CITY OF COVINGTON COMPREHENSIVE PLAN UPDATE 2015

REVIEW OF BEST AVAILABLE SCIENCE

APPENDICES

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1.0 INTRODUCTION

The Washington State Growth Management Act and implementing rules require cities and counties to " include the 'best available science' (BAS) when developing policies and development regulations to protect the functions and values of critical areas and must give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries." (Washington Administrative Code [WAC] 365-195-900) Critical areas include geologically hazardous areas, frequently flooded areas, critical aquifer recharge areas used for potable water, wetlands, and fish and wildlife habitat conservation areas (Revised Code of Washington [RCW] 36.70A.030(5)). Inclusion of BAS in the development of locally appropriate policies and regulations must be balanced with the many other substantive goals and mandates of the GMA. Use of non-scientific information (e.g., social, legal, cultural, economic, or political) that results in departures from scientifically valid critical areas recommendations must be identified and justified, and potential consequential impacts must also be identified.

This report provides BAS for the Covington Comprehensive Plan Update. The 2015 Comprehensive Plan Update Study Area includes potential annexation of two Urban Growth Areas (see Exhibit 1 below).

BAS documents are prepared by qualified scientific experts and follow a valid scientific process. The scientific process, which produces reliable information, is generally characterized by peer review, standardized methods, logical conclusions and reasonable inferences, quantitative analysis, proper context, and references. Common sources of scientific information include research, monitoring, inventory, modeling, assessment and synthesis (WAC 365-195-905).

The report authors compiled BAS references for each section or discipline. BAS documents were selected based on their significance to the City of Covington and the city's urban growth area (see Figure 1 below), common use in each discipline, and relevance to current scientific practices or principals. BAS summaries recently completed for the Cities of Burien (The Watershed Company 2011), Newcastle (The Watershed Company 2014), and Woodinville (The Watershed Company 2013) were utilized as local references.

The scientific body of knowledge evolves as new studies are conducted and new technologies are employed. While the BAS information provided here is intended to provide a framework for critical area protections, it may not provide definitive criteria for all regulatory decisions. Ecologic systems, including urban environments, are complex and based on both landscape-scale and local processes, comprised of many variables. Where definite guidance is lacking or studies in the scientific literature show variable methods and results, a range of values is commonly provided here. In accord with WAC 365-195-920, where scientific information is incomplete with regard to a land use, a precautionary or no risk approach should be taken.

This BAS review is intended to guide the development or revisions of policy in the Comprehensive Plan and any necessary revisions to the city's existing Critical Areas Ordinance (CAO) language in the City of Covington Municipal Code (CMC, Chapter 18.65, Critical Areas). Local factors, including projected growth, the nature and intensity of land uses within the city, natural resources at risk, and the ability of the city to implement its CAO, should be considered during the update process (WDOE 2012).

This BAS review will be referenced as the city moves forward with their Comprehensive Plan Update, including a CAO update.

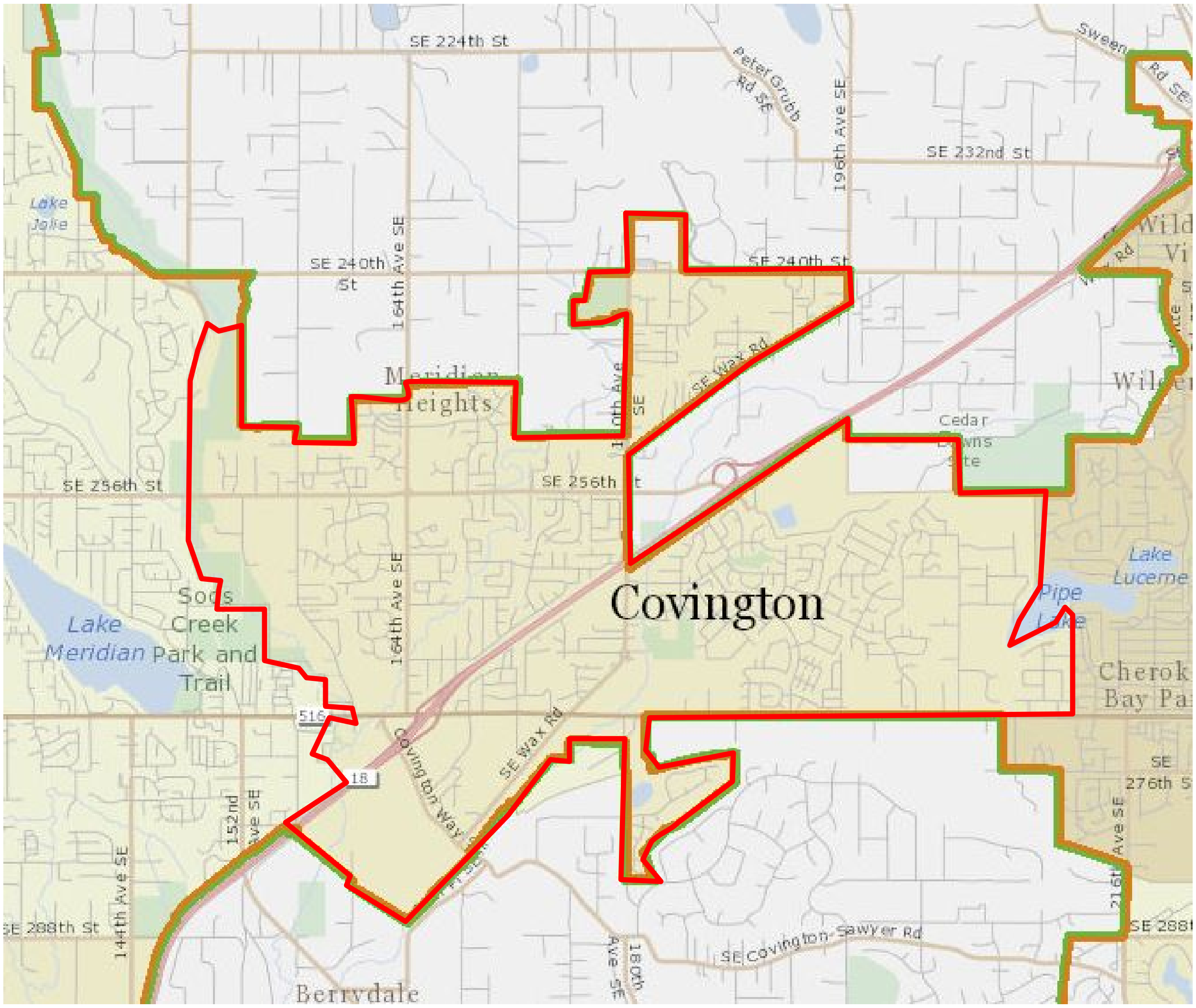

Exhibit 1. City of Covington and its Urban Growth Area.

Source: King County iMAP.

2.0 CRITICAL AQUIFER RECHARGE AREAS (CARA)

Groundwater is a valuable source of drinking water as well as fresh water for stream, lakes, estuaries, wetlands and springs, and the habitat that such areas provide. Critical Aquifer Recharge Area designations are meant to protect this resource by:

1. identifying aquifers that provide potable water, and
2. protecting those areas that provide recharge to aquifers so that water quality and water quantity can be maintained.

The vulnerability of an aquifer is the product of its susceptibility to contamination and the contaminant loading. Susceptibility is determined primarily by how easily water passes from the ground surface to the aquifer. An aquifer that easily receives water is also highly susceptible to contamination. Contaminant loading is a measure of the quantity of contaminants in the recharge area. Contamination may include any number of chemicals used for a variety of industrial or household uses, as well as some natural sources, such as salt water intrusion.

A highly vulnerable aquifer is one with high susceptibility and high contaminant loading (Aller et al, 1987; King County, 1995, 2004). A moderately vulnerable CARA may combine high susceptibility with low contaminant loading, or may combine low to moderate susceptibility with low to moderate contaminant loading.

Water quantity must also be considered when protecting CARA's (Cook, 2000; Morgan, 2005). Water quantity is a function of the amount of water being taken into the aquifer (recharge) and the amount of water being taken out of the aquifer (discharge). Discharge can include both natural releases to streams, springs, lakes, wetlands, estuaries, and shorelines, as well as human withdrawals via wells (Driscoll, 1986; Fetter, 1980, Winter et al, 1988). Development and associated increased impervious surfaces can decrease the amount of water reaching the aquifer by generating increased surface water runoff volumes (Duinne and Leopold, 1978).

Protecting CARA's involves identifying where they are, classifying them based on their vulnerability or some other rational method, and making appropriate land use decisions based on that classification. State and Federal laws regulate a number of activities and wellhead protection areas (RCW, 2013; WAC, 2013), but local jurisdictions may benefit from additional CARA protections.

2.1 CARA IN THE CITY OF COVINGTON

The City of Covington defines CARA in CMC 18.20.253 as,

> "an area designated on the critical aquifer recharge area map adopted by CMC 13.37.020 that has a high susceptibility to ground water contamination or an area of medium susceptibility to ground water contamination that is located within a sole source aquifer or within an area approved in accordance with Chapter 246-290 WAC as a wellhead protection area for a municipal or district drinking water system, or an area over a sole source aquifer for a private potable water well in compliance with Department of Ecology and Public Health standards. Susceptibility to ground water contamination occurs where there is a combination of Covington Municipal Code 18.20.255 18-22.1 (Revised 12/14) permeable soils, permeable subsurface geology and ground water close to the ground surface."

The City of Covington geologic setting includes Pleistocene continental glacial drift in upland areas, basal till layers in the subsurface, and recessional outwash deposits in stream and tributary channels (Big Soos Creek and Jenkins Creek) (Luzier,1963; WDNR, no date; Woodard et al, 1995). The Covington Channel is a major subsurface alluvial deposit in a glacial meltwater or paleochannel of the Cedar River (Mullineaux, 1970).

Soils in the area are derived primarily from glacial materials and alluvium (King County Soil Survey). The Alderwood soil series is found on glacial terraces and drift plains with moderately drained surface soils over dense till. Subsoils at depths of about 24 inches are typically massive, extremely firm, with low saturated hydraulic conductivity (King County Soil Survey Maps, no date). The Everett soil series is typically found on recessional outwash deposits with high to very high saturated hydraulic conductivity. Both soils may exhibit rapid shallow recharge and interflow to local streams, lakes, and wetlands.

Covington is in the South King County Groundwater Management Area (GWMA) (King County iMAP). It is served by three water districts: Covington Water District (formerly King County Water District 105), Water District 111 which serves some of the west side of the city, and Ham Water Company which has a pump station at 164th Avenue SE and serves parcels in that area. . The municipal water source for City of Covington is the Covington Water District (CWD). The CWD is a special district with a service area spanning approximately 55 miles. Water for the district is supplied by groundwater via ten production wells, and water from the Green River Watershed via a second supply pipeline. The CWD also has emergency connections with surrounding districts (HDR 2007, CWD 2015). These additional sources are also from groundwater wells.

Water supply wells in Covington area generally draw from permeable strata at depths of 100 to 300 feet below land surface (WDOE well logs). They often have static water levels that reflect upward pressures of groundwater discharge (increasing hydraulic head with depth). Properly cased and sealed wells in stratified glacial drift deposits with variable permeability have low susceptibility to contamination from surface sources. Their recharge areas are extensive and likely extend north and east of Covington to the Cedar River and past Maple Valley. Covington has no sole source aquifers as designated by the U.S. Environmental Protection Agency (USEPA) (http://yosemite.epa.gov/r10/water.nsf/Sole+Source+Aquifers/ssamaps).

2.2 CARA AND POTENTIAL EFFECTS OF DEVELOPMENT

The functions and values of a CARA are to provide clean drinking water and to contribute water to streams and wetlands that support wildlife (EPA, 1989, 1995). Potential impacts to CARAs can take two forms – impacts to water quality and impacts to water quantity.

An aquifer is considered to be used for potable water if it has existing wells, or is in the identified protection area for an existing well; if it is a sole-source aquifer (as designated by the USEPA and associated rules); is planned to be used for potable water in the future; or is otherwise identified as an important supply. To maintain potable water uses and potential uses of existing aquifers, both water quality and quantity must be managed.

Surface water and groundwater are frequently interacting (Morgan and Jones, 1999; Winter et al, 1998). Streams can contribute to groundwater levels, and groundwater can contribute to stream flow. Often a stream will recharge a local aquifer during wetter periods, and receive return flow or discharge during drier season. Likewise, wetlands can also serve to recharge or receive discharge from aquifers, with the function varying seasonally in some cases (Bauer and Mastin, 1997). Streams, wetlands, springs and seeps all provide critical habitat and resources for vegetation and wildlife, both aquatic and terrestrial. These functions and values are dependent on both the quantity and quality of the water in the aquifer (Alley et al. 1999, Dunne and Leopold 1978, King County 2004).

Water Quality

While aquifer recharge areas serve to replenish groundwater supplies, they can also serve as a conduit for the introduction of contaminants to groundwater (Erwin and Tesoeiero, 1997). The risk of groundwater contamination (impacts to water quality) is related to two main parameters: The susceptibility of the aquifer and the contamination loading potential or source loading (Aller et al, 1987, EPA 1989, EPA 1995).

Aquifer Susceptibility

Aquifer susceptibility refers to how easily water and pollutants can move through the ground to reach the underlying aquifer (Cleary and Cleary, 1991). A shallow, unconfined aquifer in gravel deposits would be more susceptible to contamination than a deep, confined aquifer overlain by dense glacial till. Contamination loading refers to the quantity and types of pollutants present in the area, and how they are handled. Unmanaged open space would have a low contamination loading potential, while a light industrial area would likely have a higher loading potential, and an older industrial site with multiple leaking storage containers would have a high loading potential. Together, susceptibility and loading potential determine the vulnerability of an aquifer. A highly susceptible aquifer may have a low vulnerability if the land use within the area is primarily open space. Likewise, an industrial site with multiple leaking storage containers may not create significant vulnerability if it is separated from the nearest aquifer by dense glacially-compressed clay.

The susceptibility of an aquifer can be assessed by looking at three critical factors (Morgan 2005, USGS 2002):

1. The overall permeability of the vadose zone (the unsaturated material between the aquifer and the ground surface, through which any contaminants would need to pass to reach the aquifer)
2. The thickness of the vadose zone or depth to the aquifer,
3. The amount of recharge available.

Permeability of the vadose zone can be estimated from soil and geologic mapping. The Washington Department of Natural Resources has an interactive web-based geologic map of the state which provides some insight into the permeability of the vadose zone (Washington State DNR/Geology; https://fortress.wa.gov/dnr/geology/?Site=wigm).

Depth to an aquifer can be determined by examining well logs in the vicinity. As mentioned above, well logs are available at the Department of Ecology (WDOE) website (see Washington State Department of Ecology Well Log in Section 7 for web address; http://apps.ecy.wa.gov/welllog/mapsearch.asp). In many cases, there may be several moderate to deep aquifers underlying a given location, and different wells in a given vicinity may be at widely varying depths if they are drawing from different aquifers.

The amount of water recharge available to an aquifer can also be estimated from soil permeability and rainfall data. This dynamic is discussed in greater detail in the water quantity section below.

Contamination Loading Potential

While hydrogeologic conditions determine the overall susceptibility of an aquifer, the level of urbanization in a watershed determines contamination loading potential (Fetter 1980). Common pollutants in urban environments that may contaminate groundwater are nitrate, sewage effluent, and hazardous chemicals (Driscoll 1986) and, in some cases, naturally occurring compounds such as arsenic that are disturbed or distributed by development (Parson and Allen-King, 2003).

Nitrate

Nitrate is a soluble form of nitrogen, which is stable, is not filtered by passing through soil, and which can cause health risks when it contaminates drinking water. Too much nitrate in drinking water can lead to, among other conditions, methemoglobinemia, or blue baby syndrome, in infants. This condition robs blood cells of their ability to carry oxygen, resulting in a bluish discoloration of the body. If not diagnosed and treated, this condition can lead to slow suffocation and possible death. To prevent this illness, the USEPA set the maximum contaminant level for nitrate at 10 mg/l.

Because of its solubility and stability, nearly all groundwater contains low levels of nitrate. Concentrations above 1mg/l are generally associated with anthropogenic sources, including sewage, fertilizers, livestock and pet waste.

Sewage Effluent

On-site sewage treatment can be an effective method for treating and disposing of sewage, if properly designed and maintained. As an additional benefit, such systems can be a source of aquifer recharge.

Enhancing groundwater supplies through aquifer recharge and recovery are recommended approaches to maintaining sustainable groundwater sources as global warming occurs (Binder et al. 2010). However, on-site treatment does not typically remove nitrate, pharmaceuticals and many other chemical contaminants. Dilution usually reduces the concentrations of such contaminants, but is not always effective. In areas where the use of on-site sewage treatment is concentrated, groundwater contamination can result (Dunne and Leopold 1978, Godfrey et al. 2007).

Chemicals and contaminants of concern

Chemicals and products that are used every day in an urbanized area have the potential to contaminate groundwater if improperly used. The activities and facilities that are likely to use such materials include, but are not limited to, the following: (King County 2004)

- Above/ underground storage tanks & lines
- Airports
- Automobile repair and body shops
- Boat repair facilities
- Construction
- Food Processing
- Funeral services/ taxidermy
- Furniture repair/ refinishing
- Gas stations
- Golf courses
- Hardware/ farm/ auto parts stores
- Landfills
- Machine/ metal fabricating shops
- Marinas
- Medical/ vet offices
- Mines/ gravel pits
- Office buildings/ strip malls
- Pesticide operators
- Photo processing facilities
- Research laboratories
- RV parks and facilities
- Retail stores
- Septage lagoons
- Waste transfer/ recycling areas

The Department of Ecology requires pollution prevention plans for facilities that generate more than 2,640 pounds of hazardous waste per year, but these requirements apply only to waste products, and not necessarily to those products that are used as part of a process (WAC 173-307). Smaller businesses and homeowners are not required to provide prevention plans, and while larger farms and businesses may use potential contaminants more frequently or in greater quantity, groundwater is also subject to contamination by materials used by small businesses and households, especially those on septic systems or that store materials on the ground.

Water Quantity

Maintaining water quantity within an aquifer supports both potable water uses and landscape-scale habitat functions, which are groundwater-dependent (Alley et al 1999). As noted above, surface water and groundwater are cyclic and frequently interacting.

An aquifer recharge area is an area where water from rainfall, snowmelt, lakes, rivers, streams or wetlands, flows into the ground to an aquifer. Aquifer discharge areas are where water rises toward the ground surface under geostatic or hydraulic pressure (Molenaar 1961). Such areas can include seeps, springs, wetlands, streams, lakes, estuaries, and shorelines. Wells are also considered a type of aquifer discharge. Since groundwater movement is driven by gravity and pressure, an aquifers' recharge is typically at a higher elevation than its discharge area. Higher elevations tend to be recharge areas and lower elevations tend to be discharge areas. However, in some cases subsurface conditions may result in groundwater flow that does not reflect surficial topography (Driscroll 1986).

The quantity of water available in Puget Sound aquifers is a balance between recharge, storage, and discharge (Vaccarro 1992) and how they may be affected by climate change (Binder et al 2010). Land use and development typically alters water conveyance within a basin. For example, replacing forests with buildings, roads, driveways, lawns, and even pastures typically reduces the recharge to underlying aquifers to varying extents, while simultaneously increasing the peak runoff rates to streams. In rare instances, however, some land uses can increase recharge rates. For example, if homes in an area receive water from a river or lake and discharge that water into septic systems, the result can be an increase in recharge to the underlying aquifer, and one that has potential for introducing contaminants (Dunne and Leopold 1978, Winter et al. 1998).

Recharge to an aquifer is dependent on precipitation and infiltration into the soil below the root zone. Infiltration below the root zone is controlled by a number of factors, including temperature, wind, soil type, geology, vegetation type, and land surface slope. The root zone is an important factor to consider, since evaporation and transpiration of water by plants reduces the water available for groundwater recharge, and can account for much or most of the rainfall during some months (SJC 2004).

Identifying the recharge area of an unconfined aquifer can be relatively simple. If there is no barrier between the ground surface and the aquifer, the recharge area is typically the land area contributing infiltration to the aquifer. Surface water, in lakes, streams, and wetlands, may play a role in both recharge to and discharge from unconfined aquifers, and the function may vary from season to season (Dunne and Leopold 1978, Winter et al. 1998).

Changes in groundwater recharge and withdrawal of water by wells is the primary means of reducing groundwater quantity.

