ Mature forest takes many years to develop, and bog systems depend on the existence of acidic substrate not easy to replicate.

and isolated from one another, where contamination can be high, where excavation and clearing are usually required to reclaim open space, and where the landscape processes that create and maintain estuarine sediments are no longer intact (Rice et al. 2004).

The salt marsh and seagrass components of estuarine wetlands have been the focus of most estuarine rehabilitation actions (Rice et al. 2004). Zedler (2001) summarized restoration techniques for tidal marshes and Fonseca et al. (1998) summarized them for seagrass beds. These authors list the particular qualities that must be considered in creating or restoring an estuarine wetland, but restoring “process” as opposed to “structure” is the most certain way to ensure the long-term viability of a site and reduce the need for ongoing maintenance and management of a restored or created site. By returning landscape-scale hydrodynamic and physical conditions, and removing contamination, one provides a site with the processes needed to create and maintain marsh conditions and maintain biological linkages with other sites (e.g., seed dispersal, movement of mobile animals). To the extent that these are lacking, a site may require ongoing inputs of human actions to for example, maintain an appropriate distribution of sediment grain sizes and replace organics as they are depleted from the soils. In addition, if landscape processes have been radically altered, the type of wetland originally found in the area may no longer be possible to recreate. For example, at restoration sites in Commencement Bay such as the Middle Waterway Site, salt tolerant vegetation is able to exist, but planted species such as *Carex lyngbyei*, which were likely originally present in the Nisqually Delta, are not able to persist due to the lack of freshwater and resulting high salinity conditions (Parametrix 2002). The City of Tacoma and NOAA’s DARP are involved in ongoing restoration activities in Commencement Bay (<http://www.darp.noaa.gov/northwest/cbay/index.html>).

Examples of restorations that resulted from dike removals were published in a special edition of Restoration Ecology (Volume 10, 2002). This edition included examples of dike breaching in Washington (Snohomish River), Oregon (Salmon River), and California (San Francisco Estuary) as well as examples from the east coast. Dike breaching is being considered at several sites in the Skagit River (Hood 2003 personal communication) and has also been conducted on the Bear River in Willapa Bay (Tear 2004 personal communication). When sedimentation rates are high, breaching dikes can help restore marsh elevations and vegetation (see also Anisfeld et al. 1999; Callaway 2000). After a dike is removed, several years may be required before marsh heights begin to rebuild and salt tolerant vegetation replaces freshwater vegetation, but within two years, clear changes in sedimentation rates and vegetation have been seen (see also Frankel and Morlan 1991; Simenstad and Thom 1992; Zedler 1996).

Regional examples of estuarine restoration that included some or all of excavation, leveling, and planting activities include the Sweetwater Marsh and Tijuana estuaries (Zedler 2001), the Campbell River in British Columbia (Dawe et al. 2000), the Duwamish River in Seattle (Cordell et al. 2001), and the Kunz Marsh in the South Slough National Estuarine Research Reserve (SSNER) in Charleston, Oregon (Cornu and Sadro 2002). Other restoration efforts are ongoing at SSNER (Cornu 2003 personal communication).

Rice et al (2004) also summarized response of wildlife to estuarine wetland projects. They cite studies that demonstrate that faunal use of restored estuarine habitats can occur relatively quickly; particularly by relatively large, motile species such as birds and fishes but that species richness and trophic composition may take a decade or more to resemble natural systems. There may also be an early peak in assemblage structure that will then decline over time as hydrologic processes change and stabilize. They also cite studies that indicate that fish species in rehabilitated habitats have residence times and growth rates similar to those in reference systems but that diet composition can be quite different from that at reference sites. The reasons for and significance of these dietary differences on fish growth and survival is not yet understood.

Rehabilitation of estuarine habitats is still a developing science. Attempts to restore estuarine functions are much less certain to be successful than efforts to preserve existing estuarine wetlands and the landscape processes that create and maintain them. It has not yet been shown that rehabilitation actions can restore the original structures and functions at a site and the tendency to focus restoration activities on marshes and seagrass meadows may not sufficiently protect other critical components of estuarine wetlands such as mudflats adjoining scrub-shrub and forested wetlands (Rice et al. 2004).

5.5.2 Performance Standards

Site-specific project goals or standards are a critical element of wetland mitigation plans (Ecology 2004c). Performance standards are the measures used to determine the success and compliance of a compensatory mitigation plan. They describe the level at which wetland or buffer functions should be performing in order to meet the goals or objectives of a given compensatory mitigation plan. These standards need to be measurable in the field and they need to be achievable by the methods and timeframe selected for monitoring the site. Ecology (2004c) provides a detailed explanation of how to develop performance standards for measuring success in wetland mitigation projects.

5.5.3 Monitoring

Monitoring requirements are another critical component of most wetland mitigation plans. Monitoring is used to collect data for evaluating the success or compliance of the performance standards for the project. The type of monitoring data collected and the timing of the data collection depend upon the performance standards being evaluated. Most mitigation projects are monitored for at least five years on an annual basis (Ecology 2004c)¹⁷. Monitoring reports that present the data collected and compliance with performance standards are typically provided by the project applicant and are reviewed by the regulatory agency for project success and compliance.

Whatcom County requires that a project applicant demonstrate the capability to monitor their mitigation site and to make corrections if the project fails to meet projected goals (WCC 16.16.125.D.3). The applicant must provide a surety bond, maintenance bond or similar financial guarantee to cover costs should the mitigation fail to meet the specified goals. The County Code does not specify how long a mitigation project must be monitored but it does state that the bond must be returned within 5 years of project completion.

Monitoring that is adequate for assessing the success of mitigation efforts in estuarine wetlands may be more complex than that required for freshwater wetlands. In systems as complex as estuarine wetlands, it is particularly important to begin with a conceptual model of the system that identifies important process and their interactions. The complexity of model required depends on the goals of the mitigation and the degree to which landscape processes are intact but the model should, at least identify processes that could affect the outcome of the mitigation. Although monitoring should target measures of specific actions taken and desired functional outcomes, in order to understand the outcome of the mitigation – why it succeeds or fails – some monitoring of causal processes identified in the conceptual model is required. Full discussion of different levels of monitoring and the role of monitoring in adaptive management can be found in Rice et al. (2004), Thom (2000) and Thom and Wellman (1996).

¹⁷ Ecology and the Corps of Engineers typically require 10 years of monitoring if a mitigation project is subject to state/federal permitting (which most are) and involves creation or restoration of forested communities.

5.5.4 Replacement Ratios for Restoration and Creation

Generally, wetland mitigation is implemented over a larger area than the wetland area adversely affected by a proposed project. Mitigation ratios are typically greater than 1:1 for several reasons, some of which are based on science and others that are policy-driven. Higher ratios act as disincentives to fill wetlands. They also provide an opportunity to recreate certain functions over a larger area, thus compensating for temporal loss of function from a smaller but presumably more mature impact site. In addition ratios compensate for the potential inability to achieve full replacement of lost wetland acreage (Ecology 2001; Kusler and Kentula 1990).

Several authors and agencies have recommended various replacement ratios (Castelle et al. 1992b; OCD 2002). Most ratios are based on known failures of compensatory mitigation and designed to compensate for historic loss of wetlands. Studies of the success of mitigation projects suggest that replacement ratios based on mitigation success could be between 1:1.25 and 3:1 (replacement area to impact area). Mitigation ratios for wetlands in most local jurisdictions in western Washington currently range between 1:1 and 4:1.

Ecology has recently developed new criteria for determining recommended wetland mitigation ratios based on wetland category and characteristics and on the type of mitigation proposed (i.e., creation, restoration, enhancement, or a combination of these) (Ecology 2004b). Ratios in their guidance documents range widely (from 1:1 to more than 15:1) depending upon the type of mitigation proposed and the type and category of wetland affected (Ecology 2004b).

The Whatcom County code does not require specific mitigation ratios to be used. Instead the code uses a performance standard-based approach requiring that ratios be scientifically based and appropriate for replacing any critical area functions lost as a result of the activity. The codes states that the replacement ratios cannot exceed 6:1 (replacement area to impart area) (WCC 16.16.245.D.1).

5.5.5 Enhancement and Preservation

Wetland impacts can be mitigated by wetland creation, restoration, enhancement, or preservation, or by a combination of these actions. Wetland creation and restoration are used to replace the area of wetlands lost or modified to meet the goal of “no net loss” of wetland acreage. Wetland enhancement usually entails planting native vegetation and removing non-native invasive plant species in wetland and buffer areas (Ecology 2004b). The goal of wetland enhancement is to increase or improve one or more functions to compensate for lost wetland or buffer functions. Ecology has concerns about the use of enhancement in mitigation plans because a recent study of mitigation in Washington State has found that many enhancement projects:

- Fail to control invasive plant species;
- Ignore the potential for improving other wetland functions besides native habitat; and
- Result in a net loss of hydrologic functions and only modest gain of habitat functions (Ecology 2004b).

Ecology recommends that preservation only be used to compensate for wetland losses in exceptional circumstances (Ecology 2004b). Wetland preservation is appropriate compensation when it is used for protecting high quality wetlands that might not otherwise be protected in the long term. In Whatcom County this might be appropriate for undisturbed bog and fen systems, mature forested wetlands, or estuaries, especially if the altered wetlands are of much lower quality. Preservation generally requires much higher ratios than wetland creation or restoration (Ecology 2004b).

5.5.6 Banking

This issue is addressed in Chapter 8.

5.5.7 Other Wetland Protection Measures

Other measures for protecting wetlands in Whatcom County include agricultural conservation programs, clustering, transfer of development rights (TDR), incentives, and low impact development (LID). The Whatcom County Code includes these measures along with current regulations to protect and restore wetlands, although TDRs, incentives, and LID projects have been rarely used (Sim 2004 personal communication). Whatcom County policies support the development of public utilities and capital facilities where they will not adversely affect critical areas including wetlands (WCPD 2003).

5.5.7.1 Agricultural Programs

There are two mechanisms through which property owners conducting agricultural activities can comply with applicable critical area requirements – adhere to the requirements of WCC 16.16, or choose to meet the requirements of WCC 16.16 – Appendix A – Conservation Program on Agriculture Lands (CPAL). The purpose of the CPAL program is to provide environmental protection on agricultural lands sufficient to meet the requirements of the GMA. Landowners work with the Whatcom Conservation District (WCD) to prepare conservation plans in accordance with CPAL Environmental Quality Standards and Conservations Practice Standards outlined in the WCD Conservation Planning Handbook, and with NRCS National Handbook of Conservation Standards. The Whatcom County Extension Office also provides best practices information for calculating nutrient loading, appropriate application rates of fertilizers, and composting manure among other topics designed to conserve resources including wetlands. WCPD staff have noted concerns regarding the CPAL program, as required Best Management Practices (BMPs) are minimal and there is limited oversight of the program (WCPD 2004b). Whatcom Conservation District (WCD) responds that measurable water quality improvement has been achieved in areas where conservation plans have been implemented, and in addition to protecting streams, the conservation plans prescribe buffers and other protective measures for watercourses not otherwise protected by the CAO to achieve the protection of critical areas (WCD 2004).

5.5.7.2 Clustering

Whatcom County recommends the use of clustering development to conserve critical areas including wetlands. Land divisions may be clustered where permitted by zoning and as appropriate to reduce disturbance to regulated wetlands and buffers (WCC 16.16.640). With clustering the distance between developments in a given area is closer than the normal land use designation allowing the remaining area to be preserved as open space such as wetlands. Clustering is encouraged for certain communities in several Whatcom County Comprehensive Plan policies. Clustering is encouraged for the development of new subdivisions in Birch Bay, Sudden Valley, and Columbia Valley/Kendall urban growth areas (WCPD 2003 – 2AA-10). Whatcom County has taken the position that clustering can be required.

5.5.7.3 TDR

Transfer of development rights programs provide another mechanism for protecting valuable wetland areas while accommodating economic growth in an area facing increasing development pressure. Whatcom County has a policy to work with Bellingham to establish a TDR program for transferring development rights from the Lake Whatcom Watershed and from other environmentally sensitive areas in the Bellingham Urban Growth Area to density receiving zones in Bellingham and its Urban Growth Area (WCPD 2003 – Policy 2T-5). The establishment of other TDR programs is also encouraged to conserve

rural areas and watershed protection areas by transferring densities into other urban areas such as Blaine and their growth areas (WCPD 2003).

5.5.7.4 Incentives

Incentives can be used with willing landowners to purchase property or easements or encourage voluntary restoration of critical areas. Whatcom County has a policy to use education and incentive programs to protect and encourage voluntary restoration of wetlands and other critical areas (WCPD 2003 – Policy 2SS-1). Whatcom County also has an open space taxation program to support the conservation of fish and wildlife (WCPD 2003 – Policy 2VV-3). The federal government also has incentive programs such as the Wetland Reserve Program (WRP) and Conservation Reserve Enhancement Program (CREP) that are resulting in the restoration of many acres of wetlands in Whatcom County. For instance, approximately 500 acres of prior converted cropland are currently being restored to wetland and riparian habitat along 18,000 feet of the Lower Nooksack River near Marietta (Gillies 2004 personal communication). Currently, the total number of signed CRP’s is 127 and the total area in the program encompasses 1,188 acres of land and 69.9 miles of riparian habitat.

5.5.7.5 Low Impact Development

Low impact development techniques can be encouraged in developed or developing areas to reduce peak storm water runoff, improve water quality in wetlands, and preserve wetland habitats. Low impact development is a broad term used to describe site designs that minimize project footprints, protect important features such as mature trees and wetlands, and provide natural drainage features that improve wildlife habitat, water quality, and flood water functions. Whatcom County encourages the use of low impact development for transportation systems by promoting designs that preserve habitat, water quality, and flood flow functions (WCPD 2003 –Policy 6E).

5.6 FINDINGS AND CODE RECOMMENDATIONS

5.6.1 General Findings and Recommendations

The Whatcom County Critical Areas Ordinance (WCC16.16) is generally consistent with the requirements of the Growth Management Act with regard to wetlands. However, there are a number of ways that the code can be strengthened and clarified to provide more specific protection for wetlands and wetland functions based upon best available science. The majority of our recommendations are related to a re-evaluation of the buffer requirements. Other recommendations are to regulate all wetlands, regardless of size or connection to other surface water systems, under this code. The recommendations in this document are based upon the scientific record to date and focus only on this CAO regulatory program. We recognize that the County needs to balance all GMA goals and can look to this and other land management, stormwater, and roads/maintenance programs in total to assess progress toward protecting wetland functions.

General Findings and Recommendations	
Findings	WCC 16.16.600 establishes the purpose of these regulations consistent with GMA and the comprehensive plan. These are to recognize and protect the beneficial functions provided by wetlands.
Recommendations	Add ESA compliance and consistency with BAS as goals of this section (WAC 365-195-900 through 365-195-925).
BAS Sources	Sheldon et al. (2003)

Designation Findings and Recommendations	
Findings	<p>The definition of wetlands in WCC 16.16.610 (B) is consistent with the GMA guidelines. The non-regulated wetlands section, defined in WCC 16.16.610 (C), is not consistent with the GMA guidelines, as it exempts isolated wetlands less than 1/3 acre in size or dominated by invasive species or pasture grasses. Small wetlands do provide some level of functions. The scientific literature states that mitigation should be required for wetland impact based upon function and values.</p> <p>Determination of wetland boundaries in WCC 16.16.630 cites the <i>Army Corps Wetlands Delineation Manual</i> (1987). Although this is scientifically sound, the Washington Administrative Code (WAC) requires use of the <i>Washington State Wetland Identification and Delineation Manual</i> (Ecology 1997) for wetland boundary determinations (WAC 173-22-080).</p>
Recommendations	<p>We recommend updating the entire definition section. Include a definition for estuarine wetlands.</p> <p>We recommend using the wetland definition found in the "Example Code Provisions for Designating and Protecting Critical Areas" in: <i>Critical Areas Assistance Handbook</i>. (CTED, 2003).</p> <p>The list of wetlands types in the definition should include "wet pastures" and "riparian wetlands." As these are common wetland types in Whatcom County. We recommend having minimum standards for wetland reports to facilitate staff review and ensure consistency during the permit review process.</p> <p>Use of the <i>Washington State Wetland Identification and Delineation Manual</i> (Ecology 1997) is recommended for determining wetland boundaries as required by WAC 173-22-080</p>
BAS Sources	Ecology (2004b);

Buffers and Setbacks	
Findings	<p>Standard buffers of 100 feet for all regulated wetlands are established in WCC 16.16.640(B). The code does not specify any setback requirements outside of the standard 100 ft buffer.</p> <p>Isolated wetlands not characterized as mature forested, fens, sphagnum bogs, or estuarine wetlands are protected by a 50 foot buffer, as established in WCC 16.16.640(C)1.</p> <p>Isolated wet meadows are exempt from standard buffer requirements when they primarily provide stormwater storage or attenuation (WCC 16.16.650(C)2). There is no scientific basis for exempting isolated wetlands from protection measures. Scientific research indicates that buffers should be established based upon the function and values to be protected.</p> <p>Buffer width averaging is described in WCC 16.16.650. It is allowed in the case of hardship to the applicant caused by circumstances particular to the property, when it will not adversely affect the wetland, and when the total area within the buffer remains the same. Increased buffer widths are allowed at the discretion of the County, when site conditions require additional protection.</p> <p>Reduced buffer widths are allowed under WCC 16.16.650(C). The section states that "The County shall reduce the standard buffer widths" under several conditions, including demonstration that the reduced buffers will adequately protect the wetland, river, or stream function.</p> <p>WCC 16.16.660 describes use of "degraded wetlands" for management of stormwater. Direct discharge is allowed into degraded wetlands if the use of upland sites is infeasible and the activity enhances the existing wetland.</p>

Buffers and Setbacks	
Recommendations	<p>We recommend using the four wetland categories described in “Example Code Provisions for Designating and Protecting Critical Areas” in: <i>Critical Areas Assistance Handbook</i>. (CTED, 2003) or using the revised <i>Wetland Rating System for Western Washington</i> (Ecology 2004a) as the basis for the wetland ratings.</p> <p>We recommend using the buffers associated with the wetland categories described in “Example Code Provisions for Designating and Protecting Critical Areas” in the <i>Critical Areas Assistance Handbook</i>. (CTED 2003) or on of the buffer approaches suggested by Ecology in the <i>Wetlands in Washington State. Volume 2: Guidelines for Protecting and Managing Wetlands</i> (Ecology 2004b).</p> <p>We recommend regulating isolated wetlands consistent with their classification and relative function and value. According to Sheldon et al. (2003), there is no scientific information supporting exemption of small wetlands from regulation. We recommend using mitigation or fee-in-lieu as long as performance standards are established and monitored.</p> <p>The County should consider requiring structure to be setback from the outer edge of the buffer to minimize damage to the buffer. Setbacks are typically in the range of 8 to 12 ft.</p> <p>We recommend using the language on buffer width averaging found in: “Example Code Provisions for Designating and Protecting Critical Areas” in the <i>Critical Areas Assistance Handbook</i>.</p> <p>Based upon CTED (2003) and best available science, we recommend reduced buffers be eliminated, and that buffer averaging be employed to provide flexibility for site design. Should buffer reduction be employed by the County, then buffer enhancement could be used to achieve overall improvement in buffer functions and values.</p> <p>We recommend that buffer averaging continue to be allowed, based upon no loss of area or function.</p> <p>The “Example Code Provisions for Designating and Protecting Critical Areas” in the <i>Critical Areas Assistance Handbook</i> limits stormwater management activities to dispersion outfalls and bioswales located in the outer 25 percent of Category III or IV wetland buffers. They are further limited to situations where other alternatives are infeasible and the facilities will not degrade the functions or values of the wetland.</p>
BAS Sources	<p>Castelle et al. (1992a); Sheldon et al. (2003); Desbonnet et al. (1994); Knutson and Neff (1997); Wong and McCuen (1982); Richter and Azous (2001); Johnson and O’Neill (2001); Booth (2000); McMillan (2000).</p>

Mitigation	
Findings	<p>Mitigation for wetlands, streams, and rivers and their buffers is described in WCC 16.16.245. Mitigation should maintain or enhance the functions of the critical area.</p> <p>The mitigation guidelines (WCC 16.16.245(D) are clear and are in line with best available science. Determining Mitigation Requirements (WCC 16.16.245(c) bases required ratios on a case-by-case analysis, not to exceed 6:1 ratio. Although this is scientifically sound, it does not provide consistent standards for the application of the Code, and requires case-by-case evaluation by staff.</p> <p>The code should also address preservation as a mitigating measure.</p>
Recommendations	<p>We recommend using the language on mitigation found in: “Example Code Provisions for Designating and Protecting Critical Areas” in the <i>Critical Areas Assistance Handbook</i>., including the description of wetland mitigation banks. Alternatively the mitigation ratios suggested by Ecology in <i>Wetlands in Washington State. Volume 2: Guidelines for Protecting and Managing Wetlands</i> (Ecology 2004b) could be used.</p> <p>We recommend having minimum report standards for wetland mitigation plans to facilitate staff review and ensure consistency in the permit review process. The minimum standards could reference use of the last mitigation planning guidelines developed by Ecology and other resource agencies (Ecology 2004c).</p>
BAS Sources	<p>Kusler (1992); Bedford (1996); Ecology (2004b); Ecology (2004c)).</p>

Conservation Program on Agricultural Lands (Appendix A)	
Findings	<p>There are two mechanisms through which property owners conducting agricultural activities can comply with applicable area requirements – adhere to the requirements of WCC 16.16, or choose to meet the requirements of this program CPAL.</p> <p>WCC 16.16.285 allows pre-existing agricultural activities to be conducted within Wetlands, Fish and Wildlife Habitat Conservation Areas or there buffers, or Aquifer Recharge Areas upon completion of a conservation plan in conformance with the <i>Conservation Program On Agricultural Lands</i> (CPAL) if: 1) the pre-existing activity involves no more than five animal units and two acres or less of tilled cropland; and 2) the activity is consistent with Whatcom Conservation District best management practices including management of livestock waste. The purpose of the program is to provide environmental protection on agricultural lands sufficient to meet the requirements of the GMA.</p>
Recommendations	<p>Providing an alternative method for agricultural land owners to comply with protection of wetlands as required by the GMA is practical and scientifically sound. However, the application of the program may be inconsistent. We recommend conducting a best available science review specifically targeted on the methods for developing the conservation plans and requirements of the CPAL Program, including monitoring of success and effectiveness. Conversion of agricultural land to other uses should trigger review under the Critical Areas Ordinance.</p> <p>Institute a program to monitor conservation plan implementation once developed.</p>
BAS Sources	Ecology (2004b); NRCS (1998); Dillaha et al. (1989) and Magette et al. (1989), <i>in</i> King County (2003)

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6. FISH AND WILDLIFE HABITAT CONSERVATION AREAS¹⁸

Fish and wildlife habitat conservation means land management for maintaining species in suitable habitats within their natural geographic distribution so that isolated subpopulations are not created (WAC 365-190-080). Isolated subpopulations are at greater risk of extinction than the population as a whole (Lemkuhl et al. 2001). Habitat conservation rules provide a framework for classifying, protecting, and in some cases restoring fish and wildlife habitat. This analysis is focused on wildlife species and habitats on non-federal lands in Whatcom County, or approximately the western third of the County (fish and streams are covered in Chapter 7). The Growth Management Act (GMA) goal is no net-loss of habitat functions and values, which is to be accomplished through habitat protection. State GMA guidelines (Ousley et al. 2003) suggest the following habitat types should be designated as fish and wildlife habitat conservation areas (FWHCAs) in accordance with the GMA procedural criteria for adopting comprehensive plans and development regulations (WAC 365-190):

- Areas with which state or federally listed species (endangered, threatened, candidate, or sensitive) have a primary association.

The U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) are responsible for designating federal special status species and should be consulted for current listing status. The Washington Department of Fish and Wildlife (WDFW) is responsible for designating state special status species and maintains the current list of these species (Ousley et al. 2003).

- State priority habitats and areas associated with state priority species.

The Priority Habitats and Species (PHS) database is updated on a regular basis with input from WDFW field biologists and other scientists and represents the best available science on the distribution of special status wildlife species and habitats in Washington. The PHS habitats identified by WDFW are considered a priority for conservation and management due to their high fish and wildlife species density and/or diversity, important habitat functions, importance to priority species, limited distribution or rarity, vulnerability, or their cultural value (e.g., commercial or recreational) (Ousley et al. 2003; WDFW 2004a). WDFW (2004a) has designated 18 priority habitats statewide, 15 of which occur in northwestern Washington (Table 6-1).

Table 6-1. WDFW Designated Priority Habitats Found in Northwestern Washington (WDFW 2004a).

Habitat Type	Riparian
Estuary/estuary-like	Rural natural open space
Freshwater wetlands and fresh deepwater	Urban natural open space
Instream	Vegetated marine/estuarine (eelgrass, kelp, turf algae)
Marine/estuary shorelines	Habitat Element
Old-growth/mature forests	Caves
Oregon white oak woodlands	Cliffs
Prairies and steppe	Snags and logs
	Talus

¹⁸ Fish and aquatic species are discussed in Chapter 7.

- Habitats and species of local importance.

These could include a seasonal range or habitat elements with which a given species has a primary association, and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long-term. Examples are areas of high relative density or species richness, breeding habitats, winter ranges, movement corridors, and habitats that are of limited availability or high vulnerability to alteration, such as cliffs, talus, and wetlands. Local jurisdictions may designate habitats and species of local importance because of their value to the local environment (Ousley et al. 2003).

- Commercial and recreational shellfish areas.

Commercial and recreational shellfish areas include public and private tidelands that support shellfish harvest (Ousley et al. 2003).

- Kelp and eelgrass beds, and herring and smelt spawning areas.

Kelp and eelgrass beds are highly productive ecosystems that provide essential rearing and foraging habitat for a variety of important food and forage fish including rockfish, salmon, smelt and herring as well as Dungeness crab (WAC 365-190-080; WAC 220-110-250; Murphy et al. 2000).

- Naturally occurring ponds under twenty (20) acres.

Naturally occurring ponds and ponds created for wetland/critical areas mitigation may provide fish and wildlife habitat and other wetland functions. These ponds do not include other manmade ponds (farm ponds, detention ponds) (Ousley et al. 2003).

- Waters of the state.

Waters of the state include surface waters and watercourses within state jurisdiction as defined in WAC 222-16-030 or WAC 222-16-031 (Ousley et al. 2003).

- Lakes, ponds, streams, and rivers planted with game fish by a government or tribal entity.

These waters provide a valuable public recreational and commercial resource.

- State natural area preserves and natural resource conservation areas.

Natural area preserves and natural resource conservation areas, owned and administered by the Washington State Department of Natural Resources (WDNR), represent unique or high quality undisturbed ecosystems and habitats (WDNR 2004).

- Land essential for preserving connections between habitat blocks and open space.

Maintaining habitat connectivity for fish and wildlife species is necessary to sustain population viability. Habitat connectivity enables individuals to move between habitat patches in obtaining requisite resources, the dispersal of individuals, and genetic exchange between populations. Isolated populations are at greater risk of extinction due to natural population fluctuations, random events, and inbreeding (Morrison et al. 1998; Lemkuhl et al. 2001).

Beaches are not explicitly identified as a FWHCA in the GMA guidelines. Beaches are the unconsolidated shoreline zone along the marine coast and large water bodies between the water's edge and landward vegetated areas (Buchanan et al. 2001). Beaches provide important habitat for many invertebrate, fish, crustacean, bird and small mammal species, are limited in distribution, are vulnerable to alteration, and have been identified by some resource managers as a habitat type that warrants protection as a FWHCA in Whatcom County. Beaches could be designated a habitat of local importance by Whatcom County to conserve their habitat values for fish and wildlife.

For the most part, Article VII of the WCC 16.16 designates FWHCAs consistent with the GMA requirements for these habitat types. The waterbody classification in the current WCC differ from the organization of the GMA water types, but WCC 16.16 protects many of the same water features. Lands that provide habitat connectivity are not specifically designated as FWHCAs in the current WCC. Whatcom County has identified and designated 45 wildlife species or species groups, including cavity nesting birds, diving birds, seabirds, shorebirds and swans, as locally important (WCC Title 16.16, Appendix C). To date, the County has not formally identified or designated any locally important habitat types.

