SAN JUAN COUNTY

BEST AVAILABLE SCIENCE SYNTHESIS

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The many landowners who kindly gave Dr. Adamus permission to access their property.

LIST OF ACRONYMS AND ABBREVIATIONS

BAS – Best Available Science
BMPs – Best Management Practices
CAO - Critical areas ordinance
CARA – Critical Aquifer Recharge Area
CD&P – San Juan County Community Development and Planning Department
CSO – Combined sewer overflow
CTED – Washington State Department of Community Trade and Economic Development
Corps – U.S. Army Corps of Engineers
DMMP – Dredged Material Management Program
DNR – Washington Department of Natural Resources
Ecology – Washington State Department of Ecology
EPA - U.S. Environmental Protection Agency
ESU - Evolutionarily Significant Unit
FWHCA -Fish and Wildlife Habitat Conservation Area
GMA – Washington State Growth Management Act
HPA – Hydraulic project approval
H&CS - San Juan County Health and Community Services Department
LID – Low Impact Development
LWD Large woody debris
MHW – Mean High Water
MHHW – Mean Higher High Water
MLLW – Mean Lower Low Water
MSA – Marine Stewardship Area
NOAA – National Oceanic and Atmospheric Administration
NRCA – Natural Resources Conservation Area
NRCS – Natural Resources Conservation Service
NPDES - National Pollution Discharge Elimination System
OHWM – Ordinary High Water Mark
OSS - on-site sewage system
PAMC – Port Angeles Municipal Code
PHS – Priority Habitats and Species
RCW - Revised Code of Washington
SJCC - San Juan County Code
SMA – Shoreline Management Act
SMP – Shoreline Master Program
UIC – Underground Injection Control
UGA – Urban Growth Area
USACE - United States Army Corps of Engineers
USFWS - U.S. Fish and Wildlife Service
USGS – U.S. Geological Service
WAC - Washington Administrative Code
WDFW - Washington Department of Fish and Wildlife
WDNR – Washington Department of Natural Resource
WDOE - Washington State Department of Ecology
WNHP – Department of Natural Resources Natural Heritage Program

LIST OF UNIT ABBREVIATIONS	
ac. - acres BIBI - Benthic Index of Biotic Integrity cm/sec – centimeters per second colonies/ml – colonies per milliliter cy/d - cubic yards per day d - days dbh – diameter at breast height ft. – feet ft/min - feet per minute gal/d – gallons per day gal/kWh - gallons per kilowatt hour gpd – gallons per day hr. - hours in. – inches in/hr – inches per hour kg/ha/year – kilogram per hectare per year km - kilometers	m – meters mi. - miles m^3 - cubic meters mg/L – milligrams per liter mg/m^2 - milligrams per square meter mm – millimeters mo - months no./ha/year – number per hectare per year °C - Degrees Celsius °F - Degrees Fahrenheit ppm - parts per million ppt - parts per thousand PSU - Practical Salinity Units s - seconds SPTH - Site Potential Tree Height yd. - yards yr - year

1 INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

In 1990 the Washington State Legislature adopted the Growth Management Act (GMA). This statute mandates that local jurisdictions adopt policies and regulations that protect the ecological functions and values of Critical Areas (formerly referred to as Environmentally Sensitive Areas). Critical Areas include Critical Aquifer Recharge Areas (CARAs), Frequently Flooded Areas, Geologically Hazardous Areas, Wetlands, and Fish and Wildlife Habitat Conservation Areas. In 1991, San Juan County adopted its first Critical Areas Ordinance.

In 1995, the legislature amended the GMA to require that cities and counties consider the Best Available Science (BAS) in designating and protecting Critical Areas (RCW § 36.70A.172(1)). In meeting this requirement, cities and counties are not required to conduct new research or characterize the extent of local problems.

In 2000, procedural criteria were adopted to implement these changes and provide guidance for identifying BAS. According to this guidance, BAS means current scientific information derived from research, monitoring, inventory, survey, modeling, assessment, synthesis, and expert opinion, that is:

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

Generally, science is undertaken by the establishment of an assumption, or hypothesis, which is then supported or negated by conducting experiments or otherwise gathering evidence. The evidence is then published in scientific journals or books in order for the larger scientific community to examine the methods of data collection and interpretation of results. Scientists who criticize aspects of a previous study may present alternative hypotheses and conduct additional experiments to build the body of knowledge about the topic of interest or inquiry. Consensus often forms over time as additional scientists review the published studies and conduct more investigations that support, refute, or alter the hypothesis. Although a minority of dissenting opinions may persist, scientific consensus is arrived at when many different scientists are able to replicate results over time and through different approaches.

In searching for evidence of causal relationships, definitive proof of cause and effect is not always attainable. This is particularly true of ecological systems, in which the interplay of many variables is highly complex. Interconnected factors such as habitat conditions, the stability of food webs, and biological changes within species can have some obvious causal relationships, but these factors can also have unknown relationships or even some incidences where direct impacts become magnified. Scientific study is always evolving and the application of science must sometimes rely upon the preponderance of evidence rather than irrefutable proof.

In cases where the existing scientific information is inadequate to support a proposed action, or where there is uncertainty about whether a proposed action will protect Critical Area functions and values, the WAC encourages a precautionary approach with an adaptive management program to ensure no net loss of Critical Area functions and values (WAC 365-195-920). Adaptive management involves strategic monitoring and the testing of hypotheses to see how well plans, ordinances, and programs are protecting Critical Areas. As conditions change or more is learned, the regulations and programs are to be modified.

Some Critical Areas that must be protected in order to meet the requirements of the Growth Management Act are located within 200 feet of the shoreline. This is within the jurisdiction of the State Shoreline Management Act. The two laws have historically not been well coordinated, and there has been considerable legislation and litigation focused on trying to discern how they relate to one another.

In 2010 the State Legislature once again tried to clarify their intent through the adoption of Engrossed House Bill 1653. This bill, which applied retroactively to July 27, 2003, affirmed that Critical Area regulations adopted under Growth Management Act procedures apply within shorelines until the Department of Ecology approves their incorporation into a jurisdiction's Shoreline Master Program in accordance with Shoreline Management Act procedures.

As part of this bill, the Legislature also adopted a provision stating that, during the interim period (*i.e.*, prior to Ecology approval of separate shoreline Critical Area regulations), "a use or structure legally located within shorelines of the state that was established or vested on or before the effective date of the local government's development regulations to protect critical areas may continue as a conforming use and may be redeveloped or modified if a) the redevelopment or modification is consistent with the local government's master program; and b) the local government determines that the proposed redevelopment or modification will result in no net loss of shoreline ecological functions. The local government may waive this requirement if the redevelopment or modification is consistent with the master program and the local government's development regulations to protect critical areas."

Finally, Engrossed House Bill 1653 requires that local shoreline regulations provide a level of protection to critical areas that assures "no net loss" of the shoreline ecological functions necessary to sustain shoreline natural resources.

This document includes summaries of the science related to Critical Areas in San Juan County and management options the County might employ to better protect these areas. This information was compiled by a team of scientists and natural resource planners. Chapters 1, 5, 6 (Introduction, Frequently Flooded and Geologically Hazardous Areas) and the maps included in Chapter 8 were primarily compiled by County planners. Chapters 2 and 4 (Wetlands and Upland Fish and Wildlife Habitat Conservation Areas) were primarily drafted by Dr. Paul Adamus. Chapters 3 and 7 (Marine Fish and Wildlife Habitat Conservation Areas and Stormwater Alternatives) were primarily authored by the Watershed Company/ Herrera team of scientists, along with Dr. Richard Strathmann (primary author of the discussion on discharge from desalination systems), and County planners who worked with the consulting scientists. The document went through both internal and external peer review processes. Herrera used an established internal system of quality assurance and quality control reviews to ensure the accuracy of its authored chapters (chapters 3 and 7) and the validity of the sources used. Chapter 3 was reviewed by senior experts in marine ecology, coastal geomorphology, water quality, and stormwater management. Chapter 7 was reviewed by senior experts in water quality and stormwater management.

Prior to release to the public, the members of the team also reviewed one another's sections, provided comment to the author(s), and, where necessary, participated in discussion to resolve any issues. The draft document was then released for review by the public, and local, State and Federal agencies. Individuals submitting expert comment were asked to provide information on their education and work experience in order to identify their area of expertise. Agency staff who commented within the scope of their position were also considered to be experts. Comments submitted by experts and the authors' responses to the comments are included in Chapter 9.

This document includes many citations for scientific papers and sources of information which were considered. In cases where no citation is given, it should be assumed that the statement is the professional opinion of the author(s).

When completed, this BAS Synthesis document will be adopted by the San Juan County Council. The Synthesis and, if necessary, the references it cites will then be used in reviewing existing regulations and selecting actions that are suitable for San Juan County.

1.2 COUNTY PROFILE

San Juan County is located in the northwestern portion of Washington State between the mainland of Washington and Vancouver Island, Canada. The County consists of 428 islands (those exposed at high tide) that are part of the San Juan/Gulf Island archipelago, with a total land area of 172 square miles and a total of 408 miles of marine shoreline, more than any other county in the contiguous United States. The islands that make up the County range in size from 36,432 acres to considerably less than one acre. Many of the smaller islands are uninhabitable or are in public ownership; fewer than fifty are potentially available for private development. Only the four largest islands are served by the Washington State Ferry System: Orcas (36,432 acres), San Juan (35,448 acres), Lopez (18,847 acres), and Shaw (4,937 acres).

The topography of individual islands varies. Orcas Island has the greatest relief, ranging from sea level to 2,407 feet, with seven peaks higher than 1,000 feet above sea level. Though water catchment areas on the islands are small and streams are primarily intermittent, some support spawning of salmonids. Chum in particular do not need extensive freshwater streambeds and can spawn at stream mouths. In addition, the freshwater-seawater interface supports an abundant environment for young, migrating salmon and their prey (San Juan County County 2004).

According to the U.S. Census Bureau, San Juan County's year-round population (as of 2009) is 15,484 (U.S. Census Bureau 2010). The Washington State Office of Financial Management ranks the County's population as 32nd (overall) out of the State's 39 counties. The population density in the County is approximately 89 people per square mile, 10th among Washington counties. The County is experiencing population growth, with an increase of 13.1% between 2000 and 2009. (These numbers do not account for increases in non-resident and summer transient populations, which peak in July and August). The summer population is approximately double that of the winter resident population. Due to the large number of seasonal homes owned by people who do not live in the County, the built environment (homes, roads, utilities and other infrastructure) exceeds that which would normally be expected in a community of 16,000.

Most of the County is rural in nature, with 75% of the population living outside the "urban" areas of Friday Harbor, Eastsound, and Lopez Village. The Town of Friday Harbor on San Juan Island is the only incorporated municipality, with a population of 2,220. Rural residential development is concentrated along the shoreline in small subdivisions, villages, hamlets and resorts including Rosario and Roche Harbor Resorts, Orcas Village, Doe Bay, Olga, Deer Harbor, Westsound, and North Rosario. Excluding shoreline natural areas and parks, the mean or average size of shoreline parcels is 5.37 acres, the median or middle value is 1.32 acres, and the most common size is 0.68 acres (Friends, 2010). Average parcel sizes for the larger islands are shown below.

Island	Average without Public Land	Average with Public Land
San Juan	4.771258	5.682304
Orcas	5.078986	7.185284
Lopez	5.32743	6.085425
Shaw	7.796889	10.628358
Blakely	3.982656	17.619602
Stuart	4.663432	5.434339
Decatur	4.92241	4.96334
Waldron	9.21194	11.757493
Henry	4.527502	5.242775
Crane	2.006734	2.745211
Obstruction	2.851221	4.202983
Johns	3.224352	3.261496
Center	0.82031	0.84069
McConnell	10.33518	7.144419

Table 1-1: Average Parcel Size by Island

The economy of San Juan County is largely based upon residential and commercial construction, particularly the construction of summer homes. Demographically, many island residents do not depend upon the economy of the islands for their sustenance; investment income makes up 46% of the total income, while wage and salary is only 27%. Excluding government, average pay in all the top employment sectors is quite low. Many of those who work for a living do so in low wage occupations with no readily apparent wage premium for working in what is clearly a high cost county (Barney and Worth 2007).

The lack of affordable housing in the County is a significant problem. Between 2001 and 2006 the median home price rose 165%, compared to 61% in the rest of Washington State. The affordability index is 37 (22 for first time buyers) which is the lowest in the State (San Juan County 2007). (One hundred is the level at which a typical family can buy a median priced home.) A 2003 survey by the Community Land Trust Alliance of the San Juan Islands found that 18% of respondents did not anticipate being able to find market price housing that would meet their needs and that they could afford. Based on this survey, 111 households in the "Very Low," "Low," and "Moderate" income households were seeking affordable housing at that time (Rook 2003).

1.3 HISTORY

The San Juan and Gulf islands have been seasonally occupied by Central Coast Salish tribes from approximately 5,000 years ago through the eighteenth century. The Songhees, Saanich, Lummi, and Samish all had winter villages in the southern Gulf and San Juan islands, as well as many permanent structures for other seasons (Heater et al. 2000). The seasonal and local availability of fish had a great impact on the population movements and settlement patterns of local Indian tribes. During summer months, populations commonly disbanded and dispersed to locations where food was available. Small units of people left their winter villages and migrated to optimal fishing and plant gathering areas, where they resided in temporary lodges. It is thought that Native Americans influenced grasslands and oak woodlands through the use of fire (Agee and Dunwiddie 1984). The population of native peoples of the San Juan islands declined by over 80 percent within 100 years of the arrival of Europeans in 1774, due to the introduction of disease and the later removal of these peoples to mainland reservations.

European settlement of the islands began in 1850, when the Hudson's Bay Company established a fish-salting station at Salmon Banks on the southern tip of San Juan Island. Bellevue Farm was established in 1853 as an agricultural station with over 4,000 head of livestock. By the time American soldiers arrived on southern San Juan Island in 1859, native grasslands were already disturbed by the extensive grazing activities. Until 1872, the San Juan Islands were claimed both by the United States and Great Britain. Military forces from both countries jointly occupied the islands until October 1872, when the San Juans was officially declared part of the United States. Within 20 years, settlers had spread to Lopez, Shaw, Orcas, Decatur, and Blakely Islands, raising sheep, cattle, and poultry on small subsistence farms. Sheep farming was the most important livestock industry on the islands. Vegetables and fruits were also grown for markets on the mainland.

Extensive logging at the beginning of the 20th century removed all old growth and valuable timber on most of the islands. Establishment of the local lime industry consumed great amounts of wood to run kilns, as well as young trees to make barrels for the lime. The lime company at Roche Harbor continued to operate until 1956. Quarrying activities for sandstone used in the streets of Seattle were extensive on Waldron, Sucia, and Stuart Islands. Fishing was also a major industry in the islands, with canneries located at Friday Harbor and Deer Harbor. The collapse of the herring fishery, as well as the virtual shutdown of commercial salmon fishing due to population declines, brought an end to the natural resource based economy that historically supported the County's population.

1.4 CLIMATE

The climate of San Juan County is maritime and characterized by cool dry summers and moderately wet winters (Orr et al. 2002, Klinger et al. 2006). Winters are typically drier than in other areas in the Puget Sound. The average daily high temperature in summer is 65° F, and the average low in winter is 40° F, though there may be cold periods when arctic air funnels down the Fraser River Valley from Canada. From nearly 120 years of observations, the National Weather Service gauge at Olga reports that temperature has averaged 57.1°F over that time, with an all-time record high of 93°F observed in July 2009 and a record low of -8°F in January 1950 (Western Regional Climate Center 2010).

The variation in rainfall throughout the county is indicative of geographic differences which can create micro-climates depending on position in the landscape – commonly referred to as the "rain shadow" effect. Precipitation at sea level increases from south to north as the rain shadow influence dissipates. Spatially, precipitation varies significantly throughout the County, with Mount Constitution being by far the wettest area, receiving more than 48 inches of rain on average per year (Orr et al. 2002). In the southern part of the County, precipitation at low to moderate altitudes ranges from about 19 inches to 35 inches. Precipitation on Lopez Island ranges from 19" at the south end of the island, to 24" at the center of the island (data provided by Scott Rozenbaum). Precipitation at Olga has varied between 15 and 38 inches, with an average of 29 inches.

Snowfall is not a significant factor in the San Juan Islands (Orr et al. 2002) and there is no appreciable snow pack, even at the highest elevations. Only 6.7 inches of snow falls on average each year at Olga, one of the snowier places in the County (Western Regional Climate Center 2010).

1.5 GEOLOGY

Bedrock geology dominates the landscape in the County, and surface elevations range from sea level to 2,407 feet (at the summit of Mt. Constitution on Orcas Island). Two distinct types of geologic landforms are prevalent. The first consists of bedrock domes thinly covered with late Quaternary (glacial) sediments, which are commonly found on San Juan and Shaw islands. The second type, found on Lopez, Waldron, and Decatur islands, is composed of bedrock buried beneath deposited sediments. Neither formation is exclusive to any single island.

The geology of the County is best discussed by separately addressing bedrock and surficial (sedimentary) components, as has been common practice in geologic mapping for the area (Pessl et al. 1989, Whetten et al. 1988). Consequently, the geology discussion provided below is divided into bedrock and sedimentary.

1.5.1 BEDROCK GEOLOGY

Although the rocks of the San Juan Islands are structurally related to rocks found in the northwest Cascades (Brown et al. 2007), the geology of the San Juan Islands is distinct enough from the mainland to warrant their own stratigraphic section and formation names such as the Fidalgo Complex, Constitution Formation, Turtleback Complex, and Orcas Chert (McKee 1972).

Prior to glaciation, this region was augmented by small micro-continents traveling eastward on the Juan de Fuca plate. As these land masses impacted the main North American continent, the terranes accreted to the North American continent in the late Jurassic Period (100 to 500 million years ago) and then assembled into a series of overlapping thrust sheets, forming faults along tectonic lenses and plates. Most units in the San Juan Island sequence show evidence of high-pressure, low-temperature metamorphism that occurred during the late Cretaceous thrusting, which occurred approximately 84 to 100 million years ago (Brown et al. 2007). These thrust systems include Paleozoic granites and volcanic arc rocks, Mesozoic pillow basalts, late Paleozoic to Jurassic chert and limestone, high-pressure metamorphics, and a clastic sequence of Jurassic sandstone. Additionally, during Pleistocene time, some of the islands of San Juan County consisted of two or more islands, which were bridged together with glacial till deposited by the advancing ice that filled inter-island waterways (*e.g.*, the bridging of Orcas Island at Eastsound) (WSDOE 1975).

Repeated glaciations during the last ice age shaped the bedrock and developed the rugged landscape of the islands. During the early to middle Pleistocene Epoch, climatic changes caused the continental ice sheet to move south from British Columbia and over the San Juan archipelago (WSDOE 1975). The region was scoured by a blanket of ice as deep as one mile thick that carved out marine channels. As the glaciers advanced from north to south they created numerous bays and waterways including San Juan Channel, West Sound, East Sound, and Lopez Sound. Higher elevations of bedrock were carved, scraped, and rounded. When the glaciers began melting, the resulting sediment was left behind, blanketing low-lying areas with unconsolidated glacial deposits of clay, silt, sand, gravel, and boulders.

The Paleo-sea level record is also much more complicated in San Juan County than elsewhere in Puget Sound (Dethier et al. 1996). Following the collapse of the Puget Lobe, there was a period of time when the ice sheet was near or on top of the County, but marine exchange had been restored to most of Puget Sound. This period of time is called the Everson Interstade. The proximity of the ice sheet to the County suppressed the land surface, yielding local sea levels as much as 300 feet higher than today (Dethier et al. 1996).

The bedrock geology described above is important for understanding the physical controls on the occurrence and distribution of the County's critical areas and understanding the spatial extent of bedrock aquifers used by the majority of private wells.

1.5.2 SEDIMENTARY GEOLOGY

In the County, glacial and interglacial deposits are relatively thin compared to other areas in Puget Sound, where this type of deposition may be several thousand feet thick. Contour maps of sediment thickness generated from county well logs show most of the San Juans to have less than 20 feet of sediment cover, with some areas thicker than 300 feet on Lopez, Waldron, and Decatur Islands (Dethier et al. 1996, Orr et al. 2002). This thickness, compared to the Quaternary sediment layers in other parts of the Puget Lowland, is miniscule, and reflects the role that the bedrock elevations played in the glacial history of the islands. Glacial sediment distribution in the County varies greatly, with large pockets scattered throughout low-lying areas and little or no sediment found elsewhere. The two largest concentrations of sediment are located on Lopez and Orcas Islands, where some sections extend below sea level.

Another aspect of the sedimentary geology of the County are those shoreline features generated since sea levels stabilized approximately 6,000 years ago (Finlayson 2006). The shoretypes found in the County include spits and barriers, tombolos, sub-estuaries, bluffs, rocky platforms, plunging rocky shores, pocket beaches, and eroding bluffs (MacLennan and Johannessen 2008). Many of these shoreline features are also expressed above modern sea level, owing to features placed during the Everson Interstade, as they are in other portions of northern Puget Sound (Kovanen and Slaymaker 2004).

Most of the San Juan County coastline is composed of exposed bedrock; however, a considerable portion of the coast is composed of unconsolidated sediment in coastal bluffs. These are the County's most recent geologic formations, resulting from the last ice sheet advance (the Vashon advance). Bluffs erode and recede at a slow rate, and episodic landslides have been noted as rare in San Juan County (MacLennan et al. 2010). The erosion of coastal bluffs is important because most of the County's beaches rely upon the constant input of sand and gravel from these "feeder" bluffs. In San Juan County, there are no major river systems to deliver sediment to the beaches; rather, the coastal bluffs provide the beach substrate.

The morphology and composition of the beaches are influenced by sediment input, wave climate, and shore orientation (MacLennan et al. 2010). The size of the sediment input is a function of the type of material eroding from the bluff as well as the wave energy. Coastal bluffs erode through various processes, at both the top and toe of the slope.

The wave climate affects coastal erosion rates and beach substrate. Wave characteristics are influenced by fetch (the open water distance over which winds blow unobstructed) and the orientation of the shoreline relative to the incoming waves. Beaches with low wave energy are composed of poorly sorted sediment and have a relatively narrow backshore and intermittent vegetation. Higher wave energy beaches are composed of well-sorted sediment, often dominated by cobbles (MacLennan et al. 2010).

While erosion of a bluff is necessary to feed the beach below, the beach also serves as a buffer to protect the bluff from waves that erode the toe. Beaches are the most effective at this when they contain nearshore vegetation or woody debris to absorb the wave energy (Envirovision 2007). The stability of a coastal bluff is directly linked to its beach below and the beaches located down-drift within the drift cell. Drift cells and important feeder bluffs in the County have recently been mapped by MacLennan et al. (2010).

1.6 HYDROLOGY

The residents of San Juan County rely almost exclusively on groundwater for their primary source of fresh water. Because the islands have no rivers or seasonal snow pack, recharge of the many small aquifers on the islands occurs from the infiltration of precipitation. Surface runoff, infiltration, groundwater recharge, and groundwater yield are largely controlled by topography and the water-bearing characteristics of the underlying geologic landforms.

The hydrology of the County can generally be separated into three broad categories: 1) groundwater in glacial aquifers, 2) groundwater in bedrock aquifers, and 3) surface water and runoff. Understanding the types and locations of aquifers in San Juan County is important, as groundwater discharge can affect nearshore ecology and the ecological health of streams and wetlands.

1.6.1 GLACIAL AQUIFERS

Glacial aquifers occur in glacial sediments overlying the local bedrock of the San Juan Islands. The glacial deposits vary in thickness and, where saturated, generally yield large quantities of water to wells. Water wells in the county range from six to 460 feet in depth, with varying yields (WSDOE 1975). Although their distribution is limited and they often occupy relatively small areas, San Juan County's glacial aquifers are the highest producing groundwater sources on several islands. They also provide recharge areas for the lower-producing bedrock aquifers.

About 80 percent of Lopez Island is overlain by saturated glacial deposits with thicknesses greater than 300 feet. About 40 percent of San Juan Island is overlain by glacial deposits, but only as thin, discontinuous sheets, with thicknesses generally less than 30 feet. Although many of the glacial deposits on San Juan Island are not saturated, the extreme southern part of the island is overlain by relatively thick, saturated glacial deposits, as deep as 100 feet thick. About 15 percent of Orcas Island is overlain by glacial deposits (in many small pockets) with thicknesses as deep as 300 feet at the northern end of the island and west of Eastsound between Turtleback Mountain and Mount Woolard (Orr et al. 2002). Less than 10 percent of Shaw Island (only one small area) is overlain by glacial deposits (WSDOE 1975).

The final melting of the glaciers supercharged the area with groundwater, filling all available underground spaces. Today, all of the "resupply" or "recharge" comes from rainfall; San Juan County has no rivers and no snow pack by which to replenish groundwater supplies. Actual infiltration of precipitation into groundwater is determined by several factors including the volume and timing of the water at the surface, infiltration capacity of the soil, the condition, type, and amount of vegetative cover, porosity of the underlying geology, and aquifer characteristics such as storage capacity and topography. Orr et al. (2002) estimated groundwater recharge using a daily near-surface water-balance Deep Percolation Model. Results of the study found the following average recharge rates for the four largest islands: Lopez Island, 2.49 inches per year; San Juan Island, 1.99 inches per year; Orcas Island, 1.46 inches per year; and Shaw Island, 1.44 inches per year (Orr et al. 2002).

1.6.2 BEDROCK AQUIFERS

Despite the quality of local glacial aquifers, most wells in the County obtain water from bedrock aquifers, which are less productive. Most of the bedrock in San Juan County is nonporous and water occurs primarily in its joints and fractures, which makes the provision of water less predictable (Orr et al. 2002).

Bedrock generally yields only small quantities of water, sufficient only for single-family domestic use. The low storage coefficients of the bedrock found throughout the County restricts the amount of water that can be stored underground. Further, when the amount of water being used exceeds the amount being stored, salt water can intrude into the present fresh water aquifers (WSDOE 1975). Due to the distance from recharge areas, structural complexity, and accretionary nature of the bedrock, there are no pathways along which groundwater can travel from the mainland to the islands. Generally, groundwater flows outward from the centers of each island toward the shorelines. Because of a high ratio of shoreline length to land area in the County, there is an appreciable flow of groundwater to the sea (Orr et al. 2002).

As with glacial aquifers, it is important to understand bedrock aquifers because they are the groundwater source for most wells in the County.

1.6.3 SURFACE RUNOFF

The amount of precipitation converted to surface runoff varies depending on the amount of precipitation, land surface gradient, depth, type and condition of soil, amount of impervious area, and the type and condition of vegetation. Forested conditions result in the least runoff . Surface runoff estimates for an undeveloped landscape indicate that annual runoff varies from a low of three inches in the southern parts of the County to a high of over 13 inches on Mount Constitution (WSDOE 1975). Runoff occurs chiefly from December through March when soils are already saturated and rainfall is heaviest. Runoff estimates indicate that 28 percent of average annual precipitation becomes runoff, although this amount varies from 11 to 45 percent, depending on location (WSDOE 1975).

As part of a groundwater recharge analysis, USGS gauged several streams in San Juan County from October 1996 through September 1998. During that time, stream flow volumes equaled approximately 25 percent of precipitation volumes on Orcas and San Juan Islands, and 13 percent on Shaw and Lopez Islands. Drainage basins overlain by glacial deposits have less stream flow and are dry for longer periods because greater quantities of water can percolate into the soil and groundwater. Because the soils stay moist for longer periods of time, more water is lost to evapotranspiration (Orr et al. 2002). San Juan Island's False Bay watershed has the greatest volume of runoff for any basin in the county, with an average of 3,154 acre-feet per year. The next largest volume of runoff is for the Crow Valley basin, with 2,276 acre-feet per year. The largest drainage on Lopez drains to Davis Bay, with a volume of 743 acre-feet per year (Heater et al. 2000).

Evaporation and transpiration, or evapotranspiration, is the process by which water is cycled back to the atmosphere from surface water, soil, and plant surfaces. Evapotranspiration can have a substantial impact on the volume of surface water runoff. In the San Juan Islands, the rate of evapotranspiration typically exceeds the amount of precipitation from mid-April through September, causing water to be depleted from the soil (Orr et al. 2002).It is estimated that an average of 42 – 49 percent of annual precipitation is lost to evapotranspiration, although individual basins vary depending on land cover and topography (Heater et al. 2000). Approximately 67 percent of the annual precipitation at Olga returns to the atmosphere through this process (Heater et al. 2000), whereas the Trout Lake watershed, which is steep and forested, loses only about 26 percent (Heater et al. 2000). Evapotranspiration rates are highest during the summer months when precipitation is minimal and plants are actively respiring.

Surface runoff is an important factor in understanding the local water budget and gains to groundwater recharge. Surface runoff is also a key physical control on streams, wetlands, and nearshore ecology, and the means by which organic material, sediment and pollutants move from upland areas into water bodies. Stormwater runoff, pollutants and management options are discussed in greater detail in subsequent chapters.

1.6.4 NATURALLY OCCURRING WATER CONTAMINANTS

Several ongoing (and yet to be completed) studies have found relatively high levels of arsenic and cadmium in groundwater, surface water, marine waters and shellfish in San Juan County. This could be naturally occurring from local bedrock, but additional information is needed. Researchers from Kwiaht, the Huxley College of the Environment (Western Washington University), the University of Washington, USGS, and the Pacific Shellfish Institute are currently involved in these studies.

Other naturally occurring contaminants include bacteria and nutrients from wildlife, particularly waterfowl.

1.7 SOILS

Material deposited or accumulated through geologic forces is modified by climate, vegetation and other living organisms, resulting in the formation of soil. The soil is then further modified by topography and the length of time the parent material has been in place. Soil is composed of varying sizes of mineral particles, organic matter and multiple species of living organisms, with biological, chemical and physical properties that are in a constant state of flux.

Many processes take place in soil. It acts as a filter to protect the quality of water. The permeability of soil influences the infiltration of rainfall and the quantity of surface water runoff. The regulation of water flow through soil affects the movement of soluble materials, such as pesticides, fertilizers and toxic materials. Soil is a physical, chemical and biological environment in which water, nutrients, and heat are exchanged between plants and animals. Soil surveys classify soils by the limiting factors that restrict the ability of the soils to fully perform the processes listed above.

There are three principal limiting factors that occur in the soils of San Juan County (Schlots 1962). Fifty-seven percent of the soils in San Juan County are limited by the shallowness of the rooting zone, stones in the soil profile, and low moisture-holding capacity in the root zone. Many of the soils in this limitation class are less than 30 inches deep and sit atop a cemented glacial till layer (hardpan) that restricts the downward flow of water. The soils that are deeper than 30 inches are located above coarse layers of sand and gravel that tend to allow water to drain through the soil very rapidly.

Excessive water is a hazard or limitation affecting the use of about 23% of the soils in the San Juan soil survey. This hazard/limitation includes poor soil drainage, soil wetness, and a high water table. Susceptibility to erosion is the dominant hazard or limiting factor for 19% of the soils in the County. The majority of the soils and soil complexes in this classification have slopes in excess of 30%, and are mapped as rock areas or soil and rock complexes.

Soil erosion is a natural process that can be affected by human action. Removal of the protective vegetative cover exposes the soil to the impacts of rainfall. This impact clogs the air spaces in the soil making it less permeable, increasing runoff, and causing individual soil particles to break loose and be carried downslope. The shallowness and relatively high clay content of San Juan County soils make them particularly susceptible to compaction, such as when heavy equipment or farm animals are placed on wet soils. These processes cause a loss in soil nutrients, making plant growth more difficult, and soils that move off site can negatively affect streams, wetlands, and marine habitats.

1.8 LAND COVER

Land cover is an important feature of the natural and built environment, directly influencing the infiltration of precipitation, base stream flows, erosion potential, and wildlife habitat. Forests are the dominant type of land cover in the San Juan Islands. In 2001, forests covered approximately 61% of the landscape, slightly less than the 62% land cover present in 1991 (WSDOE 2010). These areas consist primarily of Douglas fir, pine, Western hemlock, and Western red cedar, with some areas of Big-leaf maple and Red alder. The remaining land cover is grassland used for hay or pasture; scrub/shrub plant communities such as willow, Nootka rose, bitter cherry, and ocean spray; rock outcrops; and beaches.

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APPENDIX 1.A 365-195 WAC GUIDANCE ON BAS

365-195-900

Background and purpose.

(1) Counties and cities planning under RCW 36.70A.040 are subject to continuing review and evaluation of their comprehensive land use plan and development regulations. Every five years they must take action to review and revise their plans and regulations, if needed, to ensure they comply with the requirements of the Growth Management Act. RCW 36.70A.130.

(2) Counties and cities must include the "best available science" when developing policies and development regulations to protect the functions and values of critical areas and must give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries. RCW 36.70A.172(1). The rules in WAC 365-195-900 through 365-195-925 are intended to assist counties and cities in identifying and including the best available science in newly adopted policies and regulations and in this periodic review and evaluation and in demonstrating they have met their statutory obligations under RCW 36.70A.172(1).

(3) The inclusion of the best available science in the development of critical areas policies and regulations is especially important to salmon recovery efforts, and to other decision-making affecting threatened or endangered species.

(4) These rules are adopted under the authority of RCW 36.70A.190 (4)(b) which requires the department of community, trade, and economic development (department) to adopt rules to assist counties and cities to comply with the goals and requirements of the Growth Management Act.

365-195-905

Criteria for determining which information is the "best available science."

(1) This section provides assessment criteria to assist counties and cities in determining whether information obtained during development of critical areas policies and regulations constitutes the "best available science."

(2) Counties and cities may use information that local, state or federal natural resource agencies have determined represents the best available science consistent with criteria set out in WAC 365-195-900 through 365-195-925. The department will make available a list of resources that state agencies have identified as meeting the criteria for best available science pursuant to this chapter. Such information should be reviewed for local applicability.

(3) The responsibility for including the best available science in the development and implementation of critical areas policies or regulations rests with the legislative authority of the county or city. However, when feasible, counties and cities should consult with a qualified scientific expert or team of qualified scientific experts to identify scientific information, determine the best available science, and assess its applicability to the relevant critical areas. The scientific expert or experts may rely on their professional judgment based on experience and training, but they should use the criteria set out in WAC 365-195-900 through 365-195-925 and any technical guidance provided by the department. Use of these criteria also should guide counties and cities that lack the assistance of a qualified expert or experts, but these criteria are not intended to be a substitute for an assessment and recommendation by a qualified scientific expert or team of experts.

(4) Whether a person is a qualified scientific expert with expertise appropriate to the relevant critical areas is determined by the person's professional credentials and/or certification, any advanced degrees earned in the pertinent scientific discipline from a recognized university, the number of years of experience in the pertinent scientific discipline, recognized leadership in the discipline of interest, formal training in the specific area of expertise, and field and/or laboratory experience with evidence of the ability to produce peer-reviewed publications or other professional literature. No one factor is determinative in deciding whether a person is a qualified scientific expert. Where pertinent scientific information implicates multiple scientific disciplines, counties and cities are encouraged to consult a team of qualified scientific experts representing the various disciplines to ensure the identification and inclusion of the best available science.

(5) Scientific information can be produced only through a valid scientific process. To ensure that the best available science is being included, a county or city should consider the following:

(a) **Characteristics of a valid scientific process.** In the context of critical areas protection, a valid scientific process is one that produces reliable information useful in understanding the consequences of a local government's regulatory decisions and in developing critical areas policies and development regulations that will be effective in protecting the functions and values of critical areas. To determine whether information received during the public participation process is reliable scientific information, a county or city should determine whether the source of the information displays the characteristics of a valid scientific process. The characteristics generally to be expected in a valid scientific process are as follows:

1. Peer review. The information has been critically reviewed by other persons who are qualified scientific experts in that scientific discipline. The criticism of the peer reviewers has been addressed by the proponents of the information. Publication in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.

2. Methods. The methods that were used to obtain the information are clearly stated and able to be replicated. The methods are standardized in the pertinent scientific discipline or, if not, the methods have been appropriately peer-reviewed to assure their reliability and validity.

3. Logical conclusions and reasonable inferences. The conclusions presented are based on reasonable assumptions supported by other studies and consistent with the general theory underlying the assumptions. The conclusions are logically and reasonably derived from the assumptions and supported by the data presented. Any gaps in information and inconsistencies with other pertinent scientific information are adequately explained.

4. Quantitative analysis. The data have been analyzed using appropriate statistical or quantitative methods.

5. Context. The information is placed in proper context. The assumptions, analytical techniques, data, and conclusions are appropriately framed with respect to the prevailing body of pertinent scientific knowledge.

6. References. The assumptions, analytical techniques, and conclusions are well referenced with citations to relevant, credible literature and other pertinent existing information.

(b) **Common sources of scientific information.** Some sources of information routinely exhibit all or some of the characteristics listed in (a) of this subsection. Information derived from one of the following sources may be considered scientific information if the source possesses the characteristics in Table 1-1. A county or city may consider information to be scientifically valid if the source possesses the characteristics listed in (a) of this subsection. The information found in Table 1-1 provides a general indication of the characteristics of a valid scientific process typically associated with common sources of scientific information.

Table 1

SOURCES OF SCIENTIFIC INFORMATION	**CHARACTERISTICS**					
	Peer review	Methods	Logical conclusions & reasonable inferences	Quantitative analysis	Context	References
A. Research. Research data collected and analyzed as part of a controlled experiment (or other appropriate methodology) to test a specific hypothesis.	**X**	**X**	**X**	**X**	**X**	**X**
B. Monitoring. Monitoring data collected periodically over time to determine a resource trend or evaluate a management program.		**X**	**X**	**Y**	**X**	**X**
C. Inventory. Inventory data collected from an entire population or population segment (e.g., individuals in a plant or animal species) or an entire ecosystem or ecosystem segment (e.g., the species in a particular wetland).		**X**	**X**	**Y**	**X**	**X**
D. Survey. Survey data collected from a statistical sample from a population or ecosystem.		**X**	**X**	**Y**	**X**	**X**
E. Modeling. Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.	**X**	**X**	**X**	**X**	**X**	**X**
F. Assessment. Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.		**X**	**X**		**X**	**X**
G. Synthesis. A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.	**X**	**X**	**X**		**X**	**X**

H. Expert Opinion. Statement of a qualified scientific expert based on his or her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.			X X		X X	X X

X = characteristic must be present for information derived to be considered scientifically valid and reliable

Y = presence of characteristic strengthens scientific validity and reliability of information derived, but is not essential to ensure scientific validity and reliability

(c) **Common sources of nonscientific information.** Many sources of information usually do not produce scientific information because they do not exhibit the necessary characteristics for scientific validity and reliability. Information from these sources may provide valuable information to supplement scientific information, but it is not an adequate substitute for scientific information. Nonscientific information should not be used as a substitute for valid and available scientific information. Common sources of nonscientific information include the following:

(i) Anecdotal information. One or more observations which are not part of an organized scientific effort (for example, "I saw a grizzly bear in that area while I was hiking").

(ii) Nonexpert opinion. Opinion of a person who is not a qualified scientific expert in a pertinent scientific discipline (for example, "I do not believe there are grizzly bears in that area").

(iii) Hearsay. Information repeated from communication with others (for example, "At a lecture last week, Dr. Smith said there were no grizzly bears in that area").

(6) Counties and cities are encouraged to monitor and evaluate their efforts in critical areas protection and incorporate new scientific information, as it becomes available.

365-195-910

Criteria for obtaining the best available science.

(1) Consultation with state and federal natural resources agencies and tribes can provide a quick and cost-effective way to develop scientific information and recommendations. State natural resource agencies provide numerous guidance documents and model ordinances that incorporate the agencies' assessments of the best available science. The department can provide technical assistance in obtaining such information from state natural resources agencies, developing model GMA-compliant critical areas policies and development regulations, and related subjects. The department will make available to interested parties a current list of the best available science determined to be consistent with criteria set out in WAC 365-195-905 as identified by state or federal natural resource agencies for critical areas.

(2) A county or city may compile scientific information through its own efforts, with or without the assistance of qualified experts, and through state agency review and the Growth Management Act's required public participation process. The county or city should assess whether the scientific information it compiles constitutes the best available science applicable to the critical areas to be protected, using the criteria set out in WAC 365-195-900 through 365-195-925 and any technical guidance provided by the department. If not, the county or city should identify and assemble additional scientific information to ensure it has included the best available science.

365-195-915

Criteria for including the best available science in developing policies and development regulations.

(1) To demonstrate that the best available science has been included in the development of critical areas policies and regulations, counties and cities should address each of the following on the record:

(a) The specific policies and development regulations adopted to protect the functions and values of the critical areas at issue.

(b) The relevant sources of best available scientific information included in the decision-making.

(c) Any nonscientific information -- including legal, social, cultural, economic, and political information -- used as a basis for critical area policies and regulations that depart from recommendations derived from the best available science. A county or city departing from science-based recommendations should:

(i) Identify the information in the record that supports its decision to depart from science-based recommendations;

(ii) Explain its rationale for departing from science-based recommendations; and

(iii) Identify potential risks to the functions and values of the critical area or areas at issue and any additional measures chosen to limit such risks. State Environmental Policy Act (SEPA) review often provides an opportunity to establish and publish the record of this assessment.

(2) Counties and cities should include the best available science in determining whether to grant applications for administrative variances and exemptions from generally applicable provisions in policies and development regulations adopted to protect the functions and values of critical areas. Counties and cities should adopt procedures and criteria to ensure that the best available science is included in every review of an application for an administrative variance or exemption.

365-195-920

Criteria for addressing inadequate scientific information.

Where there is an absence of valid scientific information or incomplete scientific information relating to a county's or city's critical areas, leading to uncertainty about which development and land uses could lead to harm of critical areas or uncertainty about the risk to critical area function of permitting development, counties and cities should use the following approach:

(1) A "precautionary or a no risk approach," in which development and land use activities are strictly limited until the uncertainty is sufficiently resolved; and

(2) As an interim approach, an effective adaptive management program that relies on scientific methods to evaluate how well regulatory and nonregulatory actions achieve their objectives. Management, policy, and regulatory actions are treated as experiments that are purposefully monitored and evaluated to determine whether they are effective and, if not, how they should be improved to increase their effectiveness. An adaptive management program is a formal and deliberate scientific approach to taking action and obtaining information in the face of uncertainty. To effectively implement an adaptive management program, counties and cities should be willing to:

(a) Address funding for the research component of the adaptive management program;

(b) Change course based on the results and interpretation of new information that resolves uncertainties; and

(c) Commit to the appropriate time frame and scale necessary to reliably evaluate regulatory and nonregulatory actions affecting critical areas protection and anadromous fisheries.

365-195-925

Criteria for demonstrating "special consideration" has been given to conservation or protection measures necessary to preserve or enhance anadromous fisheries.

(1) RCW 36.70A.172(1) imposes two distinct but related requirements on counties and cities. Counties and cities must include the "best available science" when developing policies and development regulations to protect the functions and values of critical areas, and counties and cities must give "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries. Local governments should address both requirements in RCW 36.70A.172(1) when developing their records to support their critical areas policies and development regulations.

(2) To demonstrate compliance with RCW 36.70A.172(1), a county or city adopting policies and development regulations to protect critical areas should include in the record evidence that it has given "special consideration" to conservation or protection measures necessary to preserve or enhance anadromous fisheries. The record should be developed using the criteria set out in WAC 365-195-900 through 365-195-925 to ensure that conservation or protection measures necessary to preserve or enhance anadromous fisheries are grounded in the best available science.

(3) Conservation or protection measures necessary to preserve or enhance anadromous fisheries include measures that protect habitat important for all life stages of anadromous fish, including, but not limited to, spawning and incubation, juvenile rearing and adult residence, juvenile migration downstream to the sea, and adult migration upstream to spawning areas. Special consideration should be given to habitat protection measures based on the best available science relevant to stream flows, water quality and temperature, spawning substrates, instream structural diversity, migratory access, estuary and nearshore marine habitat quality, and the maintenance of salmon prey species. Conservation or protection measures can include the adoption of interim actions and long-term strategies to protect and enhance fisheries resources.

CHAPTER 2

BEST AVAILABLE SCIENCE
Wetlands

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CHAPTER 2 CONTENTS

Appendices

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2.1 Wetlands Overview

After providing definitions and a general overview of wetlands of San Juan County (SJC), this chapter of the Best Available Science document describes strategies for determining widths of **buffers**[2] that protect the functions of wetlands, streams, and other habitats, and describes wetland impacts and strategies to address them. Except where supported by citation of specific literature, all statements in this chapter are either commonly accepted knowledge among wetland scientists or are the interpretation of the chapter author who is a wetland scientist and wildlife biologist.

2.1.1 What Are Wetlands?

The State of Washington requires San Juan County, as well as other counties and cities, to consider the Best Available Science and identify and protect the functions and values of wetlands. This is one of the five types of "Critical Areas" identified in the Growth Management Act and its implementing regulations (RCW 36.70A, WAC 365-190 and WAC 365-195). In addition to local regulations mandated by the Washington Growth Management Act there are other State and Federal laws and regulations that apply to wetlands. These are found in the Federal Clean Water Act; the Washington Water Pollution Control Act (RCW 90.48); and the Washington Shoreline Management Act (RCW 90.58). RCW 36.70A.175 requires use of the wetland delineation manual adopted by the Dept. of Ecology, and WAC 365-190-090 requires use of the State definition of wetland found in RCW 36.70A.030 which states:

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

Wetlands include many—but not necessarily all—areas known locally as wet farmed pastures, wet prairie, subirrigated pasture, alder thickets, swales, aquatic weed beds, and riparian areas.

[2] In general, the term buffers refers to terrestrial areas surrounding a wetland, stream, water body or other area of high ecological, geological, or hydrological importance, and whose purpose is to reduce or prevent impacts to the functions of the protected resource, such as may occur from adjacent land uses. In comparison, setbacks are regulatory tools used to protect land from encroachment by structures, but do not generally specify how the setback area must be managed. Like setbacks, buffers are measured a specified distance between a development and the resource being protected. Unlike setbacks, buffers usually are considered off-limits to some activities and land uses which themselves may impact the functions of the wetland. Buffers are often (but not necessarily) configured to completely encircle a wetland, lake or other resource, whereas setbacks are confined to just a direct path between the development and the wetland being protected.

However, not all of these are subject to the same legal requirements. A perception is often voiced that if an area never contains water, it can't be a wetland. However, science supports the practice of designating areas as wetlands if they meet the above criteria. Wetlands can include areas that *never* have visible surface water so long as their soils (within 12 inches of the land surface) remain saturated for about two weeks (WDNR 2000) and they meet the other criteria above[3]. The reason is that saturation profoundly changes the geochemistry of soil. As a result, this changes the plants and animals that can live there, the functions wetlands perform, and the practical services they can provide to society. In fact, some of the wetlands that are most effective in providing functions that people value (like natural water purification) are the wetlands that don't always contain surface water. It is important to note that man-made ponds and ditches are excluded from the legal definitions of "wetlands" <u>only</u> when they are constructed on non-wetland sites.

Figure 2-1. Examples of San Juan County wetlands.

Wetlands occur most consistently in areas mapped as having the following soils, which are called "dominantly hydric":

> Coveland loam 0-5 percent slopes, Coupeville loam 0-5 percent slopes, Limepoint-Sholander complex 0-8 percent slopes, Shalcar muck 0-2 percent slopes, Semiahmoo muck 0-2 percent slopes, Coveland-Mitchellbay complex 2-15 percent slopes, Bazal-Mitchellbay complex 0-5 percent slopes, Orcas peat 0-2 percent slopes, Dugualla muck 0-2 percent slopes.

These comprise 13% of SJC's land area, according to the NRCS (2009) (Appendix 2D-1.9). About 68% of the area mapped as possible wetland (see section 2.1.3) occurs within these soil map units.

[3] This statement is intended as a general "rule of thumb" and is not as a regulatory definition. Accurate determination of wetland jurisdictional boundaries is actually more complex.

To a somewhat lesser extent wetlands also occur naturally in areas mapped in the soil survey of San Juan County (NRCS 2009) as having the following soils, which are called "partially hydric":

> Sholander-Spieden complex 0-5 percent slopes, Deadmanbay-Morancreek complex 2-15 percent slopes, Beaches-Endoaquents, Deadmanbay-Bazal-Cady complex 2-20 percent slopes, Mitchellbay gravelly sandy loam 0-5 percent slopes, Mitchellbay-Sholander-Bazal complex 0-5 percent slopes, Limepoint-Alderwood warm-Sholander complex 2-12 percent slopes, Xerorthents-Endoaquents, Sucia-Sholander complex 5-20 percent slopes, Mitchellbay-Rock outcrop-Killebrew complex 3-13 percent slopes

Together, the hydric and partially hydric soils comprise 29% of SJC's land area, according to the NRCS (2009), and 15% of the area mapped as possible wetland (section 2.1.3) occurs within these soil map units.

Where man-made ponds and ditches occur where these soil types are present (especially those in the first list), a preliminary inference can be made that their construction or expansion was not legal unless allowed under limited exemptions for certain types of ongoing agriculture or public infrastructure, or unless they were constructed prior to the enactment of wetland regulations. Estimates of the proportion of existing ponds that might have resulted from excavation or permanent damming of wetlands range from 37% to 59%, very approximately[4] As will be explained later in this chapter, just because an area meets the definition of wetland, that does not mean all human activities within it are prohibited or even regulated.

Wetlands can also occur on soils that are not mapped as hydric, due partly to the coarse resolution of the NRCS soil maps. About 16% of the areas mapped as possible wetlands are in these situations.

Of the total acreage of possible wetlands, 2% occur on undrained soils classified by NRCS as potentially supporting "farmland of statewide significance," and 14% occur on undrained soils classified as potentially supporting "prime farmland."

2.1.2 Delineating Wetland Boundaries

The determination of whether an area legally qualifies as "wetland"—and therefore is subject to specific agency regulations (i.e., a "jurisdictional wetland") -- ultimately must be made by a wetlands professional with advanced skills at identifying plant species and soils, and with experience using the procedures in the approved Federal wetland delineation manual and applicable regional supplements (US Army Corps of Engineers 1987, 2010) (WAC 173-22-035). There is good reason why some plant species have been designated as wetland indicators: they are the ones that thrive best in the sort of wetland geochemical conditions where most other

[4] As part of this BAS effort, GIS was used to overlay the NRCS county soils map with the County's map of ponds and lakes and the new map of "possible wetlands." Ponds located on soils characterized as "hydric" by the NRCS maps were presumed more likely to have originally been wetlands than not, although it is recognized that some wetlands are naturally ponded. The lower estimate used only soils that are mapped as dominantly hydric and the higher estimate included soils mapped as partially hydric as well. These estimates are preliminary until soils at individual sites are examined in the field to determine if they are indeed hydric, and ideally, historical aerial imagery is examined to determine if the ponding is a recent condition.

plants cannot (Tiner 1991). Introductory training in the official adopted procedures for delineating wetlands is available through the Washington Department of Ecology, University of Washington, and a few private institutions, e.g., Wetland Training Institute (http://www.wetlandtraining.com/). There currently is no state or federal program to officially certify wetland delineators, though it has been discussed often.

Although it is possible for untrained individuals to recognize many wetlands, some wetlands are not casually identifiable (NRCS 2010). In addition, the transition boundary between wetlands and uplands is often complex and indistinct, requiring experience in the use and interpretation of the standardized procedures and criteria, and a determination to follow these exactly. In particular, recognizing and delineating wetlands properly requires the ability to notice and identify the 328 different species of San Juan County plants that are officially designated as wetland indicator species (Appendix 2B-1). Many look similar to non-wetland plants and some can be differentiated from upland species only by measuring particular diagnostic features that are just millimeters long. Very few persons calling themselves wetland planners or consultants can accurately identify all or most of these indicator species, especially if their education did not include field courses in plant identification. Persons doing legal delineations should first be tested for these identification skills.

Figure 2-2. Plants as wetland indicators in San Juan County.

Although superficially these grasses all look similar, only the last two are wetland indicator species.

Despite the aforementioned concerns, it is important to understand that the presence of a single individual of one of these indicator plants does not make an area a wetland. Collectively the area they cover must be greater than that of plants that are not on the official list, and criteria for wetland soil indicators and saturation must also be met in most cases as well. Of the county's 328 wetland indicator plant species (Appendix 2B-1), about one-third (which are called "facultative" indicators) occur mostly in areas that lack water on the land surface for most of the year and thus are unlikely to be recognized offhand as wetlands, were it not for these diagnostic plants. Dominance by these plants or other wetland indicators within a particular unit of land is associated with a dramatic increase in the levels of many natural functions being performed by that unit of land, so their use as indicators is well-founded upon science. Another one-third of the wetland indicator plants occur in areas likely to be recognized as wetlands by most people, and the remaining third occur in areas that are obviously wetlands, ponds, lakes, or shorelines of estuaries or marine waters.

Only a few dozen of the indicator species are widespread and dominant among SJC wetlands, frequently covering a significant area within any wetland. Of the wetland species, about 92 (29 %) are grass or grasslike plants, 23 (7%) are shrubs, 7 (2%) are trees, and the rest are forbs (wildflowers, ferns, other leafy plants). They comprise about 32% of all plant species documented from the county. The most common woody plants that are wetland indicators in SJC are red alder, salmonberry, Nootka rose, hawthorn, twinberry honeysuckle, and four species of willow. For more information on identifying the more common wetland plants in this region, see:
Island County Wetland Identification Guide:
www.islandcounty.net/planning/documents/WetlandIDGuideFINAL.pdf

Also see a new document from the US Army Corps of Engineers:
Vegetation Sampling for Wetland Delineation: A Review and Synthesis of Methods and Sampling Issues (Gage & Cooper 2010).

Finally, it is important to understand that although delineating a wetland's boundaries can be a technically challenging task in many cases, there is a firm scientific and legal basis for the criteria that are used to define what is a wetland.

Under federal regulations, landowners are required to have the boundaries of a wetland delineated exactly (they may not simply use the boundaries shown on a published map) if they propose filling any part of a wetland, with some exceptions. The US Army Corps of Engineers ultimately determines the acceptability of delineations performed if the alterations involve filling even a small part of a wetland of any size. Even when a wetland is not regulated by Federal regulations, State and County regulations still apply. In addition to covering filling activities, these include some restrictions on draining soggy soils and clearing of vegetation on lands that are not actively cultivated.

2.1.3 Wetland Maps

Like all maps, maps of wetlands suffer from errors of commission (showing a wetland where there isn't any) and errors of omission (failing to show a wetland where there is one). Because of the challenges noted above in delineating wetlands, especially without on-site inspection by a qualified professional, the latter types of errors are much more common. For several years in the 1980s the most complete maps of San Juan County wetlands were those prepared by the National Wetlands Inventory (NWI): http://www.fws.gov/wetlands/Data/Mapper.html

Over time it has become apparent that many wetlands were missed or inaccurately portrayed on that map, which is unsurprising because it was based on interpretation of coarse-scale aerial photographs from that time and was not ground checked. Some ground checking occurred in the early 1990's, partly by a qualified wetland consultant contracted by the County (Sheldon Associates 1993), and some wetlands were added to those mapped by NWI, resulting in what became known as the "1993 Wetland Inventory Maps". However, available resources and lack of access to private property significantly limited the completeness and accuracy of those maps, which the County continued to use in the absence of anything better. As was noted on those maps and in subsequent public discussions, neither those maps nor the ones from the NWI were ever intended to definitively inform landowners of the absence of wetlands or the precise location of wetland boundaries. All counties in Washington face the same situation of incomplete and partly inaccurate wetland maps. Also during the 1990's, a wetland mapping effort covered just the San Juan National Historical Park (Holmes 1998).

Before and during the preparation of this chapter, an urgent need was identified for improving the County's wetland maps, a priority echoed by many local groups (e.g., San Juan Initiative Policy Group 2008). In 2010 the County committed limited resources to do so for several reasons, among them:

1. New technology and better aerial imagery has become available since the 1990s, enhancing the ability to identify and map wetlands more accurately and completely. Using these new tools further supports the County's assertion that it has used Best Available Science in the preparation of the Wetlands part of the CAO;

2. For the County Council to understand fully the potential economic effects any new regulations might have on landowners and property rights, wetlands should be depicted as completely as possible with available resources;

3. To enhance the ability of landowners and county staff to identify some of the situations where contracting with a wetland delineator may be prudent before applying for a building permit.

Responding to this need, in April 2010 the County directed its CAO wetlands contractor to use the best available resources (recent color aerial imagery, LiDAR topographic imagery, new soils maps, earlier wetland maps) to prepare a new countywide wetlands map. Other studies have demonstrated the usefulness of LiDAR as a tool for mapping wetlands (Creed et al. 2003, Shoutis et al. 2010). The mapping methods that were used are described in Appendix 2A-1. When available, ground-based professional delineations of individual wetlands done previously for private landowners or the County were used in lieu of interpreting boundaries only from aerial images. The new map that resulted from analysis of all these sources is titled "Possible Wetlands" and should be considered as a "yellow light" suggesting caution and a heightened need for a formal wetland delineation. No implications should be made regarding the completeness of this map or whether particular areas shown or not shown are or are not subject to any wetland regulations.