2.3 CARA POTENTIAL PROTECTION MEASURES

Protecting CARA functions and values requires the following: (Morgan 2005)

- Identifying where groundwater resources occur
- Classifying the risk potential by area
    - Determining how susceptible the groundwater resource is to potential contamination
    - Identifying and quantifying the potential sources of contamination (contamination loading)
    - Assessing the vulnerability of the water resources
- Planning Oversight
    - Protect those areas and land use and activities that pose risks to the resource
    - Ensure that protections are enforced
    - Manage withdrawals to maintain future supply for both drinking water and for streams and wetlands

CARA Identification

Identifying CARAs involves 1) identify aquifers used for potable water, and 2) identifying the areas that recharge those aquifers. CARA mapping was last updated in the 2014 Covington Comprehensive Plan (see Figure 7.4 of Appendix A).

For public water supply wells, much of this work has already been done under the Safe Drinking Water Acts Source Water Assessment Program, which identifies wellhead protection zones, determines the susceptibility of the well to contamination, and inventories contamination sources within the protection zone. Public water supply wells and their protection zones are identified by both the Washington State Department of Health Source Water Assessment Maps and Department of Ecology Facility/Site Atlas (see References for websites). WDOE requires well logs for all wells drilled in the state, and maintains a map of the location of each well logged (see WDOE, Well Logs in Section 7 for web address). While well logs are required for all wells in the state, there are some older wells that were not logged. In some instances, a well log may not reflect the proper well location. Well logs are mapped as a point in the center of the reported quarter section (A quarter-section is a 40-acre square). Assuming that the well driller reported the correct quarter section for the well, the actual well location may be anywhere within that 40-acre area.

The most reliable way to map recharge areas is to examine well logs, geologic mapping for the area, and water levels in wells and use that data to map regional water levels or piezometric surfaces. The City of Covington has well logs, geologic mapping, and water level data for the public water supply wells used by the Water Districts.

Classification of Potential Risk

Classification of CARAs is typically achieved by combining the susceptibility of the aquifer with the contaminant load in the recharge area. Susceptibility refers to how easily a contaminant can make its way to the aquifer, while contaminant load refers to the quantity and type of contaminants in the CARA and how likely it is for such contaminants to enter the ground.

Wellhead protection zones are defined as areas where a spill incident could result in contamination of the well within a specified time period, ranging from 6 months to 10 years. These time-of-travel zones are mapped, though with varying levels of accuracy. Some are mapped using groundwater modeling programs, while others are mapped by simply drawing circles of varying size around the wellhead.

King County has mapped groundwater susceptibility to contamination. Areas within the County are mapped as one of three categories:

1) *Category I critical aquifer recharge areas include those mapped areas that King County has determined are highly susceptible to groundwater contamination and that are located within a sole source aquifer or a wellhead protection area.*
2) *Category II critical aquifer recharge areas include those mapped areas that King County has determined:*
    - *have a medium susceptibility to ground water contamination and are located in a sole source aquifer or a wellhead protection area; or*
    - *are highly susceptible to ground water contamination and are not located in a sole source aquifer or wellhead protection area.*
3) *Category III critical aquifer recharge areas include those mapped areas that King County has determined have low susceptibility to groundwater contamination and are located over an aquifer underlying an island that is surrounded by saltwater.*

This mapping can be viewed on King County's iMap system at the website listed in Section 7 (King County iMap/Groundwater): http://www5.kingcounty.gov/iMAP/viewer.htm?mapset=GroundWater.

King County mapping of CARA considers the susceptibility of groundwater, as well as the location of wells. This information, when supplemented with well location data from WDOE and the Department of Health can help to identify where nonpublic wells are and how susceptible they might be to contamination. Zoning, business licenses, and WDOE data on existing pollution prevention plans can provide estimates of contamination loading.

Classifying the vulnerability of CARAs can be done in several different ways. For example, two methods suggested by WDOE (2005) include categorization by susceptibility alone and categorization by priorities and risk.

Categorization by susceptibility has the advantage that it can be accomplished through use of geologic mapping, soil mapping and well data, all of which are publically available. Once classified, decisions can be made to determine what activities should be allowed and what protections should be put in place for each category, regardless of the contaminant loading of the area. Such a categorization system might include the following categories, in order of decreasing susceptibility:

1. Water table sand and gravel aquifers
2. Deeper, less susceptible aquifers
3. Confined aquifers

A more targeted categorization system based on priorities and risk would assess what wells are the most important and provide the best protection for aquifers; travel time for contaminants could be used as a basis for the protection area. For example, such a prioritized list might include the following categories:

- Large public water supply systems one-year time of travel protection zone
- Densely populated areas that rely on ground water
- Medium public water supply system protection zones
- Rural areas with high dependence on groundwater
- Discontinuous local drinking water of limited extent
- Sole source aquifers.

Based on the above considerations, Critical Aquifer Recharge Areas (CARA) in Covington could be defined along the northeast and southern riparian corridors (Big Soos and Jenkins Creek) to protect shallow groundwater recharge and unconfined aquifer discharge to streams, lakes, and wetlands. In these areas, the soils are permeable and groundwater is often perched and closer to the surface. These areas could be mapped as Category II Critical Aquifer Recharge Areas. Except in a few cases, these sources are not used for potable water supplies in areas served by one of the water districts.

Although some CARA are mapped near the city limits in earlier drafts of the Covington Comprehensive Plan, they reflect mapping provided by King County for several adjacent CARA and wellhead protection areas (Aspect Consulting, 2008; Hart Crowser, 1996). These boundaries consider soil conditions and local groundwater recharge to streams and tributaries. The deeper aquifers (generally greater than 100 feet) used by the water districts in Covington are moderately to slightly susceptible to groundwater contamination from surface sources due to stratified glacial tills with low permeability below the surface, confined hydrostatic pressures, and general groundwater discharge conditions. There are no designated sole source aquifers in the Covington area (EPA, 2015). Category II CARA designations for local groundwater recharge to streams, tributaries, lakes, and wetlands could be used to protect water quality and quantity for associated environmental benefits although they are not generally used for Class A potable water supplies.

Planning and Regulatory Oversight

WDOE (2005) recommends that local jurisdiction consider prohibiting certain high risk uses in high-priority CARAs. Such uses may include landfills, wood treatment facilities, metal plating facilities, tank farms, and any other facilities that treat, store, use, or transfer large quantities of chemicals. Moderate to low risk facilities may be acceptable in high-priority CARA's, provided that adequate pollution prevention plans and practices are in place and properly maintained, with appropriate contingency plans for emergency situations.

Water rights require regulation of the amount of water withdrawn from an aquifer, but several exemptions exist (RCW 90.44.050), including;

- Water for livestock
- Water for non-commercial lawn or garden one-half acre or less
- Water for a single or group of homes, up to 5,000 gallons per day

- Water for industrial purposes, including irrigation, up to 5,000 gallons per day

3.0 FLOOD HAZARD AREAS

Frequently flooded areas are regulated to manage potential risks to public safety. Such areas also provide valuable fish and wildlife habitat benefits, both in-stream and downstream as well.

Criteria for identification and classification of frequently flooded areas are provided in WAC 365-190-110:

"Frequently flooded areas. Flood plains and other areas subject to flooding perform important hydrologic functions and may present a risk to persons and property.

1) Classifications of frequently flooded areas should include, at a minimum, the 100-year flood plain designations of the Federal Emergency Management Agency (FEMA) and the National Flood Insurance Program (NFIP).
2) Counties and cities should consider the following when designating and classifying frequently flooded areas:
    (a) Effects of flooding on human health and safety, and to public facilities and services;
    (b) Available documentation including federal, state, and local laws, regulations, and programs, local studies and maps, and federal flood insurance programs, including the provisions for urban growth areas in RCW 36.70A.110;
    (c) The future flow flood plain, defined as the channel of the stream and that portion of the adjoining flood plain that is necessary to contain and discharge the base flood flow at build out;
    (d) The potential effects of tsunami, high tides with strong winds, sea level rise, and extreme weather events, including those potentially resulting from global climate change;
    (e) Greater surface runoff caused by increasing impervious surfaces."

Frequently flooded areas are important to identify and protect, both because they present flood hazards and because they perform valuable hydrologic and habitat functions.

3.1 FLOOD HAZARD AREAS IN THE CITY OF COVINGTON

Flood hazard areas are identified by FEMA in a preliminary Flood Insurance Rate Map (FIRM) within the City of Covington; however, the preliminary FIRM has not yet been adopted. Flood hazards are mapped in Figure 7.3 of the 2014 Covington Comprehensive Plan (see Appendix A). The preliminary FIRM identifies a 100-year floodplain along Big Soos Creek, Little Soos Creek, and the lower reaches of Jenkins Creek, and floodway along Big Soos Creek.

The city is affected by both riverine flooding and urban flooding, with low-lying areas particularly susceptible. Flood events are most common from November through April, typically occurring when storms move in from the Pacific, dropping heavy precipitation in the region. Properties in and near the floodplains of Covington are subject to flooding almost annually, and urban portions of the city annually experience nuisance flooding related to drainage issues. Large floods that can cause property damage typically occur every three to five years, and are usually the result of heavy rains of two-day to five-day durations augmented by snowmelt at a time when the soil is near saturation from previous rains. Approximately 10 to 20 percent of all flood-related damage from past floods in Covington has been located along small creeks and drainage areas susceptible to manmade flooding, which are outside of the FEMA-mapped flood hazard areas (Tetra Tech 2014). See Figure 9.2 from the 2014 Hazard Management Plan in Appendix A.

Flooding in the city's natural drainage basins becomes a problem when human activities infringe on the natural floodplain. According to the city's Hazard Mitigation Plan (Tetra Tech 2014), 25 structures lie within the city's 100-year floodplain and 26 lie within the 500-year floodplain. In the 100-year floodplain, 84 percent are residential and 16 percent are commercial. Approximately 32 percent of parcels in the 100-year floodplain are currently vacant or public park spaces, but the vast majority are zoned as urban separator or medium density residential and allow for future development.

3.2 FLOOD HAZARD AREAS FUNCTIONS AND POTENTIAL EFFECTS OF DEVELOPMENT

Floodplain Processes

Floods are natural events, and the process by which floodplains are created. As a rule of thumb, a typical stream in equilibrium with its surroundings will tend to be sized so that it fills to the top of the banks about once per year (Leopold 1994). As a result, when the stream flow is greater than the annual event, water will spill over the top of the banks. Streams carry sediment along with water, especially during flood events, and the amount of sediment that can be carried is a function of the quantity and velocity of the water. When water overflows the banks, its velocity slows compared to the water in the channel. As a result, the overbank flow drops its sediment load, which, over time, forms a floodplain (Dunn and Leopold 1978, Knighton 1998).

Floodplains are dynamic and highly productive environments. Dynamic hydrologic processes, including mobilization of large woody debris and other allocthonous inputs, can be critical to the maintenance of fish and wildlife habitat (Naiman and Decamps 1997, Gurnell 2005). High flow channels carved into floodplains provide important habitat for a variety of fish species, particularly in creating areas of refuge from the high flows. Overbank flow serves as a short-term storage area for streams, helping to reduce the peak flood flows downstream of the flooding location. Some of the water on the floodplain infiltrates into the soil and contributes to aquifer recharge. According to the Washington State Department of Ecology such storage and infiltration may be a more cost effective way to address flooding problems than other structural solutions (WDOE 1991).

Effects of Development

Stream health, floodplain functions, and patterns of urban development are all inter-related. Development in and upstream of frequently flooded areas can have a negative impact on floodplain functions, both to the area itself and to the development in and around the area. Total impervious surface within a basin, patch size of impervious surfaces and forest land, and the number of road crossings all affect watershed-scale processes.

Urban environments are characterized by increased runoff to streams, as undetained flow from impervious surfaces increase the magnitude and frequency of peak flow events. As development occurs, stream channels are often straightened and armored to accommodate development within the urban grid (Booth 1990). Flood protection measures, such as levees and dikes, may be built or maintained to protect structures and property in the floodplain from flooding events. These alterations impact floodplains and in some cases, disconnect them entirely from the stream they once served.

Increased impervious surfaces from buildings, driveways, roads, and the conversion of forest to lawn cause increases in peak flow magnitude and frequency (Booth 2002). These increases in surface water flow tend to scour or down-cut stream channels, which reduces floodplain connectivity and functions.

(Bolton and Shellberg 2001). Such downcutting can, in some areas, lead to bank over-steepening, exacerbate erosion problems, and even increase the risk of landslide hazard. The stress on the bed of a stream caused by flow is a function of the flow velocity and the weight of the water pressing down on the bed, so as flow depths increase, the stress on the bed of the channel increases, and the channel downcuts. As the channel downcuts, the depth of the flow before it spills over the bank increases, which in turn increases the stress on the bed of the creek, setting up a negative feedback mechanism in which the more a stream downcuts, the more able it is to erode the bed. As a result, downcutting often continues until some other factor comes into play to stop it, such as the channel cuts down to a less erosive material (dense clay or rock), or is halted by woody debris, or some gradient control like a downstream culvert prevents further downcutting. Such downcutting can lead to bank over-steepening. This can exacerbate erosion problems in erosion hazard areas, and may also increase the risk of landslide hazard on a marginally stable slope (Booth 1990).

Total impervious surface area is commonly used as a measure of urbanization in a basin, which impacts stream and floodplain ecology. Increased impervious area is correlated with decreased stream health. As noted by Booth et al. (2004), stream environments are complex and integrated management of these resources requires more detail than total impervious area figures alone provide. A study of the impact of urban patterns on aquatic ecosystems in the Puget lowland sub-basins found statistically significant relationships between landscape patterns and stream health. In that study, the mean patch size of urban land cover and the number of road crossings were found to explain variability in stream health better than total impervious area alone. Patterns of urban development are relevant to watershed functions and both increased impervious surface area and its aggregation or patch size directly impact stream ecosystems (Alberti et al. 2006). Hydrology of urban streams is often typified by runoff-driven increases to peak flows and higher recurrence of flood intervals (Booth 1990).

Climate Change

It is now generally accepted that anthropogenic global climate change is occurring. Climate models project annual temperature increases totaling 2.0 degrees Fahrenheit by 2020 and 3.2 degrees Fahrenheit by the 2040s (Mote and Salathe 2010). Global climate change is projected to impact climatic variation and natural resources in the Pacific Northwest. A reduction in regional snowpack, a subsequent reduction in summer water supply, and hardships for salmon and forests are expected to pose a challenge to natural resource management (Mote et al. 2003). Seasonal changes in the Pacific Northwest are projected to entail wetter autumns and winters and drier summers (Mote and Salathe 2010). As a result, increased precipitation in autumn and winter may result in more frequent flood events.

3.3 FLOOD HAZARD AREAS POTENTIAL PROTECTION MEASURES

Frequently flooded areas are regulated to reduce the risk to people and property, typically by limiting development, requiring that structures be raised above flood levels, and requiring compensatory storage for any fill within the frequently flooded area (FEMA 2013, King County 2004, ASFPM 2003). Because frequently flooded areas often coincide with other critical areas, such as streams, wetlands, and aquifer recharge areas, protecting frequently flooded areas may also contribute to protection of other functions, including habitat and water quality (Bolton and Shellberg 2001).

Most current floodplain management strategies are premised on “no net impact” or “no adverse impact” (ASFPM 2003). Under such a strategy, the actions of one floodplain property owner does not adversely affect the flood risk of other property owners in terms of flood stage, flood velocities, increased flow volumes, or increased erosion risk. Regulatory actions to help achieve this goal include compensating for lost floodplain storage due to development and requiring no net increase in flood elevations. These strategies can be most effective at protecting not only development, but the natural processes of floodplains when they are combined with structural solutions such as setting back existing levees and reconnecting disconnected side channels.

The city uses building codes, zoning codes, and other planning strategies to restrict development in areas of known hazards. The city's existing critical areas regulations prohibit all development in the floodway. Development in the floodplain cannot raise the base flood elevation, and all habitable floors must be at least one foot above base flood elevation. The city's Hazard Mitigation Plan (Tetra Tech 2014) identifies a number of flood hazard mitigation initiatives, which include programmatic initiatives, such as converting from emergency participation status to the regular NFIP once floodplain maps have been adopted by FEMA, as well as projects to reduce localized flooding, such as evaluating, prioritizing, and replacing culverts that contribute to flooding problems.

Within the Puget Sound area, participation in the NFIP also entails a responsibility for jurisdictions to address floodplain functions and processes to ensure protection of listed species, including threatened salmonids and southern resident killer whales. Where development occurs in mapped floodplain areas, habitat assessments must evaluate impacts to stormwater, floodplain capacity, and vegetative habitat.

4.0 GEOLOGICALLY HAZARDOUS AREAS

According to RCW 36.70A.030(9) and WAC 365-190-120, Geologically Hazardous Areas are "those areas that are susceptible to erosion, sliding, earthquake, or other geological events and are not suited to the citing of commercial, residential, or industrial development consistent with public health and safety concerns". The four main types of geologically hazardous areas recognized in the GMA are 1) erosion hazard areas, 2) landslide hazard areas, 3) seismic hazard areas, and 4) areas subject to other geologic evens such as coal mine hazards and volcanic hazards.

Whereas the goal with most other GMA mandated critical areas is to protect a valued ecological resource, the purpose of regulating activities in geologically hazardous areas is to protect the public from the hazard. These areas are subject to periodic events that can result in property damage, injury and the loss of life. Human activity in these areas can pose a safety concern, and, in some cases, may actually increase the potential for a hazardous event. Such hazard events have the potential to affect not just one property, but also the neighboring properties. For example, improperly clearing a parcel in a sloping landslide area may increase the potential for a landslide that could damage not only the cleared property, but also the neighboring properties above and below it. Therefore, it is important to identify where such hazard areas are, and to ensure that activities and development in those areas is appropriate.

GMA Guidelines indicate that "Some geological hazards can be mitigated by engineering, design, or modified construction or mining practices so that risks to health and safety are acceptable" [WAC 365-190-080(4)]. However, the same section of the code also states that "When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided."

Steep slopes and other geologically hazardous sites that pose an erosion, landslide or seismic hazard should be included in critical area regulations to reduce potential risks to public health and safety. Mass wasting events can also be detrimental to habitat, particularly in-stream habitat. Landslide hazards include areas with all three of the following characteristics: slopes steeper than 15 percent, hillsides intersecting geologic contacts with relatively permeable sediment over relatively impermeable sediment or bedrock, and springs or groundwater seeps. Any areas where the slope is "40 percent or steeper and with a vertical relief of ten or more feet except areas composed of consolidated rock" is also deemed a steep slope that poses a landslide hazard (WDC 2003 and WAC 365-190-120).

Because the goal of identifying geologically hazardous areas is to protect human life and property, avoidance is often the best option. However, structural and engineering solutions can help to mitigate such hazards, if done appropriately and if properly maintained. Thorough geotechnical analysis and engineering design is critical to achieve such mitigation. Such analysis should include an assessment of the property in question as well as the properties surrounding the site. Also, since geologically hazardous areas are often interconnected, such analysis should include all the hazards likely to affect the site. For example, in a landslide hazard area on a slope above a creek, a proper analysis should include an assessment of the neighboring properties, as well as all the properties above and below the site on the slope, and should include an assessment of the potential for erosion from the creek at the bottom of the slope, as well as an assessment of the seismic stability of the site and the proposed structure.

It should also be mentioned that, unlike some other critical areas, off-site mitigation with respect to geologically hazardous areas is not feasible.

4.1 GEOLOGICALLY HAZARDOUS AREAS IN THE CITY OF COVINGTON

Geologically Hazardous Areas include areas of erosion hazard, landslide hazard, seismic hazard, and volcanic hazard. Unlike most other critical areas, the goal of regulating geologically hazardous areas is to reduce the risk of harm to people or property that are associated with such areas, rather than to protect those areas from being harmed or degraded.

The City of Covington Hazard Mitigation Plan (HMP)(Tetra Tech 2014) includes analyses and mapping of earthquake and liquefaction, landslides, and volcanic hazards in the city. These geologic hazardous areas are mapped in Figures 8-2 through 8-9 of the 2014 Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A). As noted in this plan:

- The City of Covington is in an area of King County that is less vulnerable than surrounding areas to extensive damage from earthquakes and most of the city is on soils (Alderwood and Everett series) with low to very low susceptibility to liquefaction (King County Soil Maps). Known peat deposits and areas of deep organic soils are generally protected in wetlands. Seismic hazards are shown in Figures 8-2 through 8-7, and 8-9 (see Appendix A). Covington is about 35 miles from the Seattle Fault (Blakely and Johnson, 2002) and is not likely to experience ground ruptures from a seismic event along the fault (Keefer, 1983).
- Soils in the City of Covington generally have a low risk of liquefaction. Liquefaction occurs when soil behaves like liquid, causing damage to pipes, roads, and buildings. Liquefaction susceptibility in the city of Covington is mapped in Figure 8-8 of the 2014 Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A).