The WDFW and the Washington Natural Heritage Program (WNHP) compile and map much of the best available science for fish and wildlife habitats throughout the state. There are also numerous studies for specific species and habitat types that apply to Whatcom County.

Whatcom County has traditionally relied on the information provided by the WDFW as well as the Lummi Nation and Nooksack Tribes and other resource managers for protection of fish and wildlife habitat. For most priority habitats and wildlife species, the PHS database offers the best available information on their presence and distribution, including site-specific data. Once disseminated, WDFW recommends that PHS data should be updated every six months for site-specific evaluations (WDFW 2004a).

6.1 OVERVIEW OF INVENTORY

The vast majority of Whatcom County's land base (74 percent) is comprised of vegetated cover, either as forest or agricultural lands, that provide habitat for a variety of wildlife species, including listed species such as bald eagles, peregrine falcons, and marbled murrelets (for scientific names see Appendix C). In addition, the marine waters of Whatcom County support a number of special status species and priority habitats and species. Whatcom County is situated between the Fraser River and Skagit River, the largest estuaries on Puget Sound/Georgia Basin and major Pacific Flyway waterfowl wintering areas. The Skagit estuary supports the highest numbers of wintering waterfowl in Puget Sound and the Fraser estuary is the most important waterfowl wintering area in western Canada (WDFW 1999a; Ducks Unlimited Canada 2004). Waterfowl and shorebirds often move between these two estuaries passing through or stopping in Whatcom County. The high numbers of waterfowl and shorebirds attract wintering raptors (bald eagle, gyrfalcon, merlin) as well.

Large wilderness tracts in the Cascade Mountains in both the U.S. and Canada serve as refugia and dispersal corridors for mammals, including gray wolves, wolverine, and moose (Rodrick and Milner 1991). There have been occasional reports of individuals of these species in the foothills or lowlands in the County to the west of the Cascades. A resident herd of Rocky Mountain elk is found along the South Fork of the Nooksack River. Elk are a culturally significant animal to Native Tribes in the Pacific Northwest as well nontribal recreational hunters. In recent years the size of the Nooksack herd has declined, prompting state and tribal wildlife managers to augment the herd with translocated elk from the Mount St. Helens area (Davison 2002; WDFW 2004b).

State and federal agencies have documented habitats of particular importance to wildlife in Whatcom County. In compiling their FWHCA inventory, Whatcom County used PHS, WNHP, and NWI data, as well as WDNR stream layers. The PHS and WNHP data are updated and reviewed annually. As described below, the principal wildlife priority habitats on non-federal lands in the County are found along the marine shoreline, the Nooksack River and its major tributaries, Lake Samish, and Lake Whatcom (WCPDS 2004). In addition, publicly owned wildlife areas are found at Lake Terrell and Tennant Lake near Ferndale.

Whatcom County offers a diversity of habitat types from the crest of the Cascade Mountains in the eastern County to the marine shoreline and waters of the western County. Priority habitats within the County currently include bald eagle breeding territories along the marine shoreline and Nooksack River drainage, communal roosts, and concentrated foraging areas along the North Fork of the Nooksack River; migratory waterfowl and shorebird foraging habitat in the Nooksack Delta and Drayton Harbor; elk foraging and wintering areas in the agricultural fields along the South Fork of the Nooksack River and calving areas in the hills to the east; great blue heron rookeries are found in the County at Point Roberts, Pangborn Lake, Cherry Point, the Lummi Peninsula, and east of Everson (WCPDS 2004; Neatherlin 2004 personal communication). Great blue heron rookeries are typically located in large stands of deciduous trees near foraging areas (Quinn and Milner 2004).

High quality and unique habitat types are found in Whatcom County. The Washington Natural Heritage Program has identified 17 high quality native habitat areas in Whatcom County, including the 661-acre Lummi Island Natural Resources Conservation Area on southwest Lummi Island (WCPDS 2004; WDNR 2004). WDNR has proposed establishing the Cherry Point Aquatic Reserve between Birch Bay State Park and the Lummi Reservation to protect one of the largest historic spawning stocks of Pacific herring in Washington State, which has declined precipitously in recent years (Bargmann 2001; WDNR 2003). Eliza Rock, south of Eliza Island is included in the San Juan Islands National Wildlife Refuge and access is restricted to protect listed species, breeding colonies of shorebirds, and marine mammals (WCPDS 1997). The Nature Conservancy has acquired 4 sites for conservation in the lowlands and marine shoreline of Whatcom County (The Nature Conservancy 1993). Birch Bay State Park, Tennant Lake, and the North Fork Nooksack River between Deming and Kendall have been identified as high quality wildlife viewing areas (La Tourette 1992). Whatcom County is one of only two counties in western Washington with confirmed nesting common loons (Richardson et al. 2000). Extensive wetlands and riparian habitat along the Nooksack River provide high value habitat for a number of wetland-associated species. Many migratory songbirds (warblers, flycatchers, swallows) and cavity-nesting birds nest in riparian forests (Knutson and Naef 1997; Kauffman et al. 2001; Sheldon et al. 2003). Whatcom County's FWHCAs are discussed below.

6.1.1 Species and Habitats

6.1.1.1 Listed Species Habitat

Maps (1998, 2004) prepared by Whatcom County Planning and Development Services (WCPD) show the locations of listed species habitat on non-federal lands in Whatcom County. Listed species with mapped polygons include bald eagles, peregrine falcons, sandhill cranes, and Pacific Townsend's big-eared bat. The listed species polygons represent breeding territories and areas of regular concentrations (roost and foraging sites) for many of the listed species identified in the WCC, Chapter 16.16 Appendix C (Table 6-2).

Thirty-eight bald eagle polygons, including breeding territories, regular concentrations, and communal roosts have been identified in the PHS data for Whatcom County. Most of the bald eagle polygons are found along the marine shoreline and the Nooksack River. Peregrine falcon habitat is found in the Nooksack delta downstream of Ferndale and along the marine shoreline in the central County associated with waterfowl and shorebird wintering areas. Sandhill crane habitat is found in the agricultural fields north of Everson and east of Lynden. Pacific Townsend's big-eared bat habitat is found in the vicinity of Chuckanut Mountain. Common loons, a relatively rare breeding bird in Washington, have nested in Lake Terrell and Lake Whatcom (Smith et al. 1997; Richardson et al. 2000; WCPD 2004).

Table 6-2. Listed, Sensitive, and Candidate Species Known or Suspected to Occur in Whatcom County.

Table 6-2. Listed, Sensitive, and Candidate Species Known or Suspected to Occur in Whatcom County (continued).

Species	Status¹	Habitat Requirements and Distribution
Bald eagle	FT, ST	Numerous nest territories and foraging areas in major drainages and along marine shorelines of western Washington. ^{2a}
Brandt's cormorant	none, SC	Winter resident seabird of inland marine waters. Breeds on outer coast. ^{2b}
Brown pelican	FE, SE	Occasional summer sighting in marine waters. ^{2b}
Cascades frog	Fco, SM	Wetlands and small streams in between 2,000 ft and 6,2000 ft elevation in Wash. & Ore. Whatcom County population is disjunct from populations to south. ^{2c}
Columbia spotted frog	Fco, SC	Aquatic habitat, especially emergent vegetation in wetlands, ponds, and streams in the Cascade Mountains and in eastern Washington. ²ⁿ
Common loon	none, SS	Nests on secluded shorelines of lakes larger than 30 acres; winters on lakes and marine waters. ^{2d} Known to occur at Lummi Bay and Lummi Flats.
Common murre	none, SC	Winter resident seabird of inland marine waters. Breeds on outer coast. ^{2o}
Fisher	Fco, SE	Very rare forest carnivore closely associated with late-successional coniferous and mixed forests of Olympic and North Cascade Mtns. ^{2a}
Golden eagle	none, SC	Uncommon western Washington raptor associated with open country. Nests on cliffs or large trees. ^{2a}
Gray whale	none, SS	Migratory marine mammal found in coastal waters in spring and summer. Often forages on or near bottom, ingesting sediment. ^{2f}
Gray wolf	FT, SE	Rare carnivore of forested and open habitat requiring adequate ungulate prey. Occasional recent records from North Cascades National Park. ^{2g}
Grizzly bear	FT, SE	Rare omnivore of wilderness areas. Occasional recent records from North Cascades National Park. ^{2g}
Killer whale (orca)	none, SE	Resident marine mammal of coastal waters, including Strait of Georgia. Salmon principal prey in Puget Sound. ^{2b}
Lynx	FT, ST	Forest carnivore of subalpine and boreal forests ^{2p}
Marbled murrelet	FT, ST	Uncommon seabird that nests in late-successional conifer forests within 50 miles of marine shoreline. Winters in nearshore marine waters. ^{2a}
Northern Abalone	none, SC	Shellfish found in subtidal rock reefs, low abundance, harvest closed. ^{2m}
Northern goshawk	Fco, SC	Raptor that nests in relatively dense mature conifer and mixed forests. Sensitive to clear-cut timber harvest in nest and foraging stands. ^{2d}
Northern spotted owl	FT, SE	Resident in coniferous forests below 5,000 feet elevation. Closely associated with late-successional forests. ²ⁱ
Olympia oyster	none, SC	Shellfish found in intertidal gravel, locally extirpated in Whatcom Co., restoration effort in progress. ^{2m}
Pacific harbor porpoise	none, SC	Relatively shy marine mammal of inland marine waters. ^{2b}
Peregrine falcon	Fco, SS	Year-round resident; nests in cliffs (> 150 ft in height); and feeds on birds, especially shorebirds and waterfowl. ^{2d} Occurrences at Nooksack Delta and Portage Bay.
Pileated woodpecker	none, SC	Large resident woodpecker of mature forests requiring trees > 17-inch diameter for nesting and roosting. Important primary excavator providing cavities for a number of species. ^{2d}
Purple martin	none, SC	A migratory, cavity-nesting songbird that nests over or near water. Will use artificial nest boxes. ^{2d}

Table 6-2. Listed, Sensitive, and Candidate Species Known or Suspected to Occur in Whatcom County (continued).

Species	Status¹	Habitat Requirements and Distribution
Red legged frog	Fco, none	Found from sea level to 2,800 ft elevation in western Washington. Breeds in freshwater wetlands and slow-moving streams. ^{2c}
Sandhill crane	none, SE	Nests, and roosts in relatively open, large wet meadows and emergent wetlands. Highly wary and sensitive to disturbance. Will forage in upland meadows, pastures, and agricultural fields. Seen in Washington primarily during migration; a few nesting pairs in eastern Washington. ^{2d}
Steller (Northern) Sea lion	FT, ST	A sea lion that breeds in the northern Pacific and winters as far south as California. Seen on Washington's inland waters occasionally in winter. ^{2d, 2j}
Tailed frog	Fco, SM	Stream-dwelling frog of cold, rock substrate streams up to 5,250 ft elevation. ^{2c}
Townsend's big-eared bat	Fco, SC	A year-round resident that inhabits caves and abandoned mines and buildings. Extremely sensitive to human disturbance. ²ⁱ Recent records from Chuckanut Mtn. ^{2k}
Vaux's swift	none, SC	A summer resident and breeder of western Washington closely associated with late-successional conifer forests. Requires hollow, large-diameter snags for nesting and roosting. ^{2d}
Western grebe	none, SC	A winter resident on inland waters, especially Samish and Bellingham Bays. ^{2b}
Western toad	Fco, SC	Found near emergent wetlands and small lakes from 0 to 6,530 ft elevation. ^{2c}
Willow flycatcher	Fco, none	A neotropical migrant that breeds in forested or shrub riparian habitat or forests. ^{2f}
Wolverine	Fco, SC	A wide-ranging scavenger that requires large tracts of remote boreal or montane habitat. Rare in Washington, but recent Whatcom County records. ^{2l}

For special status fish, please see Chapter 7.

1 FE = federal endangered, FT = federal threatened, Fco = federal species of concern; SE = state endangered, ST = state threatened, SC = state candidate, SS = state sensitive, SM = state monitor (WDFW 2004a).

2 Sources: ^a Rodrick and Milner (1991); ^b Angell and Balcomb (1982); ^c Leonard et al. (1993); ^d Larsen et al. (2004); ^f Smith et al. (1997); ^g National Park Service (2004); ⁱ King County (2003); ^j NOAA (2004); ^k WCPD (2004); ^l Lewis and Stinson (1998); ^m Penttila (2004); ⁿ Nordstrom and Milner (1997); ^o Cassidy (2003); ^p Stinson (2001).

6.1.1.2 State Priority Habitats and Species

State priority habitats and habitats associated with state priority species include areas associated with high recreational value (waterfowl, trumpeter swans, Rocky Mountain elk) or relatively rare species (band-tailed pigeons, turkey vultures) (Table 6-3) (WDFW 1999b). The polygons mapped as priority habitat by Whatcom County include aquatic and wetland priority habitats and habitats associated with particular priority species (bald eagle nesting territory, waterfowl concentrations) but do not include any of the terrestrial WDFW priority habitats (old-growth forest, cliffs) (WCPD 1998, 2004). The majority of Whatcom County's mapped priority habitat polygons are found along the marine shoreline and the Nooksack River (WCPD 1998, 2004). Scattered trumpeter swan and band-tailed pigeon habitat polygons are shown in the central County from Custer to the east side of Black Mountain (WCPD 2004). The WCC does not explicitly designate priority habitats or identify priority species as a separate class of protected wildlife. However, many of the species of local importance identified in Chapter 16.16, Appendix C of the WCC are classified by WDFW (2004a) as priority species.

Table 6-3. Priority Species Known or Suspected to Occur in Whatcom County.¹

Species/Sites	Criteria	Whatcom County Species of Local Importance
Band-tailed pigeon – breeding areas, regular concentrations, occupied mineral springs	RCT	Yes
Bats – roosting concentrations of big brown bat, Myotis bats, pallid bat	VA	No
Blue grouse – breeding areas, regular concentrations	RCT	No
Brant – regular large concentrations	VA, RCT	Yes
California sea lion – haulout areas	VA	Yes
Cavity-nesting ducks (wood duck, Barrow's goldeneye, common goldeneye, bufflehead, hooded merganser) – breeding areas	RCT	Yes
Columbian black-tailed deer – regular large concentrations migration corridors	RCT	No
Cormorants and alcids – breeding concentrations	VA	Yes
Dall's porpoise – regular concentrations	VA	Yes
Dungeness crab – breeding areas, regular concentrations	VA, RCT	No
Geoduck – regular concentrations	VA, RCT	No
Great blue heron – breeding areas	VA	Yes
Harbor seal – haulout areas		Yes
Harlequin duck – breeding areas, regular marine concentrations	VA, RCT	No
Manila clam – regular concentrations	VA, RCT	No
Marten –regular occurrences	RCT	Yes
Mink –regular occurrences	RCT	Yes
Moose – regular concentrations	RCT	No
Mountain goat – breeding areas, regular concentrations	RCT	No
Native littleneck clam	VA, RCT	No
Nonbreeding concentrations of Barrow's goldeneye, common goldeneye, bufflehead	VA, RCT	Yes
Nonbreeding concentrations of loons, grebes, cormorants, alcids	VA	Yes
Nonbreeding concentrations of plovers, sandpipers, phalaropes	VA	Yes
Pacific oyster – regular concentrations	VA, RCT	No
Pandalid shrimps – regular concentrations	VA, RCT	No
Red urchin – regular concentrations	RCT	No
Roosevelt elk – regular concentrations, calving areas, migration corridors	RCT	No
Snow geese – regular concentrations	VA, RCT	No
Trumpeter and tundra swans – regular concentrations	VA, RCT	Yes
Waterfowl concentrations (other than Canada geese in urban areas) – significant breeding areas and regular large wintering concentrations	VA, RCT	No

See Chapter 7 for Priority Fish.

¹ VA = vulnerable aggregations, RCT = recreational, commercial, or tribal importance vulnerable to habitat loss or degradation (WDFW 1999b).

6.1.1.3 Habitats and Species of Local Importance

The 1998 Critical Areas map for Whatcom County identified habitats and species of local importance at Point Roberts, Birch Bay State Park, Lake Terrell, and along portions of the Nooksack River upstream of Everson (WCPD 1998). However, many species of fish are associated with protected habitats such as wetlands and streams. Several species of resident fish, such as the Nooksack Dace and the Salish Sucker are only known to inhabit Fishtrap and Bertrand Creeks in the United States. Kokanee, the landlocked sockeye salmon of Lake Whatcom, are also a good candidate for a species of local importance. Habitats of local importance are defined in the WCC as habitats supporting vulnerable and recreationally important species listed in Appendix C of Chapter 16.16 (Table 6-4). The WCC does not identify particular habitat types or locations of habitats of local importance.

Although not specifically designated as such by Whatcom County, Drayton Harbor has been identified as an Important Bird Area by Washington Audubon because of the high numbers of wintering water birds and raptors found there (Cullinan 2001). Brant are specifically designated as a locally important species, and a Washington Brant Festival, held in Blaine and Birch Bay, was established in 2003 to foster public awareness of brant and to support the local area economy (Washington Brant Foundation 2004). In recent years, wildlife watching has grown in popularity and can be an important source of income to local communities. In 2001, wildlife watching expenditures in the U.S. exceeded \$38 billion, or an average of \$738 per individual (USFWS and U.S. Department of Commerce, U.S. Census Bureau 2002).

Table 6-4. Species Designated as Locally Important in Whatcom County (WCC 16.16 Appendix C).

Common Name	Status Federal, State ¹	Habitat Requirements/Distribution
American black oystercatcher	none, Priority Species	Marine rocky shorelines. ^{2a}
Band-tailed pigeon	Game, Priority Species	Summer breeder in conifer forests of western Washington, winters in California. Mineral springs especially important. ^{2a}
Black Brant	Game, Priority Species	Sea goose that winters in marine waters of western Washington. Eelgrass is an important food source. ^{2b} Concentrations found at Lummi Bay/ Lummi Flats
Black-crowned night heron	none, Priority Species	Inhabitant of wetlands. Very rare breeder in western Washington. ^{2c}
Cavity nesting ducks: Wood duck, Barrow's goldeneye, Common goldeneye, Bufflehead, Hooded merganser	Game, Priority Species	Winter in western Washington lakes and marine waters. Breed in Washington, but only hooded merganser and wood duck in western Washington. Require excavated cavities in trees > 12-inch dbh near water body. Will use nest boxes. ^{2a}
Dall's porpoise	none, Priority Species	Marine mammal most common in summer. Occasionally seen in Strait of Georgia. ^{2d}
Diving Birds: Loons, Grebes, Cormorants, Alcids	none, Priority Species	Residents and winter migrants in marine waters and lakes of western Washington. ^{2d} Concentrations near Lummi Bay and Nooksack Delta.
Great blue heron	none, Priority Species	Closely associated with wetlands and marine waters. Colonial nester in trees near water; suitable nesting and foraging habitat are limiting. ^{2a} Occurrences near Cherry Point, Lummi Peninsula, Point Roberts, and Birch Bay.

Table 6-4. Species Designated as Locally Important in Whatcom County (continued)

Common Name	Status Federal, State ¹	Habitat Requirements/Distribution
Harbor seal	none, Priority Species	Common year-round resident of inland waters. Sensitive to disturbance at haulout sites on rocky shores and beaches. ^{2d}
Killer Whale	none, SE	State listed species.
Marten	none, Priority Species	Carnivore found in mature coniferous forests of Washington. Requires large trees/logs or talus for denning and relatively large blocks of closed canopy forest. ^{2e}
Mink	none, Priority Species	Resident carnivore strongly associated with wetlands and streams, primarily freshwater. ^{2f} Prefers riparian areas with > 75% canopy cover. ^{2g}
Osprey	none, none	Summer resident breeding near water bodies and wetlands throughout Washington. Feeds almost exclusively on fish and nests are usually in tree or utility pole near water ^{2e}
Sea Lion, California	none, none	Winter migrant to marine waters of Washington. Haulout sites may be a limiting habitat. ^{2d}
Seabirds: Cormorants, Terns, Alcids (Common murre, pigeon guillemot, Cassin's auklet, rhinoceros auklet, tufted puffin)	none, Priority Species	Feed in marine waters and nest on rocky shores or sea cliffs in western Washington. Sensitive to human disturbance, especially when nesting. ^{2d}
Shorebirds: Plovers, Sandpipers, Phalaropes	none, Priority Species	Shorebirds include year-round residents, summer breeders, and migrants. Forage in a variety of wetland and shoreline habitats, especially estuaries. Drayton Harbor important migratory feeding site. ^{2a, 2h}
Swans: Trumpeter swan, Tundra swan	Game, Priority Species	Migrants that winter in western Washington. agricultural fields of Skagit and Whatcom Counties support large numbers of swans. ²ⁱ
Turkey Vulture	none, none	A summer breeder in Washington, relatively rare in western Washington. Nests on cliffs and rock outcrops. ^{2c}

1 Source: WDFW 2004a.

2 Sources: ^a Larsen et al. (2004); ^b Washington Brant Foundation (2004); ^c Smith et al. (1997); ^d Angell and Balcomb (1982), ^e Rodrick and Milner (1991); ^f Maser (1998); ^g King County (2003); ^h Cullinan (2001); ⁱ Anderson (in press).

6.1.1.4 Shellfish Conservation Areas

Shellfish encompasses a broad group of organisms including oysters, clams, crabs, shrimp and mussels. Some of these shellfish genera, including clams and mussels, are also found in freshwater habitat. In Whatcom County this includes littleneck, horse, geoduck, Manila, heart cockle, and butter clams, mussels, red rock crab, shrimp, Pacific oysters, Dungeness crab, and crayfish (WCMRC 2003a). Several of these species are harvested commercially as well as recreationally. Shellfish Habitat Conservation Areas are found in the Drayton Harbor and its associated watershed, Lummi Bay, and between Portage Island and the Lummi Reservation (WCPD 1998). Commercial and/or recreational shellfish harvest has been closed by the Washington Department of Health (WDOH) in Drayton Harbor, the western shoreline of Sandy Point, and portions of Gooseberry Point, Birch, Portage, Bellingham, and Chuckanut Bays due to concerns for human health (WCMRC 2003b). A portion of Drayton Harbor was recently conditionally approved for commercial and recreational shellfish harvest (Drayton Harbor Shellfish Protection Advisory Committee 2004). For information on shellfish harvest areas see WDOH 2003 annual survey of commercial and recreational shellfish growing areas at: <http://ww4.doh.wa.gov/gis/growingareas.htm>

6.1.1.5 Kelp and Eelgrass Beds

Kelp and eelgrass beds are found north of Portage Island, in Lummi Bay, Birch Bay, Drayton Harbor, and around Point Roberts. Eelgrass is one of the principal foods of brant geese, which can be seen in Birch Bay and Drayton Harbor during spring migration (Washington Brant Foundation 2004). Eelgrass beds provide food and cover for a variety of other organisms including crabs, clams and fishes including juvenile salmonids (Kozloff 1973). Eelgrass and kelp beds are an important spawning substrate for Pacific herring (Bargmann 2001; WDNR 2003). Diatoms and other microscopic plants that live on eelgrass leaves are an important component of the marine food chain.

Along the eastern Pacific coast, annual and perennial species of kelp are found in cold, clear marine waters up to 130 feet in depth. Kelp may form dense, highly productive forests that are the basis of an ecosystem that supports a number of recreationally and economically important species of fish (Marine Biology Web undated). The principal kelp beds in Whatcom County are found between Point Whitehorn and Neptune Beach (WCMRC 2003c).

6.1.1.6 Naturally Occurring Ponds

Naturally occurring ponds less than 20 acres are found throughout the lowlands of the western portion of the County. In Whatcom County, naturally occurring ponds are currently protected as wetlands as well as a FWHCA. The County potential wetlands map depicts a number of small wetlands to the north of Bellingham, north and west of Ferndale, and north of Custer (WCPD 2004). Ponds provide critical breeding habitat for a number of Pacific Northwest amphibians (Leonard et al. 1993).

6.1.1.7 Waters of the State

Waters of the state within Whatcom County include the marine shoreline, the Nooksack River and its tributaries, and the lakes found throughout the County.

6.1.1.8 Waters with Planted Game Fish

Information on water bodies with planted game fish is not available in the PHS data. In 2004 WDFW (2004c) planted catchable trout in Cain, Padden, Silver, Squalicum, Terrell, and Toad Lakes. WDFW (2004c) planted no catchable trout in Whatcom County streams in 2004. In western Washington WDFW does not typically plant other game fish species or trout fry (2004c).

6.1.1.9 State Natural Areas

The Lummi Island Natural Resources Conservation Area (NRCA) is a 661-acre preserve on the southwestern slopes of Lummi Mountain that includes rocky cliffs that provide habitat for raptors (WDNR 2004). NRCAs are designated by the state based on their value as habitat and low impact recreation areas, a less restrictive category than the Natural Area Preserve (WDNR 2004). The Critical Areas Assistance Handbook (Ousley et al. 2003) recommends designating NRCAs as a FWHCA. The WCC does not currently include NRCAs as a FWHCA category. There are currently no state Natural Area Preserves in Whatcom County (WDNR 2004; WCPD 1998).

6.1.1.10 Lands Essential for Habitat Connectivity

Whatcom County has not identified or designated any lands essential for habitat connectivity as recommended in the Critical Areas Assistance Handbook (Ousley et al. 2003). However, the existing wetlands along the Nooksack River (identified on the draft 2004 priority species map) provide potential

wildlife habitat connectivity between the eastern and western portions of the County. Similarly, the riparian corridors of the North and South Forks of the Nooksack River provide a potential north-south wildlife corridor in the central County. There is good connectivity of habitats along the County's marine shoreline with Bellingham and Blaine and scattered residential developments being the principal barriers to wildlife movement and migration. There are still extensive areas of the County's marine shoreline along Birch Point, between Point Whitehorn and Neptune Beach, the Nooksack Delta, Chuckanut Bay and Drive, and Lummi Island that remain relatively undisturbed and continue to provide habitat for wildlife.

The Chuckanut Range south of Bellingham remains a relatively undeveloped habitat link to the Cascade Mountains to the east and may offer the best opportunity to establish/maintain an east-west habitat connection in Whatcom County. Supporting a number of important habitat types, habitat elements (caves, cliffs, grassy balds) and wildlife species including the listed Townsend's big-eared bat, the Chuckanut Range is the only location on the eastern coast of Puget Sound/Strait of Georgia in Washington where the mountains reach the marine shoreline (Cedar River Group 2002; Neatherlin 2004 personal communication). Interstate 5, a four-lane divided highway and the principal north to south highway in western Washington, passes through the Chuckanut Range to the east of Lake Samish and represent a dispersal barrier for some wildlife species.

6.1.1.11 Other Potential FWHCA's for Whatcom County

Beaches

The character of the Whatcom County shoreline varies from exposed bedrock along Chuckanut Drive and Lummi Island to sand and mud beaches at Lummi Bay and Drayton Harbor. The expansive sand and mud beaches and intertidal areas at Birch Bay and Drayton Harbor have developed over the millennia from sediment deposited by the Fraser River (Johnston 1921; Easterbrook 1962; Terrain Sciences Division 2002). The low wave energy within these bays has allowed for the continued accretion of fine sediments (Downing 1983). Cobble and gravel beaches are found primarily between Gooseberry Point and Semiahmoo Spit. These varied beach and shoreline types provide habitat for a diversity of fish and wildlife including spawning beds for Pacific herring, surf smelt and sand lance, seabird and shorebird foraging and nesting sites, and harbor seal pupping and haulout sites.

Nearshore Habitat

Nearshore habitat, the indefinite zone that extends seaward from the shoreline to a water depth of approximately 20 meters (66 feet), is rich biologically, providing important habitat for a diversity of plant and animal species (Voigt 1998; WDNR 2002). The nearshore zone is also an attractive area for recreational, commercial, and industrial development and nearshore habitat loss is a significant threat to this habitat type (Berry et al. 2001; WDNR 2002). The nearshore zone provides essential spawning and rearing habitat for juvenile salmonids, forage fish, a number of recreationally and commercially important shellfish, including crabs and hardshell clams, and foraging habitat for waterfowl and shorebirds (Buchanan et al. 2001; WDNR 2002).