2.1.4 Wetland Studies in San Juan County

2.1.4.1 Prior Studies

Studies of San Juan County wetlands have almost always been limited to simply mapping the boundaries of wetlands on someone's property. Dozens of such delineations have been done. However, they provide little reliable information about the relative quality of the wetland, the levels of the functions it performs naturally, or the species that live there. Indeed, a computer search of professional journals using Water Resources Abstracts yielded no hits for a combination of the terms (Wetlands + San Juan County or Islands), or the terms (Streams or Buffers + San Juan County or Islands), except for a few documents focused only on marine systems. An online query using Google Advanced Search in October 2010 identified 3100 items with the combination (Wetlands + San Juan County + Washington) while excluding San Juan Counties in Colorado and New Mexico. However, none of the identified items were peer-reviewed publications that analyzed data collected systematically from the county's wetlands.

2.1.4.2 The 2010 Wetland Study

The County Council in April 2010 approved the idea of an intensified data collection effort led by Dr. Paul Adamus, a wetland scientist who previously had designed and conducted a similar effort for Island County in order to support a required update of their Wetlands Ordinance (Adamus et al. 2006, Adamus 2007). Partly because of the near-absence of prior countywide studies of SJC wetlands, and the need to have such data in order to measure and understand the implications of potential changes in the County's wetland regulations, the 2010 Study was initiated with three main objectives:

1. Refine the existing map of possible wetlands in the county using new imagery and technology, as described generally in section 2.1.3 above and in more detail in Appendix 2A-1.

2. Update the WDOE's Best Available Science for Wetlands document, written over 5 years ago, by reviewing considerably more literature and with an emphasis on judging the applicability of technical literature to SJC conditions in particular.

3. Collect field data needed to:
    - a) measure errors of commission in the new map,
    - b) determine the extent of private land potentially affected by wetland buffers of various widths in response to site-specific conditions in SJC, and
    - c) partly establish baseline conditions so that future changes resulting from maintaining existing wetland protections or adopting new ones may be measured.

As detailed in Appendix 2A-2, the field data were collected from a large statistically random, spatially distributed sample of the County's wetlands by two persons with prior wetland training who were retrained and then accompanied to several sites by Dr. Adamus at the beginning, middle, and end of the field season. Of the 104 sites visited and confirmed to be wetlands, 2 were tidal wetlands, 4 were lacustrine, 7 were mainly slope wetlands, and the rest were depressional wetlands based on the WDOE (Hruby 2004) classification. The standardized field protocols and data forms that were used in the 2010 survey can be found in Appendix 2A-2.

The study did not attempt to rigorously determine the health of SJC wetlands, determine trends in wetland acreage or alterations, or determine the degree to which existing regulations are achieving their objectives. This was impossible because no baseline data exist regarding the condition of the county's wetlands prior to passage of its current wetland regulations. Some of the indicators of wetland health that are most diagnostic cannot be measured meaningfully over short (<1 year) time spans and within realistic county budgets. These include soil chemistry, sediment and water quality, long-term water table changes, flashiness of water levels in response to storm runoff, sedimentation rates, and reproductive success and usage of wetlands by fish and wildlife – especially rare species and those most sensitive to human presence or to specific types of habitat alterations. These indicators of wetland health have not been measured systematically by surveys associated with CAO updates in any county of Washington.

With regard to the second objective listed above (BAS review), the effort emphasized (a) *peer-reviewed* information on buffers or effects of habitat fragmentation. It especially focused on studies *published since the earlier reviews of these topics* prepared by the Washington Department of Ecology (WDOE) (Sheldon et al. 2005) and Knutson & Naef (1997). A limited number of older studies from outside SJC were reviewed if they seemed (based initially on their titles or summaries) particularly well-executed, comprehensive, or notably applicable to the conditions of SJC.

In parallel, the County publicly solicited SJC citizens for their suggestions, and many were received. The resulting lists were then combined, their entries were indexed by topic, and were then prioritized for review. With few exceptions, the prioritization was based on the degree to which an item appeared to meet the above criteria based on its title, type of source, and abstract. Dr. Adamus conducted the entire BAS review for this chapter and Chapter 4.

The number of technical papers and reports published on wetlands, buffers, and habitat fragmentation is in the thousands, according to the author's keyword searches of Google, Google Scholar, and most importantly, Water Resources Abstracts. None of the previous syntheses on these topics, such as the many reviews of effective riparian buffer widths by governmental or private authors, claim to have reviewed all of them. Similarly, this effort did not attempt to review all or even most such studies. Available time and resources allowed review of about 400 technical publications that came closest to meeting the above criteria.

2.1.5 Characteristics and Distribution of Wetlands in San Juan County

As explained in the preceding sections, studies in 1993 and in 2010 attempted to comprehensively map "possible" wetlands. However, a determination of which of these are *actual* wetlands subject to County regulation requires a site visit by a qualified wetland professional, and for each of the previous studies only a tiny fraction of the total mapped wetlands could be visited. Mainly because of newer technology and different criteria for joining vs. splitting neighboring wetlands, the number of possible wetlands shown on County maps as a result of the 2010 study has more than doubled and the acreage has been increased by 52% (Table 2-1). The largest area of possible wetlands is on San Juan Island (43% of total), followed by Orcas Island (30%), Lopez (20%), Blakely (3%), and Shaw (2%). A significant portion (26%) of the acreage of possible wetlands is partially or wholly on lands managed for conservation, which are termed "Protected."

Table 2-1. Area and number of possible wetlands mapped in SJC in 1993 and 2010, by island:

ISLAND	1993 Acres	1993 Number	2010 Acres	2010 Number
Blakely	27	19	197	40
Crane	0	1	0.27	1
Decatur	51	16	48	36
Henry	33	5	16	18
James	1	1	0.43	1
Johns	2	1	8	1
Little Sucia	0	0	0.46	1
Lopez	1012	228	1333	554
McConnell	0.27	1	0	0
Orcas	1158	339	1942	868
San Juan	1785	503	2838	1012
Shaw	185	61	105	70
Stuart	24	12	31	10
Sucia	0	0	8	2
Waldron	47	17	52	23
TOTAL	4325	1204	6580	2637

Table 2.1

Characterization Based on GIS Compilation of Existing Spatial Data

Compiling the Best Available Science not only involves compiling information from published literature, but also from the best available spatial data (digital maps) that are available for a county or city and relevant to understanding the particular type of critical area being addressed. Accordingly, after creating the new map of possible wetlands, we used GIS to intersect it with several existing theme maps, and compiled the quantitative results. This is useful for understanding the gross structure of SJC wetlands, their landscape context, related resources, and potential stressors – both site-specifically and overall. As with all such efforts, the reliability of the compiled information is no better than the quality of the original data. Much of that has significant constraints, many of which (when known) are noted throughout Appendix 2D and in metadata files provided to the CD&P.

Appendix 2D provides the following compilations in tabular format:

- 2D-1.1. Protection status of possible wetlands, by island
- 2D-1.2. Possible wetlands on protected lands, by owner
- 2D-1.3. Possible wetlands on undeveloped parcels
- 2D-1.4. Possible wetlands on developed parcels
- 2D-1.5. Possible wetlands within various distances of the marine shoreline
- 2D-1.6. Acreage of tidal wetlands by island
- 2D-1.7. Possible wetlands by lithology mapped at 1:100,000 scale
- 2D-1.8. Possible wetlands by aquifer recharge potential

The electronic files used to generate these tables, and which provide all the above for any individual wetland and its associated tax parcels, will be available from the CD&P at the completion of this project. In addition to compiling the above for all the possible wetlands, we compiled data on the same themes for areas immediately surrounding each possible wetland (in zones located 50, 75, 100, 150, 200, and 250 ft from the mapped perimeter of each wetland), and for each wetland's contributing area. Those tables are not included in this report, but will also be available at the conclusion of the project. Wetland "contributing areas" are those parts of the land surface that potentially contribute the most runoff to wetlands. These are analogous to each wetland's individual watershed, and can include different wetlands located farther upslope. For this study, LiDAR topographic data were used to estimate the boundaries of the contributing areas of most possible wetlands in SJC. These boundaries were not field-checked and are very approximate, especially for wetlands situated in areas of relatively flat terrain, or where groundwater seepage is a major input, or where ditches and subsurface drains have redirected flow. Nonetheless, compilation of environmental data from wetland contributing areas helps characterize the potential stesses to which a wetland may be exposed.

<u>Wetlands Characterization Based on 2010 Field Survey</u>

As part of this project, the application of WDOE's *Western Washington Wetlands Rating System* (Hruby 2004) to 104 visited wetlands resulted in 24% being rated as Category IV (the category associated with the least regulation), 57% as Category III, 19% as Category II, and none as Category I[5]. Because the wetlands were chosen according to an accepted statistical protocol, these results can be interpreted as being the likely situation for all SJC wetlands, if the County decides to adopt the current version of the WDOE *Rating System.* However, if that happens, it is anticipated that at least a few wetlands would fall into Category I, most likely some tidal wetlands. In 2005 the WDOE informally applied their Rating System to 122 wetlands in western Washington, of which 65 were depressional wetlands. Those wetlands were not

[5] Under the WDOE's *Rating System*, tidal wetlands would automatically be Category I or II. All those included in this project's field assessment effort were determined to be Category II under the *Rating System*. No wetlands qualifying as bogs were assessed during the field effort, likely because of their extreme rarity and the relatively small sample size. Nonetheless, some are known to be present and would be Category I under the WDOE's *Rating System*.

selected according to any statistical protocol, and many were in parks and preserves. Their total scores averaged much higher than for the depressional wetlands we sampled in SJC, with 22% falling into Category I, 40% in Category II, 43% in Category III, and just 3% in Category IV (data supplied by T. Hruby, WDOE, November 2005). Among the WDOE-visited wetlands, the scores for all three rating components (Water Quality Services, Hydrologic Services, Habitat Function) averaged higher than those component scores in the SJC depressional wetlands (only depressional wetlands are compared here because we had too few lacustrine and slope wetlands to permit comparison). The Rating System does not assign scores to tidal wetlands, automatically designating them all as Category I or II.

Also, it is important to understand that *existing County wetland maps that have labeled wetlands by WDOE Category are not valid* because (a) they were based on a 1990's version of the WDOE Rating System which differed significantly from the current version, (b) neither version of the Rating System has been customized for conditions nearly unique to SJC (see section 2.1.6), and (c) many of the wetlands so categorized were never visited, yet on-site inspection is mandatory for accurate application of the Rating System.

Although our 2010 field survey was not intended to survey the plants in each visited wetland comprehensively, a total of 197 plant species were identified among 412 quadrats in 102 wetlands. There were 4 quadrats per wetland, arranged in a cluster around one random pre-selected point in each wetland (see procedures in Appendix 2A-2). The field survey found an average of 18 plant species per wetland (range 3 - 39), averaging 3.23 species per 1 m x 1 m quadrat (range 1-10). The average Wetland Prevalence Index value was 2.28 (where 1.00 indicates vegetation cover is entirely obligate wetland species and 3.00 is generally the highest number before conditions at a given point no longer define a wetland, if corroborated with soil and hydrologic indicators). Of 105 sites visited, there were four where no evidence (vegetative, soils, or hydrology) of wetland conditions was found anywhere on the accessible parcel, indicating either a map error or less likely a recent alteration. In other words, the County's new map of "Possible Wetlands" was determined to have a 3.8% commission error (but as noted earlier, omission errors could not be quantified). In addition, in 5 of the visited sites, all 4 quadrats lacked sufficient wetland vegetation indicators but diagnostic evidence of wetland condition was found elsewhere on the site. In 6 sites, 3 of the 4 quadrats did not meet wetland criteria; in 18 sites half did not; and in 15 sites one did not.

Of all plant *species* found among all visited wetlands, 63% are listed officially as wetland indicator species, 71% are native, 48% are both native and wetland species, and 7% are considered invasive in wetlands according to the WDOE (2004). In an average quadrat, the relative *cover* of vegetation consisted of 62% native species, 51% native wetland species, 32% exotic species, and 24% invasive species (Appendices 2C-3 and 2E). About 28% of the species were dominant (>50% cover) in at least one quadrat in at least one wetland. Species found at more than half the visited sites were *Phalaris arundinacea* (73% of sites), *Alnus rubra* (65%), *Equisetum arvense* (59%), *Rosa nutkana* (58%), *Holcus lanatus* (54%), *Agrostis* spp. (52%), *Juncus effusus* (52%), and *Rubus ursinus* (52%). Although the sample that was visited on private lands comprised only 4% of the unprotected possible wetlands in SJC (according to the new map developed for this project), approximately 126 (39%) of the 328 wetland plant species previously documented from SJC (according to the *Floristic Atlas of the San Juans* and other sources) were found.

Wetland indicator species (Appendix 2B-1) comprise about 27% of all species in the more-comprehensive county plant list. As of 1985 approximately 33% of all vascular plant species in SJC were believed to be exotic (Atkinson & Sharpe 1985). That percentage is likely to now be larger.

Potential stressors or threats to wetlands were also noted during our 2010 survey on private lands, and are tabulated Appendices 2C-3 and 2C-4.

2.1.6 What's Different About San Juan County

Each county and city has its own unique set of circumstances, but those of San Juan County are in several ways dramatically different from those of the rest of western Washington.

- Not mainland. This is noteworthy because islands everywhere have less ecological resilience. Native wildlife and plants are especially sensitive to introduced species, e.g., feral cats.
- Longest marine shoreline of any county in the United States. Implications for salmon and other marine resources.
- No rivers or river floodplains. Few perennial streams.
- The entire county is designated as a sensitive aquifer.
- Not much urban land. No industrial facilities and little commercial agriculture.
- Huge blocks of habitat, much of it containing rare species and biological communities, are protected by the County's Land Bank, Preservation Trust, and Open Space Program, while more continues to be added each year.
- Upland land parcels are mostly large, with an average parcel size ranging from .84 acres on Center Island, to 17.6 acres on Blakely Island. In most areas, the minimum residential density for new development allowed under the County Comprehensive Plan is 1 per 5 acres.
- Traffic on most roads is infrequent. No highways.
- Precipitation is significantly lower than in the rest of western Washington. There is no snowpack or large watersheds to feed wetlands throughout the summer.
- In the absence of large predators (cougar, coyote, bobcat), populations of herbivores (deer, European rabbit) have increased dramatically in many parts of SJC, probably eliminating some native plant species that were historically present, and reducing understory vegetation in general (see Chapter 4, section 4.3.2.1; Peterson & Hammer 2001).
- Beaver, a major factor in wetland creation and functioning, are absent except for a small population on Orcas and Waldron Islands.
- The predominant threats to wetlands are different. Illegal pond construction and drainage of small wet areas near residences are perhaps more common than elsewhere.
- Shallow soils (bedrock near surface) could mean that proportionately more of the pollution, especially from septic systems, travels in shallow subsurface root zones rather than infiltrating below the root zone. This might mean that buffers can be shorter because, by keeping runoff in the near-surface root zone rather than allowing deep infiltration, biological processing is enhanced (Hill 1996, Lowrance et al. 1992, Christensen 2000). But it could also shorten the time available for

processing pollutants before they reach sensitive water bodies, and it could mean that even moderate storm events could quickly saturate the shallow subsurface zone, quickly causing more water to flow across the surface.

2.2 Why SJC Wetlands Are Important

2.2.1 Basics of Wetland Functioning

Wetlands are widely acknowledged as being important because they do several things (called "functions") that humans value:

- **Purify Water**: Wetlands can purify runoff before it reaches streams, lakes, aquifers, and marine waters;
- **Stabilize Soil**: Wetlands can dampen severe runoff that follows storms, thus minimizing the formation of gullies and erosion of soils;
- **Provide Habitat**: Wetlands can provide habitat for plants, fish, and wildlife that thrive in few other habitats, including several species that are endangered, threatened, highly sensitive, or declining regionally;
- **Beautify the Landscape**: Wetlands can provide open space and natural vistas important for maintaining residential property values, tourism, and recreational opportunities.

Most of these wetland functions have never been measured directly in SJC wetlands, but are inferred from studies of wetlands in similar areas. Typically, wetlands perform most of these functions to a greater degree than do non-wetland natural areas of comparable size. Yet not all wetlands perform these functions to an equal degree. Distinguishing **which** wetlands or wetland groups ("complexes") are of greatest importance to a particular function, or to all functions combined, is not a simple matter. For example, one cannot assume that "wetter" wetlands are universally more important than "drier" wetlands, that tidal wetlands are inevitably more valuable than freshwater wetlands, or that wetlands overrun by non-native weeds are automatically less functional than ones with a diverse assemblage of native species. In reality, all these factors—and many more—must be integrated when attempting to identify the most important wetlands, in terms of both their functions and health. Some of the factors important to determining the levels of specific functions and values have been incorporated into the WDOE's *Washington State Wetland Rating System for Western Washington (Revised)* (Hruby 2004). These factors do not automatically equate to wetland health, because the healthiest wetlands are not always the highest-functioning wetlands and vice versa. More comprehensive discussions of wetland functions, their economic importance, and the factors that predict them are provided by Adamus et al. (1991, 2009) and Sheldon et al. (2005).

At the most fundamental level, the major wetland functions are supported primarily by several key natural *processes*, which are dynamic physical, biological, and chemical interactions. These form and maintain both wetlands and the watersheds in which
movement, and loss of:

- Water (e.g., infiltration, recharge, discharge)
- Sediment

- Chemical elements and compounds
- Aquatic organisms (bacteria, algae, invertebrates, fish)
- Detrital material (wood, dead herbaceous plants)

The main drivers or mediators of these movements are precipitation, topography, vegetation, soils, and surficial geology. Some wetlands connect to other wetlands via streams or subsurface connections, while others appear to be isolated from other wetlands and "perched" above water table for most of the year. However, discerning groundwater connections among wetlands with certainty requires intensive field measurements and monitoring over extended periods.

Paradoxically, wetlands in SJC, as elsewhere, require some degree of disturbance in order to remain healthy, adaptive, and high-functioning. Natural disturbance can include occasionally-extreme floods and droughts, and occasional partial removal of vegetation by wildlife, windstorms, salinity incursions (into freshwater coastal wetlands), and fires. Long before the county was settled, glaciers, beavers, and landslides created a few of the wetlands by blocking segments of the small streams that were present. Most types of moderate disturbance allow wetland plant communities to become more diverse. Drought that exposes wetland sediments to the air also accelerates the cycling of many elements, thus increasing wetland productivity over the long term. In contrast, for most wetland types, maintaining water at a constant level minimizes disturbance to such a degree that it can eventually lead to stagnation of biological communities in some types of wetlands (Magee & Kentula 2005). Despite the ecological requirement for some kinds of occasional minor disturbances, if disturbance within wetlands is prolonged or severe—such as resulting from many drainage ditches, dikes, dams without control structures, soil compaction, severe erosion, chronic sedimentation, or contamination by persistent toxins -- the long-term effects on most functions, and consequently the services wetlands deliver to society, will be detrimental.

Two organizing systems are widely used at a national scale for *classifying* wetlands. They are the classification used by the US Fish and Wildlife Service in their National Wetlands Inventory (Cowardin et al. 1979), and a less-detailed hydrogeomorphic (HGM) classification developed with the support of the US Army Corps of Engineers (Brinson 1993). In addition, British Columbia has a classification system for wetlands based on their vegetation, geomorphic, and regional setting (MacKenzie & Shaw 2000). All of these classification systems are intended for scientific use, not as a basis for prioritizing or legally regulating wetlands.

2.2.2 Purifying Water and Protecting Water Quality

2.2.2.1 Importance in SJC

First, it is important to understand that the "water quality function" of a wetland is not the same as the actual quality of water in a wetland. **Water quality function** refers to a wetland's ability to filter and process runoff before that water contaminates underlying aquifers, outflowing streams, estuaries, and marine water. At any instant in time, a wetland that is performing this function effectively may or may not have good water quality, because what is important is not what's measured in the wetland, but rather the difference between incoming and outgoing contaminant loads. The function can be quantified only by measuring the volume of all the water inputs and outputs (including groundwater), and simultaneously measuring their contaminant concentrations. No studies of that type have been done in San Juan County.

For decades, water quality research and management actions have focused on (a) ways to better control pollution sources and (b) how to reduce impacts (e.g., with vegetated buffers) once pollutants got into surface water. However, a new wave of research is now emphasizing the importance of the factors that influence pollutant *transport* (Walter et al. 2009, Walsh & Kunapo 2009) Scientists increasingly speak of the key role of "variable source areas" and the need to map those and the intermittent channels that connect them (e.g., Bren 2000, Walter et al. 2000, Creed et al. 2003, Tomer et al. 2009, Grabs et al. 2009). They are localized spots, usually in topographic sinks or convergences, where most runoff originates during storms when poor infiltration is combined with rising ground water tables (Mankin et al. 2007). And unsurprisingly, *nearly all of the variable source areas are wetlands and intermittent drainageways* (i.e., Hydrologic Group D soils, and type Ns streams and drainageways mapped by this project, see Chapter 4, section 4.2.1.1).

Recent research is finding that a program of mapping these source areas, protecting their vegetation, and widening buffers where more runoff is likely to occur ("hydrologically-informed buffer design"), is more likely to protect downstream waters effectively and at less cost than using uniform-width buffers (e.g., Creed et al. 2008 a, b, Gorsevecki et al. 2008, Qiu 2009a,b). As one group of engineers and hydrologists (Walter et al. 2009) puts it:

> "Riparian buffers are commonly promoted to protect stream water quality. A common conceptual assumption is that buffers "intercept" and treat upland runoff. As a shift in paradigm, it is proposed instead that riparian buffers should be recognized as the parts of the landscape that most frequently *generate* storm runoff. Thus, water quality can be protected from contaminated storm runoff by disassociating riparian buffers from potentially polluting activities."

At the most basic level, identifying and mapping these source areas involves mapping wetlands and using LiDAR to quantify topographic indices of potential soil wetness (Creed et al. 2008), as this Wetlands BAS study has done. Even better spatial resolution and accuracy, leading to fine-tuning of site-specific buffer widths, could be obtained by more extensive ground-truthing or aerial monitoring of seasonal variation in soil wetness patterns (Gorsevecki et al. 2008).

Section 4.2.2.1 of Chapter 4 provides additional discussion of potential sources of waterborne pollution within San Juan County, and summarizes some of the data which indicates causes for concern. However, as noted in that section, little is known about the concentrations and loads of many potential pollutants in the county's wetlands, aquifers, and wildlife because a comprehensive ongoing, countywide monitoring program has not existed.

Water quality functions of wetlands potentially include (a) altering loads of contaminants, (b) altering the loads of nitrogen which in high concentrations is hazardous to humans and aquatic life, (c) altering the concentrations of harmful bacteria, (d) altering stream temperature, and (e) filtering out and stabilizing fine sediments that are suspended in the water column. Each will

now be discussed as it applies to SJC, whose wetlands cumulatively comprise an average of 10% of the watersheds in which they occur (Appendix E).
When particular wetlands are able to detoxify contaminants, that clearly is a benefit to underlying aquifers used for drinking water, as well as to the fish and wildlife of the wetlands, receiving streams, estuaries, and Puget Sound. The ability of *wetlands* to support this function depends partly on the substance being detoxified.

Wetlands are capable of retaining several **metals**, of both human and natural origin, which in high concentrations harm aquatic life (especially fish) in downstream areas. Typical sources of copper, lead, and other potentially toxic metals were described in section 4.2.2.1 of Chapter 4. As runoff increases, some potential elements are diluted (e.g., calcium, silica), but most toxic metals (e.g., copper, lead, zinc) and some nutrients such as nitrate (Bedard et al. 2005) are mobilized from sediments more effectively and their concentration in surface water increases (Kerr et al. 2008). Numeric standards have been legally adopted for many toxic metals. Among the potentially toxic metals, copper is especially susceptible to retention in wetlands because it tends to be retained the best under the low oxygen concentrations that typify wetland sediments (Kerr et al. 2008).

Due to their abundant and diverse microbial assemblages, some wetlands are also capable of detoxifying mild loads of **petroleum hydrocarbons**, such as from road runoff and pesticides. These hydrocarbons are a concern due to their detrimental effects on the food chains of Puget Sound fish and wildlife (Redman 1999, Long et al. 2001).

A growing body of recent research has suggested that various **household chemicals and personal care products** may interfere with fish and wildlife populations by influencing fertility, natural chemical cues needed for homing and communication, and/or disease susceptibility (Staples et al. 2004, Klaschka 2008, Fent 2008, Caliman & Gavrilescu 2009). These include some surfactants (detergents, shampoo, antibacterials), pharmaceuticals, estrogens, synthetic fragrances, fire retardants (organobromines), and plastics (phthalates, bisphenol-A). In contrast to pathogenic bacteria and nutrients, many of these substances are not consistently removed by onsite septic systems (Standley et al. 2008, Wu et al. 2009, Stanford & Weinberg 2010). They can contaminate aquifers (Zessner et al. 2007) and have been found in Puget Sound (Swarzenski et al. 2010) and in SJC (Barsh 2007, 2008a&b, 2009, 2010). The capacity of naturally-occurring *wetlands* to detoxify most of these foreign substances is unknown. The width of riparian buffer needed to detoxify these foreign substances also is unknown.

In Washington and elsewhere, *wetlands* typically are among the most effective components of the landscape for removing **nitrate** (and related forms of nitrogen such as ammonium) from aquatic systems (Geyer et al. 1992). Nitrate is essential to plants and can increase native plant diversity within wetlands (Houlahan et al. 2006) but in high concentrations can harm wetlands, other ecosystems, and human health. Wetlands remove dissolved nitrate mainly by converting it to a gas via a microbial process known as denitrification. Some wetlands also can retain **phosphorus**, another nutrient which in high concentrations is harmful to aquatic life. Wetlands retain phosphorus mainly as a result of chemical adsorption to clay particles which settle in wetlands, and as a result of forming chemical complexes with organic matter so prevalent in wetlands (Mitsch & Gosselink 1993). Wetlands whose sediments are rich in iron or aluminum are especially effective for retaining phosphorus.

The role of *wetlands* in reducing populations of some **viruses and bacteria**, notably coliform bacteria, is variable and uncertain. The long water retention times typical of many wetlands sometimes allow for reductions in bacteria due to natural die-off or consumption by less harmful microbes; this is the principle of wastewater treatment facilities (Hemond & Benoit 1988). However, harmful bacteria can be found in high concentrations in many wetlands due to: (a) many wetlands have deposits of fine sediments, and these are a major reservoir for harmful bacteria that have been washed in, (b) birds and other wildlife which are a common source of bacteria and viruses often crowd into the remaining wetlands, especially in regions where wetland acreage has been reduced greatly over time, and pathogens associated with these animals can be introduced in the water column, (c) when surface water sits in unshaded wetlands for long periods of time, it can be heated by the sun and the resulting higher temperatures typically stimulate rapid increases in bacterial numbers. In summary, it is not possible to determine in advance which wetlands will benefit society by diminishing the numbers of harmful waterborne pathogens.

The role of *wetlands* in maintaining cool **temperatures** in waters used by salmon and other aquatic life is variable and uncertain. Forested wetlands cool water largely by providing shade (e.g., Monohan 2004). Wetlands with long water retention times and a limited canopy of vegetation allow for solar heating of the water. In the same or other wetlands, discharging ground water (which tends to be much cooler than surface water, and is a common feature of many wetlands) can lower water temperatures.

Fine suspended sediments are a concern for reasons described in Chapter 4, section 4.2.2.1. When particular *wetlands* are able to filter and/or stabilize sediments that are suspended in the water column, this can be beneficial or harmful to the wetlands as well as downstream areas. Harm can occur when excessive amounts of sediment are transported by wind or runoff from developed lands into wetlands and remain there. This poses a dilemma of whether to encourage the continued use of wetlands as filters that delay the entry of these substances into downslope streams, lakes, estuaries, and Puget Sound, or to protect the wetlands from the harmful effects of sediment.

Many wetlands are very capable of retaining sediments, phosphorus, and heavy metals at least temporarily, but the potential benefits of these functions do not accrue equally across a watershed. The benefits depend on whether (and where) higher priority is given to protecting aquatic life in wetlands, or in downslope streams, lakes, estuaries, and Puget Sound. The best approach of course is to minimize erosion at its source.

2.2.2.2 Key Factors Affecting Water Purification Functions of Wetlands

Factors most useful for predicting a particular wetland's capacity to process whatever pollution reaches it are reviewed in detail by Mitsch & Gosselink (1993) and Adamus et al. (1991, 2009). In the case of nitrate, removal is usually greatest in wetlands whose sediment or soil is rich in organic matter but not acidic, and which have little or no surface water during the summer, as well as warm winter microclimates (Hefting et al. 2006). In the case of phosphorus and most metals, retention is usually greatest in wetlands whose sediment or soil has elevated levels of calcium (e.g., limestone, clay), iron (e.g., from discharging groundwater), sulfide (e.g., tidal marshes), or aluminum, and in which water is relatively deep and water levels are mostly stable. In the case of petroleum hydrocarbons and manufactured chemical products, factors important for processing are poorly known.

Regardless of the pollutant, wetlands that lack outlets or otherwise have long water retention times are usually more effective at retaining and processing pollutants than wetlands that are more hydrologically open. Few studies have shown conclusively that the type of wetland vegetation (e.g., woody vs. herbaceous) by itself significantly influences the retention or removal of pollutants. When wetland plants die at the end of a growing season, most of the pollutants they take up during their growth earlier in the season are reintroduced to aquatic food chains and soils, sometimes at distant locations, as the plant matter decomposes. However, other aspects of wetlands can support long-term removal or retention of pollutants.

2.2.3 Supporting Habitat and Species

2.2.3.1 Importance of Habitat Functions of SJC Wetlands

All of the County's wetlands provide habitat for plants and wildlife, and some also provide habitat for fish. Especially relevant to this chapter are species that have an *obligate* or *primary* association with wetlands. *Obligate* species are those that require wetlands for some part of their life cycle, and would disappear if wetlands or waters of a particular type were unavailable. *Primarily-associated* species are those that occur in wetlands (or wetlands of a particular type) disproportionately to their occurrence in other habitat types in SJC. In this chapter obligate and primarily-associated species together are termed *wetland dependent* species (Appendices B1 and B2), although the degree of wetland dependency varies across a continuum rather that being a matter of distinct categories.

Wetland dependency for many primarily-associated species is uncertain. This is partly because in some regions where habitat affinities were investigated, the only undeveloped land remaining happened to be predominantly wetlands, so that was where the species was found to concentrate. That does not mean the species would not prefer another habitat if it were equally or more available. Also, many species require both wetland and non-wetland habitats to survive, so simply finding a species (e.g., great blue heron) occasionally in a non-wetland habitat does not mean the species is not strongly dependent on wetlands. Also, many wetland species use non-wetlands if local wetlands become degraded, but that does not mean they are less wetland-dependent, because the productivity of such species will suffer over the long term if they are forced to continue non-wetland habitats.

Appendix 2B-2 indicates which of the county's wildlife species are most likely to occur in wetlands and similar surface waters. Many of these species cannot adapt and reproduce successfully in alternative habitats when the wetlands they prefer are destroyed or degraded. Many (particularly wetland mammals) do not routinely move long distances, especially inter-island, to find remaining wetlands, because doing so exposes them to predators and the elements. Some of these species require specific combinations of microclimate, soils, water regimes, and vegetation in order to reproduce successfully in wetlands.

Although comprehensive biological surveys have not been conducted, based largely on their complex and varied vegetation structure, SJC wetlands as a whole are likely to host more species per unit area than any other habitat type present in the county (see Appendix 4-B in Chapter 4). At least 198 wildlife species (162 birds, 22 mammals, 7 amphibians, and 6 reptiles), of which 73 (37%) are considered by WDFW to be Priority Species[6], regularly use wetlands and fresh surface waters. This represents 75% of the county's total fauna, and 65% of the county's 113 Priority Species. Species that are restricted almost entirely to freshwater wetlands, ponds, and lakes number about 16.

As habitat, some wetland types may be considered more important than others in SJC because

(a) they have the potential to support a wider array of species,
(b) they are a rare type, or
(c) the species they support are considered especially important[7].

Wetland types meeting any of these criteria are described in section 2.4.3.

2.2.3.2 Key Factors for Predicting Habitat Functions

For most species, "suitable wetland habitat" is predicted by characteristics including vegetation structure; the depth, duration, and flow rate of water; size of a patch of vegetation or water; proximity and connectivity to other patches of natural habitat; and the amount and distribution of standing and fallen dead wood. When comprehensive species surveys are lacking, as they are in SJC, there are two common strategies for assessing the habitat functions of a region's wetlands:

1) Called the "species approach," one strategy involves
   (a) using technical literature and expert opinion to summarize the habitat characteristics associated with use of wetlands by all or most of the wetland-dependent species that occur in a region, (b) identifying wetlands in which those characteristics occur, and then (c) compiling the information as lists of potentially-occurring species. This strategy is limited by availability of detailed information on the habitat structures needed by most individual species.

2) The other approach is to identify characteristics or structures believed to be important to wetland-dependent wildlife, fish, and plants "in general," and use that information to identify wetlands anticipated to support the most species. This assumes that maximizing the

[66] "Priority Species" include amphibian, reptile, bird, and mammal species of recreational, commercial, or tribal importance that the WDFW considers to be especially vulnerable. They need not also be legally listed as threatened, endangered, or sensitive – but all species so listed are also considered to be Priority Species. Priority Species "require protective measures for their perpetuation" according to WDFW.

[7] Some wetlands may meet the criteria for more than one type. In that case, the more restrictive regulations will apply.

number of "niches" in an individual wetland, and thus the wetland's number of species, is a desirable objective. It assumes that as the number of species potentially supported by a wetland increases, the needs of the greatest number of species whose requirements are only poorly known are more likely to be accounted for as well. This latter approach and objective have been adopted by the WDOE in their *Rating System* (Hruby 2004).

Many biologists would argue that "Habitat Function" is a much broader concept than just the number of niches and species. It should include the reproductive and foraging success of those species, their abundance, and population viability – characteristics that are not measured by the *Rating System* or any other rapid assessment tool. In any case, maximizing the number of niches and species is of less significance if all the supported species are common, widespread in the region, and not heavily dependent on wetlands.

2.2.4 Supporting Other Natural Functions and Values

Wetlands potentially support dozens more functions and values. A few of the more notable ones are discussed below under the subheadings "Hydrologic Values" and "Open Space Values."

2.2.4.1 Hydrologic Functions and Values

Many wetlands elsewhere in Washington potentially *reduce downstream flood damages* and *minimize stream erosion*. However, in San Juan County flooding of buildings and other valued property as a result of streams is not a widespread concern due partly to the absence of large streams. Instead, nearly all flood damage occurs along the marine shoreline as a result of storm-generated waves. Tidal wetlands along the county's marine shoreline are seldom located in front of structures or erosion-sensitive cliffs where they otherwise could protect these from damaging erosion caused by waves. Although wetland vegetation helps protect streambanks and gentle slopes from erosion, nearly any type of vegetation could do the same. Moreover, streams are dynamic and it is normal for them to shift location from time to time.

Some wetlands potentially promote *infiltration* of runoff into underlying aquifers, because they are located in topographically low places where runoff accumulates and is given time to infiltrate. Infiltration decreases erosion in gullies and small channels, and in some cases helps to maintain base flow in streams during summer. Infiltration of fresh runoff is most important near the marine shoreline, where salt water can gradually migrate laterally into aquifers important for domestic uses unless countered by a sufficient volume of infiltrating fresh water. Although many wetlands in SJC are probably not the most effective areas for infiltration and aquifer recharge (because they are at least partially sealed by clay, shallow bedrock, or other confining material that is prevalent in SJC—which is one reason they are wetlands), some lateral and downward leakage has been shown to occur seasonally in similarly "perched" wetlands in other regions, and can eventually contribute to recharge of aquifers. Wetlands more typically are located in areas where underlying geologic patterns cause ground water to be discharged as "seeps" at the surface (which is why many such areas become wetlands) rather than in areas where infiltration can occur rapidly.

The primary water quality reason for protecting wetlands and their buffers in SJC is not to increase infiltration or filtering of overland runoff, but rather to prevent potential sources of pollution and runoff (i.e., development) from being placed on top of hydrologic source areas, which are the areas most responsible for rapidly transporting any pollution to sensitive water bodies downslope or downstream (Wigington et al. 2003, Creed et al. 2008 a, b, Qiu 2009 a,b).

The capacity of wetlands for *storing water* is very important to species that occur in and around wetlands,. That is true because accessible fresh surface water that persists through the dry summer is less extensive in the island environment than in some nearby mainland areas which are fed by a much denser network of streams. In some cases the water stored in wetlands and excavated ponds with outlets can *help sustain summer flow* in small streams. This is more likely to be the case in wetlands that have a spongelike substrate of accumulated plant material or peat that drains slowly. However, in many wetlands it is perhaps equally or more likely that water which otherwise might contribute to stream flow is first lost via enhanced evaporation (especially in ponded wetlands whose unshaded condition promotes warming and wind exposure) or via transpiration by wetland plants. Partly for these reasons the ability of most wetlands to augment low flows in streams has been judged by the WDOE to be relatively unimportant (Hruby et al. 1999).

In some instances the water in sheltered wetlands and ponds might help maintain narrow zones of slightly elevated humidity in uplands that are immediately adjacent. This *microclimate effect* around wetlands has seldom if ever been measured. If it exists, it could assist the survival of frogs and salamanders, which are very sensitive to desiccation and which require natural land cover not only in wetlands, but in the areas that surround them (Rittenhouse & Semlitsch 2007).

2.2.4.2 Open Space Values

Tourism is essential to the San Juan County economy. Many visitors are visually attracted to the combination of the county's many diverse water features (ocean, bays, lakes, ponds, wetlands), pastures, and forests. Wetlands contribute to this attraction. Although large portions of the San Juan County landscape have been protected as open space and many of these areas contain wetlands, wetlands in other parts of the county help *maintain visually diverse landscapes*. In doing so, they help support the county's reputation as a desirable rural place in which to vacation or retire, thus helping support real estate sales during better economic times. Also, allowing infrastructure to be built in wetlands frequently adds to long-term maintenance costs for that infrastructure. That is partly because drained soils often subside unevenly, eventually causing structural damage, or alternatively, requiring greater up-front costs for mitigation. When the infrastructure is public, taxpayers eventually end up paying the cost. Prohibiting construction in wetlands avoids this burden on future taxpayers. Improving drainage around buildings constructed near wetlands also sometimes results in runoff being diverted onto property of neighbors, with conflicts and lawsuits often being the result.

2.3 Potential Impacts to SJC Wetlands

The scientific literature on impacts to wetlands was compiled in two documents (Adamus & Brandt 1990; Adamus et al. 2001) published by the USEPA and posted on their web site (http://water.epa.gov/type/wetlands/assessment/publicat.cfm#two). The Washington Department of Ecology also used those documents as a partial foundation for their BAS document (WDOE 2005). Information that largely updates those syntheses is presented throughout this chapter and Chapter 4.

Not all land uses have the same impact on wetlands or wetland buffers. Some disturb wildlife and imperil wetland plants to a greater degree, and the same or other land uses may export greater amounts of pollutants to a wetland. Few if any studies have made direct comparisons of multiple land uses with regard to their relative levels of impact on wetlands. Impacts to wetlands, and the ability of vegetated buffers to ameliorate them, will depend on a host of other factors including proximity of the land use; its density, permanency, and proportion of the wetland contributing area occupied; and associated soils, slope, runoff regime, and best management practices.

No peer-reviewed studies are available specifically from San Juan County that quantify harm to wetland-dependent wildlife species as a result of past or ongoing development. However, there are plentiful studies from elsewhere that document how development harms habitats and species.

Native wetland plants, bogs, and forested wetlands are particularly sensitive to slight changes in microclimate, changes in the duration of seasonally high water tables, and changes in water chemistry (Adamus & Brandt 1990, Adamus et al. 2001). These changes typically accompany the construction of homes near wetlands, as vegetation is removed, drains are installed around structures, septic systems are installed, ponds are created, and wells are dug. But even before widespread home construction, is likely that some SJC wetlands that are now dominated by non-native plants arrived in that condition when early settlers intentionally planted non-native forage grasses as they sought to establish more productive pastures, and as wildfires and massive erosion associated with extensive logging occurred throughout the islands over a century ago. Prior to that time, there were perhaps more bogs, forested wetlands, and sedge fens (a diverse type of wetland dependent on prolonged shallow subsurface flow). Plowing of small depressional wetlands (vernal pools) and intentional drainage of wetlands to create conditions more suitable for growing crops was common. A key force in wetland creation – beavers – was removed from most islands as a result of intensive trapping. The disappearance of beavers from SJC was to some extent offset by new features that created wetlands by blocking drainageways (roads and small dams used to create farm ponds). However, the hydrologic characteristics of the new wetlands likely differed from those created by beavers, and native plant communities were altered as a result.

2.3.1 Effects of Removing Water from Wetlands

By area, most of the naturally-occurring non-tidal ("upland") wetlands in SJC do not contain surface water year round. They depend entirely on shallow groundwater (springs and seeps) and runoff during and immediately after rainstorms. Thus, the hydrologic balance and continued existence of these wetlands is always precarious. Removal, diversion, or accelerating the outflow of even small volumes of ground or surface water reaching these types of wetlands will likely cause them to eventually cease being wetlands. When that happens, their habitat values and the water purification services they provide to society will be diminished or lost. Most vulnerable are the smaller wetlands (e.g., vernal pools), especially those on smaller islands and peninsulas, whose underlying aquifers and runoff-contributing areas are typically small.

Large portions of the county are already at a point where extraction of groundwater for domestic uses exceeds local recharge. When groundwater is not adequately recharged, and stormwater runoff is routed to the ocean more quickly through ditches and pipes rather than through natural wetlands, this shortens the duration of flooding or saturation in wetlands. Areas designated for high-density growth in the county's comprehensive plan and where groundwater supplies are especially limited include Eastsound, Orcas Landing and Deer Harbor (San Juan County, 2004 Water Resource Management Plan WRIA 2). Where formerly grassy wetlands start being overrun by shrubs, this is an early sign that groundwater supplies have been depleted or that water has otherwise been diverted away from a wetland.

Any development that involves increasing the area of lawn or impervious surface is likely to increase runoff amount and concentrate it within shorter time periods, i.e. "pulses" "flashiness" (Booth & Jackson 1997, Booth et al. 2002, DeGasperi et al. 2009). This has been shown to make wetlands more susceptible to invasion by non-native plants (Magee & Kentula 2005), which in turn threaten less tolerant and uncommon native species as well as simplifying habitat structure with consequent potential for impacts to some wildlife species.

If runoff is diverted away from downslope wetlands, such as in road ditches or drainage tile, then those wetlands will become drier. When they do, they will have less opportunity to purify the runoff (Wigington et al. 2005, Hogan & Walbridge 2007). Even when runoff is not diverted from the wetlands, if the volume of runoff entering a wetland per unit time increases, the wetland will be less effective in treating the runoff. That is because increased runoff will often cause tiny channels to develop within the wetland, or will increase the dimensions of existing ones. These factors will decrease the detention time and pollutant contact with vegetation, because most of the vegetation will be positioned apart from the water flowing through in the small channels (McBride & Booth 2005, Alberti et al. 2007). Thus, the best way to allow effective natural treatment of runoff and thus save infrastructure costs is first, do not re-route any of it away from wetlands, and second, minimize impervious surfaces in order to minimize the hydrologic pulses that could reach any downslope wetlands.

2.3.2 Effects of Constructing Ponds or Otherwise Adding Water

Many wetlands currently existing in SJC have formed along the margins of ponds dug long ago from non-wetland soil or were the results of small dams placed across drainageways that lacked wetlands. However, a perhaps greater number resulted – and continue to result -- from excavation within areas that were and are jurisdictional wetlands. By Washington law this is illegal, for good scientific reasons. Excavation potentially removes the biologically-essential organic substrate present in naturally-occurring wetlands, or at least may cause some compaction of the organic substrate currently present. Also, except where excavation intercepts springs, instream ponds excavated from natural wetlands can adversely impact aquatic life by warming the water and removing dissolved oxygen (see Chapter 4, section

4.2.2.1). As a whole, they are probably less effective for processing nitrate, metals, and most contaminants, but are sometimes more effective for retaining sediment and phosphorus, depending partly on their outlet characteristics.

Making existing wetlands deeper by excavating ponds often provides habitat for amphibians that breed only in ponds and deep wetlands. However, as soon as non-native fish are introduced into a pond, these predators reduce whatever benefit the new pond provided to amphibians. The excavation of hundreds of instream ponds in SJC has probably increased the local abundance of some native waterbirds that typically shun heavily vegetated wetlands, such as ruddy duck.

The amount of water a wetland receives may increase for a few years if surrounding forests are logged. Logging often causes water tables to rise towards the surface, as loss of water via transpiration by trees is curtailed. However, as vegetation regrows, water levels usually return to their earlier levels.

2.3.3 Effects of Degrading the Water Quality of Wetlands

It important to understand that wetlands, like an overworked garbage disposal, have only a limited capacity to retain and process many pollutants if the loading rate of these substances becomes too great, i.e., too much received in too short a period of time, such as during major storms or in smaller doses repeated often. For example, one study found that buffers and wetlands become less effective for removing nitrate when loads exceed about 50 g of N per square meter per year (Hefting et al. 2006).

When wetlands are unable to process the pollutants they receive, the waterbirds, amphibians, and plants that depend on wetlands are put at risk. Unfortunately the tolerance thresholds for most wetland organisms are unknown. Moreover, it is widely acknowledged that many of the water quality standards appropriate for running waters and their organisms (e.g., for dissolved oxygen and pH) are inappropriate for most wetlands and their organisms. Excessive deposition of sediments in wetlands is known to reduce the duration of time wetlands are saturated and prevent the germination of some wetland plants (Wardrop & Brooks 1998, Mahaney et al. 2005) as well as reduce the survival of pond-breeding amphibians (Knutson et al. 2004). On the other hand, in moderation, deposited fine sediments can provide a substrate for establishment of wetland plants around ponds and along channels.

2.3.4 Effects of Removing Vegetation In or Around Wetlands

Removing tall vegetation around wetlands will benefit some wetland species while making habitat less suitable for others. Removing vegetation entirely will cause more pollutants to reach a wetland, will disrupt the humid upland microclimate needed by dispersing wetland frogs and salamanders, and will increase access of humans and pets to wetlands with associated increase in adverse effects of predation and disturbance of wetland wildlife. Clearing vegetation, or burying it with too much incoming sediment, or compacting the soil – these all reduce the effectiveness of some of the biological processes that are partly responsible for purifying runoff. Additional impacts of fragmenting or altering vegetation are described in sections 4.2.2.3 and 4.3.2.1 of Chapter 4.

2.3.5 Effects of Human Presence

The simple presence of humans and especially their pets can dissuade many wildlife species from using productive habitat areas around single-family homes, wetlands, and shorelines. Because no entity can realistically monitor some behaviors of citizens and their domestic animals continually, the County must consider restricting the locations of buildings in order to protect wildlife indirectly from human disturbance. A more detailed discussion of these impacts can be found in section 4.3.2.2 of Chapter 4.

2.3.6 Development Intensity

Because of the complexity in assessing the potential for each of the above-mentioned impacts in each development permit application, planners often just create a limited number of categories intended to reflect the likely cumulative intensity of pollution, vegetation alteration, hydrologic disruption, and other disturbance associated with particular land use types. For example, the WDOE (in Table 8C-3 of Granger et al. 2005) rates various proposed expansion or creation of particular land uses as High, Moderate, or Low Intensity as follows:

HIGH: Residential with more than 1 dwelling unit/acre; industrial; commercial; high-intensity recreation (e.g., golf course, athletic field), or conversion to high-intensity agriculture such as dairies, nurseries, greenhouses, or lands for growing and harvesting crops and requiring annual tilling, or conversion to lands for raising and maintaining animals, hobby farms, etc.

MODERATE: Residential with 1 dwelling unit per multiple acres; logging roads, driveways, paved trails; right-of-way or utility corridor shared by several utilities; or conversion to moderate-intensity agriculture such as orchards, hay fields.

LOW: Forestry (tree-cutting only), unpaved trails, utility corridor without a maintenance road and little or no vegetation management.

An alternative approach is to base the intensity categories on the proportion of vegetation cleared, impervious surface created, or other measurable features.

2.4 Strategies for Protecting Wetland Functions

2.4.1 Enforcement of Regulations

Fair and effective enforcement of existing regulations is the front line of defense against gradual loss of the important ecological services that wetlands provide. No matter how active and exemplary any current programs for restoration and land purchase may be, if existing regulations are not enforced, losses may exceed gains and the services that wetlands provide to society will gradually diminish, with economic consequences to the public as a whole. Even if

BAS indicates a jurisdiction's wetland laws are weaker than science shows are necessary, active enforcement of existing laws can slow the loss of wetlands and their services.

Effective enforcement requires an unwavering commitment from County government to fund the staff positions and training needed to ensure that wetland violations are discovered and damages to wetlands are prevented or, if unavoidable, are adequately mitigated (see section 2.4.6). Alternatively, the County could retain a qualified contractor in the community who performs all these duties regularly but on a part-time basis. When violations are documented (e.g., from roadside reviews, regular review of aerial imagery, or citizen complaints) there should be legal consequences for the violator. However, a better option is to avoid at least the unintentional violations in the first place by educating landowners, real estate agents, architects, and sanitary engineers on how to recognize situations where small wetlands may be present despite not being shown on the best available county wetland maps. County staff or contractor should not rely only on complaints from citizens to discover violations. And protecting wetland functions requires not only the enforcement of wetland regulations, but also the regulations that pertain to water quality, noise, and other environmental disturbances.

2.4.2 Protective Purchasing

Like all counties, SJC lacks the financial resources to buy up all wetlands and their surrounding buffers, even knowing that the loss or degradation of substantial numbers of wetlands will cause irreversible disappearance of some plant and wildlife species, as well as increasing costs to neighbors and the public at large, e.g., for stormwater management. However, two land trusts are active in the county and will continue to play a significant role in purchasing wetlands as well as other natural lands. Policies that support this should continue and be strengthened. At the same time, citizens who wish to alter wetlands should normally not be allowed to pay into a fund (for a third party to purchase a wetland of at least equal area and function located elsewhere as claimed compensation) if alteration of that wetland is already regulated by the law, as most wetlands are. Otherwise, the result will be a net loss of wetland area and/or function.

2.4.3 Prioritizing Wetlands

Not all wetlands are created the same. The levels of the functions that a wetland supports depend not just on past impacts to the wetland from humans, but also on geography. Geography reflects key natural differences in geology, hydrology, soils, climate, and the pool of available species – all of which influence wetland functions and thus the importance of a specific wetland.

Guidance from state agencies (WaCTED 2003) as well as common sense suggests that the restrictiveness of regulations or incentives be varied in rough proportion to the levels of functions, social values, and sensitivity of a given wetland. These three factors can and should be used, therefore, in prioritizing a county's wetlands. To standardize that process and make it more objective, the Washington Department of Ecology developed and encourages use of its *Wetland Rating System for Western Washington (Revised)* (Hruby 2004), which assigns a wetland to one of four categories that are tied to recommendations for widths of wetland buffers. The *Rating System* does not, however, include several factors important to characterizing a wetland's sensitivity, as well as some factors important to predicting wetland functions and values. Moreover, not all of the functions, values, and indicators it uses are relevant to conditions in SJC. Tools that are more comprehensive, sensitive, and technically sophisticated are available (e.g., Hruby 1999, Adamus et al. 2009, 2010). However, use of the *Rating System* is specified in SJC's existing UDC, and throughout Washington only the *Rating System* has been used widely by counties. That is largely because it has been the only tool available for explicitly connecting output scores that describe a wetland's functionally relevant characteristics to numeric suggestions for wetland buffer widths and mitigation – essential components of county Critical Areas Ordinances. Other tools or criteria could be expanded to do the same.

Based on this BAS review, this document presents an approach using four factors, not necessarily of equal importance, to prioritize or categorize SJC wetlands, as needed to determine site-specifically the appropriate widths for a buffer around any wetland. These are detailed below, and are:

A. Wetland Sensitivity
B. Wetland Water Quality Functions
C. Value of Water Purification Functions
D. Habitat Quality

A. Wetland Sensitivity. The most sensitive wetlands respond quickly (low resistance) to abnormal stress, and/or recover most slowly from it (low resilience). This can be evidenced partly by abnormal changes in their biological communities, water regimes, and biogeochemical processes (Brouwer et al. 1998). Sensitivity is not the same as wetland ecological condition, health, integrity, or quality; some wetlands in excellent condition are relatively resistant to change whereas some in poor condition can easily suffer further harm (i.e., are sensitive) if previous impacts to them have pushed their biological communities and functions close to critical thresholds. Sensitivity also may include *susceptibility* or *vulnerability,* that is, the risk that nearby uplands, because of their inherent characteristics, will contribute to the degradation of a wetland if they are disturbed. The actual or potential *threat* posed to particular types of wetlands by human alteration of their surrounding landscape (e.g., land use intensity) is not considered part of their sensitivity. Note that not all sensitive wetlands are important, and not all important wetlands are sensitive. The basic principle is that the more intrinsically sensitive a wetland is, the stronger its level of protection should be. It is recognized that the *type* of disturbance also may dictate the sensitivity of a particular wetland type. For example, wetlands that are most sensitive to changes in watershed runoff regime are not necessarily the same wetlands whose animals are most likely to be disturbed by increased human traffic.

Several characteristics were identified by Adamus & Stockwell (1983) as being especially relevant to defining which wetlands are the most sensitive. In SJC, a wetland should be considered more sensitive (wider buffer) if it has at least one of these characteristics:

1. No surface water outlet (not even a seasonal one)
2. Soil type is predominantly clay or organic (peat or muck)
3. Wetland vegetation is predominantly native species
4. Wetland is small and/or narrow
5. Water alkalinity or hardness is low
6. Surrounding steep terrain with highly erodible soils.

These are now described in more detail:
1. **No surface water outlet** (not even a seasonal one). In these and other wetlands with very long water residence times, there is a greater risk of wetland functions being degraded and species harmed from bioaccumulation of toxins and from sediment carried into the wetland by runoff (Whited 2001, Whigham & Jordan 2003, Leibowitz 2003). This runs counter to the water quality and hydrologic *functions* of wetlands, which tend to be higher in such closed systems (Hruby et al. 1999). Wetlands on slopes (Cole et al. 1997) and tidal wetlands may be the least sensitive to pollutants because they typically have the shortest water residence times. Slope wetlands in some regions tend to be less sensitive to invasion by non-native plants (Magee & Kentula 2005), especially when shaded by a forest canopy. However, they are sometimes highly sensitive to alteration of local water tables (Fizgerald et al. 2003). A Pennsylvania study found that slope wetlands tended to have the lowest sediment accretion rates of any wetland type (HGM class), and had moderate to high rates of organic matter accretion (Wardrop & Brooks 1998). Estimates from existing spatial data suggest that approximately 44% of the county's mapped wetlands may lack outlets (even intermittent ones).

2. Soil type is predominantly **clay or organic** (peat or muck). These soils are most susceptible to compaction, which often degrades their water quality and habitat functions. Also, the native plant communities on organic soils tend to be especially sensitive to even small changes in water regime and water chemistry.

3. Wetland vegetation is **predominantly native species**, or a wetland's surrounding land uses imply that native species are probably predominant. Compared with non-native (alien) species, most native plant species are less resistant and resilient to future disturbances in or near a wetland. Non-native plants tend to invade wetlands as a result of disturbances. Simply because they tend to have more species, wetlands with a predominance of native species have more species to lose and thus could be considered to be more sensitive to impacts. In contrast, once wetlands become dominated by non-native (exotic) species, the plant community structure is simplified (e.g., Perkins & Willson 2005). Non-natives tend to have broad environmental tolerances, so wetlands dominated by them and thus having low species richness are more resistant to further change (Werner et al. 2002, Wigand et al. 2003). By itself, increased species richness in a wetland does not always confer increased resistance (decreased sensitivity) of a wetland's functions to artificial changes (e.g., Engelhardt & Kadlec 2001).

4. **Small and/or narrow**. Other factors being equal, wetlands that are small and/or narrow (especially forested wetlands with an average width of less than about 100 ft; Brosofke et al. 1997) tend to be more sensitive. If the adjoining uplands are not forested, a greater proportion of the trees in narrow wetlands are subject to blowdown, and the wetland's plants and animals are more subject to extremes of the surrounding microclimate as well as disturbance from humans in nearby uplands (see section 2.3.5, and Chapter 4 section 4.3.2.2). Some evidence also suggests that predation rates on nesting birds are higher in narrow strips of vegetation than in wider ones (Hansen et al. 2005). Also, in narrow strips or small patches of vegetation, the native plant communities are more vulnerable to invasion from non-native species from adjoining lands (Hennings & Edge 2003). There does not appear to be a minimum size or width threshold below which all wildlife species will fail to use a wetland.

5. **Hard water.** Toxicity of some contaminants declines with increasing water hardness, and alkaline waters tend to be better at buffering rapid changes in the acidity and chemical content of runoff (Kessel-Taylor 1985). Among wetland types that occur in SJC, bogs[8] are perhaps the most sensitive because of their typically low chemical buffering capacity (as implied by low hardness and alkalinity), whereas tidal wetlands are perhaps the least sensitive to some pollutants, this being due to their higher hardness and alkalinity. Hardness of SJC non-tidal surface water ranges about 30-60 mg/L according to the WDOE's data, suggesting relatively "soft" (poorly-buffered) water (Appendix 4E-1 in Chapter 4).