- Except for slopes along a northeast reach of upper Big Soos Creek, Covington has few areas prone to landslides. Ninety-Six percent (96%) of landslide risk areas in Covington are in public parks or nonresidential areas. Landslide hazards are shown in Figures 10.5 and 10.6 of the 2014 Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A).

- Covington is outside the probable zones of lava and pyroclastic flows, as well as lahars, from potential eruption of the nearest volcano (Mt. Rainier, about 40 miles SE of the city). The city could be affected by ash fall.

4.2 GEOLOGICALLY HAZARDOUS AREAS FUNCTIONS AND POTENTIAL EFFECTS OF DEVELOPMENT

Erosion

Erosion is part of the natural dynamic that builds floodplains and beaches, enables channel migration on rivers and streams, and facilitates the recruitment of woody debris into streams and other bodies of water. Erosion occurs when wind, streamflow, waves or even ice move particles from where they had previously rested. Material that is transported via erosion is carried with the flow of the medium that caused the erosion until that medium no longer has sufficient energy to carry the material, at which point the material is deposited.

Erosion and deposition are natural processes for both streams and beaches, and the flora and fauna that use such areas are generally adapted to a certain level of erosion and deposition. However, excessive erosion, and resulting excessive deposition, can be harmful to stream channels, shorelines, and the plants and animals that use them. Erosion hazards are commonly associated with steep slopes and are located primarily along Big Soos Creek in Covington. Because the hazards are located in riparian areas on shorelines, they are addressed in the Shoreline Management Act, Master Program for Covington. Erosion is one of the primary mechanisms for recruiting large woody debris to streams, and in Western Washington, such debris is highly beneficial to salmonids and other aquatic species. However, erosion also produces fine sediment, which can deposit in the gravels that many fish species use to spawn, causing eggs to suffocate and die (Nelson and Booth 2002).

In an urban setting, erosion can become a hazard when structures are placed in areas susceptible to erosion, or land use actions cause formerly stable areas to begin eroding. Urban development such as parking lots, roads and buildings, prevent rain from infiltrating into the soil, generating more rapid runoff from the land into nearby streams and rivers. This results in an increase in peak flow volumes in the streams, which in turn produces higher energy and increases the potential for streambank erosion (Booth 1990, Booth 1991, Nelson and Booth 2002).

Erosion Hazard is the susceptibility of the land to the prevailing agents of erosion (Houghton and Charman 1986). The magnitude of the hazard is determined by a variety of factors, including the soil type, topography, vegetation, rainfall patterns, and basin-wide land use and development patterns. Erosion hazard areas include areas likely to become unstable, such as bluffs, steep slopes, and areas with unconsolidated soils (WAC 365-190-120).

The hazard from erosion-prone areas includes direct damage as a result of the erosion as well as increased risk from landslide as a result of erosion. During storm events and under other extreme conditions, erosion can happen very rapidly, putting at risk any structures located in the area being eroded, and potentially risking injury or death to people using such structures at the time of erosion (Booth 1991).

Removal of vegetation can also contribute to increased erosion potential in susceptible areas. Vegetation intercepts rainfall, preventing a significant portion of rainfall from reaching the ground where it can cause erosion (Watson and Burnett, 1995). In cleared areas, the impact of rain drops can initiate the erosion process, freeing small particles to be carried downslope. As water accumulated on the ground, it tends to concentrate in small channels, and as the water gains in depth and volume, larger particles can be mobilized by the flow. In this way, small channels or rills can eventually develop into gullies.

Significant erosion in the region is typically limited to those areas where runoff has been concentrated by human activity or where vegetation has been removed from erodible soils. Vegetation reduces erosion by preventing a significant amount of rainfall from reaching the soil and physically binds the soil together with root materials (Booth et al. 2002, Niaman and Decamps 1997).

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Landslides

Landslides include a wide variety of processes that involve the downward and outward movement of slope-forming material by sliding, toppling, falling, or spreading (USGS 2004). In most cases, landslides deliver material from the hillslopes into streams and rivers. Trees that are involved in the landslide often end up being delivered to these streams, rivers, and beaches, where they become important habitat. Such large woody debris provides nutrients, shelter and shade, while helping to stabilize stream channels, and ultimately beaches.

Areas prone to landslides are commonly slopes comprised of relatively permeable materials, such as sand and gravel, over a less permeable material, such as bedrock or clay (USGS 2004; Varnes 1978). Water that infiltrates through the upper soil layer, but cannot penetrate the lower layer as quickly, it builds up at the interface between the two layers (Menashe 1993). This water adds weight to the slope and causes a loss of cohesion, which allows the slope to fail. Slope stability in Covington is mapped in the Hazard Mitigation Plan (Tetra Tech 2014)(see Figure 10-6 in Appendix A.)

Landslide hazard areas are described in the WAC (365-190-120) and shown on Figure 10-5 in the 2014 Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A).

> *Landslide hazard areas include areas subject to landslides based on a combination of geologic, topographic, and hydrologic factors. They include any areas susceptible to landslide because of any combination of bedrock, soil, slope (gradient), slope aspect, structure, hydrology, or other factors, and include, at a minimum, the following:*
>
> 1) *Areas of historic failures, such as:*
>   a. *Those areas delineated by the United States Department of Agriculture Natural Resources Conservation Service as having a significant limitation for building site development;*
>   b. *Those coastal areas mapped as class u (unstable), uos (unstable old slides), and urs (unstable recent slides) in the department of ecology Washington coastal atlas; or*
>   c. *Areas designated as quaternary slumps, earthflows, mudflows, lahars, or landslides on maps published by the United States Geological Survey or Washington department of natural resources.*
> 2) *Areas with all three of the following characteristics:*
>   a. *Slopes steeper than fifteen percent;*
>   b. *Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock; and*
>   c. *Springs or groundwater seepage.*
> 3) *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 this epoch;*
> 4) *Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials;*
> 5) *Slopes having gradients steeper than eighty percent subject to rockfall during seismic shaking;*
> 6) *Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action, including stream channel migration zones;*

7) *Areas that show evidence of, or are at risk from snow avalanches;*
8) *Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding; and*
9) *Any area with a slope of forty percent or steeper and with a vertical relief of ten or more feet except areas composed of bedrock. A slope is delineated by establishing its toe and top and measured by averaging the inclination over at least ten feet of vertical relief.*

Landslides can occur in a variety of different ways, from fast to slow, and deep to shallow, originating from the bottom of a slope or the top of a slope, or somewhere in between. A variety of classification schemes have been used to describe landslides. The classification by Varnes (1978) is likely the most widely used, and classifies slides by the type of movement and the material involve. A more simple classification, uses three basic types of landslides common to this area: 1) Rapid-Shallow, 2) Block Fall, and 3) Deep-Seated (King County 2004). As the names imply, a rapid-shallow landslide is one that does not extend deeply into the ground, and usually moves quickly down a slope. This is the most common type of landslide in the Puget Sound region, where the glacial deposits often result in surface layers that are more permeable then the deeper layers, causing water to build up on the interface between the two layers. The weight and pressure from the water causes the upper layer to fail, and slide over the deeper, more resistant layer. Block falls are common where erosion is occurring at the toe of a slope, either through wave energy or streamflow. As the toe is over-steepened, at some point the slope above the toe becomes unstable and the entire slope collapses as more-or-less a single unit. Deep-seated landslides are generally larger than the other types of landslide, and involve one or more large blocks of both soil and the underlying substrate moving together. Such slides can move extremely slowly, taking years, decades or longer to reach equilibrium. However, even moving slowly, such deep-seated landslides can cause significant damage to structures.

Activities associated with urban development, including vegetation removal, and increased impervious surfaces, can increase the landslide hazard of susceptible areas. Vegetation plays a significant role in landslide potential by intercepting a substantial amount of rainfall, preventing it from infiltrating into the soil. Roots from vegetation also take up and transpire some of the water that does reach the soil (Watson and Burnett 1995). This reduces the amount of water that rests on the interface between the permeable and impermeable layer. A dense matrix of roots can also lend considerable strength to the soil on a slope (Schmidt, et al. 2001), decreasing the likelihood of slope failure and shallow-rapid landslides.

The hazard associated with landslide prone areas includes damage to structures on the unstable slope, at the bottom of the slope where the material from a landslide deposits, and at the top of the slope that may be destabilized by the slide. During faster land sliding events, the danger of personal injury or death can be significant.

In addition to personal and property damage, landslides may have an adverse effect on plants and animals in the vicinity. Landslides, like erosion, are a natural phenomenon that is relatively common in the Pacific Northwest, and the flora and fauna of the region is adapted to landslides to a certain extent. However, persistent slides and an overabundance of slides can be harmful to a number of species. For example, landslides that produce abundant fine sediment can be damaging to fish that spawn in streams that receive the fine sediment.

Seismic Hazard Areas

Seismic Hazard areas have a risk of damage as a result of ground shaking, slope failure, settlement or subsidence, soil liquefaction, surface faults or tsunamis that are caused by an earthquake. Ground shaking is the primary cause of earthquake damage in Washington, and can cause the ground to settle (Langston and Lee, 1983). The strength of ground shaking is primarily affected by the magnitude of the earthquake, the distance from the source of the earthquake, the type or thickness of the surface materials, and the type of geologic structure affected (Stover and Coffman 1993, WAC 365-190-120 (7)). Seismic hazard areas in the City of Covington are shown on Figure 7.8 of the city's 2014 Comprehensive Plan (see Appendix A).

Western Washington is part of the "Ring of Fire", a series of tectonic plate boundaries that more or less outlines the Pacific Ocean. Where tectonic plates meet, they do one of three things: converge, diverge, or slide past each other laterally. In Western Washington, the last remnant of the Juan de Fuca plate is converging with the North American plate. The Juan de Fuca plate is an oceanic plate, while the North American plate is a continental plate. Oceanic plates are made of more dense material than continental plates, and where the two types of plates converge, the oceanic plate is driven under the continental plate. Such is the case in Western Washington, part of the Cascadia Subduction Zone, defined as the area affected by the subduction of the Juan de Fuca plate under the North American plate. This subduction is the primary driver of seismic activity in the Pacific Northwest.

Subduction zones are responsible for most of the largest magnitude earthquakes, including the 2011 Tohoku earthquake in Japan, (9.0 magnitude), the Alaskan earthquake in 1965 (9.2 magnitude) and Great Chilean earthquake of 1964 (9.5 magnitude). In the book *The Orphan Tsunami of 1700*, Brian Atwater, et al. (2005) provides evidence that a Cascadia subduction zone earthquake occurred on January 26, 1700 and was, per his estimate, in the 8.7-9.2 magnitude range. The precision of the date stems from records of a tsunami in Japan that was caused by the quake. There is geologic evidence for 13 or more of these "great quakes" in the Cascadia subduction zone, occurring at intervals ranging from 300-900 years apart.

In addition to these "great quakes", lesser, but still potentially damaging quakes occur in the region on a more frequent basis, including the 2001 Nisqually quake and the 1965 Olympia quake. These and other, smaller earthquakes are associated with smaller faults that occur in the Puget Sound region. One such fault is the Southern Whidbey Island Fault Zone (SWIFZ). USGS mapping indicates the SWIFZ extends southeastward beneath the mainland and between Seattle and Everett. Paleoseismological evidence indicates that the SWIFZ has produced four earthquake events since deglaciation (approximately 16,400 years ago) (Sherrod et al. 2005). Smaller earthquakes and their shallower depth can produce a great deal of ground motion, especially on susceptible soils.

In an earthquake, all the ground can be expected to move, but ground shaking is typically worse in areas where unconsolidated sediment, either naturally deposited (i.e. river sediments) or artificial, is present (Gerstel et al. 1997). The thickness of such layers may also play a role in the amount of motion that the area experiences. In some cases, the frequency of the earthquake waves may create a resonance in a sediment layer of the proper thickness, creating greater ground motion in a localized area than in other nearby areas where the layer is more or less thick and resonance does not occur. Similarly, underlying geologic structures may serve to focus earthquake seismic waves, depending on depth and frequency (Langston and Lee 1983).

Depending on the type of earthquake and the relative motion of the ground, movement along the faults can lead to subsidence and/or uplift along the fault line. During the 1964 Alaska earthquake, parts of the Gulf of Alaska were uplifted by 11 meters (36 feet) while other areas subsided by over 2 meters

(Stover and Coffman 1993). Surface faulting is when movement along a fault causes a rupture in the ground surface. Such faulting can destroy buildings, make roads impassable, and sever underground utilities, including gas, electric, water, sewer, and communications. These utilities problems can lead to fires, flooding, sink holes, and contamination.

Ground shaking can also cause a number of different types of ground failure, including landslides, soil liquefaction, and settling (Keefer 1983). Landslides can be triggered when a marginally stable slope is subjected to ground shaking. Liquefaction occurs when saturated, loose, sandy soil is subjected to shaking. Shaking causes the loose, sandy soil to compress, and if it is saturated (i.e. water fills all the spaces between soil particles), the water is displaced by the compressing particles and forced upwards. Under normal conditions, soil particles are in direct contact with each other, and that contact is what makes the soil capable of supporting a load like a building. But when liquefaction occurs, the pressure from the upward-migrating water breaks the contact between the soil particles, and the strength of the soil is lost, such that it behaves more like a liquid than a solid. Any buildings that rely on the soil for support (as opposed to pilings or other engineered structure) can essentially sink into the soil like quicksand. Where soils are not saturated, the compression can still lead to settling, which can break utility lines and, if such settling occurs unevenly under a building, may cause the foundation to break, or in severe instance, may cause the building to fail.

Seismic hazards include both direct and indirect personal and property damage from earthquakes. Direct damage can vary from the relatively minor, such as broken glass, overturned furniture, and damage to brickwork (chimneys tend to be particularly vulnerable due to their height and narrow cross-section) and foundations to complete collapse of structures. Those areas where soils and underlying geology would increase the magnitude of ground shaking would experience more severe damage. Ground shaking may also increase the hazard of landslide hazard areas by destabilizing marginally stable slopes, especially if the quake hits during or after a winter storm even when soil saturation levels peak. Indirect damage can include fires triggered by broken gas and/or electric lines, loss of information from severed data lines, flooding from broken water lines, contamination and illness from leaking sewer lines, etc.

Other Geologically Hazardous Areas

Other geologically hazardous areas include areas subject to potential volcanic hazards, and areas where old coal mines may pose a hazard, per WAC 365-190-120 (8).

Volcanoes

Volcanoes in Washington are the result of the subsidence of the Juan de Fuca plate under the North American continent. As the oceanic plate is forced under the continental crust, heat from the earth begins to melt the rock, starting with those minerals with the lowest melting point, such as quartz and feldspar. This melted material is less dense than the surrounding material and rises upward, and where it can reach the surface, a volcano is formed.

There are five Cascade volcanoes – Mt. Adams, Mt. St. Helens, Mt Rainer, Glacier Peak, and Mt. Baker. Of these, Mt Rainier is in closest proximity to Covington at approximately 35 miles. Frequency of volcanic eruptions for volcanoes in the region is documented in Figure 12-1 of the Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A). Lahars, which are mudflows or debris flows caused by the rapid melting of mountain snow from a volcanic eruption or other volcanic activity, have historically traveled similar distances – along the Green River from Mt. Rainier, and along the Sauk and Skagit rivers from Glacier Peak. However, lahars are driven by gravity, and flow along the lowest ground. Pyroclasitc flows and debris avalanches occur only within close proximity to their source, and are therefore not a significant hazard in Covington.

Volcanic hazards can include pyroclastic flows, debris avalanches, debris flows, tephra fall (fine tephra fall is commonly referred to as ash), and flooding associated with volcanoes. The probability of tephra accumulation in the Pacific Northwest is mapped in Figure 12-2 of the Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A). During the explosive eruptions typical of Cascade volcanoes, hot, pressurized volcanic gasses released by an eruption carry rock and ash into the air. As the energy that carried the material upward dissipates, the particles begin to fall back to the ground, with the larger particles falling first and closest to the volcano, and the smaller particle being carried farther with the wind before depositing; this material is called tephra fall. The result is a thick deposit of coarse material nearest the site of the eruption, grading to thinner and finer deposits as the distance from the volcano increases (Wolfe & Pierson, 1995).

The only volcanic hazard likely to be experienced within Covington is tephra fall or ash. The major hazard potential from tephra fall are the impact from falling material, burial of structures and pathways, and the presence of abrasive materials in the air and water. Given the distance between Covington and any Cascade volcanoes, the impact potential is negligible, since larger particles fall nearest the volcano, and burial of structure would require a very severe eruption, since the depth of tephra decreases with distance from the volcano. However, volcanic ash can be problematic up to several hundred miles downwind of its source, causing eye and respiratory irritation, damaging engines on airplanes, automobiles, trucks, and trains, reducing visibility, and potentially short-circuiting power transmission lines (WMD 2012). Such problems can occur during the initial ashfall, and later as wind and/or vehicles re-suspend ash particles. Additionally, wet ash on buildings can be heavy enough to cause roof damage or even collapse (Wolfe & Pierson, 1995). Ash suspended in water can also damage sewer treatment facilities.

4.3 GEOLOGICALLY HAZARDOUS AREAS POTENTIAL PROTECTION MEASURES

Geologic hazard areas can potentially damage property and/or cause injury or death. Unlike other critical areas, where the potential impact is to a resource that is valued and being protected, with geologic hazards, the goal is to protect people and property from potential damage associated with the area.

A variety of measures can be taken to protect property and people from geologically hazardous areas. Careful planning and engineering can help to reduce the magnitude of, and maybe even prevent, certain erosion and landslide events from happening. Unfortunately, there is as yet no known way to prevent earthquakes or volcanic events, and even predicting such events is still a very imprecise endeavor. However, while such events cannot be prevented, the amount of damage that the events are likely to cause can be reduced or eliminated with proper planning and preparation. Identifying and mapping potential hazard areas is an important first step in developing protection measures.

Erosion Hazard Areas

Erosion Hazard Areas can be protected by promoting sound development practices. Temporary Erosion and Sedimentation Control (TESC) Plans and their associated Best Management Practices (BMPs) can be effective at preventing erosion associated with construction and grading activities in erosion hazard areas. According to WDOE, typical BMPs are temporary and permanent seeding, protecting areas of exposed soil, slowing down runoff velocity, and trapping sediment through the use of straw bales, temporary ponds or silt fences.

Vegetation management is also an important component, since vegetation provides a good deal or protection against erosion (Fredricksen and Harr 1981, Gray and Sotir 1996, Menashe 1993). Vegetation protects soil on slopes from falling water, while the roots provide mechanical strength to the soil. On stream banks and shorelines, this root strength can protect against shear stress from waves and flow.

Development that concentrates flows or creates higher peak flows than in the pre-developed condition are likely to make erosion hazards more severe. This can be a localized effect (e.g. a homeowner that drains footings to a steep slope, causing erosion) or can be more drainage-basin in scale (e.g. parking lots in the upper basin causing higher peak flows downstream, increasing the potential for erosion from the parking lot outfall to all points downstream).

Erosion Hazard Areas should be mapped and classified based on their potential for erosion. Slope stability in Covington is mapped in Figure 10-6 of the Covington Hazard Mitigation Plan (Tetra Tech 2014)(see Appendix A). Erosion hazard mapping includes the following five categories of hazard (King County 2004):

Slight. Indicates no appreciable erosion damage is likely to occur during and after the development or continuation of a particular land use under consideration. Soil conservation management should include simple practices such as rapid establishment of ground cover as soon as possible.

Moderate. Implies significant erosion may occur during development of a particular land use. Provided appropriate soil conservation measures are adopted during development, both short-term and long-term erosion problems may be avoided.

High. Implies significant erosion may occur. Intensive soil conservation measures are required to control erosion that will occur during development or continuation of a particular land use. Short-term measures are required in the initial stages of development. Long-term erosion control would involve intensive measures being implemented.

Very High. Implies that significant erosion will occur both during and after development of a particular land use is established, even with intensive soil conservation measures. Planning will need to carefully consider the balance between long-term erosion damage and the maintenance and repair needed to ensure the viability of the land use.

Extreme. Implies soil erosion will occur to such an extent that erosion control is impractical. These areas are best retained as green timber and not used. Where urban development proceeds in spite of this recommendation, detailed engineering, geotechnical and other studies will be necessary.