Extending from the shoreline-beach interface to water depths that include the subtidal zone, the width of the nearshore zone varies depending on local topography. Along steep bluffs and rocky shorelines, nearshore habitat may be very narrow in extent, while it may be hundreds of yards in width on low gradient bays and estuaries (Berry et al. 2001). To a large degree, the nearshore morphology (rocky shoreline, cobble beach, mud bay) determines the biotic community found at a given site (Buchanan et al. 2001). Whatcom County includes 147 miles of marine shoreline, of which approximately 49 miles have

been modified by development (WDNR 2002). A 1995 inventory of 110 miles of Whatcom County marine shoreline south of Point Whitehorn identified 9 substrate types and 7 nearshore vegetation types (Berry et al. 2001). Sand was the most abundant substrate (5,556 acres) and eelgrass (2,923 acres) the most abundant vegetation type identified in the inventory (Berry et al. 2001). Extensive sand and mud nearshore habitat is found in Birch Bay and Drayton Harbor.

Habitats for Marine Mammals

The marine waters of Whatcom County are inhabited by a number of marine mammals both resident and migratory. Seals and sea lions may be found in the marine waters or marine shorelines throughout the County. Pacific harbor porpoise, orcas, and minke and gray whales have been documented in the Strait of Georgia (Angell and Balcomb 1982; PSEP 1992; Thompson 2004 personal communication). Harbor seals are year-round residents, while the other marine mammals found in Whatcom County waters are often found during migration or are more common during the summer (Angell and Balcomb 1982; Wiles 2004). Foraging on a number of marine fish and crustaceans, harbor seals use rocky shores and beaches for pupping and hauling out, where they may be very sensitive to human disturbance (Angell and Balcomb 1982). PHS harbor seal polygons are shown along the shorelines of Point Roberts, Birch Point, Point Whitehorn; Lummi, Eliza, and Portage Islands; Lummi and Viti Rocks; and Chuckanut Bay (WCPD 2004). Additional haulout sites have been documented in Bellingham Bay, the Nooksack Delta, Semiahmoo Bay and Spit, and Drayton Harbor (Jeffries et al. 2000). Orca whales are present much of the year in the Strait of Georgia along the western County boundary (Wiles 2004).

6.1.2 Landscape-scale Habitat Assessment

The WDFW, in partnership with The Nature Conservancy (TNC), TNC Canada, British Columbia Data Centre, Washington Department of Natural Resources, and Oregon State Natural Heritage Information Center are in the process of identifying areas of high biological diversity within each of Washington's 9 ecoregions. Ecoregions are defined by similar climate, geology, and vegetation characteristics and may cross state and federal boundaries. Although there is no legal nexus between ecoregional assessment areas and Washington's Growth Management Act, and local jurisdictions are not required to protect ecoregional biodiversity, the information generated through the ecoregional assessment process provides a framework for understanding fish and wildlife habitat conservation in Whatcom County. Within Whatcom County, these Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment sites can be grouped into 6 general landscape focal areas (Neatherlin 2004 personal communication) are described below:

6.1.2.1 Landscape Focal Area 1

Located in the northwest portion of Whatcom County within the Drayton Harbor and Birch Bay watersheds, this focal area includes Semiahmoo Bay, Drayton Harbor, the Birch Point shoreline, and Birch Bay. This shoreline extends from northern Drayton Harbor for about 40 km (25 miles) around Semiahmoo Spit and Birch Point to southern Birch Bay.

Drayton Harbor is an important shellfish area. In addition, Drayton Harbor and Birch Bay are waterfowl concentration areas with regularly occurring species of dabbling, diving, and sea ducks including harlequin duck, western grebe, red-necked grebe, brant, loons, and scoters.

Drayton Harbor is one of Washington's highest-ranking shorebird concentration areas with over 22,000 birds observed during peak times. Eight species of shorebirds regularly occur here including black-bellied plovers, short-billed dowicher, semi-palmated plover, greater yellowlegs, whimbrel, western sandpipers, least sandpiper, and dunlin. The mudflats, sand and gravel beaches, and tidal and subtidal vegetation

including seagrass, salt marshes, and spit and berm communities support Pacific sand lance, Pacific herring, and surf smelt spawning.

Bald eagles use the shoreline with 7 documented nest sites and associated territories. There are 3 documented Harbor seal haulout areas where seals sun themselves and rest. The largest haulout concentration area extends for a few miles around Birch Point. There is also a great blue heron nesting colony located along the southern end of Birch Bay. This colony has been growing steadily from the 1990s with approximately 260 nests currently. It is the third largest colony in the region with over 300 breeding pairs.

6.1.2.2 Landscape Focal Area 2

Located south of Birch Bay in the Birch Bay watershed and portions of the Lummi Bay watershed, this focal area extends along the shoreline for approximately 6 miles from Point Whitehorn along the Strait of George south to Lummi Tribal lands.

Shoreline ecological and littoral processes such as beach erosion, accretion from feeder bluffs, and deposition of woody debris combined with a range of high and low wave-energy areas results in a diverse structural and biological shoreline (Berry and Ritter 1997). The seagrass, kelp beds, intertidal and subtidal plant communities support an abundance of forage fish spawning habitat for Pacific herring and surf smelt.

Bald eagles nest and forage all along this shoreline with 7 documented nest locations. The area around Point Whitehorn is a harbor seal haulout and resting area. There is a great blue heron nesting colony inland from Neptune Beach area with greater than 150 nests and 30 individuals regularly observed.

6.1.2.3 Landscape Focal Area 3

This focal area is located partially within the Lummi Bay, Lummi Peninsula, and Silver/Nooksack Channel and Delta watersheds and includes all of Lummi Bay, Lummi Flats, and the shoreline along Hale Passage, northern Portage Island, and the Nooksack Delta. This focal area also includes the Lummi Floodplain, which extends from Lummi Bay and the Nooksack Delta north to Ferndale. The majority of this focal area lies within the boundaries of the Lummi Reservation. Tribally held lands within the Lummi Reservation are not subject to regulation by the County.

The Lummi Bay and Lummi Flats shorelines support a diversity of intertidal habitat types including sand and mudflats with seagrass, saltmarsh, and subtidal vegetation communities. These areas supports Pacific herring spawning and have large, regularly occurring waterfowl concentrations including harlequin duck, western grebe, red-necked grebe, brant, loons, and scoters. Lummi Bay and the associated Lummi Flats area ranks as one of Washington's top 10 shorebird concentration areas with greater than 8,000 individuals occurring during peak times. Species of shorebirds regularly observed using the area for wintering or seasonal migration include black-bellied plovers, killdeer, sanderlings, western sandpipers, and dunlin. Raptors such as bald eagles, peregrine falcons, and merlins regularly use the bay and mudflats for foraging. At the southern end of Lummi Bay there are 3 bald eagle nests and one great blue heron nest colony with as many as 80 nests. In the northern end of Lummi Bay there is a harbor seal haulout area. White pelicans are occasional visitors to Lummi Bay during migration.

Approximately 13 miles of shoreline extending between the Nooksack Delta, Portage Channel, and northern Portage Island is identified as eco-regionally significant. The Nooksack Delta shoreline is predominantly mud flats, estuarine salt marshes, and tidally influenced wetlands. Portage Island shoreline

consists of sand and gravel beaches and sand flats, with associated seagrass and kelp communities. Portage Island shoreline supports Pacific sand lance, Pacific herring, and surf smelt spawning.

The area between Portage Island and Nooksack Delta supports large concentrations of waterfowl including regularly occurring species of dabbling and diving ducks, western grebes, brant, loons, scoters, and red-necked grebes. Greater than 4,000 shorebirds at a time concentrate in the mudflats of the Nooksack Delta and include black-bellied plovers, black turnstones, western sandpipers, and dunlin.

Eleven bald eagle nests are concentrated primarily around Portage Island. There is a harbor seal concentration area located between Brant Island and Brant Point. Bald eagles, peregrine falcons, and merlins use the Nooksack Delta and Portage Island area for foraging.

Extending from Lummi Bay and the Nooksack Delta, this area includes the floodplain of both the Lummi and Nooksack Rivers downstream from Ferndale. The Lummi floodplain is a complex of wetlands and open water areas within the migration channel of the Lummi and Nooksack Rivers that is important in maintaining ecological processes such as water storage, groundwater recharge, and hydrological connectivity between these two rivers. The Lummi floodplain's function as a waterfowl and wintering raptor concentration area is partially reliant on its proximity to the adjacent bay and delta. Peregrine falcons, merlins, rough-legged hawks, northern harriers, short-eared owls, and bald eagles all use this area for foraging.

The Lummi River and Nooksack River riparian corridor is a waterfowl concentration area for dabbling and diving ducks such as harlequin, pintail, canvasback, and occasional swans. Bald eagles nest and forage along the Lummi and Nooksack Rivers.

6.1.2.4 Landscape Focal Area 4

This focal area is wholly within the Lummi/Eliza Islands watershed and includes the heavily forested portion of Lummi Island around Lummi Mountain and adjacent shoreline. This area has about 2,500 acres of mature conifer forests. These Douglas-fir–western hemlock–western redcedar and dry evergreen forests support globally ranked plant communities such as Douglas-fir–pacific madrone/orange honeysuckle and Douglas-fir/baldhip rose-oceanspray.

Peregrine falcons nest along the western cliffs of Lummi Island and there are regular large concentrations of harbor seals hauling out and resting along the shoreline and on the islands just offshore. Black oystercatchers, pigeon guillemot, rhinoceros auklets, cormorants, and bald eagles nest along the shoreline and islands offshore.

6.1.2.5 Landscape Focal Area 5

This focal area includes the Bellingham Bay, Lake Whatcom, Samish Bay watersheds and portions of the area between Lake Whatcom and Samish Bay watersheds in the southwest part of Whatcom County below Bellingham.

The area extending east from Chuckanut Mountain including Lookout Mountain, Squalicum Mountain, and the northern portions of Anderson Mountain represent the last remaining place in the Puget Trough where the Cascades continue unobstructed to the shore of Puget Sound (Kruckeberg 1991). This expanse of relatively undeveloped lowland and moderate elevation Douglas-fir–western hemlock–western redcedar and dry evergreen forests supports a diversity of unique aquatic and terrestrial habitats including herbaceous balds and bluffs, cliffs, caves, bogs, fens, and headwater lakes and streams.

Northern goshawks, bald eagles, osprey, band-tailed pigeons, big-eared bats, tailed frog, and marbled murrelets are all documented breeding or foraging in this area.

6.1.2.6 Landscape Focal Area 6

This focal area is located within the Upper Mainstem Nooksack watershed and includes the Nooksack River riparian corridor upstream of Everson. The riparian forests and shrublands include Douglas-fir–western hemlock–western redcedar and dry evergreen forests. This is a bald eagle wintering and foraging area.

6.2 OVERVIEW OF HABITAT FUNCTIONS AND VALUES

Habitat refers to the physical and biotic features of the environment that sustain and support fish or wildlife and may be assessed at a variety of scales from the ecoregional (Puget Trough) to a specific site (a high elevation talus slope). The predominant vegetation (conifer forest) and/or the presence of particular structural elements (e.g., snags, cliff faces) are typically used to classify wildlife habitat (McComb 2001). Habitat preference varies between wildlife species and over the course of the year for a given species of fish or wildlife. Generally, as habitat type changes, the assemblage of fish and wildlife species will also change; as habitat diversity increases the number and diversity of fish and wildlife species increases; ecotones (habitat type edges) have a high diversity of fish and wildlife species; and larger habitat blocks support a greater number of species than smaller habitat units (Castelle et al. 1992; O'Connell et al. 2000; O'Neil et al. 2001; Sheldon et al. 2003).

6.2.1 Habitat Functions

Habitat provides the resources necessary for individuals of a species to survive and reproduce. Habitat functions are often described as the ability to provide food (foraging habitat), protection from the weather and predators (cover), and allowing for successful reproduction (breeding habitat) (O'Neil et al. 2001). An additional function of habitat is to allow the movement of animals over the landscape through dispersal, allowing genetic mixing between populations; and migration; which allows a species to maximize available resources (Lemkuhl et al. 2001; McComb 2001). Wildlife species vary in their habitat requirements and use of a particular habitat type will vary by season and over the life of the individual. Habitat generalists, such as deer or red-tailed hawks thrive in a variety of habitat types, while habitat specialists, such as the harlequin duck require very specific habitat types and features. For most species, the habitat type selected for foraging will differ from habitat selected for thermal or security cover. Most species require specialized habitat features for reproduction (cavities for cavity-nesting birds) and for many species the availability of these breeding habitat features is used to determine the suitability of habitat (Anderson and Gutzwiller 1994; McComb 2001; Sheldon et al. 2003).

The suitability of habitat for a given wildlife species is determined by the habitat occurring within the species' range, the size of the habitat patch, whether the habitat is accessible (connectivity), the presence of requisite structural elements, and the amount of habitat alteration and disturbance (Morrison et al. 1998; McComb 2001). Some habitats may only be used for a short period of time but are critical in sustaining a species. During migration, shorebirds are dependent on intertidal mud bays for foraging where they may stop for a few days at a particular site.

Providing travel corridors for wildlife that maintain connectivity between habitat blocks is an important role of habitat. This connectivity reduces the likelihood of populations becoming isolated and prone to extinction due to random events or inbreeding (Morrison et al. 1998; Lemkuhl et al. 2001; King County 2003). If wide enough and suitable vegetation/structure is present, corridors may serve as habitat in their

own right (O'Connell et al. 2000; Kauffman et al. 2001; King County 2003). The potential value of corridors to wildlife is not entirely positive as corridors may contribute to the spread of fire, invasive species, and disease and may dampen speciation by contributing to genetic mixing (King County 2003). In a review of the value of habitat corridors to wildlife, King County (2003) determined that overall the benefit of maintaining connectivity between habitat patches and wildlife populations outweighs the risks to wildlife populations, particularly in landscapes with a high degree of human development.

Migration and dispersal habitat within Whatcom County includes the marine waters for marine mammals and salmon (Angell and Balcomb 1982); the Nooksack River and associated riparian habitat; and the foothills of the Cascades. As mentioned, the County provides important wintering and stopover habitat for migratory waterfowl, shorebirds, and raptors.

6.2.2 Habitat Values

The value of habitat for wildlife will depend on whether the habitat is suitable for the fish or wildlife species, the function (breeding, feeding, cover) the habitat is providing, if the habitat is accessible to the species, and the condition or quality of the habitat. Many species of waterfowl, shorebirds, and raptors are more abundant in northwestern Washington during the winter and migration. For waterfowl, such as snow geese or trumpeter swans, agricultural lands provide high quality foraging habitat (Anderson in press). Feeding in agricultural fields is an adaptation that has been associated with high winter survival and high reproductive rates for some species of waterfowl (Mitchell 1994).

There are 38 bald eagle nesting territories and 2 communal roosts depicted in the PHS data for Whatcom County (WCPD 2004). Bald eagles require relatively secluded sites in large trees near water for nesting and secluded sites for roosting. The high number of nesting territories indicates that for nesting bald eagles, there are several areas in the County with high value nesting habitat. The North Fork Nooksack River has supported one of the highest populations of wintering bald eagles in the contiguous U.S. (La Tourette 1992).

6.3 HUMAN ACTIVITY AND HABITAT FUNCTIONS

For wildlife, disturbance may include a behavioral and an ecological component. The behavioral aspect of disturbance may be defined as any action, such as human presence or noise from machinery, which alters the behavior of an animal (Dahlgren and Korschgen 1992; Martin 2001). The ecological component of disturbance includes an alteration of the structure and/or floristics of wildlife habitat. Disturbance may include spatial and temporal components and direct and indirect effects. Factors such as the size of the affected area, the timing of disturbance, and the duration of the disturbance influence the degree of disturbance. Wildlife species vary in their tolerance of disturbance and habitat alteration and this tolerance may vary over the course of the year (Martin 2001; McComb 2001). The sensitivity of a fish or wildlife species to disturbance may depend on the distance of the activity from the subject species, screening vegetation or terrain, and in some cases, the previous exposure (habituation) of the individual to the activity.

6.3.1 Ecological Disturbance

Habitat alterations may be temporary (clear cutting a forest stand) or permanent (converting a grassland to a residential development). These alterations often refer to changes in vegetation structure (converting mature forest to a seedling stand) or floristics (deciduous forest to shrub field) and may include introducing exotic species and disrupting nutrient cycling processes (Table 6-5). Habitat fragmentation, the isolation of habitat patches, is a source of disturbance that may affect habitat suitability well beyond

the site of the altered habitat. For wildlife species such as the wolverine, the presence of a road may serve as a dispersal barrier, fragmenting the habitat and rendering otherwise suitable habitat on the far side of the road inaccessible (Claar et al. 1999; Lemkuhl et al. 2001). Habitat alteration may change the vegetative community and structural elements of a site, affecting the density or species assemblages of wildlife using the site (McComb 2001). Generally, as the size of the habitat area increases the number of species and individuals the area can sustain also increases. The maximum number of individual animals of a given species that a particular area can support is referred to as carrying capacity (Robinson and Bolen 1984). Habitat alterations may decrease or increase a site's carrying capacity. For most wildlife species, as the size of a habitat patch is reduced or as the habitat is converted to more urbanized uses, carrying capacity is reduced. The remaining habitat patches have greater edge habitat, are more exposed to domestic animals that prey on native wildlife, and have less connectivity to other habitat areas.

Table 6-5. Effects of Disturbance and Habitat Alteration on Wildlife

Activity	Habitat Effect	Sensitive Species	Areas at Risk in Whatcom County
Clearing	Changes in habitat composition, complexity, and structure, loss of snags and large-diameter trees, habitat fragmentation, alteration of local hydrology, potential introduction of non-native species.	Snag dependent species (pileated woodpeckers, cavity-nesting ducks), forest interior or old-growth associated species (fisher, northern goshawk). Large trees in riparian/shoreline areas important for bald eagle and great blue heron nest and perch sites.	Much of old-growth in analysis area has been harvested. Potential for habitat loss throughout the County, especially near urban areas. Riparian and shoreline areas especially important as habitat.
Grading	Loss of soil organic layer, potential soil compaction, alteration of local hydrology, increased sedimentation of local waters, potential for landslides, mass wasting on steep slopes.	Aquatic and wetland dependent species (bull trout, juvenile salmonids, amphibians)	Identified geologically hazardous areas, areas with erodible soils (Chuckanut Range, Stewart Mountain), shoreline areas with steep bluffs (Birch Point, Point Whitehorn).
Urbanization	Loss of open space, breeding, feeding, cover, and dispersal habitat; loss of unique habitats and species diversity, habitat fragmentation, increased prevalence of introduced species, increased wildlife injury/mortality from vehicle collisions, domestic cats and dogs, increased behavioral disturbance from human presence.	Species intolerant of human activities or with large home ranges (gray wolf, wolverine), ground-nesting birds (California quail, Dark-eyed junco), species associated with unique habitats (rare plants, butterflies)	Open space and natural lands adjoining urban centers – Bellingham, Ferndale, Blaine, Lynden
Shoreline development	Loss/alteration of shoreline vegetation, habitat fragmentation, alteration of shoreline morphology (shoreline armoring, jetties) and currents, degraded water quality (runoff, faulty septic systems).	Species intolerant of human activities (bald eagles, harbor seals at haulout sites) or dependent on clean water and intact shoreline ecosystem (spawning surf smelt, Pacific herring).	Birch Point, Point Whitehorn to Neptune Beach, Chuckanut Bay
Agricultural practices	Alteration of local hydrology, degraded water quality from agricultural runoff. Many wildlife species benefit from agriculture and are dependent on crops as	Species associated with habitat edges (red-tailed hawk) sensitive to loss of natural areas. Waterfowl, including swans, and sandhill cranes may	

Table 6-5. Effects of Disturbance and Habitat Alteration on Wildlife (continued)

Activity	Habitat Effect	Sensitive Species	Areas at Risk in Whatcom County
	a source of food. Crop damage is potential source of conflict for wildlife.	depend on crops as food during winter, migration. Elk, deer populations may be controlled to reduce crop damage.	
Introduction of nonnative species	Potential loss of breeding, feeding, and cover habitat; displacement and extirpation of native species; ecosystem simplification. In riparian habitat as an example, alteration of native riparian habitat functions including associated wildlife refuge, insect litter, replacement of coniferous shade producing trees.	Insects dependent on rare native plants, aquatic or wetland associated species (marsh wren, beaver), neotropical migrant birds.	County wide, especially riparian/wetland habitats, marine shorelines
Increased noise/light	Flushing from breeding or foraging areas, interruption or interference with courtship, potential increased susceptibility to predation.	Species intolerant of human activities (marbled murrelets, nesting alcids, northern goshawks).	Undeveloped areas of the County with relatively low levels of ambient noise and light (Chuckanut Range, Lummi Island, Cascade foothills).
Human presence/recreational activities	Flushing from breeding or foraging areas, interruption or interference with courtship, potential increased susceptibility to predation.	Species intolerant of human activities (marbled murrelets, nesting alcids, northern goshawks, great blue herons).	Heron rookeries; undeveloped areas of the County with relatively low levels of human use (Chuckanut Range, Lummi Island, Cascade foothills).

Source: Ferguson et al. (2001); Lemkuhl et al. (2001); Sheldon et al. (2003).

While the majority of Whatcom County’s land base remains in open space, much of the open space has been altered for agriculture or forestry and the habitat value of these lands have been reduced from historic conditions. Significant portions of the wetlands in Whatcom County have been converted to agricultural lands, particularly in the north-central County. The human population of the County continues to grow, converting acreage to developed conditions. The County is served by an extensive road and highway system, but these roads may represent barriers to wildlife dispersal and contribute to wildlife mortality. State Route 9, State Route 538 (Guide Meridian Road), and Interstate 5 are major north-south arterials that may limit the east-west dispersal of wildlife. Residential development along the marine shoreline of Chuckanut, Bellingham, Birch, and Semiahmoo Bays, Drayton Harbor, Gooseberry and Sandy Points have reduced the habitat value for fish and wildlife in these areas. Industrial development in the Cherry Point area may be related to the decline of the Pacific herring spawning stock (Bargmann 2001).

6.3.2 Behavioral Disturbance

Direct effects of behavioral disturbance on wildlife can include an interruption of activity, flushing, and abandonment of a site or young. Indirect effects may include weight loss due to reduced food intake, or population decline as a result of lower breeding success for disturbed pairs (Castelle et al. 1992). Human presence may be sufficient to disturb some wildlife species, while other species may be relatively tolerant of humans. The time of year or wildlife activity may influence the sensitivity of wildlife to disturbance. Some species may be tolerant of human presence or activities while foraging but are highly sensitive to human presence while breeding or rearing young (McComb 2001; Stinson et al 2001; Quinn and Milner 2004). Common loons are highly sensitive to human development and activities at nesting lakes and have abandoned nests as a result of human disturbance (Richardson et al. 2000). Activities such as the use of heavy equipment, blasting, and pile driving may disturb species for up to a 0.25 mile beyond the source of

the noise (Ruediger et al. 2000; Watson and Rodrick 2002; Kennedy 2003). Recreation can be a major source of disturbance in breeding and wintering habitat (Claar et al. 1999; Stinson et al. 2001). Conflicts with farmers as a result of crop damage may have contributed to the decline of the Nooksack elk herd (Davison 2001). Wildlife viewing also may be a source of disturbance. Recreational boaters and whale-watching boats have disturbed orcas (Wiles 2004), while fisherman and bird watchers have interrupted feeding bald eagles (Watson and Pierce 1998; Stinson et al. 2001).

Federal and state agencies and local jurisdictions may mitigate human disturbance of wildlife by prohibiting the intentional disturbance of wildlife species/ individuals and designating areas as off limits to public entry. Management recommendations for a number of species (lynx, bald eagles, great blue herons) include restricting human activities around nesting or breeding sites (Ruediger et al. 2000; Watson and Rodrick 2002; Quinn and Milner 2004). During the hunting season, public access is restricted to portions of Lake Terrell to provide a sanctuary for waterfowl.

While the WCC addresses alterations to fish and wildlife habitat (Section 16.16.710- 16.16.730), it does not effectively address disturbance to wildlife species.

6.4 HABITAT MANAGEMENT AND PROTECTION TOOLS

Protection and management of FWHCAs requires protection of individual species and populations as well as the habitat areas that meet all of their life stage needs. Appropriate identification and mapping of species and habitats, use of buffers, restrictions on the timing of certain land use activities, and habitat restoration/mitigation are effective tools for accomplishing these goals.

6.4.1 Acquisition, Designation, Rating, and Classification

Fish and wildlife habitat may be protected through the purchase and ownership of property by private parties, non-profit organizations (The Nature Conservancy, Trust for Public Lands), and natural resource agencies such as National Park Service, U.S. Fish and Wildlife Service (USFWS), WDNR, WDFW, or Whatcom County Parks; or by classification/designation through state and federal laws or local jurisdiction's land use ordinances. The USFWS may designate critical habitat for federally listed species. Land use in designated critical habitat is usually restricted and requires consultation with the USFWS prior to actions by other federal agencies. The WDFW PHS Program identifies lands used by priority species and management recommendations may limit the timing or extent of land use actions. Public agencies may designate their lands for the management of fish and wildlife habitat or condition land use practices through rules and permitting requirements. Chapter 16.16 of the WCC identifies critical areas where land use may be restricted, often to the benefit of fish and wildlife habitat.

The Critical Areas Assistance Handbook recommends that local jurisdictions use PHS data in designating FWHCA and that when possible, large, round or square blocks of habitat should be emphasized for FWHCA rather than small or linear tracts.

6.4.2 Buffers

Buffers are vegetated lands separating critical areas from more intensive land uses and are intended to reduce potential impacts to the critical areas from activities beyond the buffer (O'Connell et al. 2000; Sheldon et al. 2003). Land use regulations have required buffers around wetlands and streams for a number of years and buffers have been the subject of numerous scientific studies and reviews (Castelle et al. 1992; Knutson and Naef 1997; O'Connell et al. 2000; Kauffman et al. 2001; Sheldon et al. 2003).

For wildlife, the principal functions of buffers are to provide habitat (feeding, cover, breeding) and travel corridors; microclimate modification; organic input; and to ameliorate the impacts of human disturbance (light, noise, human intrusion) (Castelle et al. 1992; Kauffman et al. 2001; Sheldon et al. 2003). Because buffers are often ecotone habitats between upland and aquatic or wetland areas, they often have a high diversity of wildlife (Castelle et al. 1992; Knutson and Naef 1997; O'Connell et al. 2000; Kauffman et al. 2001). The habitat suitability of buffers for wildlife is related to the width and floristic composition of the buffer (Castelle et al. 1992; Knutson and Naef 1997; Sheldon et al. 2003). Generally, wider buffers with more complex plant communities have higher habitat value. Forested buffers provide more habitat niches and functional value to wildlife than scrub-shrub buffers, which in turn are more effective as habitat than buffers dominated by herbaceous vegetation (Castelle et al. 1992; Knutson and Naef 1997; Sheldon et al. 2003).

Buffers provide habitat for a significant proportion of the Pacific Northwest's wildlife species, from invertebrates to large mammals (Castelle et al. 1992; Knutson and Naef 1997; Kauffman et al. 2001). Because amphibians require moist conditions protected from temperature extremes, they are more closely associated with wetland and riparian buffers than other wildlife taxa. Many amphibian species breed and rear young in open/standing water, yet spend the majority of their life cycle in the adjacent upland habitats. Of the 33 amphibian species documented in the Pacific Northwest, all require free water or moist terrestrial sites for breeding (Leonard et al. 1993). Vegetated buffers can provide essential cover, foraging, and dispersal habitat within the environmental conditions needed by amphibians (Castelle et al. 1992; Knutson and Naef 1997; Sheldon et al. 2003).