6. The terrain adjoining (and uphill from) the wetland is **steep with highly erodible soils**. Wetlands whose adjoining soils intrinsically are highly erodible[9] are more susceptible to being gradually filled in by sediment, especially when vegetation in the wetland buffer is cleared (e.g., Martin & Hartman 1987). Soil erodibility also has been used to predict the movement of some other runoff-borne pollutants, such as fecal coliform bacteria, into wetlands (Sanders et al. 2005). Soil erodibility and slope are two of the three factors recommended for setting wetland buffer widths under the "Advanced Buffer Determination Method" proposed by McMillan (2000). The third factor is vegetation which is best evaluated on-site. Studies that have specifically linked increased slope in a watershed or buffer strip to increased delivery of pollutants to surface waters include Trimble & Sartz (1957), Dillaha et al. (1988, 1989), Phillips (1989), and Nieswand et al. (1990). Slope begins to have a significant negative effect on retention of sediment and sediment-bound pollutants at about 10% slope (Zhang et al. 2010). The NRCS (2009) lists erodibility as the major hazard or limiting factor for up to one-third of the county's soils[10].

B. Wetland Water Quality Functions. A wetland should be considered to have more potential capacity to purify runoff or groundwater (and thus a wider recommended buffer) if:
1. **No surface water outlet**. Surface water detention time is usually shorter in sloping wetlands than in flat wetlands. Shorter detention times result in less effective processing of pollutant loads in runoff. Existing spatial data suggest that about 44% of the county's possible wetlands may lack outlets.
2. Soil type is predominantly **clay or organic** (peat or muck). These soil types are usually the most effective for retaining metals, including phosphorus. Only 1% of the county's mapped soils are peat or muck, and none are predominantly clay. Determination of the presence of this type of soil in a particular wetland will require a site visit by a qualified wetland professional or soil scientist.
3. Wetland is **not sloping**. About 35% of the county's possible wetlands occur on slopes of less than 2 percent, and about 81% occur on slopes of less than 10%.

C. Value of Water Purification by Wetlands. If a wetland is likely to be purifying water effectively as evaluated by (B), then it should be considered to be of greater value (and thus a

[8] Bogs are low-nutrient, acidic wetlands with organic soils and extensive cover of characteristic mosses and shrubs.
[9] Erodibility is influenced by the texture, stability, infiltration capacity, cohesiveness, organic content, and chemical composition of the soil.
[10] In San Juan County, this includes components of the following soils (map symbols): 3001, 3006, 3008, 3012, 3014, 4003, 4006, 5001-5006, 5008-5015.

wider recommended buffer) wherever downstream or downslope water bodies in the same watershed are recognized as being especially important (see following discussion) and those water bodies either adjoin the wetland or are connected via a stream or other mapped drainageway shorter than some specified distance. In the freshwater environment, the most important water bodies are:

1. Domestic Water Supply Lakes. This includes the contributing areas of Trout Lake, Briggs Pond, Cascade Lake, Mountain Lake, and Purdue Reservoir.
2. Perennial Streams. This includes the contributing areas of Cascade Creek, Nettle Creek, UW Creek, Crow Valley Creek, San Juan Valley Creek, and Beaverton Valley Creek.
3. Salmonid Streams. See Chapter 4, section 4.2.1.1.

Enhanced protection could also be considered for wetlands situated a specified distance upslope from marine areas of special significance or sensitivity (see Chapter 3), as well as wetlands located within the 600-ft radius areas around public wells that currently are designated as wellhead protection areas. There are about 170 such public wellheads countywide (San Juan County Health and Community Services 2007).

D. Habitat Quality.
A wetland in SJC should be considered to have habitat of higher quality (and thus a wider recommended buffer) if it is (or has) any of the following:

1. **Bog**. These are wetlands within which some portion has a deep layer of accumulated moss (rooted or floating on water), or which have more than 30% canopy cover of Sitka Spruce, Western Red Cedar, Western Hemlock, or Lodgepole Pine, and which harbor plants characteristic of acidic conditions (pH <5.0) as listed in Table 3 of the WDOE *Rating System*. Bogs have low chemical buffering capacity and are highly sensitive to trampling, pollution, and changes in water supply. Once altered, they are nearly impossible to restore or re-create. In SJC, they host rare plants such as few-flowered sedge (*Carex pauciflora*), twayblade (*Liparis loeselii)*, Adder's-tongue (*Ophioglossum pusillum*), and rush aster (*Symphyotrichum boreale*). Information on the locations of bogs in SJC is not comprehensive. However, as in most other lowland parts of western Washington, they appear to be quite rare. Bog wetlands are known from Point Colville on Lopez Island, from slopes of Mt. Constitution, near Killebrew Lake on Orcas Island, and formerly at the location of the Eastsound Airport. Many are (or once were, until altered) located in areas shown on NRCS soil maps as Orcas Peat, Shalcar Muck, Semiahmoo Muck, or Dugualla Muck. Historically, some may have been partially drained, filled, or harvested for peat. Determination of the presence of this wetland type on a particular parcel will require a site visit by a qualified wetland professional.

2. **Wet prairie**. These wetlands mostly lack shrubs and other woody plants, and either lack surface water or have it for only a few days per year. Their soils have not been tilled for many years, if at all. Their vegetation is dominated by characteristic native grasses (*Danthonia californica* and others which are listed as wetland indicators). When relatively free of disturbance they sometimes contain vernal pools. Vernal pools are very shallow wetlands, usually <0.5 acre in size and in flat terrain (like large puddles), that dry out in summer and are dominated by characteristic native forbs such as Camas (*Camas* spp.) and Oregon gumweed (*Grindelia integrifolia*). In SJC, rare plants such as white meconella (*Meconella oregona*) and

California buttercup (*Ranunculus californicus*) have been found in this type of wetland, and where vernal pools are present, the rare Nuttall's quillwort (*Isoetes nuttallii)* and sharpfruited peppergrass (*Lepidium oxycarpum*). Short-eared Owl and perhaps Northern Harrier nest in these wetlands in SJC. They are recognized as a Priority Habitat by WDFW. Historically, some may have been burned during drier periods by Native Americans. They often are present on clay-rich soils in areas of glacial outwash. Many were probably plowed under or drained for agriculture. No comprehensive information exists on their prevalence and locations in SJC. Determination of the presence of this wetland type on a particular parcel will require a site visit by a qualified wetland professional.

3. **Tidal wetland**. These are wetlands that receive a tide-driven influx of marine water at least once annually. Most are dominated by non-woody plants and are called **salt marshes** (a narrower category). Also included are **tidal lagoons**, which are coastal ponds with fresh or brackish waters and a connection to marine waters that is intermittent (generally only a few times per year) due to natural topography (not a constructed dike, roadway, or tidegate). Tidal lagoons are present, for example, on Lopez Island (Port Stanley) and on San Juan Island (Jackle's Lagoon). A broader category is estuarine wetlands, which also includes kelp and eelgrass (which the county regulates as habitat conservation areas, not as wetlands). There are over 186 acres of tidal wetlands countywide. Tidal wetlands are valued highly due to their relative scarcity (3% both by the number of wetlands in SJC and by area), large historical losses in the region, high usage by wintering and migratory waterfowl, and important role in supporting salmonids, forage fish, and marine life generally. Plant communities of tidal marshes are relatively simple, with high redundancy among tidal wetlands (e.g., Phillips 1977, Burg et al. 1980). High annual production of native tidal marsh plants potentially results in significant sequestration of carbon and effective processing of some soluble pollutants.

Because tidal wetlands (except lagoons) are more hydrologically open than most non-tidal wetlands in SJC, flushing rates are relatively high and pollutants may tend not to accumulate as rapidly as in many non-tidal wetlands. This might make tidal wetlands less sensitive than non-tidal wetlands to low-intensity development of their upland buffers. Still, large loads of sediment from eroding uplands can gradually increase the elevation of adjoining marshes and thus reduce their duration of tidal inundation, moisture, and salinity unless countered by a rise in average sea levels (Byrd & Kelly 2006). Also, nonsaline water seeping from septic systems or irrigation located immediately upslope can dilute their salinity and add nutrients, resulting in changes to plants and animals of tidal wetlands. Historically, many tidal marshes were diked and tidegated, eliminating the influence of tides and increasing the ponding of freshwater. In some instances this has redistributed and concentrated waterfowl use but whether this has truly increased regional populations of waterfowl is unknown (Lovvorn & Baldwin 1996).

4. **Wetland adjoining a tidal wetland**. These are wetlands that are contiguous to tidal marshes, but they do not receive a tide-driven influx of marine water at least once annually. They include wetlands that originally were salt marshes, but were diked off and/or tidegated by early settlers to create pastures and haylands. They also include drainageways and slopes that connect directly to tidal wetlands and are dominated by characteristic wetland vegetation. These wetlands are important because they serve as refuges for many animals when adjoining

tidal marshes are flooded by spring tides. If mean sea levels rise in the future as a result of climate change, some of these wetlands will become the new tidal marshes.

5. **Mature forested wetland**. These are areas having at least 0.1 acre of mature forested wetland, defined as areas where most individuals of the following wetland-associated tree species have a diameter (measured at 4.5 ft above the ground) exceeding 18 inches. Support for that particular tree diameter as a basis for defining mature trees specifically in wetlands is based on a peer-reviewed study in western Washington by Painter (2009). Only the following tree species are considered: Sitka Spruce, Western Red Cedar, Western Hemlock, Red Alder, Black Cottonwood, and Lodgepole Pine. No comprehensive information exists on their prevalence and locations in SJC. They are important because of their local rarity, the habitat they provide for a few highly specialized species or animals (e.g., marbled murrelet if conifer forest) and plants (rare lichens, mosses, and vascular plants), and their relative abundance of snags and downed woody material important to wildlife. Mature Forest is recognized as a Priority Habitat by the WDFW. This habitat sometimes occurs in association with Bogs (see above).

6. **Aspen or Cottonwood wetland**. These are wetlands with a significant component of trembling aspen (*Populus tremuloides*) or the related black cottonwood (*Populus balsamifera*, formerly *P. trichocarpa*). Not all aspen and cottonwood stands are in wetlands, but many are. Cottonwood stands are known to occur mostly along seasonal drainageways on San Juan Island. Aspen stands are present, for example, near Cattle Point on San Juan Island, Crescent Beach on Orcas Island, in the Odlin Park watershed on Lopez, and on Ripple Island. Both cottonwood and aspen provide exceptional habitat for many cavity-nesting wildlife species. Aspen stands are recognized as a Priority Habitat by WDFW. No comprehensive information exists on the prevalence and locations of these wetlands in SJC. Determination of their presence on a particular parcel will require a site visit by a qualified wetland professional or botanist.

7. **Salmonid fish wetland**. These are any wetlands known or reasonably assumed to be physically accessible for even a short period during most years to coastal cutthroat trout and/or any other native salmonid species. Even when these wetlands are not accessible to fish, their outflow may feed downslope waters that do support fish, as described in section 4.2.1.1 of Chapter 4. Data are mostly lacking on use of the county's non-tidal ("upland") wetlands by native and introduced fish.

8. **Lakeside wetland**. These are wetlands that are part of ponded water bodies larger than 20 acres, and whose water levels fluctuate in near synchrony with those of the lake. They typically are along the shoreline fringe of a lake, but may also comprise islands within the lake. The county has relatively few lakes and they attract many bird species that use small ponds much less consistently (e.g., Western Grebe, Canvasback, Scaup). Especially in late summer when many ponds and most streams dry up, the county's lakes provide the only remaining freshwater source. They also provide critical ice-free refuge for many semi-marine birds during severe winter storms, and support plant species that are locally or regionally rare, such as water lobelia (*Lobelia dortmanna*), blunt-leaved pondweed (*Potamogeton obtusifolius*), and water horsetail (*Equisetum fluviatile*). It includes all wetlands on the following lakes: Mountain, Cascade, Sportsmans, Horseshoe, Spencer, Trout, Zylstra, Roche Harbor, Martin, Hummel,

Woods, Dream, and an unnamed lake on Orcas Island. These total 876 acres of wetlands, of which 315 acres (36%) are not within protected lands. These acreage figures include some deep water as well as vegetated wetland.

9. **Large ponded wetland**. This includes all wetlands that border or contain patches of standing water larger than about 5 acres during all or most of the year. Larger ponded wetlands are less prone to totally drying out during summer and freezing in winter. Northwestern Salamander, a species known from relatively few SJC wetlands, appears to require this wetland type. Large ponded wetlands total 253 acres, of which 130 acres (51%) are not within protected lands. These acreage figures include some deep water as well as vegetated wetland.

10. **Wetland Used Regularly by Other Rare Species.** These are wetlands not included in any of the categories above, but which are known to regularly support *locally-reproducing* populations of:

(a) plant species listed as Threatened, Endangered, or Endangered, as shown in Appendix 4-C of Chapter 4,
(b) bighead sedge (*Carex macrocephala*), a rare grasslike plant growing at only a few seaside locations in the county,
(c) animal species listed by WDFW as Priority Species, such as Western Toad, Bald Eagle, Peregrine Falcon, Wilson's Snipe, and others mentioned in sections 4.3.1.2 and 4.3.1.4 of Chapter 4.
(d) other wetland-dependent species which due to their sensitivity to humans and limited distribution with SJC are most vulnerable to countywide disappearance. These include nesting Short-eared Owl and some others. No comprehensive information exists on the prevalence and locations of these species in SJC.

11. **Wetland connected to large areas of undeveloped land cover.** These are any wetlands that are situated within a large block or corridor of contiguously wooded uplands (especially contiguous woodlands of >100 acres, with few or no roads), as evaluated using the LiDAR imagery and other sources. While it is true that some species are disfavored where large unfragmented blocks of closed-canopy forest are maintained or encouraged (see Chapter 4, section 4.3.2.1), there are perhaps more species that will benefit from maintaining that closure and connectivity. More importantly, most of the species that will benefit from maintaining unfragmented blocks of habitat are native species that probably are relatively uncommon in SJC or are uncommon or declining in the region. In contrast, many of the species that would flourish with increased "edge effects" (i.e., forest fragmentation) are species that are widespread in the region (e.g., deer, raccoons, crows, ravens, weedy plants) and are unlikely to disappear entirely from the county.

12. **Structurally diverse wetland**. These are wetlands that contain many height classes of vegetation in relatively equal proportions, as well as other indicators of complex vegetation structure as quantified comprehensively using LiDAR imagery as part of this BAS study. At a very localized scale, such wetlands tend to support more species, especially more bird species. LiDAR is a proven method for analyzing many structural components of wildlife habitat (e.g.,

Seavy et al. 2009, Goetz et al. 2010). The LiDAR-based structural measurements for all "possible wetlands" in SJC are presented by wetland in Appendix E.

13. **Wetland with little or no cover of invasive plants**. These are wetlands that overall contain less than 5 percent cover of invasive plant species ("noxious weeds" according to the SJC Weed Control Board) in their tree, shrub, and herbaceous layers. The number of wetlands meeting this criterion in SJC is unknown, but is probably small compared to most other areas of western Washington. The WDNR's Washington Natural Heritage Program considers "high quality undisturbed wetlands" to be particularly deserving of extra protection, and those are most often defined as ones whose vegetation canopy (cover) is predominantly native species. Such wetlands also tend have more species, and thus more species to lose. Determination of the presence of this wetland type on a particular parcel will require a site visit by a qualified wetland professional.

2.4.4 Establishing Minimum Wetland Size for Regulation

Another part of a countywide strategy for protecting wetland functions is to specify a minimum size above which all wetlands will be subject to some type of regulation. The WDOE (Granger et al. 2005) states that "we do not believe it is appropriate to recommend a general threshold for exempting small wetlands in Washington because the scientific literature does not provide support for such a general exemption." They suggest that for practical purposes, local jurisdictions may want to vary such thresholds based on zoning categories, wetland type, or wetland importance. The WDOE has suggested that different rules apply to wetlands smaller than 1000 square feet, 1000 to 4000 square feet, and larger than 4000 square feet. For regulated timber harvest operations around wetlands, the WDNR uses 0.25 acre (10,875 sq. ft) as the minimum. The US Army Corps of Engineers, which is responsible for enforcing federal wetland regulations, does not specify a minimum size below which they will allow wetland alterations without a permit. In SJC, mapped wetlands occur at a density of approximately 24 wetlands per 1000 acres, and areawise, they comprise 5.9% of the county's land area. However, local wetland professionals who have worked in the county for many years report that the actual acreage of wetlands is likely to be much higher than these estimates (personal communication, Scott Rozenbaum).

Although some wetlands are too small to encompass the entire daily home range of many animals, they may nonetheless support rare wetland plants, as well as serve as corridors[11] or

[11] Corridors are areas of natural vegetation (usually with a tree canopy) that connect wetlands or other regulated areas, generally in landscapes that are otherwise dominated by cropland, unvegetated areas, or developed lands (e.g., Bentrup & Kellerman 2004). Long unbroken buffers along streams are sometimes counted as corridors. Reserves are patches of generally-terrestrial areas of contiguous natural vegetation, typically many acres in size. Like corridors, they are generally in landscapes that otherwise are dominated by cropland, unvegetated areas, or developed lands. Although their vegetation should be "natural" (not regularly disturbed by plowing or subject to intensive grazing), neither buffers, corridors, nor reserves must inevitably be wooded or dominated by *native* plants in order to be useful to wildlife. Many wildlife species use these areas regardless of the "quality" of the vegetation, but perhaps most species thrive better when vegetation is natural and wooded. Forest fragmentation is the dividing of blocks of contiguous forest into smaller and/or more widely separated pieces as a result of logging, other vegetation clearing, or roads.

hospitable resting stops for animals moving between larger but more distant wetlands. Smaller wetlands are often more sensitive to impacts because they tend to have less "reserve" (chemical buffering capacity, species functional redundancy) to fall upon when resisting or recovering from disturbances. Because their core area tends to be smaller, they also are more vulnerable to edge effects such as windthrow of trees, altered microclimate, and increased exposure of wildlife to predation and human disturbance.

Minimum size thresholds for regulation ideally account not only for an individual wetland's size, but also the proximity and cumulative area of nearby wetlands. Multiple wetlands located near each other – termed wetland mosaics or complexes—tend to have greater abundance and/or diversity of wetland-dependent plants (Lopez et al. 2002) and wildlife than the same number of wetlands located farther apart and/or separated by developed land. This effect is greatest when the wetlands are different types (as defined mainly by vegetation and water duration), when they are not separated by roads, and when they are connected by contiguous corridors of natural vegetation. When deciding whether particular wetlands should be exempt from certain provisions, the WDOE currently encourages consideration of whether a small wetland (<4000 sq. ft., and especially, <1000 sq. ft) is part of a wetland "mosaic".

Patches of natural (but not necessarily native)[12] vegetation that are too small or close to urban lands to support some wide-ranging wildlife species (<100 acres, Donnelly 2004) could actually be detrimental to long term viability of the population of such species. This is because of a higher probability that such habitat fragments could become population "sinks" (ecological traps) rather than "sources" especially in agricultural and developed landscapes. This happens partly because of (a) the increased vulnerability of small patches to invasion by non-native species, (b) concentrating of predators and parasites, (c) excessive isolation of individuals of breeding age, and/or (d) microclimate disturbance (Edge 2001). Such an effect was found among Song Sparrows nesting in wetlands of coastal British Columbia (Rogers et al. 1997) and among Red-winged Blackbirds in the wetlands along the western Great Lakes (Grandmaison & Niemi 2007) . However, breeding wetland birds sometimes do persist in small disturbed wetlands as long as much larger undisturbed wetlands nearby remain productive (e.g., Vermaat et al. 2008). This highlights the importance of considering wetland mosaics when establishing minimum sizes for regulated wetlands.

2.4.5 Wetland Buffers

2.4.5.1 Introduction to Buffers

Establishing buffers of undeveloped or lightly-developed land around wetlands is perhaps the most popular strategy for protecting their functions, although not always the most effective. The following are often cited as potential benefits of buffers:

[12] The distinction between natural vs. artificial land cover, as opposed to native vs. non-native vegetation, is important. "Natural" land cover can include both native and non-native vegetation, such as pasture grasses on untilled soils, which can provide habitat whose structure grossly resembles native prairie and therefore is extensively used by many wildlife species. Artificial land cover includes lawns, buildings, roads, and other artificial features that provide little or no habitat for wildlife.

- Providing an alternative to impervious surface or other land cover types that would offer little or no habitat for native wildlife and can damage other wetland functions.
- Intercepting and stabilizing sediment before it fills wetlands or shallow pools in streams and damages their plants and animals.
- Intercepting and processing excessive nutrient loads before they alter wetland plant communities and in some cases, before they contaminate susceptible underlying aquifers and streams.
- Intercepting and removing minor amounts of pesticides and other toxics before they damage stream or wetland plants and animals.
- Maintaining shade, water temperature, and microclimate in streams and wetlands as necessary to protect some of their plants and animals.
- Minimizing excessive windthrow loss of trees within forested wetlands.
- Exporting wood and other organic matter to streams and wetlands in a manner beneficial to aquatic life.
- Maintaining vegetated connections among wetlands and stream riparian areas as required for essential movements of some wetland- or riparian-dependent animals.
- Hindering human access to wetlands and thus minimizing threats such as trampling of vegetation, soil compaction by off-road vehicles, and disturbance of wildlife during sensitive periods.

Three basic types of buffer regulations are generally recognized: variable-width, fixed-width, or some combination. These are described as follows:

<u>Fixed-Width Approach</u>
A fixed-width approach, as its name indicates, specifies that the same buffer width be applied around all wetlands in a county or other jurisdiction. Such buffers are often intended to protect just one feature or function of a wetland. This provides predictability and is easiest to administer. The down side of this "one-size-fits-all" approach is that it results in some buffers being too small to adequately protect wetland functions, and some buffers being larger than necessary to protect wetland functions. Over time, this inequity may erode support for the buffer program. Frustrated landowners can point to the "over-regulation" of those buffers that are larger than necessary, while environmentally minded citizens can point to those buffers that are smaller than needed to protect wetland functions. It also is difficult to determine an appropriate standard width, because no single size buffer can be demonstrated to protect all wetland types adequately in all situations unless that standard width is very large. Furthermore, it is difficult to argue that a fixed-width approach reflects the best available science since the scientific literature clearly recommends different buffer widths based on a variety of different site-specific factors. In summary, fixed buffer widths do not fully reflect the hydrologic characteristics of the landscape, especially in landscapes where the substrate has an important control on wetland water levels (Buttle 2004). Consequently, for a given wetland, the fixed-width buffer prescriptions may be too protective or insufficiently of water quality (Belt & O'Laughlin 1994, Schultz et al. 2004, Polyakov et al. 2005, Johnson & Buffler 2008, Bentrup 2008) and habitat of sensitive species (Ekness & Randhir 2007).

Variable-Width Buffer Approach

The variable-width approach is a case-by-case approach that is most consistent with what scientific literature says about buffer effectiveness (Haberstock et al. 2000, Creed et al. 2003, Tomer et al. 2009, Walter et al. 2009). This approach involves consideration of site-specific factors such as wetland type, adjacent land use, vegetation, soils, slope, and wildlife species – measuring and analyzing these in some cases with detailed protocols and formulas that are believed to predict buffer effectiveness. It also features a consideration of the intensity of the proposed new development. By considering that plus the relevant site-specific factors prior to determining the appropriate buffer width, this approach helps ensure that the buffer is adequate to protect a wetland without being any larger than is necessary.

This approach may require that the permit applicant hire a consultant to conduct the necessary analysis, or that County staff conduct the analysis, in which case the staff must have appropriate training and expertise to conduct or review the analysis. Alternatively, if maps are available covering the entire county and showing the key factors important to determining the correct wetland buffer sizes, those maps can depict a "default" buffer width for each wetland. This can become the official requirement when a permit application is for a low-intensity development, while for larger developments, or where a landowner's observations differ with those on the map, County staff or a qualified consultant hired by a landowner would conduct a ground-level verification of the estimated buffer boundaries and supporting information.

Buffer averaging is sometimes appropriate. In this approach, the width of a buffer on one side of a wetland is allowed to be less provided the width on the opposite side is expanded, so that average width overall is the same as would normally be recommended for the particular site. The *narrowing* is most appropriate in the portion of the surrounding lands where there are no pollution sources or where such sources are located downhill from the wetland and thus are least likely to contribute pollution to the wetland directly. *Widening* a buffer on one side (and compensating by narrowing on the other) may be desirable where such localized widening, by including other natural habitat, would create a habitat corridor to another wetland or to a particularly important natural feature nearby that otherwise would remain legally unprotected. For example, although Goates et al. (2007) found that uniformly-configured 100-ft streamside buffers were inadequate to protect habitat of one rare species, 92% of the species habitat would be protected if the buffers were extended selectively to encompass groundwater seeps and intermittent parts of streams. Best available science does not support narrowing a buffer on one side of a wetland just to accommodate development or parcel boundaries.

2.4.5.2 Applying Best Available Science to Buffer Width Requirements

One component of Best Available Science (BAS) is "Synthesis" of existing information. For updating regulations pertaining to wetlands, some jurisdictions are consulting the following synthesis document:

> Sheldon, D., T. Hruby, P. Johnson, K. Harper, A. McMillan, S. Stanley, and E. Stockdale. 2005. *Freshwater Wetlands in Washington State - Vol. 1: A Synthesis of the Science.* Washington Dept. of Ecology, Olympia.

When applying information from that document to decisions about **buffer widths,** some jurisdictions are consulting two other synthesis documents:

Granger, T., T. Hruby, A. McMillan, D. Peters, J. Rubey, D. Sheldon, S. Stanley, and E. Stockdale. 2005. *Wetlands in Washington State - Volume 2: Guidance for Protecting and Managing Wetlands*. Publication #05-06-008. Washington Dept. of Ecology, Olympia.
Hruby, T. 2004. *Washington State Wetland Rating System for Western Washington, Revised.* Washington Dept. of Ecology, Olympia.

The most recent WDOE recommendations for buffer widths in Western Washington are those in the document listed above by Granger et al. (2005). That document states that its recommendations are based on BAS, and specifically names the WDOE document (Sheldon et al. 2005) as the source of the BAS[13]. It suggests that local jurisdictions might tailor their recommendations partly using the wetland categories defined by the Hruby (2004) document. The Sheldon document does not recommend buffer widths, but cites several publications that do. These documents were a starting point for this chapter's synthesis.

The applicability of results from previous studies depends largely on (a) the study's experimental design and (b) similarity of the study environment to conditions that currently typify SJC wetlands. However, even studies that are judged to be highly applicable can be misinterpreted or overinterpreted. Thus, it also is important that (c) BAS not only be identified and used, but that it be used in a manner that is faithful to its sources and sensitive to its limitations. As Sheldon et al. (2005) note:

> "The conclusions of a scientific study done at one time in one wetland with specific characteristics may not be directly transferable to circumstances that develop in the future or at sites that have different characteristics or situations. Science rarely supplies us with precise solutions for protecting and managing natural resources. Very few experiments demonstrate true cause-and-effect relationships."

Thus it should be understood that in all jurisdictions, despite the attempts to base critical area regulations – including buffer widths -- on BAS, BAS is not *perfect* science. The question then becomes: "Below what threshold should a published study not be considered, even when it is the best of several studies available, because its design and those of the others was so severely flawed and/or their conclusions were drawn with excessive bias or illogic?"

<u>BAS Limitations Related to Availability or Choice of Literature</u>
Perhaps fewer studies have been done of buffers narrower than 32 ft than on wider buffers. If true, this could potentially result in a bias for larger buffers (Hickey & Doran 2004). And like all science, the science behind buffers and wetlands is constantly changing and being revised as new studies are completed and understanding increases. Although the WDOE's BAS document was released officially in 2005, only 1% of the citations were from 2004, and none were from 2005. In the five years since then, dozens more peer-reviewed studies of buffers have been published. Moreover, the WDOE document intentionally excluded tidal and other tidal wetlands, as well as streams and other upland habitats. Thus, before drafting the material in this chapter, we

[13] A substantial portion of the Sheldon et al. document had earlier been adapted, with permission, from a comprehensive review prepared for the USEPA by the author of this chapter (Adamus et al. 2001: *<u>Indicators for Monitoring Biological Integrity of Inland Freshwater Wetlands: A Survey of North American Technical Literature, 1990-2000</u>*<u>).</u>

identified an additional 138 references that are pertinent to buffers, and read key parts of approximately 76 of these.

BAS Limitations Related to Research Designs in Published Studies

To credibly determine the effects of various buffers widths on wetland functions, an experimental approach is preferred. That is, key variables should be measured in a series of otherwise similar wetlands that differ only with regard to widths of their surrounding buffers. Alternatively, buffers surrounding a single wetland could be narrowed progressively over time while monitoring wetland condition and functions. Together, these two common research designs are termed BACI (Before-After, Control-Impact), yet very few of the published studies that are commonly cited to support buffer recommendations have used the highly-desirable BACI design. As Fennessy & Cronk (1997) noted, "…many studies that make recommendations regarding the minimum width necessary have arrived at the figure as a byproduct of sampling design rather than deriving it experimentally."

BAS Limitations Related to Measured Response Variables

For representing the *water quality* of wetlands, most studies of the effects of buffers of various widths measure the surface water directly. Although this is appropriate, the conclusions from such studies are often misrepresented to include substances not studied. For example, a well-based finding that correctly-positioned buffers that are only 20 feet wide can retain most of the runoff-borne coarse sediment they receive is broadened to imply that a buffer that narrow can retain finer sediments and any harmful chemical, including soluble pollutants, human pathogens, detergents, and potentially harmful decay-resistant antibacterial products that may occur commonly in septic system outflows.

For representing *habitat* functions of wetlands, buffer studies typically only measure (a) the presence/ absence of species in wetlands with various buffer widths, (b) the presence/ absence of species in *buffers* of various widths, or (c) the number (richness) of species in (a) or (b). Interpreting such data is problematic partly because the mere presence of an individual animal does not mean it is reproducing successfully, and population sustainability as indicated by successful reproduction – not simply by species presence or absence—is the truest test of the actual worth of a habitat or area (van Horne 1983). Thus, although studies that show large numbers of individuals of a wetland species (such as beaver) being present at considerable distance from a wetland, and such studies are helpful for documenting complementary *use* of multiple habitats, it remains unclear how critical such peripheral areas may be to the species' long term survival.

Although a common assumption is that buffers must be wooded, few studies have documented the specific types and intensities of land use ("permeability of the landscape matrix" is the term ecologists use, see Chapter 4, section 4.3.1.5) that will render a buffer inhospitable to movement of individuals of a given species. For example, there are no peer-reviewed data that demonstrate avoidance of hayfields and lightly-grazed pastures by the dispersing amphibians, mammals, or birds that inhabit SJC or other areas of the Pacific Northwest.

There also are no peer-reviewed regional studies that show populations of any non-nesting wetland species being harmed by occasional disturbance of individuals as a result of humans approaching wetlands on foot (as opposed to disturbance from motorboats). Buffer widths designed to protect wildlife from disturbance, if based only on flight (flushing) distances of particular wildlife species, or presence/ absence of individuals of a species at various distances from a wetland, do not meet any reasonable threshold for "science," even if they are the only data that are available.

In addition, species richness is a poor way to represent the value of buffers. This is partly because the presence of a large variety of species in a wetland says little about a wetland's health or natural ecological condition if most of the species are upland or non-native species, or if they are using the wetland only infrequently and failing to successfully reproduce either in the wetland or elsewhere. Indeed, some wetlands that support only a few species may be critically important to regional biodiversity if those species are specialized wetland obligates that occur in few other wetlands.

<u>BAS Limitations Related to Extrapolating from Study Environments</u>
Much subjectivity is involved in deciding when it is appropriate to extrapolate from published research to conditions present in a specific area or habitat type. For example:

- If the study was done in an urban or forested landscape, are the results valid for agricultural areas in SJC?
- If the study was done in an agricultural area of North Dakota, are the results valid for agricultural areas in SJC?
- If the study was from western Washington but involved data collected only during the summer, are the buffer widths it supports valid for wildlife species that depend on wetlands or streams during the winter?
- If the study involved only grassy depressional wetlands in eastern Washington, are the buffer widths it supports valid for forested slope wetlands in SJC?

The reality is that no area where buffer studies have been done is an exact match for SJC wetlands in terms of species, wetland types, and wetland settings. And finding the closest matches to relevant SJC conditions (even if they were quantified and thoroughly understood, which they are not) would be extremely tedious because of the sheer quantity of buffer studies, which now number in the hundreds. Even within SJC, wetlands and their surrounding landscapes show a great degree of variation. In addition, the relevant details given in published studies are seldom sufficient to confidently match them with conditions presumed to exist in SJC.

2.4.5.3 Buffers for Protecting Wetland Water Quality

<u>Background</u>
Where natural vegetation is allowed to dominate an upland area next to a wetland, that not only reduces (in most cases) the risk of the upland area becoming a pollution source, it also provides an opportunity for the upland area to immobilize or process the pollution it receives, thus maintaining the water quality of the adjoining wetland and all its functions. This is the principle behind using buffers to maintain wetland water quality. Vegetated buffers (also called vegetated filter strips) have been widely promoted as a best management practice for maintaining the water quality of lakes and streams, and more recently wetlands. Riparian

buffers (in contrast to vegetation and other factors located far from streams) can be responsible for up to 70% of the reduction in nutrient loads to streams (Diebel et al. 2009, Roberts & Prince 2010). Note that factors other than buffer characteristics can control a wetland's water quality. These include underlying soils and geology, groundwater discharge or recharge rates, topography, plants and animals within a wetland, and proximity to the ocean (Feller 2005). A buffer's *effectiveness* for reducing pollution is typically expressed as the *percent of incoming pollution that is retained or removed*. Ideally, this is expressed per unit of time (e.g., pounds of phosphorus retained per foot of buffer per year) and the resulting levels (e.g., parts per million of phosphorus) of the pollutant in the receiving wetland's surface water and sediments are quantified relative to some standard or threshold.

Key Considerations

Although discussions of buffer design typically focus mainly on the buffer's width, several other buffer characteristics probably have a greater effect on a buffer's effectiveness (Mayer et al. 2005). These include vegetation type and density, surface roughness, water source, flow pattern (concentrated vs. diffuse), slope, soil type and condition, location of the buffer relative to major paths by which water enters the wetland, contributing area size relative to buffer size, and the amount and dosing rate of the pollutant. Effects of these characteristics are now described:

1. Pollutant Type, Amount, Dosing Rate, and Duration: Buffer effectiveness is greatest when incoming polluted runoff or groundwater arrives in small doses (low loading rates) rather than in concentrated flows and high volumes, e.g., during severe storms (Lee et al. 2003). There is some evidence (e.g., Mukherjee et al. 2009) that vegetated buffers which have received sediment or phosphorus-bearing runoff for many years may lose their effectiveness, thus jeopardizing the water quality of their associated wetland or stream. Studies of this phenomenon are too few to predict situations (loading rates, durations, wetland types) where it is likely to occur. Also, one study showed buffer effectiveness did not decline even during several successive days of pollutant inputs (Syversen 2005), but did not examine long term effects.

Wetlands and their buffers cannot process some types of pollutants at all. Over 63,000 synthetic chemicals are in common use in the United States, many in households with septic systems incapable of effectively detoxifying them. More than 200 of these chemical substances have been found in groundwater, but only where someone has checked (and monitoring most of these is extremely expensive). Only a tiny fraction of these synthetics have been tested for their possible effects on humans, let alone on the thousands of species of plants and animals occurring in SJC. When testing has been done, it most often has focused only on direct toxicity, rather than effects on reproduction and behavior which can be almost equally damaging to populations over the long term.

2. Vegetation Type and Configuration: Pollutant processing by buffers usually has very little to do with plant uptake of pollutants (partly because plants die and return the pollutants to the soil), but much to do with the capacity of plants to promote infiltration and support microbial communities responsible for considerable processing of pollutants. Many studies have compared grass vs. wooded buffers. Some have found grass filters (buffers) to be more effective, especially for filtering sediment-bearing runoff. Most others have found wooded buffers to be more effective, especially for removing nitrate, a pollutant from farms and septic systems when it occurs in high concentrations (Mayer et al. 2005). Some studies have found mixtures of both to be most effective (Sovell et al. 2000, Schultz et al. 2004, Lowrance & Sheridan 2005). The differences are probably explained by underlying differences in vegetation patterns, species, root structures, surface roughness, season, pollutant type, and/or other characteristics described below that correlate with vegetation type. Although vegetation roots can promote pollutant processing by increasing infiltration, vegetation (especially trees) are almost equally likely to be detrimental to that goal if large roots create "macropores" through which the movement into streams and wetlands of subsurface polluted subsurface water is accelerated (Kelly et al. 2007).

For pollutant removal, there are no data that indicate buffers dominated by non-native plant species are less or more effective than ones dominated by native plants. However, one relationship that does appear to be relatively certain is that wooded buffers dominated by nitrogen-fixing shrubs such as red alder tend to be sources, not sinks, for nitrate (a potential pollutant) during at least some seasons of the year, and thus may be ineffective as buffers if the primary intent is to protect wetlands from overenrichment (Monohan 2004). A statistical sample of SJC wetlands visited in 2010 found that at least 65% contained some amount of alder.

3. Water Source and Flow Path: Vegetated buffers are more effective in protecting the quality of wetlands when most water enters the wetland as shallow subsurface lateral flow or discharging groundwater, rather than channel flow or surface runoff (Wigington et al. 2003, Mayer et al. 2005). That is because pollution transported towards the wetland via shallow subsurface routes is most likely to pass slowly through the biologically-active root zones of plants in the buffer, thus maximizing the potential uptake and processing (Bedard-Haughn et al. 2004). However, for at least one pollutant (nitrate), some evidence suggests that when most of the pollutant load is borne mainly in shallow subsurface flow, buffer width (travel distance) is less important than soil type and other factors in predicting its removal rate (Mayer et al. 2005).

4. Flow Pattern: Flow pattern is perhaps the most important factor influencing buffer effectiveness. Vegetated buffers are most effective in protecting the quality of wetlands when major inflows are diffuse (surface sheet flow or subsurface lateral flow) rather than concentrated in rills and gullies (Dillaha et al. 1989, Dosskey et al. 2001, Wigington et al. 2003). This depends on typical rainfall patterns (steady drizzle vs. concentrated in storm events, Lee et al. 2003) as well as soil type (coarser soils tend to promote infiltration and less gullying), extent of drainage alterations such as foundation or curtain drains that concentrate runoff, and slope (Abu-Zreig 2001, Mancilla et al. 2005). In one study, only 9-18% of the vegetation in a buffer was actually in contact with runoff, due to the buffer's topography. Although under uniform flow the buffer could potentially remove 41-99% of sediment, the actual removal rate was 15-43% (Dosskey et al. 2001). Buffers in rural New York were found to be ineffective when crossed by small unmapped drainageways (e.g., roadside ditches) that were not buffered but were connected to pollution sources (Madden et al. 2007). In SJC, an unknown proportion of wetlands are partially fed, at least during major storms, by ditches and subsurface pipes from roads, subdivisions, or agricultural lands. Those features partially circumvent the pollution-filtering purpose of buffers.

5. Slope: Vegetated buffers are most effective in protecting the quality of wetlands when the buffers are in relatively flat terrain (Jin & Romkens 2001). That is because flat terrain allows water more time to move slowly downslope through the roots of the buffer vegetation (Wigington et al. 2003). Depending on soil type, steep slopes can foster the formation of gullies and rills, short-cutting the naturally diffuse flow paths necessary for effectively purifying runoff (see Flow Pattern, above). However, the magnitude of the effect is unclear. For example, despite a buffer slope of 16%, Dillaha et al. (1989) measured 70% retention of runoff-borne sediment in buffer that was only 30 ft wide. An Ontario study found the slope of the contributing area had relatively little effect on concentrations of nitrate and carbon in a downslope riparian area. Soil carbon was more responsible for increasing nitrate removal, and soil carbon was actually greater on steeper slopes in that study area (Hazlett et al. 2008).

Various rules-of-thumb have been proposed for increasing required buffer widths to compensate for the effects of slope (Table 2-2).

Table 2-2. Slope adjustments for buffer widths as suggested by other authors

Note: Slope can be measured in degrees from horizontal (0-90), or as percent slope (which is the rise divided by the run, multiplied by 100). A slope of 45 degrees equals 100 percent slope.

	increase buffer width by:	**Source:**
For every 1 **degree** increase in slope…	1 ft	State of Maryland timber harvest regulations(1)
	2 ft	Georgia Department of Natural Resources (2)
	3 ft	Connecticut Assn. of Wetland Scientists (3)
	3 ft, if 10-30 degrees	Nova Scotia (4)
	10 ft	Minnesota Dept. of Natural Resources (5)
For every 1 **percent** increase in slope…	2 ft	Wenger 1999
	4 ft	City of Sacramento; Shrewsbury Township, PA; and North Carolina Department of Environment, Health and Natural Resources (6)
	4 ft (only if >15% slope, and no more than 10 ft beyond the top of the slope)	cities of Salisbury & Easton, MD (7)
	5 ft	Palone & Todd 1997
For all slopes >30%.	50% more than the width otherwise recommended	Washington Dept. of Ecology (Granger et al. 2005)

Table 2-2

Sources:

(1) http://www.gadnr.org/glcp/Documents/Evaluation_Criteria.pdf
(2) http://agroecology.widgetworks.com/data/files/pdf/1077145814_89267.pdf
(3) http://www.ctwetlands.org/Draft%20Buffer%20Paper%20Version%201.0.doc
(4) http://www.for.gov.bc.ca/tasb/legsregs/fpc/pubs/westland/report/2-18.htm
(5) http://www.pca.state.mn.us/publications/wq-strm2-16d.pdf
(6) http://www.p2pays.org/ref/03/02178.pdf
(7) http://www.ci.salisbury.md.us/CityClerk/Title12-Streets-Sidewalks-and-Public-Places.html

6. Soil Type and Infiltration Rate: Vegetated buffers usually are most effective in protecting the quality of wetlands when the buffers are on moderately coarse soils, such as loams and silts (Polyakov et al. 2005). Finer-textured soils (e.g., clay) near the land surface (A horizon) tend to become saturated quickly, allowing incoming pollutants to sometimes "float" over the root zone where most pollutant processing otherwise occurs (White et al. 2007). However, clay soils with abundant macropores (e.g. shrinkage cracks, earthworm channels, tile drains) at the soil surface can support infiltration capacities that are as high as some coarse-textured soils (Jarvis and Messing 1995). Compaction of clay or silty soils by machinery reduces infiltration and the opportunity for pollutants to be processed in the biologically rich near-surface soil strata, while increasing their risk of being washed downslope. However, if soils are so coarse that water infiltrates very rapidly through the root zone, or if subsurface drains (tiles) have been installed, there may be too little time for pollutants to be fully processed before moving downslope. In one study where there was a confining layer situated beneath very coarse soils, buffers with widths of up to 577 feet were required to remove 90% of the incoming nitrate (Vidon & Hill 2006). Chemical properties associated with coarse-textured soils also make them less effective in retaining or removing many pollutants.

Soil organic matter is extremely important. Dark soils that have not been recently tilled or compacted and which remain moist throughout much of the growing season, are most capable of removing nitrate over shorter distances, if most of that nitrate is in shallow subsurface flow. This is especially true if they also remain warmer due to their topographic aspect (sun exposure, sheltering from wind) (Kim et al. 2007), while not being dried out to less than 70% saturation by those warmer conditions (Hefting et al. 2006). Soils having less than 65% silt and clay have very limited capacity to remove nitrate via denitrification, a finding based on a study in southwest Alaska (Pinay et al. 2003). Localized areas of high organic content within soil map units can have high denitrification (nitrate removal) rates even if the mapped soil type generally does not, if the soils are not too acidic and remain moist for long periods (Hefting et al. 2006).

7. Buffer Location: If the sole purpose of a wetland buffer is to protect the wetland's water quality, then the usual buffer widths might be reduced where the surrounding land, that otherwise would be part of the buffer, slopes *away from* the wetland. Such non-contributing areas do little or nothing to intercept polluted runoff that otherwise would reach the wetland. Spatial analysis of data from SJC wetlands indicates that if buffers were configured to include only the contributing areas of wetlands, rather than a uniform sized-buffer on all sides of a wetland, the resulting new buffer, if based only on water quality functions, would occupy much less land.

8. Contributing Area Ratio: Small buffers that are expected to bear responsibility for processing runoff from very large contributing areas tend to be ineffective, because storm runoff quickly overwhelms their processing capacity (Misra et al. 1996, Creed et al. 2008, Tomer et al. 2009). Not all buffer studies have found the ratio of buffer area to contributing area to be a good predictor of buffer effectiveness, but authors of those that have suggest the vegetated buffer acreage should be at least 15% of the acreage of its contributing area, especially the part of the contributing area that is capable of generating polluted runoff (Leeds et al. 1994). A review of studies published on herbicide retention by buffers concluded that the ratio of the acreage of the herbicide source area to that of the buffer did not generally influence buffer effectiveness in the area ratio range of 5:1 to 45:1 (Krutz et al. 2005). For nitrate, computer model simulations showed that a buffer occupying 10-50% of the contributing area could lead to 55-90% reduction in nitrate runoff during an average rainfall year. Buffers occupying 10-20% of the contributing area were found to be more efficient in reducing nitrate when placed along the contour than when placed along the river. Across SJC, the ratio of wetland to contributing area generally decreases slightly at lower elevations, suggesting a possible need to increase width requirements for buffers lower in a watershed. However, it could also be argued that slopes around wetlands tend to be steeper in the higher parts of most watersheds, thus suggesting a possible need for equivalent buffer widths there.

Buffer Widths Needed to Purify Water

Suspended sediment is considered to be a potential pollutant because excessive concentrations harm aquatic life. When deposited, excessive sediment can clog drainage ditches and ponds as well as shorten the lifespan of wetlands. Sediment tends to be filtered out by vegetated buffers over shorter distances than is nitrate. A literature review by Castelle et al. (1994) indicated that effective retention of runoff-borne sediment requires buffers of between 30 and 200 ft. The same range was noted by Melcher & Skagen (2005), and Sheldon et al. (2005) indicated a range of 66 to 328 ft. In his review of riparian buffer literature, Wenger (1999), concluded "a 100 ft buffer is sufficiently wide to trap sediments under most circumstances, although buffers should be extended for steeper slopes" and "50 ft buffers should be sufficient under many conditions." However, a review of 80 studies of sediment interception by vegetated buffers (Liu et al. 2008) concluded that for retaining sediment, buffers of 33 ft are usually optimal, with additional widths retaining only slightly more sediment. A study in Georgia (White et al. 2008) found even the finest sediment particles were removed within 52 feet, and that although greater roughness of ground surface within the buffer increased sediment retention, the influence of that factor (which reflects the amount of downed wood, leaf litter, etc.) was minor.
Timber harvest rules (WAC222-30-010 and -021) in Washington specify that forested buffers of between 25 and 200 ft width shall be applied near logging operations depending on the types of wetland, which are specified. Width is measured from the point where the nonforested part of a wetland (i.e., emergent vegetation) becomes forested wetland. The Code of Federal Regulations (30 CFR 816.57 and 30 CFR 817.57) prohibits surface mining activities within 100 ft of perennial or intermittent streams unless the owner can demonstrate no pollution will occur. In its Conservation Reserve Program, the NRCS usually does not award credits for buffers wider than 350 ft, or with an average width greater than 180 ft. (Mayer et al. 2007).

Many studies have shown that sediment retention is greatest in the first 5-20 ft of a buffer, that is, the most uphill portion, which is closest to potential inputs of runoff-borne sediment (Polyakov et al. 2005, White et al. 2007). However, this depends on steepness of the terrain, erodibility and infiltration capacity of the soil, ground cover, antecedent soil saturation, sediment particle size, and runoff intensity. Wider buffers are required when runoff carries finer-sized particles (e.g., clay).

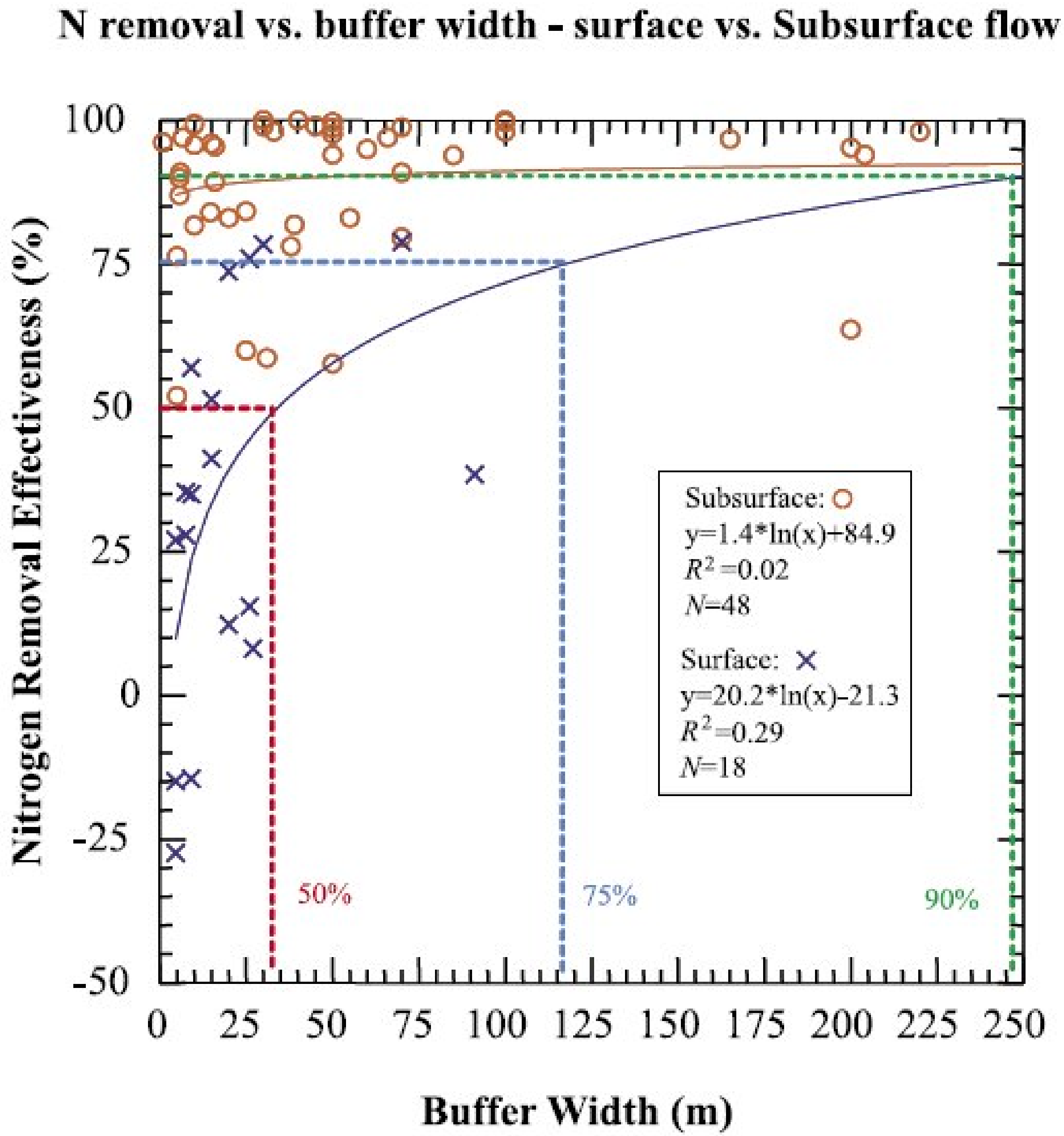
For **nitrate** (which in excessive amounts can harm aquatic life and human health), literature reviews by Barling & Moore (1994) and Mayer et al. (2005) have noted that there are several studies (Jacobs and Gilliam 1985, Lowrance 1992, Cey et al. 1999, Clausen et al. 2000) which have found that buffers as narrow as 15 feet can sometimes remove more than 85% of nitrate, and buffers of 33-164 feet wide can sometimes remove 90-99%. In North Carolina, a stream buffer of 33 ft appeared to protect aquatic life from slightly elevated nitrate in runoff from a logging operation (Knoepp & Clinton 2009); increasing buffer widths from 33 to 100 ft decreased nitrate in shallow groundwater to less than 1 mg/L, a generally harmless level (Smith et al. 2006). Nearly the same range of buffer widths was found to be effective by Vought et al. (1995) and Lowrance & Sheridan (2005). In contrast, a study in Ontario found 577 ft was required to remove 90% of the incoming nitrate (Vidon & Hill 2006).

Within just a few years of planting an 82 ft-wide riparian buffer in Iowa, the nitrate concentration in underlying shallow groundwater had dropped significantly whereas in an unplanted control no change occurred. When cropland plots in Nebraska were planted with natural vegetation in a buffer 25 ft wide, within 3 years the filtering or retention effectiveness of the vegetation improved progressively for nitrate, phosphorus, and sediment. This was mainly due to the vegetation spreading into bare gaps in the buffer and improving infiltration (Dosskey et al. 2007). Timber removal at one location in British Columbia resulted in higher levels of soil nitrate even 7 years after harvest (Hope et al. 2003). However, after a Nova Scotia forest was clear cut, nitrate increased in only one of 6 streams where riparian buffers were at least 66 ft wide; selective cutting within the buffers reduced their removal effectiveness (Vaidya et al. 2008).

A nonwooded buffer in Oregon that was only 20 ft wide reduced the concentration of nitrate in agricultural groundwater to undetectable levels (Davis et al. 2007). When nitrate was transported through a wetland entirely via shallow groundwater, 95% of the nitrate from a sheep pasture was removed in the first 3 ft of a New Zealand buffer (Burns & Nguyen 2002) and in the first 13 ft of a California pasture buffer (Bedard-Haughn et al. 2004). However, buffer performance is less reliable when buffers are this narrow (Lowrance et al. 2001, Mayer et al. 2005). Within a buffer, spatial variation is often high in regard to the capacity of the soils and vegetation to remove nitrate (Hefting et al. 2006).

Reviews of published literature by Fennessy & Cronk (1997) and Wenger (1999) suggested that 100-ft buffers would be necessary to remove nearly 100% of nitrate inputs. A more recent, comprehensive, and sophisticated analysis that used statistical procedures (meta-analysis) to synthesize results from over 60 peer-reviewed studies of nitrate removal by buffers in temperate climates found that widths of approximately 10 ft, 92 ft, and 367 ft are needed to achieve 50%, 75%, and 90% removal efficiencies for nitrate (Mayer et al. 2005, Mayer et al. 2007)(Figure 1). This assumed that most inputs are through subsurface flow. When surface flow dominates (as often occurs during storms, and where subsurface storm drains have been installed around homes), buffers of 109 ft, 387 ft, and 810 ft are needed to achieve the same removal efficiencies (Mayer et al. 2005). In some cases, the effect of buffer width on nitrate reaching streams may be barely detectable. For example, an Australian study found nitrate was best predicted by the number of septic tanks per unit area within a stream's contributing areas, almost without regard to the proximity of the septage to the stream or the extent of storm drain conduits (Walsh & Kunapo 2009).

Reflecting a concern for potable groundwater, in SJC new wells for individual residences are required to be at least 100 feet from the edge of septic drainfields (WAC 246-291-100 and 246-290-135 Source Water Protection, Sanitary Control Area). In addition, potential sources of contamination must be evaluated within 600 feet of SJC wellheads intended to provide a public water supply (San Juan County Health and Community Services 2007).



Based on statistical analyses of data from 63 buffer studies (Mayer et al. 2005).

Phosphorus is another nutrient of concern because of its potential to trigger growths of algae that deplete oxygen important to aquatic life. The ability of vegetated buffers to attenuate phosphorus before it reaches wetlands or streams depends largely on the form of the phosphorus. If it is mainly attached to sediment (as often it is), then buffer widths sufficient for sediment retention may be almost as effective as those specified for retaining phosphorus (White et al. 2007). But if phosphorus is mostly in dissolved form (orthophosphate, or soluble reactive phosphorus), then vegetated buffers may need to be very large or may not be effective at all (Prepas et al. 2001, Hoffman et al. 2009). A study in Iowa found that buffers dominated by plants that put on most of their growth late in the growing season were less effective for retaining phosphorus, because most phosphorus there is attached to sediment and thus is transported to the buffer by heavy runoff during the early part of the growing season when the ground cover of plants is less dense (Tomer et al. 2007).

Pesticides applied around buildings, gardens, orchards, pets (flea control), and row crops can also find their way into streams, wetlands, aquifers, and tidal waters where they harm aquatic life. A sufficiently wide vegetated buffer, when maintained next to the pesticide application area, can help reduce this transport (Reichenberger et al. 2007) but buffers are not a panacea. Under calm wind conditions, densely vegetated buffers with a width of 10 to 33 ft (Brown et al. 2004) was found reduce the drift of aerially applied pesticides before they reach surface waters. At higher wind speeds, either a 66-ft wide hedgerow or the same 32-ft hedgerow plus a dense tree stand was effective. Another study found dense hedgerows of about 25 ft height were effective in intercepting >73% of the pesticide sprayed at 3-6 ft above the ground (Lazzaro et al. 2008). However, runoff can still carry these substances to nearby water bodies. A pesticide runoff study in Georgia demonstrated retention of some pesticides by a 125-ft buffer containing a mature hardwood riparian forest (Lowrance et al. 1997, Vellidis et al. 2002). Computer models developed by Rodgers and Dunn (1993) suggested that buffers of at least 330 ft width would be needed to retain and detoxify one common herbicide (atrazine) during times of peak runoff. This finding was confirmed in wetland studies by Moore et al. (2001), although Gay et al. (2006) found 92-100% of atrazine could be retained within 105 ft under the right conditions. Even larger buffers would be needed to retain chlorpyrifos or metolachlor, insecticides which are more toxic to aquatic life (Moore et al. 2001, 2002).