Landslide Hazard Areas

Buffers or setbacks around landslide hazard areas, including the tops and toes of steep slopes, can be an effective way of preventing or limiting damage (Gerstel et al., 1997). If development is proposed within the buffer or slide area, rigorous design and construction standards should be adhered to in order to prevent the development from causing slope instability, either at the site or elsewhere on the slope. Any such development in the hazard area or its buffer should be evaluated on a site-specific basis by a licensed geotechnical engineer or engineering geologist. Data used in such analyses should be site-specific, and include subsurface exploration and testing of soils at an appropriate frequency across the site. The City currently regulates landslide hazard areas under CMC 18.65.280.

Seismic Hazard Areas

Given the difficulty in predicting where, when, and how large, an earthquake will be, the safest course of action is to assume that a structure will at some point in its useful life be subjected to an earthquake. The Washington State Building Code (WAC 51-50) offers guidance from the 2009 International Existing Building Code with amendments specific to the State, including several directly related to seismic standards. Adherence to such guidance is an effective way to mitigate seismic hazards. The City currently regulates steep slopes under CMC 18.65.310.

Other Geologically Hazardous Areas

Volcanoes

Areas at risk from lahars and associated phenomena from a volcanic eruption at Glacier Peak and Mount Rainier are documented in the Washington State Enhanced Hazard Mitigation Plan (WMD 2012). Covington is outside of identified lahar paths. Tephra fall or ash is essentially the only volcanic hazard in Covington (see Appendix A, Figure 12-2).

Mines

No coal mines are mapped in the DNR coal mine inventory map for Covington. Therefore, mine-specific protection measures are not warranted.

5.0 WETLANDS

Historically, wetlands were commonly drained or filled to accommodate agriculture or development. However, today they are recognized as high functioning ecosystems that provide a wide range of valuable services, including flood control, aquifer recharge/discharge, and wildlife habitat.

Wetlands exhibit a diversity of characteristics, such as permanent or seasonal inundation, organic or mineral soils. Wetlands are distinguished from adjacent areas by anaerobic wet soil conditions within the root zone during the growing season, unique soil profiles, and water dependent or water tolerant plant species. Transitions between wetland and non-wetland or upland areas may be gradual or plainly defined, often by topographic breaks. Since interest in managing and protecting wetland resources began in the mid-fifties, ecologists have struggled to develop a wetland definition based on scientifically defensible criteria. Implementation of the 1977 Clean Water Act requires a scientifically based legally defensible wetland definition (Mitsch and Gosselink 2000).

The commonly used wetland definition as issued by the USEPA, the U.S. Army Corps of Engineers (Corps), Shoreline Management Act, Growth Management Act and recorded in WAC 173-22-030(10) is:

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

5.1 WETLANDS IN THE CITY OF COVINGTON

Wetlands in Covington were mapped as part of the King County Wetlands Inventory, which focused on the larger wetlands in the County. In 2002, an additional inventory of wetland and stream resources within the city was completed, and 32 additional wetland areas were identified. Most wetlands in Covington are freshwater forested/shrub or freshwater emergent, and are generally associated with major streams and tributaries and Pipe Lake. Larger wetland areas occur along Big Soos Creek on the west side of the city; along Jenkins Creek adjacent to Wax Road just south of Kent-Kangley; and along the upper portions of Jenkins Creek in the north part of the city. An additional wetland fringes the freshwater pond in "The Reserve," a regional stormwater facility and park

Primary sources of water for Covington's lakes and wetlands are direct precipitation, surface water runoff, flows from rivers and streams, and subsurface groundwater flows. Water leaves the city's wetlands and lakes primarily through direct evaporation, surface outflows, and seepage into groundwater. During flood conditions, water overflows stream banks and enters wetland soils, which act like groundwater reservoirs and store surplus groundwater during wet periods, discharging this stored water into streams later to augment base stream flows.

Wetlands in Covington are currently buffered according to the city's critical areas regulations, which assign buffers depending on wetland category, type, and/or habitat score. Existing buffers are shown in Exhibit 5-1, below.

Exhibit 5-1 Wetland buffers under existing critical areas regulations

Wetland category	Characteristics	Buffer width (feet)
Category I	Bog	215
	Habitat score 29-36 points	225
	Habitat score 20-28 points	150
	All others	125
Category II	Habitat score 29-36 points	200
	Habitat score 20-28 points	125
	All others	100
Category III	Habitat score 20-28 points	125
	All others	75
Category IV		50

Source: Covington Municipal Code (CMC) 18.65.320

5.2 WETLAND FUNCTIONS AND POTENTIAL EFFECTS OF DEVELOPMENT

Physical, chemical, and biological processes that occur within a wetland and the surrounding landscape are commonly referred to as wetland functions. Wetland scientists generally acknowledge that wetlands perform the following eight functions:

1) flood/storm water control,
2) base stream flow/groundwater support,
3) erosion/shoreline protection,
4) water quality improvement,
5) natural biological support,
6) general habitat functions,
7) specific habitat functions, and
8) cultural and socioeconomic values (Cooke Scientific Services 2000).

The capacity of an individual wetland to perform functions is dependent upon climate, geomorphic or topographic location, the hydrology source and hydrodynamics. Wetland functions also vary, both positively and negatively, due to processes or changes occurring at the watershed scale. The Bedford "process-structure-function" model is a tool for evaluating wetland functions and values at a greater landscape scale. This model assumes that land use choices affect processes key to wetland and other aquatic system functions (Sheldon et al. 2005). Additionally, a study conducted by Poiani et al. (1996) demonstrates that regional land uses, corresponding pollutant inputs, and watershed characteristics, such as soils and topography, affect wetland processes, particularly in regard to nitrogen cycling.

While wetlands perform many ecological functions, scientific literature acknowledges that the value assigned to any given wetland function is subjective. Wetlands naturally perform several functions at low cost relative to engineered solutions, such as water storage, flood protection, water reserve, pollutant and nutrient retention, and provisional fisheries habitat; these are valued as human services (Hattermann et al. 2008). For practical applications, such as the WDOE rating system, wetland functional values are broadly grouped into three categories: 1) water quality functions, 2) flood storage or hydrologic functions, and 3) habitat functions (Sheldon et al. 2005).

Wetlands are unique and potentially high functioning ecosystems. Many wetland functions such as water quality, flood control, and wildlife habitat, are valued in urban areas. As the literature documents, urbanization stresses and degrades wetland ecosystems. Through local planning and oversight, direct and cumulative impacts to wetlands can be reduced.

Wetland Hydrology

Primary hydrologic functions wetlands provide are peak flow reduction and flood-flow desynchronization, reduced downstream erosion, and groundwater recharge (Sheldon et al. 2005). As described by Hruby et al. 1991 and Adamus et al. 1991, flood-flow desynchronization is a landscape-scale process whereby stormwater is stored in wetlands across the watershed and slowly released down-gradient. Cumulatively this reduces the magnitude and intensity of peak flows (Sheldon et al. 2005). In turn, reducing the velocity of water flow across the watershed reduces downstream erosion (Reinelt and Horner 1995, Adamus et al. 1991). Wetlands also recharge groundwater to varying degrees based on site-specific conditions including groundwater flow rates, wetland storage capacity, landscape position or hydrogeomorphic class, and evapotranspiration rates (Adamus et al. 1991, Hunt et al. 1996).

Urbanization typically alters wetland hydrology by increasing or decreasing flows that enter the wetland from the surrounding landscape (Sheldon et al. 2005). A Puget Sound wetland study found that even 4% urbanization can measurably alter wetlands and severe wetland degradation correlates with impervious cover in excess of 20% (Schueler 2000).

High impervious surface cover characteristic of urban areas leads to greater peak flows. In an urban setting, peak flow rates for a single storm event increase as much as five-fold relative to less developed areas (Booth 1991). Under these conditions, McMillan (2000) concludes that buffers are not likely to protect a wetland's hydroperiod if they are located in a basin with impervious surface exceeding 15 percent. Changes to flow conditions associated with urbanization are known to increase erosion, down-cut stream channels, bury vegetation, increase depth of ponding, and alter seasonal water regimes (Sheldon et al. 2005).

Modified drainage patterns in urban areas are found to increase water level fluctuations in wetlands by a foot or more; this stresses many native plant species and tends to result in more invasive or aggressive plant species establishment (Schueler 2000).

Other improvements typical of urban areas may reduce the amount of water entering a wetland. For example, stormwater management may have unintended consequences for wetland hydrology. When road ditches, drainage tiles or other stormwater features are installed down-slope wetlands may become drier (Wigington et al. 2005, Hogan and Walbridge 2007). As is typical of ecosystem processes, hydrologic maintenance is linked to many other wetland and buffer functions.

Water Quality

Wetlands improve water quality by intercepting runoff, retaining inorganic nutrients, converting organic wastes, settling sediment and removing contaminants (Sheldon et al. 2005). Recent research indicates that wetlands and associated buffers protect water quality through the following mechanisms: 1) remove pollutants from groundwater through interaction with deep-rooted plants in the soil; 2) infiltrate polluted surface waters and reduce stormwater velocity (Hruby 2013).

While wetlands are known to provide water quality functions, research indicates that household chemicals, pharmaceuticals and personal care products are entering aquatic systems and negatively impacting fish and wildlife populations (Staples et al. 2004, Klaschka 2008, Fent 2008, Caliman & Garvilescu 2009); the ability of wetlands to neutralize these pollutants is unknown at this time.

The water quality functions provided by an individual wetland vary by site-specific characteristics including hydrogeomorphic class and basin condition (Granger et al 2005). Water quality functions are also dependent on several factors including residence time of polluted waters, percent slope and length of slope, vegetation structure and density, and soil surface roughness, soil infiltration, and adjacent land use practices (Hruby 2013). A longer residence time allows sediment and other solids to settle. Ungrazed vegetation acts as a filter to capture sediment particles entering the wetland (Hruby 2004). Research has shown that a vegetated wetlands and riparian buffers can be expected to capture more than 90% of sediment and other non-point source pollutants in runoff (Gilliam 1994). However, saturation with sediment and phosphorus can reduce a wetland and buffer areas' capacity to perform water quality functions (Hruby 2013). Due to the absorption properties of heavy metals, phosphorus, and some toxic compounds, sediment capture in wetlands also reduces these pollutants in downstream environments. According to Kerr et al. 2008, low oxygen concentrations that are common to wetland environments make them particularly good sinks for copper. The major processes by which wetlands reduce runoff pollutants are both biotic and abiotic and include sedimentation, adsorption, precipitation, oxidation, bio-degradation, and plant uptake (Adamus el al. 1991, ITRC 2003).

Nutrient uptake in wetland systems also protects down-gradient waters by preventing nutrient spikes that can disrupt trophic indices; such disruptions can cause eutrophication. The primary nutrients wetlands remove are nitrogen and phosphorus. Wetland plants and microorganisms are known to uptake or remove nitrogen through the biochemical processes of nitrification and denitrification, which occur in aerobic and anaerobic conditions, respectively (Sheldon et al. 2005, Hruby 2013). As noted above, phosphorus is captured in settled sediments; wetlands also remove phosphorus through adsorption, particularly to clay soils, and precipitation with calcium (Sheldon et al. 2005, Hruby 2013). However, phosphorus retention in wetlands is not permanent and seasonal fluctuations in phosphorus release have been documented in some studies (Aldous et al. 2005).

Negative correlations between urbanization and wetland water quality have been documented in the Puget Sound region (Schueler 2000, Azous and Horner 2010). For example, increased water volumes within a wetland can alter plant communities and anaerobic soil processes thus diminishing water quality functions (Schueler 2000, Sheldon et al. 2005). A decrease in water entering wetlands results in less opportunity to provide water quality functions (Wigington et al. 2005, Hogan and Walbridge 2007). Urbanized watersheds also release more nutrients, sediment and toxins into wetlands (Sheldon et al.

2005), further straining systems that are already compromised. When excess nutrients are transported via runoff into lakes and ponds, eutrophication may occur; a process that reduces levels of dissolved oxygen and causes aquatic fauna mortality. Eutrophication in Lake Leota has been linked to urbanization within that watershed (Falter 2007).

Wildlife Habitat

Wetlands provide important wildlife habitat within the landscape due to the presence of unique structures and processes. Ecological features that are linked to species richness and abundance in a landscape include structural complexity, connectivity to other ecosystems, plentiful sources of food and water, and a moist moderate microclimate (Knutson and Naef 1997). Wetlands, depending on site-specific conditions, landscape position, and surrounding land use, will have some or all of these habitat features.

Wetlands provide habitat for a broad range of fauna including invertebrates, reptiles and amphibians, anadromous and resident fish, wetland-associated birds, and wetland-associated mammals. Aquatic invertebrates that depend on wetland ecosystems are important to aquatic trophic systems or food webs (Rosenberg and Danks 1987, Wissinger 1999, in Sheldon et al. 2005). Native frogs and salamanders require wetlands for breeding. Buffer condition, habitat interspersion, wetland hydro-period, and diameter of emerged plant stems are all important factors that impact amphibian richness and abundance (Sheldon et al. 2005). Wetlands with surface connections to salmon-bearing streams can provide backwater refuge for anadromous fish if they also have ponded water at least 18 inches deep, low flow conditions, and cover such as overhanging or submerged plants (Sheldon et al. 2005). Resident fish also inhabit wetlands. Waterfowl rely upon wetlands for all or part of their life cycle (Kauffman et al. 2001, in Sheldon 2005). Suitability of wetland habitat for birds is dependent on buffer condition and width, presence of snags or other perches, corridor connections, open water, and forest canopy cover (Sheldon et al. 2005). Wetland-associated mammals, such as beaver and muskrat, also seek out well buffered vegetated corridors, interspersed habitat with open water, and a seasonally stable water level (Sheldon et al. 2005). According to a Washington Department of Fish and Wildlife (WDFW) study conducted by Knutson and Naef (1997) a predominance of terrestrial vertebrate species in Washington are dependent on streams and riparian areas, including wetlands. Wetland and surrounding upland areas that provide critical life requirements for wetland-dependent species are referred to in recent literature as “core habitats.” Some researchers recommend providing a buffer for “core habitat” areas, which are typically within a wetland buffer. Herptiles and wetland-associated birds are dependent on these core habitat areas. Core habitat documented for amphibians and wetland-associated birds ranges from 1,000 feet to 0.6 mile (Hruby 2013).

Wetlands also provide habitat for many native plants species. Wetland characteristics that are correlated with plant richness are the hydro-period, duration of flooding, and variety of water depths (Schueler 2000 and Sheldon et al. 2005). Vegetated areas surrounding wetlands perform several important functions that in turn protect wetland functions.

Habitat fragmentation is a consequence of urbanization. As land is developed, continuous tracts of native habitat are reduced to patches, which become progressively smaller and more isolated. Dale et al. (2000) found that ecologic impacts of development are often overlooked and landscape-scale changes, particularly habitat fragmentation, alter the structure and function of those ecosystems.

The performance of wetland habitat functions is affected to varying degrees by the width and/or character of the surrounding buffer. Urbanization reduces wetland buffering and increases human encroachment. Disturbance vectors include noise; nighttime light; physical intrusion by equipment, people, or pets; and garbage. Each of these vectors can result in one or more of the following:

disruption of essential wildlife activities, damage to native vegetation and invasion of non-native species, erosion, or wetland fill, among others. Semlitsch and Bodie (2003) found that upland areas surrounding wetlands are core habitats for many semi-aquatic species, such as amphibians and reptiles. Additionally, Attum et al. (2007) concluded in their study of wetland-upland linkages that wetland surroundings and wetland areas are likely of equal importance to wildlife. Therefore, smaller habitat patches inevitably diminish habitat value.

Cumulative impacts of direct and indirect wetland alterations, including hydrologic changes, compromised water quality, and habitat fragmentation tend to reduce the habitat functions and values an urban wetland provides (Sheldon et al. 2005, Azous and Horner 2010, Hruby 2013).

Wetland Loss

Urbanization is known to have repercussions that impact both individual wetlands and broad-scale watershed processes. Land use changes typically involve wetland fill, loss of forest, modified drainage systems, increased pollutants, and more impervious surface (Sheldon et al. 2005).

Due to the planned density that defines urban areas, impacts to natural areas including wetlands, are common. Nationally it is estimated that 85 percent of urban wetlands have been filled (Kusler and Niering 1998, in Sheldon et al. 2005). For example, linear improvement projects, public facility improvements, and legal lot requirements can each cause unavoidable wetland impacts, particularly in an urban core. To protect wetland resources under these conditions regulation of direct and indirect wetland impacts is necessary. Direct wetland impacts are activities that drain, fill or clear a wetland. Indirect impacts stem from changes in the surrounding landscape that degrade a wetland by altering the wetland hydroperiod, microclimate or habitat connectivity, for example (McMillan 2000).

5.3 WETLAND POTENTIAL PROTECTION MEASURES

As the city grows, BAS-based protection measures may be employed to maintain wetlands and the functions they provide. The primary tools regulators rely on to retaining wetland functions and values are: accurate wetland identification and classification, buffer width requirements, and compensatory mitigation.

Wetland Identification and Classification

In accord with Washington State Legislature Senate Bill 5776, wetland determinations are made using methodology from the *Washington State Wetlands Identification and Delineation Manual* (State Manual) (Washington Department of Ecology [WDOE] 1997; Ecology Publication # 96-94). To address regional wetland characteristics and improve wetland delineation accuracy, the Corps issued regional supplements to their Wetland Delineation Manual (1987) on which the State Manual is based. Therefore, current wetland methodology is based on the Manual and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region (Version 2.0)* (Regional Supplement) (Corps May 2010). Both the State and Corps Manuals provide parameters and methods for determining presence or absence of jurisdictional wetlands within the landscape. Following this methodology, wetland determinations are based on an examination of vegetation, soils, and hydrology.

While some wetlands are inundated and obvious, many wetlands have little, no or only seasonal surface water. A scientifically sound wetland determination is one made by a qualified professional who can evaluate and document present or absence of the three wetland parameters, vegetation, soils and hydrology in a manner consist with current regulations and accepted BAS practices. Currently, there is no state licensing or certification requirement for soil and wetland science professions. However, bills

HB 1313 and SB 5225, which would require professional licensing, have been introduced to the Washington State Legislature and may be adopted; the bills have been reintroduced by resolution, but no action has been taken to date.

Once a wetland is identified, classification allows regulators to determine the relative rarity and functional value of an individual wetland feature. A wide range of tools and techniques have been used to categorize or manage wetland resources starting with gross scale National Wetland Inventory (NWI) mapping by the U.S. Fish and Wildlife Service using the Cowardin classification system (Cowardin et al. 1979). The Cowardin system is still widely used and has been incorporated into more recent tools, such as the Washington State Department of Ecology *Washington State Wetland Rating System for Western Washington* (WDOE Rating System), which was updated in 2014 (Hruby 2014; Ecology Publication # 14-06-029).

The WDOE Rating System is the most commonly used and regionally-accepted wetland classification system. It is a four-tier wetland rating system, which grades wetlands on a points-based system in terms of functions and values. WDOE specifically developed this tool to allow for relatively rapid wetland assessment while still providing some scientific rigor (Hruby 1999, Hruby 2014). This rating system incorporates other classification elements, such as Cowardin (Cowardin et al. 1979), hydrogeomorphic) classifications (Brinson 1993), and special characteristics such as bogs and mature forests. As described in the WDOE Rating System guidance: "This rating system was designed to differentiate between wetlands based on their sensitivity to disturbance, their significance, their rarity, our ability to replace them, and the functions they provide" (Hruby 2014). The rationale for each wetland categories under the WDOE Rating System is described below. The fundamental scientific

- Category I: These are the most unique or rare high-functioning wetland types that are highly sensitive to disturbance and/or relatively undisturbed wetlands with functions that are impossible to replace in a human lifetime.
- Category II: These wetlands are high functioning and difficult, though not impossible, to replace.
- Category III: These wetlands provide a moderate level of functions. They have generally been disturbed in some way and are characterized by landscape fragmentation and less diversity.
- Category IV: These wetlands are low functioning and can be replaced or improved. They are characterized by a high level of disturbance and are often dominated by invasive weedy plants.

Wetland Buffers

Protection of wetland functions from effects of surrounding land uses is most commonly achieved through fixed buffers. Widely recognized buffer functions include limited moderation of precipitation and stormwater inputs (hydrology maintenance), removal of sediment, excess nutrients, and toxic substances (water quality improvement), influencing microclimate, maintaining adjacent habitat critical for wetland-dependent species, and maintaining habitat connectivity (wildlife habitat), and screening adjacent disturbances (disturbance barrier)(Sheldon et al. 2005). The factors that influence the performance of a buffer include vegetative structure, percent slope, soils, and buffer width and length. The scientific literature identifies four primary factors important in determining buffer width to adequately protect wetlands. These are 1) the functions and values of the subject wetland, 2) the characteristics of the buffer itself, 3) the intensity of surrounding land uses and their expected impacts and 4) the specific functions the buffer is intended to provide (Sheldon et al. 2005, Hruby 2013).