As travel or dispersal habitat, buffers are preferred habitat for a number of wildlife taxa including amphibians, birds, small mammals, and large mammals. Because small mammals and amphibians often have relatively small home ranges and are limited in their ability to move long distances, buffers provide the necessary cover and microclimate for these species to access water bodies and wetlands (Knutson and Naef 1997; Kauffman et al. 2001; Sheldon et al. 2003). Overhead canopy is essential for adequate security cover for a number of species (lynx, fishers, northern spotted owls, pileated woodpeckers) that tend to avoid crossing open areas. Due to their linear nature, riparian corridors are especially valuable for connecting blocks of suitable habitat (Kauffman et al. 2001; Sheldon et al. 2003).

Buffers moderate the microclimates of wetlands, streams and adjacent uplands by providing shade, reducing the temperature range, and diminishing the effects of wind and precipitation (Kauffman et al. 2001; Sheldon et al. 2003). Shading and moderating water temperature are important buffer functions in maintaining water quality and a high dissolved oxygen content required by stream invertebrates and salmonids (Sheldon et al. 2003).

Wetlands and riparian areas are often very productive habitats with high primary production (plants) supporting diverse ecosystems (Kauffman et al. 2001). The high plant productivity and low geographic positions contribute to the development of deep, fertile soils. Because riparian areas, including the vegetated edges of wetlands, are transitional between aquatic and upland habitats, they have a higher diversity of plant and animal species than the adjoining uplands (Castelle et al. 1992; Kauffman et al. 2001; Sheldon et al. 2003).

How wide a buffer needs to be to provide effective habitat is highly dependent on the wildlife species of interest (Table 6-6). For many forest birds and deer and elk, riparian buffers should be at least 200 feet in width (Knutson and Naef 1997). To maintain the species number of neotropical migrant birds, Keller et al. (1993) and Hodges and Kremetz (1996) recommended buffers of at least 328 feet (as cited in Knutson and Naef 1997).

Table 6-6. Recommended Riparian Buffer Widths to Provide Effective Wildlife Habitat.

Wildlife Taxa	Buffer Width (ft)¹
Invertebrates	100
Reptiles and amphibians	100 to 312
Forest dwelling birds	200
Neotropical migratory birds	328
Bald eagle	164 to 656
Great blue heron	328 to 984
Small mammals	39 to 305
Large mammals	200 to 328

Buffers are applied to wetlands and streams and in part to protect wildlife habitat functions and values. The WCC defines buffers as vegetated areas surrounding wetlands and streams where native vegetation is to be retained in order to minimize impacts to these critical areas from surrounding land uses (WCPD 2003). The WCC 16.16 requires a 100-foot buffer on wetlands (Section 16.16.640) and salmonid streams (Section 16.16.720) except for most isolated wetlands, which will have a 50-foot buffer and streams that are not directly connected with salmonid streams. However, wildlife species that are not highly associated with wetland or riparian habitats are not protected by these buffer provisions and may warrant species- or habitat-specific buffer standards. Where development may impact fish and wildlife habitat, the WCC 16.16 requires the applicant to prepare a habitat management plan that should include provisions to retain native vegetation and buffer habitat areas. By comparison, the Pierce County Development Regulations for critical areas specify that point locations (nest or den site) for special status wildlife should be protected by a 1,000-foot diameter buffer and that habitat areas should be protected by a 100-foot buffer.

6.4.3 Timing Restrictions

Some species of wildlife may be particularly sensitive to disturbance during their breeding seasons and restrictions on mechanized activities within a given distance of nest/den sites are a means of habitat protection. The WDFW management recommendations for bald eagles recommend restricting activities within 880 feet of an active bald eagle nest, January 1 through August 15 (Watson and Rodrick 2002) and within 0.5 mile of northern goshawk nests, March 1 through September 30 (Desimone and Hays 2003). The USFWS and NOAA Fisheries have also developed timing restrictions for work that may impact listed species (see Timing Restrictions, Section 1.5.2 below).

6.4.4 Habitat Mitigation

Mitigation refers to the avoidance or minimization of project related impacts to critical areas. Mitigation may also include the restoration or enhancement of existing fish and wildlife habitat or the creation of new habitat. Where required, mitigation often includes the approval of a mitigation plan, monitoring of the mitigation site for a specified period (~5 to 10 years), and the posting of a mitigation bond. Except for wetlands, rivers and streams, specific guidelines for mitigation of fish and wildlife habitat are not specified in the WCC. WCC 16.16.720 requires a habitat management plan when a proposed project may affect a FWHCA. The plan should include measures to mitigate for impacts to FWHCA based on WDFW management recommendations and should be developed by consulting with WDFW biologists.

6.5 FINDINGS AND CODE RECOMMENDATIONS

The following tables summarize the findings and proposed recommendations for revising Article VII of WCC 16.16 to address GMA requirements for FWHCAs in Whatcom County. These recommendations are based on the best available science review outlined above. The recommendations are grouped into general policy related recommendations and recommendations for specific regulatory protections.

6.5.1 General Findings and Recommendations

Sections WCC 16.16.700 and 710 establish the overall framework for the County’s habitat protection regulations. These sections identify and designate the species and habitats that are subject to the code requirements in accordance with GMA guidelines. Habitat and species designations could be clarified to facilitate implementation of the code provisions, reduce overlap and duplication of regulations, and improve/enhance predictability and consistency during development review. Also, many of the existing regulations rely on compliance with other provisions of the code (e.g., Article VI-Wetlands) or other state or federal regulations (e.g., state water quality standards) but as currently written, these other provisions may not provide complete protection for species or habitat functions. For example, the regulatory requirements for shellfish habitat conservation areas (WCC 16.16.720C) indicates that they are protected from dredging or filling through WCC Article VI - Wetlands, but the existing wetland regulations do not expressly prohibit dredging or filling in shellfish areas. So while, minimizing duplication of regulations is an appropriate goal, the County must take care to ensure that the development regulations are well integrated across titles, chapters, articles, and sections.

Habitats and species of local importance are defined as a FWHCA in WCC 16.16.720B, but the WCC does not specify the process for designating these areas. The Skagit County CAO (Section 14.24.500[3]) clearly defines the process for nominating and designating a species or habitat of local importance. In Skagit County an individual or group may petition the County to designate a species or habitat as locally important if the species/habitat is in decline, is sensitive to habitat alteration, and is of social value; if feasible management measures are included in the petition; and mapped (1:24,000 scale) locations are provided.

General Findings and Recommendations	
Finding #1	WCC 16.16.700 establishes the purposes of the regulations consistent with GMA. These are to protect fish and wildlife and their habitats to maintain their natural geographic distribution Existing regulations have a strong emphasis on protection of aquatic species and habitats, including salmonid habitat.
Recommendations	Revise purpose statements to include habitat rehabilitation as one of the goals of the regulations. Revise purpose statements to include preservation of terrestrial, marine, and nearshore habitat functions and values (as well as river and stream functions) to support wildlife. Add ESA compliance and consistency with BAS as goals of this Article.
BAS Sources	Ousley et al. (2003)

Designation Findings and Recommendations	
Finding #2	<ul style="list-style-type: none"> The County's designated FWHCAs per WCC16.16.710 are generally consistent with GMA guidelines (WAC 365-190), however some designations could be clarified. The Code identifies and designates habitats species of local importance (WCC 16.16 Appendix C) as a FWHCA, but the specifics of the designation are unclear and there is overlap with other FWHCA designations. Current designation for state natural areas does not include NRCAs. Current designation for locally important FWHCAs is limited to species; no habitats are identified. The County FWHCA designation does not include habitats that provide connectivity (although riparian corridors are included). The procedure for designating and identifying habitats and species of local importance sites is undefined.
Recommendations	<ul style="list-style-type: none"> Revise the designation categories in WCC 16.16.710 to match the GMA guidelines. Delete wetlands as a FWHCA since they have a separate critical area designation. Group lakes and ponds as one category instead of lakes and marine waters. Group marine waters, rivers and streams as one category (Waters of the US). Group kelp, eelgrass, herring, sand lance, and smelt spawning areas as one category, include NRCA as natural area preserve. Identify NOAA National Marine Fisheries Service as one of the agencies that identifies listed species (WCC 16.16.720 A) Define the procedure and criteria for designating habitats and species of local importance and for updating the designations over time. Clarify the distinction between these 3 categories of FWHCAs: Areas with which Listed Species Have a Primary Association, Priority Habitats and Species, and Habitats and Species of Local Importance. Define Priority Habitats (snags, cliffs, caves, etc.) and Habitats of Local Importance. Revise Appendix C to address all 3 categories and reduce overlap. Identify Habitats of Local Importance to include the following: Beaches, the habitat corridor from the Chuckanut Range to the east slope of the Cascades, WNHP high quality communities. Clarify that locally important species are a specific subset of PHS and listed species with specific value/importance for Whatcom County. Suggested locally important species are: <ul style="list-style-type: none"> Osprey, Turkey vulture.
BAS Sources	Ousley et al. (2003)

Mapping Findings and Recommendations	
Finding #3	<ul style="list-style-type: none"> The County inventory maps show the boundaries of known FHWCA habitat types (e.g., shellfish habitat conservation areas), but it is unclear how areas that are not presently mapped would be identified as being subject to the code. Similarly, for regulations linked to species, as opposed to habitats, it is unclear how staff will determine if a proposed development could affect a particular species or group of species. Sources of mapped information are not well documented and procedure for keeping maps and designations accurate and up-to-date over time is unclear.
Recommendations	<ul style="list-style-type: none"> Tie habitat management plan (HMP) requirements for any development activity that involves significant (> 1 acre) clearing and grading of existing native vegetation, unless it can be clearly documented that the development site and surrounding area potentially impacted by the development contain no suitable habitat for listed, priority or locally important species. Reference sources of mapped data and codify procedures for updating mapping.
BAS Sources	King County (2003); Ousley et al. (2003)

6.5.2 Recommendations for Regulatory Requirements (Protection and Management)

The existing provisions of WCC 16.16 Article VII include relatively broad performance standards with few prescriptive requirements. Many of the regulatory standards in WCC 16.16.720 and 730 give considerable discretion to staff, which allows flexibility during the development review process but may result in insufficient or inconsistent management approaches. The challenge of interpreting some of the existing regulations may be exacerbated by gaps in the code, namely the lack of specific buffer standards for habitat types other than streams and rivers; lack of specific mitigation requirements to compensate for adverse effects on species or habitats; and lack of specificity as to how effects on species and habitats are to be measured, reported and/or monitored. The County may improve protection and management of FWHCAs by adding prescriptive standards that address the size, amount, location, configuration, and other habitat characteristics that are needed to maintain populations of target species in Whatcom County.

Buffers	
Finding #4	<ul style="list-style-type: none"> • Buffers are an essential means of protecting breeding, foraging, and rearing habitats. WCC 16.16.720 does not require or identify buffers around FWHCAs with the exception of river/stream buffers. Lack of buffers reduces protection of important species and habitat and could put some species at risk of adverse effects from human disturbance.
Recommendations	<ul style="list-style-type: none"> • Determine buffer requirements for species consistent with BAS and WDFW management guidelines. Recommended buffers (radius) are as follows: <ul style="list-style-type: none"> ➤ Bald eagle nest sites – 800 ft; communal roosts – 400 ft; assess potential impact to exposed foraging areas within 1,500 ft.¹ ➤ Sandhill crane nest sites – 1,312 ft. for foot and vehicular traffic, 2,625 ft. for logging in nesting season; no roads or buildings within 1,640 ft of night roosts or 2,625 ft. of feeding areas.¹ ➤ Common loon nest sites – restrict and disturbance during nesting season and new structures within 492 ft. of nest sites and brood rearing areas.¹ ➤ Great blue heron rookeries – 984 ft. for habitat alteration or disturbing activities during nesting season, no logging within 3,281 ft. during nesting season; 328 ft. buffer on wetland foraging areas within 2.5 miles of rookery.¹ ➤ Marbled murrelet – 0.5 mile around nest tree.² ➤ Northern spotted owl – 0.7 mile around nest tree.² ➤ Northern goshawk nest sites – 30 acres; post-fledging areas, 420 acres.¹ ➤ Peregrine falcon nesting cliffs – avoid disturbance and restrict access during breeding season within 0.5 mile of cliff rim, 0.25 mile of cliff face.¹ ➤ Pileated woodpecker – retain forested stands, 7 acre minimum in suitable habitat.¹ ➤ Harlequin duck nest sites – maintain stream buffers ≥ 164 ft., restrict water activities on nesting streams during nesting season.¹ ➤ Vaux's swift nest sites – 400 ft.² ➤ Townsend's big-eared bat nursery sites – 450 ft.² ➤ Fisher travel corridors – maintain riparian buffers at least 1,200 ft. wide.² ➤ Gray wolf den sites – restrict access and mechanized activity within 0.25 mile.²
BAS Sources	Ousley et al. (2003); Sheldon et al. (2003); ¹ Larsen et al. (2004); ² King County (2003)

Timing Restrictions	
Finding #5	<ul style="list-style-type: none"> WCC 16.16.720 does not include provisions to restrict certain activities or regulate development during key wildlife life stages such as breeding periods.
Recommendations	<ul style="list-style-type: none"> Include limitations on development activities during breeding/nesting periods for important species as follows: <ul style="list-style-type: none"> Bald eagle – January 1 to August 31.¹ Sandhill crane – March to September.¹ Common loon – April 1 to September 1.¹ Great blue heron – February 15 to July 31.¹ Marbled murrelet – April 1 to September 15.² Northern spotted owl – February to June.³ Northern goshawk – March 1 to September 30.¹ Peregrine falcon – March to July.¹ Pileated woodpecker – late March to early July.¹ Harlequin duck – April to August.¹ Vaux's swift – early May to September.¹ Townsend's big-eared bat nursery sites – November 1 to February 28.⁴ Gray wolf den sites – April 1 to June 15.⁴
BAS Sources	¹ Larsen et al. (2004); ² Ritchie and Rodrick (1998); ³ City of Seattle (2000); ⁴ King County (2003)

Protection of Primary Association Habitats for Listed Species	
Finding #6	<ul style="list-style-type: none"> The code regulates activities in areas where listed species have a primary association, but no standards are provided for identifying the limits or boundaries of the association area. Activities that could affect bald eagles require a cooperative HMP be prepared in coordination with WDFW. It is unclear if this is a different standard than the HMP requirements listed in WCC16.16.730. Counties responsibilities under this provision are unclear.
Recommendations	<ul style="list-style-type: none"> For each listed species, include criteria to define the geographic limits that trigger the need for an HMP. Suggested guidelines are: <ul style="list-style-type: none"> Bald eagle – activity within 800 feet of the nest; 400 ft of communal roosts¹ Sandhill crane – activity within 1,312 ft. of nest site, 2,625 ft. for logging; 1,640 ft of night roosts; 2,625 ft. of feeding areas.¹ Common loon – activity within 492 ft of nest sites and brood rearing areas.¹ Great blue heron – activities within 984 ft. of nesting colony, no logging within 3,281 ft during nesting season; 328 ft for wetland foraging areas within 2.5 miles of rookery.¹ Marbled murrelet – 0.5 mile around nest tree.² Northern spotted owl – 0.7 mile around nest tree.² Northern goshawk – activity within 420 acres centered on nest site.¹ Peregrine falcon – activity within 0.5 mile of nesting cliffs.¹ Pileated woodpecker – activity within suitable habitat.¹ Harlequin duck – activity within 164 ft. of stream edge and within the stream channel within suitable nesting habitat.¹ Vaux's swift – activity within 400 ft. of suitable nesting habitat.² Townsend's big-eared bat – activity within 450 ft. of known or potential nursery sites.² Fisher travel corridors – activity within 600 ft. of suitable habitat.² Gray wolf – activity within 0.25 mile of den sites.² Expand protection of bald eagles (WCC16.16.720A3) to require HMPs for activities that could affect bald eagle wintering and foraging/perching sites (in addition to nests and communal roosts).
BAS Sources	¹ Larsen et al. (2004); ² King County (2003)

Habitats and Species of Local Importance	
Finding #7	<ul style="list-style-type: none"> The code (WCC16.16.720B2) permits activities that may affect habitats or species of local importance subject to conditions that avoid adverse impacts, but provides no guidance on what constitutes avoidance of adverse effects. The code (WCC16.16.720B2) requires a habitat management plan where proposed projects may disrupt habitats of local importance, but does not explicitly identify habitats of local importance.
Recommendations	<ul style="list-style-type: none"> Include performance standards that ensure avoidance of adverse effects. These could include requiring developments to protect key habitat components: <ul style="list-style-type: none"> maintain minimize patch size (>2 acres), retain snags and downed logs, retain structural diversity, protect travel corridors and access to water. Include WNHP high quality habitats/communities as a Habitat of Local Importance.
BAS Sources	Knutson and Naef (1997); King County (2003); Ousley et al. (2003)

Mitigation	
Finding #8	<ul style="list-style-type: none"> WCC 16.16.730 specifies that when required, HMP should include provisions to reduce or eliminate impacts to habitat features.
Recommendation	<ul style="list-style-type: none"> Strengthen HMP requirements to include mitigation measures, in accordance with SEPA mitigation sequence (avoid, minimize, reduce, rectify, compensate, monitor), for impacts to FWHCA based on WDFW management recommendations and should be developed by consulting with WDFW biologists. HMP should emphasize: <ul style="list-style-type: none"> maintaining or restoring habitat connectivity, maintaining or enhancing biological functions.
BAS Sources	Ousley et al. (2003)

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7. FISH AND OTHER AQUATIC SPECIES

This analysis is focused on fish and other aquatic species and their habitats on non-federal lands in Whatcom County (approximately the western third of the County), with special emphasis on anadromous salmonids. State Growth Management Act (GMA) guidelines (Ousley et al. 2003), suggest the following habitat types that should be designated as fish and wildlife habitat conservation areas (FWHCAs) in accordance with the GMA procedural criteria for adopting comprehensive plans and development regulations (WAC 365-190):

- Areas with which state or federally listed species (endangered, threatened, or sensitive) have a primary association.

The U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) are responsible for designating federal special status species and should be consulted for current listing status. The Washington Department of Fish and Wildlife (WDFW) is responsible for designating state special status species and maintains the current list of these species (Ousley et al. 2003).

- State priority habitats and areas associated with state priority species.

The Priority Habitats and Species (PHS) database is updated on a regular basis with input from WDFW field biologists and other scientists and represents the best available science on the distribution of special status wildlife species and habitats in Washington. The PHS habitats identified by WDFW are considered a priority for conservation and management due to their high fish and wildlife species density and/or diversity, important habitat functions, importance to priority species, limited distribution or rarity, vulnerability, or their cultural value (e.g., commercial or recreational) (Ousley et al. 2003; WDFW 2004a). WDFW (2004a) has designated 18 priority habitats statewide, 15 of which occur in northwestern Washington. Of the 15 priority habitats found in northwestern Washington, those most associated with fish species include instream habitats, riparian habitat, freshwater wetlands/fresh deepwater, marine/estuary shorelines, estuary/estuary-like habitats, and vegetated marine/estuarine areas (eelgrass, kelp, turf algae).

- Habitats and species of local importance.

These could include a seasonal range or habitat elements with which a given species has a primary association, and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long-term. Examples are areas of high relative density or species richness, breeding habitats, winter ranges, movement corridors, and habitats that are of limited availability or high vulnerability to alteration, such as riparian areas, wetlands, and shorelines. Local jurisdictions may designate habitats and species of local importance because of their value to the local environment (Ousley et al. 2003).

- Commercial and recreational shellfish areas.

Commercial and recreational shellfish areas include public, tribal and private tidelands that support shellfish harvest (Ousley et al. 2003).

- Kelp and eelgrass beds, Pacific sand lance, and herring and smelt spawning areas.

Kelp and eelgrass beds are highly productive ecosystems that provide essential rearing and foraging habitat for a variety of important food and bait fish including rockfish, salmon, smelt and herring as well as Dungeness crab (WAC 365-190-080; WAC 220-110-250; Murphy et al. 2000).

- Naturally occurring ponds under twenty (20) acres.
Naturally occurring ponds and ponds created for wetland/critical areas mitigation may provide fish and wildlife habitat and other wetland functions. These ponds do not include other manmade ponds (farm ponds, detention ponds) (Ousley et al. 2003).
- Waters of the state.
Waters of the state include surface waters and watercourses within state jurisdiction as defined in WAC 222-16-030 or WAC 222-16-031 (Ousley et al. 2003).
- Lakes, ponds, streams, and rivers planted with game fish by a government or tribal entity.
These waters provide a valuable public recreational and commercial resource.
- State natural area preserves and natural resource conservation areas.
Natural area preserves and natural resource conservation areas, owned and administered by the Washington State Department of Natural Resources (WDNR), represent unique or high quality undisturbed ecosystems and habitats (WDNR 2004).
- Land essential for preserving connections between habitat blocks and open space¹⁹.
Maintaining habitat connectivity for fish and wildlife species is necessary to sustain population viability. Habitat connectivity enables individuals to move between habitat patches in obtaining requisite resources, the dispersal of individuals, and genetic exchange between populations. Isolated populations are at greater risk of extinction due to natural population fluctuations, random events, and inbreeding (Morrison et al. 1998; Lemkuhl et al. 2001).

As noted in Chapter 6, beaches are not explicitly identified as a FWHCA in the GMA guidelines. Beaches provide important habitat for many fish, crustacean, bird and small mammal species, are limited in distribution, are vulnerable to alteration, and have been identified by some resource managers as a habitat type that warrants protection as a FWHCA in Whatcom County. Beaches could be designated a habitat of local importance by Whatcom County to conserve their habitat values for fish and wildlife.

7.1 OVERVIEW OF INVENTORY

The aquatic habitats of Whatcom County support a number of special status species and priority habitats and species. Within the County there are over 3,000 miles of riverine/stream habitat, numerous large lakes, several large estuaries, and over 130 miles of marine shoreline. The Nooksack river system is the largest river system in the County draining 826 square miles. The Nooksack system supports all five species of Pacific salmon as well as Bull trout/Dolly Varden, longfin smelt, and green sturgeon (Anchor Environmental 2003). The principal aquatic priority habitats on non-federal lands in the County are found along the Nooksack River and its major tributaries, along the marine shoreline, and at Lake Samish and Lake Whatcom (WCPD 2004). Further discussion of Whatcom County's FWHCAs with respect to fish species and aquatic habitat is provided below.

¹⁹ These areas are not listed in the definition of fish and wildlife habitat conservation areas per WAC 365-190-080(5). However, Ousley, et al. (2003) suggest that these lands be included in the designation of FWHCAs.

7.1.1 Species and Habitats

7.1.1.1 Listed Species Habitat

Listed fish species found within Whatcom County include the Puget Sound evolutionarily significant unit (ESU) of Chinook salmon (*Oncorhynchus tshawytscha*) and bull trout (*Salvelinus confluentis*). As defined and administered by NOAA Fisheries, the Puget Sound ESU of Chinook salmon is the only anadromous ESA-listed species potentially occurring in Whatcom County waters. As defined and administered by USFWS, bull trout are a threatened species that potentially occurs throughout the Nooksack watershed and in coastal and estuarine nearshore waters of Whatcom County. An overview of habitat requirements and distribution of Chinook salmon and bull trout in Whatcom County, including listing status, is included in Table 7-1.

7.1.1.2 State Priority Habitats and Species

The WCC does not explicitly designate priority habitats or identify priority species as a separate class of protected wildlife. Many of the species of local importance identified in Chapter 16.16, Appendix C of the WCC are classified by WDFW (2004a) as priority species, but no fish species are included in that appendix.

State priority habitats and habitats associated with state priority species include areas having high recreational value or relatively rare species. Of particular importance or concern in Whatcom County are salmonids listed as State priority species. Salmonid-bearing streams in Whatcom County generally contain several anadromous and/or resident priority salmonid species that include Chinook, coho, chum, pink, and sockeye salmon (including kokanee), bull trout, rainbow/steelhead trout, and coastal cutthroat trout (Table 7-1). Salmon are also associated with other types of priority habitats and species, particularly in relation to riparian areas, so the protection of salmonid habitats serves to protect other species dependent on similar or associated habitats. River lamprey are another anadromous species potentially found in Whatcom County streams. Other priority habitats and fish species occur in estuarine and nearshore areas. Species include Pacific herring, Pacific sand lance, surf smelt, longfin smelt, and numerous species of Rockfish (Table 7-1).

7.1.1.3 Habitats and Species of Local Importance

Habitats of local importance are defined in the WCC as habitats supporting vulnerable and recreationally important species listed in Appendix C of Chapter 16.16, but no fish are listed in the appendix. WCC does not identify particular habitat types or locations of habitats of local importance. However, many species of fish are associated with protected habitats such as wetlands and streams. Several species of resident fish, such as the Nooksack dace (*Rhinichthys* sp.) and the Salish sucker (*Catostomus* sp.), both having restricted distributions, are known only to inhabit Fishtrap and Bertrand Creeks in the United States. Kokanee, the landlocked Sockeye salmon of Lake Whatcom, is also a good candidate for Species of Local Importance because of its use as broodstock for Washington State and because of its importance as a sportfish.

7.1.1.4 Shellfish Conservation Areas

Shellfish encompasses a broad group of organisms including oysters, clams, crabs, shrimp and mussels. Some of these shellfish genera, including clams and mussels, are also found in freshwater habitat. In Whatcom County this includes littleneck, horse, geoduck, Manila, cockle and butter clams, mussels, red rock crab, shrimp, Pacific oysters, Dungeness crab, and crawfish (WCMRC 2003a). Several of these species are harvested commercially as well as recreationally. Shellfish Habitat Conservation Areas are

found in the Drayton Harbor and its associated watershed, Lummi Bay, and between Portage Island and the Lummi Reservation (WCPD 2004). Commercial and/or recreational shellfish harvest has been closed by the Washington Department of Health along the western shoreline of Sandy Point, and portions of Gooseberry Point, Birch, Portage, Bellingham, and Chuckanut Bays because of water quality problems (WCMRC 2003b). Until recently, all of Drayton Harbor was also closed to shellfish harvest due to water quality concerns. However, the central portion of Drayton Harbor (near the Canadian border in the northwest corner of Whatcom County), and a portion of Portage Bay have recently been conditionally opened for commercial and recreational shellfish harvest (WCPD staff personal communication) based on improved water quality. The conditional approval is based on rainfall, where a rainfall of on-half inch or greater in a 24-hr period will close the areas for five days because the resulting stormwater may temporarily cause violations of water quality standards. Current commercial growing areas are located in Birch Bay, Lummi Bay, areas around Lummi Island, Portage Bay, Samish Bay, and the conditionally approved portion of Drayton Harbor. Maps of these growing areas can be found at <http://ww4.doh.wa.gov/gis/growingareas.htm>.

7.1.1.5 Kelp and Eelgrass Beds

Kelp and eelgrass beds are found north of Portage Island, in Lummi Bay, Birch Bay, Drayton Harbor, and around Point Roberts. Kelp and eelgrass beds are also important rearing and feeding habitats for juvenile salmonids, particularly during the first year after entry into saltwater, and prior to entering the open ocean. Eelgrass beds provide food and cover for a variety of other organisms including crabs and clams (Kozloff 1973). Diatoms and other microscopic plants that live on eelgrass leaves are an important component of the marine food chain.

Along the eastern Pacific coast, annual and perennial species of kelp are found in cold, clear marine waters up to 130 ft in depth. Kelp may form dense, highly productive forests that are the basis of an ecosystem that supports a number of recreationally and economically important species of fish (Marine Biology Web undated). The principal kelp beds in Whatcom County are found between Point Whitehorn and Neptune Beach (WCMRC 2003c).

7.1.1.6 Naturally Occurring Ponds

Refer to Wildlife Chapter

7.1.1.7 Waters of the State

Waters of the state within Whatcom County include the marine shoreline, the Nooksack River and its tributaries, and the lakes found throughout the County.

7.1.1.8 Waters with Planted Game Fish

Information on water bodies with planted game fish is not available in the PHS data. In 2004 WDFW (2004b) Spring 2004 Hatchery Trout Stocking Plan for Lakes and Streams planted catchable trout in Cain, Padden, Silver, Squalicum, Terrell, and Toad Lakes. WDFW (2004b) planted no catchable trout in Whatcom County streams in 2004. In western Washington WDFW does not typically plant other game fish species or trout fry (2004b).