Because they have been detected in SJC waters, the pyrethroid pesticides are of particular interest. A study in Mississippi which dosed a wetland with pyrethroid insecticides found the wetland was relatively effective at retaining this toxin (Moore et al. 2009) but effects on wetland organisms were not monitored. Test results indicated that if only 1% of the pyrethroid pesticide typically applied to an agricultural contributing area of 35 acres reached a wetland, the wetland would need to be about 1.6 acres in size (and 705 ft long) to effectively reduce that load. Concentrations of pyrethrins and some other pesticides also can be reduced by vegetation within well-vegetated ditches that commonly drain fields (Cooper et al. 2004, Bennett et al. 2005, Needelman et al. 2007).

2.4.5.4 Buffer Widths for Protecting Habitat and Wetland Species

Background

"Habitat" is the area within which plants and animals exist to meet their needs, including but not limited to food, water, and shelter from the elements and predators. Every species has a specific set of environmental conditions that define its habitat. Some species are very tolerant and can thrive under almost any set of environmental conditions, whereas other have narrow tolerances and occur in just one or a few habitat types. For most species, habitat requirements are poorly known and can be influenced by the types of co-occurring species (e.g., predators, competitors) at a given location. Virtually every square inch of the planet provides habitat for some organism.

In this BAS report, as in BAS reports from other counties, "habitat" is addressed both in a "Fish and Wildlife Habitat Conservation Areas" chapter (Chapters 3 and 4) and in this Wetlands chapter as one of several functions wetlands perform. Within SJC there regularly occur at least 988 species of vascular plants, 7 amphibians, 7 reptiles, 201 birds, 35 mammals (Chapter 4, Appendix 4-A), close to a dozen fish species, and perhaps over a thousand species of invertebrates. Those that occur regularly and specifically in wetlands (Appendix 2B-2) include at least 328 plants, all the fish and amphibians, 6 of the reptiles, 162 (81%) of the birds, 22 (63%) of the mammals, and unknown numbers of invertebrate species.

Vegetated buffers around wetlands potentially do several things that are relevant to supporting habitat. They (a) filter runoff-borne sediment before it clogs wetlands and threaten their fish and wildlife, (b) limit human traffic into wetlands, that otherwise can disturb plants and wildlife, (c) limit the spread of non-native plants into wetlands, some of which provide poorer habitat than native plants, (d) help maintain microclimate conditions (temperature, humidity) within the wetland that are important to some of its species, and (e) provide habitat directly for upland species (i.e., species that are not wetland-dependent), as well as for some wetland-dependent species that require or use both upland and wetland habitats in close proximity.

Factors other than habitat frequently control wildlife populations. In the case of amphibians, these limiting factors include roads (Trombulak & Frissell 2000, Gucinski et al. 2001), introduced predators such as bass and sunfish (Pearl et al. 2005), herbicides and fertilizers used commonly in gardens, lawns, and along roads[14] (Bortleson & Ebbert 2000, Voss et al. 1999, Relyea 2005, Relyea et al. 2005), fungal infections, ultraviolet radiation from the sun (Hatch & Bluestein 2003), and land alterations or groundwater withdrawals that can result in lower and less persistent water levels in wetlands. Long term climate change also is likely to profoundly shift the species, functional capacities, and even the extent of SJC wetlands. Unless these impacting factors are managed as best they can be to limit their harm, adding wider buffers to wetlands may have only a marginal effect on sustaining populations of wetland species.

It is not necessary that a buffer always be wooded (dominated by trees and shrubs) in order for it to benefit local biodiversity, but that often helps. On one hand, woody vegetation helps shelter the water in wetlands from high winds, facilitating the aerial foraging activities of birds and bats (Whitaker et al. 2000), and from intense sunlight, thus maintaining cooler water temperatures essential to many native fish. Dense shrublands in particular can minimize wildlife disturbance by limiting wetland access by people and predators. Dense vegetation provides a visual screen, reducing frequent disturbance of waterfowl by people. Unlike the situation with streams, there is less evidence from wetland studies that maintenance of cool shaded conditions is essential to most aquatic species (aside from salmonids and other coldwater fish) that use non-tidal wetlands in SJC. Thus, if a wetland lacks a surface connection to a salmonid

[14] Even herbicides such as glysophate (Roundup, Rodeo) which have a reputation for being relatively benign, have been shown to kill Pacific Treefrog and Western Toad at concentrations well below USEPA standards (at 0.43 ppm and 2.66 ppm respectively). Mortality may be the result of the dispersal agent rather than the herbicide itself (Chen et al. 2004, King & Wagner 2005).

stream, there is no obvious need for a wooded buffer around the wetland that is two or three tree-lengths wide (as is commonly recommended to maintain microclimate along salmonid streams). However, there could sometimes be other reasons for having such buffers around some wetlands. According to the LiDAR analysis, about 41% of the county's wetlands have a major component of trees or shrubs, but few of these wetlands are accessible to salmonids.

Although wooded surroundings are important to a few wetland-dependent species, many more species (e.g., most waterfowl, shorebirds) seem not to have this need, as suggested partly by their frequent use of flooded agricultural lands (Hirst & Easthope 1981, Lovvorn & Baldwin 1996; Shepherd & Lank 2004, Slater 2004). For those species, trees next to wetlands sometimes discourage wetland use by attracting avian predators that use the trees as perches (Shepherd & Lank 2004). Partly for this reason some larger waterfowl species (swans and geese) usually avoid small wetlands if they are completely surrounded by trees. In some cases, buffers of woody vegetation could provide less late-summer water to wetlands and streams, causing them to dry up sooner as a result of greater soil moisture uptake and loss via transpiration. Although submerged wood is important to many fish and invertebrates in streams, wetlands in SJC are probably not a major source of wood because few are connected to perennial streams.

In contrast to woody buffers, buffers consisting of tall mostly-ungrazed herbaceous or shrub vegetation provide better cover to the few waterfowl species that nest in SJC. As noted by Cushman (2006), "The suggestion that *forest* cover in the [buffer] landscape benefits amphibians may not apply to all species that are fully aquatic or that depend on nonforested upland habitat." Also, Pearl et al. (2005) found only one of five amphibian species to be correlated with surrounding forest cover, and another one of the amphibians (Pacific Treefrog) was negatively correlated with it. In some cases a lightly-grazed pasture that comprises a portion of an otherwise wooded buffer may be sufficient or even desirable to protect the habitats of some wetland animals, and thus might be counted in the buffer width measurement. Moreover, in parts of SJC there are areas on "prairie" soils that have been without forest cover for over a century. Native plant communities in these areas include some that may not tolerate woody buffers. In summary, requirements for wooded buffers around all wetlands might benefit some species -- such as Rough-skinned Newt, Pacific (Winter) Wren -- but could have detrimental effects on others (e.g., Pacific Treefrog, Marsh Wren, shorebirds, geese) according to published research. Appendix 2B-2 shows wetland-associated species of SJC, and what is known about the general types of wetlands they prefer.

Buffer Purposes and Widths for Wetland Species and Habitat Protection

Buffers around wetlands **provide habitat for wetland-dependent species that require both wetlands and uplands**. A few SJC species which have an *obligate* relationship to wetlands might fit this category: Northern Red-legged Frog, Northwestern Salamander, Rough-skinned Newt, and perhaps Western Toad. In addition, Bald Eagle, Osprey, Wood Duck, and Hooded Merganser have a *primary* relationship to wetlands and also require uplands that are **wooded** (or at least a few trees) as complementary habitat. For Wood Duck and Hooded Merganser, there are no data to indicate that wooded buffers must be contiguous to wetlands. Nests of Wood Duck may be located as far as 1149 ft from water, but 262 ft is average in Minnesota (Gilmer et al. 1978). Both species regularly use artificial nest boxes, often placed in open areas close to human habitation. For wildlife, wide wooded buffers seem to be most beneficial around permanently or semipermanently-flooded forested and shrub wetlands because those tend to support the types of species that benefit the most from wooded buffers, and the wooded buffer augments the patch size of woodland available to "forest-interior" upland species.

Another suite of wetland-dependent species has not been proven to require wooded surroundings. This includes Western Toad, Long-toed Salamander, and an unknown number of wetland-obligate plants. For these species, open native grasslands and semi-open woodlands may be preferred because, like many amphibians, they thrive less well in cooler climates, as may typify heavily shaded woodlands. Populations of Western Toad became established in the nearly barren landscape surrounding the explosion of Mount St. Helens in the 1980s, and this species thrives in rangelands of eastern Washington and Oregon, so it perhaps does not always require a contiguous forest canopy.

A key factor that has led some biologists to recommend enormous buffers around wetlands is the fact that frogs and salamanders, after partially maturing in wetlands, habitually move into surrounding uplands and then travel long distances. For this reason, buffers as wide as 538 ft have been recommended for species in the southeastern United States (Semlitsch 1998), despite there being few data to directly support this specific width, especially in the Pacific Northwest. This was judged necessary to protect the microclimate important to salamanders *around* (not necessarily within) wetlands.

In Idaho, toads spent almost 60% of their time in terrestrial areas farther than 33 ft from the pond where they were born, which dried up late in the season. On a daily basis individuals traveled 127 ft, and seasonally they typically moved at least 0.36 (females) to 0.69 miles (males) from the pond, generally favoring shrublands and open forest (Muths 2003, Bartelt et al. 2004). Red-legged Frog and Rough-skinned Newt are two local species that, at least on the mainland, are known to disperse long distances overland from their natal wetlands.

A second purpose of buffers is to limit the spread of non-native plants into wetlands (see Chapter 4, section 4.3.2.1). However, studies demonstrating this effect are few. Potentially, seeds of some non-native plants can be carried for miles by wind and water, so no buffer is likely to eliminate this threat completely. Data collected from a statistical sample of SJC wetlands in 2010 revealed 69% had some invasive wetland plant species (as defined by the WDOE, Hruby 2004), but invasives dominated the cover in only 18% of the wetlands. Non-natives (including invasives) dominated in 31%.

Other purposes of wetland buffers include limiting disturbance to wildlife, maintaining microclimate in and near wetlands, and limiting treefall. These are discussed in sections 4.2.2.3 and 4.3.2.1 of Chapter 4.

2.4.6 Restoration, Enhancement, Establishment of Wetlands and Their Functions

When all or part of a wetland must be altered because no alternative exists, regulations at the federal, state, and local level require that the loss be compensated by undertaking actions in wetlands or potential wetlands elsewhere that are termed restoration, enhancement, establishment, or preservation. Confusion regarding the precise definitions of these terms is common and often leads to legal actions and misunderstandings in the permitting process, so understanding their differences is crucial. Although restoration, enhancement, establishment, and preservation are key parts of wetland regulatory programs, it should also be noted that there are many individuals and organizations who are motivated by a commitment to community service and undertake such projects on a voluntary basis.

Most ecologists consider wetland **restoration** to involve more than just the removal of weeds and/or planting of native vegetation, because without sustained labor-intensive maintenance, these typically increase wetland functions only temporarily. For an area to qualify ecologically as wetland restoration, it must not currently be a wetland. It must be a formerly intact wetland that was drained, filled, or diked at a time when those activities were legally allowed (typically before the 1970's). For such wetlands, restoration consists of a reversal of those actions (e.g., breakage of drain tile, blocking of ditches)[15], thus resulting in an increase in wetland acreage Restoration of tidal wetlands and other shoreline areas must be addressed in a county's Shoreline Master Program.

Some agencies, such as the WDOE and Corps of Engineers, have broadened the definition of restoration to include any manipulation that repairs the natural or historic functions of a degraded wetland, even if it does not increase wetland acreage. They term this *rehabilitation,* as opposed to the traditional definition of restoration which they term *re-establishment.* No operational criteria are specified as to what shall constitute a functionally "degraded" wetland for purposes of crediting rehabilitation. As noted in the official guidance (WDOE et al. 2006), "The distinction between rehabilitation and enhancement ... is not clear-cut and can be hard to understand. Actions that rehabilitate or enhance wetlands span a continuum and cannot be strictly defined as one or the other." In practice, situations that qualify as *rehabilitation* are those where the original water regime is returned to areas that have been partially drained but which still are jurisdictional wetlands. An example is the intentional blockage of old drainage ditches within a jurisdictional wetland.

Enhancement is done only in areas that *currently* qualify as wetlands (including most ponds) or wetland buffers. Enhancement is the manipulation of the physical, chemical, or biological characteristics of a wetland to heighten, intensify or improve specific function(s) or to change the growth stage or composition of the vegetation present. Enhancement typically involves one or more of the following actions – but only when the permit applicant can demonstrate that some combination of these actions will increase one or more wetland functions:

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[15] Although not carried out for purposes of compensatory mitigation, several restorations of tidal lands have occurred recently in SJC. Examples are at Shoal Bay (4 acres), Turn Point (2 acres), and Neck Island (2 acres). For more information go to: http://www.conservationregistry.org/

- maintaining long-term control of non-native or invasive species
- reintroducing populations of native species and maintaining them
- modifying site elevations (regrading)
- changing the proportion of open water
- improving a connection to tidal waters or a stream network
- increasing habitat complexity (e.g., adding large woody debris, creating small openings in stands of monotypic vegetation, conducting a controlled burn, creating meanders and restoring natural contours in a ditched stream)
- surrounding a wetland and its buffer with fences to exclude or redirect the movements of domestic animals away from sensitive vegetation.

While enhancement changes some wetland functions, it often simultaneously decreases the levels of others (e.g., as demonstrated by Turner et al. 2001, Magee et al. 1999, Johnson et al. 2002). Consequently, scientific support for its use as a mitigation measure has recently declined. Enhancement should be undertaken mainly in the most degraded wetlands. It does not result in a gain in wetland acres, so in a literal sense it does not compensate for wetland loss.

Establishment of wetlands (also called wetland creation) is the manipulation of the physical, chemical, or biological characteristics to develop a wetland on an upland or deepwater site where a wetland did not previously exist. This typically involves excavating down to the water table in areas that currently lack wetland indicators (e.g., creating ponds from upland) or legally impounding seasonal drainageways sufficiently to support typical wetland plants and soil conditions. Establishment results in a gain in wetland acres. Creating some types of wetlands is nearly impossible, and creating a full suite of wetland functions is often difficult.

Preservation is the removal of a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland. This can involve permanently securing all development or water rights to a wetland or its upland buffer using full-fee acquisition, deed restrictions, or permanent conservation easements. Preservation is applicable only where there are no laws to adequately protect the object wetland. Thus, preservation is applicable mainly to wetlands that are too small to be legally regulated, or which for other reasons are exempt from regulations, e.g., some farmed wetlands. Priority for preservation is often given to the wetlands that are most threatened with unregulated nearby development. Preservation does not result in a gain in wetland acres, so it does not fully compensate for losses elsewhere.

Compared with other counties, wetland projects meeting the above definitions and conducted as compensation for wetland impacts have been uncommon in SJC. This is partly because County government has lacked the capacity to manage and monitor a mitigation program. Record-keeping even of permitted wetland alterations and gains has been incomplete. It appears that permit applicants and the County have more often invoked “Reasonable Use” to allow wetlands or their buffers to be impacted, without consistently requiring mitigation.

Before any of the above compensatory actions are undertaken, consideration must be given to existing laws which require permit applicants to demonstrate that every effort has been made to **avoid** placing a proposed development in or near a wetland or its buffer. If property lines or other factors make avoidance of a wetland physically impossible (i.e., not solely a matter of convenience and cost), then laws require that every effort be made to **minimize** the potential effects of the development on the wetland and its functions. This can involve widening all or part of a buffer beyond normal requirements, decreasing the size and density of roads, subsurface drains and structures; and increasing the infiltration of water from developments located uphill (but depending on subsurface flow paths, this may rob wetlands of ecologically necessary water or increase their exposure to polluted runoff). Guidance on mitigation policies, how to select a good mitigation site, mitigation banking, and related topics can be found in several documents: Granger et al. 2005, Hruby et al. 2009, Hruby 2010.

Monitoring of the potentially affected wetland ensures that minimization is achieving its goal of reducing impacts to wetland functions. Monitoring of the compensatory wetland, if any, also ensures that restoration and enhancement actions in areas being used for mitigation are achieving the goal of increasing some wetland functions without significant detriment to others (enhancement) or increasing both functions and area (restoration). Ideally, an **adaptive management** approach is used, wherein monitoring data are collected regularly and used to identify when critical resources are being harmed by insufficiently strong regulations, weak enforcement, or poor placement and design of compensatory mitigation. Such documentation is then used to suggest changes in the content or implementation of regulations.

Monitoring data should ideally be collected both before and after a wetland alteration occurs. Preferably, monitoring should involve sampling water quality in the wetland during storm events, measuring pond levels and water table levels in and near the wetland at least once monthly. Also useful would be annual surveys of the percent cover of plants by species (especially invasive and rare species), and perhaps also monitoring changes in use by all species of amphibians, fish, aquatic invertebrates, and birds. Monitoring data should be interpreted relative to conditions in the year(s) prior to the permitted alteration. If such data cannot be collected, then interpretation should be relative to other local wetlands that have been sampled and are of similar size, elevation, soil type, and vegetation type. No numeric standards exist for wetland water quality, hydrology, or biological conditions, but avoidance of "impairment" of designated uses is required by State law. Significant differences from baseline (pre-development) or reference (other similar wetland) conditions are cause for concern because they suggest that minimization or compensation have failed.

Another way of categorizing wetland mitigation approaches is as permittee-responsible mitigation, credit purchases from a mitigation bank, or in-lieu fee payments. For many years **permittee-responsible mitigation** has been the most common approach throughout Washington and the United States. Permit applicants pay another landowner for the rights to establish, restore, or enhance a wetland on that owner's land, and then pay the costs to design and implement that effort. **Mitigation banking** is similar, except the second party is typically someone who has already established, restored, or enhanced one or more wetlands, or has farmed land with high potential for restoring wetlands. After having the land approved and registered with the State of Washington as a "wetland bank", the wetland banker may then sell "credits" to permit applicants so the applicants can meet obligations for mitigation at other locations. **In-lieu fee (ILF)** payments are where permit applicants are allowed to pay a fee to a fund held by a third party such as a government agency or conservation organization, provided all fees accumulated in such a manner are used within a specified time period to establish, restore, enhance, or preserve other wetlands. This approach has been widely criticized, partly because not all wetland applicants have the same financial resources to pay into the fund, and partly because some such funds in other regions have been mismanaged and fees not used for their legally intended purposes.

Both the County's UDC and the WDOE's guidance recommend the use of **mitigation ratios** whenever wetlands are altered. These ratios require that a greater acreage of wetlands be restored, enhanced, or established than was altered. The scientific justification for that is the fact that many peer-reviewed studies have shown that these mitigation actions have high rates of failure, so ratios greater than 1:1 are recommended to help cover the risk of failure. The purpose of the ratios is to ensure there is no net loss of critical areas, their functions or values.

Mitigation ratios depend on two factors: (1) the form of mitigation (restoration, enhancement, establishment, or preservation), and (2) the importance of the wetland as determined by its type, level of functions, sensitivity, and other factors. The lowest ratio is 1.5: 1 (meaning that for every acre of wetland that is altered, compensation is considered adequate if 1.5 acres of new wetland is established successfully) and the highest is 24:1 (if a mature forested wetland is being altered and the only mitigation option is to preserve an unregulated wetland elsewhere). New guidance on mitigation ratios will be provided by WDOE's new document (Hruby 2010): *Calculating Credits and Debits for Compensatory Mitigation in Western Washington*.

2.5 Data Gaps and the Need to Expand the Knowledge Base

A fundamental strategy for improving the protection of wetland functions over the longer term is to improve knowledge of local wetlands through well-designed studies that gather new data or analyze existing data in more focused ways. For example, sampling programs could be established countywide (not just at mitigation wetlands) to regularly monitor water quality, vegetation, and perhaps other sensitive resources in wetlands and streams. With appropriate sampling design and subsequent statistical analysis, this would help determine if wetland buffers are achieving their protective objectives overall. It also could provide a reference data set against which data from monitored wetlands with permitted developments can be compared, to evaluate whether the permitted developments are causing changes that are "within the range of natural variation" of the monitored variables and thus are benign, or outside that range and thus are probably harmful. Island County, for example, has monitored wetland water quality and vegetation countywide since 2006. As a result the County has established an excellent database that quantifies the natural and unnatural variation in the county's wetlands and streams, and can be used to evaluate when and where conditions fall outside of this range and therefore deserve of remedial action.

Studies could also be designed to periodically survey wetlands for sensitive species, improve wetland maps, and measure trends in wetland area through interpretation of regularly-obtained aerial imagery and analysis of permit databases. Although studies that would establish conclusively the causes of possible "harm" to wetland biological resources and functions are not legally required and would cost far more than the funds available to the County and State government, less ambitious but well-designed data collection efforts can contribute meaningfully to better management of the county's wetlands over the long term.

Taken as a whole, the buffer literature pertaining to wildlife has several major limitations:

1. Many studies recommend wetland buffer widths based on the total number of species found in buffers of increasing width, without differentiating between "wetland-dependent species only" and the "total of all species" which includes terrestrial species that almost never occur in wetlands. Without such differentiation, the conclusion is inevitable that wider buffers will have more species and more habitat structure, because they encompass a larger area and the number of species and habitat structural components is commonly known to increase with increasing area. However, there are few or no studies that convincingly demonstrate that the habitat structural complexity or the abundance or productivity of *wetland-dependent species* is greater in wetlands that are surrounded by buffers that are wider. Moreover, wetland-dependent species are the appropriate focus for sections of an ordinance that is intended to protect *wetlands*.

2. Most studies of buffers have been conducted in the eastern United States, on species assemblages vastly different from those in SJC wetlands. Just because large buffers of natural vegetation are important to salamanders, frogs, and/or birds in other regions does not mean they are important in SJC or even in Washington, where the assemblage of species within these groups is different. As noted by Zuckerberg & Porter (2010), "incorporating ecological thresholds in environmental planning should be species-specific." This seems particularly true when consideration is limited just to SJC species that are wetland-dependent.

3. Many buffer studies were conducted where buffers and surrounding lands were severely fragmented by urbanization and clearcutting, rather than by low-intensity land uses as is mostly the case in SJC. To maintain native wildlife populations, it is likely that buffers would need to be wider in heavily urbanized areas than in predominantly rural areas such as SJC, because in rural areas the surrounding upland "matrix" is generally more supportive (Rodewald & Bakermans 2006).

4. With regard to the size of buffers needed to reduce disturbance of wildlife by people, the type and frequency of disturbance is also important, but there are few if any published data on disturbance distances of SJC species. Some planners, perhaps not understanding the source of the data, have recommended wetland buffer widths based on studies of birds disturbed by motorboats, but this is inappropriate because most wetlands do not support motorboating or have analogous types of disturbances.

5. Many studies describe instances of wetland-dependent wildlife species using terrestrial areas hundreds or thousands of feet from the nearest wetlands. This does not automatically mean these species *require* contiguous wooded buffers of that extend out that far. In some cases these observations may be of infrequent random occurrences. Even when frequent, this does not necessarily mean that populations of the species would suffer significantly if those areas were unavailable. For example, it has not been demonstrated that populations of SJC amphibian species whose dispersal is limited somewhat by natural or artificial barriers (e.g., highways, tidal

waters) are less sustainable and unable to gradually adjust to such barriers. It also is unclear if the tendency of individual frogs and salamanders to disperse long distances overland might be rendered less essential if habitat closest to a wetland were maintained in optimal condition, e.g., extensive downed wood, animal burrows.

6. Even if individuals of some wetland-dependent species do require complementary areas located thousands of feet (Crawford & Semlitsch 2007, Rittenhouse & Semlitsch 2007, Semlitsch 2008) or even dozens of miles (Tittler et al. 2009) from their natal wetlands, this begs the question of whether a buffer comprising only a tiny fraction of that needed area can have enough effect to benefit the species measurably, and whether that small benefit, if it exists, should be considered substantial enough to offset possible economic losses from associated regulatory requirements.

7. Many or most published studies of amphibian relationships to surrounding land use have been of short duration, despite the large known interannual variation in amphibian populations. Many studies have occurred on landscapes that were disturbed previously by logging or agriculture, thus limiting effective comparisons between current and historical distributions of amphibians and immediate vs. prolonged impacts of those activities (Kroll 2009). Also, environmental regulations and their enforcement have changed over the last two decades in the Pacific Northwest .

8. An assumption is often made that buffers must be wooded, and this is valid for some species. However, buffers of natural vegetation need not be *wooded* in order to benefit many wildlife species that are wetland-dependent. Wooded buffers will actually discourage wetland use by some. In particular, populations of most of SJC's sensitive reptile species will suffer loss or degradation of the type of habitat they need if the extent of densely wooded areas is expanded, as from a large buffer requirement. Thus, a requirement that all buffers be wooded implicitly trades off one suite of species for another.

9. An assumption is often made that buffers must be free of invasive plants. While this helps maintain or restore the richness of the native flora of upland plants in the buffer, there are no studies demonstrating that upland buffers must be free of invasive plants in order to protect the flora and fauna of wetlands from harm. Most invasive upland plants do not thrive well in wetlands.

Taken as a whole, the literature on buffer effects on water quality also has significant limitations, as is noted in dozens of reviews on this topic (e.g., Castelle et al. 1992, Barling & Moore 1994, Desbonnet et al. 1994, Fennessy & Cronk 1997, Wenger 1999, McMillan 2000, Broadmeadow & Nisbet 2004, Melcher & Skagen 2005, Sheldon et al. 2005, Polyakov et al. 2005, Mayer et al. 2005, Dorioz et al. 2006, Reichenberger et al. 2007, Bentrup 2008). These include the following:

1. The number of studies published on the effects of buffers on water quality is so large and their test conditions are so vaguely documented, that it is not practical to attempt matching them, case by case, with conditions most similar to those found in SJC.

2. Few buffer studies have been conducted in the Pacific Northwest, and many did not examine a wide range of buffer widths under different runoff regimes, soil types, slope gradients, and vegetation types. No published studies have examined a full array of buffer widths under a wide variety of conditions of slope, soil type, vegetation type, contributing area size, and dosing rates. Computer models intended to do that have not been widely validated.

3. Conclusions about polluted runoff being reduced by buffers are severely limited unless the studies have monitored the buffer year-round and preferably for several years. The reason is that plants routinely take up nutrients and other pollutants early during the growing season but then release them back into the environment at the end of the growing season, thus potentially making the buffers a pollutant source rather than a filter at that time. Similarly, buffer vegetation can accumulate sediments for years, only to release much of it during major storms. For sediment and phosphorus, removal efficiency typically declines with increased loading and loading over long periods of time. True protection of water quality as a result of buffers occurs only when the buffers *remove* pollutants *permanently* from the flow path that connects polluting land uses with wetlands. This partially occurs with nitrogen (via denitrification, which converts soluble nitrate to a gas) and some pesticides, but less so with other pollutants.

4. As noted by Sheldon et al. (2005), much of the existing literature on buffer widths describes percent-reduction in pollutants resulting from buffers of various widths, but does not say whether the reduction was enough to bring the polluted runoff into compliance with government standards or to otherwise cause no harm to aquatic life. A 95% pollutant removal efficiency means nothing if the incoming runoff is severely polluted , and a 10% pollutant removal efficiency can be outstanding if the incoming runoff is polluted only minimally. In addition, a focus only on percent reduction associated with a buffer fails to recognize that the amount of pollutants delivered to the environment is a result of both the incoming quantity and the percent reduction, and that the reduction in pollutants can be accomplished through a variety of mechanisms either standing alone or in combination with a buffer.

5. Buffers can fail their intended purpose of keeping excessive nutrients and harmful bacteria out of wetlands if cattle and pets are still allowed free access to water within an unfenced buffer, or if ditches and subsurface drains from fields empty directly into wetlands. In lightly grazed areas buffers may, however, continue to be useful for retaining sediment and supporting wildlife habitat.

6. Many or most pertain to studies of buffers used to protect streams from urban development, intensive agriculture, or timber harvest activities. Few address directly the ability of buffers to process contaminated runoff from low-density residential development and the associated introduction of pollutants via ineffective septic systems and domestic animals. Even fewer focus specifically on wetlands. Placing buffers around wetlands is particularly important, because sediment and some chemicals are often more likely to concentrate in wetlands, as opposed to streams, due to their confined condition.

7. Most buffer studies have focused only on the ability of buffers to retain sediment and excessive nutrients. Relatively little is known about their ability to remove the dozens of other substances expected in septic effluent.

8. No water quality standards exist for dozens of contaminants that are known to adversely affect aquatic life, and hundreds more whose potential behavioral and physiological effects remain unstudied. Statistics on buffer effectiveness for retaining contaminants is of little relevance if nothing is known about what levels of those contaminants are harmful.

9. Several studies suggest that the effectiveness of buffers has less to do with their width and vegetation type than the type of underlying soils and geologic formations. However, width is the only characteristic that can be measured objectively and at reasonable cost, and so has commonly become the basis for regulations.

Despite the above data gaps and information needs, the County's efforts to protect its wetlands should not be put on hold until more information is available. State laws, the public trust, and popular concern for wetlands and the need to protect them from long-lasting harm dictate that both voluntary and regulatory efforts proceed with urgency using the best available science, whatever its current limitations.

2.6 Synopsis and Options

<u>Synopsis</u>

1. Buffers are not always the best way to protect the water quality of wetlands and other water bodies. Stopping stormwater and other pollution at its known or likely sources, especially before it reaches ditches and drainageways that connect to streams and wetlands, is often a better strategy.

2. The effectiveness of buffers is attributable less to their vegetation's active role in filtering and taking up pollutants, than to the simple fact that well-configured buffers can passively exclude development – with its concomitant removal of vegetation, increase in impervious surfaces, erosion and compaction of soils, installation of drains and ditches, and introduction of new pollutants -- from areas where development impacts, due to on-site hydrologic factors, are most likely to be magnified. Several studies suggest that the effectiveness of buffers for protecting downslope water quality has less to do with their width and vegetation type than with the type of underlying soils and geologic formations. However, buffer width is nearly the only characteristic relevant to predicting water quality that can be measured objectively and at reasonable cost, and so has commonly become the basis for regulations.

3. The necessary width or distance to remove or retain pollutants depends partly on the *intensity and extent of a proposed development activity or land use*. The most intensive activities or uses require higher percent-removal rates in order to maintain quality of receiving waters. There are limits -- both technical and financial -- as to what improved engineering for stormwater treatment can accomplish in SJC. Nonetheless, as detailed in Chapter 7, more could be done to improve the management and treatment of stormwater throughout the county in ways that will minimize changes to the water regimes of wetlands and streams and reduce the load of pollutants that reach wetlands. For stormwater treatment systems that are

designed to increase the infiltration of runoff after it is treated, an appropriate setback will still be needed to allow that infiltration to occur.

4. The buffer width or distance also depends on whether the soluble pollutants commonly transported to wetlands are transported mainly via *subsurface seepage* (e.g., high water table), *sheet flow* (diffuse surface runoff), or channelized *surface runoff* (ditches, gullies, subsurface pipes). The latter require larger buffers. A determination of which transport route prevails at a particular wetland location cannot legitimately be based only on county soil maps, topography, and one-time field observations; it requires an expensive geohydrological investigation at each location. Results would vary seasonally and sometimes even hourly as water tables rise after a storm and sheet flow channelizes for indeterminant periods. In lieu of requiring such investigations for each permit application, the County could adopt simpler criteria for assessing *transport and sensitivity* factors.

5. Under ideal conditions buffers of only a few feet width can remove most coarse sediment that is carried towards a wetland by diffuse sheet flow. However, for the removal or retention of some *soluble* substances that can harm aquatic life, much larger (wider) buffers are generally necessary.

6. Depending on the terrain and local surficial geological formations, infiltration of stormwater can sometimes be increased by implementing particular LID (Low Impact Development, see Chapter 7) measures, thus potentially converting surface flow to less hazardous subsurface seepage. However, there are no data quantifying the amount of buffer reduction that could be allowed if LID or other mitigative measures were implemented to varying degrees.

7. Many species of plants and animals benefit from wetlands, while a fewer number *require* wetlands or similar surface waters. Water quality buffers designed according to the above factors are likely to offer the most protection to water-dependent plants and animals from impacts of stormwater. However, buffers are intended to protect wetland plants and animals from other impacts of development besides those just described for stormwater. Specifically, maintaining the natural *microclimate* (temperature and moisture regimes in the air and soil) in both the wetland and its surroundings is essential, especially to some of SJC's aquatic species that characteristically must also survive in uplands during a prolonged part of their life cycle. An example is the Northern Red-legged Frog.

8. Although buffers provide important wildlife habitat, buffers alone cannot meet all habitat needs of local wildlife. Science has demonstrated that protecting and enhancing habitat quality across entire landscapes (including agricultural and residential lands) is a sounder strategy than expecting riparian buffers to meet all habitat needs. In particular, for the survival of individuals of some SJC amphibians that have both an aquatic and a terrestrial phase, it is likely some or most individuals would require much larger areas than can be achieved by wetland buffers alone. However, there is no credible data that would specify exactly how much terrestrial habitat area would be needed. Also, most studies have found that making large buffers even larger does not increase their likelihood of hosting the same bird species found in unfragmented forests (Marczak et al. 2010).

9. In forested wetlands, amphibian populations and the diversity of native wetland plants are likely to be impacted adversely if vegetation in wooded uplands contiguous to the forested wetland is removed such that a gap of wider than about 100 feet is created between the wetland and the upland forest, or if the upland forest becomes a fragment that is narrower than 150 feet and surrounded on all sides by open land or water. Under those conditions, many forest bird species will be adversely impacted and forest microclimate conditions essential to several amphibians will be compromised.

10. Where lands surrounding a wetland are wooded, maintaining those wooded conditions implicitly trades off the survival of some wetland-dependent species that prefer grasslands (e.g., most nesting waterfowl) for others that may prefer wooded areas (e.g., Red-legged Frog). Moreover, provided that a buffer is densely vegetated, whether it is forested or not has little effect on its surface roughness, resistance to erosion, and perhaps its capacity to retain or remove most pollutants. Nonetheless, existing regulations and guidance specify the continued maintenance of whatever natural cover types currently exist around a wetland. This can constrain the diversity of habitat at a landscape scale.

11. Many waterbird and raptor species are susceptible to being disturbed simply by the *presence of people* on foot and their unrestrained pets. Although some individuals of these wildlife species can habituate to mild or infrequent disturbance, frequent or severe disturbance will impose an energy and survival cost on many other individuals, as they must repeatedly change locations. Wetland buffers can reduce this disturbance, both by reducing physical access to wetlands by people and pets, and by providing a visual screen. For most waterbirds and raptors, this function could be served by a 25-ft wide buffer that completely encircles a wetland, if the buffer is vegetated so densely that it is almost impenetrable, and it extends to a height of at least 10 feet. Much wider buffers are necessary for Bald Eagle and Peregrine Falcon (see section 4.3.1.2).

<u>Options</u>

Based on the Best Available Science, the County could implement the following:

1. Adopt the countywide map titled "Possible Wetlands" (that was developed as part of this project using LiDAR and new aerial imagery) as an operational replacement for the wetlands map the County currently uses.

2. Adopt a standardized, variable width buffer determination procedure as one tool to help protect wetlands and their functions.

3. Adopt an alternative approach to buffers that involves *adaptive management* consistent with WAC 365-195-920, wherein larger buffers would be required only where monitoring indicated ground or surface water quality conditions are not in compliance with standards. There are several problems with such an approach. First, by the time a violation of standards is discovered, aquatic life may already have harmed, perhaps irreversibly, and a new development that caused the problem cannot realistically be removed to make way for a buffer that is being widened in response. Time lags of many years are common between when a development

occurs and when resulting pollution plumes reach groundwater and are discovered (Meals et al. 2010). Second, unless monitoring occurred in every stream and wetland and analyzed every potential pollutant at every season and storm event, there would be no assurance that aquatic life was not being harmed. Third, for the reasons detailed in section 4.2.2.1 of Chapter 4, even if no violations of water quality standards were found, this would not necessarily mean aquatic life was unharmed by development. Finally, protecting water quality is not the only reason buffers are necessary; they are also essential for maintaining habitat of many fish and wildlife species. Annual monitoring of the populations of all those species, as would be necessary under an adaptive management approach to ensure no harm, would be an extremely costly endeavor, and it might be impossible to attribute population declines to development in a specific area, as opposed to pollution carried from afar, or climate change, predators, or other factors.

2.7 Literature Cited

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CHAPTER 2 APPENDICES

Appendix 2A. Procedures Used to Prepare This BAS Chapter

Appendix 2A-1. Procedures used to improve previous map of SJC wetlands

Sources
The San Juan County portions of the following layers were loaded into the County's GIS:
-- **June 2008 color orthophotos**
-- **SJC Wetlands**: This layer was derived originally from NWI but was modified by Sheldon Associates in 1991, based mainly on interpretation of aerial imagery available then. Sheldon Associates reported that they had field-verified about 42% of the 1204 wetlands they identified from aerial imagery.
-- **Flat Land** (where "aspect" as had been determined to be 0 by LiDAR imagery).
-- **Minimal Slope** (Percent Slope >0.01 and <3.00% (as determined by LiDAR)
-- **Dominantly Hydric Soil** (these soil series: Coveland loam 0-5 percent slopes, Coupeville loam 0-5 percent slopes, Limepoint-Sholander complex 0-8 percent slopes, Shalcar muck 0-2 percent slopes, Semiahmoo muck 0-2 percent slopes, Coveland-Mitchellbay complex 2-15 percent slopes, Bazal-Mitchellbay complex 0-5 percent slopes, Orcas peat 0-2 percent slopes, Dugualla muck 0-2 percent slopes)
-- **Partially-hydric Soil** (these soil series: Sholander-Spieden complex 0-5 percent slopes, Deadmanbay-Morancreek complex 2-15 percent slopes, Beaches-Endoaquents, Deadmanbay-Bazal-Cady complex 2-20 percent slopes, Mitchellbay gravelly sandy loam 0-5 percent slopes, Mitchellbay-Sholander-Bazal complex 0-5 percent slopes, Limepoint-Alderwood warm-Sholander complex 2-12 percent slopes, Xerorthents-Endoaquents, Sucia-Sholander complex 5-20 percent slopes, Mitchellbay-Rock outcrop-Killebrew complex 3-13 percent slopes)
-- **Lakes** (interpreted by SJC from June 2008 orthophotos, includes small artificial ponds)
-- **Streams** (from WDNR, including water type classification for fish support as modified by SJ Wild Fish Conservancy during 203-2008)
-- **Predicted streams:** From LiDAR topographic data and using Stahler stream order process. The County had assumed uniformly for the whole county that 100 potentially-contributing contiguous raster cells would be needed to accumulate enough runoff and groundwater to trigger at least one surface flow event per year at that point in the channel; greater or lesser accumulation areas might be needed at specific locations depending on local climate, gradient, and geology.

Methods
While viewing the aerial image at a scale of 1:5000, every part of the County was searched systematically and possible wetlands were delineated as follows, listed in decreasing order of certainty and frequency with which that criterion was applied:
-- all Lakes
-- Dominantly Hydric Soil with
    -- Flat Land with SJC wetlands
    -- Flat Land
    -- SJC wetlands (especially those previously field-verified)
-- Partially-hydric Soil with
    -- Flat Land with SJC wetlands
    -- Flat Land
    -- SJC wetlands (especially those previously field-verified)
-- Non-hydric Soil with
    -- Flat Land with SJC wetlands
    -- Flat Land
    -- SJC wetlands (especially those previously field-verified)
-- Streams or Predicted Streams with Minimal Slope

-- on Dominantly Hydric Soil

- The view of the aerial image was magnified on the monitor to 1:1000 or finer scale when identification of a suspected wetland area was particularly ambiguous.
- Areas confirmed as wetlands during field inspections by consultants as part of permit applications to San Juan County were also hand-digitized and added.
- Polygons identified as possible wetlands and located within 100 ft of each other were aggregated. The smallest delineated polygon that was retained was 1000 sq ft.
- A separate layer containing only tidal marshes was created. It consisted of all NWI wetlands coded as Estuarine Emergent.

Results, Comments, and Limitations

- For all of San Juan County, the Possible Wetlands layer identifies 2637 polygons comprising 6580 acres (all but about 34 of the polygons are non-tidal). The County's previous Wetlands layer identified 1204 polygons comprising approximately 4325 acres. The difference is the result of the use of finer-resolution aerial imagery, finer-resolution topographic data (LiDAR), and integration of the two using GIS.
- For just the portion of SJC that is subject to CAO regulations, the new layer identifies 2460 polygons comprising 5395 acres.
- A very small portion of the polygons delineated in the new layer as possible wetlands may contain no wetland that meets jurisdictional criteria. The subsequent field work determined this to be approximately 4%.
- An unknown number of wetlands was not detected. Determining this number was not within the scope of the planned field work.
- Of the 2637 polygons in the new Possible Wetlands layer, all or part of 36% were previously identified as wetlands in the SJC Wetlands layer.
- Although the new Possible Wetlands layer considers lakes to consist entirely of wetlands, the deeper portions of lakes (deeper than 6 ft) would not generally be considered to be wetlands by legal criteria. Field checking or bathymetric data would be necessary to determine just the wetland parts.
- Many small artificial ponds not previously shown in the Lakes layer were identified and added to the Possible Wetlands layer.
- A very few of the small flat areas identified as possible wetlands may have actually been gardens, parking areas, beaches, building roofs, or similar. All obvious incidences of these were eliminated.
- Many of the Flat Land polygons were not delineated as possible wetlands, especially wher located on non-hydric soil.
- Dense tree canopy and shadows prevented positive determination (as wetlands) of many flat areas and depressions noticed in forested areas, even when the image was zoomed as large as possible without distortion.
- Within cultivated or pasture wetlands, it was difficult to distinguish wetland from non-wetland portions.
- The query criteria that were used tended to disfavor the identification of wetlands occurring on slopes greater than 3%. However, many wetlands are known to occur in such settings, and some that met that condition were retained if they reportedly were verified by field inspections during creation of the SJC Wetlands layer in 1991.

Appendix 2A-2. Standardized Protocol for On-site Assessments of SJC Wetlands

I. Site Selection

Candidate sites for wetland assessment were selected by Dr. Donald Stevens (Statistics Department, Oregon State University) using his well-known protocol (GRTS[16]) for drawing spatially-balanced random samples of any mapped resource (Stevens & Olson 1999, 2003, 2004; Stevens & Jensen 2007). Use of GRTS minimizes problems associated with spatial autocorrelation, which otherwise limits making valid statistical inferences from site-level data to an entire County. Using the GRTS software, he drew a sample of 500 candidate sites from the new (2010) spatial data layer of possible wetlands created by Dr. Adamus (described in Appendix 2A-1). To minimize assumptions, the population of wetlands was not pre-stratified by any environmental theme prior to beginning the selection. However, GRTS selected the 500 candidate sites in proportion to the total number of mapped wetlands on each island. The version of the map of possible wetlands from which the sample was drawn excluded wetlands in protected areas (e.g., public lands, conservation easements). The GRTS algorithm ranked the 500 sites in a manner that facilitates spatial dispersion.

The San Juan County CD&P then identified landowners of the candidate sites and contacted them by letter and then by phone. Field personnel visited wetlands, to which access permission had been granted, in the order in which GRTS had ranked those sites, thus supporting spatial dispersion among the sites to which access had been granted.

II. Field Protocol

A. In Advance of Site Visit:

1. From the list provided by the statistician, determine which wetland should be visited next.

2. Make sure the landowner has granted permission for a visit, and check to see if he/she indicated they need to accompany you. If so, contact the landowner and schedule a time.

3. Use the office GIS to create and print a zoomed orthophoto of each site you plan to visit in the coming week, and showing the wetland (boundary line only, not solid fill), parcel lines, Strahler streams, roads, buffer rings, and sample point. Then before going into the field each day, take the images for the sites being visited, as well as their GPS coordinates, landowner contact info, and other items on the Checklist. Be sure all electronics are fully charged.

B. On Site:

4. Talk briefly with landowner if present.

5. Navigate to the designated GPS point if accessible and continue to #6.

If point is not physically accessible (is inundated too deeply, blocked by impenetrable thicket, other hazards), or has coordinates that place it outside the property or wetland polygon, relocate the point to the nearest accessible location within the same mapped wetland polygon and property. Proceed to #6.

6. At the designated point, and in a spot where digging is physically possible:

    6.1. Examine the soil in the upper 12 inches and evaluate wetland indicators. If any are present AND wetland indicator plants are prevalent, proceed to #6.2. If not, move to the nearest depression, ravine, or other low spot. Repeat. If conditions not met after trying 3 spots, STOP. Abandon this site and proceed to the next site on the list. Otherwise continue with 6.2.

[16] General Randomized Tessellation Stratified sampling

6.2 Record the soil characteristics (texture, mottles, chroma, saturation, etc.) on Form W.

6.3 If soil is sphagnum peat, measure depth (from surface down to 16 inches).

6.4 From the point, stretch the measuring rope 5 meters due north. If trees, unvegetated water, logs, pavement, or other obstructions are encountered, you may adjust the orientation.

6.5 From the tip of the rope, measure back one meter. In a 1x1m quadrat (on right side of rope looking outwards from point), estimate absolute percent cover of each plant species shorter than 1 m, in 5% intervals (but if <5%, record it as 1%). Record this in your field notebook using the standard species codes. Bag and label any plants you can't immediately identify to species. Also photograph them if you can get a photo that has diagnostic potential.

6.6 Repeat for plants in 1x1 m quadrats located due south, east, and west.

6.7 For the 10 x 10m plot, identify all plants 1-20 ft tall (shrubs) and record percent canopy closure by species in field notebook. Repeat for plants over 20 ft tall (trees).

6.8 Finally, search the 10 x 10m plot for any species not seen in the 4 quadrats and record in field notebook IF they seem to occupy more than 1 square meter (cumulatively), are invasive, or are considered exceptionally rare (see reference lists). Simply list them (no cover estimate needed).

7. Staying within the property, walk around and view as much of the wetland as possible. If the wetland is so large you can't walk it in less than 1 hour, at least try to visit all parts that appear to have different vegetation cover types, as depicted in the orthophoto.

7.1 Take photos at good viewing points.

7.2 Look for the transition boundary between wetland and upland, as indicated by a shift from dominance of wetland indicator plants to upland species. Then on the orthophoto, redraw the approximate wetland boundary if warranted.

7.3 Search for invasive species, and list any that you find (no percent cover estimates needed).

7.4 Search for all plants comprising >10% of the herbaceous part of the wetland, or which cover >10% of the herbaceous part of the wetland *on the property*, and which you didn't find in the veg plot.

7.5 Record % of the wetland you could view (% just on this property, % of entire wetland).

7.6 Fill out the rest of Form W (except the columns pertaining to Adjacent Upland).

7.7 Fill out the data form for the WDOE Rating Method:

7.7.1 First, decide if this wetland should be split into 2 or more units and the Rating Method applied separately to each. That will be the case if part of the wetland is separated from the rest by an unculverted driveway or road, or if a mound of upland isolates some parts of the wetland from the rest.

7.7.2 Apply the Rating Method (Depressional Wetland section) to the entire wetland polygon, not just the portion that is in the parcel you are visiting. If you cannot access other parcels that comprise the entire wetland, try viewing from the road or making assumptions from the aerial image or from other apparently similar wetlands. You must make an educated guess for ALL items on the WDOE Rating forms.

7.7.3 If this is a Lake-fringe wetland, Slope wetland, or is on a perennial stream (Riverine), you must use the WDOE data forms for those wetland types, which can be printed from the appendix in the WDOE Manual.

7.8 Attempt to access all areas shown as streams on the orthophoto, that flow into the wetland *at least once annually*. Some professional judgment will be required. Number these on the orthophoto, and fill out one column in Form S for each inflow or outflow stream. If some are on parcels for which access has not been given, inspect them from the nearest road if possible.

7.9 On the orthophoto, cross out any mapped streams or ditches that seemingly have not flowed for more than a year.

7.10 Search for gullies, ravines, and similar areas that might contain ephemeral surface flow into the wetland but were not mapped as streams on the orthophoto. If any contain evidence of having flowed in the past year and extend for at least 50 ft uphill from the wetland (or the place marked tentatively as a wetland), draw their entry or exit points on the orthophoto, and number them. Then add those to Form S, and fill out one column for each inflow or outflow stream.

8. Walk along what appears to be the wetland-upland boundary (based on indicator plant species) and walk through or look into the non-wetland (upland) areas within approximately 100 ft of the wetland, excluding those downslope, but don't spend more than 30 minutes doing this. Estimate the % of this zone that you were able to inspect. Fill out the rest of Form W (the columns pertaining to the Adjacent Upland).

9. Check all data forms for completeness.

10. Proceed to next closest wetland on list with approved access.

11. If not enough wetland-containing properties with pre-approved access are available for visit on this particular day on this island (a problem we hope to avoid!), you should assess any wetlands shown on the map regardless of their inclusion or rank on the statistically-based list, if you can knock on doors to get permission, or view enough of their area from a road to do at least a partial assessment.

<u>C. In the Office</u>:

The next time you can get to the County offices (about 1 time per week):

12.1 Download photos from your camera, and the coordinate data from your GPS. Label their folders and file names distinctly.

12.2 Press unknown plants between newspapers and label them by date and location (actually, do this at home each day and leave the collection in office when you go in).

12.3 Access the GIS, overlay the orthophoto and wetlands layers, locate the sites you visited, and digitally redraw (if warranted) the wetland-upland boundary of wetlands you visited, using your recollections and your marked-up orthophoto. Also, if you needed to split the wetland into multiple sites (due to hydrologic interruption etc.) and did separate assessments on each of those sites, redraw and relabel the original wetland polygon accordingly in the GIS.

12.4 Viewing the orthophoto, refine if warranted your answers to some of the data form items (e.g., number of wetlands within 0.5 mile as requested by WDOE Rating form).

12.5 Place all your data forms in a file cabinet, for safekeeping and later data entry. Also store a photocopy of the latest entries you made in your field notebook.

12.6 Enter your data on the computer, using the standard data template, on days when weather or other factors are least favorable for site visits.

12.7 Print enlarged color copies of the images of the wetlands you are scheduled to visit in the coming week (#3 above).

12.8 Press any remaining unknown plant specimens and mail to Dr. Adamus for identification or store them until his next visit. (Voucher collection stored at SJCD&P office).

D. Field Data Forms

FORM W. WETLAND #_______________		**Wetland in parcel**	**Up 100 ft in parcel**	**Wetland (entire)**	**Up 100 ft (entire)**
Percent Viewable=					
Veg Plot Dimensions (100 sq. m total):					
Soil Pit:	saturated? (no/ some/ much)				
	mottle/ rusty roots/ gley? (no/ some/ much)				
	texture (**L**oam, cl**A**y, **O**rganic, **C**oarse) [write Clay or Organic if anywhere in pit, otherwise record upper layer texture]				
	Munsell (of darkest soil in pit):				
	depth of peat (if any)				
Veg Plot Cover (10 x 10 m)	% water (today)				
	% bare / rock				
	% moss ("S" if any Sphagnum)				
	% graminoids (sedge, grass, rush, cattail, etc.)				
	% forbs (ferns, flowering plants, iris, duckweed, etc.)				
	% woody canopy (aerial view, tree + shrub)				
Overall	% water (today)				
	% bare / rock/ road				
	% moss ("S" if any Sphagnum)				
	% graminoids (including pasture, hayfield)				
	% herbs (graminoids + forbs)				
	% woody canopy cover (aerial view)				
	% cultivated (tilled <1 yr ago) or garden				
	graminoid invasives as % of graminoid cover				
	forb invasives as % of forb cover				
	herb invasives as % of all herbaceous cover				
	shrub invasives as % of shrub cover (3-20 ft)				
Alder in wetland	as % of shrub canopy cover				
Wetland trees >21” : any?	Only if alder, willow, cedar, cottonwood, Sitka spruce, aspen, or hawthorn				
Wetland trees >15” : any?					
Wetland trees >21” : >8/acre?					
Wetland trees >15” : >8/acre?					
Water Persistence in Wetland	% with >4" water for >9 months/yr				
	% with >4" water for >2 months/yr				
	% with >4" water for >2 wks/yr				
	% never inundated (but wetland plants dominate)				
Water Distribution (during May-June)	% of ponded water that is under veg (vs. in open)				

		Wetland in parcel	Up 100 ft in parcel	Wetland (entire)	Up 100 ft (entire)
# of Dwellings within 100 ft of wetland (uphill sides only)	inhabitated almost daily most of year				
	seasonal only (usually)				
	occasional use (e.g., 1x/wk)				
Stressor Distance to Wetland (in ft, **N** if none within 300 ft)	Min. distance down from septic (ft)				
	Min. distance down from open canopy (ft)				
	Min. distance down from crops/ lawn/ garden				
	Min. distance down from bare/ paved (ft)				
	Min. distance down from flow restriction (ft)				
Potential Stessors (indicate **N**o/ **S**ome/ **M**uch)	Old Excavated/ Regraded				
	New Excavated/ Regraded				
	Old Dammed/Diked				
	New Dammed/Diked				
	Old Ditched or Tile				
	New Ditched or Tile				
	New Fill				
	New Timber Cut/ Shrub Clear				
	New Mowed/ Hayed (<1 yr ago)				
	New Plowed (<1 yr ago), Garden, or Compost				
	Vehicle tracks (in mud or vegetation)				
	Burned				
	Pasture				
	other:				
Wildlife	Fish (No/ Possible/ Yes)				
	Bullfrog				
	other frog or salamander				
	Turtle				
	Toad				
	Ducks				
	Heron				
	Eagle				
Was boundary redigitized?	(extended or contracted) (Y/N)				
Was wetland polygon split?	(created a polgon with a different ID number)				

FORM S. Assessment of Inflowing Streams							
		Stream or Ditch #					
ID# of Associated Wetland:							
Previously mapped stream?							
Ravine (15 ft deep) within 100 ft upstream?	yes/ no						
Any surface water today?	**N**o/ **S**ome/ **M**uch						
Flowing in today?	**N**o/ **S**ome/ **M**uch						
Water marks, stains, scour? (<25 ft upstream)	**N**o/ **S**ome/ **M**uch						
Entrained leaves? (<25 ft upstream)	**N**o/ **S**ome/ **M**uch						
New sediment deposit? (<25 ft upstream)	**N**o/ **S**ome/ **M**uch						
Iron stain/ precipitant? (<25 ft upstream)	**N**o/ **S**ome/ **M**uch						
Any **wetland** plants in channel? (<25 ft up)	**N**o/ **S**ome/ **M**uch						
More than 1000 sq.ft. of wetland plants up?	yes/ no						
More than 5000 sq.ft. of wetland plants up?	yes/ no						
Plant **density** in input stream	**N**ormal/ **T**hin/ **S**parse						
Condition of channel:	% altered: **N**o/ **S**ome/ **M**uch						
Min. distance down from septic	in ft, **N** if none within 300 ft						
Min. distance down from open canopy	in ft, **N** if none within 300 ft						
Min. distance down from crops/ lawn/ garden	in ft, **N** if none within 300 ft						
Min. distance down from bare/ paved	in ft, **N** if none within 300 ft						
Min. distance down from dam/ culvert	in ft, **N** if none within 300 ft						

Appendix 2B. Lists of Wetland Species

Appendix 2B-1. Wetland plants of San Juan County

sources: *Floristic Atlas of the San Juan Islands* (online), *USDA Plants* (online).
Wetland Indicator Status (WIS) from US Fish & Wildlife Service (1988, 1993) official lists. The indicator status of all species is currently under regional review by federal agencies and plant ecologists. An update of the official list resulting from this review is anticipated in 2011 or 2012, and should supercede the designations below.
FAC= About equally likely to occur in wetlands (estimated probability 34% - 66%) or non-wetlands, but a predominance of species with this attribute indicates a jurisdictional wetland.
FACW= Usually occurs in wetlands (estimated probability 67% - 99%), but occasionally found in non-wetlands.
OBL= Almost always occurs (estimated probability > 99%) in wetlands under natural conditions.
Many species that are not listed below occur frequently in wetlands.