A synthesis of scientific studies summarizing, among other wetland topics, effectiveness of various buffer widths relevant to Western Washington was published by the Washington State Department of Ecology (Sheldon et al. 2005). Water quality is the wetland function that has been studied most comprehensively in the context of adequate buffer width. Water movement and quantity, habitat, and disturbance protection functions have been addressed to a lesser extent. General studies on stream buffer widths were also deemed relevant to discussions of wetland buffer widths because a vegetated buffer often operates independently of the sensitive area it is intended to protect, particularly for "sink" functions such as sediment and pollutant removal. The effective buffer width ranges given below (Table 5.1) are broad and variations are largely dependent on buffer condition, landscape setting, and specific metrics. For example, buffer widths that can effectively maintain water quality functions differ for sediment removal, nutrient removal, and pathogen removal. Even for sediment removal, effective buffer widths vary by particle size (Sheldon et al. 2005). Generally the minimum buffer deemed necessary to protect a wetland under most conditions is between (15-30 meters) 50-100 feet wide. To maintain conditions suitable for most wildlife, a minimum buffer of (60 meters) 197 feet is recommended (Sheldon et al. 2005). Exhibit 5-2 summarizes general recommended buffer width ranges for protecting specified wetland buffer functions.

Exhibit 5-2 Range of Effective Wetland Buffer Widths in Existing Literature for Applicable Functions

Function	Range (ft) of Effective Buffer Widths	Sources Consulted
Stormwater control (hydrology maintenance)	50-300 (generally); vegetative structure and impervious surface in basin are more important factors	Wong and McCuen 1982; McMillan 2000; Azous and Horner 2001
Erosion control	Unknown: wetland size and buffer type are more important factors; sediment removal 30-100	Cooke Scientific Services 2000; Kleinfelter et al. 1992, in McMillan 2000; Hruby 2013
Water quality	15-325	Horner and Mar 1982; Lynch et al. 1985; Lee et al. 1999; Shisler et al. 1987, in McMillan 2000; Dillaha and Inamdar 1997; Daniels and Gilliam 1996; Magette et al. 1989; Sheldon et al. 2005; Hruby 2013
Wildlife habitat	45-1,000 400-900[1]	Castelle et al. 1992b; Desbonnet et al. 1994; Semlitsch 1998; Richter 1997, in McMillan 2000; Cooke 1992; Hruby 2013
Disturbance barrier	45-200	Cooke 1992; Shisler et al. 1987, in McMillan 2000; Desbonnet et al. 1994

1 Based on a recent literature review, the buffer needs of wildlife species typical of Washington State is 400-feet minimum, and optimally 900-feet. (Hruby 2013).

Source: Compilation of sources listed above.

Exhibit 5-3 below categorizes buffer width ranges according to two primary functions, habitat and water quality. Water quality stressors are commonly inferred by categorizing the intensity of adjacent land use. In this model, land uses are deemed high, moderate or low intensity. Dense residential development (>1 unit/acre), institutional, commercial, and high use recreation (e.g. ball fields) are considered high-intensity impacts. Moderate-density residential developments (1 unit/acre or less) and moderate-intensity open space (parks with paved trails) are examples of moderate-intensity land uses. Low-intensity land use would be open spaces or natural areas with unpaved trails for low impact activities like hiking (Granger et al. 2005).

Exhibit 5-3 Range of Effective Wetland Buffer Widths based on Habitat Functions and Land-Use

Habitat functions	Adjacent Land Use	Range of Effective Buffer Widths (ft)
minimal	low-intensity	25 to 75
moderate	moderate- or high- intensity	75 to 150
high	low-, moderate- or high-intensity	150 to 300+

Source: Sheldon et al. 2005.

Determining set buffer widths for wildlife in general is difficult, due to variability among species (Sheldon et al. 2005). As habitat functions increase, effective buffer widths are increasingly contingent on life-history needs of wetland dependent species. Protecting wildlife habitat generally requires larger buffers than protecting water quality. A recent literature review completed by Dr. Hruby indicates buffer widths would have to be larger than recommended in the 2005 synthesis (Granger et al 2005)(Exhibit 5-3) to adequately protect wetland-dependent wildlife. Based on current literature, the optimal buffer with is about 900 feet and the minimum recommendation is 400 feet to protect wetland-dependent wildlife (Hruby 2013).

Exhibit 5-4 Current Wetland Buffer Recommendations for Western Washington[1]

Wetland Category	Standard buffer width (ft) 3-4 habitat points	Additional buffer width (ft) if wetland scores 5 habitat points	Additional buffer width (ft) if wetland scores 6-7 habitat points	Additional buffer width (ft) if wetland scores 8-9 habitat points
Category I: Based on total score	75	105	165	225
Category I: Bogs	190	190	190	225
Category I: Forested	75	105	165	225
Category II (all)	75	105	165	225
Category III (all)	60	105	165	NA
Category IV (all)	40	NA	NA	NA

1 These buffer widths should be applied when the minimization measures in Exhibit 5-5 are required under the code (WDOE 2012).

Sources: Sheldon et al. 2005, WDOE 2012.

As Exhibits 5-2, 5-3 and 5-4, above, show, recommended buffer widths vary widely depending on individual characteristics such as adjacent stressors, targeted functions, buffer condition, and species-specific habitat niche requirements. Exhibit 5-4 summarizes the most current guidance, which determines wetland buffer widths according to both the wetland category and habitat functions score; this buffer approach requires implementation of minimization measures listed in Exhibit 5-5 on a project-specific basis (WDOE 2012). The habitat score ranges in Exhibit 5-4 align with the updated Wetland Rating System for Western Washington (WDOE 2014, Hruby 2014). WDOE is not proposing any changes to the buffer width recommendations in the 2005 guidance, as summarized in Exhibit 5-4 above, for the 2015-2019 critical areas ordinance update cycle (Hruby 2014).

Exhibit 5-5. Required measures to minimize impacts to wetlands.[1]

Disturbance	Required Measures to Minimize Impacts
Lights	▪ Direct lights away from wetland
Noise	▪ Locate activity that generates noise away from wetland ▪ If warranted, enhance existing buffer with native vegetation plantings adjacent to noise source ▪ For activities that generate relatively continuous, potentially disruptive noise, such as certain heavy industry or mining, establish an additional 10’ heavily vegetated buffer strip immediately adjacent to the outer wetland buffer

Disturbance	Required Measures to Minimize Impacts
Toxic runoff	▪ Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered ▪ Establish covenants limiting use of pesticides within 150 feet of wetland ▪ Apply integrated pest management
Stormwater runoff	▪ Retrofit stormwater detention and treatment for roads and existing adjacent development ▪ Prevent channelized flow from lawns that directly enters the buffer ▪ Use Low Intensity Development techniques (per PSAT publication on LID techniques)
Change in water regime	▪ Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
Pets and human disturbance	▪ Use privacy fencing OR plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the ecoregion ▪ Place wetland and its buffer in a separate tract or protect with a conservation easement
Dust	▪ Use best management practices to control dust
Disruption of corridors or connections	▪ Maintain connections to offsite areas that are undisturbed ▪ Restore corridors or connections to offsite habitats by replanting

1 Measures are required, where applicable to a specific proposal. These minimization measures should be implemented along with the buffer widths in Exhibit 5-4.

Source: WDOE 2012.

Hydrology Maintenance

Similar to stream systems, vegetated wetland buffers can affect water quantity and hydrology in the wetland by moderating the input of precipitation in a number of ways. Vegetation slows the movement of water from above and outside of the buffer, allowing the water to infiltrate into the soil and/or groundwater. Over time, this stored water will slowly be released into the wetland. Leaf and other vegetative litter on and in the soil also capture water and improve the soil's infiltration capacity (Castelle et al. 1992b). Depending on the size of the basin, the type of wetland, and the degree to which stormwater falling on impervious surfaces is routed away from the buffer (either directly to the sensitive area protected by the buffer, to a detention or infiltration pond, or to some other facility), the contribution of a specific buffer to water quantity maintenance in a wetland may be high or low (McMillan 2000). In either case, water quantity maintenance as related to buffer width has not been sufficiently studied. However, buffer characteristics that influence performance of this function are: "vegetation cover, soil infiltration capacity, rainfall intensity and antecedent soil moisture conditions" (Wong and McCuen 1982).

Upland buffers also function to control erosion by slowing water flow and allowing greater time for infiltration. Buffer vegetation can reduce sediment input to the wetland through soil stabilization by roots, and reduction in rain energy by the vegetation canopy and organic material on the soil (Castelle et al. 1992b). The plant species growing in buffers are an important factor in the buffers' ability to perform this function. Plants with fine roots are most effective at preventing erosion by binding the soil (Kleinfelter et al. 1992, in McMillan 2000).

The literature does not recommend a specific buffer size or range of buffer sizes for hydrology maintenance.

Water Quality Improvement

As described in Section 5.2, buffers protect water quality in wetlands through removal of sediment and suspended solids, nutrients, and pathogens and toxic substances (Desbonnet et al. 1994; McMillan 2000; Castelle et al. 1992b). Performance of the water quality improvement function depends on a number of variables, including residence time and type of pollutants, percent slope and length of slope, vegetation density and composition, leaf and wood litter, soil roughness and infiltration, and adjacent land use practices (Hruby 2013). In general, optimum performance could be achieved with a diverse mix of trees, shrubs and groundcovers; poorly drained clay-loam soils with organic content; abundant downed wood and leaf litter; and no slope. Sediment and pollutants can either be prevented from reaching the wetland through physical mechanisms, such as wood or leaf litter holding or binding these materials, or through chemical/biological means, such as breakdown or uptake of certain pollutants by root systems or microorganisms in the soil (Desbonnet et al. 1994; McMillan 2000; Castelle et al. 1992b). Buffer vegetation can reduce sediment input to the wetland through stabilization of soils by roots, and reduction in rain energy by the vegetation canopy and organic material on the soil (Castelle et al. 1992b). Shading and wind reduction by buffer vegetation also influences water quality by maintaining cooler temperatures. Water temperature in wetlands can be critical to survival of aquatic wildlife species, but more importantly from a water quality perspective, it helps maintain sediment-pollutant bonds, increases the water's dissolved oxygen capacity (McMillan 2000), and limits excessive algal growth (Castelle et al. 1992b).

The 2005 WDOE literature summary concluded that effective sediment control, 60% removal or greater, requires buffer widths in the range of 16 feet to 200 feet. Widths vary widely depending on buffer condition and sediment size. Nutrient removal relative to buffer width also varies widely; documented buffer widths range from 12.5 feet to >850 feet (Sheldon et al 2005). According to Desbonnect et al. 1994, approximately 70 percent or greater sediment and pollutant removal was obtained at buffer widths between approximately 65 and 100 feet. Between 60 and 70 percent of sediment and pollutant removal, except for phosphorus, occurs in buffers between 25 and 50 feet (Desbonnet et al. 1994). Phosphorus removal efficiencies of 60 percent or more are found in buffers greater than 40 feet wide (Desbonnet et al. 1994). McMillan's (2000) summary analyzed a range of buffer widths by specific water quality function and identified the following effective buffers: 5 to 100 meters (16 to 330 feet) for sediment removal; 10 to 100 meters (33 to 330 feet) for nitrogen removal; 10 to 200 meters (33 to 656 feet) for phosphorus removal; and 5 to 35 meters (16 to 100 feet) for bacteria and pesticide removal.

Wildlife Habitat

Vegetated wetland buffers provide essential habitat for a wide variety of wildlife species, particularly those that are wetland-dependent, but require adjacent upland habitat for some part of their life cycle (e.g., some amphibians, waterfowl, some mammals). They also provide habitat for non-wetland-dependent species that prefer habitat edges, use the wetland as a source of drinking water, or use the protected buffer corridors to travel between different habitats. Studies have been done to determine necessary wetland buffer widths for wildlife in general, for particular species, and for particular life stages of particular species.

The recommended buffer widths range widely in the literature and are clearly species dependent. For example, a study conducted in urban King County (Milligan 1985) found that bird diversity was positively correlated with vegetated buffers of 50 feet or greater. One literature summary reports an effective buffer range of 50 feet (15 m) for many bird species up to 3,280 feet (1,000 m) for native amphibians (Milligan 1985 and Richter 2001, in Sheldon et al. 2005). A large number of studies recommend buffers between 150 and 300 feet (WDW 1992 in Castelle et al. 1992b). Triquet et al. (1990 in Desbonnet et al. 1994) recommend minimum buffer widths of 50 to 75 feet to provide general avian habitat. A minimum recommended wildlife corridor is 98 feet (Shisler et al. 1987 in McMillan 2000), although 490 feet was also recommended as a minimum travel corridor by Richter (1997). According to the 2005 synthesis published by WDOE, recommended buffer widths for habitat protection range between 50 and 300 feet depending on factors including wetland habitat conditions, target species, buffer condition, and surrounding land uses (Sheldon et al. 2005). However, a recent review of the 2005 synthesis found that those buffer widths may be inadequate to protect life cycle requirements for wetland-dependent wildlife (Hruby 2013). A recent literature review found that wetland-dependent wildlife, such as herptiles and wetland-associated birds, require a buffer width in the range of 400 to 900 feet (Hruby 2013).

Disturbance Barrier

Dense, vegetated buffers also provide a barrier between a wetland and the various vectors for human encroachment, including noise, light, trampling of vegetation, and the introduction of garbage and other pollutants. Buffer widths necessary to effectively reduce impacts vary by intensity of the adjacent land use. Buffer widths of 49 to 98 feet can effectively screen low-intensity land uses, such as agriculture and low-density residential. High-intensity land use, such as high-density residential, commercial and industrial, require buffer widths of 98 to 164 feet (Shisler et al. 1987 in Sheldon et al. 2005). The buffer itself, and the functions that it provides, is subject to human-related disturbance. Cooke (1992 in Castelle et al. 1992a) found that buffers less than 50 feet wide experienced the most loss of buffer function related to human disturbance, and this loss is related to gradual reduction in buffer width as adjacent land uses encroach. WDOE recent guidance recommends a minimum buffer width of 40 feet for low-functioning (Category IV) wetlands (WDOE 2012).

Wetland Mitigation

Mitigation is a sequence of steps taken “to reduce the severity of an action or situation” (WDOE et al. 2006a). To bolster protection of our national wetland resources, a no net loss policy was adopted in 1988 by then president George H.W. Bush and has been upheld by all following presidents up through the present Obama administration.

In 2008, the USEPA issued the Wetlands Compensatory Mitigation Rule. This rule emphasizes BAS to promote innovation and focus on results. *“Specifically, the rule:*

- Emphasizes that the process of selection a location for compensation sites should be driven by assessments of watershed needs and how specific wetland restoration and protection projects can best address those needs;
- Requires measurable and enforceable ecological performance stands for all types of compensation so that project success can be evaluated;
- Requires regular monitoring to document that compensation sites achieve ecological performance standards;
- Clearly specifies the components of a complete compensation plan based on the principles of aquatic ecosystem science; and
- Emphasizes the use of science-based assessment procedures to evaluate the extent of potential water resource impacts and the success of compensation measures.”

Mitigation Sequencing

Wetland mitigation is typically achieved through a series of steps known as mitigation sequencing. WDOE recommends that the CAO contain clear language regarding mitigation sequencing. The mitigation sequence according to the implementing rules of SEPA (Chapter 197-11-768 WAC) follows:

1) Avoiding the impact altogether by not taking a certain action or parts of an action;

2) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
3) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
5) Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or
6) Monitoring the impact and taking appropriate corrective measures.

The ABCs of mitigation sequencing are to Avoid, Buffer, and Compensate for impacts. The WDOE publication, *Wetland Guidance for Small Cities* (see Appendix B), provides sample code language for this approach (WDOE 2012).

Mitigation ratios are intended to replace lost functions and values stemming from a proposed land use while also accounting for temporal losses. Mitigation ratios recommended by WDOE can be found in Table 3 below. As noted above, the Corps and WDOE have a mandate to maintain "no net loss" of wetlands. To that end, wetland creation and restoration are preferable to enhancement alone. WDOE guidance does allow for enhancement as sole compensation for wetland impacts at quadruple the standard ratio (Granger et al. 2005, WDOE 2006b).

Per WDOE, compensatory mitigation should replace lost or impacted functions, unless out-of-kind mitigation can meet formally identified goals for the watershed. WDOE recommends prioritizing mitigation actions, location(s) and timing.

Mitigation Ratios

A relatively low success rate of wetland mitigation through both creation of new wetlands and restoration of historic wetlands (Castelle et al. 1992a; Johnson et al. 2002; NRC 2001) is generally acknowledged in the literature. Although more recent evaluations of wetland mitigation found that most wetland creation is at least moderately successful (WDOE 2008), the goal of no net loss is not being achieved (Johnson et al. 2002). The goal of no net loss of wetland function cannot be achieved through mitigation alone, but may be met through a number of factors, including adequate monitoring and maintenance and appropriate performance standards. NRC (2001) identifies factors that reduce the risk of mitigation failure, such as detailed functional assessment, high success standards, detailed mitigation plans, larger bonds, high replacement ratios, and greater expertise.

Mitigation estimates in the literature are most often based on temporal losses and known failure rates. Because compensatory mitigation implemented in the past has not fully replaced lost wetland area and functions, and because an immediate loss of habitat occurs when mitigation installation is delayed, compensation should never be made in less than a 1:1 ratio (Josselyn et al. 1990, Granger et al 2005). Other research suggests that compensation should be made in substantially larger ratios to account for both the possibility of failure and the lapse of time between mitigation implementation and functionality; (Josselyn et al. 1990; Willard and Hiller 1990, WDOE 2006a).

WDOE provides a range of mitigation ratio recommendations as listed in Exhibit 5-5, below, which vary by impact wetland classification and type of mitigation (e.g. wetland creation, wetland enhancement, etc.). WDOE recommends the following wetland replacement ratios for local governments within Washington State: 6:1 for forested Category I wetlands, 4:1 for most other Category I wetlands, 3:1 for Category II wetlands, 2:1 for Category III wetlands, and 1.5:1 for Category IV wetlands. WDOE's *Guidance on Wetland Mitigation in Washington State* (WDOE et al. 2006a) also suggests criteria to be met in consideration of lowering or raising ratios on a project-specific basis.

Exhibit 5-5 WDOE Recommended Mitigation Ratios

Category of Wetland Impact	Creation	Rehabilitation Only	Creation and Rehabilitation	Creation and Enhancement	Enhancement Only
Category IV	1.5:1	3:1	1:1 C and 1:1 RH	1:1 C and 2:1 E	6:1
Category III	2:1	4:1	1:1 C and 2:1 RH	1:1 C and 4:1 E	8:1
Category II	3:1	6:1	1:1 C and 4:1 RH	1:1 C and 8:1 E	12:1
Category I: Forested	6:1	12:1	1:1 C and 10:1 RH	1:1 C and 20:1 E	24:1
Category I: Bog	Not possible	6:1 RH of a bog	Not possible	Not possible	Case-by-case
Category I: based on total score	4:1	8:1	1:1 C and 6:1 RH	1:1 C and 12:1 E	16:1 E

Legend: C = Creation, RH = Rehabilitation, E = Enhancement

Source: Granger et al. 2005. (Appendix 8-C)

Mitigation ratios are based primarily on area and do not account for specific functional losses. For example temporal functional loss is higher for slow growing coniferous forests than for more rapid growing deciduous forests and higher for forests than for shrub or emergent plant communities (Hruby 2011).

To give regulators and applicants a functions-based alternative to set mitigation ratios, the Washington State Department of Ecology recently developed a tool called the credit-debit method. This method, like the WDOE wetland rating form, is a peer reviewed rapid assessment tool. The credit-debit approach may be used to calculate functional gain of the proposed mitigation and functional loss due to proposed wetland impacts. This generates acre-points that can be compared in a balance sheet. Depending on specific site conditions, this may result in less or more mitigation than would be required under a set the standard mitigation ratio guidance (Hruby 2011).

Types of Compensatory Mitigation

Following mitigation sequencing, after demonstrating that a proposed wetland impact is unavoidable and has been minimized to the extent practical, compensatory mitigation is required by local, state and federal agencies. In general order of preference the agencies recommend wetland compensation in the form of: 1) restoration (re-establishment or rehabilitation), 2) creation (establishment), 3) enhancement, and 4) preservation (WDOE et al. 2006a).