7.1.1.9 State Natural Areas

Refer to Wildlife Chapter

7.1.1.10 Lands Essential for Habitat Connectivity

Refer to Wildlife Chapter

7.1.1.11 Other Potential FWHCA's for Whatcom County

Refer to Wildlife Chapter

7.1.2 Aquatic Habitats

The predominant aquatic habitats in Whatcom County are the marine waters of the western county, and the numerous rivers and streams found throughout the County and primarily contained within the Nooksack River watershed. The marine waters include a diversity of habitat types from the nearshore areas such as the shallow, low salinity Nooksack River estuary in Bellingham Bay and rocky shorelines along Chuckanut Bay and Lummi Island to the deep waters of the Strait of Georgia. These marine habitats support fish species, a number of which are priority species (e.g. salmon and Pacific herring) due to their high economic and/or recreational importance. WDNR has proposed establishing the Cherry Point Aquatic Preserve between Birch Bay State Park and the Lummi Reservation to protect one of the largest historic spawning stocks of Pacific herring in Washington State. Spawning habitat for Pacific herring has declined precipitously in recent years (Bargmann 2001; WDNR 2003).

Relatively few inland freshwater lakes occur in Whatcom County. The most notable lake systems in Whatcom County include Lake Whatcom, Samish Lake (which drains into Skagit County), Lake Terrell, Lake Padden, and Silver Lake. The largest lake in the county, covering an area of over 5000 acres, is Lake Whatcom located near the city of Bellingham. Lake Whatcom is the source of water for Bellingham, and also provides water to the Lake Whatcom Water and Sewer District, several smaller water districts, and homes that draw water directly from the lake. Overall, Lake Whatcom supplies water to about half of all Whatcom County residents. Water in Lake Whatcom is occasionally supplemented with flow from the Middle Fork Nooksack River via a diversion dam on the Middle Fork Nooksack River, which diverts flow into Anderson Creek before it enters Lake Whatcom. However, flow diversion has been reduced in recent years due to concerns of maintaining adequate flows in the Middle Fork Nooksack River. Increased urbanization and residential development are thought to contribute to water quality problems in Lake Whatcom, such as a decreasing trend in dissolved oxygen concentrations, and elevated levels of ammonia, phosphorus, iron, and hydrogen sulfide that are symptomatic of low oxygen conditions (Smith 2002). Mercury has also been detected in Lake Whatcom.

Several short tributary creeks drain into Lake Whatcom including Olson, Smith, Brannian, Fir, Carpenter, Anderson, and Austin Creeks. These creeks support native cutthroat trout and kokanee as does Lake Whatcom, but Whatcom Falls near RM 3 on Whatcom Creek prevents anadromous salmonid access to Lake Whatcom (WDNR 1997). The native cutthroat population in Lake Whatcom declined by 65 percent severely between 1987 and 1999 (Johnston 1999). The native Lake Whatcom basin population of kokanee serves as the broodstock for the Lake Whatcom Hatchery population. Though the native population of Kokanee has declined, the hatchery-origin kokanee remain numerous, and serves as the only WDFW source of kokanee eggs and fry in Washington State (WDNR 1997).

Other sportfish species found in Lake Whatcom, and which are typical of lakes having recreational use in Whatcom County, include brook trout (*Salvelinus fontinalis*), lake trout (*Salvelinus namaycush*), yellow perch (*Perca flavescens*), brown bullhead (*Ictalurus nebulosus*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieu*).

While freshwater aquatic habitats support a wide variety of aquatic organisms, but of special concern is the condition of freshwater aquatic habitats necessary to support anadromous salmonids. A discussion of habitat requirements of anadromous salmonid species is presented in the following section.

7.1.2.1 Habitats for Anadromous Salmonid Species

All anadromous salmonid species in Whatcom County are considered priority species. Habitats for anadromous salmonid species include both fresh and marine waters. Habitat use is dependent on the life-stage and species, but in general there is considerable overlap in the range of habitat variables used by different salmonid species. Freshwater streams provide spawning and early-rearing habitat for all anadromous fish species, whereas marine waters are where anadromous fish grow to maturity prior to returning to freshwaters to spawn. Freshwater salmonid life stages require cold-water streams having complex structural habitat and clean gravels free of fine sediment. Upon hatching, juveniles spend varying lengths of time (from days to >2 yrs. depending on species and stock) in freshwater prior to migrating to sea. After entering the estuary, juvenile salmonids typically spend a period of time inhabiting and foraging among coastal and estuary shoreline habitats.

The streams and rivers of Whatcom County that contain anadromous salmonid species are numerous, and many of the areas designated as FWHCAs support habitats required by anadromous salmonids. The Nooksack River and associated tributaries drain the majority of Whatcom County. Major river reaches and tributaries include the mainstem, South Fork Nooksack, North Fork, and the Middle Fork Nooksack, all of which contain several anadromous salmonid species and stocks. Other smaller drainages independent of the Nooksack watershed also support anadromous salmonid populations. Baker Lake, which contains sockeye salmon, Lake Samish, Reed and Cain Lakes, Lake Diablo, and Ross Lake all drain to the Skagit watershed although they are within Whatcom County. An overview of the status, habitat associations and distribution of anadromous salmonid species in Whatcom County is found in Table 7-1.

Table 7-1. Habitat Associations and Distribution of Priority and Listed Fish Species in Whatcom County

Species	Federal and State Status ¹	General location/distribution
<p>Chinook salmon (Puget Sound ESU) <i>Oncorhynchus tshawytscha</i></p>	<p>FT, SC, Priority Species</p>	<p><i>Habitat:</i> Juveniles and adults require cold, well-oxygenated water. Spawning generally occurs in riffle areas with clean gravel and cobble substrates. Juveniles use pool habitat and instream cover such as LWD, spaces among cobbles, and undercut banks as resting areas and/or for refuge from predators. Cobble substrate and off-channel habitats such as secondary channels, backwaters, or ponds provide important refuge from flows for overwintering juveniles. After river entry, adults on spawning migration use resting pools, which provide refuge from river currents and high water temperatures that are often encountered in the summer and early autumn. Nearshore marine areas are important for feeding and refuge for juveniles after entering the ocean.</p> <p><i>Distribution:</i> Whatcom County supports both fall and spring Chinook salmon stocks. Late run (fall) Chinook spawn in portions of the mainstem, North Fork, Middle Fork, and South Fork Nooksack Rivers, and in tributaries that include Anderson, Bertrand, Fishtrap, Hutchinson, Smith, and Tenmile Creeks. Fall Chinook salmon have also been documented in the Sumas River, and in Dakota, Squalicum, and Whatcom Creeks. Two spring Chinook runs are found in Whatcom County. One stock primarily spawns in the North Fork Nooksack between RM 45 and RM 64 and in the lower Middle Fork Nooksack to a lesser extent. The other spring Chinook stock spawns in the South Fork Nooksack River and some larger tributaries such as Hutchinson, Skookum, Deer, and Plumbago Creeks.</p> <p><i>When habitats are occupied:</i> Spring Chinook adults migrate and are in streams from February to October and spawn from July to October. Fall Chinook adults migrate and are in streams from June to November and spawn from September to December. Juveniles of both stocks can be found rearing in streams year-round.</p>
<p>Coho salmon <i>Oncorhynchus kisutch</i></p>	<p>Priority Species</p>	<p><i>Habitat:</i> Similar general habitat associations as Chinook salmon (see above). Juveniles use pool habitat and instream cover such as LWD, spaces among cobbles, and undercut banks as resting areas and/or refuge. Juvenile coho salmon overwinter in freshwater so overwinter habitat such as deep pools and off-channel habitats are of particular importance for survival, especially in coastal streams subject to high fall and winter flows.</p> <p><i>Distribution:</i> Coho salmon occur throughout all three forks of the Nooksack watershed and associated tributaries, and in many smaller independent drainages including California, Chuckanut, Colony, Dakota, Oyster, Padden, Silver, Squalicum, Terrell, and Whatcom Creeks.</p> <p><i>When habitats are occupied:</i> Coho salmon adults migrate and are in streams from July to as late as February, and spawn from October to as late as February. Juveniles can be found rearing in streams year-round.</p>
<p>Chum salmon <i>Oncorhynchus keta</i></p>	<p>Priority Species</p>	<p><i>Habitat:</i> Chum salmon rear in freshwater for only a few days to weeks before migrating downstream to saltwater, therefore juveniles have limited habitat needs in freshwater. Migrating spawning adults require cold well-oxygenated water, resting pools, and clean gravel spawning substrate. Chum salmon also often spawn in shallower, slower-running streams and side channels in low gradient lower reaches of rivers.</p> <p><i>Distribution:</i> Two stocks of chum salmon occur in the Nooksack River Basin. One spawns in the South Fork and mainstem Nooksack Rivers and tributaries, while the other spawns in the North Fork Nooksack River and below the diversion dam on the Middle Fork Nooksack River. Other populations are found in smaller independent watersheds such as the Chilliwack, Lummi, and Sumas Rives, and in Chuckanut, Colony, Oyster, Padden, Squalicum, and Whatcom Creeks.</p> <p><i>When habitats are occupied:</i> Chum salmon adults migrate and are in streams from August to February, and spawn from October to February. Fry can be found in streams from February to July, but fry migrate seaward shortly after hatching and there is no juvenile rearing in freshwater.</p>

Table 7-1. Habitat Associations and Distribution of Priority and Listed Fish Species in Whatcom County (continued)

Species	Federal and State Status ¹	General location/distribution
<p>Pink salmon <i>Oncorhynchus gorbuscha</i></p>	<p>Priority Species</p>	<p><i>Habitats:</i> Similar early life history and freshwater habitat requirements as for chum salmon (see above). <i>Distribution:</i> Two stocks of odd-year pink salmon identified in the Nooksack basin as well as small numbers of even-year pink salmon. One stock is distributed found in the mainstem and tributaries of Middle Fork (up to the diversion dam) and the North Fork up to Nooksack Falls (RM 65). The other stock is found in the South Fork Nooksack and spawn up to RM 25, and also in some tributaries including Deer, Cavanaugh, Hutchinson, Plumbago, and Skookum Creeks. <i>When habitats are occupied:</i> Pink salmon adults migrate and are in streams from June to October, and spawn from August to October. Fry can be found in streams from December to June, but fry migrate seaward shortly after hatching and there is no juvenile rearing in freshwater.</p>
<p>Sockeye salmon/ Kokanee <i>Oncorhynchus nerka</i></p>	<p>Priority Species</p>	<p><i>Habitat:</i> Similar general instream habitat requirements for migration and spawning as other salmonid species. Sockeye salmon are unique in that juveniles rear in freshwater lakes for up to a year prior to migrating to the ocean. Kokanee rear and reproduce in freshwater lakes. <i>Distribution:</i> Small numbers of sockeye salmon have been documented in the North and South Fork Nooksack Rivers and occasionally recorded in the lower reaches of the Middle Fork. A native population of kokanee reproduces in the Lake Whatcom watershed. A hatchery at the south end of the lake produces native kokanee brood stock for lakes around the world. <i>When habitats are occupied:</i> Sockeye salmon adults migrate and are in streams from April to November, and spawn from August to November. Fry and juvenile rearing occurs year-round in freshwater lakes.</p>
<p>Bull trout <i>Salvelinus confluentus</i></p>	<p>FT, Priority Species</p>	<p><i>Habitat:</i> Similar general instream habitat requirements as other salmonids except that bull trout require much colder water temperatures than other salmonid species, and require relatively pristine habitats. Migratory forms of bull trout inhabit lower river reaches and nearshore marine habitats for migration, rearing, and feeding. <i>Distribution:</i> Because bull trout require very cold water temperatures for certain life-history stages, the distribution of bull trout is generally restricted to upper reaches of sub-basins. Bull trout have been found in the North Fork sub-basin up to RM 65, and in Boulder, Canyon, Cornell, Glacier, Kenney Racehorse, Thompson, and Wells Creeks. In the Middle Fork Nooksack River, bull trout are found upstream of the diversion dam, and are either present or presumed to be present in Canyon Lake, Clearwater, Green, Rankin, Ridley, Sisters, and Warm Creeks. In the South Fork Nooksack sub-basin, bull trout are known to spawn in the mainstem of the South Fork and in Bells, Howard, and Wanlick Creeks. Bull trout/dolly varden are also known to spawn in the Chilliwack River system outside of the Nooksack system. However, because portions of bull trout populations have an anadromous life history strategy and may migrate upstream and downstream for foraging, spawning, and dispersal, all tributaries of the Nooksack and Fraser River watersheds are considered potentially inhabited by bull trout unless data indicates that water quality (primarily water temperature) is impaired to an extent that resident or migratory life-stages of bull trout cannot be supported. In general though, the larger lower reaches of main tributaries and the mainstem Nooksack River are primarily used as migratory corridors for bull trout. <i>When habitats are occupied:</i> Though portions of some populations are anadromous, this behavior is not obligatory and bull trout adults and juveniles may occur in freshwater year-round.</p>

Table 7-1. Habitat Associations and Distribution of Priority and Listed Fish Species in Whatcom County (continued)

Species	Federal and State Status ¹	General location/distribution
Rainbow Trout/steelhead <i>Oncorhynchus mykiss</i>	SC, Priority Species	<p><i>Habitat:</i> Similar general instream habitat requirements as other salmonids. Steelhead have an extended freshwater juvenile as with Chinook and coho salmon, but also require habitat for feeding and resting during an extended adult freshwater phase.</p> <p><i>Distribution:</i> Three winter-run and one summer-run stock are found in Whatcom County. These stocks include the Mainstem/North Fork stock, the Middle Fork stock, and the South Fork stock. A summer-run stock spawns in the upper South Fork Nooksack River. Winter steelhead also occur in Chuckanut, Dakota, Padden, Squalicum, Terrell, and Whatcom Creeks, and in the Sumas River. In addition, native resident rainbow trout are found in the upper North Fork and Middle Fork Nooksack River sub-basins as well as some South Fork Nooksack tributaries.</p> <p><i>When habitats are occupied:</i> Resident rainbow trout are found in freshwaters year-round. Summer steelhead adults are potentially found in streams year-round, but spawning occurs from February to April, with surviving adults outmigrating to the ocean shortly thereafter. Winter steelhead are found in streams from October to July, and spawning may occur from December to July. Juveniles of both life-history forms rear in freshwaters year-round prior to outmigrating to the ocean.</p>
Coastal Cutthroat Trout <i>Oncorhynchus clarki</i>	Priority Species	<p><i>Habitat:</i> Cutthroat trout have similar general requirements as all salmonids and display varying degrees of migratory behavior, often moving out to nearshore marine waters and estuaries to feed in the summer and migrating freshwater streams to overwinter prior to spawning in the spring.</p> <p><i>Distribution:</i> One stock of coastal cutthroat trout is widely found throughout Whatcom County streams upstream and downstream of most migration barriers.</p> <p><i>When habitats are occupied:</i> The life-history of coastal cutthroats is highly variable. Portions of populations are anadromous, but this behavior is not obligatory and coastal cutthroat trout adults and juveniles occur in freshwaters year-round.</p>
River Lamprey <i>Lampetra ayresi</i>	SC	<p><i>Habitat:</i> River lamprey are anadromous and require clean gravel substrate in streams for spawning and egg incubation. After hatching, lamprey burrow in silt and mud, often in off-channel areas, where they typically remain for a period of years. During this stage, lamprey require relatively stable habitats (Close et al. 1995).</p> <p><i>Distribution:</i> Found in coastal streams from northern California to southeastern Alaska, but little information available regarding the population status of river lamprey in Washington. <i>When habitats are occupied:</i> River lamprey migrate up small freshwater streams in the fall and spawn in the winter and spring. However, the ammocoete (juvenile) stage lasts several years so river lamprey would be expected to occur year-round in streams where they are found.</p>
Pacific Herring <i>Clupea pallasii</i>	SC	<p><i>Habitat:</i> Most spawning occurs in shallow sub-tidal zones from 0 to -10 ft in tidal elevation. Eggs are deposited on vegetation or other shallow water substrate.</p> <p><i>Distribution:</i> Herring are abundant throughout the northeast Pacific Ocean. Significant spawning concentrations are found in the Cherry Point, and Samish-Portage Bay areas. Puget Sound stocks spend their first year in Puget Sound. Some stocks remain entirely in Puget Sound while other migrate to other coastal areas of Washington and southern British Columbia (Bargmann 1998).</p> <p><i>When habitats are occupied:</i> Pacific herring stocks spawn from late January through early April. A notable exception is the Cherry Point stock (the largest in the state), which spawns from early April through early June.</p>

Table 7-1. Habitat Associations and Distribution of Priority and Listed Fish Species in Whatcom County (continued)

Species	Federal and State Status ¹	General location/distribution
Pacific sand lance <i>Ammodytes hexapterus</i>	Priority Species	<p><i>Habitat:</i> Pacific sand lance deposit their eggs in sand-gravel substrates between the mean high tide line and about +5 ft in tidal elevation. Eggs incubate in beach substrate for about one month before emerging. Larvae are a common component of the nearshore plankton. Incubating sand lance eggs occur in the same substrate with the eggs of surf smelt spawning populations, both species using the same stretches of beach for spawning at the same times of year.</p> <p><i>Distribution:</i> The Pacific sand lance is found from southern California around the north Pacific Ocean. It is common in nearshore marine waters throughout Washington state. Spawning areas are scattered along nearshore areas in Whatcom County (Bargmann 1998).</p> <p><i>When habitats are occupied:</i> Sand lance inhabit marine near-shore areas year-round, with spawning in intertidal areas occurring annually from November 1 through about February 15.</p>
Surf smelt <i>Hypomesus pretiosus</i>	Priority Species	<p><i>Habitat:</i> Similar spawning and nearshore habitat requirements as the Pacific sand lance. Surf smelt have an entirely marine/estuarine life history (Bargmann 1998).</p> <p><i>Distribution:</i> The surf smelt occurs from southern California to central Alaska and are widespread in Washington. In Whatcom County, surf smelt are found in similar areas as Pacific sand lance.</p> <p><i>When habitats are occupied:</i> Surf smelt inhabit marine near-shore areas year-round, and spawning may occur year-round.</p>
Longfin smelt <i>Spirinchus thaleichthys</i>	Priority Species	<p><i>Habitat:</i> Longfin smelt are anadromous and spawn in freshwater streams. Spawning substrate is sand and gravel similar to that used by surf smelt in nearshore areas.</p> <p><i>Distribution:</i> Spawning populations occur locally throughout western Washington, but the species is poorly understood or studied. Spawning is known to occur in the lower Nooksack River, but actual spawning sites have not been identified (Bargmann 1998).</p> <p><i>When habitats are occupied:</i> The longfin smelt spawning season in the lower reaches of the Nooksack River is thought to only occur from November until as late as April.</p>
Numerous Rockfish species	<i>Sebastes</i> spp.	<p><i>Habitat, Distribution, and when habitats are occupied:</i> Rockfish and other groundfish species can be found in marine nearshore and offshore areas year-round. Estuaries often attract early life phases of groundfish species.</p>

Primary sources: Smith (2002), WDF et al. (1993), WDFW (1998, 2000), Bargmann (1998), Close et al. (1995), Anchor Environmental (2003).

¹ FT = Federally Threatened, SC = State Candidate, SS = State Sensitive. Note: Candidate species are not required to be included in the definition of fish and wildlife habitat conservation areas (WAC 366-190.080)

7.2 OVERVIEW OF AQUATIC HABITAT FUNCTIONS AND VALUES

Productive salmonid habitat is necessarily complex owing to the myriad requirements of various life-stages. Salmonids require cold clean waters, silt-free substrates, natural flow conditions, and structurally complex habitat suitable for spawning, rearing, and migration. The aquatic habitat features important for supporting salmonid populations include riparian condition, LWD recruitment, fish passage, floodplain connectivity, channel migration, bank stability, pools, off-channel habitat, substrate/fines, water quality, and hydrology.

Riparian areas are the zones where aquatic and terrestrial ecosystems interact. Riparian vegetation provides habitat for many species of wildlife, and streamside or shoreline vegetation provides habitat functions for streams, and fish such as shade, bank stability, sediment/nutrient filtering, and organic nutrient input. In addition, riparian vegetation interacts with natural erosional and depositional processes of streams as channels migrate across valley bottoms to form instream habitat. As channels move back and forth through this channel migration zone (CMZ), instream pools and riffles are formed. Channel migration also promotes floodplain connectivity and recruitment of LWD, which can be a primary factor influencing channel form by the creation pools, riffles and off-channel habitats that are essential to support all life stages of anadromous salmonids (May 2000).

Historically, natural riparian corridors in the Pacific Northwest were nearly continuous and the importance of riparian continuity is widely recognized (May et al. 1997; Naiman and Bilby 1998; Wenger 1999). Riparian corridor continuity is particularly important in smaller headwater streams because smaller streams generally make up most of the stream length within a watershed, and the influence of riparian vegetation on some stream habitat functions is greater for small streams (Binford and Bucheneau 1993; Wenger 1999; Beschta et al. 1987). Such areas upstream of fish-bearing waters help determine water quality, the magnitude and timing of flows, stream temperature, sediment, nutrients, and prey production in downstream waters.

Along marine and lake shorelines, riparian vegetation is also a key element of ecological function and has a significant influence on the habitat value of the riparian zone, and in adjacent aquatic and terrestrial areas (Zelo and Shipman 2000). Though not as well defined as for riverine systems, both marine and freshwater shoreline riparian zones serve many of the same functions (e.g. LWD, shading, organic matter production, sediment filtration, microclimate), as well as some additional functions unique to shorelines (Gregory et al. 1991; Naiman et al. 1992).

The following discussion is a review of major riparian functions and the level of functionality afforded by riparian buffers of varying widths as reported in the literature. Tables 7-2, 7-3, and 7-4 summarize the conclusions and recommendations for riparian buffer widths in frequently cited literature reviews of riparian buffer functions. These tables are not intended to be prescriptive, but do serve to illustrate the wide range of effective buffer widths reported in the literature, and also provide recommendations based on providing a reasonable level of habitat functionality under most conditions. However, it must be recognized that a single prescription is not necessarily appropriate or warranted for all situations. Buffer recommendations and functionality is frequently expressed in terms of site-potential tree height (SPTH), which is the height of mature trees that a given site can be expected to support.

Following the tables, further discussion of riparian functionality and considerations for determining buffer effectiveness is provided. In addition, riparian functions for lake and marine shorelines are included in the discussion where appropriate.

Table 7-2. Stream Riparian Functions and Appropriate Widths Identified by May (2000)²⁰.

Function	Range of Effective Buffer Widths	Minimum Recommended Width	Notes On Function
Large Woody Debris	10 to 100 m (33 to 328 ft)	80 m (262 ft)	1 SPTH based on long-term natural levels
Water Temperature	11 to 43 m (36 to 141 ft)	30 m (98 ft)	Based on adequate shade
Sediment removal and erosion control	8 to 183 m (26 to 600 ft)	30 m (98 ft)	For 80% sediment removal
Pollutant Removal	4 to 262 m (13 to 860 ft)	30 m (98 ft)	For 80% nutrient removal
Microclimate	45 to 200 m (148 to 656 ft)	100 m (328 ft)	Optimum long-term support

Table 7-3. Stream Riparian Functions and Appropriate Widths Identified by Knutson and Naef (1997)

Function	Range of Effective Buffer Widths (ft)
Large Woody Debris	100 to 200
Water Temperature	35 to 151
Erosion Control	100 to 125
Sediment filtration	26 to 300
Pollutant Removal	13 to 600
Microclimate	200 to 525

Table 7-4. Stream Riparian Functions and Appropriate Widths Identified from FEMAT (1993)

Function	Number of SPTH	Equivalent (ft) ²¹
Large Woody Debris	1.0	200
Shade	0.75	150
Sediment Control	1.0	200
Bank Stabilization	0.5	100
Organic Litter	0.5	100
Microclimate	up to 3	up to 600

²⁰ May (2000) recommendation for an overall minimum buffer width is 30 m (98 ft), with the understanding that full effectiveness may not be achieved for some functions such as LWD, wildlife habitat, and microclimate.

²¹ Note that this is based on a 200-ft SPTH (or that expected on a Class I site), and that equivalent functionality may be achieved by narrower buffers on sites having a narrower SPTH.

As specified in WDNR Forest and Fish Report (1999, 2003), SPTH has been determined for different stream site classes in western and eastern Washington (Table 7-5)²². Site classes are based on soil conditions and range from the most productive to the least productive sites (Goldin 1992). It has been determined that the most productive sites (Site Class I) in Western Washington would have a SPTH of 200 feet and the least productive sites (Site Class V) would have a SPTH of 90 feet. Based on these site potentials and stream size, riparian buffer prescriptions have been developed that are most applicable to forested lands. Differences in stream size for a given site class are used to further modify prescribed buffer dimensions within the overall riparian management zone (RMZ; which is equivalent in width to the SPTH) so that different portions of the buffer (core, inner, and outer areas) have different dimensions to provide appropriate levels of protection (Table 7-5).

Table 7-5. Example of Riparian Buffer Width Prescriptions from WDNR (2003)

Site class	RMZ/SPTH ¹ width	Core zone width (measured from outer edge of the bankfull width or CMZ, whichever is greater)	Inner zone width (measured from outer edge of core zone)		Outer zone width (measured from outer edge of inner zone)	
			Stream width ≤10 ft	Stream width >10 ft	Stream width ≤10 ft	Stream width >10 ft
I	200	50	83	100	67	50
II	170	50	63	78	57	42
III	140	50	43	55	47	35
IV	110	50	23	33	37	27
V	90	50	10	18	30	22

¹ The RMZ defined in WDNR (1999, 2003) is equivalent to the SPTH that has been determined for different site classes

Riparian functions and concepts covered in the following text include:

- Channel migration zones
- LWD recruitment
- Stream shading/temperature
- Bank stabilization/habitat formation
- Filtering of sediment, nutrients and chemicals
- Organic input and nutrient source
- Microclimate

Though the following discussion is primarily focused on stream habitats, additional discussion of how riparian vegetation influences marine, lake, or estuarine shorelines is included where appropriate.

²² According to WDNR (1999, 2003), SPTH means the distance represented by the approximate mid-point of one of five site classes projected to a stand age of 100 years. See Table 5. Note also that the SPTHs presented in Table 7-5 were derived from Douglas Fir stands and adjustments to the SPTH values are likely appropriate for stands in which other species are dominant.

7.2.1 Channel Migration Zones (CMZ)

The importance of protecting the CMZ is well-documented, and to protect habitat functions supported by the CMZ, many investigators recommended that riparian buffers be measured laterally from the edge of CMZs where they occur, rather than from the ordinary high water mark (OHWM) as is typically required by existing code regulations (Knutson and Naef 1997; May 2000; WDNR 1999, 2003; Smith 2002). Knutson and Naef (1997) state "the channels of some streams, particularly larger streams and rivers in broad, alluvial valleys, may migrate across the valley as a result of natural erosional and depositional processes; the area over which the channel is expected to migrate is called the channel migration zone". As stream channels migrate across valley bottoms, riparian vegetation interacts with natural erosional and depositional processes, which promotes floodplain connectivity, LWD recruitment potential and the formation of instream habitat (May 2000).

From a regulatory standpoint, the definition of CMZs varies. The Washington Forest Practices Board (WDNR 1999) defined CMZs as "...the area that streams have recently occupied (in the last few years or less often decades), and would reasonably be expected to occupy again in the near future." However, the Forests and Fish Report (WDNR 1999) provided the following guidance for defining CMZs:

"Operationally, the CMZ should be equivalent to the area that a stream is expected to occupy in the time period it takes to grow a tree of sufficient size to provide geomorphic/ecological functions in the channel. On smaller streams, it may be appropriate to be concerned where the stream could move within 100 years or less. However, larger wood is needed to function in larger, high-energy channels. To be functional, recruitment trees must be very large, with root wads attached. As a consequence, on a larger stream, it may be necessary to include areas in the CMZ that the stream could occupy in the next 200 years or more."