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Acer glabrum	FAC	shrub	Aceraceae	Rocky Mountain maple
Adiantum aleuticum	FAC	fern	Pteridaceae	Aleutian maidenhair
Agrostis capillaris	FAC	graminoid	Poaceae	colonial bentgrass
Agrostis exarata	FACW	graminoid	Poaceae	spike bentgrass
Agrostis microphylla	FACW	graminoid	Poaceae	small-leaf bentgrass
Agrostis scabra	FAC	graminoid	Poaceae	rough bentgrass
Agrostis stolonifera	FAC	graminoid	Poaceae	creeping bentgrass
Alisma plantago-aquatica	OBL	forb	Alismataceae	European water plantain
Alnus rubra	FAC	tree	Betulaceae	red alder
Alnus sinuata	FACW	shrub	Betulaceae	Sitka alder
Alnus viridis	FACW	shrub	Betulaceae	green alder
Alopecurus aequalis	OBL	graminoid	Poaceae	shortawn foxtail
Alopecurus carolinianus	FAC	graminoid	Poaceae	Carolina foxtail
Alopecurus geniculatus	OBL	graminoid	Poaceae	water foxtail
Alopecurus pratensis	FACW	graminoid	Poaceae	meadow foxtail
Amaranthus blitoides	FACW	forb	Amaranthaceae	mat amaranth
Anagallis arvensis	FAC	forb	Primulaceae	scarlet pimpernel
Angelica lucida	FAC	forb	Apiaceae	seacoast angelica
Aquilegia formosa	FAC	forb	Ranunculaceae	western columbine
Argentina egedii	OBL	forb	Rosaceae	Pacific silverweed
Armeria maritima	FAC	forb	Plumbaginaceae	thrift seapink
Athyrium filix-femina	FAC	fern	Dryopteridaceae	common ladyfern
Atriplex patula	FACW	forb	Chenopodiaceae	spear saltbush
Barbarea orthoceras	FACW	forb	Brassicaceae	American yellowrocket
Barbarea vulgaris	FAC	forb	Brassicaceae	garden yellowrocket
Betula pendula	FACW	shrub	Betulaceae	European white birch
Botrychium multifidum	FAC	forb	Ophioglossaceae	rattlesnake fern
Brasenia schreberi	OBL	forb	Nymphaeaceae	watershield
Callitriche heterophylla	OBL	forb	Callitrichaceae	twoheaded water-starwort
Callitriche palustris	OBL	forb	Callitrichaceae	vernal water-starwort
Calypso bulbosa	FAC	forb	Orchidaceae	fairy slipper
Camassia leichtlinii	FACW	forb	Liliaceae	large camas
Camassia quamash	FACW	forb	Liliaceae	small camas

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Cardamine occidentalis	FACW	forb	Brassicaceae	big western bittercress
Cardamine oligosperma	FAC	forb	Brassicaceae	little western bittercress
Cardamine pensylvanica	FACW	forb	Brassicaceae	Pennsylvania bittercress
Carex aperta	FACW	graminoid	Cyperaceae	Columbian sedge
Carex aquatilis	OBL	graminoid	Cyperaceae	water sedge
Carex arcta	OBL	graminoid	Cyperaceae	northern cluster sedge
Carex athrostachya	FACW	graminoid	Cyperaceae	slenderbeak sedge
Carex aurea	FACW	graminoid	Cyperaceae	golden sedge
Carex cusickii	OBL	graminoid	Cyperaceae	Cusick's sedge
Carex densa	OBL	graminoid	Cyperaceae	dense sedge
Carex exsiccata	OBL	graminoid	Cyperaceae	western inflated sedge
Carex harfordii	OBL	graminoid	Cyperaceae	Harford's sedge
Carex hendersonii	FAC	graminoid	Cyperaceae	Henderson's sedge
Carex hoodii	FAC	graminoid	Cyperaceae	Hood's sedge
Carex interior	FACW	graminoid	Cyperaceae	inland sedge
Carex lasiocarpa	OBL	graminoid	Cyperaceae	woollyfruit sedge
Carex lenticularis	FACW	graminoid	Cyperaceae	lakeshore sedge
Carex leptalea	OBL	graminoid	Cyperaceae	bristlystalked sedge
Carex leptopoda	FAC	graminoid	Cyperaceae	taperfruit shortscale sedge
Carex lyngbyei	OBL	graminoid	Cyperaceae	Lyngbye's sedge
Carex macrocephala	FAC	graminoid	Cyperaceae	largehead sedge
Carex obnupta	OBL	graminoid	Cyperaceae	slough sedge
Carex ovalis	FACW	graminoid	Cyperaceae	eggbract sedge
Carex pachystachya	FAC	graminoid	Cyperaceae	chamisso sedge
Carex pansa	FAC	graminoid	Cyperaceae	sanddune sedge
Carex pauciflora	OBL	graminoid	Cyperaceae	fewflower sedge
Carex praticola	FACW	graminoid	Cyperaceae	meadow sedge
Carex rostrata	OBL	graminoid	Cyperaceae	beaked sedge
Carex stipata	OBL	graminoid	Cyperaceae	awlfruit sedge
Carex subbracteata	FACW	graminoid	Cyperaceae	smallbract sedge
Carex utriculata	OBL	graminoid	Cyperaceae	Northwest Territory sedge
Carex viridula	FACW	graminoid	Cyperaceae	little green sedge
Castilleja ambigua	FACW	forb	Scrophulariaceae	johnny-nip
Centaurium erythraea	FAC	forb	Gentianaceae	European centaury
Centaurium muhlenbergii	FACW	forb	Gentianaceae	Muhlenberg's centaury
Ceratophyllum demersum	OBL	forb	Ceratophyllaceae	coon's tail
Chenopodium album	FAC	forb	Chenopodiaceae	lambsquarters
Chenopodium rubrum	FACW	forb	Chenopodiaceae	red goosefoot
Cicuta douglasii	OBL	forb	Umbelliferae	western water hemlock
Circaea alpina	FAC	forb	Onagraceae	small enchanter's nightshade
Claytonia perfoliata	FAC	forb	Portulacaceae	miner's lettuce
Claytonia sibirica	FAC	forb	Portulacaceae	Siberian springbeauty
Comarum palustre	OBL	forb	Rosaceae	purple marshlocks
Conioselinum chinense	FACW	forb	Apiaceae	Pacific hemlockparsley

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Conioselinum gmelinii	FAC	forb	Apiaceae	Pacific hemlockparsley
Conium maculatum	FAC	forb	Apiaceae	poison hemlock
Cornus unalaschkensis	FAC	shrub	Cornaceae	western cordilleran bunchberry
Cotula coronopifolia	FACW	forb	Asteraceae	common brassbuttons
Crataegus douglasii	FAC	shrub	Rosaceae	black hawthorn
Deschampsia cespitosa	FACW	graminoid	Poaceae	tufted hairgrass
Deschampsia danthonioides	FACW	graminoid	Poaceae	annual hairgrass
Deschampsia elongata	FACW	graminoid	Poaceae	slender hairgrass
Distichlis spicata	FACW	graminoid	Poaceae	saltgrass
Dodecatheon pulchellum	FACW	forb	Primulaceae	darkthroat shootingstar
Drosera rotundifolia	OBL	forb	Droseraceae	roundleaf sundew
Dulichium arundinaceum	OBL	graminoid	Cyperaceae	threeway sedge
Egeria densa	OBL	forb	Hydrocharitaceae	Brazilian waterweed
Eleocharis acicularis	OBL	graminoid	Cyperaceae	needle spikerush
Eleocharis macrostachya	OBL	graminoid	Cyperaceae	pale spikerush
Eleocharis palustris	OBL	graminoid	Cyperaceae	common spikerush
Elodea canadensis	OBL	forb	Hydrocharitaceae	Canadian waterweed
Elymus repens	FAC	graminoid	Poaceae	quackgrass
Elymus trachycaulus	FAC	graminoid	Poaceae	slender wheatgrass
Epilobium ciliatum	FACW	forb	Onagraceae	fringed willowherb
Epilobium densiflorum	FACW	forb	Onagraceae	denseflower willowherb
Epilobium hirsutum	FACW	forb	Onagraceae	codlins and cream
Epilobium palustre	OBL	forb	Onagraceae	marsh willowherb
Epilobium torreyi	FACW	forb	Onagraceae	Torrey's willowherb
Equisetum arvense	FAC	horsetail	Equisetaceae	field horsetail
Equisetum fluviatile	OBL	horsetail	Equisetaceae	water horsetail
Equisetum hyemale	FACW	horsetail	Equisetaceae	scouringrush horsetail
Equisetum telmateia	FACW	horsetail	Equisetaceae	giant horsetail
Eriophorum chamissonis	OBL	graminoid	Cyperaceae	Chamisso's cottongrass
Eriophorum gracile	OBL	graminoid	Cyperaceae	slender cottongrass
Festuca arundinacea	FAC	graminoid	Poaceae	tall fescue
Festuca rubra	FAC	graminoid	Poaceae	red fescue
Galium trifidum	FACW	forb	Rubiaceae	threepetal bedstraw
Geum macrophyllum	FACW	forb	Rosaceae	largeleaf avens
Glaux maritima	FACW	forb	Primulaceae	sea milkwort
Glyceria borealis	OBL	graminoid	Poaceae	small floating mannagrass
Glyceria occidentalis	OBL	graminoid	Poaceae	western mannagrass
Gnaphalium palustre	FAC	forb	Asteraceae	western marsh cudweed
Gnaphalium uliginosum	FAC	forb	Asteraceae	marsh cudweed
Grindelia integrifolia	FACW	forb	Asteraceae	Puget Sound gumweed
Heracleum maximum	FAC	forb	Apiaceae	common cowparsnip
Hippuris montana	OBL	forb	Hippuridaceae	mountain mare's-tail
Hippuris vulgaris	OBL	forb	Hippuridaceae	common mare's-tail
Holcus lanatus	FAC	graminoid	Poaceae	common velvetgrass
Hordeum	FACW	graminoid	Poaceae	meadow barley

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
brachyantherum				
Hordeum depressum	FACW	graminoid	Poaceae	dwarf barley
Hordeum jubatum	FAC	graminoid	Poaceae	foxtail barley
Hypericum anagalloides	OBL	forb	Hypericaceae	tinker's penny
Hypericum scouleri	FAC	forb	Hypericaceae	Scouler's St. Johnswort
Iris pseudacorus	OBL	forb	Iridaceae	paleyellow iris
Isoetes nuttallii	OBL	forb	Isoetaceae	Nuttall's quillwort
Jaumea carnosa	OBL	forb	Asteraceae	marsh jaumea
Juncus acuminatus	OBL	graminoid	Juncaceae	tapertip rush
Juncus arcticus	FACW	graminoid	Juncaceae	arctic rush
Juncus articulatus	OBL	graminoid	Juncaceae	jointleaf rush
Juncus bolanderi	OBL	graminoid	Juncaceae	Bolander's rush
Juncus breweri	FACW	graminoid	Juncaceae	Brewer's sedge
Juncus bufonius	FACW	graminoid	Juncaceae	toad rush
Juncus effusus	FACW	graminoid	Juncaceae	common rush
Juncus ensifolius	FACW	graminoid	Juncaceae	swordleaf rush
Juncus gerardii	FACW	graminoid	Juncaceae	saltmeadow rush
Juncus nevadensis	FACW	graminoid	Juncaceae	Sierra rush
Juncus tenuis	FACW	graminoid	Juncaceae	poverty rush
Kalmia microphylla	OBL	shrub	Ericaceae	alpine laurel
Lactuca ludoviciana	FAC	forb	Asteraceae	biannual lettuce
Lathyrus palustris	OBL	forb	Fabaceae	marsh pea
Ledum groenlandicum	OBL	shrub	Ericaceae	bog Labrador tea
Leersia oryzoides	OBL	graminoid	Poaceae	rice cutgrass
Lemna minor	OBL	forb	Lemnaceae	common duckweed
Lemna trisulca	OBL	forb	Lemnaceae	star duckweed
Leontodon autumnalis	FAC	forb	Asteraceae	fall dandelion
Lepidium oxycarpum	OBL	forb	Brassicaceae	
Lilaeopsis occidentalis	OBL	forb	Apiaceae	western grasswort
Liparis loeselii	FACW	forb	Orchidaceae	yellow widelip orchid
Lobelia dortmanna	OBL	forb	Campanulaceae	Dortmann's cardinalflower
Lonicera involucrata	FAC	shrub	Caprifoliaceae	twinberry honeysuckle
Lotus corniculatus	FAC	forb	Fabaceae	bird's-foot trefoil
Ludwigia hexapetala	OBL	forb	Onagraceae	water primrose
Ludwigia palustris	OBL	forb	Onagraceae	marsh seedbox
Luzula comosa	FAC	graminoid	Juncaceae	Pacific woodrush
Luzula parviflora	FAC	graminoid	Juncaceae	smallflowered woodrush
Lycopus uniflorus	OBL	forb	Lamiaceae	northern bugleweed
Lysichiton americanus	OBL	forb	Araceae	American skunkcabbage
Lysimachia nummularia	FACW	forb	Primulaceae	creeping jenny
Lysimachia thyrsiflora	OBL	forb	Primulaceae	tufted loosestrife
Lythrum salicaria	FACW	forb	Lythraceae	purple loosestrife
Maianthemum dilatatum	FAC	forb	Liliaceae	false lily of the valley
Malus fusca	FACW	tree	Rosaceae	Oregon crab apple
Medicago lupulina	FAC	forb	Fabaceae	black medick
Mentha arvensis	FACW	forb	Lamiaceae	wild mint

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Menyanthes trifoliata	OBL	forb	Menyanthaceae	buckbean
Mimulus alsinoides	OBL	forb	Scrophulariaceae	wingstem monkeyflower
Mimulus guttatus	OBL	forb	Scrophulariaceae	seep monkeyflower
Mimulus moschatus	FACW	forb	Scrophulariaceae	muskflower
Montia dichotoma	FAC	forb	Portulacaceae	dwarf minerslettuce
Montia fontana	OBL	forb	Portulacaceae	annual water minerslettuce
Montia howellii	FACW	forb	Portulacaceae	Howell's minerslettuce
Montia parvifolia	FACW	forb	Portulacaceae	littleleaf minerslettuce
Myosotis arvensis	FAC	forb	Boraginaceae	field forget-me-not
Myosotis discolor	FACW	forb	Boraginaceae	changing forget-me-not
Myosotis laxa	OBL	forb	Boraginaceae	bay forget-me-not
Myosotis scorpioides	FACW	forb	Boraginaceae	true forget-me-not
Myosotis sylvatica	FAC	forb	Boraginaceae	woodland forget-me-not
Myosurus minimus	OBL	forb	Ranunculaceae	tiny mousetail
Myriophyllum sibiricum	OBL	forb	Haloragaceae	shortspike watermilfoil
Najas flexilis	OBL	forb	Najadaceae	nodding waternymph
Nanozostera japonica	OBL	forb	Zosteraceae	dwarf eelgrass
Nasturtium officinale	OBL	forb	Brassicaceae	watercress
Nemophila pedunculata	FAC	forb	Hydrophyllaceae	littlefoot nemophila
Nuphar lutea	OBL	forb	Nymphaeaceae	yellow pond-lily
Nymphaea odorata	OBL	forb	Nymphaeaceae	American white waterlily
Oenanthe sarmentosa	OBL	forb	Apiaceae	water parsely
Ophioglossum pusillum	FACW	forb	Ophioglossaceae	northern adderstongue
Osmorhiza purpurea	FAC	forb	Apiaceae	purple sweetroot
Packera indecora	FACW	forb	Asteraceae	elegant groundsel
Parentucellia viscosa	FAC	forb	Scrophulariaceae	yellow glandweed
Perideridia gairdneri	FAC	forb	Apiaceae	Gardner's yampah
Petasites frigidus	FACW	forb	Asteraceae	arctic sweet coltsfoot
Phalaris arundinacea	FACW	graminoid	Poaceae	reed canarygrass
Phleum pratense	FAC	graminoid	Poaceae	timothy
Phyllospadix scouleri	OBL	forb	Zosteraceae	Scouler's surfgrass
Physocarpus capitatus	FACW	shrub	Rosaceae	Pacific ninebark
Picea sitchensis	FAC	tree	Pinaceae	Sitka spruce
Pinus contorta	FAC	tree	Pinaceae	lodgepole pine
Plagiobothrys scouleri	FACW	forb	Boraginaceae	Scouler's popcornflower
Plagiobothrys tenellus	FAC	forb	Boraginaceae	Pacific popcornflower
Plantago elongata	FACW	forb	Plantaginaceae	prairie plantain
Plantago lanceolata	FAC	forb	Plantaginaceae	narrowleaf plantain
Plantago major	FAC	forb	Plantaginaceae	common plantain
Plantago maritima	FACW	forb	Plantaginaceae	goose tongue
Platanthera dilatata	FACW	forb	Orchidaceae	scentbottle
Poa annua	FAC	graminoid	Poaceae	annual bluegrass
Poa palustris	FAC	graminoid	Poaceae	fowl bluegrass
Poa pratensis	FAC	graminoid	Poaceae	Kentucky bluegrass
Poa trivialis	FACW	graminoid	Poaceae	rough bluegrass
Polygonum amphibium	OBL	forb	Polygonaceae	water smartweed

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Polygonum aviculare	FACW	forb	Polygonaceae	prostrate knotweed
Polygonum fowleri	FACW	forb	Polygonaceae	Fowler's knotweed
Polygonum lapathifolium	FACW	forb	Polygonaceae	curlytop knotweed
Polygonum persicaria	FACW	forb	Polygonaceae	spotted ladysthumb
Polypogon monspeliensis	FACW	graminoid	Poaceae	annual rabbitsfoot grass
Populus balsamifera	FAC	tree	Salicaceae	black cottonwood
Populus tremuloides	FAC	tree	Salicaceae	quaking aspen
Potamogeton amplifolius	OBL	forb	Potamogetonaceae	largeleaf pondweed
Potamogeton foliosus	OBL	forb	Potamogetonaceae	leafy pondweed
Potamogeton gramineus	OBL	forb	Potamogetonaceae	variableleaf pondweed
Potamogeton illinoensis	OBL	forb	Potamogetonaceae	Illinois pondweed
Potamogeton natans	OBL	forb	Potamogetonaceae	floating pondweed
Potamogeton obtusifolius	OBL	forb	Potamogetonaceae	bluntleaf pondweed
Potamogeton praelongus	OBL	forb	Potamogetonaceae	whitestem pondweed
Potamogeton pusillus	OBL	forb	Potamogetonaceae	small pondweed
Pseudognaphalium stramineum	FAC	forb	Asteraceae	cottonbatting plant
Psilocarphus tenellus	OBL	forb	Asteraceae	slender woollyheads
Puccinellia nutkaensis	OBL	graminoid	Poaceae	Nootka alkaligrass
Puccinellia nuttalliana	FACW	graminoid	Poaceae	Nuttall's alkaligrass
Puccinellia pumila	FACW	graminoid	Poaceae	dwarf alkaligrass
Pyrola chlorantha	FAC	forb	Ericaceae	greenflowered wintergreen
Ranunculus acris	FACW	forb	Ranunculaceae	tall buttercup
Ranunculus californicus	FAC	forb	Ranunculaceae	California buttercup
Ranunculus cymbalaria	OBL	forb	Ranunculaceae	alkali buttercup
Ranunculus flammula	FACW	forb	Ranunculaceae	greater creeping spearwort
Ranunculus occidentalis	FAC	forb	Ranunculaceae	western buttercup
Ranunculus repens	FACW	forb	Ranunculaceae	creeping buttercup
Ranunculus sardous	FAC	forb	Ranunculaceae	hairy buttercup
Ranunculus sceleratus	OBL	forb	Ranunculaceae	cursed buttercup
Ranunculus uncinatus	FAC	forb	Ranunculaceae	woodland buttercup
Rhynchospora alba	OBL	graminoid	Cyperaceae	white beaksedge
Ribes divaricatum	FAC	shrub	Grossulariaceae	spreading gooseberry
Ribes lacustre	FAC	shrub	Grossulariaceae	prickly currant
Rorippa curvisiliqua	OBL	forb	Brassicaceae	curvepod yellowcress
Rorippa islandica	OBL	forb	Brassicaceae	northern marsh yellowcress
Rosa nutkana	FAC	shrub	Rosaceae	Nootka rose
Rubus parviflorus	FAC	shrub	Rosaceae	thimbleberry
Rubus spectabilis	FAC	shrub	Rosaceae	salmonberry
Rumex conglomeratus	FACW	forb	Polygonaceae	clustered dock
Rumex crispus	FAC	forb	Polygonaceae	curly dock
Rumex maritimus	FACW	forb	Polygonaceae	golden dock
Rumex obtusifolius	FAC	forb	Polygonaceae	bitter dock
Rumex salicifolius	FACW	forb	Polygonaceae	willow dock

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Ruppia maritima	OBL	forb	Potamogetonaceae	widgeongrass
Sagina maxima	FAC	forb	Caryophyllaceae	stickystem pearlwort
Sagina procumbens	FAC	forb	Caryophyllaceae	birdeye pearlwort
Salicornia depressa	OBL	forb	Chenopodiaceae	Virginia glasswort
Salix alba	FACW	shrub	Salicaceae	white willow
Salix geyeriana	FACW	shrub	Salicaceae	Geyer willow
Salix hookeriana	FACW	shrub	Salicaceae	dune willow
Salix lucida	FACW	shrub	Salicaceae	shining willow
Salix scouleriana	FAC	shrub	Salicaceae	Scouler's willow
Salix sitchensis	FACW	shrub	Salicaceae	Sitka willow
Saxifraga caespitosa	FAC	forb	Saxifragaceae	tufted alpine saxifrage
Schoenoplectus acutus	OBL	graminoid	Cyperaceae	hardstem bulrush
Schoenoplectus maritimus	OBL	graminoid	Cyperaceae	cosmopolitan bulrush
Schoenoplectus pungens	OBL	graminoid	Cyperaceae	common threesquare
Schoenoplectus subterminalis	OBL	graminoid	Cyperaceae	swaying bulrush
Scirpus cyperinus	OBL	graminoid	Cyperaceae	woolgrass
Scirpus microcarpus	OBL	graminoid	Cyperaceae	panicled bulrush
Scutellaria galericulata	OBL	forb	Lamiaceae	marsh skullcap
Sidalcea hendersonii	FACW	forb	Malvaceae	Henderson's checkerbloom
Sisyrinchium californicum	FACW	forb	Iridaceae	golden blue-eyed grass
Sisyrinchium idahoense	FACW	forb	Iridaceae	Idaho blue-eyed grass
Sium suave	OBL	forb	Apiaceae	hemlock waterparsnip
Solanum dulcamara	FAC	forb	Solanaceae	climbing nightshade
Sonchus asper	FAC	forb	Asteraceae	spiny sowthistle
Sparganium emersum	OBL	graminoid	Sparganiaceae	European bur-reed
Spartina anglica	OBL	graminoid	Sparganiaceae	common cordgrass
Spergularia canadensis	FACW	forb	Caryophyllaceae	Canadian sandspurry
Spergularia macrotheca	FAC	forb	Caryophyllaceae	sticky sandspurry
Spergularia rubra	FAC	forb	Caryophyllaceae	red sandspurry
Spergularia salina	OBL	forb	Caryophyllaceae	salt sandspurry
Spiraea douglasii	FACW	shrub	Rosaceae	rose spirea
Spiranthes romanzoffiana	FACW	forb	Orchidaceae	hooded lady's tresses
Spirodela polyrrhiza	OBL	forb	Lemnaceae	common duckmeat
Stellaria crispa	FAC	forb	Caryophyllaceae	curled starwort
Stellaria graminea	FAC	forb	Caryophyllaceae	grass-like starwort
Stellaria longipes	FACW	forb	Caryophyllaceae	longstalk starwort
Stuckenia pectinata	OBL	forb	Potamogetonaceae	sago pondweed
Symphyotrichum boreale	OBL	forb	Asteraceae	northern bog aster
Symphyotrichum chilense	FAC	forb	Asteraceae	Pacific aster
Symphyotrichum eatonii	FAC	forb	Asteraceae	Eaton's aster
Symphyotrichum hallii	FAC	forb	Asteraceae	Hall's aster
Symphyotrichum subspicatus	FACW	forb	Asteraceae	saltmarsh aster
Thuja plicata	FAC	tree	Cupressaceae	western redcedar

Scientific Name	Wetland Indicator Status	Form	Family	Common Name
Tiarella trifoliata	FAC	forb	Saxifragaceae	threeleaf foamflower
Torreyochloa pallida	OBL	graminoid	Poaceae	pale false mannagrass
Trientalis borealis	FACW	forb	Primulaceae	starflower
Trifolium hybridum	FAC	forb	Fabaceae	alsike clover
Trifolium microcephalum	FAC	forb	Fabaceae	smallhead clover
Trifolium repens	FAC	forb	Fabaceae	white clover
Trifolium variegatum	FAC	forb	Fabaceae	whitetip clover
Triglochin concinna	OBL	forb	Scheuchzeriaceae	slender arrowgrass
Triglochin maritima	OBL	forb	Scheuchzeriaceae	seaside arrowgrass
Typha latifolia	OBL	graminoid	Typhaceae	broadleaf cattail
Urtica dioica	FAC	forb	Urticaceae	stinging nettle
Utricularia macrorhiza	OBL	forb	Lentibulariaceae	common bladderwort
Utricularia minor	OBL	forb	Lentibulariaceae	small bladderwort
Vaccinium oxycoccos	OBL	shrub	Ericaceae	small cranberry
Vaccinium uliginosum	FACW	shrub	Ericaceae	bog blueberry
Valeriana scouleri	FAC	forb	Valerianaceae	Scouler's valerian
Veronica americana	OBL	forb	Scrophulariaceae	American speedwell
Veronica anagallis-aquatica	OBL	forb	Scrophulariaceae	water speedwell
Veronica peregrina	OBL	forb	Scrophulariaceae	neckweed
Veronica scutellata	OBL	forb	Scrophulariaceae	skullcap speedwell
Veronica serpyllifolia	FAC	forb	Scrophulariaceae	brightblue speedwell
Vicia americana	FAC	forb	Fabaceae	American vetch
Viola adunca	FAC	forb	Violaceae	hookedspur violet
Viola glabella	FACW	forb	Violaceae	pioneer violet
Viola macloskeyi	OBL	forb	Violaceae	small white violet
Vulpia myuros	FAC	graminoid	Poaceae	rat-tail fescue
Wolffia borealis	OBL	forb	Lemnaceae	northern watermeal
Wolffia columbiana	OBL	forb	Lemnaceae	Columbian watermeal
Zostera marina	OBL	forb	Zosteraceae	seawrack

Appendix 2B-2. Wetland wildlife of San Juan County (by island)

<u>Sources</u>: Jensen (2010), WDFW (2009), Cassidy & Grue (2006), Lewis & Sharpe (1987), Barsh (pers. comm.), Myhr (pers. comm.), Adamus (personal observations)

<u>Legend</u>:
Native to WA: Y= yes, N- no
Times Present: R= resident; N= nesting season only; MW= migration/ wintering only; ? = nesting unconfirmed
Distribution by Island: C= confirmed by reliable report, P= probable based on known habitat preferences, ? = unknown but possible based on habitat
Listing Status:
Fed (Federal): E= Endangered, T= Threatened, SC= Species of Concern
State: M= species of potential concern whose status should be determined or monitored, C= Candidate (species that will be reviewed by WDFW for possible listing as Endangered, Threatened, or Sensitive according to the process and criteria defined in WAC-232-12-297), E= Endangered, T= Threatened
State PS (Priority Species): 1= state-listed species, 2= protect vulnerable aggregations, 3= species of recreational or commercial importance

	Most-used Wetland Types					Occurrence by Island				Listing Status			
Common Name	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	PHS	Scientific Name
Northwestern Salamander	1	1		Y	R	P	C	C	?				Ambystoma gracile
Long-toed Salamander	1		1	Y	R	?	C	P	C				Ambystoma macrodactylum
Rough-skinned Newt	1	1		Y	R	C	C	C	C				Taricha granulosa
Western Toad	1	1		Y	R	?	P	?	P	SC	C	1	Bufo boreas
Pacific Treefrog	1	1	1	Y	R	C	C	C	C				Hyla regilla
Northern Red-legged Frog	1	1	1	Y	R	P	C	C	C				Rana aurora
Bullfrog	1	1		N	R	C	C	C	?C				Rana catesbeiana
Western Painted Turtle	1	1		Y	R	C	P	C	?				Chrysemys picta
Northern Alligator Lizard			1	Y	R	P	C	P	?				Elgaria coerulea
Rubber Boa			1	Y	R	C	?	?	?				Charina bottae
Sharptail Snake			1	Y	R	P	C	?	?				Contia tenuis
W. Terrestrial Garter Snake	1	1	1	Y	R	P	P	C	?				Thamnophis elegans
Northwestern Garter Snake	1	1	1	Y	R	P	P	C	?				Thamnophis ordinoides
Common Garter Snake	1	1	1	Y	R	P	P	C	?				Thamnophis sirtalis
Common Loon	1			Y	MW	C	C	C	C		S	1, 2	Gavia immer
Pied-billed Grebe	1	1		Y	R	C	C	C	C			2	Podilymbus podiceps
Horned Grebe	1			Y	MW	C	C	C	C		M	2	Podiceps auritus
Eared Grebe	1			Y	MW	C	P	P	?			2	Podiceps nigricollis

Common Name	Most-used Wetland Types			Native to WA	Times Present	Occurrence by Island				Listing Status			Scientific Name
	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen			SJ	Orcas	Lopez	Shaw	Fed	State	PHS	
Western Grebe	I			Y	MW	C	C	C	C		C	I, 2	Aechmophorus occidentalis
Double-crested Cormorant	I	I		Y	R	C	C	C	C			2	Phalacrocorax auritus
American Bittern	I			Y	R?	C	P	P	P				Botaurus lentiginosus
Great Blue Heron	I	I		Y	MW	C	C	C	C		M	2	Ardea herodias
Green Heron	I	I		Y	N?	C	P	P					Butorides virescens
Tundra Swan	I			Y	MW	C		P				2, 3	Cygnus columbianus
Trumpeter Swan	I	I		Y	MW	C	C	C	P			2, 3	Cygnus buccinator
Greater White-fronted Goose	I			Y	MW	C	C	P				2, 3	Anser albifrons
Canada Goose	I			Y	R	C	C	C	C			2, 3	Branta canadensis
Cackling Goose	I			Y	MW	C	P	P				2, 3	Branta hutchinsii
Wood Duck	I	I		Y	R	C	C	P	P			2, 3	Aix sponsa
Green-winged Teal	I			Y	R	C	C	C	C			2, 3	Anas crecca
Mallard	I	I		Y	R	C	C	C	C			2, 3	Anas platyrhynchos
Northern Pintail	I			Y	R?	C	C	C	P			2, 3	Anas acuta
Blue-winged Teal	I			Y	R	C	C	P	P			2, 3	Anas discors
Cinnamon Teal	I			Y	R	C	C	P	P			2, 3	Anas cyanoptera
Northern Shoveler	I			Y	R?	C	C	C	P			2, 3	Anas clypeata
Gadwall	I			Y	R	C	C	C	P			2, 3	Anas strepera
Eurasian Wigeon	I			Y	MW	C	C	C	P			2, 3	Anas penelope
American Wigeon	I	I		Y	MW	C	C	C	C			2,	Anas americana

	Most-used Wetland Types					Occurrence by Island				Listing Status			
Common Name	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	PHS	Scientific Name
												3	
Canvasback	I			Y	MW	C	C	P	P			2, 3	Aythya valisineria
Redhead	I			Y	MW	C	P	P	P			2, 3	Aythya americana
Ring-necked Duck	I			Y	R	C	C	P	P			2, 3	Aythya collaris
Greater Scaup	I			Y	MW	C	C	C	C			2, 3	Aythya marila
Lesser Scaup	I			Y	R?	C	P	P	P			2, 3	Aythya affinis
Common Goldeneye	I	I		Y	MW	C	C	C	C			2, 3	Bucephala clangula
Barrow's Goldeneye	I			Y	MW	C	C	C	C			2, 3	Bucephala islandica
Bufflehead	I	I		Y	MW	C	C	C	C			2, 3	Bucephala albeola
Hooded Merganser	I	I		Y	R	C	C	C	C			3	Lophodytes cucullatus
Common Merganser	I	I		Y	R	C	C	C	C			2, 3	Mergus merganser
Ruddy Duck	I			Y	R?	C	P	C	P			2, 3	Oxyura jamaicensis
Turkey Vulture	I	I	I	Y	R	C	C	C	C		M		Cathartes aura
Osprey	I	I		Y	R	C	C	C	P		M		Pandion haliaetus
Bald Eagle	I	I	I	Y	R	C	C	C	C	SC	S	I	Haliaeetus leucocephalus
Northern Harrier	I			Y	R?	C	C	C	C				Circus cyaneus
Sharp-shinned Hawk	I	I	I	Y	R	C	C	C	C				Accipiter striatus
Cooper's Hawk	I	I	I	Y	R	C	C	C	P				Accipiter cooperii
Northern Goshawk		I	I	Y	R?	C	C	C	C	SC	C	I	Accipiter gentilis
Red-tailed Hawk	I	I	I	Y	R	C	C	C	C				Buteo jamaicensis
Rough-legged Hawk	I			Y	MW	C	P	P	P				Buteo lagopus
Golden Eagle	I		I	Y	R	C	C	C	P		C	I	Aquila chrysaetos
American Kestrel	I	I	I	Y	R	C	C	P	P				Falco sparverius
Merlin	I	I	I	Y	R?	C	C	C	P		C	I	Falco columbarius

	Most-used Wetland Types					Occurrence by Island				Listing Status			
Common Name	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	PHS	Scientific Name
Peregrine Falcon	I	I		Y	R	C	C	C	P	SC	S	I	Falco peregrinus
Ring-necked Pheasant	I		I	N	R	C	C	C	P			3	Phasianus colchicus
Sooty (Blue) Grouse		I	I	Y	R	?	C					3	Dendragapus obscurus
Wild Turkey		I	I	N	R	C						3	Meleagris gallopavo
California Quail	I		I	N	R	C	C	C	C				Callipepla californica
Virginia Rail	I			Y	R	C	C	C	C				Rallus limicola
Sora	I			Y	R	C	C	P	C				Porzana carolina
American Coot	I			Y	R	C	C	C	P			2, 3	Fulica americana
Sandhill Crane	I			Y	MW	C	P	P			E	I	Grus canadensis
American Golden-Plover	I			Y	M	C		P				2	Pluvialis dominica
Pacific Golden-Plover	I			Y	M	C		P				2	Pluvialis fulva
Killdeer	I			Y	R	C	C	C	C			2	Charadrius vociferus
Greater Yellowlegs	I			Y	MW	C	C	C	C			2	Tringa melanoleuca
Lesser Yellowlegs	I			Y	M	C	P	C	P			2	Tringa flavipes
Solitary Sandpiper	I			Y	M	C	P	P	P			2	Tringa solitaria
Spotted Sandpiper	I			Y	R?	C	C	C	C			2	Actitis macularia
Western Sandpiper	I			Y	MW	C	C	C	C			2	Calidris mauri
Least Sandpiper	I			Y	M	C	P	C	P			2	Calidris minutilla
Baird's Sandpiper	I			Y	M	C	P	C	P			2	Calidris bairdii
Pectoral Sandpiper	I			Y	M	C	P	P	C			2	Calidris melanotos
Dunlin	I			Y	MW	C	C	C	C			2	Calidris alpina
Long-billed Dowitcher	I			Y	M	C	P	C	P			2	Limnodromus scolopaceus
Wilson's Snipe	I	I		Y	R	C	C	C	C			2	Gallinago delicata
Mew Gull	I			Y	MW	C	C	C	C				Larus canus
Ring-billed Gull	I			Y	MW	C	P	P	?				Larus delawarensis
California Gull	I			Y	MW	C	C	C	C				Larus californicus
Herring Gull	I			Y	MW	C	C	C	C				Larus argentatus
Thayer's Gull	I			Y	MW	C	C	C	C				Larus thayeri
Western Gull	I			Y	MW	C	P	P	P				Larus occidentalis
Glaucous-winged Gull	I			Y	R	C	C	C	C				Larus glaucescens
Caspian Tern	I			Y	MW	C	C	C	C		M	2	Hydroprogne caspia

	Most-used Wetland Types					Occurrence by Island				Listing Status			
Common Name	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	PHS	Scientific Name
Band-tailed Pigeon		I		Y	R	C	C	C	C			3	Columba fasciata
Mourning Dove	I	I	I	Y	R	C	C	C	C				Zenaida macroura
Barn Owl	I			Y	R	C	C	C					Tyto alba
Western Screech-owl	I	I	I	Y	R	C	C	C	?				Otus kennicotti
Great Horned Owl	I	I	I	Y	R	C	C	C	P				Bubo virginianus
Snowy Owl	I			Y	MW	C	P	P			M		Nyctea scandiaca
Northern Pygmy-owl		I		Y	R?	C	C	P	?				Glaucidium gnoma
Barred Owl	I	I		Y	R?	?	P	C	?				Strix varia
Long-eared Owl	I	I	I	Y	R	C	C	C	C				Asio otus
Short-eared Owl	I			Y	R?	P	P	C					Asio flammeus
Northern Saw-whet Owl		I	I	Y	R	C	P	C					Aegolius acadicus
Common Nighthawk	I	I	I	Y	N	C	C	C					Chordeiles minor
Black Swift	I			Y	NB	C	C	C		SC	M		Cypseloides niger
Vaux's Swift	I	I	I	Y	N?	C	C	C	?		C	I	Chaetura vauxi
Rufous Hummingbird	I	I	I	Y	N	C	C	C	C				Selasphorus rufus
Belted Kingfisher	I	I		Y	R	C	C	C	C				Ceryle alcyon
Red-breasted Sapsucker		I	I	Y	MW?	C	C	C	?				Sphyrapicus ruber
Downy Woodpecker		I	I	Y	R	C	C	C	C				Picoides pubescens
Hairy Woodpecker		I	I	Y	R	C	C	C	C				Picoides villosus
Northern Flicker		I	I	Y	R	C	C	C	C				Colaptes auratus
Pileated Woodpecker		I	I	Y	R	C	C	C	C		C	I	Dryocopus pileatus
Olive-sided Flycatcher		I		Y	N	C	C	C	C				Contopus borealis
Western Wood-pewee		I	I	Y	N	C	C	P	P				Contopus sordidulus
Willow Flycatcher		I		Y	N	C	C	P	?				Empidonax traillii
Hammond's Flycatcher		I		Y	N?		P						Empidonax hammondii
Pacific-slope Flycatcher		I	I	Y	N	C	C	C	C				Empidonax difficilis
Purple Martin	I			Y	N	C	C	C			C	I	Progne subis
Tree Swallow	I	I	I	Y	N	C	C	C	C				Tachycineta bicolor
Violet-green Swallow	I		I	Y	N	C	C	C	C				Tachycineta thalassina
N. Rough-winged Swallow	I			Y	N	C	C	C	C				Stelgidopteryx serripennis
Cliff Swallow	I			Y	N	C	C	C					Hirundo pyrrhonota
Barn Swallow	I			Y	N	C	C	C	C				Hirundo rustica

Common Name	Most-used Wetland Types			Native to WA	Times Present	Occurrence by Island				Listing Status			Scientific Name
	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen			SJ	Orcas	Lopez	Shaw	Fed	State	PHS	
Steller's Jay		I		Y	R		C						Cyanocitta stelleri
American Crow	I	I	I	Y	R	C	C	C	C				Corvus brachyrhynchos
Common Raven	I	I	I	Y	R	C	C	C	C				Corvus corax
Chestnut-backed Chickadee		I		Y	R	C	C	C	C				Poecile rufescens
Bushtit		I	I	Y	R	C	C	C	?				Psaltriparus minimus
Red-breasted Nuthatch		I	I	Y	R	C	C	C	C				Sitta canadensis
Brown Creeper		I	I	Y	R	C	C	C	C				Certhia americana
Bewick's Wren	I	I		Y	R	C	C	C	C				Thryomanes bewickii
House Wren		I	I	Y	N	C	C	C	C				Troglodytes aedon
Pacific (Winter) Wren		I	I	Y	R	C	C	C	C				Troglodytes troglodytes
Marsh Wren	I			Y	R	C	C	C	C				Cistothorus palustris
American Dipper		I		Y	R?		C						Cinclus mexicanus
Golden-crowned Kinglet		I	I	Y	R	C	C	C	C				Regulus satrapa
Ruby-crowned Kinglet	I	I	I	Y	MW	C	C	C	C				Regulus calendula
Western Bluebird		I	I	Y	R	C	C	C					Sialia mexicana
Mountain Bluebird			I	Y	M	C							Sialia currucoides
Townsend's Solitaire		I	I	Y	MW	C	C	C	C				Myadestes townsendi
Swainson's Thrush		I	I	Y	N	C	C	C	C				Catharus ustulatus
Hermit Thrush		I	I	Y	MW	C	C	C	C				Catharus guttatus
American Robin	I	I	I	Y	R	C	C	C	C				Turdus migratorius
American Pipit	I			Y	MW	C	C	C	P				Anthus rubescens
Cedar Waxwing	I	I	I	Y	R	C	C	C	P				Bombycilla cedrorum
Northern Shrike	I			Y	MW	C	P	C	?				Lanius excubitor
European Starling	I	I	I	N	R	C	C	C	C				Sturnus vulgaris
Hutton's Vireo		I	I	Y	R	C	C	C	C				Vireo huttoni
Warbling Vireo		I	I	Y	N	C	C	C	C				Vireo gilvus
Cassin's Vireo			I	Y	N	C	C	C	C				Vireo cassinii
Orange-crowned Warbler		I	I	Y	N	C	C	C	C				Vermivora celata
Yellow Warbler		I	I	Y	N	C	C	C	C				Dendroica petechia
Yellow-rumped Warbler	I	I	I	Y	R	C	C	C	C				Dendroica coronata
Black-throated Gray Warbler		I		Y	N	C	C	C	C				Dendroica nigrescens
Townsend's Warbler		I	I	Y	R	C	C	C	C				Dendroica townsendi

	Most-used Wetland Types					**Occurrence by Island**				**Listing Status**			
Common Name	Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	PHS	Scientific Name
MacGillivray's Warbler		I	I	Y	N	C	C	P	?				Oporornis tolmiei
Common Yellowthroat	I	I		Y	N	C	C	C	C				Geothlypis trichas
Wilson's Warbler		I		Y	N	C	C	C	C				Wilsonia pusilla
Western Tanager		I	I	Y	N	C	C	C	C				Piranga ludoviciana
Black-headed Grosbeak		I	I	Y	N	C	C	C	C				Pheucticus melanocephalus
Spotted Towhee		I	I	Y	R	C	C	C	C				Pipilo maculatus
Chipping Sparrow			I	Y	N	C	C	P	?				Spizella passerina
Savannah Sparrow	I			Y	N	C	C	C	C				Passerculus sandwichensis
Fox Sparrow		I	I	Y	R?	C	C	C	C				Passerella iliaca
Song Sparrow	I	I	I	Y	R	C	C	C	C				Melospiza melodia
Lincoln's Sparrow	I			Y	MW	C	P	P					Melospiza lincolnii
Golden-crowned Sparrow	I	I	I	Y	MW	C	C	C	C				Zonotrichia atricapilla
White-crowned Sparrow	I			Y	R	C	C	C	C				Zonotrichia leucophrys
Dark-eyed Junco		I	I	Y	R	C	C	C	C				Junco hyemalis
Red-winged Blackbird	I			Y	R	C	C	C	C				Agelaius phoeniceus
Western Meadowlark	I			Y	NB	C	P	P					Sturnella neglecta
Brewer's Blackbird	I	I	I	Y	R	C	C	C	?				Euphagus cyanocephalus
Brown-headed Cowbird	I	I	I	Y	N	C	C	C	C				Molothrus ater
Purple Finch		I	I	Y	R	C	C	C	C				Carpodacus purpureus
Red Crossbill		I		Y	R	C	C	C	C				Loxia curvirostra
Pine Siskin		I	I	Y	R	C	C	C	C				Carduelis pinus
American Goldfinch	I	I	I	Y	R	C	C	C	C				Carduelis tristis
Evening Grosbeak		I		Y	R	C	C	P	C				Coccothraustes vespertinus
Vagrant Shrew	I	I	I	Y		C	P	C	C				Sorex vagrans
Little Brown Myotis (Bat)	I	I	I	Y		C	P	P	?			2	Myotis lucifugus
Yuma Myotis	I	I	I	Y		P	P	P	?			2	Myotis yumanensis
Keen's Myotis	I	I	I	Y		P	P	P	?		C	I, 2	Myotis keenii
Long-eared Myotis	I	I	I	Y		P	P	P	?	SC	M	2	Myotis evotis
Long-legged Myotis	I	I	I	Y		C	P	P	?	SC	M	2	Myotis volans
Californian Myotis	I	I	I	Y		C	P	P	?			2	Myotis californicus
Silver-haired Bat	I	I	I	Y		P	P	P	?				Lasionycteris noctivagans

Common Name	Most-used Wetland Types: Herbaceous Wetlands, Ponds, or Lakes	Wooded Wetlands or Streams	Aspen	Native to WA	Times Present	Occurrence by Island: SJ	Orcas	Lopez	Shaw	Listing Status: Fed	State	PHS	Scientific Name
Big Brown Bat	I	I	I	Y		P	P	P	?			2	Eptesicus fuscus
Hoary Bat	I	I	I	Y		P	P	P	?		M		Lasiurus cinereus
Townsend's Big-eared Bat	I	I	I	Y		P	P	C	?	SC	C	I, 2	Corynorhinus (Plecotus) townsendii
Townsend's Chipmunk		I		Y	R	C	?	C					Neotamias townsendii
Northern Flying Squirrel		I	I	Y	R	C	P	?	?				Glaucomys sabrinus
American Beaver	I	I	I	Y	R		C						Castor canadensis
Deer (White-footed) Mouse	I	I	I	Y	R	C	C	C	C				Peromyscus maniculatus
Townsend's Vole	I	I		Y	R	C	C	C	?		M		Microtus townsendii
Muskrat	I	I		Y	R	C	C	C	?				Ondatra zibethicus
Red Fox	I	I	I	Y	R	C							Vulpes vulpes
Raccoon	I	I	I	Y	R	P	P	C	C				Procyon lotor
Mink	I	I	I	Y	R	P	P	C	P			3	Mustela vison
Northern River Otter	I	I	I	Y	R	C	P	C	P				Lontra canadensis
Black-tailed Deer	I	I	I	Y	R	C	C	C	C			3	Odocoileus columbianus

Appendix 2C. Results From On-site Assessment of SJC Wetlands

Appendix 2C-1. Scores from the WDOE Rating Method, by SJC wetland visited in 2010

See Hruby (2004) for details of how these factors are estimated, scored, and used to determine the regulatory category.
See section 2.1.5 of this chapter for interpretation.

WetID	FieldID	HGM Type	Water Quality Service score	Hydrologic Service score	Habitat Function score	Total Score	Resultant WDOE Category
6393	1347	Depressional	28	10	29	67	Category II
5254	247	Depressional	16	12	24	52	Category II
5859	837	Depressional	15	8	29	52	Category II
5945	922	Depressional	15	8	29	52	Category II
7430	2284	Depressional	16	12	23	51	Category II
5133	130	Lacustrine	12	24	21	57	Category II
5293	286	Estuarine	n/a	n/a	n/a	n/a	Category II
6834	1746	Estuarine	n/a	n/a	n/a	n/a	Category II
6000	967.1	Depressional	11	9	30	50	Category III
7192	2086	Depressional	16	12	21	49	Category III
5131	128	Depressional	14	9	25	48	Category III
5385	377	Depressional	11	5	32	48	Category III
5773	775	Depressional	15	12	21	48	Category III
5954	931	Depressional	14	8	26	48	Category III
5444	436	Depressional	16	10	21	47	Category III
6072	1039	Depressional	11	8	28	47	Category III
6191	1152	Depressional	12	8	27	47	Category III
6890	1801	Depressional	15	10	22	47	Category III
5700	686	Depressional	16	14	16	46	Category III
5882	859	Depressional	12	7	27	46	Category III
6000	967	Depressional	11	8	27	46	Category III
6266	1225	Depressional	14	10	22	46	Category III
6120	1087	Depressional	16	12	16	44	Category III
6126	1093	Depressional	16	14	14	44	Category III
5327	319	Depressional	15	8	20	43	Category III
6488	1433	Depressional	12	10	21	43	Category III
5024	23	Depressional	16	12	14	42	Category III
5347	339	Depressional	15	8	19	42	Category III
5843	821	Depressional	10	8	24	42	Category III
6057	1024	Depressional	10	10	22	42	Category III
6204	1165	Depressional	8	10	24	42	Category III
6601	1525	Depressional	15	5	22	42	Category III
7483	2317	Depressional	10	10	22	42	Category III
6008	975	Depressional	13	10	18	41	Category III
6467	1412	Depressional	6	10	24	40	Category III
6544	1484	Depressional	14	9	17	40	Category III
5683	669	Depressional	10	8	21	39	Category III
6105	1072	Depressional	14	8	17	39	Category III
6363	1318	Depressional	5	10	24	39	Category III
6452	1398	Depressional	9	2	28	39	Category III

WetID	FieldID	HGM Type	Water Quality Service score	Hydrologic Service score	Habitat Function score	Total Score	Resultant WDOE Category
6534	1475	Depressional	11	12	16	39	Category III
6830	1742	Depressional	18	8	13	39	Category III
6659	1582	Depressional	10	12	16	38	Category III
5905	882	Depressional	8	12	17	37	Category III
6974	1884	Depressional	14	12	11	37	Category III
7446	2298	Depressional	10	4	23	37	Category III
5039	38	Depressional	7	8	21	36	Category III
5605	594	Depressional	12	7	17	36	Category III
6055	1022.2	Depressional	12	5	19	36	Category III
7433	2287	Depressional	16	9	11	36	Category III
5256	249	Depressional	11	10	14	35	Category III
6711	1628	Depressional	11	8	16	35	Category III
6761	1678	Depressional	12	7	16	35	Category III
6955	1866	Depressional	9	8	18	35	Category III
5466	458	Depressional	8	7	19	34	Category III
5350	342	Depressional	11	2	20	33	Category III
5396	388	Depressional	15	2	16	33	Category III
6243	1203	Depressional	12	7	14	33	Category III
6652	1575	Depressional	10	7	16	33	Category III
5667	653	Depressional	9	10	13	32	Category III
6108	1075	Depressional	7	14	11	32	Category III
5714	697	Depressional	7	7	17	31	Category III
5515	506	Depressional	11	7	12	30	Category III
5736	719	Depressional	10	9	11	30	Category III
6055	1022	Depressional	8	5	17	30	Category III
6118	1085	Depressional	11	9	10	30	Category III
5123	120	Lacustrine	14	0	25	39	Category III
6668	1590	Lacustrine	10	4	22	36	Category III
5590	579	Lacustrine	7	4	20	31	Category III
6514	1458	Slope	6	2	33	41	Category III
5420	412	Slope	4	4	22	30	Category III
6071	1038	Depressional	14	7	8	29	Category IV
6870	1782	Depressional	11	6	12	29	Category IV
6886	1797	Depressional	6	6	17	29	Category IV
5311	303	Depressional	11	10	7	28	Category IV
5445	437	Depressional	11	7	10	28	Category IV
5472	464	Depressional	13	5	10	28	Category IV
5690	676	Depressional	8	2	18	28	Category IV
7007	1916	Depressional	8	5	15	28	Category IV
7182	2085	Depressional	7	9	12	28	Category IV
6296	1254	Depressional	12	7	8	27	Category IV
7008	1917	Depressional	5	8	14	27	Category IV
5097	96	Depressional	5	5	16	26	Category IV
6075	1042	Depressional	10	7	9	26	Category IV
6295	1253	Depressional	5	10	11	26	Category IV
7389	2256	Depressional	11	2	13	26	Category IV
5586	575	Depressional	9	2	14	25	Category IV

WetID	FieldID	HGM Type	Water Quality Service score	Hydrologic Service score	Habitat Function score	Total Score	Resultant WDOE Category
5795	776	Depressional	7	5	13	25	Category IV
5115	112	Depressional	7	2	15	24	Category IV
5943	920	Depressional	7	5	12	24	Category IV
6055	1022.3	Depressional	10	2	11	23	Category IV
7032	1940	Depressional	6	4	13	23	Category IV
5059	58	Depressional	3	7	12	22	Category IV
5229	223	Depressional	3	8	11	22	Category IV
7075	1983	Depressional	7	5	10	22	Category IV
7294	2177	Depressional	6	7	9	22	Category IV
5099	98	Depressional	3	6	12	21	Category IV
6945	1856	Depressional	5	5	9	19	Category IV
7090	1998	Depressional	3	7	6	16	Category IV
5658	644	Slope	1	2	20	23	Category IV
5243	236	Slope	0	2	19	21	Category IV
5304	297	Slope	0	2	16	18	Category IV
5584	573	Slope	1	2	15	18	Category IV
5194	190	Slope	0	2	15	17	Category IV

Appendix 2C-2. Summary of conditions in statistical sample of SJC wetlands, summer 2010, *numeric* indicators

Note: Distances were visually estimated, not measured.

	Accessible Wetland				Entire Wetland			
Indicators of Wetland Condition	# of sites	Mean	Minimum	Maximum	# of sites	Mean	Minimum	Maximum
% water (today) - plot	104	15.54	0	95				
% bare / rock - plot	107	11.35	0	70				
% moss ("S" if any Sphagnum) - plot	108	0.84	0	25				
depth of peat (if any) (ft) - plot	104	0.01	0	0.5				
% graminoids (dead or alive) - plot	105	52.24	0	100				
% forbs (dead or alive) - plot	104	16.70	0	100				
% woody canopy cover - plot	107	33.89	0	100				
% water (today)	106	30.02	0	100	104	31.01	0	95
% bare / rock	103	7.92	0	70	103	8.10	0	70
% moss ("S" if any Sphagnum)	103	1.58	0	80	103	0.50	0	10
% graminoids	104	44.21	0	100	102	43.30	0	100
% herbs (graminoids + forbs)	105	51.37	1	100	103	44.29	0	100
% woody canopy cover	101	30.18	0	100	101	27.68	0	100
% cultivated (tilled <1 yr ago)	105	4.38	0	100	103	4.56	0	100
graminoid invasives as % of graminoid cover	105	29.71	0	100				
forb invasives as % of forb cover	105	10.07	0	90				
herb invasives as % of all herbaceous cover	105	24.28	0	100				
shrub invasives as % of shrub cover	105	5.55	0	100				
Alder as % of shrub canopy cover	105	16.16						
% with >4" water for >9 months/yr	105	39.44	0	95				
% with >4" water for >2 months/yr	105	19.67	0	80				
% with >4" water for >2 wks/yr	105	19.20	0	90				
% never inundated (but wetland plants dominate)	105	40.87	0	100				
% of ponded water that is under veg (vs. in open)	105	30.77	0	100				
Min. distance down from septic (ft)	104	98.75	0	300	53	96.82	0	300
Min. distance down from open canopy	104	7.24	0	200	53	8.08	0	150
Min. distance down from crops/ lawn	104	34.25	0	200	53	42.76	0	250
Min. distance down from bare/ paved	104	29.93	0	300	53	26.75	0	300

Appendix 2C-3. Summary of conditions in statistical sample of SJC wetlands and associated surroundings, summer 2010, *categorical* indicators

	Wetland in parcel				Entire wetland				Wetland Surroundings in parcel			
	No/Non e	Som e	Muc h	Ye s	No/Non e	Som e	Muc h	Ye s	No/Non e	Som e	Muc h	Ye s
New Dammed/Diked	96	6	1		3	2						
New Ditched or Tile	103	1			5							
New Excavated/ Regraded	95	6	2		5							
New Fill	98	6			5							
New Mowed/ Hayed (<1 yr ago)	52	33	18	1	5			1	38	36	20	2
New Plowed (<1 yr ago)	95	8		1	6				71	23		1
New Timber Cut/ Shrub Clear	99	5			6				90	5		1
Old Dammed/Diked	58	30	15	1	2	2	1					
Old Ditched or Tile	78	25	1		4	1						
Old Excavated/ Regraded	25	57	21	1	3	2						
Pasture	92	7	5		4	2			78	11	7	
Burned	104				6				95			
Vehicle tracks	91	13			6				81	14		
Soil saturated? (no/ some/ much)	27	39	37									
Wetland trees >15" : >8/acre?	94			10								
Wetland trees >15" : any?	68			37								
Wetland trees >21" : >8/acre?	98			6								
Wetland trees >21" : any?	88			16								
Fish (no/ possible/ yes)	52			8	45			10				
Bullfrog	44			6	35			7				
Ducks	45			12	35			14				
Heron	42			8	33			10				
Eagle	6			8	9			9				

Appendix 2C-4. Summary of conditions in uplands immediately *surrounding* each wetland in the statistical sample of SJC wetlands, summer 2010, numeric indicators

	Accessible Surrounding Area				Entire Surrounding Area (estimated)			
Indicators of Wetland Condition	# of sites	Mea n	Minimu m	Maximu m	# of sites	Mea n	Minimu m	Maximu m
% water (today)	103	0.24	0	10				
% bare / rock	103	10.87	0	80				
% moss ("S" if any Sphagnum)	103	1.01	0	30				
% graminoids	101	51.26	1	100	98	45.53	0	100
% herbs (graminoids + forbs)	102	49.90	0	100	99	47.10	0	100
% woody canopy cover	101	41.62	0	100	98	41.80	0	100

Indicators of Wetland Condition	Accessible Surrounding Area				Entire Surrounding Area (estimated)			
	# of sites	Mean	Minimum	Maximum	# of sites	Mean	Minimum	Maximum
% cultivated (tilled <1 yr ago)	102	5.40	0	100	99	6.43	0	100
graminoid invasives as % of graminoid cover	102	24.85	0	100				
forb invasives as % of forb cover	102	8.79	0	90				
herb invasives as % of all herbaceous cover	102	21.74	0	100				
shrub invasives as % of shrub cover	102	6.76	0	100				
Number of Dwellings within 100 ft of wetland								
inhabitated almost daily most of year	104	0.74	0	8	102	1.43	0	17
seasonal only (usually)	104	0.09	0	2	102	0.16	0	3

Appendix 2C-5. Wetland Prevalence Index and native and invasive plant species percent cover in quadrats sampled during summer 2010 visit to SJC wetlands

-- Designation of "Invasive" was based only on WDOE's (Hruby 2004) list of wetland-invasive species.
-- Lower values for the Wetland Prevalence Index indicate wetter conditions (e.g., more cover of OBL and FACW than FAC and upland species, see Appendix 2B-1). For each sampled quadrat, the index is calculated by multiplying each species' WIS rating (OBL=1, FACW=2, FAC=3, FACU= 4, UPL= 5) by its percent cover, then dividing by percent cover summed across all species having a WIS rating. The Wetland Indicator Status (WIS) designations are from US Fish & Wildlife Service (1988, 1993) official lists. The indicator status of all species is currently under regional review by federal agencies and plant ecologists. An update of the official list resulting from this review is anticipated in 2011 or 2012, and could change the figures in the table below.