Wetland restoration occurs when a historic or degraded wetland is returned to a naturally higher functioning system through the alteration of physical or biologic site characteristics. Restoration may involve re-establishment or rehabilitation. Re-establishment is typically achieved by modifying or restoring a hydrologic regime; this may include removing fill or plugging ditches. Rehabilitation is achieved by repairing or restoring historic functions. Restoring a floodplain connection by breaching a dike is an example of rehabilitation. Rehabilitation does not result in new wetland area.

Wetland creation or establishment is the development of a wetland at a site where a wetland did not naturally exist.

> "Landscape position and proximity to a reliable water source are critical for the successful creation of wetlands. This cannot be over emphasized" (WDOE et al. 2006a).

Both wetland enhancement and preservation result in a net loss of wetland acreage and are therefore, less preferable. Wetland enhancement typically increases structural diversity within a wetland, thus improving functions. Preservation of high functioning wetland systems in danger of decline may also be proposed as mitigation. While preservation does not increase wetland acreage, it may result in long-term functional gains (WDOE et al. 2006a).

There are several approaches that can fulfill the compensatory mitigation requirement, including advance mitigation, programmatic mitigation, or consolidated mitigation (WDOE et al. 2006a). Examples of a consolidated mitigation approach would be an in-lieu fee program or mitigation bank. Individual applicants may also partner on a mitigation project.

Mitigation Site Selection

The Agencies (WDOE, Seattle District Corps, and the USEPA Region 10) recommend selecting mitigation sites based on proximity to the impact and potential ability to replace impacted functions. In order of preference, a mitigation site should be:

> "in the immediate drainage basin as the impact, then the next higher level basin, then the other sub-basins in the watershed with similar geology, and finally, the river basin" (WDOE et al. 2006a).

In the past decade, national and state policies have shifted toward using a broader scale approach for mitigation site selection. A recent forum convened by WDOE and comprised of regulators, businesses, and environmental/land use professionals recommend that local jurisdictions "establish an ecosystem- or watershed-based approach to mitigation" (WDOE 2008). Due to the limited success of on-site mitigation, particularly in highly developed areas, a broader watershed scale approach is increasingly desirable and is viewed by the regulatory agencies as more sustainable (WDOE 2008). To guide practical applications of BAS-based compensatory mitigation, the Agencies issued a WDOE publication, *Selecting Wetland Mitigation Sites Using a Watershed Approach* (Hruby et al. 2009). As noted by Azous and Horner 2001 (in Hruby et al. 2009), recreating or maintaining wetland functions in a highly developed landscape may not be sustainable. To account for this, the watershed approach may require a combination of on- and off-site mitigation to achieve functional gains equivalent to the proposed losses.

As summarized in the Covington Shoreline Master Program, protection and restoration opportunities have been identified in the Soos Creek and Jenkins Creek watersheds. Identified restoration opportunities generally include replacing stream bank armoring with soft armoring and riparian vegetation, reconnecting floodplains and associated wetlands, enhancing and restoring riparian zones including wetlands, and creating or enhancing cool water refuges for migrating salmon (AHBL 2008).

6.0 AQUATIC AREAS

Aquatic areas are protected under the CMC as a component of the GMA requirement to designate and protect Fish and Wildlife Habitat Conservation Areas.

6.1 AQUATIC AREAS IN THE CITY OF COVINGTON

The City of Covington is located within the Green River Watershed (Water Resource Inventory Area 9). Streams generally drain to the south or southwest into Big Soos Creek, which drains into the Green River approximately 4.5 miles southeast of the City of Covington, just east of the City of Auburn.

Little Soos Creek meets Big Soos Creek just north of Highway 18 on the far western edge of the City of Covington. The confluence of Jenkins Creek and Big Soos Creek occurs just south of the city. Cranmar Creek and the North Jenkins Creek Tributary are both tributaries to the mainstem of Jenkins Creek. Cranmar Creek flows west along the southern boundary of the city near the Burlington Santa Fe Railroad. The creek crosses into the city for approximately 0.1 miles before meeting Jenkins Creek in an unincorporated area owned by the City of Kent. The North Jenkins Creek Tributary flows south through a residential community in the northern portion of the City of Covington north of SE Wax Road and meets Jenkins Creek just north of Jenkins Creek Natural Area outside of the City of Covington.

Pipe Lake is the only lake within the City of Covington, although smaller open water areas occur elsewhere in the city. Pipe Lake is situated between Covington and Maple Valley. The lake drains to the east into Lake Lucerne, which eventually drains northward into a tributary of Jenkins Creek. There are no stream inflows into either lake.

Exhibit 6-1 identifies the major streams and lakes in the City of Covington, as well as their status relative to shoreline jurisdiction and known anadromous fish use based on WDFW's Salmonscape (electronic reference). Note that 'modeled presence' in WDFW's Salmonscape is based on stream slope, but it does not necessarily indicate actual presence of the species.

Exhibit 6-1 Major Streams and Lakes in the City of Covington

Waterbody Name	Shoreline Status	Anadromous Fish Use
Big Soos Creek	Shoreline of the State (downstream from confluence with Little Soos Creek)	Chinook, coho, steelhead, cutthroat, chum (modeled)
Little Soos Creek	Shoreline of the State associated wetland at confluence with Big Soos Creek	Chinook, coho, steelhead, cutthroat, chum (modeled)
Jenkins Creek	Shoreline of the State (downstream from confluence with North Jenkins Tributary)	Chinook, coho, steelhead, cutthroat, chum (modeled)
North Jenkins Tributary		Coho, chum (modeled), Chinook (modeled),
Cranmar Creek		Coho, chum (modeled), Chinook (modeled),
Pipe Lake	Shoreline of the State	

Source: City of Covington, 2008, WDFW, 2015

Among the anadromous fish documented or modeled to use watercourses in the City of Covington, Chinook salmon are federally listed as threatened and listed as a state candidate species, steelhead are federally listed as threatened, and coho salmon are federally designated a species of concern. All of the anadromous fish identified in Exhibit 6-1 are considered priority species by Washington State (WDFW 2008).

Pipe Lake is not known to support any priority or anadromous fish species. The lake likely supports a variety of warm water species in the centrarchid (sunfish) family.

Streams are commonly classified based on flow conditions and fish use. Under the current code, stream typing in Covington is similar to, but slightly distinct from the permanent water typing system recommended by the Washington State Department of Natural Resources (WAC 222-13-030). Exhibit 6-2 provides a comparison between the two stream typing approaches.

Exhibit 6-2 Comparison between Water Typing Approaches

WAC 222-13-030 Water Type	Brief Description	CMC 18.65.355 Water Type	Brief Description
Type S	Shoreline stream	Type S	Consistent with WAC definition

WAC 222-13-030 Water Type	Brief Description	CMC 18.65.355 Water Type	Brief Description
Type F	Fish bearing stream	Type F	Consistent with WAC definition
Type Np	Perennial, non-fish bearing natural stream	Type N	Non-fish bearing stream that is physically connected to a Type S or Type F water by an above-ground connection.
Type Ns	Seasonal, non-fish bearing natural stream	Type O	Non-fish bearing stream that is NOT physically connected to a Type S or Type F water by an above-ground connection.

Source: WAC 222-13-030, Covington Municipal Code (CMC)

6.2 RIPARIAN AND AQUATIC HABITAT FUNCTIONS AND POTENTIAL EFFECTS OF DEVELOPMENT

Under natural conditions, a dynamic equilibrium between aquatic areas and associated riparian areas supports long-term resilience of species and habitats. The various components and interactions that support fish and wildlife are described below.

Disturbance Events

Natural disturbances (e.g. floods, fire, landslides, channel migration) lead to spatial heterogeneity and temporal variability, which lead to numerous habitat niches and ecological diversity (Naiman et al. 1993; Gregory et al. 1991). Unmodified riparian corridors are characterized by high dynamism and disturbance events, which, in smaller streams, consist primarily of landslides and debris flows. Disturbance events in larger streams are typically characterized by floods and channel migration (Naiman et al. 1993).

Erosion processes that occur during flood events and subsequent changes in channel direction support large woody debris recruitment and gravel and sediment transport. These processes can also form off-channel habitat such as oxbows and side channels or even smaller incremental changes such as lateral bank scour and pool/riffle formations. Off-channel and floodplain habitats are particularly significant for salmonid over-winter survival and growth (e.g., Solazzi et al. 2000; Sommer et al. 2005; Tschapalinski and Hartman 1983). Together, these structural changes can result in increased habitat quality and complexity for salmon spawning and rearing, as well as for other aquatic species.

Land use can also have a significant effect on the frequency and intensity of disturbance events (Nakamura et al. 2000), either by making such events more common (e.g., by increasing the frequency and intensity of high flow events) or less common (e.g., limiting channel changes by stabilizing streambanks). Urban land cover is correlated with increased high flows, increased variability in daily streamflow, reduced groundwater recharge, and reduced summer low flow conditions (Burges et al. 1998, Jones 2000, Konrad and Booth 2005, Cuo et al. 2009). Changes in hydrology related to development are generally associated with soil compaction, draining, and ditching across the landscape, increased impervious surface cover, and decreased forest cover (Booth and Jackson 1997, Moore and Wondzell 2005). Together, these changes reduce infiltration, evapotranspiration, and groundwater storage, and they increase surface flows.

The altered hydrology that is associated with development alters the geomorphic condition of streams, as well as sediment and pollutant transport (Arnold and Gibbons 1996, Booth and Jackson 1997, Booth and Henshaw 2001). Konrad et al. (2005) suggest that streams in urbanized watersheds may lack the longer duration high flows necessary to maintain stable channel conditions because development tends to result in shorter duration and more frequent high flow conditions. Changes in a stream's hydrograph associated with increased impervious surface coverage and decreased forest cover have been linked to decreased bank stability and increased erosion (May et al. 1997, Booth et al. 2002). In King County, Washington, stream instability was noted in watersheds with both rural (approximately 4 percent impervious surface coverage) and urban (over 10 percent impervious surface coverage) development densities, and the extent of instability was dependent on the percentage of forest cover retained (Booth et al. 2002). Based on the findings of Booth et al. (2002), in rural areas where less than 60 percent of forest cover is retained, unstable channels may occur, and if forest retention is less than 40 percent, unstable channels are expected to occur (Booth et al. 2002). Furthermore, Booth and Henshaw (2001) found that under highly susceptible conditions, post-development channel changes occur so rapidly that remediation efforts could only be successful if implemented prior to development. In urban environments, successful stream rehabilitation requires a clear understanding of the causes of degradation, integrative management to address those causes, and remedies at both the local (backyards) and regional (stormwater system) levels (Booth et al. 2004).

Increased erosion and bank instability associated with development and reduction of forest cover often simplifies stream morphology, leading to incised, wider, straighter stream channels (Arnold and Gibbons 1996, Booth and Jackson 1997, Booth 1998, Konrad et al 2005). In turn, simplified stream channels accelerate water transport and reduce temporary instream flood storage capacity (Kaufmann and Faustini 2012), thereby exacerbating flooding downstream and reducing infiltration potential.

Changes in fish assemblages have been correlated with changes in stream temperature and base flow as a result of increased impervious surface coverage (Wang et al. 2003). Increases in flood frequency and volume have been correlated to declining salmon populations in some Puget Sound lowland streams (Moscrip and Montgomery 1997). While, impervious surface area alone is not the only component to predicting stream biological conditions (Booth et al. 2004), riparian quality has been shown to be inversely proportional to the level of urbanization (May et al. 1997b).

In general, development is known to have detrimental effects on salmonids, particularly with spawning abundance and success. Pess et al. (2002) found that wetland occurrence, local geology, stream gradient, and land use were significantly correlated with adult coho salmon abundance. While positive correlations were found between spawner abundance and forested areas, negative correlations were found between spawner abundance and areas converted to agriculture or urban development. Fish species diversity has been found to decline with increasing levels of urban development, while cutthroat trout (O. clarki) tend to become the dominant salmonid species (Lucchetti and Fuerstenberg 1993; Ludwa et al. 1997).

Water Quality

Water quality is characterized by several physical and biological factors, including suspended sediment, nutrients, metals, pathogens, and other pollutants. Water quality characteristics are controlled by upslope, as well as riparian conditions. Water temperature is also a component of water quality, which will be addressed separately.

When development results in reduced infiltration and increased surface flows, sediment and contaminants are transported more directly to receiving bodies without interfacing with natural soil filtration processes. Because of this, urban areas tend to contribute a disproportionate amount of sediment and contaminants to receiving waters relative to the percentage of urbanized area within the watershed (Sorrano et al. 1996). Heavy metals, bacterial pathogens, as well as PCBs, hydrocarbons and endocrine-disrupting chemicals are aquatic contaminants that are commonly associated with urban and agricultural land uses.

The full suite of sublethal and indirect effects of these contaminants and combinations of contaminants on aquatic organisms is not fully understood (Fleeger et al. 2003). Some contaminants with potentially severe repercussions for fish and wildlife have yet to be identified. For example, recent research in the Puget Sound region has identified mature coho salmon that return to creeks and die prior to spawning, a condition called pre-spawn mortality (Feist et al. 2011, Sholz et al. 2011). The specific cause of the condition has not yet been identified; however, the condition is linked to urbanized watersheds and is positively correlated with the relative proportion of roads, impervious surfaces, and commercial land cover within a basin (Feist et al. 2011). A model of the effects of pre-spawn mortality on coho salmon populations indicates that, depending on future rates of urbanization, localized extinction of coho salmon populations could occur within a matter of years to decades (Spromberg and Scholz 2001, McCarthy et al. 2008). This finding emphasizes the significance of efforts to address both point-source and non-point-sources of contaminants in the landscape.

Nutrients

In excess concentrations, nitrogen and phosphorus can lead to poor water quality conditions, including reduced dissolved oxygen rates, increased pH, and eutrophication (Mayer et al. 2005, Mayer et al. 2007)). Excessive amounts of nitrogen and phosphorus speed up eutrophication and algal blooms in receiving waters, which can deplete the dissolved oxygen in the water and result in poor water quality and fish kills (Mayer et al. 2005, Dethier 2006, Heisler et al. 2008).

Riparian zones can reduce nitrogen pollution through nutrient uptake, assimilation by vegetation, and through denitrification (Sobota et al. 2012). The rate of nitrogen removal from runoff varies considerably depending on local conditions, including soil composition, surface versus subsurface flow, riparian zone width, riparian composition, and climate factors (Mayer et al. 2005, Bernal et al. 2007, Mayer et al. 2007). Nutrient assimilation is also dependent on the location of vegetation relative to the nitrogen source, the flowpath of surface runoff, and position in the landscape (Baker et al. 2006).

Nutrients enter waterways through channelized runoff, groundwater flow, and overland flow. Nitrogen loading is often associated with agricultural activities, whereas low density residential development has been found to result in nitrate levels comparable to a forested basin (Poor and McDonnell 2007).

As a result of this variability, a meta-analysis of studies of nutrient removal in riparian buffers ranging from 1-200 m (3-656 ft) concluded that buffers wider than 50 m (164 ft) remove nitrogen more effectively than buffers less than 25 m (82 ft) wide; however, within the categories of 0-25 m (0-82 ft), 25-50 m (82-164 ft), and >50 m (164 ft), factors other than buffer width determine nitrogen removal effectiveness (Mayer et al. 2007). Riparian zones less than 15 m (49 ft) actually contributed to nitrogen loading in some cases (Mayer et al. 2007). Another meta-analysis of nutrient removal studied buffers up to 22 m (72 ft) wide, and found that these buffers effectively removed 92 and 89.5 percent of nitrogen and phosphorus, respectively (Zhang et al. 2010).

Mayer et al. (2005, 2007) found that riparian zones ranging from 1-200 m (3-656 ft) generally removed 89% of subsurface nitrates regardless of riparian zone width. On the other hand, nitrate retention from surface runoff was related to riparian zone width, where 50%, 75%, and 90% surface nitrate retention was achieved at widths of 27 m (88 ft), 81 m (266 ft), and 131 m (430 ft) respectively (Mayer et al. 2007). This suggests that surface water infiltration in the riparian zone should be a priority to promote effective nutrient filtration. Where soils are poorly drained and infiltration capacity is limited, the effectiveness of nutrient removal in riparian buffers may also be limited (Wigington et al 2003).

The composition of the riparian zone also affects the efficiency of nutrient removal. Reviews of buffer effectiveness have found that forested riparian zones remove nitrogen and phosphorus more efficiently than grass/forested riparian zones (Zhang et al. 2010). And Mayer et al. (2007) found that herbaceous buffers had the lowest effectiveness compared to forested wetland, forested, and forested/herbaceous buffers. Other studies have found conflicting results, indicating that grass buffers remove nitrogen and phosphorus as well or better than forested buffers (reviewed in Polykov 2005). Where nitrogen-fixing species predominate, such as red alder, these buffers tend to have higher soil nitrate concentrations (Monohan 2004). These findings indicate that the nitrogen removal efficiency of buffers can vary depending on the size and species composition of the buffer.

Removal of phosphorus by riparian buffers is dependent on the form of phosphorus entering the buffer. Whereas phosphorus that is adsorbed by soil particles is effectively removed through sediment retention within a buffer, the retention of soluble phosphorus relies on infiltration and uptake by plants (Polyakov et al. 2005). One long-term study found that phosphorus uptake was directly proportional to the plant biomass production and root area over the four-year study period (Kelly et al. 2007). If a riparian buffer becomes saturated with phosphorus, its capacity for soluble phosphorus removal will be more limited (Polyakov et al. 2005). Another long-term study found that following a 15-year establishment period, a 40-meter (131 ft) wide, three-zoned buffer reduced particulate phosphorus by 22 percent, but dissolved phosphorus exiting the buffer was 26 percent higher than the water entering the buffer, so the buffer resulted in no net effect on phosphorus (Newbold et al. 2010).

In summary, most riparian zones reduce subsurface nutrient loading, but extensive distances are needed to reduce nutrients in surface runoff. Filtration capacity decreases with increasing loads (Mayer et al. 2005), so best management practices across the landscape that reduce nutrient loading will improve riparian function.

Metals

Although all metals can be toxic at high concentrations, cadmium, mercury, copper, zinc, and lead are particularly toxic even at low concentrations. Chronic and acute exposure to heavy metals have been found to impair, injure, and kill aquatic plants, invertebrates, fish, and particularly salmonids (Grant and Ross 2002, ESV Environment Consultants 2003, Dethier 2006, Hecht et al. 2007, Sandahl et al. 2007, McIntyre et al. 2008, McIntyre et al. 2012). A review of contaminant effects on aquatic organisms summarized the factors affecting the toxicity of metals as follows:

- Duration and concentration of exposure
- The form of the metal at the time of exposure
- Synergistic, additive or antagonistic interactions of co-occurring contaminants
- Species sensitivity
- Life stage
- Physiological ability to detoxify and/or excrete the metal and,
- The condition of the exposed organism (ESV Environment Consultants 2003).

Metals are typically transported to the aquatic environment through fossil fuel combustion, industrial emissions, municipal wastewater discharge, and surface runoff (ESV Environment Consultants 2003). In general, heavy metals and hydrocarbons are found in road runoff, and these contaminants can reach the city's streams directly through existing stormwater systems. Stormwater systems that circumvent buffers limit the opportunity to filter runoff through adjoining soils and vegetation. Accordingly, stream buffers are typically underutilized for treatment of hydrocarbons and other pollutants found in typical stormwater runoff.

Pathogens

Waterborne pathogens associated with human and animal wastes are a concern for direct and indirect human exposure. Although pathogens include a suite of bacteria and viruses, fecal coliform bacteria is typically used as an indicator of the presence of these pathogens. Fecal pollution tends to be positively correlated with human population densities and impervious surface coverage (Glasoe and Christy 2004). The main sources of fecal pollutants include municipal sewage systems, on-site sewage systems, stormwater runoff, marinas and boaters, farm animals, pets, and wildlife (Glasoe and Christy 2004). As municipal wastewater systems have improved treatment quality and capacity in recent years, increasingly, non-point source (septic systems, stormwater, and pets) pollution is responsible for fecal contaminants in surface water (Glasoe and Christy 2004).

Herbicides and Pesticides

Commonly used herbicides and pesticides may also affect aquatic communities, and the acute and chronic effects of these chemicals or combinations of chemicals are not always well understood. Additionally, effects documented in the laboratory may differ significantly from effects identified in a field setting (Relyea 2005, Thompson et al. 2004). Despite our limited understanding, the effects of these chemicals may be long-lasting, as has been observed for legacy pesticides such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in salmon, seabirds, and marine mammals in the Puget Sound (Calambokidis et al. 1984, O'Neill et al. 1998, Ross et al. 2000, Wahl and Tweit 2000, Grant and Ross 2002, West et al. 2008).