Regardless of the time frame used to define a CMZ, what ultimately determines the presence of a CMZ is physical evidence of channel migration such as inactive channels, old meander bends, sloughs, oxbows, or floodplain terraces. By definition, such features only occur within CMZs and any classification system of channel migration potential can only be derived from such evidence of channel migration. In general though, channel migration can be expected to occur in lower gradient streams and rivers having broad valleys (that were often formed by such channel migration processes over long periods of time), which are typical of those reaches designated as "Shorelines of the State" (i.e. having a mean annual flow ≥ 20 cfs) in Whatcom County. However, CMZs often occur in smaller streams and reach specific delineations, which are currently ongoing in Whatcom County, must be conducted to determine the presence and extent of CMZs. Additional details and protocols for identifying and delineating CMZs can be found in WDNR (2003).

7.2.2 LWD Recruitment

LWD in streams influences coarse sediment storage, creates hydraulic heterogeneity, moderates flow disturbances, provides cover, and contributes to overall channel complexity. LWD traps and accumulates sediment, small woody debris, and other organic matter (Bilby 1981). The complex, submerged structure formed by LWD and entrapped smaller woody debris provides flow refugia and essential cover in which salmonids conceal themselves from predators and competitors and find profitable feeding positions, as inferred from observations under both natural and laboratory conditions (McMahon and Hartman 1989; Fausch 1984). The removal of riparian forest reduces woody debris in streams, which in turn leads to adverse changes in channel and habitat-forming processes (Bilby 1984; Heifetz et al. 1986; McDade et al. 1990; Van Sickle and Gregory 1990; Bilby and Ward 1991).

Riparian buffer widths of 100 to 200 ft (equal to about 1 site potential tree height or SPTH) generally provide adequate LWD recruitment potential, depending on site conditions such as stream size, channel confinement, gradient, and buffer vegetation characteristics (i.e. type, maturity, and density) (Murphy and Koski 1989; Robison and Beschta 1990; McDade et al. 1990; Thomas et al. 1993). With respect to stream size, the role of LWD varies, with riparian vegetation generally exerting a greater influence on smaller streams (Knutson and Naef 1997). Large woody debris is not easily transported in small streams, regardless of gradient, thus individual pieces (logs, root wads, etc.) can greatly influence channel morphology, instream cover, food resources, and sediment transport. As stream size increases, the influence of riparian vegetation and individual pieces of LWD decreases, and more substantial logjams are needed to affect instream structural complexity, which was characteristic of the historic Nooksack River (Collins and Sheikh 2002). Larger buffer widths (>200 ft) may be required for long-term natural recruitment of woody material (FEMAT 1993; May 2000). Humans can “import” woody debris to streams and rivers, but these artificial recruitment efforts provide limited short-term, benefits to stream habitat (e.g., fish cover, localized hydraulic complexity). Therefore, while human installation of LWD is not an adequate substitute for the natural recruitment potential of healthy riparian areas, nor does it provide many other important long-term benefits provided by native vegetation buffers, but artificially introduced LWD can provide some habitat benefits in the absence of riparian buffers and natural recruitment (e.g. highly managed agricultural areas), or as an interim measure while existing or newly established riparian buffers mature.

LWD is a natural component of marine shorelines. LWD accumulates in backshore areas at high tides, and serves to help stabilize the shoreline by absorbing wave energy, and trap sediment as is seen in riverine and freshwater lake shorelines where current and wave action would otherwise cause erosion (Zelo and Shipman 2000). LWD is also a source of organic matter and nutrients as with freshwater systems. LWD along shorelines supports a variety of habitats for aquatic species such as foraging, refuge, and spawning substrate for fishes and invertebrates (Brennan and Culverwell 2004).

7.2.3 Shading and Temperature

As was reviewed in GEI (2002), thermal modeling results indicate that stream temperature in any given location is primarily dependent on the temperature of water directly upstream, or the input water temperature. Riparian vegetation generally serves to reduce solar heating and maintain water temperatures. Under undisturbed conditions, stream temperatures are maintained because the surface and groundwaters than comprise streamflow are thermally protected by upland and riparian vegetation and soils. As forested area in a watershed is removed, thermal protection is removed and the ratio of surface-to-groundwater in a stream increases. Combined with loss of thermal protection, stream temperatures increase. Therefore, actions in upper watersheds can lead to increased water temperatures in lowland areas, but adequate shading is required in lowland areas to prevent further solar heating.

The value of riparian buffers in moderating stream temperatures is well-established, but the effectiveness of different buffer widths varies depending on site conditions. Several authors (Beschta et al. 1987) have concluded that buffer strip widths of 100 feet or more generally provide the same level of shading as that of an old growth forest in the Pacific Northwest while several authors have recommended a minimum buffer width of 30 feet (Davies and Nelson 1994). In forested areas, harvest treatments that leave overstory vegetation buffers adjacent to streams have been shown to have no significant impact on stream temperature (Lee and Samuel 1976; Rishel et al. 1982; Lynch et al. 1984; Sugimoto et al. 1997). In coastal British Columbia, Gomi et al. (2003) conducted a 6-year field experiment to evaluate the effects of riparian buffer widths on stream and riparian ecosystems, including stream temperature response. Treatments included no timber harvesting, harvesting with 33-ft and 100-ft wide riparian buffers, and clear-cut harvesting with no buffer. The results indicated that water temperature in the streams with 33-ft

and 100-ft wooded buffers did not exhibit statistically significant warming. Todd (2000) examined various buffer functions and found that smaller riparian buffers (as narrow as about 40 feet) are required to protect water temperature and food web functions, and Johnson and Ryba (1992) recommend a similar buffer width of from 30 to 100 feet to effectively protect stream temperature. However, Brown and Kryier (1971) noted that on very small streams, adequate shade may be provided by brush species.

Along lake and marine shorelines, shading from vegetation reduces light levels and helps regulate heating of the nearshore areas or the upper intertidal zone. Shading also reduces mortality and stress to insects, marine invertebrates, as well as fish eggs deposited in intertidal areas, including those of sand lance and surf smelt (Pentilla 2000). Juvenile anadromous salmonids rely upon shallow-water habitats, especially those vegetated with algae and eelgrass, for prey resources and shelter from predation, making shallow nearshore habitats critical for the survival of these species (Healey 1982; Simenstad et al. 1982; Johnson et al. 1997).

7.2.4 Bank Stabilization and Habitat Formation

Streams tend to erode the outer banks of meander bends while depositing sediment as bars on the inside of the meander bends. Through this continual process of erosion and deposition, the location and quality of habitats, and the meander pattern and position within the valley, changes over time. This process acts in response to natural and unnatural disturbances within a watershed and serves to create and recreate salmonid habitat. For any given disturbance, the rate, magnitude, and nature of channel response in part depends on the condition of riparian vegetation.

Vegetation resists shoreline erosion, but often not as effectively as artificial structures. Diverse native vegetation can be expected to moderately resist shoreline erosion allowing channels to physically respond to disturbances, thereby forming and reforming salmonid habitat features over time (Reeves et al. 1995). As reviewed in Spence et al. (1996), roots bind streambank soils and slow water currents, thereby stabilizing stream banks. Stream currents carve the material underneath the root zone creating shelter and structural habitat for salmonids and terrestrial and aquatic macroinvertebrates that support fish populations such as. Other benefits of the natural channel formation and migration process include erosion of gravels from streambanks, which replenishes spawning substrate, and the undercutting of streamside trees, which become a primary source of LWD.

In many areas of the populated and developed lowland areas of Whatcom County, natural channel formation processes have been interrupted by armoring streambanks with artificial structures such as rock-riprap, concrete bulkheads, or steel sheet-piling to protect lives and property. This interruption of channel-forming processes may be necessary and permanent, but it must be acknowledged in such cases that complete resistance to shoreline erosion does not support reliance on natural habitat forming processes, and other means of providing habitat features, if possible, would be necessary.

As concluded in FEMAT (1993), an appropriate width for providing bank stabilization is 0.5 SPTH (Table 3). Based on this criterion, this distance will vary depending on site conditions, but would be expected to range from about 50 to 100 ft. While relatively narrow buffers of immature vegetation may provide adequate bank stabilization, particularly in low-gradient reaches of smaller streams, other studies recommend a width of about 100 ft as generally sufficient to control streambank erosion, even in areas of high mass wasting (Knutson and Naef 1997; May 2000; Cederholm 1994).

7.2.5 Filtering of Sediment, Nutrients and Chemicals

Uptake of dissolved chemicals, and filtration of sediments from overland-runoff and flood water is an important riparian function (Cummins et al. 1994). The chemicals that constitute plant nutrients may be

largely incorporated in the riparian zone's biomass. This combined with the trapping of sediment within the riparian landscape contributes to the building of "new land" involved in channel or shoreline migration. Any action, such as clearing, that degrades the integrity of the riparian zone will hamper to some degree these chemical filtering, uptake and land-building functions.

Literature analysis by FEMAT (1993) indicated that healthy riparian zones greater 200 ft from the edge of a floodplain probably remove most sediment from overland flow. Sufficiency of buffer widths is dependent on slope steepness, with wider buffers required for steeper slopes (Vanderholm and Dickey 1978). Given this, widths of 100 to 300 ft appear to be generally sufficient for filtering substantial proportions of sediment (50 to 90 percent) originating from hill slopes (Karr and Schlosser 1977; Johnson and Ryba 1992; Belt et al. 1992; Lowrance et al. 1986, 1988). While these recommendations are based mainly on short-term studies, some long-term studies have been conducted that also support a recommended buffer width of 100 to 300 ft for filtering sediment (Lowrance et al. 1986, 1988).

Buffer widths reported for removal of pollutants, nutrients and chemicals can vary widely based on vegetation type, soil type, and slope. Knutson and Naef (1997) report that buffer widths ranging from 13 ft to more than 850 ft are adequate for nutrient reduction or removal depending on site conditions. Though there is a wide range of effective buffer widths reported in the literature, widths of 100 ft are generally sufficient for removing nutrient or bacterial pollution (Lynch et al. 1985; Terrell and Perfetti 1989). Terrell and Perfetti (1989) also report riparian widths of 200 and 600 ft as necessary for removing pesticides and animal waste and nutrients from croplands.

But numerous studies reported in GEI (2002) illustrate that significant sediment filtering and water quality benefits can be achieved in agricultural areas (generally low-gradient systems with little side-slope) by buffers or vegetation filter strips ranging from 25 to 50 feet, particularly in combination with suitable BMPs. If buffers are the primary means of protection against input of sediments, nutrients, pesticides and pathogens, then relatively wide buffers may be required. However, by employing appropriate BMPs such as sediment controls, and managing the application of fertilizer and pesticides can markedly reduce the risk of transport into streams, thereby reducing the riparian buffer width required to effectively protect streams from these impacts.

7.2.6 Organic Input and Nutrient Source

Riparian trees and other vegetation furnish fresh and marine waters with a "litter fall" of plant particles (leaves, pollen grains, etc.), and with terrestrial insects. These organic materials compose a major energy source for food webs that sustain production of salmonids, particularly in low- and mid-order streams (Gregory et al. 1991; Naiman et al. 1992; Cummins et al. 1994). Along small stream channels, outside sources of nutrients such as litter fall from healthy stands of riparian vegetation is a greater contributor to the aquatic food web than in-channel algae production, which tends to predominate as the basis in wider, less shaded streams (Vannote et al. 1980) and in standing waters. Clearing riparian vegetation will may reduce or destroy the nutrient-providing function depending on the extent of the action and the relative importance of litter fall in sustaining nutrient input into the system.

7.2.7 Microclimate

Microclimate, defined as the local climate (humidity, wind speed, and air temperature) within the stream-riparian ecosystem, is primarily affected by the quality and extent of riparian vegetation (Pollack and Kennard 1998). Watershed scale microclimate also influences stream temperatures, contributing to lower temperatures in forested watersheds than in urbanized or otherwise cleared watersheds. Brosofske et al. (1997) documented that riparian microclimate is important to consider in management because it affects plant growth, therefore influencing ecosystem processes such as decomposition, nutrient cycling, plant succession, and plant productivity. Thus microclimate alterations can affect structure of the riparian forest, the waters within it, and the well-being of many animals, including fish. Riparian buffer widths

necessary for microclimate control are generally much wider than those necessary for other functions, with the exception of habitat for some species of wildlife. A riparian buffer width of 200 ft may provide minimum or partial microclimate function in some circumstances; however, widths greater than 300 ft are generally required to provide full microclimate protection (Spence et al. 1996; Chen et al. 1990; Brosopfke et al. 1997; Franklin and Forman 1987).

7.3 HUMAN ACTIVITY AND AQUATIC HABITAT FUNCTIONS

Puget Sound streams and rivers once flowed through dense forested areas and broad vegetated floodplains. These streams had natural flow regimes, excellent water quality, and complex instream cover. Today, healthy riparian areas are scarce or inadequate, and streams and rivers are frequently confined or controlled, or are realigned to accommodate agricultural or development activities. Human activities have had similar effects on nearshore and estuarine habitats. The effects of human activities on aquatic habitats are summarized in Table 7-6.

Table 7-6. General effects of Different Human Activities on Aquatic Habitats

Activities	Effects
Removing riparian vegetation	Reduced channel complexity, simplified channel morphology, increased stream velocities, loss of pools for holding and rearing, loss of spawning gravel, loss of side channels, loss of wood recruitment, loss of connectivity with floodplain and riparian zone, reduced shade and cover; increased solar radiation; increased erosion and sedimentation, elevated water temperatures and reduced leaf litter.
Introducing invasive non-native vegetation	Altering native riparian habitat functions including associated wildlife refuge, insect litter, replacement of coniferous shade producing trees, etc.
Creating impervious surfaces, filling and draining of wetlands, and increasing water allocations	Altered flow regimes (timing and magnitude of flows), degraded water quality/increased stream temperatures, increased stormwater runoff, and altered instream habitat
Streambank modifications	Loss of natural meander/habitat-forming processes, disconnected floodplains and subsequent loss of floodplain processes
Discharging sewage effluent	Degraded water quality, altered water temperatures, reduced dissolved oxygen concentrations, and increased contaminant levels
Agricultural runoff	Degraded water quality including increased nitrogen and fecal coliform, and reduced dissolved oxygen levels
Livestock access	Degraded water quality, loss of riparian vegetation, streambank instability
Constructing culverts, pipes, and ditches	Obstructed upstream passage of fish and reducing the downstream movement of wood and gravel
Filling/altering estuarine and nearshore habitats	Reduced availability of freshwater to saltwater smolt transition habitat (including cover and food production), and staging and holding habitats for adult salmon
Constructing bulkheads and docks	Increased habitat for predators, altered nearshore currents and gravel movement
Construction activities	Increased erosion, turbidity and inputs of fine sediment during construction and prior to revegetation
Recreational activities	Degraded water quality, and increased contact with listed species

7.3.1 Freshwater Riverine Habitats

As presented in the WRIA 1 Limiting Factors Analysis (Smith 2002), riparian and floodplain conditions have been heavily altered throughout the Nooksack River sub-basin. Riparian impacts include timber harvest, agriculture, residential/commercial/industrial development, and livestock access to stream channels. The Nooksack River and most tributaries have extremely degraded riparian and instream conditions due to lack of stream shading, extensive bank erosion, low large woody debris (LWD) recruitment, and lack of organic inputs (Smith 2002). Alteration of land cover and native vegetation throughout the Nooksack watershed has increased the magnitude and timing of peak streamflows. Such problems are more prevalent in lowland streams where land has been converted to agricultural or urban use, and where stream channelization, water withdrawals, loss of wetlands, invasive plant introductions, and increased impervious surface are most evident.

Perhaps the greatest impact to salmonid habitat in Whatcom County is the loss of floodplain connectivity and associated functions (Smith 2002). The major tributaries of the Nooksack River were historically meandering channels, but these streams have been straightened and diked, and much of the floodplain off-channel and wetland habitat has been lost. Overall, floodplain and riparian functions tend to be more degraded in the lower mainstem (downstream of the forks) and South Fork Nooksack (including tributaries) than in the North and Middle Forks because the watersheds of the North and Middle forks is less developed (greater percentage of forest cover, less impervious surface, etc.).

Most of the salmonid spawning habitat in the Nooksack River watershed is located in the three forks of the Nooksack River where sedimentation is a considerable problem (Smith 2002). Landslides and bank erosion are the major sources of sediment. The lack of adequate riparian cover and instream LWD contributes to sedimentation by destabilizing banks and impairing the sediment transport processes. Increased sedimentation also contributes to the lack of adequate pool habitat by filling in pools.

The Middle Fork diversion dam, which channels water from the Middle Fork of the Nooksack River to Lake Whatcom, is the most significant single fish passage barrier in Whatcom County because it prevents access to approximately 17 miles of potential habitat for anadromous salmonids. An inventory of all Whatcom County road crossings began in 2000 and the final report is due to be delivered to Whatcom County by March 2005. To date, the inventory has identified approximately 500 culverts that block fish passage either completely or during high flow events. The main type of potential passage barriers are the numerous culvert and small dam barriers that tend to occur mostly in smaller lowland tributaries, but have been identified in virtually all Nooksack River subbasins and the independent watersheds in the County. The highest numbers of culvert and dam barriers appear to occur in Hutchinson and Tinling Creeks in the South Fork drainage, several small tributaries that drain directly into the North Fork Nooksack, Tenmile/Deer Creeks, Terrell Creek, Dakota Creek, Squalicum Creek, and among the numerous small tributaries that drain directly into Lake Whatcom and Lake Samish. There relatively few passage barriers identified in the South Fork and Middle Fork Nooksack drainages other than those already mentioned.

To effectively address these impacts to aquatic habitats, it is necessary to prioritize management strategies based on habitat needs. Smith (2002) describes the condition of habitat features and limiting factors of streams and rivers throughout WRIA 1, and the analysis of limiting factors is a necessary step in defining management priorities. But it should be stressed that prioritization of habitat and restoration needs is dependent not only on existing habitat conditions and current species use, but also on the expectations and potential for conservation or restoration given the entire suite of existing and anticipated land-uses.

7.3.2 Nearshore and Estuarine Habitats

The primary disturbances to nearshore and estuarine habitats are estuarine habitat loss, shoreline modifications, overhead structures, and impacts on water/sediment quality. The condition of the estuarine and nearshore habitat in Whatcom County varies considerably depending on location. Estuary habitat loss has been documented in Bellingham, Lummi, and Samish Bays (Smith 2002). Shoreline modifications such as bulkheads, rip-rap, and fills are common along Point Roberts, the Peace Arch, Blaine, Birch Bay, Neptune Beach, Sandy Point Shores, Lummi Bay, Bellingham Bay, and Samish Bay (Smith 2002). Areas of shoreline modification typically have poor riparian or shoreline vegetation, which reduces or eliminates the function of shoreline vegetation as described in Section 1.2. In addition, quick spreading invasive non-native plants such as Giant Japanese Knotweed are rapidly replacing native marine and estuarine shore plants in areas such as Blaine, the Nooksack Delta, Bellingham Bay and Whatcom Creek.

Major overwater structures also impact eelgrass beds by shading out sunlight, and can alter salmonid behavior and survival. Such major overwater structures in Whatcom County include Arco Pier, Intalco Pier, British Petroleum Pier, Gooseberry Point Ferry Terminal, Lummi Island Ferry Terminal, inner Bellingham Bay, Point Roberts Marina, Blaine Marina, Birch Bay Marina, Sandy Point Shores Marina, Semiahmoo Marina, and Squalicum Marina. Light is a primary factor limiting the survival and distribution of eelgrass (Dennison et al. 1993). The loss of eelgrass habitat due to overwater structures can reduce prey resources and cover, thereby impacting habitat-use, migration patterns, and survival of juvenile fish species, including salmonids (Weitkamp and Schadt 1982). In addition, direct shading during the day and increased lighting at night (from artificial lighting) can also change fish species assemblages and increase the risk of predation by changing the migration, activity, and location of both predators and prey species (Weitkamp and Schadt 1982; Ratte and Salo 1985; Pentec Environmental 1997).

Inner Bellingham Bay contains numerous contaminated sediment sites. Detected toxins such as mercury, arsenic, and PCBs can cause tumors and suppress immune systems in salmonids, and be lethal for organisms that are food resources for salmonids. Creosote-treated materials and oil spills are also important water quality concerns within nearshore areas of Whatcom County.

7.4 HABITAT MANAGEMENT AND PROTECTION TOOLS

7.4.1 Designation, rating, and classification

WCC does not designate or classify streams according to any stream typing system. New water types have been established in WAC 222-16-030, but this system will not go into effect until fish habitat water type maps have been adopted by the State. Until such time, the interim water typing system established in WAC 222-16-031 will continue to be used by the State. New water types are presented below for informational purposes along with a conversion table for the interim and new water types.

As excerpted from WAC 222-16-030, new water types are as follows:

- **Type S Water** - all waters, within their bankfull width, as inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated pursuant to chapter 90.58 RCW including periodically inundated areas of their associated wetlands.
- **Type F Water** - segments of natural waters other than Type S Waters, which are within the bankfull widths of defined channels and periodically inundated areas of their associated wetlands, or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water and which in any case contain fish habitat.

- **Type Np Water** - means all segments of natural waters within the bankfull width of defined channels that are perennial non-fish habitat streams. Perennial streams are waters that do not go dry any time of a year of normal rainfall. However, for the purpose of water typing, Type Np Waters include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.
- **Type Ns Water** - means all segments of natural waters within the bankfull width of the defined channels that are not Type S, F, or Np Waters. These are seasonal, non-fish habitat streams in which surface flow is not present for at least some portion of a year of normal rainfall and are not located downstream from any stream reach that is a Type Np Water. Ns Waters must be physically connected by an above-ground channel system to Type S, F, or Np Waters.

Conversion between the water types is presented in WAC 222-16-031 as follows:

<u>Permanent Water Typing</u>	<u>Interim Water Typing</u>
Type S	Type 1
Type F	Types 2 and 3
Type Np	Type 4
Type Ns	Type 5

7.4.2 Buffers

WCC buffer designations for rivers and streams are not tiered to current or proposed State water typing classifications. WCC currently requires buffers of 100 ft from the OHWM on all rivers and streams, provided that a standard 50 ft buffer be applied to those streams that do not contain salmonid populations, or to those streams that do not directly flow into such waterways. Where forested buffers do not exist, and agricultural activities are ongoing proximate to these watercourses, WCC further provides that buffer width may be reduced by combining USDA- Natural Resources Conservation Service Field Office Technical Guide vegetative, structural and management practices as expressed in a conservation plan.

For protection of instream salmonid habitat conditions, a wide range of recommended riparian buffer widths is presented in existing studies (see previous discussion of riparian buffer functions). Variation in recommendations or buffer effectiveness is frequently due to variation in site conditions such as side-slope angle, stream type, geology, climate, etc. However, no studies recommend zero width, nor do the studies recommend the equivalent of more than several site potential tree heights. Design of riparian buffers must consider the ecological, cultural, and economic values of the resource, land use characteristics, and existing riparian quality throughout watersheds in order to address the cumulative impacts on stream functions and the resources being protected (Johnson and Ryba 1992; Castelle et al. 1994; Wenger 1999).

Appropriate buffer sizes will depend on the area necessary to maintain the desired riparian or stream functions for the given suite of land-use activities. A wider buffer may be desired to protect streams from impacts resulting from activities such as unpermitted ad hoc trail construction, recreation, pets, garbage, and tree removal for unpermitted view improvements and hazard reduction. These concerns are associated more with areas of high-intensity land use and thus wider buffers, or restrictions (such as building setbacks) that keep a potential hazard from occurring, may be needed, while narrower buffers may suffice in areas of low-intensity land use (May 2000). It should be noted though that opportunities for protection or improvement of buffer conditions in areas of high-intensity land use are often effectively foreclosed by existing development, or the existing habitat conditions are already highly altered. Under such conditions,

establishing buffers wide enough to provide an effective full-range of riparian functions is likely unattainable, and other actions may be required to improve habitat conditions beyond what riparian buffers are able to provide. In addition, buffer vegetation type, diversity, condition, and maturity are equally as important as buffer width, and the best approach to providing high-quality buffers is to strive for establishing and maintaining mature native vegetation communities (May 2000).

Pollack and Kennard (1998) recommended buffer widths of 250 ft on all perennial streams. Buffer widths of one SPTH would reasonably provide for a full range of riparian functions, and therefore, not contribute significantly to the loss of salmonid habitat. May (2000) and other extensive reviews provide detailed summaries of buffer width sizes necessary to achieve stream and riparian functions (Knutson and Naef 1997; FEMAT 1993). The conclusions of those reviews are presented in Tables 7-2, 7-3, and 7-4. However, as was previously discussed, these recommended buffer widths are largely driven by providing adequate long-term LWD recruitment potential, and are not necessarily inclusive of all situations. For example, along highly managed streams such as in agricultural, residential, or commercial areas, some functions normally provided (at least in part) by riparian buffers, such as flow attenuation or filtration of pollutants, can be provided by application of appropriate BMPs in combination with smaller buffers.

In addition, the importance of protecting the CMZ is well documented. Many researchers recommend that buffer widths be measured from the edge of the CMZ on streams with active channel migration zones (Knutson and Naef 1997; May 2000; WDNR 1999; Smith 2002). Incorporating CMZs into County regulations should be provided for, but using CMZs as the basis for buffer determination poses some challenges in a regulatory context because the extent of the channel migration zone will vary from parcel to parcel and has not been determined for most streams and rivers in Whatcom County. However the task of determining CMZs in Whatcom County is underway and the information will be incorporated into determinations of appropriate buffer widths as it becomes available. Nearshore and Estuarine Habitats

7.4.2.1 Nearshore and Estuarine Habitats

Maintaining viable forage fish spawning grounds is a significant challenge to managing nearshore and estuarine habitats for species such as Pacific herring, sand lance, and surf smelt (Bargmann 1998). Present regulatory policies emphasize the protection of all natural nearshore habitats because there is no known mitigation method for replacing destroyed spawning habitats into perpetuity. Additional measures include protecting or establishing natural nearshore buffers in spawning areas.

7.4.3 Timing restrictions

Timing restrictions for conducting in-water work are necessary to protect habitat and life-stage requirements that differ by species and time of year. No timing restrictions for in-water work are specified in the WCC, but windows for conducting work within the OHWM of freshwater and marine systems have been established by state and federal resources agencies. The approved fish work windows for most Whatcom County streams is from July 1 to September 30. For some streams, the work window is extended to begin earlier on June 15. Work windows vary by species of interest in marine or estuarine waters. Marine work windows are established for salmon (July 2 to March 2), bull trout (July 16 to February 15), Pacific herring (from April or June 15 until January 31 depending on location), sand lance (March 2 to October 14), and surf smelt (year-round).

7.5 PROTECTION AND MANAGEMENT OF ANADROMOUS SPECIES

Habitat used by anadromous fish is potentially found in all types of FWHCAs listed in WCC 16.16.710. The WCC does not provide specific guidelines for protecting anadromous salmonid species, but the

protection and management of anadromous salmonids is provided for in regulations potentially applicable to aquatic habitats.

The protection and recovery of anadromous salmonids species is a primary focus in Whatcom County. The County, resource agencies, Tribes, and private interests have coordinated protection and management efforts for anadromous species in Whatcom County. Existing habitat conditions, habitat limiting factors, and proposed protection measures for anadromous salmonids in Whatcom County have been presented in several completed or ongoing management documents (Smith 2002; Nooksack Indian Tribe 2004; Whatcom County 2004a,b). These documents have been developed with the intent of identifying specific habitat issues throughout the Nooksack River watershed and other waters of Whatcom County, and proposing protections and strategies for conserving anadromous salmonid populations. Protection measures and goals that have been identified within and outside of the Nooksack River watershed include:

- Improve riparian conditions throughout Whatcom Country watersheds;
- Reduce bank hardening and investigate areas for dike removal and reconnection of the floodplain. High impact areas include the mainstem Nooksack, the South Fork Nooksack, and the lower reaches of lower river tributaries. These areas are frequently dominated by agricultural, residential, and municipal land-uses;
- Prevent further loss of wetlands, which can contribute to improved water quality, groundwater recharge, instream flows, and other floodplain functions;
- Prevent further loss of native riparian and wetland buffers (freshwater, marine & estuarine) through the aggressive elimination and/or management of non-native invasive plants;
- Reconnect tidal floodplains, marsh, and wetlands;
- Improve passage barriers, particularly at the Middle Fork diversion dam and at identified high-priority culverts;
- Increase LWD by adding to streams, or preferably by improving natural LWD recruitment in the long-term;
- Decommission or treat roads that are of moderate to high risk of mass-wasting, which is a leading source of sediment in throughout the Nooksack watershed;
- Reduce pollution runoff from urban, industrial, and agricultural sources; and
- Reduce water withdrawals, enforce instream flows, increase stream sinuosity, and increase watershed land cover to improve instream flows.