Field ID #	Wetland Prevalence Index, mean of quadrats	Wetland Prevalence Index, minimum of quadrats	Percent Cover, Native Wetland Plants	Percent Cover, All Native	Percent Cover, Exotic	Percent Cover, Invasive
38	2.90	2.80	59%	59%	18%	1%
58	3.71	3.33	29%	100%	0%	0%
96	3.59	3.21	45%	88%	0%	0%
98	2.98	2.00	66%	83%	17%	3%
112	1.91	1.02	100%	100%	1%	1%
120	3.09	2.41	30%	62%	37%	36%
128	1.83	1.00	89%	89%	7%	4%
130	2.00	2.00	0%	0%	100%	100%
190	2.75	2.21	60%	61%	28%	15%
223	2.22	1.00	78%	100%	0%	0%
236	1.93	1.54	18%	18%	83%	83%
249	3.52	2.40	27%	97%	0%	0%
256	2.00	2.00	6%	6%	93%	93%
297	1.95	1.06	94%	100%	0%	0%
303	2.43	2.00	46%	46%	39%	0%
319	1.91	1.75	17%	17%	83%	83%
339	2.00	2.00	0%	0%	100%	100%
342	2.04	1.78	16%	16%	81%	81%
377	3.70	3.30	44%	95%	5%	5%
388	1.60	1.00	80%	99%	1%	0%

Field ID #	Wetland Prevalence Index, mean of quadrats	Wetland Prevalence Index, minimum of quadrats	Percent Cover, Native Wetland Plants	Percent Cover, All Native	Percent Cover, Exotic	Percent Cover, Invasive
412	2.38	1.00	63%	84%	16%	16%
436	2.00	2.00	0%	0%	100%	100%
437	2.13	2.00	1%	5%	95%	93%
458	3.05	2.11	10%	45%	53%	25%
464	3.13	2.51	32%	61%	39%	39%
506	2.19	1.67	32%	32%	68%	68%
573	2.36	1.00	33%	72%	28%	28%
575	2.01	2.00	20%	20%	80%	80%
579	1.45	1.17	67%	67%	31%	31%
594	1.46	1.00	93%	100%	0%	0%
644	2.98	1.11	50%	100%	0%	0%
653	1.55	1.00	57%	57%	20%	20%
669	2.65	1.50	39%	59%	24%	0%
676	2.85	2.67	95%	95%	4%	1%
697	3.54	3.45	41%	85%	6%	6%
719	1.53	1.00	95%	95%	3%	0%
755	2.10	1.14	63%	75%	25%	25%
776	1.92	1.00	72%	78%	23%	13%
821	1.00	1.00	100%	100%	0%	0%
837	2.12	1.15	79%	79%	21%	21%
859	1.05	1.00	100%	100%	0%	0%
882	2.15	1.69	54%	54%	46%	46%
915	1.38	1.00	83%	83%	18%	16%
920	1.91	1.17	41%	41%	59%	52%
922	1.29	1.00	99%	100%	0%	0%
931	1.67	1.00	100%	100%	0%	0%
967	2.86	2.14	76%	93%	3%	3%
967.1	1.78	1.00	58%	58%	40%	25%
975	2.20	1.89	25%	25%	75%	75%
1022	2.04	1.00	50%	60%	23%	13%
1022.2	2.11	1.00	73%	77%	15%	10%
1023	2.77	2.21	13%	14%	85%	40%
1024	2.00	2.00	0%	0%	100%	100%
1038	3.07	2.94	11%	11%	78%	5%
1039	2.08	1.90	48%	48%	53%	53%
1042	2.24	1.00	26%	27%	46%	31%
1072	1.31	1.17	88%	88%	13%	13%
1075	1.71	1.00	77%	77%	21%	12%
1085	2.88	2.42	26%	26%	41%	12%
1087	1.99	1.00	67%	67%	33%	3%
1093	1.92	1.00	60%	67%	28%	0%
1152	2.48	1.00	71%	84%	16%	16%
1165	2.38	1.00	55%	73%	5%	5%
1203	2.17	2.17	9%	9%	45%	0%
1225	2.40	2.10	3%	22%	78%	78%
1253	2.88	2.82	51%	51%	49%	9%

Field ID #	Wetland Prevalence Index, mean of quadrats	Wetland Prevalence Index, minimum of quadrats	Percent Cover, Native Wetland Plants	Percent Cover, All Native	Percent Cover, Exotic	Percent Cover, Invasive
1254	2.00	2.00	0%	0%	100%	100%
1318	2.94	1.00	56%	100%	0%	0%
1347	2.65	1.13	47%	47%	53%	46%
1398	2.30	1.33	82%	98%	0%	0%
1412	2.91	1.00	52%	100%	0%	0%
1433	2.54	2.22	54%	75%	0%	0%
1458	2.80	2.40	87%	87%	7%	7%
1475	1.57	1.08	62%	62%	27%	0%
1484	1.66	1.00	77%	82%	18%	9%
1526	1.75	1.10	51%	51%	27%	27%
1533	1.09	1.00	100%	100%	0%	0%
1575	2.82	2.30	76%	84%	14%	3%
1582	1.92	1.00	59%	60%	40%	8%
1590	2.13	1.83	100%	100%	0%	0%
1628	1.90	1.11	51%	63%	34%	27%
1678	3.22	2.02	28%	75%	24%	0%
1742	1.68	1.00	88%	95%	3%	0%
1746	3.15	2.36	43%	72%	15%	15%
1782	2.00	2.00	0%	0%	100%	100%
1797	3.61	3.23	9%	59%	33%	1%
1801	1.69	1.15	31%	31%	69%	69%
1856	2.00	1.80	14%	15%	85%	84%
1866	1.53	1.53	63%	63%	26%	16%
1884	2.48	1.17	36%	47%	11%	0%
1916	1.59	1.00	31%	33%	68%	47%
1917	3.03	2.00	41%	86%	11%	11%
1940	3.28	3.00	33%	36%	4%	3%
1983	3.39	2.78	30%	83%	10%	0%
1998	3.00	3.00	38%	38%	32%	0%
2085	3.00	3.00	24%	24%	30%	0%
2086	1.08	1.00	97%	100%	0%	0%
2177	1.58	1.00	75%	75%	25%	24%
2182	2.26	1.40	92%	100%	0%	0%
2256	3.14	3.00	54%	54%	32%	0%
2284	1.91	1.00	63%	72%	22%	13%
2287	1.94	1.00	65%	65%	20%	6%
2298	3.26	2.53	14%	52%	26%	25%
2317	2.51	2.11	30%	33%	53%	39%
2320	1.10	1.01	93%	93%	7%	7%

Appendix 2C-6. Frequencies of vascular plant taxa among sites and quadrats sampled during summer 2010 visit to SJC wetlands

-- Sorted in descending order of frequency among sites and then among plots.
-- No attempt was made to survey plant species comprehensively at any site. Four 1x1 m quadrats were surveyed at most of the sites visited.
-- Designation of "Invasive" in red font in the table below was based only on WDOE's (2004) list of wetland-invasive species.

--- WIS (Wetland Indicator Status) from US Fish & Wildlife Service (1988, 1993) official lists:

FAC= About equally likely to occur in wetlands (estimated probability 34% - 66%) or non-wetlands, but a predominance of species with this attribute indicates a jurisdictional wetland.

FACW= Usually occurs in wetlands (estimated probability 67% - 99%), but occasionally found in non-wetlands.

OBL= Almost always occurs (estimated probability > 99%) in wetlands under natural conditions.

NOL= not on list

NI= not a wetland indicator

UPL= upland species

Scientific Name	**# of Sites**	**% of Sites** (of 102)	**# of Quadrats**	**% of Quadrats** (of 422)	**Maximum Percent Cover**	**WIS**	**Native**	**Invasive**
Phalaris arundinacea	74	73%	134	32%	100	FACW	No	**Yes**
Alnus rubra	66	65%	15	4%	100	FAC	Yes	No
Equisetum arvense	60	59%	69	16%	80	FAC	Yes	No
Rosa nutkana	59	58%	38	9%	100	FAC	Yes	No
Holcus lanatus	55	54%	65	15%	90	FAC	No	No
Rubus ursinus	53	52%	64	15%	90	FACU	Yes	No
Agrostis spp.	53	52%	46	11%	90			
Juncus effusus	53	52%	36	9%	95	FACW	Yes	No
Cirsium arvense	48	47%	25	6%	60	FAC	No	**Yes**
Rubus spectabilis	45	44%	33	8%	95	FAC	Yes	No
Rubus armeniacus	43	42%	15	4%	40	FACU	No	**Yes**
Pseudotsuga menziesii	42	41%	1	0%	100	FACU	Yes	No
Symphoricarpos albus	36	35%	27	6%	80	FACU	Yes	No
Festuca rubra	35	34%	39	9%	90	FAC	Yes	No
Carex obnupta	35	34%	37	9%	95	OBL	Yes	No
Pteridium aquilinum	33	32%	14	3%	60	FACU	Yes	No
Typha latifolia	31	30%	14	3%	50	OBL	Yes	No
Polystichum munitum	31	30%	10	2%	40	FACU	Yes	No
forb sp.	29	28%	48	11%	70			
Ranunculus repens	29	28%	21	5%	60	FACW	No	**Yes**
Urtica dioica	26	25%	16	4%	75	FAC	Yes	No
Rumex crispus	26	25%	9	2%	70	FAC	No	No
Crataegus monogyna	25	25%	11	3%	80	FAC	No	**Yes**
Dactylis glomerata	25	25%	8	2%	30	FACU	No	No
Spiraea douglasii	24	24%	10	2%	95	FACW	Yes	No
Lemna minor	23	23%	32	8%	80	OBL	Yes	No
Eleocharis palustris	23	23%	26	6%	70	OBL	Yes	No
Thuja plicata	23	23%	1	0%	85	FAC	Yes	No
Galium trifidum	22	22%	10	2%	20	FACW	Yes	No
Poaceae	21	21%	27	6%	100		Yes	No
Trifolium repens	21	21%	11	3%	60	FAC	No	No
Epilobium ciliatum	20	20%	12	3%	40	FACW	Yes	No
Salix lucida	20	20%	7	2%	100	FACW	Yes	No
Potamogeton natans	20	20%	5	1%	40	OBL	Yes	No
Salix	20	20%	2	0%	60		Yes	No
Carex	19	19%	12	3%	90		Yes	No
Hypochaeris radicata	17	17%	14	3%	35	FACU	No	No
Rubus laciniatus	17	17%	6	1%	20	FACU	No	**Yes**
Pinus contorta	16	16%	1	0%	100	FAC	Yes	No

Scientific Name	# of Sites	% of Sites (of 102)	# of Quadrats	% of Quadrats (of 422)	Maximum Percent Cover	WIS	Native	Invasive
Daucus carota	15	15%	2	0%	20	NOL	No	No
Arrhenatherum elatius	14	14%	14	3%	60	UPL	Yes	No
Oenanthe sarmentosa	14	14%	13	3%	90	OBL	Yes	No
Lotus corniculatus	14	14%	11	3%	40	FAC	No	**Yes**
Juncus arcticus	14	14%	8	2%	70	FACW	Yes	No
Holodiscus discolor	14	14%	4	1%	80	NI	Yes	No
Salix scouleri	14	14%	2	0%	80	FAC	Yes	No
Scirpus microcarpus	13	13%	12	3%	90	OBL	Yes	No
Stachys cooleyae	13	13%	8	2%	90	FACW	Yes	No
Taraxacum officinale	13	13%	6	1%	10	FACU	No	No
Malus fusca	13	13%	2	0%	10	FACW	Yes	No
Senecio jacobaea	13	13%	1	0%	10	FACU	No	**Yes**
Athyrium filix-femina	12	12%	11	3%	30	FAC	Yes	No
Agrostis stolonifera	12	12%	7	2%	95	FAC	No	No
Iris pseudacorus	12	12%	7	2%	80	OBL	No	**Yes**
Poa	11	11%	5	1%	70			No
Taraxicum officinale	11	11%	2	0%	30	FACU	No	No
Gaultheria shallon	10	10%	10	2%	80	FACU	Yes	No
Veronica americana	10	10%	6	1%	15	OBL	Yes	No
Myriophyllum sibiricum	10	10%	5	1%	75	OBL	Yes	No
Lysichiton americanus	10	10%	5	1%	40	OBL	Yes	No
Plantago major	10	10%	1	0%	1	FAC	No	No
Tsuga heterophylla	10	10%	0	0%	30	FACU	Yes	No
Tiarella trifoliata	9	9%	6	1%	20	FAC	Yes	No
Juncus acuminatus	8	8%	6	1%	60	OBL	Yes	No
Salix hookeriana	8	8%	5	1%	80	FACW	Yes	No
Cynosurus echinatus	8	8%	5	1%	20	NOL	No	No
Rosa gymnocarpa	8	8%	4	1%	95	FACU	Yes	No
Carex leptopoda	8	8%	4	1%	20	FAC	Yes	No
Juncus ensifolius	8	8%	3	1%	30	FACW	Yes	No
Sarcocornia perennis	8	8%	2	0%	80	OBL	Yes	No
Nuphar lutea	8	8%	2	0%	25	OBL	Yes	No
Corallorhiza striata	8	8%	1	0%	40	FACU	Yes	No
Alopecurus pratensis	7	7%	10	2%	25	FACW	No	No
Trifolium	7	7%	10	2%	15			No
Elymus repens	7	7%	5	1%	40	FAC	No	No
Argentina egedii	7	7%	5	1%	30	OBL	Yes	No
Salix sitchensis	7	7%	2	0%	70	FACW	Yes	No
Juncus	7	7%	2	0%	10	FACW	Yes	No
Ilex aquifolium	7	7%	0	0%	10	NOL	No	No
Alopecurus aequalis	6	6%	6	1%	95	OBL	Yes	No
Sparganium emersum	6	6%	6	1%	30	OBL	Yes	No
graminoid sp.	6	6%	5	1%	95			
Schoenoplectus acutus	6	6%	4	1%	30	OBL	Yes	No
Myosotis laxa	6	6%	4	1%	25	OBL	Yes	No
Anthoxanthum odoratum	6	6%	3	1%	20	FACU	No	No
Abies grandis	6	6%	1	0%	10	FACU	Yes	No

Scientific Name	# of Sites	% of Sites (of 102)	# of Quadrats	% of Quadrats (of 422)	Maximum Percent Cover	WIS	Native	Invasive
Amelanchier alnifolia	6	6%	1	0%	10	FACU	Yes	No
Achillea millefolium	6	6%	0	0%	35	FACU	Yes	No
Acer macrophyllum	6	6%	0	0%	20	FACU	Yes	No
Vicia americana	5	5%	9	2%	10	FAC	Yes	No
Distichlis spicata	5	5%	5	1%	70	FACW	Yes	No
Galium aparine	5	5%	5	1%	10	FACU	No	No
Hippuris vulgaris	5	5%	4	1%	25	OBL	Yes	No
Vicia	5	5%	4	1%	10			No
Trifolium dubium	5	5%	3	1%	10	UPL	No	No
Geum macrophyllum	5	5%	2	0%	10	FAC	Yes	No
Plantago lanceolata	5	5%	2	0%	5	FAC	No	No
Cirsium vulgare	5	5%	0	0%	10	FACU	No	**Yes**
Cytisus scoparius	5	5%	0	0%	10	UPL	No	Yes
Ribes divaricatum	5	5%	0	0%	1	FAC	Yes	No
Rubus parviflorus	5	5%	0	0%		FAC	Yes	No
Fragaria vesca	4	4%	3	1%	10	NI	Yes	No
Adenocaulon bicolor	4	4%	3	1%	10	NOL	Yes	No
Equisetum hyemale	4	4%	2	0%	15	FACW	Yes	No
Leucanthemum vulgare	4	4%	2	0%	10	NOL	No	**Yes**
Elymus glaucus	4	4%	2	0%	1	FACU	Yes	No
Juncus bufonius	4	4%	1	0%	5	FACW	Yes	No
Gnaphalium palustre	4	4%	1	0%	1	FAC	Yes	No
Sambucus racemosa	4	4%	0	0%	10	FACU	Yes	No
Tanacetum vulgare	4	4%	0	0%	1	NI	No	No
Ribes lacustre	4	4%	0	0%		FAC	Yes	No
Cichorium intybus	4	4%	0	0%		NI	No	No
Circaea alpina	3	3%	3	1%	10	FAC	Yes	No
Lolium perenne	3	3%	2	0%	75	FAC	No	No
Galium	3	3%	2	0%	1			No
Nymphaea odorata	3	3%	1	0%	80	OBL	No	No
Triglochin maritima	3	3%	1	0%	75	OBL	Yes	No
Crataegus douglasii	3	3%	1	0%	30	FAC	Yes	No
Dryopteris expansa	3	3%	1	0%	10	FACW	Yes	No
Lonicera involucrata	3	3%	1	0%	5	FAC	Yes	No
Prunella vulgaris	3	3%	1	0%	5	FACU	Yes	No
Atriplex	3	3%	1	0%	5	FACW	Yes	No
Picea sitchensis	3	3%	0	0%	100	FAC	Yes	No
Populus balsamifera	3	3%	0	0%	20	FAC	Yes	No
Mentha arvensis	3	3%	0	0%		FACW	Yes	No
Sonchus arvensis	3	3%	0	0%		FACU	No	No
Eleocharis ovata	2	2%	6	1%	80	OBL	Yes	No
Eleocharis acicularis	2	2%	6	1%	25	OBL	Yes	No
Mentha piperita	2	2%	4	1%	30	FACW	No	No
Carex aquatilis	2	2%	2	0%	60	OBL	Yes	No
Phleum pratense	2	2%	2	0%	10	FAC	No	No
Veronica scutellata	2	2%	2	0%	5	OBL	Yes	No
Leucanthemum maximum	2	2%	2	0%	5	NOL	No	No

Scientific Name	# of Sites	% of Sites (of 102)	# of Quadrats	% of Quadrats (of 422)	Maximum Percent Cover	WIS	Native	Invasive
Geranium dissectum	2	2%	2	0%	1	NOL	No	No
shrub sp.	2	2%	1	0%	30			
Carex densa	2	2%	1	0%	20	OBL	Yes	No
Tellima grandiflora	2	2%	1	0%	10	NI	Yes	No
Conyza canadensis	2	2%	1	0%	5	FACU	Yes	No
Fragaria virginiana	2	2%	1	0%	5	FACU	Yes	No
Myosotis arvensis	2	2%	1	0%	5	FAC	No	No
Carex echinata	2	2%	1	0%	1	NI	Yes	No
Rubus leucodermis	2	2%	1	0%	1	NI	Yes	No
Galium triflorum	2	2%	0	0%		FACU	Yes	No
Deschampsia cespitosa	2	2%	0	0%		FACW	Yes	No
Leontodon autumnalis	2	2%	0	0%		FAC	No	No
Parentucellia viscosa	2	2%	0	0%		FAC	No	No
Polygonum	2	2%	0	0%				No
Salicornia	1	1%	4	1%	100	OBL	Yes	No
Hypochaeris glabra	1	1%	2	0%	10	NOL	No	No
Vicia sativa	1	1%	2	0%	10	UPL	No	No
Polygonum amphibium	1	1%	2	0%	5	OBL	Yes	No
Elymus trachycaulus	1	1%	2	0%	1	NI	Yes	No
Carex vesicaria	1	1%	1	0%	20	OBL	Yes	No
Osmorhiza purpurea	1	1%	1	0%	10	FAC	Yes	No
Callitriche	1	1%	1	0%	10	OBL	Yes	No
Ceratophyllum demersum	1	1%	1	0%	10	OBL	Yes	No
Calystegia sepium	1	1%	1	0%	10	FAC	No	No
Rubus	1	1%	1	0%	10			
Heracleum lanatum	1	1%	1	0%	5	FAC	Yes	No
Bromus pacificus	1	1%	1	0%	5	NOL	Yes	No
Carex arcta	1	1%	1	0%	5	OBL	Yes	No
Lemna trisulca	1	1%	1	0%	5	OBL	Yes	No
Claytonia sibirica	1	1%	1	0%	1	FAC	Yes	No
Oemleria cerasiformis	1	1%	1	0%	1	FACU	Yes	No
Hippurus vulgaris	1	1%	1	0%	1	OBL	Yes	No
Vulpia myuros	1	1%	1	0%	1	FACU	No	No
Vicia hirsuta	1	1%	1	0%	1	NOL	No	No
Nasturtium officinale	1	1%	1	0%	1	OBL	No	No
Bromus	1	1%	1	0%	1			No
Chamerion angustifolium	1	1%	1	0%		NOL	Yes	No
Salix geyeriana	1	1%	0	0%	40	FACW	Yes	No
Lapsana communis	1	1%	0	0%	10	NI	No	No
Arbutus menziesii	1	1%	0	0%	5	NOL	Yes	No
Prunus laurocerasus	1	1%	0	0%	5	NOL	No	**Yes**
Mahonia aquifolium	1	1%	0	0%	1	NI	Yes	No
Eriophyllum lanatum	1	1%	0	0%	1	NOL	Yes	No
Conium maculatum	1	1%	0	0%	1	FAC	No	No
Alopecurus carolinianus	1	1%	0	0%		FAC	Yes	No
Blechnum spicant	1	1%	0	0%		FAC	Yes	No
Luzula parviflora	1	1%	0	0%		FAC	Yes	No

Scientific Name	# of Sites	% of Sites (of 102)	# of Quadrats	% of Quadrats (of 422)	Maximum Percent Cover	WIS	Native	Invasive
Cerastium arvense	1	1%	0	0%		FACU	Yes	No
Goodyera oblongifolia	1	1%	0	0%		FACU	Yes	No
Pinus monticola	1	1%	0	0%		FACU	Yes	No
Betula papyrifera	1	1%	0	0%		FACW	Yes	No
Carex unilateralis	1	1%	0	0%		FACW	Yes	No
Dodecatheon pulchellum	1	1%	0	0%		FACW	Yes	No
Equisetum telmateia	1	1%	0	0%		FACW	Yes	No
Juncus tenuis	1	1%	0	0%		FACW	Yes	No
Plagiobothrys scouleri	1	1%	0	0%		FACW	Yes	No
Trientalis borealis	1	1%	0	0%		FACW	Yes	No
Epilobium minutum	1	1%	0	0%		NI	Yes	No
Luzula comosa	1	1%	0	0%		NI	Yes	No
Achnatherum occidentale	1	1%	0	0%		NOL	Yes	No
Chimaphila umbellata	1	1%	0	0%		NOL	Yes	No
Erigeron speciosus	1	1%	0	0%		NOL	Yes	No
Lonicera ciliosa	1	1%	0	0%		NOL	Yes	No
Vaccinium ovatum	1	1%	0	0%		NOL	Yes	No
Vicia nigricans	1	1%	0	0%		NOL	Yes	No
Alisma triviale	1	1%	0	0%		OBL	Yes	No
Alopecurus geniculatus	1	1%	0	0%		OBL	Yes	No
Carex exsiccata	1	1%	0	0%		OBL	Yes	No
Carex stipata	1	1%	0	0%		OBL	Yes	No
Mimulus guttatus	1	1%	0	0%		OBL	Yes	No
Rorippa curvisiliqua	1	1%	0	0%		OBL	Yes	No
Utricularia macrorhiza	1	1%	0	0%		OBL	Yes	No
Centaurium erythraea	1	1%	0	0%		FAC	No	No
Festuca arundinacea	1	1%	0	0%		FAC	No	No
Poa annua	1	1%	0	0%		FAC	No	No
Digitalis purpurea	1	1%	0	0%		FACU	No	No
Ranunculus acris	1	1%	0	0%		FACW	No	No
Aira caryophyllea	1	1%	0	0%		NOL	No	No
Madia	1	1%	0	0%				No

Appendix 2D. Environment Summary Tables from GIS Compilation of Existing Spatial Data

2D-1. Wetlands

2D-1.1. Protection status of possible wetlands, by island
2D-1.2. Possible wetlands on protected lands, by owner
2D-1.3. Possible wetlands on undeveloped parcels
2D-1.4. Possible wetlands on developed parcels
2D-1.5. Possible wetlands within various distances of the marine shoreline
2D-1.6. Acreage of tidal wetlands by island
2D-1.7. Possible wetlands by lithology mapped at 1:100,000 scale
2D-1.8. Possible wetlands by aquifer recharge potential
2D-1.9. Possible wetlands and mapped soils: hydric, partially hydric, and non-hydric

2D-1.10. Vegetation communities for which high-quality examples are rare in SJC according to the WDNR Natural Heritage Program, and which occur in possible SJC wetlands.
2D-1.11. Possible wetlands within 100 feet of cliffs taller than 25 feet according to LiDAR analysis
2D-1.12. Slope of possible wetlands according to LiDAR analysis
2D-1.13. Elevation of possible wetlands according to LiDAR analysis
2D-1.14. Associations of possible wetlands with mapped lakes
2D-1.15. Associations of possible wetlands with mapped ponds
2D-1.16. Length (ft) of streams that intersect possible wetlands, by stream type
2D-1.17. Length (ft) of streams that may intersect possible wetlands
2D-1.18. Number of buildings within possible wetlands, by building type
2D-1.19. Length (ft) of roads where they intersect possible wetlands
2D-1.20. Length (ft) of driveways where they intersect possible wetlands
2D-1.21. Land cover types predominating within or around possible wetlands during 1990's
2D-1.22. Intersection of possible wetlands with landscape disturbance scores assigned by Jacobson (2008) based mainly on maps of 1990's land use and current road density
2D-1.23. Landscape connectivity: numbers of wetlands by size of contiguous wooded area
2D-1.24. Structurally complex wetlands of SJC as identified using LiDAR

2D-1.1. Protection status of possible wetlands, by island

All SJC wetlands are protected to some degree, but those categorized as Protected here and elsewhere in this chapter are ones on government lands, or which for which conservation is the legally designated use. Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on protection status of particular wetlands can be found in accompanying electronic files.

	Wetland is not within protected lands	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Wetland is completely within protected lands except for road	Total
Blakely	197.03						197.03
Crane	0.27						0.27
Decatur	48.48						48.48
Henry	15.79		0.49				16.28
James					0.43		0.43
Johns	8.34						8.34
Little Sucia					0.46		0.46
Lopez	830.41	0.20	374.75	5.11	122.84		1333.30
Orcas	1062.73	54.77	335.22	213.00	275.84		1941.56
San Juan	1661.72	57.50	1058.41	3.06	50.58	6.94	2838.21
Shaw	94.03	2.89	0.25		7.55		104.72
Stuart	24.54				6.21		30.75
Sucia			3.29		4.63		7.92
Waldron	15.50		9.58		26.73		51.81
Total	3958.85	115.36	1781.97	221.17	495.28	6.94	6579.56

2D-1.2. Possible wetlands on protected lands, by owner

Raw data provided by San Juan County, August 2010, and no guarantee is made of its comprehensiveness or accuracy in all cases. Information on ownership of protected lands that intersect particular wetlands can be found in accompanying electronic files.

	Land Bank Full Built Out Conservation Easements	Land Bank Preserve	San Juan County Parks	San Juan Preservation Trust – Fully Protected Conservation Easement	San Juan Preserva-tion Trust Preserve	State Parks & Recreation	State Lands Division	The Nature Conservancy	US Gov.	US BLM	U. Washington	WDFW	Total (acres)
Henry				0									0
James							0.43						0.43
Little Sucia							0.46						0.46
Lopez	10.04	25.82	4.19	139.16	1.2		6.82		6.71	45.49			239.43
Orcas	3.3	136.06		83.77	18.8	14.71	64.32					34.39	355.35
San Juan	63.04	142.54		111.68	65.14		13.87		22.55		0.08		418.9
Shaw				7.64	0.02								7.66
Stuart				5.25			0.97						6.22
Sucia							7.83						7.83
Waldron				2.59				30.06					32.65
Total	76.38	304.42	4.19	350.09	85.16	14.71	94.7	30.06	29.26	45.49	0.08	34.39	1068.93

2D-1.3. Possible wetlands on undeveloped parcels

Raw data provided by San Juan County, August 2010, and no guarantee is made of its comprehensiveness or accuracy in all cases. Information on developed status of parcels intersecting particular wetlands can be found in accompanying electronic files.

	Wetland is not within protected lands and is on undeveloped parcel	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Total (acres)
Blakely	100.33					100.33
Crane	0.01					0.01
Decatur	11.95					11.95
Henry	0.55					0.55
James					0.43	0.43
Little Sucia					0.46	0.46
Lopez	388.23	0.17	130.86	4.85	67.33	591.44

	Wetland is not within protected lands and is on undeveloped parcel	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Total (acres)
Orcas	444.91	28.46	118.93	4.77	24.07	621.14
San Juan	642.35	28.07	373.52	0.01	17.77	1061.72
Shaw	32.02	0.05	0.25		6.95	39.27
Stuart	4.7					4.7
Sucia			3.2			3.2
Waldron	5.31		3.11		0.87	9.29
Total (acres)	1630.36	56.75	629.87	9.63	117.88	2444.49

2D-1.4. Possible wetlands on developed parcels

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on developed status of parcels intersecting particular wetlands can be found in accompanying electronic files.

	Wetland is not within protected lands and is on undeveloped parcel	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Total (acres)
Blakely	96.7				96.7
Crane	0.26				0.26
Decatur	36.45				36.45
Henry	15.23		0.49		15.72
Johns	8.34				8.34
Lopez	535.97		190.96		726.93
Orcas	832.97	25.21	86.37	0.31	944.86
San Juan	1150.24	28.4	533.97	0	1712.61
Shaw	61.85	2.85	0		64.7
Stuart	25.53				25.53
Sucia	4.63				4.63
Waldron	40.42		2.09		42.51
Total (acres)	2808.59	56.46	813.88	0.31	3679.24

2D-1.5 Possible wetlands within various distances of the marine shoreline

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases.

	Within 150 ft		Within 300 ft		Within 0.5 mile		Within 1 mile	
Protection Status	**Wetland acres**	**# of wetlands**	**Wetland acres**	**# of wetlands**	**Wetland acres**	**# of wetlands**	**Wetland acres**	**# of wetlands**
Wetland is not within protected lands	36.43	114	87.3	190	1375.9	1191	2834.56	1833
Wetland barely intersects protected lands			0.13	1	28.96	9	54.62	23
Wetland intersects protected lands	7.88	14	24.71	18	370.71	92	911.45	127
Wetland is almost completely within protected lands					33.34	8	217.79	15
Wetland is completely within protected lands	4.58	9	9.74	18	6.09	2	226.19	125
Wetland is completely within protected lands except for road							6.94	2
Total	48.89	137	121.88	227	1815	1302	4251.55	2125

2D-1.6. Acreage of tidal wetlands by island

Mostly as interpreted from LiDAR imagery and existing spatial data on wetlands and coastal habitats, April 2010.

Island	Sum of Acres
Decatur	12.76
Henry	29.14
Lopez	60.18
Orcas	3.72
San Juan	19.91
Shaw	2.06
Sucia	0.01

2D-1.7. Possible wetlands by lithology mapped at 1:100,000 scale

Raw data provided by San Juan County, August 2010. Lithology of individual wetlands can be found in accompanying electronic file, but due to scale of source map it may not be accurate.

	Wetland is not within protected lands	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Wetland is completely within protected lands except for road	Total (acres)
advance continental glacial outwash, Fraser-age	0.1						0.1
alluvium	0.38		0.73		14.25		15.36
artificial fill, including modified land	0.24						0.24
basalt flows	4.27						4.27
beach deposits	43.06		22.51		1.04		66.61
chert-rich marine sedimentary rocks	86.82	0.43	14.69	5.03	4.09		111.06
continental glacial drift, Fraser-age	985.16	55.64	495.4	9.83	144.61		1690.64
continental glacial outwash, Fraser-age	32.25						32.25
continental glacial outwash, marine, Fraser-age	82.15		33.76	0.74	0.96		117.61
continental glacial till, Fraser-age	621.78	14.54	147.43	5.18	13.97		802.9
continental sedimentary deposits or rocks					0.25		0.25
glacial and non-glacial deposits, undivided	0.04						0.04
glaciomarine drift, Fraser-age	654.42	11.01	687.2	1.11	21.88	6.94	1382.56
intrusive rocks, undivided	180.07	2.91	2.86	4.46	25.52		215.82
marine metasedimentary rocks	420.43	5.99	64.83		2.5		493.75
marine sedimentary rocks	218.16	7.45	38.93	23.1	44.63		332.27
mass-wasting deposits, mostly landslides	0.03						0.03
metasedimentary and metavolcanic rocks, undivided	15.91				0.86		16.77
metasedimentary rocks, chert-bearing	56.51		0.41		0.33		57.25
metasedimentary rocks, cherty	6.5				0.06		6.56
metavolcanic rocks	39.29	0.58	1.09		4.54		45.5
nearshore sedimentary rocks	29.15				5.25		34.4
peat deposits	15.16		44.81		6.95		66.92
schist, low grade	1.53				0.46		1.99
tectonic zone	2.22						2.22
volcanic and sedimentary rocks	82.21	3.37	6.66		5.11		97.35
volcanic rocks	1.93						1.93
water	378.67	13.43	213.89	171.71	197.59		975.29
Total (acres)	3958.44	115.35	1775.2	221.16	494.85	6.94	6571.94

2D-1.8. Possible Wetlands by Aquifer Recharge Potential

Raw data provided by San Juan County, August 2010. Recharge potential based only on 1962 countywide soil survey. Many other factors influence recharge. Newer soils data exist but are not reflected by this table.

	Recharge Potential			
	High	Medium	Low	Total (acres)
Wetland is not within protected lands	151.55	96.27	3986.79	4234.61
Wetland barely intersects protected lands	0.17	4.78	137.6	142.55
Wetland intersects protected lands	24.31	18.46	1937.36	1980.13
Wetland is almost completely within protected lands			37.75	37.75
Wetland is completely within protected lands	6.7	8.3	329.4	344.4
Wetland is completely within protected lands except for road	0.76	3.59	2.59	6.94
Total (acres)	**183.49**	**131.4**	**6431.49**	**6746.38**

2D-1.9 Possible wetlands and mapped soils: hydric, partially hydric, and non-hydric

Areas with hydric soils have a relatively high probability of containing wetlands, even when no wetlands are mapped. Those marked as partially hydric contain inclusions of hydric soil in some parts of San Juan County, but not consistently. Wetlands can also occur on soils that are not mapped as hydric, due partly to the coarse resolution of the soil maps, and in some cases to the creation of wetlands on those soils by excavation (e.g., farm ponds) or prolonged impoundment (unculverted roads, beaver). Raw data provided by San Juan County, August 2010, based on NRCS 2009 soil survey. Soil types mapped within individual wetlands can be found in accompanying electronic file, but due to scale of source maps that information is not always accurate.

Hydric (H) or Partially Hydric (P)	Soil Name	Acres in County	Acres in Possible Wetlands	Possible Wetlands as % of Soil Type	Acres of possible wetlands not within protected lands
H	Bazal-Mitchellbay complex, 0 to 5 % slopes	1442	202.75	14%	121.9
H	Coupeville loam, 0 to 5 % slopes	687	233.35	34%	130.11
H	Coveland loam, 0 to 5 % slopes	6366	1010.33	16%	610.39
H	Coveland-Mitchellbay complex, 2 to 15 % slopes	2538	207.2	8%	143.79
H	Dugualla muck, 0 to 2 % slopes	189	120.67	64%	32.22
H	Limepoint-Sholander complex, 0 to 8 % slopes	1479	309.22	21%	230.81
H	Orcas peat, 0 to 2 % slopes	51	48.9	96%	13.02
H	Semiahmoo muck, 0 to 2 % slopes	724	650.6	90%	204.59
H	Shalcar muck, 0 to 2 % slopes	644	529.36	82%	289.75
H	Water, fresh	1241	1194.42	96%	529.96

Hydric (H) or Partially Hydric (P)	Soil Name	Acres in County	Acres in Possible Wetlands	Possible Wetlands as % of Soil Type	Acres of possible wetlands not within protected lands
	SUBTOTAL, hydric soils	15361	4506.8	29%	2306.54
P	Beaches-Endoaquents,tidal-Xerorthents association, 0 to 5 % slopes	2383	19.05	1%	12.16
P	Deadmanbay-Bazal-Cady complex, 2 to 20 % slopes	1315	124.44	9%	98.06
P	Deadmanbay-Morancreek complex, 2 to 15 % slopes	2111	177.18	8%	166.32
P	Limepoint-Alderwood, warm-Sholander complex, 2 to 12 % slopes	484	21.25	4%	20.26
P	Mitchellbay gravelly sandy loam, 0 to 5 % slopes	3831	230	6%	184.83
P	Mitchellbay-Rock Outcrop-Killebrew complex, 3 to 15 % slopes	2137	68.8	3%	62.26
P	Mitchellbay-Sholander-Bazal complex, 0 to 8 % slopes	2982	151.78	5%	113.29
P	Sholander-Spieden complex, 0 to 5 % slopes	1167	174.99	15%	143
P	Sucia-Sholander complex, 5 to 20 % slopes	922	34.16	4%	30.55
P	Xerorthents-Endoaquents, tidal association, 0 to 100 % slopes	87	0	0%	0
	Subtotal, partially hydric soils	17419	1001.65	6%	830.73
	SUBTOTAL, hydric + partial hydric	32780	5508.45	17%	3137.27
	Alderwood, warm-Hoypus complex, 5 to 20 % slopes	236	1.16	0%	1.16
	Alderwood-Everett complex, warm, 5 to 15 % slopes	1859	36.34	2%	29.92
	Cady-Rock Outcrop complex, 25 to 75 % slopes	6824	19.61	0%	14.21
	Cady-Rock Outcrop complex, 5 to 30 % slopes	11297	84.04	1%	57.52
	Constitution-Skipjack-Kahboo complex, 5 to 25 % slopes	1747	88.84	5%	46.64
	Doebay, moist-Cady-Doebay complex, 25 to 75 % slopes	1102	3.72	0%	0.47
	Doebay, moist-Cady-Rock Outcrop complex, 10 to 30 % slopes	4178	60.17	1%	50.07
	Doebay-Cady-Rock Outcrop complex, 10 to 30 % slopes	11053	102.33	1%	84.06
	Doebay-Morancreek complex, 5 to 25 % slopes	3133	58.98	2%	51.4
	Everett sandy loam, warm, 20 to 40 % slopes	171	0.72	0%	0.57
	Everett sandy loam, warm, 3 to 20 % slopes	2453	27.33	1%	20.9
	Haro-Hiddenridge-Rock Outcrop complex, 25 to 75 % slopes	1010	0.51	0%	0.09
	Haro-Hiddenridge-Rock Outcrop complex, 5 to 30 % slopes	3487	10.7	0%	9.35
	Hoypus sandy loam, 10 to 40 % slopes	324	0.32	0%	0.32
	Hoypus sandy loam, 3 to 25 % slopes	414	1.21	0%	0.76
	Hoypus-Whidbey complex, 10 to 30 % slopes	742	2.26	0%	1.82
	Indianola loamy sand, warm, 3 to 15 % slopes	1294	11.18	1%	10.59
	Keystone sandy loam, 5 to 15 % slopes	274	1.25	0%	0.33
	Laconner gravelly sandy loam, warm, 5 to 15 % slopes	564	4.69	1%	4.69

Hydric (H) or Partially Hydric (P)	Soil Name	Acres in County	Acres in Possible Wetlands	Possible Wetlands as % of Soil Type	Acres of possible wetlands not within protected lands
	Mitchellbay gravelly sandy loam, 5 to 15 % slopes	4167	175.53	4%	134.48
	Pickett-Kahboo-Rock Outcrop complex, 25 to 75 % slopes	3817	16.13	0%	7.76
	Pilepoint loam, 2 to 8 % slopes	696	8.06	1%	7.47
	Pits, gravel	111	5.11	5%	5.11
	Roche-Haro-Rock Outcrop complex, 5 to 25 % slopes	541	20.76	4%	5.92
	Roche-Killebrew complex, 2 to 10 % slopes	4337	117.68	3%	104.85
	Roche-Killebrew-Rock Outcrop complex, 5 to 35 % slopes	5141	87.6	2%	74.34
	Roche-Mitchellbay complex, 3 to 15 % slopes	1300	12.41	1%	11.65
	Rock Outcrop-Haro complex, 25 to 75 % slopes	1199	1.22	0%	0.28
	San Juan sandy loam, 2 to 8 % slopes	440	8.65	2%	5.57
	San Juan sandy loam, 20 to 40 % slopes	55	0	0%	0
	San Juan sandy loam, 5 to 20 % slopes	264	0.16	0%	0
	San Juan-Dune land complex, 0 to 20 % slopes	78	0.46	1%	0
	Sholander gravelly loam, 2 to 8 % slopes	238	10.84	5%	3.53
	Sucia loamy sand, 2 to 10 % slopes	945	44.24	5%	40.6
	Turtleback-Cady-Rock Outcrop complex, 25 to 75 % slopes	2500	7.97	0%	6.14
	Whidbey gravelly loam, 3 to 15 % slopes	1643	24.46	1%	15.43
	Whidbey-Hoypus complex, 2 to 15 % slopes	2451	14.52	1%	13.47
	TOTAL, All Soils	180425	17596.51	10%	10233.28

2D-1.10. Vegetation communities for which high-quality examples are rare in SJC according to the WDNR Natural Heritage Program, and which occur in possible SJC wetlands.

Raw data provided by WDNR, June 2010. Some double-counting of acres may have occurred when multiple features occur in the same area. Identification number of wetlands in which these occur can be found in an accompanying electronic file.

WDNR Vegetation Community	Wetland is not within protected lands	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Total (acres)
Blunt-leaved pondweed	1.3	0.01	38.19		10.07	49.57
California buttercup	1.03					1.03
Common Marestail				17.3		17.3
Cusick's Sedge - (Sitka Sedge) / Sphagnum Spp.				17.3		17.3

WDNR Vegetation Community	Wetland is not within protected lands	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Total (acres)
Douglas-fir - Fir Forest			0.06		2.22	2.28
Douglas-fir - Pacific Madrone / American Purple Vetch					2.6	2.6
Douglas-fir - Western Hemlock / Dwarf Oregongrape	0.61		13.59		57.84	72.04
Douglas-fir - Western Hemlock / Oceanspray / Swordfern	1.03		11.32	1.57	80.6	94.52
Douglas-fir / Baldhip Rose - Oceanspray	0.61		10.71		39.52	50.84
Hard-stem Bulrush	10.62					10.62
Lodgepole Pine - Douglas-fir Forest	0.07			0.55	8.6	9.22
Lodgepole Pine Forest					0.01	0.01
Low Elevation Freshwater Wetland	14.53					14.53
Saltgrass - (Pickleweed)			2.76			2.76
Sand: Partly Enclosed, Eulittoral, Euhaline (Marsh)			2.51			2.51
Shore Pine - Douglas-fir / Salal					0.19	0.19
Sitka Sedge	1.84					1.84
Water Lobelia					132.27	132.27
Western Redcedar - Fir / Swordfern	0.15				2.56	2.71
Yellow Pond-lily				17.3		17.3
Total (acres)	31.79	0.01	79.14	54.02	336.48	501.44

2D-1.11. Possible wetlands within 100 feet of cliffs taller than 25 feet according to LiDAR analysis

Cliffs are recognized by WDFW as a Priority Habitat and are important as complementary habitat of several wetland species. Identification numbers of these possible wetlands can be found in an accompanying electronic file.

SJC Protection Status	Acres	# of wetlands
Wetland not within protected lands	34.93	98
Wetland barely intersects protected lands	0.15	2
Wetland intersects protected lands	3.6	17
Wetland is almost completely within protected lands	2.31	3
Wetland is completely within protected lands	5.53	10

SJC Protection Status	Acres	# of wetlands
Total	46.52	130

2D-1.12. Slope of possible wetlands according to LiDAR analysis

Due to spatial resolution limitations, in a limited number of cases small areas of steep slope near a wetland may have been included in acreage estimates of the mapped wetland. Slope of individual wetlands can be found in an accompanying electronic file.

Predominant Percent Slope of Possible Wetlands (from LiDAR topography)	% of all SJC wetlands
0 to 1% slope	11%
1 to 2% slope	24%
2 to 3% slope	15%
3 to 4% slope	2%
4 to 5% slope	1%
5 to 7% slope	18%
7 to 10% slope	10%
10 to 15% slope	9%
15 to 30% slope	3%
>30% slope	7%

2D-1.13. Elevation of possible wetlands according to LiDAR analysis

Due to spatial resolution limitations, in a limited number of cases small areas of higher or lower elevation near a wetland may have been included in the mapped wetland. Elevation of individual wetlands can be found in an accompanying electronic file.

SJC Protection Status	Elevation mean among wetlands (ft)	Elevation range among wetlands	Elevation maximum among wetlands
Wetland not within protected lands	199	9	2186
Wetland barely intersects protected lands	242	30	932
Wetland intersects protected lands	167	21	1129
Wetland is almost completely within protected lands	434	13	2026
Wetland is completely within protected lands	644	6	2253
Wetland is completely within protected lands except for road	123	8	132

2D-1.14. Associations of possible wetlands with mapped lakes

In most cases these acreage figures include deep water as well as vegetated wetland.

Lake (>20 acres)	Not within protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Wetland Acres
Cascade Lake			175.31		175.31
Horseshoe Lake	74.26				74.26
Hummel Lake		34.2			34.2
Martin Lake	28.63				28.63
Mountain Lake				193.68	193.68
Roche Harbor Lake	39.74				39.74
Spencer Lake	66.21				66.21
Sportsmans Lake		77.41			77.41
Trout Lake	58.89				58.89
Woods Lake	24.25				24.25
Zylstra Lake		47.89			47.89
Total (acres)	291.98	159.5	175.31	193.68	820.47

2D-1.15. Associations of possible wetlands with mapped ponds

These acreage figures include deep water as well as vegetated wetland.

	Not within protected lands	Wetland intersects protected lands	Wetland is completely within protected lands	Wetland barely intersects protected lands	Wetland is almost completely within protected lands	Total Acres
Blakely	3.21	0	0	0	0	3.21
Crane	0.27	0	0	0	0	0.27
Decatur	5.27	0	0	0	0	5.27
Henry	1.15	0	0	0	0	1.15
Lopez	35.93	9.52	0.19	0	0	45.64
Orcas	164.19	28.24	20.19	17.11	12.9	242.63
San Juan	315.56	36.37	12.15	19.12	1.86	385.06
Shaw	24.32	0.25	7.55	0	0	32.12
Stuart	1	0	0	0	0	1

	Not within protected lands	Wetland intersects protected lands	Wetland is completely within protected lands	Wetland barely intersects protected lands	Wetland is almost completely within protected lands	Total Acres
Waldron	2.86	4.75	11.82	0	0	19.43
Total Acres	553.76	79.13	51.9	36.23	14.76	735.78

2D-1.16. Length (ft) of streams that intersect possible wetlands, by stream type

Raw data provided by San Juan County, August 2010, and does not include Lopez Island or smaller islands. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on category of stream that may intersect a particular wetland can be found in accompanying electronic files.

	Wetland is not within protected lands	Wetland barely intersects protected lands	Wetland intersects protected lands	Wetland is almost completely within protected lands	Wetland is completely within protected lands	Total (ft)
Type F	78901	9922	31294	2694	2885	125696
Type Np	548			267		815
Type Ns	1007				81	1088
No Channel	1402			91		1493
Unsurveyed	59225	4542	30462	1014	1362	96604
Total (ft)	141083	14464	61755	4065	4328	225695

2D-1.17. Length (ft) of streams that may intersect possible wetlands

Raw data provided by San Juan County, August 2010, and based partly on the County's analysis of LiDAR imagery. No guarantee is made of its comprehensiveness or accuracy in all cases. Unverified information on the intermittent streams that may intersect a particular wetland can be found in accompanying electronic files.

	Wetland is not	Wetland	Wetland	Wetland is	Wetland is	Wetland is	Total (ft)

	within protected lands	barely intersects protected lands	intersects protected lands	almost completely within protected lands	completely within protected lands	completely within protected lands except for road	
Blakely	41646						41646
Decatur	10281						10281
Henry	4402		303				4705
James					62		62
Lopez	159219	60	75703	1614	15707		252303
Orcas	267022	16795	74659	30823	50432		439730
San Juan	382428	12568	171436	1278	12274	2204	582188
Shaw	22300	566			927		23792
Total	887298	29989	322101	33715	79402	2204	1354708

2D-1.18. Number of buildings within possible wetlands, by building type

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Unverified information on buildings in parcels that may intersect a particular wetland can be found in accompanying electronic files.

	Commercial	Town-owned	Residential	Other	Total
Blakely				2	2
Lopez			20	7	27
Orcas	4		24	15	43
San Juan		4	10	13	27
Total	**4**	**4**	**54**	**37**	**99**

2D-1.19. Length (ft) of roads where they intersect possible wetlands

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on roads that may intersect a particular wetland can be found in accompanying electronic files.

	Blakely	Decatur	Henry	Lopez	Orcas	San Juan	Shaw	Stuart	Total
Private	83	959	135	4672	9380	11676	234	263	27402
Public		163		5720	11358	15769	780		33790
Total	**83**	**1123**	**135**	**10392**	**20738**	**27446**	**1014**	**263**	**61193**

2D-1.20. Length (ft) of driveways where they intersect possible wetlands

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on roads that may intersect a particular wetland can be found in accompanying electronic files.

	Feet	#
Blakely	386	8
Lopez	11047	91
Orcas	16574	157
San Juan	17903	154
Shaw	161	2
Total	**46071**	**412**

2D-1.21. Land cover types predominating within or around possible wetlands during 1990's

Spatial data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases. Information on land cover that may intersect a particular wetland can be found in accompanying electronic files, but due to scale of unverified source map it may not be accurate.

Land Cover Category (from aerial interpretation)	# of Wetlands	Acres
Evergreen Forest	872	58,425,196
Grassland/ Pasture	580	58,425,196
Wetland: emergent	152	62,784,562
Low Density Settlement	138	9,445,294
Mixed Forest	133	9,706,856
Shrubland	96	10,433,417
Wetland: forested	67	16,798,091
Wetland: shrub	39	19,859,335
Deciduous Forest	31	2,266,870
Developed Open Space	31	3,564,993
Water	15	31,716,812
Medium Density Settlement	13	745,936
Wetland: Tidal	8	581,249
Cultivated Land	6	1,084,998
Bare	5	280,937
Wetland: aquatic bed	4	3,196,869

Land Cover Category (from aerial interpretation)	# of Wetlands	Acres
High Density Settlement	1	29,062

2D-1.22. Intersection of possible wetlands with landscape disturbance scores assigned by Jacobson (2008) based mainly on maps of 1990's land use and current road density

See Chapter 4, section 4.3.1.5 for description of Jacobson's Local Habitat Assessment for SJC. Information on landscape disturbance score for a particular wetland can be found in accompanying electronic files, but due to scale and time period of the unverified map of land cover used as a source, it may not be accurate.

Jacobson score	Wetland acres	# of wetlands
1 Most disturbance	0.62	8
2	22.78	52
3	194.3	670
4	196.22	654
5	264.62	578
6	770.28	819
7	225.4	431
8	1518.12	1559
9	2005.13	1277
10	247.26	213
11 Least disturbance	1123.25	435

2D-1.23. Landscape connectivity: numbers of wetlands by size of contiguous wooded area

Contiguous wooded acres determined from analysis of LiDAR imagery. Gaps wider than about 30 ft were considered to interrupt connectivity. Roads were not considered unless creating a canopy gap wider than approximately that width.

Wooded Acres Contiguous to Possible Wetlands	# of Possible Wetlands	Average Patch Area of Wooded Acreage in that Size Category
< 1 acre	996	0.10
1 – 10 acres	137	4.12
10 – 100 acres	181	42.37
100 – 1000 acres	326	362.15
1000- 10,000 acres	737	4406.36
>10,000 acres	260	11758.01

2D-1.24. Structurally complex wetlands of SJC as identified using LiDAR

These are possible wetlands for which the smallest percentage of four vegetation height categories (< 1 ft, 1-3 ft, 3-20 ft, >20 ft) was greater than 10% according to the LiDAR analysis. This correlates with relative evenness of these structural categories within or near the possible wetlands, which is an indication of the diversity of plant and wildlife species the wetlands could support. MVHC= Minimum Vegetation Height Category. A >10% threshold was used to correspond with the WDOE *Rating System*.