Herbicides and pesticides may reach aquatic systems through a number of pathways, including surface runoff, erosion, subsurface drains, groundwater leaching, and spray drift. Narrow hedgerows have been found to limit 82-97 percent of the aerial drift of pesticides adjacent to a stream (Lazzaro et al. 2008). In runoff, herbicide retention in a buffer is dependent on the percentage of runoff that infiltrates the soil (Misra et al. 1996). A study of herbicides in simulated runoff found that 6-meter-wide vegetated buffers were sufficient to reduce herbicide concentration exiting the buffer to zero (Otto et al. 2008). A meta-analysis found that filtration effectiveness increased logarithmically from 0.5 m to an asymptote at approximately 18 m (Zhang et al. 2010). In summary, relatively narrow vegetated buffers may be effective in limiting herbicides and pesticides from reaching aquatic habitats in surface runoff, erosion, and spray drift; however, transport via subsurface drainage and leaching are not affected by riparian buffers, and these processes are best managed through the use of best management practices in herbicide and pesticide applications to avoid contaminating groundwater (Reichenberger et al. 2007).

Pharmaceuticals

Pharmaceuticals are another class of contaminants, the effects of which remain poorly understood. Many commonly used pharmaceuticals are found in wastewater, particularly around more urban areas (Long et al. 2013). Many common pharmaceuticals have endocrine-disrupting properties, which can affect fertility and development in non-target aquatic species (Caliman and Gavrilescu 2009). The existing and potential population-scale effects of these chemicals in the environment are not yet well-understood (Mills and Chichester 2005, Caliman and Gavrilescu 2009).

Sediment

Sediment input to streams is supplied by bank erosion, landslides, and upland erosion processes. Other contaminants, including heavy metals and phosphorus, readily bind to suspended clay particles, and these contaminants are often transported with fine sediment in stormwater. Excess inputs of fine sediments into a stream channel reduce habitat quality for fish, amphibians, and macroinvertebrates. Fine sediment adversely affects stream habitat by filling pools, embedding gravels, reducing gravel permeability and increasing turbidity. In salmon-bearing streams, fine sediment fills interstitial spaces in redds, reducing the flow of oxygenated water to developing embryos and reducing egg-to-fry survival (Jensen et al. 2009). Higher levels of fine sediment are also correlated with lower salmonid growth rates (Suttle et al. 2004). Highly turbid water can impair fertilization success in spawning salmonids (Galbraith et al. 2006) and interfere with the respiration and reproduction amphibians (Knutson et al. 2004).

Vegetated riparian zones help stabilize stream banks and slow and filter overland flow, and temporarily store sediment that is gradually released to a stream. Sediment filtration is also high within intermittent and ephemeral streams, presumably because of the high interface with vegetative structures and the flux in water surface elevation, which allows for sediment storage along the streambanks (Dietrich and Anderson 1998).

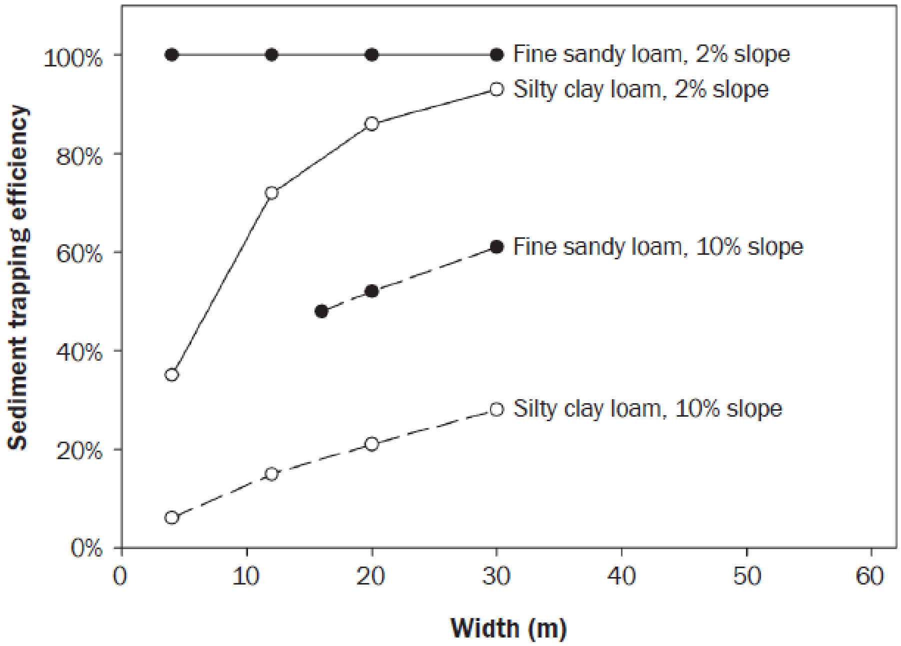
Upland clearing and grading can result in long-term increases in fine sediment inputs to streams (Gomi et al. 2005, Jackson et al. 2007). Numerous studies have investigated the effectiveness of varying widths of buffers at filtering sediment. These studies have typically found high sediment filtration rates in relatively narrow buffer areas (Sheridan et al. 1999, reviewed in Wenger 1999, reviewed in Parkyn 2004, reviewed in Yuan et al. 2009). For example, a field plot experimental study of vegetated filter strip effectiveness found sediment retention of 68 percent in a 2-meter-wide filter strip, and 98 percent in a 15-meter-wide filter strip (Abu-Zreigh et al. 2004). The same study did not find a significant improvement in sediment retention beyond 15 meters.

It is significant to note, however, that field plot experiments tend to have much shorter field lengths (hillslope length contributing to drainage) than would be encountered in real-world scenarios (i.e., ~5:1 ratio of field length to riparian width for a field plot compared to 70:1 ratio in NRCS guidelines). Since water velocities tend to increase with field length, field plot experiments may suggest better filtration than would be encountered under real-world conditions. Additionally, field-scale experiments generally do not account for flow convergence, which reduces sediment retention (Helmers et al. 2005) or for stormwater components that bypass filter strips through ditches, stormwater infrastructure, and roads (Verstraeten et al. 2006). Therefore, the effectiveness of filter strips at filtering sediment under real-world conditions and at the catchment scale is likely to be lower than what is reported in field plot experiments.

Additionally, many studies on sediment retention in riparian zones consider sediment retention from one storm event, rather than accounting for sediment accumulation over time. Two studies used Cesium-137 to track the location of sediment deposition over many years. One of these studies considered the distance that sediment traveled across a riparian forest adjacent to cropland with sandy loam soils and a mean hillslope of 2-5% (Lowrance et al. 1988 in Wenger 1999). The greatest amount of sediment was deposited 30 m (98 ft) into the forest and the strongest signal of Cs-137, which has a high affinity for fine clay particles, was found 80 m (262 ft) into the forest). Therefore, fine sediments can become transported through riparian areas for long distances. The other study found that over 50% of sediment was transported over 100 m (328 ft) into the riparian zone, over hillslopes ranging from 0 % to 20% (Cooper et al. 1988 in Wenger 1999). Together these studies suggest that riparian zones from 30-100 m (98-328 ft) or more may be necessary to provide long-term sediment retention, and that studies of short-term sediment retention underestimate the riparian zone width needed for ongoing sediment filtration.

In addition to width, the slope, vegetation density, and sediment composition of a riparian area have significant bearing on sediment filtration potential (Jin and Romkens 2001). A recent model of sediment retention in riparian zones found that a grass riparian zone as small as 4 m (13 ft) could trap up to 100% of sediment under specific conditions (2% hillslope over fine sandy loam soil), whereas a 30 m (98 ft) grass riparian zone would retain less than 30% of sediment over silty clay loam soil on a 10% hillslope (Dosskey et al. 2008) (Exhibit 6-3). This study exemplifies the effects that soil type and hillslope have on sediment retention.

Exhibit 6-3 Sediment trapping efficiency related to soil type, slope, and buffer width



Source: From Dosskey et al. 2008

Multiple studies have found that larger particles tend to settle out within the first 3-6 m (10-20 ft) of the riparian zone, but finer particles that tend to degrade instream habitat, such as silt and clay, need a larger riparian zone, ranging from 15-120 m (49-394 ft), for significant retention (reviewed in Parkyn 2004). Lee et al. (2003) found higher sediment retention rates (92% and 97% respectively) in a 7 m (23 ft) grass riparian zone and a 16 m (52 ft) grass/forested riparian zone (5% slope, fine clay loam soil) than would be predicted by the Dosskey et al. study. However, the concentration of fine particles was greater leaving the riparian zone than entering it, indicating that larger particles settled out, while fine particles passed through the riparian zone (Lee et al. 2003).

Vegetative composition within the buffer also affects sediment retention. Vegetation tends to become more effective at sediment and nutrient filtration several years after establishment (Dosskey et al. 2007). Dosskey et al. (2007) did not find a significant difference between the filtration effectiveness of established grass and forested buffers. However, a meta-analysis of 81 buffer studies indicated that all-grass and all-forest buffers tend to more effectively filter sediment compared to buffers with a mix of grass and forested vegetation (Zhang et al. 2010). Additionally, whereas thin-stemmed grasses may become overwhelmed by overland flow, dense, rigid-stemmed vegetation provides improved sediment filtration that is expected to continue to function better over successive storm events (Blanco-Canqui et al. 2004, Yuan et al. 2009).

Water Temperature and Microclimate

Stream temperatures and riparian microclimate conditions are closely tied to each other. Factors influencing water temperature and microclimate include shade, orientation, relative humidity, ambient air temperature, wind, channel dimensions, groundwater, and overhead cover.

Salmon and native freshwater fish require cool waters (55-68°F) for migrating, rearing, spawning, incubation, and emergence (USEPA 2003). Thermal tolerances differ by species; coho salmon prefer the coolest temperatures, whereas steelhead can tolerate higher temperatures. A literature review of temperature effects on juvenile salmonid growth found that optimal growth occurred in field studies when daily maximum temperatures were 61-73°F for steelhead, 61°F for Chinook salmon, and 59°F for coho salmon (WDOE 2002). Riparian microclimate affects many ecological processes and functions, including plant growth, decomposition, nutrient cycling, succession, productivity, migration and dispersal of flying insects, soil microbe activity, and fish and amphibian habitat (Brosofske et al. 1997). Amphibians have narrow thermal tolerances, and they are particularly influenced by changes in microclimate conditions (Bury 2008).

Several studies have documented significant increases in maximum stream temperatures associated with the removal of riparian vegetation (Beschta et al. 1987; Murray et al. 2000, Moore et al. 2005, Gomi et al. 2006).

A number of studies have considered the extent to which different riparian zone widths modulate stream temperature. In headwater streams in British Columbia, 10 m (33 ft) riparian zones generally minimized effects to stream temperature from timber harvest, although maximum daily temperatures reached 3.6°F higher than control streams (Gomi et al. 2006). A comparative study of 40 small streams in the Olympic Peninsula found that mean daily maximum temperatures were 2.4°C higher in logged compared to unlogged watersheds, and that logged watersheds had greater diurnal fluctuations in water temperatures (Pollock et al. 2009). Another study of streams in Washington found that stream temperatures were most closely correlated with vegetation parameters associated with the riparian area, such as total leaf area and tree height, and that the effect of buffer width was less significant, particularly for buffers larger than 30 m (98 ft) (Sridhar et al. 2004). These findings are consistent with an earlier study relating angular canopy density, a proxy for shading, to riparian buffer width; which found that the correlation between shade and riparian buffer width increases approximately logarithmically, reaching an asymptote around 30 m (98 ft) (Bestcha et al. 1987). Therefore, for buffers less than 30 m (98 ft), buffer width is expected to be more closely related to shading and stream temperatures than buffers over 30 m (98 ft). A study in British Columbia found significant cooling of up to 4°C in reaches downstream from logged areas even in relatively short lengths of shaded stream channel (200 m of 656 ft long); however, significant cooling was largely attributed to the cooling effect of groundwater in the shaded reaches (Story et al. 2003).

In addition to the effect of riparian areas, watershed-scale land uses can affect stream temperatures. For example, a study in British Columbia found that, after accounting for the effects of watershed size, air temperature, and elevation, the density of roads in a watershed was positively correlated with the summer maximum weekly average water temperature (Nelitz et al. 2007). In areas where headwater wetlands naturally moderate stream temperatures, these wetlands also tend to mitigate the effect of forest clearing on downstream temperatures (Rayne et al. 2008).

Riparian buffers necessary to maintain microclimate are controlled by edge effects, which tend to extend well within a forested area. One study in western Washington detected microclimate edge effects along the entire length of a 240 m (787 ft) buffer (Chen et al. 1995). Heithecker and Halperin (2007) found that most changes in light occurred within 20 m (66 ft) of the forest edge, and that air and soil temperatures stabilized within a range from 10-30 m (33-66 ft); but that throughout 1-hectare forested plots, air temperatures remained elevated compared to larger control plots. Another study in Western Washington found that buffers ranging from 16-72 m (52-236 ft) did little to limit elevated air temperatures associated with an adjacent clearcut in mid-summer (Dong et al. 1998). In contrast to these studies, a study of small streams in Western Washington indicated that buffers greater than 45 m (147 ft) wide are generally sufficient to protect riparian microclimate at streams (Brosofske et al. 1997). In summary, edge effects on forest microclimate extend well into forested areas adjacent to clearings and traditional riparian buffers are not expected to attain pre-disturbance microclimate conditions unless they are several hundred meters wide, but buffers ranging from 10-45 meters in width may minimize microclimate effects related to light, soil, and air temperatures.

Two studies in the Pacific Northwest considering the effects of partial forest retention on microclimate found that retention of 15 percent of a forest basal area was not sufficient to maintain microclimate conditions (Heithecker and Halperin 2006, Aubry et al. 2009); however, 40 percent basal area retention resulted in cooler mean air temperatures than clearcut conditions and light conditions similar to an undisturbed forest (Heithecker and Halperin 2006).

Bank Stabilization

Riparian vegetation helps provide bank stabilization through a complex of tree roots, brush, and soil/rock. A study in British Columbia concluded that major bank erosion is 30 times more likely on stream bends with bare banks compared to vegetated banks, and that densely vegetated banks are the most effective at resisting erosion (Beeson and Doyle 1995). Woody vegetation tends to provide greater bank stability than herbaceous vegetation because woody vegetation has larger roots that extend deeper into the streambank (Wynn and Mostaghimi 2006).

Bank stabilization functions are potentially subject to degradation in an urbanized watershed. Culp and Davies (1983) observed that a 10 m (33 ft) riparian zone maintained bank stability in a 3rd order stream in British Columbia one year after logging. Another study suggested that larger riparian zones (>15 m or 49 ft) were needed to adequately limit stream bank erosion (Whipple et al. 1981). In a study in northern California, Erman et al. (1977) found that stream channel stability (based on both bank and instream metrics), was reduced in clear-cut streams and streams with riparian zones less than 30 m (98 ft), whereas riparian zones over 30 m (98 ft) maintained stream channel stability similar to unlogged streams. As with sediment reduction, the streambank stabilization functions of vegetation increase with buffer width out to approximately 80 to 100 feet; after this point, disproportionately large increases are needed to improve riparian function (Castelle and Johnson 1998).

Hydrologic Source Areas

Hydrologic source areas occur where runoff converges and groundwater rises to form surface water drainageways (Qiu 2003, 2009). These source areas are particularly significant in controlling downstream hydrology, sediment transport, and ecological functions. These source areas are particularly interrelated to riparian conditions because they have more channel edge compared to larger streams (Vannote et al. 1980, Gregory et al. 1991, FEMAT 1993, Knutson and Naef 1997, Bilby and Bisson 1998). Riparian zones along small, low order streams have been found to be more effective at reducing downstream temperatures compared to riparian buffers along larger channels (Brazier and Brown 1973, Elliot 2003, Cristea and Janisch 2007). Riparian areas associated with headwater streams produce significant quantities of litterfall (Gomi et al. 2002) and invertebrates (Wipfli 2005; Wipfli and Gregovich 2002, Wipfli et al. 2007) that are transported downstream to fish-bearing waters. In many cases, small, intermittently flowing channels are productive rearing areas for juvenile salmonids (e.g., Wigington et al. 2006, Colvin et al. 2009). Riparian areas associated with intermittent and headwater streams also provide sheltered humid environments for amphibian dispersal (Sheridan and Olson 2003, Olson et al. 2007, Welsch & Hodgson 2008), and amphibian densities are higher in those headwater streams with riparian buffers (Stoddard and Hayes 2005).

Disturbance of hydrologic source areas may have disproportionate effects on water flow processes throughout a watershed. Hydrologic changes from development are expected to be most significant in small- to intermediate-sized streams with naturally low seasonal and storm flow variability (Konrad and Booth 2005). Qiu et al. (2003, 2009) and Tomer et al. (2009) modeled the effects of protecting these hydrologic source areas related to water quality. Because increased surface water flows are responsible for the increased transport of pollutants, they found that buffers were most effective in maintaining water quality conditions in watersheds where these hydrologic source areas were protected in riparian buffers.

Longitudinal continuity of buffers along streams is also an important factor determining the effectiveness of buffers at improving channel conditions. Riparian continuity is correlated with abundance and diversity of sensitive invertebrates (Wooster and DeBano 2006) and metrics of physical stream conditions (McBride and Booth 2005). Similarly, a watershed-scale study in Southwest Washington found that stream conditions were best maintained with continuous buffers, compared to patch buffers or no buffers (Bisson et al. 2013)

Invertebrates and Detritus

Terrestrial and aquatic invertebrates serve an important role at the base of aquatic food webs. Aquatic invertebrates are sensitive to water quality, flows, and habitat structure, and they are often considered as indicators of stream habitat conditions (Karr 1998, Utz et al. 2009). Hydrologic changes associated with basin and subbasin development have been correlated to degraded indices of invertebrate community integrity (Booth et al. 2004, Alberti et al. 2007, DeGasperi et al. 2009). DeGasperi et al. (2009) proposed that the frequency and range of flood pulses may best explain the correlation between the hydrologic effects of urbanization and the observed degradation of invertebrate communities. Utz et al. (2009) reported that sensitive aquatic invertebrates were not present when impervious cover was in the range of 3 to 23 percent, and the sensitivity of invertebrates to impervious surface cover varied with hydrogeomorphic factors.

Although urbanization at a catchment scale is correlated with a reduction in sensitive invertebrate species, those urbanized catchments with intact riparian buffers along the longitudinal stream gradient maintain a higher proportion of sensitive species compared to those without vegetated riparian corridors (Miltner et al. 2004, Moore and Palmer 2005, Walsh et al. 2007, Shandas and Alberti 2009).

In some cases, the immediate effects of forest clearing have produced unexpected results relating to invertebrate composition. For example, where clearcuts leave significant quantities of woody slash in the stream, an associated increase in collector and shredder invertebrates occurs for years following harvest (Jackson et al. 2007). On the other hand, Kiffney et al. (2003) observed an increase in tolerant Chironomid invertebrates following logging with 0, 10 m (33 ft), and 30 m (98 ft) buffers. Kiffney et al. (2003) concluded that 10- meter-wide buffers were not sufficient to protect stream invertebrate communities from the effects of logging. Kiffney et al. (2003, 2004) concluded that buffers over 30 m (98 ft) in width are necessary to avoid disturbing invertebrate communities.

In-Stream Habitat (Large Woody Debris)

Large woody debris plays a significant role in geomorphic functions such as directing stream flows to shape the channel form and influencing sediment storage, transport, and deposition rates. The collection of woody debris and the subsequent entrapment of smaller branches, limbs, leaves and other material reduce flow conveyance in small streams and increase temporary flood storage (Dudley et al. 1998). By retaining smaller organic debris, large wood provides substrate for microbes and algae, and prey resources for macroinvertebrates (Bolton and Shellberg 2001). Just as riparian areas have a more significant effect on smaller channels compared to larger channels (Vannote et al. 1980), the effects of large wood in small channels are particularly significant (Harmon et al. 1986). In small channels, large wood provides important structures in the stream, controlling rather than responding to hydrologic and sediment transport processes (Gurnell et al. 2002). For this reason, large wood is responsible for significant sediment storage in small channels (Nakamura and Swanson 1993, May and Gresswell 2003).

Large wood that partially blocks flow can also help to encourage hyporheic flow (Poole and Berman 2001, Wondzell et al. 2009).