Notwithstanding these efforts, there is a need to strengthen existing regulations at the County level to achieve the goal of no net loss of ecological functions as specified under the GMA. Specific recommendations are provided below.

7.6 FINDINGS AND CODE RECOMMENDATIONS

General Habitat Findings and Recommendations	
Finding #1	<ol style="list-style-type: none"> 1. Fish species are not included in the list of listed species and species of local importance named in WCC Ch. 16.16 Appendix C. In lieu of being included in Appendix C, criteria for determining fish species of local importance are unclear. 2. WCC does not specify that special consideration must be provided for anadromous fish species as specified in the GMA 3. In general, WCC does not include detailed performance standards or review and approval process for guiding potential actions within aquatic critical areas. See further description and recommendations under Section 1.8.2 Aquatic Habitat Functions and Values.
Recommendation	<ol style="list-style-type: none"> 1. Identify fish species that are listed or of local importance in WCC Ch. 16.16 Appendix C and provide specific implementation provisions to address these species. 2. Include language that special consideration be afforded to anadromous fish species and habitats.
BAS Sources	GMA requirement for special consideration of anadromous species

Aquatic Habitat Functions and Values	
Finding #2	<ol style="list-style-type: none"> 1. Stream buffers are measured from the OHWM with no provision for including channel migration zones (CMZ). Where channel migration occurs or is likely to occur, a buffer measured from the OHWM may not fully protect riparian functions. Of particular concern would be the ability of a stream channel to migrate (thereby recruiting LWD), and to form new instream habitat features such as pools, riffles, and off-channel areas important for several salmonid life-stages. Areas of likely channel migration need to be determined, as does the feasibility of protecting CMZs where they do or should occur. 2. Existing stream buffers are 100 ft for salmon-bearing streams and 50 ft for non-salmon-bearing streams. A 100 ft buffer is generally adequate for protecting many riparian habitat functions and features. Where buffers do not provide a full range of habitat functions, other conservation measures and BMPs may be in place to offset some land-use impacts, but some riparian functions, most notably LWD recruitment, generally cannot fully be provided by 50 to 100 ft buffers. 3. WCC does not incorporate a stream typing system for incorporating stream functions into determining appropriate management strategies. 4. Under WCC 16.16.650, adjustments are allowed for standard buffer widths depending on demonstration of the need for increased or reduced buffer width requirements on a given site. No emphasis is placed on continuity of stream buffers, which has been shown to be an important aspect of effective buffers. Standard buffer adjustments establish no minimum buffer widths for cases of buffer width averaging or reduction. Without minimum standards, buffer continuity is jeopardized. 5. There are no provisions for mitigation in instances of when buffer encroachments do occur. 6. No building setbacks from riparian buffers are required, which could result in buffer impacts due to construction activities, or impacts to structures from the riparian buffer (e.g. hazard trees). 7. There are few performance standards established for the list of "activities allowed without a permit" in WCC 16.16.225. As written, many of these allowable activities such as ditch maintenance, gravel extraction, maintenance of utilities, removal of beaver dams, and other potential construction and agricultural activities could adversely affect aquatic habitats and still be in compliance with WCC. 8. WCC states that management of shellfish habitat conservation areas, kelp and eelgrass beds, and surf smelt/sand lance spawning areas are currently primarily implemented through the Shoreline Master Program and HPA process. WCC does include shellfish protection districts with protections strategies, but there are no provisions beyond requiring that all development shall avoid or mitigate impacts to forage fish spawning areas and projects, and that shoreline protection projects should not adversely affect the supply of beach sands and gravels necessary for spawning areas. Additionally, WCC 16.16 does not include a septic system operating and maintenance program to protect shellfish from contamination.

Aquatic Habitat Functions and Values									
Recommendation	<p>1. Where a CMZ occurs or could be expected to occur, stream buffers should be measured from the lateral edge of the CMZ to protect stream migration and habitat-forming processes. CMZs should be designated throughout the county by stream reach, but in lieu of CMZ designations, flood-hazard boundaries or on-site delineation of CMZs could occur on a case-by-case basis as needed. Exceptions would be necessary in cases where bank modifications, permanent structures (ROW, levees, etc.), or existing land-uses effectively prevents channel migration.</p> <p>2. According to BAS, a buffer width of about 100 ft would reasonably provide for most stream riparian habitat functions important to fish populations. However, smaller or larger buffer widths may be necessary to provide adequate protections depending on site conditions and watercourse condition. Buffer width regulations tiered to existing or potential habitat functions (i.e., providing greater protection where appropriate) would allow regulatory flexibility and provide for stream functions that can reasonably be expected on a given site. The buffer width recommendations in this report should be implemented unless it can be demonstrated that some other buffer width would be adequate or necessary to maintain existing stream and riparian functions.</p> <p>3. It is recommended that at least the following 3 water types and minimum buffer widths be included in WCC:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td>Type 1 waters: Shorelines of the State, equivalent to WAC interim</td> <td></td> </tr> <tr> <td>Type 1 waters/new Type S waters</td> <td style="text-align: right;">150 ft</td> </tr> <tr> <td>Type 2 waters (non-shorelines having fish and fish habitat, equivalent to WAC interim Type 2 and 3 waters/and new Type F waters</td> <td style="text-align: right;">100 ft</td> </tr> <tr> <td>Type 3 waters (non-fish-bearing natural waters whether connected or not connected to Type 1 or 2 waters - equivalent to WAC interim Type 4 and 5 waters/new Type Np and Ns waters</td> <td style="text-align: right;">50 ft</td> </tr> </table> <p>4. Definitions, performance and reporting standards must be included or expanded in WCC to ensure that allowable activities within critical areas undergo a review, approval, and monitoring process. This will help ensure that either, activities will not adversely impact aquatic habitats, or that loss of habitat functions are appropriately mitigated. For example, clearing drainage ditches is an allowable activity under existing WCC, but many ditches are altered stream channels supporting salmonids. Much of such open-ended code can be improved by requiring accepted performance standards as those required in the HPA process, or by implementing accepted strategies such as those described in documents such as the Ecology stormwater manual.</p> <p>5. Establish requirements and performance standards for mitigation of buffer encroachments when they occur.</p> <p>6. Establish a minimum building setback of 10 to 15 ft from buffers.</p> <p>7. WCC should specify buffer widths for protecting nearshore areas. Tiering buffers to the State system per recommendations in this document would provide a standard shoreline buffer width of 150 ft unless it can be demonstrated that that some other buffer width would be adequate or necessary to maintain shoreline functions.</p> <p>8. Establish a minimum buffer width, or proportion of existing buffer width to be retained, in cases of standard buffer adjustments to promote buffer continuity. For example, in cases of buffer averaging, ensure that the buffer is no less than 75 percent of the required buffer width in any given location to maintain buffer continuity while retaining the overall area of required buffer unless it can be demonstrated that other options will not result in loss of riparian functionality.</p> <p>9. To protect shellfish resources, specific recommendation should flow from this BAS: Coastal Urbanization and Microbial Contamination of Shellfish Growing Areas; Stuart Glasoe and Aimee Christy Puget Sound Action Team, State of Washington Olympia, Washington June 2004. However, other measures besides buffer may be necessary to achieve protection.</p>	Type 1 waters: Shorelines of the State, equivalent to WAC interim		Type 1 waters/new Type S waters	150 ft	Type 2 waters (non-shorelines having fish and fish habitat, equivalent to WAC interim Type 2 and 3 waters/and new Type F waters	100 ft	Type 3 waters (non-fish-bearing natural waters whether connected or not connected to Type 1 or 2 waters - equivalent to WAC interim Type 4 and 5 waters/new Type Np and Ns waters	50 ft
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Type 3 waters (non-fish-bearing natural waters whether connected or not connected to Type 1 or 2 waters - equivalent to WAC interim Type 4 and 5 waters/new Type Np and Ns waters	50 ft								
BAS Sources	Knutson and Naef (1997), Pollack and Kennard (1998), May (2000), FEMAT (1993), Johnson and Ryba (1992)								

1 Buffers are applied to both sides of the stream and should be measured laterally from the edge of the OHWM or the CMZ if present.

Timing Restrictions	
Finding	1. Timing restrictions for instream work are not specified in WCC and there is no provision stating that timing restrictions established by other agencies be adhered to.
Recommendation	1. WCC should specify that all in-water work timing will be consistent with approved fish work windows determined by WDFW and presented in the WAC, including any deviations afforded by emergency or special circumstances as does WDFW.
BAS Sources	WAC

7.7 FISH REFERENCES

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8. MITIGATION BANKING

8.1 OVERVIEW OF MITIGATION BANKING

Mitigation banking is a form of compensatory mitigation that generates credits that can be used offset impacts to the environment. The practice of mitigation banking has most commonly been applied to wetlands, although banks can be used to generate a variety of habitat credits. This discussion focuses on wetland banking, but many of the concepts presented pertain to habitat banking in general.

Wetland mitigation banking is described as "the practice of restoring, creating, enhancing, or preserving off-site wetland areas to provide compensatory mitigation for authorized impacts to wetlands" (Federal Guidance for the Establishment, Use and Operation of Mitigation Banks, 60 Fed. Reg. 228, 58605-58614, 1995). Wetland banking can be used to achieve mitigation for projects permitted at the federal, state and/or local levels.

Compensatory mitigation, under the Federal Clean Water Act (CWA) Section 10/404(33 U.S.C. 1251 – 1376 as amended), is the "restoration, creation, enhancement, or in exceptional circumstances, preservation of wetlands and/or other aquatic resources for the purpose of compensating for unavoidable adverse impacts" (ACOE Federal Guidance, 1995). Whatcom County defines compensatory mitigation to include "replacing, enhancing, or providing substitute resources or environments and monitoring adverse impacts and the mitigation project and taking appropriate corrective measures (WCC16.16.245.A.1.e.)." The existing County code makes one reference to mitigation banking (16.15.245.B) but not does not provide specific guidance on the use of banks. A 1999 study prepared by David Evans and Associates provided recommendation for a County banking strategy, but no comprehensive strategy has been implemented to date.

Wetland mitigation banks are typically fairly large areas (50 to 100 acres or more), which are created expressly for the purpose of providing high quality off-site wetland restoration, creation, enhancement or rehabilitation prior to permitted impacts. Wetland restoration is often the preferred action for generating wetland mitigation credit at a bank site, as it is generally perceived to be the type of activity with the highest degree of success (Ecology 2004a; NRC 2001; ELI 2002), however, the conditions at the proposed mitigation bank site dictate which combination of restoration, creation, enhancement, rehabilitation will achieve the best results.

Wetland mitigation banks can also be used to preserve existing wetlands. However, wetland preservation should be allowed only in 'exceptional circumstances' according to the Federal Guidance. Though the Federal Guidance does not define 'exceptional circumstances' it is generally understood that there must be a demonstrable threat to a wetland system (in the form of a proposed development that would adversely affect the wetland system) to receive preservation credit. King County's administrative rules on wetland mitigation banking allow for preservation credit when it can be demonstrated that protection provided by the bank site goes above and beyond protection that would result from applying critical area regulations (i.e. wetland buffers proposed in a bank would have to be larger than those required by the critical areas regulation to receive wetland preservation credit). In addition, King County and the Federal Guidance suggest that credit for preservation be given only when proposed in combination with restoration, creation or enhancement. Washington State's Draft Administrative Rules on Wetland Mitigation Banking allow for the establishment of preservation-only banks in exceptional circumstances (WAC 173-700-360).

Bank site design is driven by on-site ecological conditions and a consideration of landscape-scale processes, and is not necessarily limited to just meeting project-based permit requirements related to no

net loss of wetland acreage, or mitigation replacement ratios. The focus of the wetland mitigation bank process is to establish a successful, high-functioning wetland site that maximizes the functional performance of the wetland, and guarantees the permitting agencies perpetual conservation, and maintenance and monitoring through the operational life²³ of the bank. In contrast, traditional compensatory mitigation (both on and off-site) is typically viewed as a regulatory requirement that is incidental to the permit action lacking long-term incentives for success and often resulting in the need to require higher mitigation ratios. This is a significant, and fundamental difference between standard or conventional compensatory mitigation and mitigation banking.

It is the process of successfully restoring, creating, or enhancing wetland area that generates wetland mitigation credit. This credit represents a tradeable commodity for the wetland mitigation banker. Credits can be sold to project applicants who have permitted unavoidable impacts to wetlands that require off-site mitigation. Credit value is determined via negotiations with the regulatory agencies during the mitigation bank design process. The banker proposes a mitigation design, and a specific number of credits to be available from the bank. This proposal is negotiated and agreed to in the Mitigation Bank Instrument (MBI)²⁴. Credit values include a consideration of existing and proposed conditions (or ecological ‘lift’ anticipated to result from restoring a site), typically including a wetland function assessment, as well as a consideration of what types of impacts the bank can compensate for. Fundamentally, the type of activity that occurs on site (restoration, creation, enhancement or rehabilitation) and the acreage or area that is affected by that activity is what establishes the basis for the negotiation of credit values. One of the substantive elements of the MBI is to establish strict performance standards based upon the desired restoration or mitigation goals. Credits are awarded based on when, and whether, performance standards are achieved. An unsuccessful mitigation design can result in little to no credit being awarded. Wetland mitigation banking thereby creates a strong financial incentive for the wetland mitigation banker to achieve an ecologically successful wetland system.

Credits are released over time, generally anticipated to be a ten-year period in Washington State. The amount and timing of credit release is also negotiated with the permitting agencies, but is tied to meeting specific performance standards related to project success (such as meeting hydrologic and vegetative performance standards). Some credits are typically released when a site has been selected; when the design has been created, negotiated, and agreed to by the agencies; and when the contract, including financial assurances and long-term maintenance and monitoring has been agreed to.

In 2001, the Washington State Department of Ecology (Ecology) established Draft Administrative Rules on Wetland Mitigation Banking. These rules define credit as:

“A unit of trade representing the increase in the ecological value of the site, as measured by acreage, functions and/or values, or by some other assessment method.” (RCW 90.84.010(3).

²³ “Operational life is the timeframe over which performance standards are met and credits are released in percentages over time as those standards are met

²⁴ A mitigation banking instrument (MBI) is a formal contract between the banker and the regulatory agencies that sets out the substantive requirements of the mitigation bank site

The Federal Guidance defines credit as:

“A unit of measure representing the accrual or attainment of aquatic functions at a mitigation bank; the measure of function is typically indexed to the number of wetland acres restored, created, enhanced or preserved.” (p. 58609). The Federal Guidance permits credits for upland areas “to the degree that such features increase the overall ecological functioning of the bank.”

Washington State’s draft rules list the following ranges of conversion ratios for determining credits available from each bank site:

- **Restoration** of wetlands shall generate credits at a ratio of 1:1 to 1:2 acre-credit to acres of restored wetland.
- **Creation** of wetlands shall generate credits at a ratio of 1:1 to 1:5 acre-credit to acres of creation.
- **Enhancement** of wetlands on bank sites shall generate credits at a ratio of 1:2 to 1:6 acre-credit to acres of enhanced wetland.
- **Preservation** in combination with restoration and creation of wetlands on bank sites shall generate credits at a ratio of 1:2 to 1:10 acre-credit to acres of protected wetland.
- **Preservation** alone shall generate credits at a ratio of 1:5 to 1:20 acre-credit to acres of preserved wetland²⁵.

8.2 REGULATORY CONTEXT AND STATUS OF MITIGATION BANKING

Compensatory mitigation is required for unavoidable impacts to wetlands under federal, state, and local regulations. At the Federal level, wetlands are regulated by the US Army Corps of Engineers (Corps) under the authority of the CWA, as well as Section 10 of the Rivers and Harbors Act (33 U.S.C 403). The Corps is also required to consult with the Federal Services (USFWS and NOAA Fisheries, formerly National Marine Fisheries Service) for issues affecting threatened or endangered species under the Endangered Species Act of 1973 (7 U.S.C. 136; 16 U.S.C. 460 et seq.). This latter issue is significant for implementing Conservation Banking, a policy similar to wetland mitigation banking, whose purpose is to create, restore, enhance, preserve and protect ESA-listed species and their habitats. Wetlands in Washington are also regulated by Ecology and by the local jurisdiction (city or county) via the critical areas regulations.

8.2.1 Washington State

Washington State has a statute (RCW 90.84) that establishes Wetland Mitigation Banking as an authorized tool for compensating for unavoidable impacts to wetlands. Ecology further developed guidance on wetland mitigation banking in its draft rules (WAC 173-700). During 2001, after completion of the draft rules public process, Ecology reduced staffing for the wetland mitigation banking program. As a result, the draft rules were withdrawn from filing, and have remained in draft status since that time. Ecology has been unable to participate in the Wetland Mitigation Banking process for lack of funding. During the 2004 legislative session, Ecology was authorized to implement a pilot rule process for the

²⁵ This information is taken from Ecology’s Draft Programmatic Environmental Impact Statement on Washington State’s Draft Rule on Wetland Mitigation Banking, WAC 173-700, Compensatory Wetland Mitigation Banking, Ecology Publication # 01-06-022, November 2001 (p.85) as well as the draft rule at WAC 173-700-354 Wetland Conversion Rates.

2005 fiscal year. The legislature appropriated \$120,000 for Ecology to test implementation of the draft rules on 4 to 5 projects with the following goals²⁶:

- Test the draft rules on real projects to ensure that they are appropriate, reasonable, and ecologically sound;
- Have a sample of projects that represent a range of proposals in terms of size, maturity, location and ownership (public and private);
- Complete two to three bank certifications over the next year.
- Demonstrate the added value that Ecology contributes to the state's banking program.

As of October 2004, there were approximately 14 wetland mitigation bank projects in the permitting process in Washington State, and only one approved wetland mitigation bank at Paine Field in Everett. The status of projects in the permitting process ranges from projects for which a final mitigation bank instrument is anticipated before the end of the year, to projects whose proponents have voiced an interest in the process, but who have not yet made formal application to Ecology for a certified Wetland Mitigation Bank site or program.

Ecology has convened the Wetland Mitigation Banking State Advisory Committee composed of agency representatives as well as private mitigation banking representatives and representatives from the environmental and development communities, to assist Ecology in implementing the pilot rule process.

Ecology has determined that it will operate a two-tiered process. Because of Ecology's limited resources, tier one projects will receive primary consideration for review and permitting as wetland mitigation banks²⁷. There is a fee for services contract agreement required with Ecology for their time. Permitting fees are estimated to range from \$30,000 to \$40,000. The following projects have been selected for, and have accepted, Tier 1 project status:

- **Snohomish Basin Mitigation Bank, Habitat Bank, LLC** – This is a 230-acre wetland restoration of former dairy land along the Snoqualmie River in Snohomish County. It is contiguous with other conservation and restoration projects, which will create a total area of approximately 600 acres of fully restored riparian wetland when completed. This project has been in the permitting process since 2001, and is very close to final approval as a mitigation bank site with a signed MBI anticipated before the end of 2004.
- **Skykomish Habitat Mitigation Bank, Environmental Restoration LLC and Academy Holdings LLC** – This is an approximately 250-acre site focused on restoring off-channel salmonid rearing habitat and creating approximately 70 acres of wetlands in the riparian floodplain along the Skykomish River just outside of Monroe, Washington in unincorporated Snohomish County. This is the only project to be actively pursuing the establishment and use of 'fish credits' to mitigate for impacts or 'take' of ESA-listed salmonid species. The project has been in the permitting process for roughly two years. The first Mitigation Bank Review Team (MBRT) meeting was held in August of 2003.

²⁶ Taken from SEA Program Wetland Mitigation Banking Pilot Rule Project FY 05, memo distributed by Lauren Driscoll, Ecology staff, to State Banking Advisory Committee Members in preparation for July 13, 2004 meeting -- goals paraphrased.

²⁷ According to Lauren Driscoll at Ecology, Ecology will try to "pick up" Tier 2 projects once the Tier 1 one projects are implemented. Tier 2 projects are described in overview in Appendix A, Proposed Wetland Mitigation Banking Projects in Washington State

- **Nookachamps Bank, Wildlands of Washington, Inc.** – 250-acre floodplain forest and wetland restoration.

In Washington State the development of a wetland mitigation bank site or program is still anticipated to require a 2 to 3 year permitting process from the time of prospectus submittal to the time of a signed MBI. The operational life of a bank site is anticipated to be about ten years.

Washington State is one of twenty-three states nationally to have adopted a statute authorizing wetland mitigation banking (ELI 2002, p.32). Only twelve of these states have authorized rules specifying the operation and use of wetland mitigation banks. Washington is not among these as its rules are in draft form at the time of this writing. King County has adopted administrative rules that establish the operation and use of wetland mitigation banks in that county; Pierce County has a wetland mitigation banking program to offset impacts resulting from County projects. However, Pierce County’s program is currently limited to mitigating for wetland impacts under 0.1 acre – as such its use is fairly limited. Pierce County Water Programs, a division of the Public Works Department, is currently in the process of developing its own departmental wetland mitigation banking program to offset wetland impacts resulting from County projects only.

In addition to governmental agencies some non-profit groups including The Nature Conservancy have guidelines for wetland mitigation banks (ELI 2002). These guidelines can help to inform the development of mitigation banking policies, but do not have the same weight or influence as guidance developed by regulatory agencies.

At the local government level, the Growth Management Act (GMA, RCW 36.70A) establishes how local governments should regulate wetlands and ensure mitigation for unavoidable wetland impacts. The GMA encourages local governments to use a wetland rating system such as Ecology’s Washington State Wetland Rating System for Western Washington, Ecology Publication 04-06-014 (Ecology 2004b) to reflect the relative function and value of wetlands in their jurisdiction (WAC 356-190-080) . The rating system can provide a basis for determining buffer requirements and replacement ratios for mitigating unavoidable impacts. Typically mitigation replacement ratios are assigned in code, though they vary from jurisdiction to jurisdiction and at the local, state, and federal levels. Generally, wetland restoration and creation are given lower wetland mitigation replacement ratios (often ranging from 1:1 to 6:1, depending on the type of wetland affected)²⁸ while replacement ratios for enhancement tend to be higher. Ecology encourages the use of mitigation banking and other types of special compensation (i.e., fee in lieu programs) as a means of achieving sustainable replacement for development impacts (Ecology 2004a)

Whatcom County prohibits alteration of wetlands, streams and buffers unless the applicant provides mitigation “sufficient to maintain or enhance functions of the critical area” (WCC 16.16.245). The existing code defines several mechanisms for mitigating impacts including avoiding, minimizing, rectifying, and reducing impacts over time, but does not explicitly establish a hierarchy or preference for avoidance over minimization or compensation. Off-site mitigation is allowed pursuant to specific performance standards and County staff have discretion to evaluate the extent and type of mitigation required based on the functional characteristics of the area or watershed, the individual and cumulative impacts of the development proposal, the observed or predicted trends regarding critical area gains and losses, and the likelihood of mitigation success (WCC16.16.245.D). There are no minimum replacement ratios identified in the code (minimum standards are driven by the requirement to provide equivalent

²⁸ Whatcom County has no minimum replacement ratio but the maximum ratio is capped at 6:1. Many other local jurisdictions have had ratios that are lower than those suggested by Ecology in the 1992 guidance document entitled *Wetland Mitigation Replacement Ratios: Defining Equivalency*.

functions), but the maximum replacement ratio is capped at 6:1 (replacement area to impact area). Whatcom County allows mitigation banking and cooperative mitigation projects among more than one applicant (WCC 16.16.245.E)

8.2.2 Outside Washington State

Wetland mitigation banking has been in existence as a policy nationally for several decades, but over the last decade, the number of wetland mitigation banks has grown 376 percent to over 219 banks in operation (ELI 2002). The Corps issued its Federal Guidance on the Operation, Use and Establishment of Wetland Mitigation Banks in 1995 and is currently developing administrative rules for wetland mitigation banking, and banking promoting on a national level as a viable component of an overall strategy to improve mitigation compliance nationally (Sudol 2004 personal communication). In addition, wetland mitigation banks are the preferred method for mitigating for unavoidable impacts to wetlands and habitat for Federal Highway Administration projects subsequent to the passage of TEA-21 (Mitigation of Impacts to Wetlands and Natural Habitat, 65 Fed. Reg. 251 82913-82926. 2000).

Permitted wetland mitigation banks range in size from just six acres (ODEC – Virginia Power Bank in Virginia and the McHugh Bank in Pacific County in Washington State – this is not a formally permitted wetland mitigation bank) to nearly 24,000 acres (Farmington Mitigation Bank in Florida). In 2001 approximately 57 percent of permitted mitigation banks in the US were over 100 acres in size. Over 40 states have approved wetland mitigation banks, with the largest number of banks located in the southeast (Florida, Louisiana, Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina and Tennessee). Overall, 92 banks, comprising 74 percent of all the permitted banks in the United States are located within these southeastern states. Other states with significant numbers of banks include Illinois, and California.

Per the ELI report: “Of the 23 states with mitigation banking rules or statutes, 12 allow public and private entities to sponsor banks. Six states have guidelines that allow public and private entities to sponsor banks. Five states have statutes or regulations that authorize only public entities to sponsor banks. Minnesota has guidelines that authorize only publicly owned banks, and New Jersey has a statute that allows only privately owned banks.” (ELI 2002, p. 33).

Some statutes, such as Michigan, Colorado, Iowa, and Minnesota, explicitly authorize wetland mitigation bank establishment on either public or privately owned land. Minnesota has adopted guidelines that clarify that when a bank is established on public land, “the value of the land rights and public contributions must be factored in to the sale price of the credits.” (ELI 2002). Illinois has guidelines that allow banks to be sited only on public lands. Land ownership (public or private) is not explicitly addressed in Washington state’s draft mitigation banking rules. The presumption is that either is approach is valid, assuming that all the other considerations of site selection (primarily ecological) (listed at WAC 173-700-320) have been considered.

8.3 SUMMARY OF SCIENTIFIC LITERATURE ON WETLAND MITIGATION BANKING

ELI studied the 219 permitted wetland mitigation banks in 2002. Of the 219 banks analyzed, background information on historic land use was available for 109 of these sites. More than 65% of these sites were found to have been located on land previously used for agriculture. This is becoming a significant issue for local governments in Washington State because some jurisdictions believe there may be an apparent

conflict between the GMA goals of preserving long-term agriculture and protecting natural resources²⁹. From an ecological perspective, siting banks on agricultural lands, particularly where those lands have less suitability for farming due to hydrologic conditions or other limitations, can be an attractive proposition. However, local communities will need to address potential policy conflicts to ensure that GMA goals and community values and interests are upheld. The State Advisory Committee on Wetland Mitigation Banking, convened by Ecology, believes that wetland mitigation banks can be sited in such a way as to be compatible with local government GMA planning goals. The group plans to include a statement to this effect in its report to the legislature in December of 2004.

One of the most significant shifts to occur within wetland mitigation banking over the last decade is the rise of private entrepreneurial banks. In 1992 over 75% of banks were publicly sponsored (typically by state highway departments, ports, or local governments). These types of banks are referred to as ‘single-user’ banks because the entity that establishes the bank intends to use the mitigation credit to offset its own impacts (from road widenings for example). As of 2002, 135 banks, or 62 % of the total banks permitted were privately sponsored. Much of this change is attributed to guidance provided at the federal and state levels on wetland mitigation banking over the last decade.