WetID	Island	Latitude	Longitude	MVHC
5009	Henry	48.6200	123.1804	16%
5041	San Juan	48.6035	123.1534	13%
5051	San Juan	48.6080	123.1386	11%
5059	San Juan	48.6135	123.1392	12%
5101	San Juan	48.5838	123.0987	13%
5110	San Juan	48.5838	123.1121	11%
5112	San Juan	48.5866	123.1040	11%
5140	San Juan	48.5937	123.1236	14%
5150	San Juan	48.5740	123.1219	14%
5152	San Juan	48.5785	123.1189	17%
5158	San Juan	48.5706	123.1016	11%
5161	San Juan	48.5818	123.0977	18%
5162	San Juan	48.5805	123.1084	14%
5163	San Juan	48.5724	123.1095	14%
5169	San Juan	48.5721	123.1097	18%
5172	San Juan	48.5708	123.0950	14%
5195	San Juan	48.5841	123.1243	17%
5214	San Juan	48.5633	123.1683	11%
5217	San Juan	48.5623	123.1541	11%
5244	San Juan	48.5601	123.0912	12%
5247	San Juan	48.5639	123.0863	11%
5255	San Juan	48.5490	123.0528	12%
5260	San Juan	48.5589	123.0784	11%
5264	San Juan	48.5513	123.0852	17%
5267	San Juan	48.5637	123.0834	13%
5288	San Juan	48.5683	123.0574	14%
5291	San Juan	48.5592	123.0271	15%
5303	San Juan	48.5571	123.0636	12%
5306	San Juan	48.5451	123.0407	12%
5318	San Juan	48.5384	123.0219	11%
5321	San Juan	48.5358	123.0343	19%
5329	San Juan	48.5550	123.0703	13%
5330	San Juan	48.5613	123.0749	11%
5339	San Juan	48.6003	123.1192	11%
5341	San Juan	48.5503	123.0083	17%
5343	San Juan	48.5524	123.1561	13%
5350	San Juan	48.5527	123.0466	12%
5363	San Juan	48.5543	123.1624	20%
5368	San Juan	48.5588	123.1476	16%
5376	San Juan	48.5495	123.1305	19%
5401	San Juan	48.5951	123.1115	13%
5406	San Juan	48.5496	123.0626	15%
5407	San Juan	48.5454	123.0782	11%
5411	San Juan	48.5480	123.0922	14%
5414	San Juan	48.5503	123.0999	16%
5418	San Juan	48.5473	123.1001	16%
5429	San Juan	48.5484	123.1154	18%
5440	San Juan	48.5312	123.0878	18%
5466	San Juan	48.5364	123.0475	17%
5469	San Juan	48.5381	123.0429	12%
5472	San Juan	48.5138	123.0240	13%
5495	San Juan	48.5284	122.9834	11%
5500	San Juan	48.5234	122.9779	11%
5510	San Juan	48.5222	123.0217	11%
5528	San Juan	48.5128	123.0313	17%
5563	San Juan	48.5349	123.0773	18%
5584	San Juan	48.5341	123.1004	13%
5601	San Juan	48.5363	123.1515	15%
5623	San Juan	48.5228	123.1087	11%
5635	San Juan	48.5114	123.1116	15%
5639	San Juan	48.5115	123.1338	22%
5648	San Juan	48.5026	123.1047	17%
5661	San Juan	48.5054	123.0976	12%
5666	San Juan	48.4888	123.0800	15%
5668	San Juan	48.5022	123.0889	15%
5684	San Juan	48.4991	123.0551	13%
5714	San Juan	48.4838	123.0789	14%
5729	San Juan	48.5037	123.0407	20%
5731	Lopez	48.4642	122.9333	11%
5734	San Juan	48.4941	123.0232	12%
5743	San Juan	48.4906	123.0739	11%
5750	San Juan	48.4915	123.0962	11%
5773	San Juan	48.4834	123.0364	13%
5784	San Juan	48.4828	123.0392	11%
5785	San Juan	48.4807	123.0445	12%
5839	Shaw	48.5570	122.9627	14%
5845	Shaw	48.5765	122.9622	18%
5848	Shaw	48.5794	122.9786	17%
5852	Shaw	48.5869	122.9652	13%
5862	Orcas	48.6237	122.9264	19%
5874	Shaw	48.5728	122.9352	19%

WetID	Island	Latitude	Longitude	MVHC
5875	Shaw	48.5773	122.9756	18%
5882	Orcas	48.5971	122.8939	15%
5883	Shaw	48.5780	122.9178	15%
5884	Shaw	48.5762	122.9284	12%
5931	Orcas	48.6328	123.0037	14%
5956	Orcas	48.6396	122.9966	13%
5958	Orcas	48.6514	122.9967	11%
5988	Orcas	48.6768	122.9742	20%
6004	Orcas	48.6875	122.9562	11%
6009	Orcas	48.6884	122.9352	14%
6051	Orcas	48.6802	122.9357	11%
6063	Orcas	48.7036	122.9298	12%
6072	Orcas	48.7043	122.8832	16%
6085	Orcas	48.6067	122.8758	11%
6147	Orcas	48.6591	122.9439	12%
6153	Orcas	48.6275	122.9972	13%
6164	Orcas	48.6578	122.9510	12%
6194	Orcas	48.6521	122.9592	13%
6203	Orcas	48.6409	122.9171	14%
6208	Orcas	48.6410	122.9288	13%
6228	Orcas	48.6173	122.9214	12%
6230	Orcas	48.6123	122.8950	11%
6232	Orcas	48.6479	122.9199	12%
6235	Orcas	48.6462	122.9536	12%
6254	Orcas	48.5956	122.9020	11%
6255	Orcas	48.6053	122.9113	13%
6260	Orcas	48.6178	122.9292	15%
6277	Orcas	48.6190	122.9412	12%
6288	Orcas	48.6159	122.9249	17%
6289	Orcas	48.6114	122.9337	11%
6302	Orcas	48.6037	122.9396	15%
6314	Orcas	48.6058	122.9137	11%
6318	Orcas	48.6051	122.9015	11%
6328	Orcas	48.6133	122.8818	11%
6356	Blakely	48.5525	122.8131	12%
6358	Orcas	48.6101	122.8694	11%

WetID	Island	Latitude	Longitude	MVHC
6361	Orcas	48.6120	122.8702	15%
6365	Orcas	48.6299	122.8522	11%
6368	Orcas	48.7102	122.8860	14%
6387	Orcas	48.7083	122.8853	15%
6468	Orcas	48.6133	122.8212	11%
6470	Orcas	48.6140	122.8172	11%
6491	Orcas	48.6354	122.8329	19%
6506	Orcas	48.6349	122.8041	14%
6518	Blakely	48.5510	122.7980	11%
6520	Orcas	48.6600	122.7737	11%
6535	Orcas	48.6560	122.7834	13%
6586	Orcas	48.6357	122.9014	14%
6591	Orcas	48.6386	122.9110	17%
6600	Blakely	48.5492	122.7953	14%
6610	Decatur	48.5152	122.8126	17%
6611	Decatur	48.5184	122.8004	21%
6612	Decatur	48.5166	122.8149	19%
6627	Decatur	48.5046	122.8010	12%
6638	Lopez	48.5032	122.8846	13%
6640	Lopez	48.5138	122.8710	11%
6647	Decatur	48.5037	122.8242	12%
6650	Decatur	48.5116	122.8225	14%
6668	Lopez	48.5217	122.8885	13%
6675	Lopez	48.5012	122.8819	12%
6688	Lopez	48.4918	122.9317	14%
6720	Lopez	48.4963	122.8956	17%
6751	Lopez	48.4332	122.8564	13%
6764	Lopez	48.4543	122.8177	12%
6770	Lopez	48.4415	122.8160	14%
6802	Lopez	48.4318	122.8506	14%
6805	Lopez	48.4300	122.8163	12%
6809	Lopez	48.4325	122.8603	13%
6875	Lopez	48.4746	122.9324	14%
6880	Lopez	48.4596	122.9314	14%
6906	Lopez	48.4838	122.9394	11%
6923	Lopez	48.4926	122.9283	11%

WetID	Island	Latitude	Longitude	MVHC
6933	Lopez	48.5081	122.8979	11%
6976	Lopez	48.5395	122.9105	14%
7013	Lopez	48.5369	122.8906	15%
7068	Lopez	48.4737	122.8762	12%
7074	Lopez	48.4819	122.8826	12%
7115	Lopez	48.4772	122.8869	15%
7128	Lopez	48.4712	122.9029	14%
7132	Lopez	48.4749	122.8932	11%
7167	Lopez	48.4610	122.8964	14%
7192	Blakely	48.5517	122.7849	15%
7195	Blakely	48.5755	122.8137	14%
7201	Blakely	48.5767	122.8091	15%
7203	Blakely	48.5642	122.7904	12%
7205	Blakely	48.5681	122.8007	16%
7206	Blakely	48.5616	122.8206	12%
7212	Blakely	48.5507	122.8012	13%
7218	Blakely	48.5603	122.7884	11%
7243	San Juan	48.6024	123.1222	11%
7261	San Juan	48.5894	123.0851	13%
7278	San Juan	48.5766	123.0954	13%
7296	San Juan	48.5455	123.0619	11%
7299	San Juan	48.5361	123.1345	14%
7321	San Juan	48.5306	123.1130	16%
7328	San Juan	48.5279	123.0972	11%
7369	San Juan	48.4960	123.1066	11%
7408	San Juan	48.4732	123.0272	11%
7423	Orcas	48.7098	122.8844	11%
7450	Orcas	48.6866	122.8668	11%
7511	Orcas	48.6519	122.8156	12%
7557	Orcas	48.6409	122.7962	12%
7576	Orcas	48.6160	122.8896	11%
7578	Orcas	48.6190	122.8969	11%
7579	Orcas	48.6169	122.8933	13%
7586	Orcas	48.6146	122.9171	15%
7593	Orcas	48.6042	122.9114	11%
7620	San Juan	48.5309	123.1146	13%

CHAPTER 3

BEST AVAILABLE SCIENCE
Marine Fish and Wildlife Habitat Conservation Areas

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MARINE FISH AND WILDLIFE HABITAT CONSERVATION AREAS: REVIEW OF THE SCIENTIFIC LITERATURE

The WAC describes fish and wildlife habitat conservation as "land management for maintaining populations of species in suitable habitats within their natural geographic distribution so that the habitat available is sufficient to support viable populations over the long term and isolated subpopulations are not created" (WAC 365-190-130). HCAs are designated to aid in local jurisdiction planning of appropriate development densities, urban growth boundaries, open space corridors, and incentive-based conservation and stewardship programs. This is done to help assure the long term viability of populations (WAC 365-190-130). The WAC (365-190-030(6a)) further defines HCAs as the following:

> "areas that serve a critical role in sustaining needed habitats and species for the functional integrity of the ecosystem, and which, if altered, may reduce the likelihood that the species will persist over the long term. These areas may include, but are not limited to, rare or vulnerable ecological systems, communities, and habitat or habitat elements including seasonal ranges, breeding habitat, winter range, and movement corridors; and areas with high relative population density or species richness."

When classifying and designating HCAs, counties should consider the following elements as specified in WAC 365-190-130:

- Creating a system of fish and wildlife habitat with connections between larger habitat blocks and open spaces, integrating with open space corridor planning where appropriate
- The level of human activity in such areas including presence of roads and level of recreation type (passive or active recreation may be appropriate for certain areas and habitats)
- Protecting riparian ecosystems including salmonid habitat, which also includes marine nearshore areas
- Evaluating land uses surrounding ponds and fish and wildlife HCAs that may negatively impact these areas, or conversely, that may contribute positively to their function
- Establishing buffer zones around these areas to separate incompatible uses from habitat areas.

State regulation (WAC 365-190-130) also requires certain habitats to be considered fish and wildlife HCA priorities for conservation, protection, and management. Although additional habitats or natural resource areas of local importance may be designated and incorporated into local land use planning and management efforts, this literature review focused on the marine HCAs that are required priorities for protection. Priority areas of consideration which contain elements related to the marine environment include the following:

Waters of the State as Defined in RCW 90.48.020
Shellfish Areas
Kelp and Eelgrass Beds
Herring, Smelt, and Other Forage Fish Spawning Areas
Areas Important to Threatened and Endangered Species

Marine Natural Area Preserves, Natural Resource Conservation Areas, and Wildlife Areas.
Habitats and Species of Local Importance[17]

This list provides the framework for the description of marine species and habitats requiring protection (Section 3.2) in this report. As stated, this document is focused primarily on the marine environment. However, some limited discussion of freshwater environments (that are also considered priorities for classification and designation of HCAs) is provided where it is applicable to the marine environment. Priority considerations for HCAs related to freshwater environments include the following:

Waters of the State as Defined in RCW 90.48.020
Lakes, Ponds, and Streams Planted With Game Fish
Naturally Occurring Ponds Less Than 20 Acres
Areas Important to Threatened and Endangered Species
State Natural Area Preserves, Natural Resource Conservation Areas and Wildlife Areas

A more detailed discussion and additional information regarding upland and freshwater HCAs is included in Section 4. The limited discussion of freshwater environments included in the literature review for marine HCAs is provided because upland land use and development activities, particularly those occurring in the vicinity of freshwater drainages that discharge to the marine environment, can have substantial effects on the marine environment (Fresh et al. 2004, Lemieux 2004 Brennan et al. 2009). This is due to interrelated natural processes and interdependent functions between freshwater and marine environments. Discussion of freshwater elements in this document is typically broad in scope and based on a general review of best available science. Specific topics are discussed to the extent that they have relevance, and likely similar influences, on the marine environment HCAs.

One goal of habitat conservation to maintain populations of species in suitable habitats. Hence, it is appropriate to consider specific San Juan County marine attributes related to habitat, species richness, and population health that may be at risk, and which may be impacted by development activities. The Marine Stewardship Area (MSA) Plan developed by the San Juan County Marine Resources Committee (MRC) identifies 16 ecological attributes (of 40 marine biological diversity attributes) that were rated as “fair”, meaning they lie “outside the range of natural variation” and “require human intervention” to prevent serious degradation. The 16 attributes include the following:

- Areal coverage of wetlands associated with the shoreline in embayments
- Substrate structure and characteristics in embayments
- Water column characteristics in embayments
- Native aquatic vegetative canopy in nearshore sand, mud, and gravel communities
- Age structure of the rockfish population
- Rockfish species richness
- Abundance of prey items for juvenile salmon (of up to 100 mm)
- Juvenile salmon habitat abundance along beaches
- Juvenile salmon habitat abundance in embayments
- Prey abundance for resident Chinook
- Resident Chinook salmon (“blackmouth”) population abundance
- Seabird nesting success

[17] Note: San Juan County has no designated Habitats and Species of Local Importance as of this report.

- Seabird food resource availability
- Population size of selected seabird species
- Seabird food resource availability and quality
- Population size and structure of resident killer whales

These marine biological diversity attributes are considered by the MRC to be priorities for marine conservation (Evans and Kennedy 2007), and generally correspond with issues (such as threats and conservation efforts) related to marine HCAs. They are mentioned here to provide background and context for the discussions that follow in this report.

NEARSHORE AND COASTAL ECOSYSTEMS

Coastal ecosystems are some of the most productive and diverse ecosystems in the world. Over 80% of the 13,200 known species of marine fish are coastal or spend at least part of their life cycle within a coastal ecosystem. Estuaries, sea grass beds, marshes and other nearshore ecosystems serve as filters and food sources for the rest of the marine environment, including the deep ocean (Preisler 2007, Belfiore 2003).

Different combinations of marine processes create conditions for different types of marine habitat, and, within those habitat types, different types of community compositions. Factors that affect marine habitats include depth, salinity, substrate, wave/current energy, dissolved oxygen, pH, light, turbidity, sediment, temperature, nutrients, organic matter, and the topography of the shoreline. For example, although kelp and sea grass can inhabit the same depths, they have very different water, energy, light and substrate requirements. Since eelgrasses are rooted sea plants, they require a sandy substrate, very clear water for photosynthesis, and low wave action. In contrast, giant kelp are macro algae. Lacking true roots, they anchor themselves to rocks and boulders with thick, root like cords called holdfasts. They can tolerate less light than sea grass because they are able to use more of the visible light spectrum in photosynthesis; however, they need more wave action or currents to bring in nutrients (Preisler 2007).

The greatest number of species in marine environments are small, secondary place holders who rely on foundation species to create the environmental conditions in which they can live. Foundation species (e.g. kelp and eelgrass) modify environmental conditions, resource availability and species interactions by changing flow velocity and turbulence, creating refuges, entraining nutrients and larvae, stabilizing substrates, increasing sedimentation and providing shade which reduces physiological stress.

As with streams and wetlands, human activities can affect coastal ecosystems: directly, through physical modification and the disturbance of shoreline and nearshore habitat and as discussed in Chapter 7, indirectly through changes to the water. For example, eelgrass beds are sensitive to changes in the clarity of water, dissolved oxygen levels, temperature (they prefer 10-15°C), salinity (5-32 ppt), and nutrients. High levels of sediments or nutrients in the water can cause excessive growth of floating and attached algae, causing a reduction in the light available to eelgrass (Borde et al. 2006).

The effects of toxins on the marine environment are most pronounced at the outfall site, and fall off with distance as the stormwater mixes with seawater. Dilution and mixing, however, depend on the interaction of longshore transport, cross shore transport, longitudinal dispersion, and turbulent diffusion, all of which depend on local wave conditions. One cannot assume that runoff, and the suspended and dissolved contaminants it contains, will quickly disperse once it is discharged, nor can one assume that placing outfalls in areas of low habitat quality will not adversely impact habitat elsewhere - it is dependant upon the nearshore transport processes and how the runoff and sediment are moved (Grant 2005, Preisler 2007).

The effect of a toxin in the marine environment also varies based on a number of factors, including whether it is introduced as a large surge or at low levels over time; how quickly the toxin breaks down in saltwater; whether the toxin bioaccumulates and travels up the food chain; and how the toxin affects particular organisms. Toxin impacts are further complicated because they rarely appear alone within a system. Marine systems are usually dealing with a combination of toxins, organic enrichment, elevated nutrients and other stressors (*e.g.*, temperature, lack of food, changes in salinity), which make impacts hard to predict (Fleeger et al. 2003, Heugens et al. 2001).

In embayments with little circulation, where the less-dense fresh water floats on top of the seawater, increasing stormwater flows increase the thickness of the freshwater layer, enhances stratification, and potentially reduces the oxygen in deeper areas. Estuaries and wetlands are particularly sensitive to changes in the timing and volume of freshwater inputs since plant community composition is determined by sedimentation, water level, flood tolerance, and salinity gradients. Where shoreline wetlands filter incoming runoff, increased and more frequent flows may not allow water to infiltrate, and may cause wetlands to export rather than trap nutrients (Lee et al. 2006).

As in upland streams and wetlands, subsurface flows are an important source of fresh water to marine environments. Groundwater naturally flows into the nearshore via subsurface seeps, contributing 17-20% of the total water flow into some estuaries (Johannes 1980). Unlike stormwater from developed areas, these seeps of freshwater flow in slowly over time and do not cause rapid and repeated changes to the temperature and water chemistry.

The character and magnitude of impacts to aquatic ecosystems resulting from climate change and anticipated sea-level rise are difficult to predict due to the complex interrelationships of the marine food-web. Changes in water temperature, freshwater supply, vegetation (both aquatic and terrestrial), and sea level, play a dynamic role in how ecosystems respond. Some of this may be bottom-up impacts, such as changes in available plankton in the marine food-web, while some may be top-down changes, such as increased pollutant input from additional surface water runoff. At a minimum, increases in sea level and the frequency and intensity of storms would likely result in additional shoreline erosion and requests for approval of new armoring structures, as well as the narrowing of beaches adjacent to existing bulkheads, with a decrease in the area available for spawning forage fish.

MARINE PHYSICAL ENVIRONMENT: WAVES AND CURRENTS

San Juan County exists within the larger oceanographic setting of the eastern Strait of Juan de Fuca and the southern Strait of Georgia. The overall landscape was defined by earlier glaciation and subglacial erosion (see Geology section for details). Boulder moraines deposited by glaciers formed sills that divide the region into three submarine basins: the western Strait of Juan de Fuca, stretching from the Pacific Ocean in the west to the Victoria-Green Point Sill in the east; the eastern Strait of Juan de Fuca and Haro Strait, reaching from the Victoria-Green Point Sill to the Boundary Pass Sill; and the Strait of Georgia, extending northward from the Boundary Pass Sill. The Victoria-Green-Point Sill has a minimum depth of about 55 m; the Boundary Pass Sill is somewhat deeper, with a minimum depth of about 150 meters (Masson and Cummings 2000, Klinger et al. 2006). The sills influence circulation within and between the three basins through hydraulic control on the flows over the sills. The interior waters are connected to the coastal ocean via the western Strait of Juan de Fuca.

Flow throughout the County's shorelines is characterized by estuarine circulation driven primarily by discharge from the Fraser River and the Strait of Georgia through Rosario Strait, Haro Strait and a series of smaller passages to the Strait of Juan de Fuca (Masson and Cummings

2000). Discharge from the Skagit River drainage and Puget Sound provide secondary influences to the system. The period of maximum discharge from the Fraser River occurs in May and June, with minimal discharge from December through March (Klinger et al. 2006). The long-term average near-surface flow through the region is seaward, with an estimated speed of 0.12 knots through Juan de Fuca Strait (Pashinski and Charnell 1979, Klinger et al. 2006), producing about 8.8 million cubic feet per second of flow on average (Labrecque et al. 1994, Thomson et al. 2007). The seaward flow of surface water is opposed by a landward flow of oceanic water at depth, some of which is mixed with surface water as it passes over the relatively shallow sills that separate the basins.

Locally, flow is strongly modulated by mixed semi-diurnal tides that create swift tidal currents that reach speeds of several knots. Intense tidal flows cause vigorous vertical mixing, especially at constrictions, both lateral and vertical. Tidal motions tend to dominate circulation over periods of less than 10 hours; other large-scale estuarine processes dominate on longer time scales (Masson and Cummings 2000).

Waves are the dominant mode of sediment transport alongshore for most of the County's shorelines (Finlayson 2006). It is likely that in areas where tidal currents are in excess of one knot, tides may play a secondary role, if those areas are also protected from swell (Curtiss et al. 2009). The County is unusual in that the source of the waves changes depending on the geographic position and aspect of the shoreline in question. For most of the County, waves are generated exclusively by local winds, just as they generally are within the confines of Puget Sound (Finlayson 2006). Locally wind-generated waves are limited by fetch, the distance over which the wind blows unobstructed. For most shorelines, particularly those within the center of the County, fetch is very restricted, meaning that the waves that sculpt the shoreline are small (generally less than three feet). Short-fetch waves also have short periods (the time interval between wave heights). The short-period waves are steep and can generate significant local shear stress (the physical process that strongly influences sediment transport), but these waves do not penetrate far down into the water column. This is important, because any human-induced alteration of a shoreline's wave characteristics could potentially affect the way sediment is transported along the shoreline.

The southwest sides of San Juan Island and Lopez Island are dominated by swell, which as previously stated, is the result of large waves produced in the open ocean. Because these waves form in the largest storms and fetch is effectively unlimited, the height and the period of these waves are large. Observed evidence of waves on the southwest side of Lopez Island at Agate Beach indicates that waves in excess of six feet are common during storms (Herrera 2009). Swell has numerous impacts to the physical processes relevant to the shoreline; the most pronounced being the development of a surf zone. When wave height is large and the wave period is long, waves come under the influence of the seabed far from the shoreline (typically hundreds of feet from where the water surface meets the shoreline). This causes them to break far from the shoreline. Short-period, fetch-limited waves generally do not break until within a few feet from the beach, making the beaches dominated by swash (the rushing back and forth of water at the point where the water surface meets the beach: Finlayson 2006). The presence of a surf zone changes the overall geomorphology of the beach and the associated ecological communities. For example, surf may preclude the presence of some aquatic vegetation (e.g., some types of sea grass) because of the energetic environment and shifting substrate within the surf zone. Sediment transport is also very intense with the surf zone, providing another stressor on the life that can inhabit that zone as it is a highly abrasive environment.

DESCRIPTION OF HABITATS AND SPECIES REQUIRING PROTECTION

As stated previously, the marine HCAs identified by San Juan County as priorities for protection, conservation, and management are the focus of this literature review. These HCAs are listed below and then described in the following sections.

- Waters of the State as Defined in RCW 90.48.020
- Shellfish Areas
- Kelp and Eelgrass Beds
- Herring, Smelt, and Other Forage Fish Spawning Areas
- Areas Important to Threatened, Endangered, and Sensitive Species
- Marine Natural Area Preserves, Natural Resource Conservation Areas, and Wildlife Areas.

Washington Department of Fish and Wildlife (WDFW) priority habitat and species (PHS) data and maps are a useful source of information regarding the location of habitats and species including fish and shellfish that have economic and cultural importance, as well as state and federally listed endangered, threatened, or sensitive species and their habitats requiring special protection or management. Species and habitats are also identified in the WDFW PHS list (WDFW 2010a) and in the Washington Department of Natural Resources (WDNR) Natural Heritage Program list of "Rare Plants and High Quality or Rare Plant Communities" (DNR 2010a). Occurrence of WDFW-listed sensitive, priority habitats and species in San Juan County is summarized in Appendix A (Table A-1). Management recommendations for individual species are also available from WDFW (WDFW 2010b). Other information sources regarding HCAs are identified in the descriptions below.

It is important to note that although data and maps such as WDFW PHS data, or kelp and eelgrass distribution maps provided in the Washington Department of Ecology's Coastal Atlas (Washington Coastal Atlas 2010), or other resource information provided by various agencies are helpful sources to flag the presence of marine HCAs; such data and maps often do not include the complete distribution or specific locations of each species or habitat requiring protection. That is to say, these data sources are sometimes incomplete, outdated, or derived from a broad, landscape-scale assessment of distribution. Effective resource protection on a local level will need to include gathering additional information, site specific resource mapping, and cooperation between land owners and agencies to implement best practices and development standards that protect fish, wildlife, and habitat resources specific to a property. Effective protection depends on requiring site-specific project planning based on valued resources as part of permitting development activities.

Waters of the State as Defined in RCW 90.48.020

As defined in the revised code of Washington (RCW 90.48.020) "waters of the state" includes lakes, rivers, ponds, streams, inland waters, underground waters, salt waters and all other surface waters and watercourses within the jurisdiction of the State of Washington. Waters of the State provide numerous beneficial functions for wildlife and humans.

The classification of water bodies allows for the development of regulations to address functions and processes that are relevant to specific types of water bodies. The Growth Management Act (Section 5.c.vi of WAC 365-190-080 Critical Areas (vi) Waters of the State) says that counties and cities should use the classification system established in Washington Administrative Code, Chapter 222-16, Section 030 (WAC 222-16-030) to classify waters of the state. Waters of the state are also defined in Title 222 WAC, the forest practices rules and regulations. Counties and cities are expected to use the classification system established in WAC 222-16-030 to classify waters of the state. WAC 222-16-030 outlines the state's classification for water bodies into three categories: Type S waters (shorelines of the state), Type F waters (fish habitat), and Type N waters (nonfish habitat). Marine shorelines are also managed under state and local policies and regulation such as the Shoreline Management Program (SMP).

San Juan County includes 408 miles of marine shoreline (SJC 2010a). The County also contains 158 miles of freshwater streams (Kerwin 2002) that eventually flow into nearshore areas. However, fewer than a dozen of these streams are naturally accessible to anadromous salmonids (SSPS 2007). The vast majority enter the marine environment from points that are naturally perched or enter at a gradient too steep for anadromous salmonid access (Kerwin 2002). Due in part to their close proximity to the marine environment, relatively small size, and potential to be affected by land use and development, these streams and the human activities occurring near them potentially influence the nearby marine environment (Fresh et al. 2004). For example, in Westcott and Garrison Bays, logging, agriculture, and residential development activities have been noted as potential or likely sources of impacts (water quality degradation) due to altered filtration capacity, altered stormwater runoff, and elevated nutrients and biocides (Klinger et al. 2006). In addition, the main tributary to Westcott Bay, Doe Creek, is currently experiencing significant erosion and downcutting, which likely contributes to adverse downstream sedimentation.

Other impairments to Waters of the State commonly associated with human use and development activities such as high fecal coliform, nutrients, suspended solids, temperature, and low dissolved oxygen levels, were identified for specific sites in the San Juan County Watershed Characterization Report and the San Juan County Monitoring Project Final Report (SJCWMC 2000; Wiseman et al. 2000). The altered water quality that can result from human impacts (for example, as shown by Barsh et al. [2009]) may result in water quality degradation that affects primary production, habitat conditions, and species higher on the food chain, ultimately degrading marine fish and wildlife habitat conservation areas. This potential impact, as well as other impacts that are associated with local land use and development practices, are described further in the following sections.

Shellfish Areas

San Juan County marine shorelines and waters provide habitat for numerous shellfish species including Pinto (or Northern) abalone (*Haliotis kamtschatkana*), sea urchins (*Strongylocentrotus* spp.), crab, shrimp, and various clams. The species and habitats associated with these HCAs are discussed in the following sections. In general, shellfish depend on specific sediment compositions (such as grain size, amount of different grain and gravel sizes, and organic content). For example, shellfish such as littleneck clam (*Protothaca staminea*) and butter clam (*Saxidomus gigantea*) prefer sediment mixed with gravel and cobble; and populations are sometimes enhanced by increased amounts of these sediments to otherwise muddy or sandy beaches (Dethier 2006). Therefore, development such as bulkhead construction, vegetation removal, or other activities that alter sediment composition (discussed in Section 3.3 regarding the effects of development) can adversely affect a variety of shellfish species. Shellfish are also affected by stormwater or sewage discharges that affect key aquatic habitat parameters (including temperature, salinity, turbidity, oxygen, and pollutants) as well as food availability (Dethier 2006).

Abalone

San Juan County Occurrence

Pinto abalone (*Haliotis kamtschatkana*) occur in San Juan County. In fact, the only part of the inside waters of Washington where they are currently found is the San Juan Islands and the Strait of Juan de Fuca (Dethier 2006). Unfortunately, their numbers appear to be decreasing. In the San Juan Archipelago, between 1992 and 2005, abalone declined from 351 animals per site to 103 animals per site at 10 long-term monitoring stations (PSAT 2007).

Habitat

Pinto abalone live in shallow subtidal rocky areas with moderate to high wave energies. They typically occur in the low intertidal zone in kelp beds along well exposed coasts, and in depths up to 35 feet (10.7 meters) (PSAT 2007). They have also been found in depths up 330 feet (100 meters) (NMFS 2007).

Food and Foraging

Pinto abalone are herbivore gastropod mollusks. Settled juveniles and adults commonly rely on kelp fragments for food (DFO 2010).

Threats

Although current population abundance of the species is not well known, overharvest is thought to be a significant problem for this species (NMFS 2007, West 1997), and populations along the west coast of the United States and Canada have experienced dramatic declines in the last few decades (NMFS 2007, PSRF 2010). An ongoing threat is that current population levels are likely too low to support effective reproduction (Dethier 2006, NMFS 2007). The decline in population is attributed to several factors including overharvest (historical overharvest and ongoing illegal, unreported harvest), predation from sea otters, and disease. These factors have contributed to densities that are too sparse to support sustainable, viable reproduction (NMFS 2007).

Protection and Conservation

Commercial harvest has never been allowed by Washington State, and recreational fisheries have been closed since 1994. Since 2004, they have been federally listed as a 'Species of Concern' (NMFS 2007). A general lack of data indicates that the existence of and extent of illegal harvest of pinto abalone is uncertain; therefore, habitat protection within their range may be a more important factor to population success than harvest pressures. Abalone, along with other mollusks, is considered an important indicator assemblage and their dwindling population has been used to highlight the need for conservation of kelp forest communities (Rogers-Bennett 2007). Therefore, it is likely that efforts to protect and preserve kelp forests (see Section 3.3.3), and reduce development related impacts to kelp habitat, will have reciprocating benefits for abalone.

Sea Urchin

San Juan County Occurrence

WDFW data indicates sea urchin (*Strongylocentrotus* spp.) distribution throughout much of San Juan County's shoreline (SJMRC undated), and their distribution is likely associated with the availability of rocky substrates (Dethier 2006).

Habitat

Sea urchins are herbivores that live in shallow to deep waters on rocky substrates, especially in the northern inside waters and the more exposed waters of the state (Dethier 2006).

Food and Foraging

Sea urchins are critical agents of subtidal community structure in rocky areas due to their intensive grazing of young and adult seaweeds. They are consumed by seastars and sea otters (Dethier 2006).

Threats

There is limited documentation on the potential or likely threats to sea urchins. There are commercial fisheries for several of the species in the San Juan Islands (Commercial Urchin Harvest Districts 1 and 2), Strait of Juan de Fuca, and outer coast. Predation by marine mammals (for example, Carter et al. 2007) is likely a major influence on population success. Land use and development that affect kelp forests could also indirectly affect urchin as urchins rely on this habitat for food and refuge from predation (see Section 3.2.3 regarding kelp).

Protection and Conservation

In general the Puget Sound sea urchin population is considered stable, although population declines in specific geographic areas have prompted harvest restrictions or closures for stock conservation (PSAT 2007). Due to their reliance on kelp forests as habitat and food, protection of kelp is critical for the survival and population success of this species.

Crab

Dungeness crab (*Cancer magister*) is an important fishery resource and listed on WDFW's priority habitat and species list. The species is also a critical component in the food web and is a vital food source for many sensitive or protected species (Fisher and Velasquez 2008).

San Juan County Occurrence

There is limited information on the distribution and habitat use of Dungeness crab specific to San Juan County. Dungeness crab is distributed throughout Washington's coastlines. Intertidal and shallow subtidal areas along the shoreline provide suitable habitat for Dungeness crab. Large estuaries like Puget Sound provide essential habitat for this species (Fisher and Velasquez 2008). In Puget Sound they are more abundant in waters north of Seattle than south (Bumgarner 1990). Dungeness crab distribution has been documented in Lopez Sound, Roche Harbor, False Bay, most of West Sound, East Sound (Buck Bay and Ship Bay), Reid Harbor, Cowlitz Bay, and surrounding Sucia Island (SJMRC undated).

Habitat

Dungeness crab are distributed throughout Washington's coastlines. Intertidal and shallow subtidal areas along the shoreline provide suitable habitat for Dungeness crab. Large estuaries like Puget Sound provide essential habitat for this species (Fisher and Velasquez 2008). In Puget Sound they are more abundant in waters north of Seattle than south (Bumgarner 1990). Adults migrate to shallow waters in spring (March through June) to mate (Fisher and Velasquez 2008). After mating occurs, larvae are dispersed by currents. Juveniles are closely associated with cover in the intertidal that can consist of bivalve shells, eelgrass (*Zostera* spp.), gravel-sand substrates, and/or macroalgae (Thayer and Phillips 1977, Dinnel et al. 1986a, Dinnel et al. 1986b; as cited in Fisher and Velasquez 2008). These forms of cover provide juveniles a refuge from birds, fish, and many other predators (Eggleston and Armstrong 1995). Juveniles eventually settle to the bottom, and progressively move to deeper water as they grow (Fisher and Velasquez 2008).

Food and Foraging

Dungeness crab are non-specific feeders, but generally consume clams and shrimp. Juveniles tend to feed on bivalves, but also consume smaller crabs, shrimp, other crustaceans, fishes, and other mollusks. Intertidal habitats are critical for juvenile feeding as those areas can have prey densities higher than subtidal habitats (Fisher and Velasquez 2008).

Threats

Fishing, disease, and development activities that result in direct disturbance or impaired water quality related to increased pollutants are likely factors in low population success. For example, hypoxic conditions has been shown to alter the feeding behavior of crabs (Bernatis et al. 2007); thus, land use and development that results in increased hypoxic conditions in nearshore areas could adversely impact crab survival. This includes the discharge of excess nutrients into local embayments, for example, East Sound, which is on the Federal Clean Water Act 303(d) list because water quality is limited due to low dissolved oxygen.

Dungeness crab is more susceptible to population impacts from harvest, disease, and development-related activities (for example, dredging) in areas where it concentrates for mating and egg incubation, but it is also susceptible to mortality from derelict fishing gear in feeding grounds (Fisher and Velasquez 2008) as well as from abandoned crab pots left by recreational fishers. Refuge from predation is considered a key post-settlement determinant of subsequent abundance of juvenile Dungeness crab (Eggleston and Armstrong 1995).

Protection and Conservation

Eelgrass is present along approximately 34 percent of the County's shoreline (personal communication from Tina Whitman, FSJ, May 13, 2011). Due to the dependence of juvenile crab on this habitat for refuge from predators, eelgrass habitat (and the conservation of eelgrass) is important for crab survival in San Juan County. Development related impacts and the subsequent loss of intertidal habitat, or alteration of habitat (such as removal of. suitable breeding substrate, or reduced water quality) are direct and indirect limiting factors for Dungeness crab populations (Fisher and Velasquez 2008). Impacts related to shoreline development and construction, including over-water and in-water structures, bulkheads, and dredging and filling in intertidal areas should be minimized for effective conservation of crab.

Shrimp

Pandalid shrimp (also called humpy shrimp) (*Pandalus goniurus*) are an arthropod that is considered a state priority species for recreational, commercial, and tribal importance, and for having vulnerable aggregations that are susceptible to population decline (WDFW 2008). There is limited information for this species with regard to habitat requirements, potential threats, and conservation.

San Juan County Occurrence

Concentrations of Pandalid shrimp have been documented throughout much of San Juan County's marine waters including in Griffin Bay, Lopez Sound, Cowlitz Bay, and other waters (SJMRC undated).

Habitat

Pandalid shrimp live mostly in the subtidal zone as adults (NMFS 2010a). They are usually over muddy substrate at depths up between 20 feet (six meters) and 1200 feet (365 meters) (ADFG 2010).

Food and Foraging

Pandalid shrimp eat polychaetes, small crustaceans such as amphipods and euphausiids, limpets, and other shrimp (NMFS 2010a).

Threats

Threats to Pandalid shrimp are not well documented, but with regard to development activities, are likely to be similar to limiting factors for crab (discussed above) to the extent that development impacts extend to deeper waters where Pandalid shrimp inhabit the subtidal zone. Alterations to water quality, which could affect the distribution of food sources or result in direct impacts on shrimp, may be of greatest potential threat.

Protection and Conservation

Along the same line as potential threats, protection and conservation efforts are likely to be similar for shrimp as with other shellfish species (see previous section regarding crab).

Oyster, Clam, and Geoduck

San Juan County Occurrence

San Juan County shorelines provide relatively isolated patches of habitat for numerous oyster and clam species. This includes non-native Pacific oyster (*Crassostrea gigas*); various clams including native littleneck clam (*Protothaca staminea*), introduced manila clam (*Venerupis philippinarum*), varnish clam (*Nuttalia obscurata*), butter clam (*Saxidomus gigantea*), and Olympia oyster, geoduck clams, and mussels. Clams and oyster beds are documented to occur in Westcott Bay and Ship Bay (SJMRC undated). Clam distribution also includes Griffin Bay, Mud Bay, and Lopez Sound in the general vicinity of Spencer Spit, and subtidal populations in isolated patches throughout the county's shorelines (SJMRC undated).

Shellfish growing areas in San Juan County include those at Buck Bay, East Sound, Hunter Bay, Mackaye Harbor, Mud Bay, Shoal Bay, Upright Channel, and Westcott Bay (Washington

Department of Health [DOH] 2010a). Annual Growing Area Review Reports and accompanying maps are available from the DOH (DOH 2010a). San Juan County currently has no shellfish sites identified on the early warning system as "threatened areas" (DOH 2010a, 2010b). San Juan County contains numerous recreational shellfish harvest areas. Recreational shellfishing opportunities occur throughout much of San Juan County shorelines along public clam and oyster beaches (WDFW 2010c).

Commercial geoduck clam fisheries are not designated in San Juan County (WDFW 2010d). However, geoduck (*Panopea abrupta*) distribution is patchy throughout the Salish Sea. Commonly found in subtidal areas, geoduck can also occur in low intertidal zones. In San Juan County it is likely precluded from most intertidal areas due to unsuitable habitat conditions; distribution has been documented and mapped by WDFW (SJMRC undated).

Habitat

Native littleneck clams are one of several commercially important shellfish. They commonly occur in the intertidal zone and shallow subtidal zone (to depths of about 35 meters), and where substrates are composed of cobble or gravel mixed with sand or mud. Fine sand is less suitable, but the clams are known to use a variety of substrates (Dethier 2006). Most often they are found in intertidal zones from –1.0 to 1.3 meters MLLW (Chew and Ma 1987). Butter clams can be found in a wide variety of substrates but prefer sand, shell, and gravel beaches. Butter clams can be found as deep as 50 ft below the low-tide ODFW 2010).

Geoduck spawn microscopic larvae which drift in currents for extended periods (up to 47 days) allowing them to travel many miles. After drifting on currents, geoduck larvae settle to the bottom, metamorphose into juveniles, and burrow two to three feet into the substrate over several years. Geoduck are most abundant in sand or mixtures of sand, silt, and gravel, but may occur in a variety of substrates. Preferable substrates of this type present in the subtidal zone are typically suitable habitat to support geoduck colonization.

Food and Foraging

Oysters and clams are bivalve mollusk filter feeders. They consume various marine plankton species by sifting food from the water column.

Threats

The Washington Department of Health maintains a map of shellfish harvest zones and a list of beaches for the purpose of notifying the public of beach health and closures (DOH 2010c). Closures commonly occur due to temporary increases in marine biotoxin levels or due to chronic pollution (for example, due to coliform bacteria).

Development activities that result in impacts to water quality, direct disturbance of substrate, or indirect alteration of substrate conditions, are potential threats to oysters and clams. Barsh et al. (2010) attributed local water quality degradation to low summer instream flows, use of the riparian corridor for cattle pasture, pesticide use, and untreated runoff from roads, and found that water quality related to local development may be contributing to pesticide contamination of bivalves in Fishing Bay (Barsh 2009). As an important food source for many other species covered under the marine HCAs, oyster and clam health and population success will likely have implications for higher trophic species (Sobocinski et al. 2010).

Geoduck clams, generally limited to deeper subtidal areas around San Juan County, would be less likely to experience direct effects from shoreline disturbance, but could still be impacted by altered water quality or habitat conditions to the extent that those impacts extend into the subtidal zone.

Protection and Conservation

Conservation efforts for oysters and clams are likely to be similar to those efforts implemented for the protection of other marine HCAs and would include protection from pollutants, protection of suitable habitat areas, and minimization of disturbance to the substrate. Inventory of substrates where clams are currently distributed, and review of site specific conditions relative to suitable habitat conditions, would be a logical step toward conservation during site development planning and building application reviews.

Kelp and Eelgrass Beds

The basis for nearly all life in the sea is the photosynthetic activity of aquatic autotrophs such as planktonic algae, cyanobacteria, benthic microalgae, benthic macroalgae (kelps and seaweeds), and seed plants (such as seagrasses and salt-marsh plants) (Nybakken and Bertness 2005). Kelp forests and eelgrass beds (also referred to as eelgrass meadows) represent major aquatic plant communities in the region and they provide important habitat for salmon, forage fish, shellfish, and other species (Mumford 2007).

Kelp

Floating kelps are found adjacent to approximately 11 percent of Washington's shoreline (Mumford 2007). The smaller, non-floating kelps are not easily monitored or mapped because they are often not readily visible in aerial photographs (EnviroVision et al. 2007). However, non-floating kelps are more widely distributed and more abundant than the floating varieties. Kelp forests form refuge habitat for a number of fish species (Mumford 2007). They provide important habitat for some rockfish species (74 FR 18521). Juvenile and subadult salmon are also known to use habitat created by kelp forests, and depend on many species that are associated with kelp forests as a food source. Through food web interactions, kelp forests are an important community for sea urchins, herring, crabs, mollusks, and a variety of marine mammals including sea otters and whales (Steneck et al. 2002, Carter et al 2007, Mumford 2007, NOAA 2010b).

San Juan County Occurrence

Kelp forests are comprised of both floating and non-floating species and both types occur in a patchy distribution throughout the subtidal zone of San Juan County's shorelines (Washington Coastal Atlas 2010). Floating kelp species occur along approximately 44 percent the county's shoreline (personal communication from Tina Whitman, FSJ, May 13, 2011). Of the 23 kelp species known to occur in Puget Sound (Mumford 2007), at least 17 have been observed in San Juan County, and were collected from subtidal sites at Cantilever Point, Reed Rock, Friday Harbor, Point George, Shady Cove, McConnell Island, and Burrows Bay (Garbary et al. 1999).

Habitat

Kelps are generally found in water with high salinity (>25 practical salinity units [psu]), low temperature (<15 Celsius), high ambient light, hard substrate, and minimal sedimentation (Mumford 2007). Most occur in the shallow subtidal zone from MLLW to about 65 feet (20 meters) below MLLW, and prefer high-energy environments where tidal currents renew available nutrients (and prevent sediments from covering young plants (Mumford 2007). Kelps are not rooted plants, although they have a root-like mass (or holdfast) that anchors the thallus to the substrate. However, unlike true roots, the holdfast does not absorb and deliver nutrients to the plant.

Threats

Kelp abundance is predominantly threatened by adverse changes in water quality, and possible impacts on substrate composition (such as from sedimentation and from direct disturbance of substrates). Vegetation removal from land development may reduce infiltration and pollutant removal capacity in the watershed, and could result in greater run-off, more pollutants, and increased turbidity from the addition of particulates and resultant plankton growth (Steneck et al 2002). Increased turbidity would reduce growth due to reduced light in the water column. Abundance and distribution of kelp could also be reduced due to increased siltation that alters the substrate (Mumford 2007). Other potential indirect threats include loss of detritus feeders (such as sea cucumbers) that help maintain water quality, and increase of herbivores that eat kelp (Mumford 2007). Of these potential threats, the impacts associated with water quality are primarily related to land development practices, and potentially occur because of increased pollutants or sediment delivery. These impacts are discussed later (Section 3.3) in the context of development activities.

Protection and Conservation

Kelp requires adequate light, cold temperatures, and nutrient levels that are suitably high but not excessively high for successful colonization and growth (Mumford 2007). Therefore, shoreline development that affects water clarity or available light can adversely impact kelp. Altered wave energy has also been shown to affect survival of kelp (Duggins et. al 2003). Kelp are also dependent on hard substrates suitable for holdfast attachments, so development that alters substrate conditions could affect the survival, distribution, and density of kelp. While direct impacts on kelp from shoreline development may be difficult to quantify on a site by site basis, methods to minimize and mitigate potential cumulative impacts on water quality would include maintaining or enhancing shoreline vegetation. Protection of kelp should include:

- Prohibitions on disturbance or removal of kelp habitat
- Maintenance of water quality discharging to kelp habitat
- Maintenance of substrate conditions
- Prohibitions on shoreline modifications or in-water structures that would adversely alter wave energy and underwater light affecting kelp habitat.

Eelgrass

The native eelgrass, *Zostera marina*, covers an estimated nine percent of Puget Sound below the mean lower low water (MLLW) mark, making it an important plant community in the region (Nelson and Waaland 1997). Aquatic vegetation, in particular eelgrass, is important cover for juvenile fish and invertebrates (Phillips 1984). Eelgrass also provides a necessary structural surface for a community of epibenthic organisms, making eelgrass communities one of the most productive ecotones in the Pacific Northwest (Ferraro and Cole 2007). Marine littoral vegetation is important for the colonization of organisms that are key prey resources for other species. Eelgrass provides both physical structure and trophic support for the biological community, and is nursery habitat for many sensitive species including salmon (Murphy et al. 2000, Mumford 2007, Bostrom et al. 2006).

San Juan County Occurrence

The Department of Natural Resources Submerged Vegetation monitoring Project (SVMP) began focus-area monitoring (more intensive than previous efforts) in the San Juan Straights region, including San Juan County, in 2004 (PSAT 2007). Eelgrass beds occur throughout the nearshore zone of San Juan County's shorelines (Washington Coastal Atlas 2010), usually as patches or narrow bands near the shore, or as solid meadows in the subtidal zone (Nelson and Waaland 1997). Eelgrass is found along roughly 20 percent of San Juan County Shoreline (SSPS 2007). However, the San Juan Archipelago has been experiencing declines in native eelgrass. Significant losses have occurred in Westcott-Garrison Bays between 2000 and 2004 (Pentilla 2007, SSPS 2007), and between 1995 and 2004 there has been a steady decline in the abundance of eelgrass in the San Juan Archipelago. During this time, approximately 82 acres of eelgrass were lost from within 11 small embayments (Dowty et al. 2005, PSAT 2007).

Habitat

Typically eelgrass beds form near MLLW and extend to depths from about 6.5 feet (2 meters) above MLLW to 30 feet (9 meters) below MLLW. The depth to which eelgrass grows is determined mainly by water clarity, and the plant's sensitivity to water clarity has been noted as particularly important in the San Juan Straits Region, where it has been observed to grow at depths greater than 30 feet (9 meters) (PSAT 2007). However, factors such as extremely low or high nutrient levels, substrate composition, presence of other species, physical disturbance, fine sediment deposition, and toxic pollutants in the water can affect eelgrass distribution and abundance (Mumford 2007). In Friday Harbor, an eelgrass meadow extends from depths of approximately five feet (1.5 meters) below MLLW to 16 feet (5 meters) below MLLW (Nelson and Waaland 1997).

Threats

The literature review revealed no conclusive evidence substantiating the exact cause of declining eelgrass abundance in San Juan County and it likely results from multiple causes. Declines in eelgrass abundance in San Juan County embayments is speculated as most likely attributable to changes in water quality, disease, or unknown invasive species (Mumford 2007). However, eelgrass loss, in general, is also widely attributed to shading and disturbance caused by construction and activities associated with shoreline development such as over-water structures (including docks and moorage floats), mooring buoys, and direct substrate disturbance from anchoring, dredging, and filling (Mumford 2007, Fresh et al 2006, SSPS 2007). These activities likely pose a current and future risk to the health and extent of eelgrass beds in the county.

In addition, the Eelgrass Stressor-Response Project concluded that eelgrass failures may also be due to stressors and processes triggered by climate change, as well as long-period climatic events such as the 18.6 year tidal epoch in the Northeast Pacific, El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PSAMP, 2010).

Although bulkheading is frequently assumed to affect eelgrass bed occurrence, Finlayson (2006) demonstrated in northern Hood Canal that bulkheads did not have a statistically significant impact on eelgrass populations. His project area had numerous small streams that contributed to the sediment supply that may have reduced the impact of bulkheading on the substrate of the low-tide terrace, where eelgrass occurs. In the County, streams are less of a contributor to sediment supply and feeder bluffs play a more dominant role. As a consequence, bulkheading that affects feeder bluffs may impact eelgrass populations in San Juan County. However, it is important to understand that the direct links between eelgrass loss and bulkheading have not been demonstrated conclusively, although the linkage is likely in certain settings.

Human activities along the shoreline such as agriculture (which can increase pollutants in stormwater runoff), as well as vessel activity that results in boat propeller scour and impacts on water quality, are also contributing factors to eelgrass bed occurrence (Mumford 2007, SSPS 2007). Development activities that alter water quality and produce increased turbidity, excess nutrients, and low dissolved oxygen levels can adversely affect eelgrass by directly impacting the conditions required for eelgrass growth (water clarity) or by increasing algae growth of potentially invasive ulvoid (*Ulva* spp) species as well as phytoplankton and epiphytes, which reduce light penetration (Borde et al. 2006, Thom 1990, Wyllie-Echeverria et al. 2003). Other stressors include low oxygen, thermal and salinity stress, grazing, and bioturbation (Wyllie-Echeverria et al. 2003).

In the 1930's, a wasting disease caused by the marine slime mold *Labyrinthula* is thought to have killed nearly 90 percent of all eelgrass on the East Coast from Canada to North Carolina (Muehlstein 1989). Local scientists have recently identified this slime mold in some eelgrass meadows in Puget Sound and are working to see if the disease has or could cause eelgrass death in San Juan County (SeaDoc Society 2010). This potential makes conservation and protection of remaining eelgrass beds of utmost importance.

Protection and Conservation

As a perennial plant, eelgrass beds form and reemerge in the spring. The bed areas vary only slightly (typically less than 10 percent) from year to year in the absence of impacts from human activities that may contribute to reduced distribution and density (Mumford 2007). Since the plants die back during the fall, it is important that inventory and survey work be done during summer months for monitoring and planning purposes and to obtain occurrence data for project specific permits (EnviroVision et al. 2007). Activities that impact water circulation, water quality, light penetration into the water column, or substrate (direct disturbance or indirect alteration) would potentially affect eelgrass habitat, and should be carefully assessed on a site-specific scale to minimize impacts.

A possible mitigation alternative for activities that impact eelgrass is eelgrass transplantation (Thom 1990). However, transplantation success can be limited by environmental constraints and should be based on careful site assessment, experimental planting, and long term monitoring for mitigation success (Thom et al. 2008, Thom 1990).

Protection of eelgrass should include:

- Prohibitions on disturbance or removal of eelgrass habitat
- Maintenance of water quality discharging to eelgrass habitat
- Maintenance of substrate conditions
- Prohibitions on shoreline modifications or in-water structures that would adversely alter eelgrass habitat (e.g., docks, bulkheads).

Herring, Smelt, and Other Forage Fish Spawning Areas

Forage fish represent a key link in the marine food web. They are an important food source for numerous sensitive species including salmon, marine birds, and marine mammals (PSP 2010). Several studies in the San Juan Islands have documented the potential and actual use of nearshore marine habitats by forage fish (Penttila 1999, Wyllie-Echeverria and Barsh 2007, Friends of the San Juans 2004a, 2004b). In San Juan County, roughly 80 miles of potential forage fish spawning beaches, and approximately 13 miles of documented spawning beaches, have been identified by WDFW and Friends of the San Juans (Friends of the San Juans 2004a; SSPS 2007), representing roughly 20 percent of local shorelines (Friends of the San Juans 2004a). However, it should be noted that the studies of beach spawning surf smelt and pacific sand lance identified locations where spawning was present at the time of the survey, and there are likely additional areas in the County where spawning occurs.

In a report, four high priority spawning habitat areas for forage fish have been identified in San Juan County (Friends of the San Juans 2004a). These are Westcott Bay on San Juan Island, the West Sound and Blind Bay regions on Orcas and Shaw Islands, respectively, the Mud and Hunter Bay region on Lopez Island, and the Mackaye Harbor region on Lopez Island (SSPS 2007). Friends of the San Juans (2004a) provides considerable information on the specific locations (including maps) of surf smelt (*Hypomesus pretiosus*) and Pacific sand lance (*Ammodytes hexapterus*), as well as information on current development related conditions that likely impair habitat quality. In general, forage fish require specific substrate types (Pentilla 2007), clean water with low suspended sediment levels (Levings and Jamieson, 2001; Morgan and Levings, 1989), and suitable spawning and refuge habitat such as eelgrass beds. Development or activities that alter these conditions or their habitat are potential threats to forage fish.

Pacific Herring

San Juan County Occurrence

Two spawning stocks of Pacific herring (*Clupea pallasii*) are identified in San Juan County. One occurs in the Westcott Bay/Roche Harbor region (Northwest San Juan Island stock), and the second occurs in the eastern region of the county including Mud and Hunter Bays on Lopez Island, West Sound and East Sound on Orcas Island, and Blind Bay on Shaw Island (Interior San Juan Island stock) (Penttila 1999, Stick and Lindquist 2009). However, WDFW did not find herring spawning in Westcott Bay in their 2007-2011 surveys.

Surveys in 2004 found herring spawn in four out of five of the known locations mentioned in the previous section, with the exception of the Westcott Bay/Roche Harbor region (Friends of the San Juans 2004b). WDFW describes the Northwest San Juan Island stock as “disappearance”, meaning it can no longer be found in its formerly consistently utilized spawning ground (Stick and Lindquist 2009). The Interior San Juan Island stock is considered “depressed”, meaning recent abundance is well below the long term mean, but not so low to expect recruitment failure (Stick and Lindquist 2009). The locations and seasons of herring spawning in Puget Sound are relatively well known. However, new spawning sites in the Puget Sound region are still being discovered (EnviroVision et al. 2007). The presence of Pacific herring has also been documented around stream mouths and marine beaches on Orcas, Shaw, and Waldron Islands during studies conducted between 2003 and 2006 (Barsh and Wyllie-Echeverria 2006; Wyllie-Echeverria and Barsh 2007).

Habitat

Pacific herring (*Clupea pallasii*) use the nearshore environment for all of their life-history stages. Herring deposit their eggs almost exclusively on marine vegetation (Penttila 2007). They primarily use eelgrass and marine algal turf as a spawning substrate but may also use middle intertidal boulder/cobble rock surfaces with little or no macroalgae (Penttila 2007). In San Juan County, spawning generally occurs on eelgrass or a fibrous red alga known as *Gracilariopsis* (Penttila 1999).

Eelgrass provides an important spawning substrate, which, if adversely affected, may also impact herring populations. For example, coincident with the loss of eelgrass from Westcott-Garrison Bays in 2004, herring spawn was not detectable during surveys between 2004 and 2006 (Penttila 2007).

Due to herring general reliance on marine vegetation for spawning, spawning sites are frequently limited to portions of the nearshore zone where there is adequate light for plant growth (Penttila 2007). The depth at which spawning can occur is largely controlled by water clarity, which in turn controls the maximum depth at which vegetation will grow. This depth corresponds to the shallow subtidal and lower half of the intertidal zone. In areas with especially clear water, the zone where herring can spawn can extend to depths of -33 feet (-10 meters) MLLW (Penttila 2007). Herring spawning around San Juan Island occurs between late January and late April (Penttila 2007).

Food and Foraging

Herring feed on marine plankton. As larvae they exhaust their yolk sac nutritional reserves after the first week of drifting and must then feed on microplankton (Penttila 2007).

Threats

Potential threats to pacific herring include mortality from predation, disease, and climate change (Stick and Lindquist 2009). Development that results in the loss of suitable spawning habitat, for example from bulkhead construction (described in Section 3.3.1), and increased exposure to pollutants (O'Neill and West 2001) are also potential threats. Recent declines in another Puget Sound location (Cherry Point), and lacking definitive explanation for the decline, have led to heightened concern about the fate of this species (PSP 2010).

Protection and Conservation

Herring, like other forage fish, are a key link in the food web between lower trophic organisms and upper trophic species. They are the primary food source for salmon and marine mammals that are also dependant on HCAs, making them an important species to the overall population success and diversity of species in the region. Due to their reliance on eelgrass, protection of eelgrass habitat is a key factor in herring conservation. Actions that protect water quality will also protect herring.

Smelt and Other Forage Fishes

San Juan County Occurrence

Moulton (2000) identified potential spawning habitat for surf smelt and sand lance on 24 islands in the area, with Lopez Island having the greatest potential habitat areas, followed by San Juan and Orcas Island. The presence of Pacific herring, surf smelt, and Pacific sand lance have also been documented around stream mouths and marine beaches on Orcas, Shaw, and Waldron Islands during studies conducted between 2003 and 2006 (Barsh and Wyllie-Echeverria 2006; Wyllie-Echeverria and Barsh 2007). Currently, there are 63 documented surf smelt and sand lance spawning sites scattered throughout the islands (SSPS 2007). Surf smelt spawning has been documented at 59 sites in San Juan County, while Pacific sand lance spawning has been documented at eight beaches.

Habitat

Like Pacific herring, surf smelt use nearshore habitat for all of their life-history stages. Pacific sand lance are a common and widespread forage fish in the nearshore marine waters throughout Puget Sound. Although there is limited life history information or population data available for Pacific sand lance (EnviroVision et al. 2007), the spawning habitat of this species resembles that of surf smelt; they spawn in the upper third of the intertidal zone, in sand-sized substrate (Penttila 2007). As a result, these two species often use the same beaches and co-occurrence of eggs is common during winter when spawning seasons overlap. Depositional shore forms such as beaches at the far ends of drift cells and sandy spits support sand lance spawning. In San Juan County, surf smelt spawning can occur throughout the year (Penttila 2007). Eelgrass is also important habitat for surf smelt and other forage fish species as it provides refuge (Penttila 2007).

During surveys in 2008, Beamer et al. (2008) indicated that pocket estuary-like habitat along San Juan County beaches was used more heavily by juvenile surf smelt than other shoreline types such as pocket beaches, barrier beaches, and bluff backed beaches.

Food and Foraging

Like herring, surf smelt and other forage fish, such as sand lance, feed on marine plankton.

Threats

For summer spawning fish, the presence of over-hanging vegetation along the upper beach area is important for moderating local climate and preventing wind and sun exposure, which can kill eggs via desiccation (Rice 2006). In addition to physical habitat needs for spawning, all life stages utilize the nearshore zone (Penttila 2007). Therefore, forage fish are vulnerable to the impacts of shoreline development, including threats from bulkheads and shoreline hardening, over-water structures, pollution runoff, and removal of shoreline and aquatic vegetation (Herrera 2007a).