Large woody debris also plays an important role in forming complex in-water habitat structures that provide flow refugia and essential cover and improved foraging conditions for fish. Fausch and Northcote (1992) found that streams containing large amounts of large wood supported populations of juvenile cutthroat and coho salmon five times greater than streams within the same river system that had been cleared of large wood. Roni and Quinn (2001) found that winter densities of coho salmon, steelhead, and cutthroat trout were higher in streams where large wood had been added.

Large woody debris can enter channels through individual trees falling into the stream, as well as through larger disturbances, such as landslides and fire (Bragg 2000). A comparison of 51 streams with varying channel form in mature forests of British Columbia found that of the approximately one-third of large wood pieces for which the source could be identified, tree mortality was the most common (65 percent) entry mechanism (Johnston 2011). Streambank erosion is a common method of wood recruitment in large alluvial channels (Murphy and Koski 1989), whereas in smaller, steeper channels, wood recruitment predominantly occurs through slope instability and windthrow (May and Gresswell 2003).

The probability of a tree entering the channel decreases as you move away from the stream (McDade et al. 1990, Grizzel et al. 2000). Past research has found that most large wood originates within approximately 30 m (98 ft) of a watercourse (Murphy and Koski 1989, McDade et al. 1990, Van Sickle and Gregory 1990, Robison and Beschta 1990). In 90 percent of the 51 streams surveyed in British Columbia, 90 percent of the large wood at a site originated within 18 m (59 ft) of the channel (Johnston 2011). May and Gresswell (2003) found that wood was recruited from distances further from the stream channel in small, steep channels (80 percent from 50 m (164 ft) from the channel), compared to broad alluvial channels (80 percent from 30 m (98 ft) from the channel) because of the significance of hillslope recruitment in narrow valleys. Trees beyond one site-potential-tree-height from a creek also influence large wood recruitment indirectly by knocking down other trees closer to the stream when they fall (Reid and Hilton 1998).

The likelihood of downstream transport of large wood is dependent on the length of wood relative to bankfull width of the stream (Lienkaemper and Swanson 1987). Wood that is shorter than the average bankfull width is transported more readily downstream compared to wood that is longer than the bankfull width (Lienkaemper and Swanson 1987). Therefore, large wood is rarely transported downstream from small channels less than 5 m (16 ft) in width (May and Gresswell).

Similar to large wood, beaver dams slow water, retain sediment, and create pools and off channel ponds used by rearing coho salmon (Naiman et al. 1988, Pollock et al. 2004). The removal of these structures throughout history has been linked to a significant reduction in coho salmon summer and winter rearing habitat in the nearby Stillaguamish River (Pollock et al. 2004).

Invasive and Non-native Species

Invasive and non-native species can impact native species and habitats through extirpation of native species (Ricciardi et al. 1998), impacts to native communities (Olden et al. 2004, Pimentel et al. 2005), and food-web simplification (Olden et al. 2004).

In 1995, the invasive plant, hydrilla, was found in Pipe and Lucerne Lakes. These are the only lakes in Washington where hydrilla has been found. Hydrilla, a native plant to Africa, Australia, and Asia, forms dense mats of vegetation that smother fish and wildlife habitat. State and local governments (King County and the cities of Covington and Maple Valley) worked together in a multi-year effort to eradicate the hydrilla infestation by using a combination of an aquatic herbicide and diver and snorkeler hand removal. Herbicide treatments stopped in 2009, and King County continues survey efforts to ensure that no hydrilla plants sprout. Surveyors have not detected any hydrilla plants in Lucerne Lake since 2004 and no hydrilla plants in Pipe Lake since 2006.

In addition to hydrilla, Eurasian water milfoil and non-native lily pads are present in Pipe Lake. Other aquatic and upland non-native, invasive, and noxious weeds are also present within the city, including in wetlands and riparian corridors.

6.3 AQUATIC AREAS POTENTIAL PROTECTION MEASURES

The literature points to a range of recommended management measures and buffer considerations to help maintain stream functions for fish and wildlife. Effective methods to reduce impacts from urbanization and associated runoff can include the following:

- Limiting development densities and impervious surface coverage
- Limiting vegetation clearing and retaining forest cover
- Concentrating impact activities, particularly roads and pollutant sources, away from watercourses
- Limiting the total area of roads and requiring joint use of new access roads
- Protecting vegetation and limiting development in or near hydrologic source areas
- Maintaining densely vegetated riparian buffers with native trees, shrubs, and groundcover species
- Low impact development (LID)
- Municipal stormwater treatment
- Public education

In establishing the appropriate level of protection for different stream classes throughout the city, various inferences must be drawn. Many of the scientific studies that critically examine the functions and values associated with riparian areas have been conducted in forested environments. As such, fundamental differences between forested, agricultural, and urban areas, including land use and hydrology, are frequently overlooked. Moreover, there is a limited body of literature on the effects of incremental changes in riparian buffer widths. Lastly, riparian studies often fail to account for the contribution of engineering and public works projects, such as surface-water detention facilities, that can supplement natural riparian function in more urban settings. Thus, although stream and riparian conservation measures should be based on BAS, some level of policy interpretation must be made by a local jurisdiction.

Buffers may be assigned based on local conditions or as a fixed width across all areas. It is noted that fixed buffer widths are more easily established, require a lesser degree of scientific knowledge to implement, and generally require less time and money to administer (Castelle and Johnson 1998). If fixed width buffers are implemented, widths at the wider end of the effective range are recommended to ensure resource protection under a variety of conditions. Buffer averaging, as allowed under CMC 18.65.356(2) provides flexibility, where limited reductions in riparian zone width are allowed so long as they are offset by wider riparian zones in adjacent areas. This type of approach is particularly effective when implemented such that the wider buffer areas are located in existing depressions or swales where surface runoff is likely to become channelized.

Exhibit 6-3 notes the ranges of effective buffer widths (as outlined in each subsection) based on each function and some notes on the functions that were studied.

Exhibit 6-3 Range of Effective Buffer Widths for Each Applicable Riparian Function

Function	Range of Effective Buffer Widths	Notes on Function
Water Quality		
Nutrients	Subsurface flow: not dependent on buffer width Surface flow: 15-131 m (49-430 ft)	In addition to buffer width, the rate of nutrient removal is dependent on infiltration, soil composition, and climate. Filtration capacity decreases with increasing loads, so best management practices that reduce nutrient loading will improve riparian function.
Metals	NA- Appropriate buffer width not established	Stormwater system improvements to slow and infiltrate runoff could help reduce metals entering aquatic systems.
Pathogens	NA- Appropriate buffer width not established	Minimizing the density of septic systems, maximizing the distance of septic systems from aquatic resource areas, and promoting pet waste management will help limit the transport of pathogens to aquatic systems.
Herbicides	6-18 m (20-59 ft)	Best management practices during application of herbicides and pesticides can help limit leeching to groundwater.
Pharmaceuticals	NA- Appropriate buffer width not established	Best management practices for disposal of pharmaceuticals may limit potential impacts.
Sediment	4-30 m (13-98 feet), up to 120 m (394 ft) for fine sediment	Filtration is widely variable depending on slope and soils.
Stream Temperature	10-30 m (33-98 ft)	Leaf cover is more closely related to stream temperature than buffer width.
Microclimate	(10-45 m) 33-150 ft	Most microclimate changes occur within 10-45 m (33 to 150 ft) from the edge, but microclimate effects extend over 240 m (790 ft) from the forest edge.
Bank Stabilization	10-30 m (33-98 ft)	Beyond 98 ft from the stream, buffers have little effect on bank stability.
Invertebrates and Detritus	30 m (98 ft)	Areas with 10 m (33 ft) buffers exhibit changes in invertebrate community composition.
In-stream Habitat (large woody debris)	18-50 m (59 to 164 ft)	Although most large wood is recruited from the area adjacent to the stream, tree-fall from beyond 1 site-potential-tree-height may affect large wood loading.
Wildlife Habitat	100 to 600 feet	Minimum width for supporting habitat varies among taxa, guides, and species. Functions include both corridor (travel and migration) and support of lifecycle stages, including breeding.

CMC 18.65.356(1)(a) applies buffers of 115 feet to Type S and F streams, 60 feet to Type N streams, and 25 feet to Type O streams. These buffers are generally near or within the range of recommended widths based on BAS.

7.0 WILDLIFE HABITAT

Covington Municipal Code 18.65.381 requires protection of an active breeding site of any species with a habitat that is identified as needing protection. The CMC does not specify how to determine whether a species is identified as needing protection. However, policy NE-34 of the Natural Environment Element of the updated Comprehensive Plan does identify protection and preservation of habitats for endangered, threatened, and sensitive species designated by the federal of state government, as required under WAC 365-190-130(2)(a).

Covington Municipal Code 18.65.383 calls for protection along any designated wildlife habitat network adopted by the Comprehensive Plan. Policy NE-9 in the Natural Environment Element of the updated Comprehensive Plan identifies vegetation conservation on steep hillsides, along stream banks and other habitat areas as a priority.

Neither the CMC nor the Comprehensive Plan identify species or habitats of local importance, as required under WAC 365-190-130(2)(b), nor a process for nominating such species. The City may choose to adopt species and habitats of local importance list when updating their Critical Areas Ordinance.

7.1 WILDLIFE HABITAT IN CITY OF COVINGTON

The City of Covington includes habitat types that are known to be used or could potentially be used by species listed as endangered, threatened, or sensitive by state or federal government. These species are listed in Exhibit 7-1 (excluding fish, which are addressed above in Section 6.0).

Exhibit 7-1 Endangered, Threatened, and Sensitive species potentially occurring in the City of Covington.

Common Name	Scientific Name	State Status	Federal Status
Birds			
Marbled murrelet	Brachyramphus marmoratus	T	T
Streaked horned lark	Eremophila alpestris strigata	E	T
Bald eagle	Haliaeetus leucocephalus	S	Co
Yellow-billed Cuckoo	Coccyzus americanus	C	T
Mammals			
Gray Wolf	Canis lupus	S	E

S=Sensitive species, C=Candidate species, Co=Species of Concern, T=Threatened, E=Endangered

Source: US Fish and Wildlife Service, 2015; WDFW, 2015

In addition to species listed as endangered, threatened, or sensitive, WDFW also identifies priority habitats and species for conservation and management.

Priority species include species with declining populations, species that are sensitive to habitat alteration, and/or species of recreational, commercial, or tribal importance. Priority habitats are habitat types or elements with unique or significant value to a diverse assemblage of species. Priority habitats and species identified within the City of Covington, not including fish species or species identified in Section 6.1, are identified in Exhibit 7-2. These species and habitats could be considered for protection as species or habitats of local importance. Other priority species may be present within the city, but not mapped.

Exhibit 7-2 Priority Habitats and Species in the City of Covington (not including fish or species identified in Exhibit 7-1)

Species	Description
Great Blue Heron	Breeding Area
Elk	Regular Concentration
Habitats	
Wetlands	Palustrine
	Lacustrine Littoral

Source: WDFW 2015

Within the City of Covington, continuous wildlife corridors are focused along riparian areas, particularly along Big Soos Creek and Jenkins Creek, and to a lesser extent along Little Soos Creek and the North Jenkins Creek Tributary. The area west of Pipe Lake also consists of contiguous forest. Narrow forested corridors also remain within the Timberlane development.

7.2 HABITAT DEGRADATION

Development in vegetated areas has the immediate impact of removing habitat for individuals, and in some cases populations, of wildlife species present in the area. Extirpation of animals occurs when a habitat patch is reduced below the needed area.

Birds are among the most-studied taxon in urbanizing areas. They often exhibit population responses to the habitat changes associated with development. Long-term viability of avian populations appears to be lowered by reduced quality, abundance, and connectivity of native forest in urbanizing areas (Belisle et al. 2001, Donnelly and Marzluff 2004). In the Vancouver, British Columbia area, Melles et al. (2003) showed an inverse relationship between species richness and level of urbanization. In this study, the presence of large conifers, berry-producing vegetation, and streams increased the likelihood of recording birds.

In a summary of the existing literature, Marzluff (2001) reported that human-driven land use cover changes that occur with development have generally resulted in increases in non-native bird species, increases in species that nest in human structures, increased nest predation, and decreases in forest-interior and ground-nesting species. Factors driving declines in forest-interior and ground-nesting species were decreased available habitat, reduced habitat patch size, increased edge habitat (the interface between different vegetative communities or habitat types), increased non-native vegetation, decreased vegetative complexity, and increased nest predation. Loss of important habitat features such as snags has also reduced density of birds (cavity-nesters) in urbanizing areas (Blewett and Marzluff 2005).

Agricultural development has been responsible for the loss of entire habitats in the United States, and secondarily leads to increases in edge, fragmentation, structural and compositional simplification, and establishment and proliferation of non-native and invasive vegetation (Southerland 1993). On the other hand, fallow fields and flooded pastures can help provide foraging habitat for wintering migratory waterfowl, (Ball et al. 1989).

Increased non-native vegetative cover, which can include ornamental species used in landscaping, was one of several factors that simultaneously led to reductions in the number and quality of urban songbird nest sites in several studies, and exotic shrub cover was correlated with an increased risk of nest predation (Marzluff 2001). Exotic ground and shrub cover was locally associated with a decrease in forest bird species and an increase in synanthropic species, or those that adapted readily to human presence in the Seattle area, although whether these changes were also the result of other concurrent effects of urbanization was unclear (Donnelly and Marzluff 2004). Ironically, dispersal of non-native plant species may be facilitated by birds in the urban landscape, leading to the propagation of discrete infestations (Reichard et al. 2001).

Patch Size and Isolation Effects

Isolated terrestrial habitat patches resulting from fragmentation were predicted from earlier collected literature to support more species as the size of the patch increases (Adams 1994). More recently, Donnelly and Marzluff (2004) demonstrated that species richness increases with habitat patch size in all landscapes (urban, suburban, and exurban). Larger reserves support greater habitat diversity and subsequently more niches for species to utilize (Donnelly and Marzluff 2004). As reserve size decreased, those species depending on intact or expansive forest were the first to disappear. Kissling and Garton (2008) also found that very large reserves supported most native forest bird species; whereas, reserves within landscapes of high (>40%) urban cover supported most of the synanthropic species. In summary, forest species occurrence decreases with decreasing habitat patch size, and synanthropic species occurrence increases with the amount of urbanization in the surrounding landscape.

Patch size has the potential to impact species with small home ranges to a greater extent than relatively mobile avian species. Higher small mammals abundance and/or richness has been demonstrated in larger patches (Pardini et al. 2005) and in patch interiors (Orrock and Danielson 2005). While species requiring smaller home ranges throughout their lifecycle may initially respond less negatively to habitat loss than species that generally need larger areas, this seeming resilience may be short-lived. While a lesser impact has been demonstrated in amphibians with lower dispersal abilities than those with greater abilities, the more tolerant species are likely to face equally negative consequences with time (Cushman 2006). Mammals and insects exhibit a similar varied response to patch size depending on life history strategies. Edge and interior species exhibit positive and negative responses, respectively, to decreasing patch size (Bender et al. 1998).

Large forest patches in the greater landscape may be important to adjacent developed areas in that they act as “sources,” protecting the long-term survival of species that may use urban areas but cannot exist without larger habitat patches in the greater vicinity. Similarly, in North Carolina development-sensitive bird species richness and abundance decreased with increasing percent cover of managed (mowed or cleared) area within and adjacent to forested greenways, with most sensitive species persisting only in the widest remaining forested tracts (Mason et al. 2007). In contrast, fragmented habitat matrices are a major influence on urban habitat patches as a source of invasive plants and predators (McKinney 2002). They may eventually become “sinks,” or areas unable to support viable populations of particular species or other taxa.

Small reserves may support one or more life history phases (e.g., foraging or rearing), but they may not be sufficient for species to complete their life cycles. For example, Kissling and Garton (2008) found that small forest patches in urban landscapes had no value as breeding areas for at least some forest bird species. The highest shrub nest densities, apart from those in large, exurban reserves, were observed in medium-sized (mean of 34.7 ha) suburban reserves. These considerable habitat patches potentially act as a means of retaining forest species in developing landscapes. In some cases, corridors may facilitate wildlife travel between small forest patches, but vegetated corridors are not always effective, particularly for migratory birds (Hannon and Schmiegelow 2002).

Habitat Fragmentation and Connectivity

A strong example of the influence of human impacts on wildlife and habitat can be seen in connectivity effects on local habitat. The pattern of habitat loss and unavoidable consequent fragmentation may exert a greater influence on wildlife, including birds, mammals, herptiles, and insects, than habitat loss alone, with declines in populations a primary impact (Bender et al. 1998).

Urban development generally causes more persistent and drastic fragmentation than other anthropogenic land uses, such as forestry and agriculture, as fragments are commonly separated by impervious surface, structures, impassable barriers, and infrastructure used by vehicles and people. Water flow is obstructed or redirected, nutrient cycling is disrupted, and ecological function may be interrupted or altered. Total habitat area is reduced; dispersal and travel by many wildlife species is altered or obstructed; and the processes of predation, parasitism and interspecies competition are affected (Marzluff and Ewing 2001). Isolated habitat fragments tend towards degradation and the establishment of non-native habitat (Marzluff 2001).

Even small breaks between habitat patches can deter wildlife travel and, in some cases, directly impact wildlife abundance. For highly mobile species, the size of gaps between forest patches determines the effects on the species. More mobile taxa may be less deterred from travel between habitat patches over unvegetated gaps. However, even some mobile species (*e.g.*, songbirds) exhibit a preference for traveling between habitat patches through wooded areas compared to open gaps, even when the wooded route was up to three times longer than the gap (Desrochers and Hannon 1997).

Forest songbirds in an urban landscape in Alberta were significantly more likely to move between vegetation patches when gaps were <30 m, and the difference was more dramatic when gaps reach 45 m (Tremblay and St. Clair 2009). Traffic also reduced movement. Railroads had a lesser effect, probably due to narrow width, and rivers had a higher impact than anthropogenic linear features.

Lehtinen et al. (1999) found that road density in particular was associated with a decline in amphibian species richness. Neotropical migrant bird abundance, richness, and diversity have been inversely correlated with road density in Portland, Oregon (Hennings and Edge 2003).

7.3 WILDLIFE POTENTIAL PROTECTION MEASURES

One solution to the negative impacts of fragmentation is to manage connectivity (Schaefer 2003). The benefit to wildlife of connected habitat areas is evident, as habitat corridors facilitate the movement of individual animals and connect even distant “source” areas to local habitat patches. Vegetated corridors tend to be correlated with watercourses in urbanizing settings because of regulatory protections on streams and rivers. The associated riparian systems make up a relatively small percentage of land cover in the western United States, yet they provide habitat for rich wildlife communities (Knopf et al. 1988, Johnson and O’Neil 2001), which in turn provide a source for habitat patches or reserves.

Many studies address the importance of vegetated corridors to wildlife, particularly in developed areas (Knopf et al. 1988, Gillies and St. Clair 2008, Gilbert-Norton et al. 2010). They are particularly valuable in fragmented habitats because they can facilitate travel among habitat patches for wildlife. Published results pertain to a wide range of taxa, including birds, small and large mammals, herptiles, and insects. The number of wildlife species present has been demonstrated to be directly proportional to corridor width (Dickson 1989, as cited in Keller et al. 1993), although other studies show conflicting results (Pearson and Manuwal 2001) and species-specific variation (Ficetola et al. 2008). Terrestrial buffers on streams and wetlands are particularly important for reptiles and amphibians, as they depend on these areas for certain lifecycle stages. A 2003 synthesis found that terrestrial core habitat (buffers associated with wetlands) of 159-290 m and 127-289 m in width were required by amphibians and reptiles, respectively (Semlitsch and Bodie 2003).

Most studies report a range of 125 to 400-m-wide corridors necessary to provide essential habitat for avian species (Shirley and Smith 2005, Peak and Thompson 2006, Kissling and Garton 2008). However, while wide corridors are optimal, even narrow buffers have been shown to provide habitat for many species (Pearson and Manual 2001, Keller et al. 1993). A 2010 review of the literature found that corridors most effectively facilitated movement or dispersal through fragmented landscapes of invertebrates, plants, and non-avian wildlife (Gilbert-Norton et al. 2010). This work showed that use of corridors was not influenced by independent variables such as total vegetated area. Despite the potential benefits of habitat corridors, it should be noted that as a result of their high edge-to-area ratio, corridors may also facilitate the establishment of invasive species.

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8.6 SECTION 6.0 AQUATIC AREAS

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8.7 SECTION 7.0 WILDLIFE HABITAT

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APPENDIX A

City of Covington Critical Area and Hazard Mitigation Plan Maps