According to Ecology’s recent publication “*Freshwater Wetlands in Washington State Volume 1: A Synthesis of the Science*” (Sheldon et al. 2003) only one study has examined the effectiveness of mitigation banks. Brown and Lant (1999) examined 68 banks that had been established by the beginning of 1996. The study found that although 74% of the individual banks achieve no-net-loss of acreage, overall, wetland mitigation banks were projected to result in a net loss of 21,328 acres of wetlands nationally, as already credited wetland acreages are converted to other uses. The authors noted that most wetland mitigation banks were using appropriate compensation methods and ratios, but that several of the largest banks use preservation or enhancement at ratios of 1:1, instead of restoration or creation. They also cautioned that mitigation banking inevitably leads to geographic relocation of wetlands, and therefore changes the functions and ecosystem services they provide, possibly resulting in a net loss of certain functions. In conclusion “wetland mitigation banking is a conceptually sound environmental policy tool, but only if applied according to recently issued guidelines that ensure no-net-loss of wetland functions and values.” (Brown and Lant 1999)

Given the wide variety of sizes and types of wetland banks established nationally, it is difficult to support such broad conclusions about bank failure based on a limited review of bank sites in existence in 1996. Findings suggesting failure and net loss of wetland acreage might appear true if one looks at the two largest banks in the country since both relied on enhancement and preservation approaches, which do not create or restore wetlands, and therefore cannot meet the no net loss goal for acreage. The Farmington Mitigation Bank in Florida is 23,922 acres in size; credits at the bank site were generated primarily through enhancement activities. Sandy Island Mitigation Bank in South Carolina is 16,826 acres, and the second largest bank in the nation – it is nearly entirely a preservation only bank. However, most mitigation banks, including those under consideration for approval in Washington State have potential to provide clear benefits because they range in size from 50 to 300 acres, many are sited on former (drained) wetlands that are (or were) used for agricultural purposes, and because most propose restoration as the primary means of credit generating activity. Restoration is believed to be the most successful method of wetland mitigation. According to the 2002 ELI study: “Of the 219 approved banking instruments, information on compensatory mitigation was documented for 143 banks. Sixty-two percent (89) of the banks conducted restoration activities; 65 percent (93 banks) conduct enhancement activities; 45 percent

²⁹ In Snohomish County where legislation that would forbid agricultural lands from being ‘restored’ to more naturally functioning ecological systems (such as riparian wetlands or off-channel salmonid rearing habitat) is under consideration.

(64 banks) conduct creation activities; and 44 percent (62 banks) conduct preservation activities [stet]. The majority of the banks – 78 percent -- employ multiple mitigation methods (e.g., restoration, creation, enhancement and preservation) at the bank site.”

8.4 OPPORTUNITIES AND CONSTRAINTS OF MITIGATION BANKING

There are many potential benefits of wetland mitigation banking. Banking allows for the consolidation of mitigation projects and is thereby able to take advantage of an economy of scale in construction mobilization at the outset of the project. This concentrated effort minimizes project costs while maximizing restored wetland acreage. Additionally, bank sites are selected with a view towards long-term sustainability, and there is a strong financial incentive for the sites to be ecologically successful. (As previously noted, an unsuccessful or failed restoration design will receive limited to no credit value). Mitigation banks are developed in advance of the impacts for which they compensate, reducing the temporal loss of wetland functions that commonly occurs with traditional mitigation projects. Traditional mitigation sites are often constructed at the time of, or after the impacts occur and they take time to become established before providing the full range of wetland functions.

Wetland mitigation banking can be a lucrative private enterprise in which a private sector entrepreneur develops a product (wetland credit) by taking on the legal responsibility to meet mitigation requirements. Though it requires upfront costs and is capitally intensive, banking can also bring large profits over a relatively long period of time (10 years).

Nationally and within Washington State, there is general support for the banking process and for implementing high quality projects at all levels of government currently involved in wetland permitting. Once permitted, a bank site greatly facilitates agency regulatory oversight and review. Monitoring is required at specific intervals. An annual agency staff visit to a single bank site can provide the needed regulatory oversight to ensure that the mitigation is functioning as designed. Contingency plans, as well as financial assurances, are also agreed to as part of the initial mitigation bank instrument negotiation, and are called in when required.

Mitigation banking can be used to achieve a broad range of environmental goals. Both the Federal Guidance and the Washington State Draft Mitigation Banking Rules support wetland mitigation banking as a means to implementing regionally identified restoration priorities. Specifically, the Federal Guidance states that:

“The overall goal of a mitigation bank is to provide economically efficient and flexible mitigation opportunities, while fully compensating for wetland and other aquatic resource losses in a manner that contributes to the long-term ecological functioning of the watershed within which the bank is to be located. The goal will include the need to replace the essential aquatic functions that are anticipated to be lost through authorized activities within the bank’s service area. In some cases, banks may also be used to address other resource objectives that have been identified in a watershed management plan or other resource assessment.” (Federal Register 60 November 28, 1995 58605-58614).

Washington State’s draft rule includes a specific section on **Integrating banks with broader land-use and watershed planning efforts** (WAC 173-700-030), which states that the rules:

“1)...should facilitate the establishment and operation of wetland mitigation banks that are integrated with local land-use plans and science-based watershed or sub-watershed management plans.

2) *Local and state agencies are encouraged to use wetland mitigation banks as a useful tool for implementing watershed management plans. Wetland banks can restore habitats and functions that are priorities in the watershed.*

3) *Wetland banks should experience an expedited review process when they are established as a part of a science-based resource management program, which has been endorsed by state and federal agencies.”*

Compared to traditional forms of compensatory mitigation, wetland banking is more compatible with land-use and watershed management strategies such as those as advocated by the NRC, which states in its recommendations on Watershed Setting that:

1) *“Site selection for wetland conservation and mitigation should be conducted on a watershed scale in order to maintain wetland diversity, connectivity and appropriate proportions of upland and wetland systems needed to enhance the long-term stability of the wetland and riparian systems. Regional watershed evaluation should greatly enhance the protection of wetlands and/or the creation of wetland corridors that mimic natural distributions of wetland in the landscape.*

2) *Riparian wetlands should receive special attention and protection because their value for stream and water quality and overall stream health cannot be duplicated in any other landscape position.” (National Research Council 2001, p. 59).*

Recent efforts to streamline the permitting process and improve mitigation success for state-sponsored road improvement projects also advocate watershed-based approaches to mitigation planning. WSDOT and state resource agencies are working together via the Transportation Permit Efficiency and Accountability Committee (TPEAC) and the Multi-Agency Permitting (MAP) Team to develop mitigation strategies that achieve wetland replacement, stormwater management and other impact compensation on a watershed or regional basis.

Ideally, once a bank site has been selected and approved by the regulatory agencies with jurisdiction, the permitting process for projects with unavoidable wetland impacts is greatly expedited because mitigation needs for impacting projects can be satisfied through withdrawal of mitigation credit from an approved wetland mitigation bank. In reality, banking may not always be so simple or straightforward.

As a fairly new policy, banking remains risky because agency procedures on wetland mitigation banks are not yet defined and there are few proven examples of successful mitigation banks in the Pacific Northwest. The Corps of Engineers has adopted Federal Guidance on how to establish wetland mitigation banks, but there is currently no dedicated staff within the Corps to work exclusively on banking. As a result projects are divided somewhat on a geographic location basis, and staff manage review of wetland mitigation banks as one of many competing projects vying for their limited time. This is inefficient and results in regulatory inconsistencies in approach from the Corps permit staff, based on their individual experience with wetland mitigation banking.

The regulatory process as it pertains to wetland mitigation banking in Washington State is still evolving. Though banking has gained in popularity over the last decade nationally, only one approved wetland mitigation bank, at Paine Field, in Everett, has been approved. King County is the only county to have adopted administrative rules, and those rules were developed with the idea that King County would manage all bank sites established within its jurisdiction. This may no longer be feasible or practical, given that the County no longer has staff to work on wetland mitigation banking. Even within King County, knowledge of the administrative rules on wetland mitigation banking is quite limited because there have been virtually no proposals that would utilize the rules. Other local governments may be at greater

disadvantage because they lack policy guidance or knowledge on the substantive elements that should be required of a wetland mitigation bank, or how to process these projects when they do come in for permit review. This presents a challenge in Washington State, where local governments control so much of the regulatory framework upon which wetland mitigation banks rely.

The Mitigation Bank Review Team (MBRT)³⁰, co-lead by Ecology and the Corps, is beginning to evolve a more predictable process for permitting mitigation banking, but only recently established regularly scheduled monthly meetings, and is finding that these meetings are insufficient to deal with the 12 to 14 projects in the permit pipeline. The MBRT has no operating protocols or procedures on basic negotiation issues such as dispute resolution, the role or responsibility of each agency staff person at the table, the time-frame required for internal review of each proposal within each agency, whether the staff representative has signature authority for mitigation bank instruments etc. This creates confusion and delays that frustrate bank applicants from both the public and private sectors. The Washington State Department of Transportation (WSDOT) signed a Memorandum of Agreement (MOA) with the agencies in 1994 that establishes general banking side-boards, but WSDOT has been working on signature of the Newaukum Creek Mitigation Banking Instrument for 6 years, and the instrument is still not final or signed. Such a lengthy process would be untenable for a private sector proponent. This lack of regulatory certainty creates a significant impediment to establishing wetland mitigation banks in Washington State.

Because of the time required to permit wetland mitigation banks and resources required to fund the technical studies related to permitting, wetland mitigation banking can be costly to implement. Because so few projects have been permitted in Washington State, it is difficult to provide an exact range, but it is estimated that it may cost \$400,000 to \$600,000 or more to complete the permit process that results in a signed MBI in Washington State. These costs represent the anticipated resources needed to secure and design a site; determine credit value, service area, credit release timing, performance monitoring, and long-term maintenance requirements; and obtain conservation easements and financial assurances. Construction costs would be additional. Depending on bank site location, size, and type of activity at the bank, as well as credit demand, credit sale prices are estimated to range from \$60,000 to \$200,000 per acre. Paine Field, in Everett, Washington, sold credits from its wetland mitigation bank to the WSDOT for \$250,000 per acre. This is believed to represent the high range of credit value in today's wetland credit market. However, the market is dependent upon many variables; wetland mitigation bank credits in urban areas, where land prices are high and development pressures are intense, may exceed this range.

While these time and cost considerations are significant, they are not entirely out of line with the permitting and mitigation cost requirements associated with large or complex projects. It can often take two or more years to secure federal, state, and local permits for a major infrastructure project and mitigation cost can easily be \$250,000 per acre for a single project. Costs associated with a recent WSDOT road improvement project in Snohomish County were close to \$193,000 per acre³¹ not including design, permitting and right-of-way purchase (Wilcox 2004 personal communication). Permitting for that project took nearly 2 years.

³⁰ The MBRT is co-chaired by Ecology or the Corps and the local jurisdiction. The MRBT is responsible for providing feedback on the bank's technical feasibility and on specific elements of the MBI such as the service area, credit/debit accounting approach, monitoring requirements, etc.

³¹ Mitigation costs for the SR 522 Fales Road Intersection Improvement Project in Snohomish County were approximately \$1.6 million dollars. This provided 8.3 acres of mitigation at two sites adjacent to the right-of-way. The \$1.6 million dollars covered site construction, mobilization, traffic control, construction engineering, sales tax, planting, site preparation excavation, and erosion and sediment control. Land purchase, permitting and design were not included.

Part of the motivation to develop effective mitigation banking regulations and successful bank sites, is attributable to studies over the last decade that have shown that traditional compensatory mitigation, both on and off-site, is not as successful as had been anticipated (Ecology 2000 and 2002; NRC 2001). Additionally, advances in conservation biology, population dynamics, and landscape ecology are contributing to how public agencies manage landscapes under ESA and watershed planning efforts (including endeavors in Washington State promoted by GMA, ESA, WRIA and the Shoreline Management Act or SMA). There is a growing recognition that mitigation money could be better and more strategically directed at achieving regional restoration goals at a watershed level. In addition, wetland mitigation banking brings private funding to bear in long-term site maintenance and management – often a challenge for government agencies with tight budgets. Resource managers increasingly see the value in restoring large wetland areas that are protected in perpetuity through conservation easements as well as maintenance and monitoring regimes.

While many regulators and wetland mitigation bankers speculate that wetland mitigation banks could also be used to compensate for outstanding wetland violations, or help to offset cumulative impacts, these claims remain speculative, at least in Washington State, since wetland mitigation banking is such a new policy that no certified wetland mitigation banks exist in the State to test this theory.

Banking is equal parts ecology, economy and politics. Because banking is still an new concept there is lingering skepticism about its effectiveness in compensating for wetland losses. Some regulators who are disillusioned with mitigation generally, and of off-site mitigation in particular may be inclined to ‘throw the baby out with the bath-water’ because they believe banking will suffer the same lack of success of many on-site mitigation projects and they are concerned about the potential for net loss of wetland habitats. The ecological risk is perceived as high by some regulators – what if the 300-acre wetland mitigation project fails? Supporters of banking respond that there would be no credit available to sell, and therefore no ecological loss, however, it remains true that banking is not well understood as a policy tool, and is therefore sometimes treated with mistrust by some jurisdictions.

Although many jurisdictions believe that banking is a sound policy tool, there is currently little to no guidance on the process to implement a wetland mitigation bank at the local level. Washington State has extremely active local governments who control the majority of the potential ‘market’ for wetland mitigation bankers. Credits from a bank cannot be sold without the participation and approval of the local government; if local, state, or federal agency staff fail to notify project applicants in need of mitigation of existing mitigation banks, there will be no customer base for credit sales, and banks will fail for financial reasons. This has happened nationally, notably in Denver with the Mile High Wetland Mitigation Bank.

There is a concern that mitigation banks may provide a disincentive to following the preferred mitigation sequence of avoiding, then minimizing, then compensating for impacts. However, the existence of a permitted bank has no bearing on the regulations, which would still require mitigation sequencing. A bank may or may not be appropriate mitigation for a given impact, but the banker does not control the market, and has no influence on the decision to use a bank site. If viable mitigation is “in the ground”, is functioning, and has been approved for use within a given service area, then it should be available for projects.

Beyond policy and financial challenges are the technical challenges of creating a successful ecological design. Substantial of time and effort (and money) are required to provide hydrologic and hydraulic modeling to ensure that there will be sufficient water to support the wetland design. Grading and earthwork, often required elements of restoration design, can be very costly to implement. Plantings can fail for a number of different reasons, invasive weeds and other species (such as bullfrogs) can be difficult and expensive to control, vandalism can destroy sites and increase costs for maintenance and monitoring.

Private sector bankers often feel that the ‘regulatory bar’ is higher for bank site design than it is for traditional compensatory mitigation because they are held accountable for site success for the operational life of the bank. In reality, all mitigation sites, whether they are banks or conventional sites, should be held to similar standards for design, monitoring, and maintenance if existing policies and regulations pertaining to no net loss are to be achieved.

The ELI in its review of wetland mitigation banks states that: *“Compensatory mitigation can be used strategically to help achieve regional conservation objectives. Government agencies can maximize the benefits of mitigation by proactively identifying, classifying, and evaluating existing wetlands and their potential for achieving wetland mitigation goals. Government agencies can strategically identify off-site areas that are ecologically suitable for mitigation, and therefore have a higher likelihood of achieving functional equivalency with an impact site or with reference wetlands. In addition, by identifying potential sites in advance, regulators can seek to maximize the compensation of lost functions. Watershed planning efforts can also seek to utilize mitigation to reduce the cumulative effects of multiple individual wetland impacts.”* (ELI 2001, p. 31).

This statement is supported by the National Academy of Sciences recommendations cited earlier in this document. Ecology discusses a landscape approach to compensatory mitigation at length in its draft publication “Freshwater Wetlands in Washington State: Volume 1, The Status of the Science.” Its findings echo those of ELI and support the concept that wetland mitigation banking can be an important tool to assist local governments in achieving regionally identified restoration priorities.

Some banks, such as Paine Field in Everett, as well as some proposed bank sites in King and Snohomish Counties, combine passive recreational use of publicly owned lands with wetland mitigation banks. In this way the public is provided an amenity, such as a park, which is managed and maintained to achieve specific ecological goals. This can be a great benefit to a public entity that has land but is unable to maintain it or provide for safe public use of the site.

8.5 FINDINGS AND CODE RECOMMENDATIONS

Whatcom County should consider establishing substantive elements required of wetland mitigation and habitat banks as part of the CAO update. These would allow for wetland and conservation banking to occur, but would leave specific negotiations up to a Mitigation Bank Review Team process, with local government participation. This allows for banks to be established in compliance with state and federal guidelines while providing Whatcom County with maximum flexibility. Substantive elements of banks include service area considerations (typically a watershed or hydrologically based unit such as a WRIA wherein credits can be sold to offset permitted impacts), site selection considerations, credit values, credit release schedules, monitoring and maintenance requirements, conservation easement requirements, contingency plans and financial assurances.

Banking should be a component of an overall Countywide restoration strategy. High priority sites can be acquired, restored, maintained and monitored in perpetuity at private cost with public benefit. Whatcom County could consider using its own land if restoration, maintenance and monitoring costs are too high – banking can provide long-term funding for these. Alternatively banks could be sited adjacent to publicly held land to leverage the benefits of large conservation areas managed for natural resource protection. Bank sites currently under consideration in Snohomish, King, Pierce, and Clark Counties leverage the conservation value of their sites by the fact that they are sited adjacent to, or sometimes on, publicly owned land.

8.5.1 General Findings and Recommendations

General Wetland Findings and Recommendations	
Finding	Wetland Banking offers a valuable policy tool to assist local governments achieving prioritized regional restoration goals
Recommendation	Adopt Code language that allows for wetland and habitat banking; establish required substantive elements, (e.g. service area considerations, credit valuation methodology, credit release rates, performance standards, maintenance and monitoring and reporting requirements, financial assurances and long-term site stewardship) but leave the complex project negotiations to existing state and federal regulatory processes, with local involvement on a specific bank site basis as needed.
BAS Sources	Banks and Fees, The Status of Off-site Wetland Mitigation in the United States, Environmental Law Institute, September 2002; Compensating for Wetland Losses under the Clean Water Act, National Research Council, National Academy Press, 2001; Freshwater Wetlands in Washington State, Volume 1: A Synthesis of the Science.

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APPENDIX A

Critical Area Maps

APPENDIX B

Technical and Citizens' Advisory Committee

APPENDIX B

Citizens' Advisory Committee Members

David Haggith	Rebecca O'Brine Willson
Roger Almskaar	Margaret (Peg) Larson
Aubrey Stargell	Skip Richards
Elizabeth Daly	Jon Sitkin
Wendy Stephensen	Richard Gilda
Robyn du Pre'	Kathy Berg
Tom Pratum	

Technical Advisory Committee Members

Lummi Nation – Jeremy Freimund, Alan Chapman, Stacy Fawell
Nooksack Tribe – Treva Coe, Ned Currence
Small Cities Caucus – Rollin Harper
Port of Bellingham – Alan Birdsall
Washington State Department of Fish and Wildlife – Dan Pentilla, Steve Seymour
Washington State Department of Natural Resources – David Roberts, Nancy Joseph
Washington State Department of Ecology – Stephen Stanley, Barry Wenger, Susan Meyer
Whatcom Conservation District/NRCS – George Boggs
Puget Sound Action Team – Hillary Culverwell
Whatcom County River and Flood Division – Paula Cooper, Paul Pittman
Whatcom County Water Resources Division – John Thompson, Erika Stroebel
Whatcom County Public Works
Whatcom County Planning and Development Services
Washington State Department of Transportation
US Army Corps of Engineers
Washington Department of Community Trade and Economic Development
Whatcom County Shellfish Protection Districts
Whatcom County Watershed Improvement Districts
City of Bellingham

APPENDIX C

Scientific Names for Fish and Wildlife

APPENDIC C

Scientific Names for Fish and Wildlife

Common Name	Scientific Name
Animals	
American black oystercatcher	<i>Haematopus bachmani</i>
American White pelican	<i>Pelecanus erythrorhynchos</i>
Bald eagle	<i>Haliaeetus leucephalus</i>
Band-tailed pigeon	<i>Columba fasciata</i>
Barrow's goldeneye	<i>Bucephala islandica</i>
Beaver	<i>Castor canadensis</i>
Big brown bat	<i>Eptesicus fuscus</i>
Black turnstone	<i>Arenaria melanocephala</i>
Black-bellied plover	<i>Pluvialis squatarola</i>
Black-crowned night heron	<i>Nycticorax nycticorax</i>
Blue grouse	<i>Dendragapus obscurus</i>
Brandt's cormorant	<i>Phalacrocorax penicillatus</i>
Brant	<i>Branta bernicla</i>
Brown pelican	<i>Pelecanus occidentalis</i>
Bufffehead	<i>Bucephala albeola</i>
Bull trout	<i>Salvelinus confluentus</i>
Butter clam	<i>Saxidomus giganteus</i>
California quail	<i>Callipepla californica</i>
California sea lion	<i>Zalophus californianus</i>
Canvasback	<i>Aythya valisineria</i>
Cascades frog	<i>Rana cascadae</i>
Cassin's auklet	<i>Ptychoramphus aleuticus</i>
Columbia spotted frog	<i>Rana luteiventris</i>
Columbian black-tailed deer	<i>Odocoileus hemionus columbianus</i>
Common goldeneye	<i>Bucephala clangula</i>
Common loon	<i>Gavia immer</i>
Common murre	<i>Uria aalge</i>
Crayfish	<i>Pacifasticus</i> spp.
Dall's porpoise	<i>Phocoenoides dalli</i>
Dark-eyed junco	<i>Junco hyemalis</i>
Dungeness crab	<i>Cancer magister</i>
Dunlin	<i>Calidris alpina</i>

Appendix C -Scientific Names for Fish and Wildlife (continued)

Common Name	Scientific Name
Animals (continued)	
Fisher	<i>Martes pennanti</i>
Geoduck clam	<i>Panopea abrupta</i>
Golden eagle	<i>Aquila chrysaetos</i>
Gray whale	<i>Eschrichtius robustus</i>
Gray wolf	<i>Canis lupus</i>
Great blue heron	<i>Ardea herodias</i>
Greater yellowlegs	<i>Tringa melanoleuca</i>
Grizzly bear	<i>Ursus arctos</i>
Harbor seal	<i>Phoca vitulina</i>
Harlequin duck	<i>Histrionicus histrionicus</i>
Heart cockle	<i>Clinocardium nuttallii</i>
Hooded merganser	<i>Lophodytes cucullatus</i>
Horse clam	<i>Tresus capax</i>
Killdeer	<i>Charadrius vociferus</i>
Killer whale (orca)	<i>Orcinus orca</i>
Least sandpiper	<i>Calidris minutilla</i>
Lynx	<i>Lynx canadensis</i>
Manila clam	<i>Tapes philippinarum</i>
Marbled murrelet	<i>Brachyramphus marmoratus</i>
Marsh wren	<i>Cistothorus palustris</i>
Marten	<i>Martes americana</i>
Merlin	<i>Falco columbarius</i>
Mink	<i>Mustela vison</i>
Minke whale	<i>Balaenoptera acutorostrata</i>
Moose	<i>Alces alces</i>
Mountain goat	<i>Oreamnos americanus</i>
Mussel	<i>Mytilus</i> spp.
Native littleneck clam	<i>Protothaca staminea</i>
Northern Abalone	<i>Haliotis kamtschatkana</i>
Northern goshawk	<i>Accipiter gentilis</i>
Northern harrier	<i>Circus cyaneus</i>
Northern pintail	<i>Anas acuta</i>
Northern spotted owl	<i>Strix occidentalis</i>
Olympia oyster	<i>Ostrea lurida</i>

Appendix C -Scientific Names for Fish and Wildlife (continued)

Common Name	Scientific Name
Orca (killer whale)	<i>Orcinus orca</i>
Animals (continued)	
Osprey	<i>Pandion haliaetus</i>
Pacific harbor porpoise	<i>Phocoena phocoena</i>
Pacific oyster	<i>Crassostrea gigas</i>
Pacific Townsend's big-eared bat	<i>Corynorhinus townsendii</i>
Pallid bat	<i>Antrozous pallidus</i>
Pandalid shrimps	<i>Pandalus</i> spp.
Peregrine falcon	<i>Falco peregrinus</i>
Pigeon guillemot	<i>Cepphus columba</i>
Pileated woodpecker	<i>Dryocopus pileatus</i>
Purple martin	<i>Progne subis</i>
Red legged frog	<i>Rana aurora</i>
Red rock crab	<i>Cancer productus</i>
Red urchin	<i>Strongylocentrotus franciscanus</i>
Red-necked grebe	<i>Podiceps grisegena</i>
Red-tailed hawk	<i>Buteo jamaicensis</i>
Rhinoceros auklet	<i>Cerorhinca monocerata</i>
Rocky Mountain elk	<i>Cervus elaphus nelsoni</i>
Roosevelt elk	<i>Cervus elaphus roosevelti</i>
Rough-legged hawks	<i>Buteo lagopus</i>
Sanderling	<i>Calidris alba</i>
Sandhill crane	<i>Grus canadensis</i>
Scoters	<i>Melanitta</i> spp.
Semi-palmated plover	<i>Charadrius semipalmatus</i>
Short-billed dowicher	<i>Limnodromus griseus</i>
Short-eared owls	<i>Asio flammeus</i>
Snow geese	<i>Chen caerulescens</i>
Steller (Northern) sea lion	<i>Eumetopisa jubatus</i>
Tailed frog	<i>Ascaphus truei</i>
Townsend's big-eared bat	<i>Corynorhinus townsendii</i>
Trumpeter swans	<i>Cygnus buccinator</i>
Tufted puffin	<i>Fratercula cirrhata</i>
Tundra swans	<i>Cygnus columbianus</i>
Turkey Vulture	<i>Cathartes aura</i>

Appendix C -Scientific Names for Fish and Wildlife (continued)

Common Name	Scientific Name
Vaux's swift	<i>Chaetura vauxi</i>
Western grebe	<i>Aechmophorus occidentalis</i>
Animals (continued)	
Western sandpiper	<i>Calidris mauri</i>
Western toad	<i>Bufo boreas</i>
Whimbrel	<i>Numenius phaeopus</i>
Willow flycatcher	<i>Empidonax traillii</i>
Wolverine	<i>Gulo gulo</i>
Wood duck	<i>Aix sponsa</i>
Plants	
Baldhip rose	<i>Rosa gymnocarpa</i>
Douglas-fir	<i>Pseudotsuga menziesii</i>
Eelgrass	<i>Zostera marina</i>
Orange honeysuckle	<i>Lonicera ciliosa</i>
Kelp	<i>Nereocystis luetkeana</i>
Oceanspray	<i>Holodiscus discolor</i>
Pacific madrone	<i>Arbutus menziesii</i>
Western hemlock	<i>Tsuga heterophylla</i>
Western redcedar	<i>Thuja plicata</i>
Fish	
Bull trout	<i>Salvelinus confluentus</i>
Chinook salmon	<i>Oncorhynchus tshawytscha</i>
Chum salmon	<i>Oncorhynchus keta</i>
Coastal Cutthroat Trout	<i>Oncorhynchus clarki</i>
Coho salmon	<i>Oncorhynchus kisutch</i>
Longfin smelt	<i>Spirinchus thaleichthys</i>
Nooksack Dace	<i>Rhinichthys</i> spp.
Pacific Herring	<i>Clupea pallasii</i>
Pacific herring	<i>Clupea pallasii</i>
Pacific sand lance	<i>Ammodytes hexapterus</i>
Pacific sand lance	<i>Ammodytes hexapterus</i>
Pink salmon	<i>Oncorhynchus gorbuscha</i>
Rainbow Trout/steelhead	<i>Oncorhynchus mykiss</i>
River Lamprey	<i>Lampetra ayresi</i>
Salish Sucker	<i>Sabestes paucispinis</i>
Sockeye salmon/ Kokanee	<i>Oncorhynchus nerka</i>
Surf smelt	<i>Hypomesus pretiosus</i>

Appendic C -Scientific Names for Fish and Wildlife (continued)