Bulkheads in particular can directly bury habitat, lower beach elevations, coarsen foreshore substrate, and be associated with removal of shoreline vegetation (Herrera 2005, Spaulding and Jackson 2001) degrading beach conditions for surf smelt and sand lance spawning. Existing roads (14 miles) along the backshore and 85 bulkhead installations on potential spawning beaches also likely impact the ability of these areas to function for spawning (SSPS 2007). Overall, approximately four percent (18 miles) of San Juan County's shoreline has been modified by bulkheads. Most of the armoring is, however, located along sensitive sand and gravel shorelines, where 22.5 percent of those areas have been armored (Friends of the San Juans 2010). Protection of the marine riparian forest along the backshore of beaches is important (EnviroVision et al. 2007) because it cools the spawning habitat area along the upper beach, which is used by summer spawning populations of surf smelt and other forage fish (Penttila 2004, Rice 2006).

Protection and Conservation

Conservation of surf smelt and other forage fish habitat will involve similar measures as for herring. Like herring, they rely on eelgrass beds for refuge and foraging opportunities, thus protection of eelgrass should benefit forage fish as well as higher trophic species. Because they are obligate upper intertidal spawners, conservation of surf smelt and sand lance requires protection of the upper intertidal area along with preserving overhanging vegetation, maintaining feeder bluffs and natural beach nourishment processes, and avoiding or minimizing impacts on water quality. These actions together will contribute to the conservation of forage fish spawning areas and thereby these species populations. Similarly, restoration of impaired beach conditions (such as removal of bulkheads that are adjacent to feeder bluffs or that interfere with natural sediment transport and deposition processes) may represent possible restoration or mitigation opportunities for activities that adversely affect spawning beach habitat. It should however be noted that the effectiveness of mitigation actions will in many cases be uncertain, due to inadequate information about why certain forage fish spawn where they do and apparently do not utilize other areas with similar habitats (i.e. providing what is believed to be suitable habitat, may not result in use of the area by spawning forage fish). Other variables (e.g. larval food sources, circulation) likely play a significant role in creating suitable spawning habitat. For this reason, mitigating impacts to forage fish spawning habitat may not be feasible (personal communication from Tina Whitman, FSJ, May 13, 2011).

Areas Important to Threatened, Endangered & Sensitive Species

MARINE MAMMALS

Resident Killer Whale

Resident killer whales (*Orcinus orca*) in the Eastern North Pacific Ocean are distributed from Alaska to California, with four distinct communities recognized: Southern Resident, Northern, Southern Alaska, and Western Alaska (Krahn et al. 2004). The Southern Resident distinct population segment (DPS) was listed as endangered under the Endangered Species Act (ESA) in 2005 (70 FR 69903). The Southern Resident population consists of three pods that numbered 87 whales in 2007 (NMFS 2008a).

San Juan County Occurrence

The Whale Museum in Friday Harbor keeps a database of verified sightings by location quadrants or "quads." Sightings may be of individual or multiple whales. Frequent sightings occur in the San Juan Islands (Orca Network 2010) and in 2009, the population using Puget Sound and likely occurring in the vicinity of the San Juan Islands included 85 individual whales (PSP 2010).

Habitat

For a portion of the year, the Southern Resident population of killer whale typically resides and forages in the Georgia Strait, Strait of Juan de Fuca, and the outer coastal waters of the continental shelf, principally during the late spring, summer, and fall (Krahn et al. 2004, NMFS 2008).

Pods have visited coastal sites off Washington and Vancouver Island, and are known to travel as far south as central California and as far north as the Queen Charlotte Islands (NMFS 2008). Winter and early spring movements and distribution are largely unknown for the population. Although there is considerable overlap in the geographic ranges of Southern and Northern Residents, pods from the two populations have not been observed to intermix (Ford et al. 2000, as cited in NMFS 2008), and may be reproductively isolated from each other (Hoelzel et al. 1998; Barrett-Lennard 2000; Barrett-Lennard and Ellis 2001).

The San Juan County shoreline lies within ESA-designated critical habitat for the Southern Resident killer whale. There are three specific areas designated as critical habitat: the Summer Core Area in Haro Strait and waters around the San Juan Islands; Puget Sound; and the Strait of Juan de Fuca. Areas with water less than 20 feet deep relative to the extreme high water mark are not included in the critical habitat designation (71 FR 69054), a demarcation that excludes some of the nearshore elements of the county's shorelines.

Prey and Foraging

Data suggest that Southern Resident killer whales have a strong preference for Chinook salmon during late spring to fall. Chum salmon are also taken in significant amounts, especially in autumn. Other prey species include coho, steelhead, sockeye, and minor amounts of non-salmonids (such as Pacific herring and quillback rockfish). Resident killer whales spend about 50-67 percent of their time foraging. Groups of killer whales often disperse over several miles while searching for salmon (Hanson et al. 2010; NMFS 2008).

Threats

The Southern Resident DPS experienced an almost 20 percent decline in population from 1996 to 2001. Since 2001 the population has increased, with 87 whales in the Southern Resident DPS in 2007 (NMFS 2008). The major threats identified in the listing were prey availability, pollution and contaminants, and effects from vessels and sound. In addition, demographics, small population size, vulnerability to oil spills and other factors were considered (NMFS 2008). The high frequency of killer whale occurrences in San Juan County and surrounding waters when salmon and other fish species are also present (Cullon 2009) suggest that the County is an important habitat and feeding ground for killer whale. The potential for development activities to impact water quality, substrate, primary production, and key prey habitats such as eelgrass, kelp, and forage fish spawning beaches (see Section 3.2) in turn, produce potential threats to higher trophic level species, such as killer whales, due to their indirect effects on prey availability and bioaccumulation of toxins (Cullon et al. 2009, PSP 2010). Though not related to land use, noise and disturbance from whale-watching vessels and other vessels including shipping vessels is also a potential threat that has been shown to alter behavior and cause stress (Lussea et al. 2009; Williams and Ash 2007; Williams et al. 2002, 2009).

Protection and Conservation

In addition to other conservation efforts, National Marine Fisheries Service (2008) identifies protection from threats that may cause disturbance, injury, or mortality, or impact habitat as necessary for the conservation of Southern Resident killer whale. Protection of habitat is the most relevant conservation effort related to land use regulation. Land use and development can alter water quality, under water noise levels and extents (such as in-water construction or increased vessel activity from marinas), food web dynamics, and prey availability. These habitat alterations can all adversely affect killer whales, and therefore should be avoided or minimized. For example, development that alters eelgrass and forage fish habitat can subsequently and cumulatively impact salmon survival and abundance, and salmon is a key food source for killer whales. Protection of habitat such as kelp forests and eelgrass beds, forage fish spawning beds, nearshore salmon rearing habitat; and protection of water quality from chemicals, sediment, and other pollutants, will provide protection and contribute to the conservation of killer whale and their habitat.

Steller Sea Lion

Steller sea lions (*Eumetopias jubatus*) were listed as threatened on April 10, 1990 (62 FR 30772). Critical habitat was designated for Steller sea lions on March 23, 1999 (64 FR 14051), however all designated critical habitat lies outside Washington State.

San Juan County Occurrence

Steller sea lions are most commonly present in the inland marine waters of Washington State, including San Juan County, between January and May, and are typically absent during the June to August breeding season when they return to coastal rookeries in Oregon, Washington, and British Columbia (Personal communication with Steve Jeffries, WDFW, July 15, 2009). In the fall, winter, and spring months an estimated 800 to 1,000 Stellar sea lions move through the Strait of Juan de Fuca and Strait of Georgia to feed on Pacific hake and dense herring stocks that spawn in British Columbia (PSAT 2007). In San Juan County Whale Rock, Bird Rocks, Peapod Rocks, Speiden Island, and Sucia Island provide haul-out sites (terrestrial areas used by adult sea lions during times other than the breeding season and by non-breeding adults and subadults throughout the year) for relatively small numbers (PSAT 2007); they have also been observed hauled out on rock reefs associated with outer islands, for example, the reefs at the east northeast end of Patos Island.

Habitat

Terrestrial sites used by Steller sea lions tend to be associated with waters that are relatively shallow and well-mixed, with average tidal speeds and gradual bottom slopes. Haul-outs and rookeries tend to be preferentially located on exposed rocky shoreline, wave-cut platforms, ledges or rocky reefs (NMFS 2010b). Sea lions display strong site fidelity to specific locations from year to year. Adult females with pups and juveniles generally stay within 20 km of rookeries and haul-out sites while other females and males may range over much larger areas to find optimal foraging conditions (NMFS 2008b).

Although federally designated critical habitat areas are all located outside San Juan County, habitat that is considered "essential to the conservation of the Stellar sea lion" includes the "physical and biological habitat features that support reproduction, foraging, rest, and refuge" (58 FR 45269). Sites used by Stellar sea lions in San Juan County are not considered "major haul-outs" which have been designated as critical habitat. However, haul-out sites including those at Whale Rock, Bird Rocks, Peapod Rocks, Speiden Island, Sucia Island and Patos Island contain key habitat elements that are considered in critical habitat. These areas provide Stellar sea lions with opportunities for rest, foraging, and refuge, and therefore they are important conservation areas.

Prey and Foraging

Steller sea lions are generalist predators that eat a variety of fish and cephalopods, and occasionally other marine mammals and birds (NMFS 2008b). They feed primarily on fish (herring, hake, salmon, cod, lamprey, rockfish, flatfish, and skates), octopus, and squid, but prey varies by season, area, and water depth. Steller sea lions commonly compete with other marine mammals for salmon, which are seasonally important and range from six to 33 percent of steller sea lions' diet (PSAT 2007).

Data on foraging behavior are relatively limited, but suggest that adult females alternate between trips to sea to feed and periods on shore when they haul out to rest, care for pups, breed, and avoid marine predators. Territorial males may fast for extended periods during the breeding season when they mostly remain on land. Females with dependent young generally feed relatively close to rookeries and haul-outs because they must return at regular intervals to feed their offspring (NMFS 2008b).

Threats

The primary threats to Stellar sea lions are environmental variability, periodic shifts in oceanic and atmospheric conditions, competition with fisheries, reduction in the biomass and quality of sea lion prey species, and predation by transient killer whales (NMFS 2010b). Exposure to toxic substances also poses a moderate threat (NMFS 2010b). Of lesser importance are incidental take due to interactions with active fishing gear, Alaska native subsistence harvest, illegal shooting, entanglement in marine debris, disease and parasites, disturbance from vessel traffic, and disturbance due to research activities (NMFS 2008b). As with other marine mammals, development activities which affect habitat and water quality conditions that are important to prey species would indirectly affect sea lion by altering prey availability.

Protection and Conservation

Protection and conservation of Steller sea lion in San Juan County should focus on two of several conservation efforts listed by NMFS (2008b) intended to reduce the extent of disturbance and potential threats; "protect from contaminants" (such as pollutants in stormwater runoff) and "ensure adequate habitat." As stated above and discussed throughout this report, habitat alteration from development activities would potentially affect food web interactions and the availability of food sources. For this reason, shoreline development activities should include preservation and restoration of suitable habitat for key species such as kelp, eelgrass, forage fish, and salmon.

Sea Otter

Before reintroduction of 59 sea otters (*Enhydra lutris*) from an Alaska population into Washington waters in 1969, the sea otter was considered extirpated from Washington State (Lance et al. 2004). Little information exists on the exact distribution of sea otters living in Washington before the population was extirpated.

San Juan County Occurrence

Large groups (50 to 100 individuals) occur along the Olympic Peninsula coastline and western Strait of Juan de Fuca. The population range is currently thought to extend from Kalaloch to the western Strait of Juan de Fuca. Abundance has increased overall since 1989, with an estimated population of over 800 sea otters (PSAT 2007). Although dispersion from the "core range" is rare, distribution shifts have been noted (Lance et al. 2004), and sea otters have been sighted in the eastern Strait of Juan de Fuca, San Juan Islands near Cattle Point, and within southern Puget Sound (Lance et al. 2004). Systematic surveys have not been conducted in the inland waters of Washington.

Habitat

Throughout their range, sea otters use a variety of shallow coastal habitats. In Washington, sea otters live in nearshore waters (seldom more than 1-2 km from shore) up to 20 fathoms deep in areas defined as tidelands and bedlands. Within the context of sea otter habitat, tidelands are shores of tidal waters between mean high water and extreme low water; bedlands are below the extreme low tide mark (based on definitions provided by the WAC 332-30-106). Sea otters are mostly associated with rocky substrates supporting kelp beds, but they also frequent soft-sediment areas where kelp is absent (Lance et al. 2004).

Prey and Foraging

While sea otters are a highly generalized consumer, most individuals specialize on one to four prey types and prey types differ widely among individuals. Sea otters in Washington have been documented to prey upon at least 19 positively identified species, with sea urchins and clams comprising the largest percentage of their diet. Sea otter forage by diving to the bottom, collecting prey, and then carrying it to the surface for handling and consumption. They capture their prey with their forelimbs, typically remaining under water for 60 to 90 seconds while finding and procuring a prey item. They are able to feel or dig for prey where the water is turbid or the substrate is soft (Lance et al. 2004).

Threats

Sea otters are highly vulnerable to oil spills. Diseases have recently been detected in California and Washington sea otters. Other threats include persistent environmental contaminants, naturally occurring marine toxins, net entanglement, commercial harvest for their pelts, habitat loss, and lack of genetic diversity (Lance et al. 2004).

Protection and Conservation

Washington Department of Fish and Wildlife (Lance et al. 2004) identifies habitat protection as an important conservation effort intended to reduce the extent of potential threats to sea otters. Protection of shellfish habitat and habitat such as kelp forests and eelgrass beds that are important in the food chain and contribute to food availability for sea otter will also lend to conservation of sea otter habitat. Avoidance or minimization of development impacts is therefore fundamental to conservation of sea otter and their habitat.

Gray Whale

The Eastern North Pacific population of gray whales was delisted from endangered status under the ESA in 1994 but are still considered “sensitive”. National Marine Fisheries Service (NMFS) completed a status review in 1999 (Rugh et al. 1999) and retained the unlisted status of the population based on population trends (NMFS 2010c). In October 2010, NMFS was petitioned to conduct a status review of the Eastern North Pacific population to determine whether to list the population as “depleted” under the Marine Mammal Protection Act (75 FR 68756). This petition is currently under review.

San Juan County Occurrence

Gray whales are increasingly sighted in the inland waters of Washington and British Columbia, usually during their migration north in the spring (Orca Network 2010). They pass through San Juan County marine waters during their migration and foraging forays into the inland waters. Gray whales travel annually between feeding grounds in Alaska and breeding grounds in Mexico. They migrate north along the Pacific coast typically between mid-February and May, and return to their breeding grounds in the fall (NMFS 2010c).

Habitat

Gray whales are found mainly in shallow coastal waters in the North Pacific Ocean (NMFS 2010c). Based on recent observations of gray whales and foraging patterns, San Juan County, as well as Puget Sound, provide suitable habitat and foraging opportunities for gray whales.

Prey and Foraging

Gray whales feed on benthic amphipods by filtering sediments from the sea floor. Summer feeding grounds are primarily located offshore of Northern Alaska and the Bering Sea where there is low species diversity but high biomass and high rates of secondary production. In high use feeding areas, gray whales have been shown to disturb at least six percent of the benthos each summer, and to consume more than 10 percent of the yearly amphipod production (Rugh et al. 1999). There are indications that this resource is being stressed and that the gray whale population may be expanding its summer range in search of alternative feeding grounds. In Puget Sound, gray whales have been observed feeding on ghost shrimp and tube worms between January and July (Orca Network 2010).

Threats

In the past, gray whales were threatened by commercial whaling which severely depleted both the eastern and western Pacific populations between the mid-1800s and early 1900s. Since the mid-1930s, gray whales have been protected by a ban on commercial hunting. Other current threats include collisions with vessels, entanglement in fishing gear, habitat degradation (such as nearshore development that affects water quality and food sources), disturbance from ecotourism and whale watching, disturbance from low-frequency noise, and the possibility that illegal whaling could deplete the population (Moore and Clarke 2002; NMFS 2010c). The Eastern North Pacific population's annual migration along the highly populated coastline of the western United States, and their concentration in limited winter and summer areas, may make them particularly vulnerable to impacts from commercial or industrial development or local catastrophic events (NMFS 2010c). Because of the gray whale's reliance on nearshore amphipods, development activities in San Juan County that affect eelgrass beds, beaches, and other nearshore habitats that support the production and survival of shrimp and other food sources, will likely have indirect implications for food availability for gray whales as they migrate through the region.

Protection and Conservation

NMFS continues to monitor the abundance of the Eastern North Pacific stock, especially as it approaches its carrying capacity (NMFS 2010c). Protection and conservation strategies are similar to those for other whale species due to similarities in documented and potential threats.

Humpback Whale

Humpback whales were listed as endangered on June 2, 1970 (35 FR 8491). Critical habitat has not been designated for this species. Humpback whales migrate to Alaska during the summer to feed, and are common in the inside waters of southeast Alaska. The Washington coast is a corridor for their annual migration north to feeding grounds and south to breeding grounds (Osborne et al. 1998).

San Juan County Occurrence

Although rare in the inside waters of Washington and British Columbia, humpback whales have been sighted with increasing frequency in recent years (Falcone et al. 2005). Since 2001, sightings of humpback whales reported through the Orca Network have increased annually. Thirteen unique individuals were identified in inside waters of Washington and British Columbia in 2003 and 2004 of which one was a juvenile identified in the San Juan Islands (Falcone et al. 2005). Due to their migration pattern, humpback whales are most likely to occur in San Juan County waters in late spring and early summer.

Habitat

Humpback whales generally stay near the surface of the ocean. Feeding typically occurs in cold water summer grounds in productive coastal waters. Winter breeding grounds are generally in warmer waters at lower latitudes (between 10 degrees and 35 degrees latitude). While feeding and calving, humpbacks prefer shallow waters and warmer waters (NMFS 2010d). Calving grounds are commonly near offshore reef systems, islands, or continental shores.

Prey and Foraging

Humpback whales feed while on the summer range (NMFS 1991). Humpbacks filter feed on small crustaceans, plankton, and small schooling fish such as herring and sand lance. They consume large amounts during the productive summer months to build up fat stores that are then utilized during the winter months. Humpbacks are known to use unique hunting methods involving columns, clouds, or nets of air bubbles to disorient and corral fish (NMFS 1991). The technique called "bubble netting" is sometimes used by multiple whales with defined roles that allow the whales to herd prey near the surface.

Threats

Potential threats to humpback whales include direct injury from entanglement in fishing gear or ship strikes; stress, reduced feeding potential, or altered behavior that can result from vessel activity; and habitat degradation (NMFS 2010d). For example, as is true for other whales and described previously regarding gray whales, impacts on eelgrass beds, sand lance spawning beaches, and other nearshore habitats that support the production and survival of food sources may reduce foraging opportunities for whales. A reduction in suitable forage fish spawning habitat would likely limit the availability of key prey species for Humpback whales.

Altered habitat conditions, habitat reduction, or direct disturbance and displacement of whales can occur as a result of increased vessel activity commonly associated with shipping, fisheries, or recreation (such as whale watching) (NMFS 1991, 2010d). Ship strikes were implicated in the deaths of at least four humpback whales between 1993 and 2000 (NMFS 2005). Ship strikes are frequently unnoticed but research by Williams and O'Hara (2009) suggests that geographic "bottlenecks" where whale and boat densities are concentrated, represent higher risk areas. San Juan County marine waters may represent such a bottleneck region due to the high level of commercial and recreational vessel activity and frequency of narrow marine channels in associated waters. Aquaculture development may also occupy or destroy humpback whale habitat (NMFS 2010d).

Protection and Conservation

As for other marine mammals, land use and development that potentially alters water quality, increases disturbance levels such as vessel noise, and impacts food web dynamics and prey availability should be avoided and minimized as they can adversely affect the humpback whale. Protection of water quality and habitat such as eelgrass beds and spawning beaches are important to the conservation of humpback whale.

Rockfish

Nineteen species of rockfish have been observed in the San Juan Archipelago (Wyllie-Echeverria and Sato 2005). Of these, three species are federally listed under the ESA; including Boccacio (*Sebastis paucispinis*), canary rockfish (*S. pinniger*), and yelloweye rockfish (*S. ruberrimus*) (75 FR 22276). These are discussed in the following sections. In general, the species rely on shallow surface waters, distribution by currents, and kelp and eelgrass during their larval and juvenile stages; and then are associated with deeper rocky habitats as they mature (Wyllie-Echeverria and Sato 2005). Recent efforts toward conservation of these species in San Juan County include mapping of eelgrass beds and rocky habitats (Greene et al. 2005, Eisenhardt et al. 2009) which should better inform management and conservation efforts.

Boccacio

San Juan County Occurrence

In general there is limited information on local presence of rock fish and habitat use by rockfish within San Juan County. In North Puget Sound and the Strait of Georgia, observations of bocaccio are rare, and records are sparse, and often based on anecdotal reports (NMFS 2008c). WDFW catch reports and Reef Environmental Education Foundation (REEF) surveys between 1994 and 2010 contain sporadic observations of bocaccio in Puget Sound (NMFS 2008c, REEF 2010), but they seem to be limited to areas around the Tacoma Narrows and Point Defiance (74 FR 18521). REEF survey data for January 1996 through October 2010 indicates that bocaccio are identified in 0.1 percent of surveys and those observed were in the Tacoma Area (REEF 2010).

Habitat

Larvae are typically less than 0.2 inches (4.0-5.0 mm) long at release, generally well-developed, have functional organs and the ability to swim and regulate buoyancy (NMFS 2009). Larvae, generally associated with surface waters and drifting kelp mats (74 FR 18521), rely on currents for dispersal. The larvae metamorphose into pelagic juveniles after 3.5 to 5.5 months (typically 155 days) and settle to shallow, algae covered rocky areas or eelgrass and sand over several months (Love et al. 1991).

Tagging data indicates that juveniles will migrate as far as 92 miles (0.9-148 km) within two years of tagging (NMFS 2008c). As the juveniles age into adulthood, the fish move into deeper waters where they tend to settle near rocky reefs and oil platforms, and remain relatively localized as they age. Adults are most commonly found in waters between 164 ft and 820 ft (50 meters to 250 meters) in depth, but can inhabit waters between 39 ft to 1568 ft (12 meters to 478 meters) deep (NMFS 2008c). Although rockfish are generally associated with hard substrata, bocaccio are found in nearly all types of substrate. They are typically not associated with the bottom and tend to be more pelagic than other rockfish species (74 FR 18521).

Prey and Foraging

Juvenile bocaccio consume copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010e).

Threats

Rockfish grow slowly, are late to mature and long-lived (up to 50 years, NMFS 2010e), and have low rates of reproduction (NMFS 2010e). Bocaccio are fished directly and are often caught as bycatch in other fisheries, including those for salmon. Currently, rockfish are commonly caught before they reach sexual maturity, eliminating their entire reproductive potential (WDFW 2010a). Overfishing (as either a target or by-catch species) is likely a significant factor in the species decline. Adverse environmental factors led to recruitment failures in the early- to mid-1990s (NMFS 2010e). Up to 61,000 rockfish may be caught in derelict fishing gear per year (Palsson et al. 2009).

Other threats (i.e., stressors) with a high relative risk of impact include those related to water quality, specifically depletion of dissolved oxygen, altered nutrients, and to a lesser extent chemical contamination (Palsson et al. 2009). Other threats with an unknown relative risk include habitat disruption, climate change, competition from other bottomfish species, salmon hatchery practices, diseases, and genetic changes. These stressors, listed in Table 3-1, are described in *Biology and Assessment of Rockfishes in Puget Sound* (Palsson et al. 2009). That report indicates relative risk for each stressor based on three criteria. The criteria include available documentation, intensity (related to the effects of the stressor on survival, fitness, or health of the stock), and extent (related to frequency or spatial extent). An unknown condition for any criteria resulted in a relative risk of "unknown".

Stressors listed in Table 3-1 that are most related to local regulation of development activities include direct habitat disruption, as well as the indirect or consequential effects of development on water quality (i.e., hypoxia/nutrients and chemical contamination) and food web dynamics. The relative risk associated with habitat disruption is unknown. This is due to limited available documentation, meaning the risk is "conceivably possible, but [there are] no publications that establish relationship"; and due to a lack of knowledge on the spatial extent and frequency of the stressor affecting rockfish. However, habitat disruption results from filling, dumping dredge spoils, sedimentation, trawling, constructing beach bulkheads, installing pipelines and cables, sunken vessels, and constructing artificial habitats. The most vulnerable rockfish habitats are shallow-water vegetated areas and deeper rocky habitats (Palsson et al. 2009). Reproduction and growth of rockfish is also likely affected by chemical contaminants such as polychlorinated biphenyls (PCBs), chlorinated pesticides (such as DDT), and polybrominated diphenyl ethers (PBDEs) (75 FR 22276). Other water quality factors such sewage, animal waste, and nutrient inputs are also a concern (75 FR 22276).

Available documentation focuses primarily on overfishing as a well-documented stressor on rockfish populations. Derelict fishing gear, rated as a likely impact of "high" (Palsson et al. 2009) is also identified as a local threat (Evans and Kennedy 2007). However, Palsson et al. (2009) also notes the importance of floating aquatic vegetation drift mats (composed of detached kelp and seagrass) to juvenile rockfish, the formation of which relies on productive nearshore areas and detachment by storms and biological processes. The principal sources of vegetation for drift mat habitats in Puget Sound are not well known, and may therefore be inadequately protected from shoreline development (Palsson et al. 2009). San Juan County likely provides ideal conditions for the formation of drift mats including high aquatic vegetation productivity, storm exposure, and invertebrate communities that dislodge kelp and other macrophytes by grazing. If this combination of factors in San Juan County results in excellent habitat for juvenile rockfish, negative impacts related to San Juan County shoreline development and habitat disturbance may have a greater effect on the species than other areas of Puget Sound.

In addition to drift mats, the sea surface microlayer, a highly productive environment, provides habitat for rockfish eggs and larvae as well as an abundant assemblage of other organisms. The microlayer is enriched with surface-active constituents, which ultimately determine its chemical composition due to the binding properties of organic carbon. Concentrations of natural organic constituents, such as proteins, sugars, amino acids, and lipids are often enriched in the microlayer compared to sub-surface water. Similarly, concentrations of natural inorganic constituents, such as ammonia, nitrate, phosphate, and trace metals are enriched in the microlayer. The abundant natural organic and inorganic matter contained in the microlayer provides necessary nutrients and food for the growth and development of microorganisms, the eggs and larvae of rockfish (as well as other fish species) and invertebrate species (Herrera and Parametrix 2001).

Table 3-1. Likely Stressors Limiting Rockfish Populations in Puget Sound (Source: Palsson et al. 2009).

Factor	Documented[1]	Intensity[2]	Extent[3]	Relative Risk[4]
Fishery Removals	Best	High	High	High
Age Truncation	Fair	Medium	High	Moderate
Habitat Disruption	Unknown	Medium	Unknown	Unknown
Derelict Gear	Best	High	High	High
Climate	Unknown	Unknown	Unknown	Unknown
Hypoxia/Nutrients	Best	High	Medium	High
Chemical Contamination	Fair	Medium	Medium	Moderate
Species Interactions				
Food Web	Best	High	High	High
Competition	Poor	Unknown	Unknown	Unknown
Salmon Hatchery Practices	Unknown	Unknown	Unknown	Unknown
Diseases	Poor	Unknown	Unknown	Unknown
Genetic Changes	Poor	Unknown	Unknown	Unknown

[1] Best = Known references in Puget Sound, Fair = Inferred in this species from published studies in nearby areas, Poor = Inferred in Puget Sound from published studies in a proxy species, Unknown = Conceivably possible, but no publications that establish relationship.

[2] High = Stressor causes direct mortality, Medium = Stressor reduces fitness by increasing susceptibility to predation or disease or impairs reproduction, Low = Stressor is unlikely to impact health, Unknown = Intensity is unknown.

[3] High = Stressor acts continuously and over broad regions, Medium = Stressor is either episodic or acts over restricted areas within a region, Low = Stressor is infrequent or acts only over limited range, Unknown = Spatial distribution and frequency unknown.

[4] High = Overall the stressor has been documented in Puget Sound, causes direct mortality, is frequent and acts on a regional basis and dramatically limits rockfish stocks in Puget Sound, Moderate = The documented stressor causes direct mortality on episodic or local scales or continuously or episodically reduces fitness on local or regional scales, Low = The poorly documented stressor is infrequent and acts on local scales, Unknown = The stressor is possible but its intensity and extent is not documented.

The organic constituents in the microlayer affect the mobilization, transport, accumulation, and removal of contaminants. Hydrophilic organic matter strongly binds with positively charged metals and hydrophobic organic matter sorbs with organic contaminants, causing these pollutants to accumulate in the microlayer. Anthropogenic sources of these contaminants are varied and are hypothesized to include wastewater treatment effluent, stormwater runoff, atmospheric deposition, and chemical or petroleum spills. The overall effects of microlayer contamination on rockfish and other fish and invertebrate populations in Puget Sound, remain largely unknown (Herrera and Parametrix 2001).

Rockfish vulnerability to development activities that affect the microlayer, drift mats, kelp, and eelgrass in the nearshore zone of San Juan County is an important consideration given the species' reliance on these habitats during the larval stage. The installation or presence of overwater structures may block light and thereby impact the ability of submerged aquatic vegetation to grow, mature and subsequently contribute to the floating drift mats utilized by rockfish. Development that alters substrate conditions or water quality can subsequently affect the availability of suitable habitat and associated prey species for rockfish. As indicated in Table 3-1, stressors related to water quality and food web dynamics, may have a higher potential for impact to rockfish than direct habitat disturbance (for which impacts are not well documented, and the relative risk is unknown). Therefore, for future conservation of rockfish it is important to consider the relationship between specific development decisions and indirect impacts on habitat conditions or water quality, in addition to considering direct habitat disruption.

Protection and Conservation

Various state restrictions on fishing have been put in place over the years. Current regulations in Washington, where the species is most at risk (NMFS 2010), limit the daily rockfish catch to ten rockfish total of any species (WDFW 2010f). In Marine Area 7, which encompasses the San Juan Islands, recreational fishing for bottomfish is restricted to a depth of no greater than 120 feet and no rockfish may be retained (with the exception of only black and blue rockfish in the western portion of the Strait of Juan de Fuca) (WDFW 2010f). Prohibiting the retention of rockfish, however, may not be effective to improve the species' survival, because they suffer severe internal lesions if rapidly brought to the surface from deep water areas (for example, Hannah et at. 2008 and Pribyl et al. 2009). These lesions can be fatal, which ultimately contravenes the purpose of retention prohibition policies.

Groundfish are managed through a number of measures including harvest guidelines, quotas, trip and landing limits, area restrictions, seasonal closures, and gear restrictions (PFMC 2008). Rockfish Conservation Areas (RCAs) have been established to reduce impacts from fishing activities. These areas are closed to fishing or have restrictions on timing, or specific types of gear (NMFS 2010f).

Voluntary bottomfish recovery zones have been established in San Juan County. However, there is little evidence that the existing protection areas are resulting in the successful recovery of bottomfish, including rockfish (Eisenhardt and The Sea Doc Society 2006, Eisenhardt et al. 2009). The effectiveness of recovery zones might be improved by increasing their size and replacing voluntary restrictions with regulatory restrictions. Given concerns about chemical contamination and water quality impacts related to rockfish (75 FR 22276), local recovery efforts should include efforts to reduce the potential for exposure to pollutants (for example, this should be considered when establishing stormwater management planning and agricultural land use policies). Because this species is so slow-growing, late to mature, and long-lived, recovery from the above threats will take many years, potentially even after the threats are no longer affecting the species (NMFS 2010e).

Canary Rockfish

San Juan County Occurrence

Although canary rockfish are a resident species in the San Juan Archipelago, little is known about this species in San Juan County specifically (Wyllie-Echeverria and Sato 2005). Canary rockfish were once considered fairly common in Puget Sound (Holmberg et al. 1967 as cited in NMFS 2008c), and most common in southern Puget Sound (74 FR 18521). Based on survey and frequency data, NMFS estimates that there are approximately 300 canary rockfish in Puget Sound Proper (south of Admiralty Inlet) while Northern Puget Sound (north of Admiralty Inlet) has slightly higher frequencies (74 FR 18521, REEF 2010).

REEF surveys indicate two to five percent of rockfish caught in North Puget Sound (around San Juan Islands and Georgia Straight) are canary rockfish, a slightly higher percentage compared to canary rockfish captures (one to two percent) in Puget Sound proper (south of Admiralty Inlet).

The majority of canary rockfish are reported in catch surveys and trawl data from the Strait of Juan de Fuca and around Vancouver Island (DFO 2008 as cited in NMFS 2008c). REEF surveys between 1996 and 2010 suggest that canary rockfish are most consistently observed in northern waters of Puget Sound, Strait of Juan de Fuca and the outer coast. The sighting frequency in San Juan County (the percentage of surveys conducted that contained individuals of canary rockfish) was reported as 3.8 percent in the vicinity of Shaw Island. However, more frequent observations (6.5 percent, and 15.1 percent) occurred in nearby areas of the Strait of Juan de Fuca and Western Vancouver Island, respectively (REEF 2010).

Habitat

Larvae and juveniles are typically found in the upper water column and surface waters. However, occasional observations of juveniles have occurred at depths up to 2750 ft (838 meters) (Love et al. 2002). The larval stage lasts for one to four months (typically 166 days) in the top 328 feet (100 meters) of the water column (NMFS 2008c; 74 FR 18521). Juveniles settle into tide pools, rocky reefs, kelp beds, low rock and cobble areas (Miller and Geibel, 1973, Love et al. 1991, Love et al. 2002). Juveniles exhibit diel migratory patterns by hanging in groups near the rock and sand interface at shallow depths during the day and moving to sandy areas at night (Love et al. 2002). At approximately three years, juveniles begin to move deeper into rocky reefs.

Canary rockfish adults are generally associated with hard bottom areas and along rocky shelves and pinnacles (NMFS 2008c). They are usually found in dense schools at or near the bottom around rocky habitat (PFMC 2004, Stewart 2009). Fishery and survey encounter rates indicate an extremely patchy distribution (Stewart 2009). As adults, canary rockfish appear to be somewhat migratory and will travel as much as 435 miles over several years (NMFS 2008c). The migration is seasonal with more distance traveled in late winter and over summer months (NMFS 2008c).

Prey and Foraging

Canary rockfish prey and foraging is similar to that of other rockfish species. Juveniles feed on copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010g).

Threats

Threats to canary rockfish are similar to those associated with other rockfish species. Declines in canary rockfish observations have been documented since 1965 and a decreasing abundance trend has been consistently confirmed in recent catch surveys (NMFS 2008c).

Protection and Conservation

Protection and conservation efforts for protecting canary rockfish are also similar to other rockfish species. Current regulations in the Washington limit the daily rockfish catch and locations where fishing can occur. Rockfish cannot be retained in catches (WDFW 2010f).

Yelloweye Rockfish

San Juan County Occurrence

Like canary rockfish, yelloweyes are often fished for in the same habitat and at depths greater than 230 feet (70 meters) (Wyllie-Echeverria and Sato 2005). Yelloweye rockfish are commonly observed throughout the Salish Sea. The highest frequencies are observed in North Puget Sound, including the vicinity of Decatur Island in the San Juan Islands (Table 3-2), and the Georgia Strait (REFF 2010). The higher incidence of observations may be attributable to a relative abundance of rocky habitat in northern areas compared to southern Puget Sound (Miller and Borton 1980, NMFS 2008c). General distribution occurs in the Georgia Strait and around the Gulf Islands in British Columbia (Yamanaka et al. 2006, NMFS 2008c, REEF 2010).

Table 3-2.Summary of observations and distribution of yelloweye rockfish in inland Washington waters in the vicinity of San Juan Islands as reported in REEF surveys between January 1996 and October 2010 (summarized from REEF 2010).

Survey Area[1]	**Sighting Frequency**[2]
Strait of Juan de Fuca	3.6
W. of Discovery Island and Cadboro Point	4.3
San Juan Islands	**1.8 (994)**
Orcas Island	**2.7 (297)**
Lopez Island	**1.6 (126)**
San Juan Island (Including Henry)	**0.5 (218)**
Stuart & Spieden Islands (Including Jones and Flattop)	**5.5 (55)**
Cypress Island	1.3 (77)
Decatur Island	**8.7 (23)**
Patos Island	**100 (1)**

[1] Survey areas in San Juan County are shown in bold.
[2] Sighting Frequency represents the percentage of surveys conducted that contained individuals of yelloweye rockfish. The total number of surveys conducted is shown in parentheses.

Habitat

As with other rockfish species, juveniles are generally found in shallow waters and move deeper as they age. Juveniles are found throughout the life stage between depths of 49-1,801 feet (15-549 m) in depth (NMFS 2008c). As juveniles settle, they are found in high relief areas, crevices and sponge gardens (74 FR 18521; Love et al. 1991). Adults are typically found at depths between 300-590 feet (91-180 m) (NMFS 2008c). The adult yelloweye rockfish tend also toward rocky, high relief zones (74 FR 18521). The adults have very small home ranges, generally displaying site-specific affinity and affiliated with caves, crevices, bases of rocky pinnacles and boulder fields (Richards 1986). Rarely, adult yelloweye rockfish are found in congregations, but are more commonly seen as solitary individuals (Love et al. 2002; PFMC 2004).

Prey and Foraging

Yelloweye rockfish prey and foraging is similar to that of other rockfish species. Juveniles feed on copepods and euphausiids of all life stages. Adults eat demersal invertebrates and small fishes (including other species of rockfish) associated with kelp beds, rocky reefs, pinnacles, and sharp drop-offs (NMFS 2010h).

Threats

Threats to yelloweye rockfish are similar to those associated with other rockfish species. Between 2000 and 2008, WDFW recreational catch surveys documented a progressive decline in the number of yelloweye rockfish caught (WDFW 2010e). In 2000, approximately 5,800 individuals were caught in recreational catches. By 2008, fewer than 1,000 were recorded, the lowest recorded since complete record keeping began in the 1970s (WDFW 2010e).

Protection and Conservation

Protection and conservation efforts for protecting yelloweye rockfish are also similar to other species. Current regulations in the Washington limit the daily rockfish catch and locations where fishing can occur. Rockfish cannot be retained in catches (WDFW 2010f).

Salmonids

Under the Growth Management Act, anadromous (migratory) fish including endangered salmon require special consideration. Multiple species of salmon including individuals from other watersheds use the island's waters during different stages of their life cycle (SSPS 2007). Although there are no known natural Chinook spawning areas in the islands, all twenty-two populations of Puget Sound Chinook salmon use San Juan County's nearshore and marine waters throughout the year, both as feeding and rearing juveniles as well as migrating adults, making these areas an essential part of salmon recovery in Puget Sound (SSPS 2007). Nearshore habitats including pocket estuaries and streams offer juvenile salmon refuge from predation, increased food resources, and additional time to make the physiological transformation from freshwater to saltwater.

San Juan County Occurrence

Most streams in San Juan County are small and many do not support anadromous or resident salmonids. Cascade Creek on Orcas Island is an exception, where the presence of salmon and trout has been documented over the past 50 years. Much of the Cascade Creek watershed is located within Moran State Park, and Cascade Creek has a series of waterfalls between its source at Mountain Lake and its outlet at Buck Bay. Storage in Mountain Lake is almost entirely managed to keep Cascade Lake full, provide for Olga and Rosario water rights, and provide recreation in Mountain Lake itself. At times no flow at all is present immediately below the Rosario diversion. Between the lower dam and the falls, however, base flow provides water to the creek. The absence of flow in some areas does not, however, preclude the presence of fish when there is water (Boessow 2005, 2007, Pacheco 2005, Schuller 1992, Olga Water 2007).

While there is quality habitat in many of the reaches between the waterfalls in Cascade Creek, in most areas there is limited opportunity for fish to move upstream more than a few hundred yards. Despite this limitation, brook and cutthroat trout survive and breed in the short reaches, and salmon return and spawn in the limited anadromous reach downstream. Lower Cascade Creek is inhabited by sea-run cutthroat trout, eastern brook trout, and coho, chum and Chinook salmon. Though some of these runs are planted, natural spawning also occurs.

An ongoing assessment of streams and salmonids is being conducted by the Wild Fish Conservancy, KWIAHT, and WDFW. Since 2004, they have examined the main reaches of 11 streams on Orcas Island, seven on San Juan Island, and six on Lopez Island. The researchers found that a total of 31 streams in San Juan County are potentially fish-bearing. Thus far, *Oncorhynchus* species (coho, chum, Chinook, sea-run coastal cutthroat) have been identified in eight streams on Orcas and San Juan Islands, and additional salmon habitat has been identified which is inaccessible due to anthropogenic (human built) features, including perched, inadequate or failed culverts under roads and driveways; runoff from residential property; reduced summer base flow; the loss of stream flow due to the construction of private dams, ponds and pond weirs; and changes in stream channel alignment associated with agricultural activities (Barsh and Murphy 2007).

San Juan County shorelines, estuaries and marine waters are an important habitat to Chinook salmon but large numbers of chum, pink, sockeye and coho salmon are also found in the nearshore from early spring through late summer (Kerwin 2002, Beamer et al. 2008). Historically there has been a strong winter blackmouth (immature Chinook salmon) fishery in the San Juans, as these fish move in to feed for extended periods on sand lance, surf smelt, herring and other forage fish. Steelhead and coastal cutthroat trout are also known to occur in the marine waters around the San Juan Islands (Kerwin 2002).

While quantitative studies remain limited, recent surveys (Wyllie-Echeverria and Barsh 2007, Beamer et al. 2008) in combination with historical and anecdotal reports (Barsh and Murphy 2007, Wyllie-Echeverria 2008, 2008b) describe salmonid use of multiple estuarine and freshwater habitats in San Juan County. Juvenile use of coarser, higher energy beaches distinguishes the San Juan Islands from most of Puget Sound, where smolts tend to congregate in much more protected delta environments and pocket estuaries (Barsh and Murphy 2007). Surveys verified the presence of Chinook, chum, pink, and coho salmon at different times of the year utilizing the intertidal beaches in San Juan County, with salmonid species documented in all nine nearshore intertidal sampling sites including those over course sediment (Wyllie-Echeverria and Barsh 2006, 2007). The largest numbers of salmon in 2006 were found along the beaches of Waldron Island and President Channel, the beaches of south Lopez, and the rocky shorelines of north San Juan (Barsh and Murphy 2007).

Habitat

The value of the San Juan Islands for salmon lies in the diverse nearshore habitats that provide shelter and food, including eelgrass beds and forage fish spawning areas. These habitat areas provide refuge and foraging opportunities for salmonids as they make the migration between freshwater and the sea. In addition, it has been found that some coho salmon acclimate to brackish water, survive and grow in estuaries and the stream-estuary ecotone, but instead of migrating to the ocean they return upstream to freshwater to overwinter before migrating to the ocean. This overwintering strategy may help ensure the resilience of the species, and restoring estuarine habitats may be essential to the recovery of depressed populations of coho (Koski 2009). The major types of nearshore habitat used by salmon in San Juan County include beaches with course sediment and with offshore eelgrass beds, steep cliffs with offshore kelp beds, and muddy “deltas” at stream mouths (Wyllie-Echeverria and Barsh 2007). Surveys suggest considerable nearshore use of pocket beaches and bluff backed beaches by Chinook, coho and chum salmon (Beamer et al. 2008). Juvenile chum and coho salmon abundance is also associated with terrestrial vegetation dominated by western red cedar (*Thuja plicata*) and mosses characteristic of mature coastal forests (Romanuk and Levings 2006). Marine riparian vegetation and vegetation along streams and wetlands draining into marine waters, are also an important source of insects and macroinvertebrate prey for Chinook salmon (Duffy et al 2010).

Juvenile salmon move along the shallows of nearshore habitat and may be found throughout the year depending on species, stock, and life history stage. During their ocean phase, steelhead are generally found within 10 and 25 miles of the shore (Wydoski and Whitney 2003). Chinook salmon are highly dependent on estuarine habitats to complete their life history, and the timing of migration to saltwater is highly variable for this species. Juvenile chum salmon migrate quickly to saltwater as small fry and are therefore highly dependent on the nearshore environment.

Typically cited nearshore habitat requirements of juvenile salmonids include (Simenstad 2000):

- Shallow-water, typically low-gradient habitats with fine, unconsolidated substrates
- The presence of aquatic vegetation, emergent marsh vegetation, and shrub/scrub or forested riparian vegetation
- Areas of low current and wave energy
- Concentrations of small, non-evasive invertebrates.

Although not consistently occurring across all shorelines, San Juan County likely includes areas representing each of the listed habitat requirements above based on a general review of available data. For example, San Juan County beaches are mainly comprised of unconsolidated gravel and sand with variable compositions depending on position and wave energy (see *Sedimentary Geology* section in Chapter 1). While parts of the county are exposed to high energy waves from the Strait of Georgia and the Strait of Juan de Fuca, other portions are more sheltered and are characteristic of low wave energy conditions (see Section 3.1 on waves and currents). In San Juan County, nearshore habitat elements important to salmonid species include kelp forests and eelgrass meadows, forage fish spawning areas, tidal marshes, and intertidal and subtidal flats (SSPS 2007). The factors described above contribute to diverse habitat conditions suitable to many species such as eelgrass and kelp (Section 3.2.3), forage fish (Section 3.2.4) and salmon.

Critical habitat has been designated throughout the nearshore areas of Puget Sound, including San Juan County, for Puget Sound Chinook and Hood Canal summer-run chum salmon. These areas have been identified as high conservation value areas (70 FR 52630). Critical habitat is under development for Puget Sound steelhead, but is likely to include nearshore areas given the high value of the habitat for the conservation of all salmonids.

Prey and Foraging

Chinook, like other salmonids, generally feed on terrestrial and aquatic insects, amphipods, small crustaceans, and other invertebrates as juveniles, with insects (a high quality prey) being a more significant food source in northern Puget Sound, possibly because of the greater influence of freshwater carrying prey items from upland streams and wetlands (Wydoski and Whitney 2003, Wyllie-Echeverria 2008), but with age increasingly feed on fish (Johnson and Schindler 2009, Wydoski and Whitney 2003, Duffy et al. 2010.). In nearshore waters of Puget Sound (Brennan et al. 2009), terrestrial insects have recently been shown to be a large component of the diet of juvenile salmonids (Romanuk and Levings 2010) and typically include insects such as midges and ants that swarm in late summer (Personal communication with Russel Barsh, Kwiáht, December 29, 2010); comprising part of the coastal food web of particular importance to Chinook and coho (Johnson and Schindler 2009).

Coastal fish species that are common Chinook prey include herring, smelt, sand lance, rockfish, and others. As adults in the marine environment, invertebrates make up a smaller portion of their diet, but include euphausiids, crustacean larvae, amphipods, copepods, shrimp, squid, and some terrestrial insects (Wydoski and Whitney 2003).

Steelhead and chum salmon diets are similar to that of Chinook in the marine environment. Studies have shown that juvenile fish, primarily sand lance and herring, make up between 20 and 91 percent of juvenile chum salmon diets, and between 10 and 50 percent of adult chum salmon diets (Wydoski and Whitney 2003).

Threats

Factors affecting Puget Sound salmonids include those related to habitat alteration, harvest practices, hatchery management, and additional factors (such as climate change, ocean conditions, and species interactions) (SSPS 2007). Factors most relevant to land use planning and development regulation include those factors related to habitat alteration. Salmon may be adversely affected by nearshore vegetation disturbance that alters the vegetation community, and subsequently reduces or alters leaf litter and insect drop into the nearshore environment (Romanuk and Levings 2006, 2010). Habitat alteration that affects available food and refuge, such as reduced eelgrass presence or altered marine riparian vegetation communities, represent a significant risk to salmonids, particularly in juvenile stages when they predominantly frequent nearshore environments. Adverse impacts may be expected from direct vegetation removal, or indirectly through water quality impacts that effect vegetation structure in the nearshore zone. This can in turn affect refuge and foraging opportunities for salmon that migrate and rear in the nearshore zone. Indirect impacts of development on habitat may also lead to altered species interactions due to changes in prey and predation opportunities.

In San Juan County, human activities including residential development and land use, vegetation removal, installation of impervious surfaces, and agricultural practices, have likely contributed to altered water quality (Barsh 2009, SJCWMC 2000, Wiseman 2000), influenced habitat forming processes such as erosion and shore drift (MacLennan et al 2010), and subsequently impaired habitat conditions over time (Klinger et al. 2006, Barsh 2009, 2010, SSPS 2007). Habitat forming processes affected by these types of anthropogenic factors are important to salmonid survival and population success, and include the following (PSAT 2007):

- Stream bank erosion
- Gravel and substrate
- Flows (high/low)
- Insects and food supply
- Water quality
- Temperature and shade
- Channel roughness: pools, riffles, cover, and refuges
- Marshes, sloughs, eelgrass, and kelp beds

Development practices and associated impacts that are present or likely to occur in San Juan County, and the potential effects on habitat conditions listed above, are generally described in Section 3.3 of this report.

Protection and Conservation

The Puget Sound Salmon recovery plan (SSPS 2007) includes background information, as well as overall goals and objectives, for salmon protection and conservation in San Juan County. Goals include restoration or protection of 27 tidal marshes including 11 identified as “at-risk” due to development related degradation, conservation of intertidal and subtidal flats that may be at risk due to road construction and residential development, and conservation of eelgrass meadows. Limiting development activities that would potentially lead to degradation of these 27 high priority areas and other important habitats that are potentially at risk will improve the chance for salmon recovery efforts in San Juan County.

Due to the well documented reliance of salmonid species on nearshore habitats such as eelgrass beds, and the relative abundance of these habitats in San Juan County marine waters, protection, restoration, and conservation of nearshore habitat structure and functions should be a priority for the conservation and recovery of salmonids in San Juan County. Implementation of the salmon recovery plan (SSPS 2007) objectives, and general (*i.e.* programmatic) measures (such as establishing riparian buffers and improving stormwater management) that reduce the potential for impacts to the marine environment would also contribute to restoration, protection, and conservation success. (Kerwin 2002, Brennan 2007 SSPS 2007, Redman et al. 2005, Barsh and Murphy 2007, Beamer et al. 2003; Fresh et al. 2006, Levings and Jamieson 2001).

BIRDS

Declines in some sea bird populations are a significant concern in this region, with 39 native species and species groups in the Puget Sound ecosystem identified as imperiled (PSP 2010). The San Juan County marine environment provides habitat for numerous waterfowl, shorebirds, and seabirds. Species that use the shorelines and off-shore areas for foraging and/or congregating in winter include loons (common, Pacific, red-throated, and yellow-billed), grebes (pied-billed, horned, eared, red-necked, western, and possibly Clark's), cormorants (double-crested, brandt's, and pelagic), swans (tundra and trumpeter), geese (snow, white-fronted, and Brandt), diving ducks (greater scaup, harlequin, long-tailed, common and Barrow's goldeneye, bufflehead), redbreasted mergansers, scoters (surf, white-winged, and black), alcids (common murre, rhinoceros auklet, ancient auklet, Cassin's auklet, tufted puffins), and numerous plovers, sandpipers, gulls, terns, and similar species. Likely breeders, depending on shoreline areas, are pied-billed grebe, Canada goose, lesser scaup, hooded and common merganser, ruddy duck, osprey, bald eagle, pigeon guillemot, and many dabbling duck species. Most birds forage in the surf and on beaches for fish, zooplankton, and invertebrates, as well as the aquatic plants that many ducks depend on.

Wintering birds are most likely to be sensitive to shifting food supplies. A number of species have been documented to congregate in response to forage fish concentrations. Protection of forage fish areas will in turn provide added protection for the bird species that prey upon them. Breeding birds are sensitive to nest disturbance by both predators and humans, and protection of special nesting features, such as bluffs and cliffs, are important to raptors and colonial seabirds in particular.

Brown Pelicans and Common Loons are described in greater detail below, including a discussion on their local occurrence, as well as local threats and conservation recommendations. These two species have been called out as specific marine species under the County's designated Fish and Wildlife Habitat Conservation Areas due to their endangered, threatened, or sensitive status.

Three additional bird species, marbled murrelet, bald eagle, and peregrine falcon, are discussed in detail in the Upland Habitat Conservation Areas sections of this report (Chapter 4). All depend on the marine environment in the County as well as upland areas. Although marbled murrelets nest in mature forest canopies, they feed on small forage fish and invertebrates in sheltered marine waters during breeding. The species winters in the San Juan marine waters, in largest concentrations in protected waters, but ventures further into the marine environment than during breeding months (Seattle Audubon Society: www.birdweb.org). Bald eagles feed along marine shorelines year-round and generally nest near large open water, most often in large trees but also on cliffs. The species forages on live and dead fish, waterfowl, and seabirds in coastal areas during all seasons. Breeding birds occur in San Juan County, and the winter eagle population includes both migratory birds from outside the area and overwintering breeders. Peregrine falcons most often nest on cliffs within sight of open water, including marine shorelines. Such coastal birds feed on ducks, shorebirds, and seabirds. Migrants may be attracted to areas of high concentration of these species in winter (Seattle Audubon Society: www.birdweb.org).

Brown Pelican

San Juan County Occurrence

Brown pelicans are non-breeding visitors to the Washington coast, most often occurring in summer and fall, rarely at other times. While most breeding birds are resident, some California birds migrate to Washington after breeding until early winter. An expansion of the species within its historic range was widely noted after the banning of toxic chemicals, most notably DDT, in California. This included an expansion into traditional Washington habitat, from which the species had been nearly absent prior to its well-documented recovery (Wahl and Tweit 2000).

Though feeding pelicans are observed in the County, records show the species occurring less frequently here than along other areas of the Washington coast. The species appears to be increasing in the state overall (Wahl et al. 2005), possibly as a result of prey abundance and availability changes due to long-term ocean temperature change (Jaques 1994). Correlations between bird population size and increasing environmental temperature have been reported elsewhere along the Pacific coast (Briggs et al. 1983).

Habitat

Brown pelicans utilize nearshore marine habitat, defined in one case as 97 to 99 percent of birds being observed at <20 meters water depth (Wahl et al. 2005). Southern California birds used waters up to 75 km from land in the non-breeding season (Briggs et al. 1981). The species becomes waterlogged after approximately an hour on the water and returns to shore for loafing and roosting. Piers, jetties, sandbars, offshore rocks, and islands are also used (Schreiber and Schreiber 1982, U.S. Fish and Wildlife Service 1983, Jacues et al. 1996). On the Washington coast, the species frequents bays, offshore islands, breakwaters, spits, and sand beaches (The Seattle Audubon Society 2005-2008). Night roosts tend to be surrounded on all side by water (Jaques and Anderson 1988).

Habitat use has been associated with the environmental parameters of water depth, distance to shore, and water temperature (Briggs et al. 1983). Some association with prey (anchovies) was observed during spring, but this did not carry over into fall. The species may exhibit a wider prey range outside of the breeding season (Briggs et al. 1983), which may explain why the pattern was not evident in fall.

Prey and Foraging

Breeding brown pelicans in Pacific coast waters depend heavily on anchovies (Anderson et al. 1980, 1982). Non-breeding birds' diets are not specifically documented, but presumably also consist primarily of small, surface-schooling fish. Prey are seized by plunge-diving, and less commonly by surface feeding as the bird sits on the water.

Peaks in brown pelican abundance off the WA coast were associated with ocean productivity changes in the early 1990s (Wahl and Tweit 2005), as well as with periods of unusually warm water (Wahl and Tweit 2000).

Threats

Commercial fishing activities may impact food availability to breeding and non-breeding brown pelicans (Anderson et al. 1980, 1982; U.S. Fish and Wildlife Service 1983). Fish abundance has been correlated with brown pelican reproductive success on both local and regional scales

(Anderson et al. 1982), but dependence of non-breeding birds on the fishery is less clear (Briggs et al. 1983).

The impacts of organochlorines, particularly DDT and its metabolite DDE, on brown pelicans are thoroughly documented, as they are the primary reason for the species' decline in the United States in the 1950s to 1970s. Organochlorine contaminants impact reproduction by interfering with calcium metabolism but it is not a cause of direct adult mortality. Recovery of the species after the banning of DDT in 1972 is recorded copiously in the literature. The substance is no longer considered a significant threat to the species.

Another well-documented impact to brown pelicans is offshore oil from drilling operations and accidents, refineries, commercial traffic, and storage facilities. Direct mortality to both breeding and non-breeding pelicans has been recorded after fouling with oil (U.S. Fish and Wildlife Service 1983). Cleaned and released individual birds experience decreased survival, as well as long-term behavioral impacts, such as lengthened dispersal distances (Anderson et al. 1996). The direct physiological effects of oil, as well as the stress of handling, may be contributing factors. In at least one case, a brown pelican death was the likely result of resuspension of oil from a spill six weeks prior (King et al. 1979).

Research specific to non-breeding birds in California revealed the greatest source of direct human disturbance to roosting birds to be waterfowl hunting (primarily gunshots), followed by recreational activities (beach walking, surfing) (Jaques et al. 1996). Air traffic caused some disturbance, although the birds in the study appeared habituated to it. Seabirds in general tend to habituate to humans in frequently disturbed locations (Rodgers and Schwikert 2003). Humans approaching on foot caused greater disturbance to brown pelicans on a Florida refuge than approaching vehicles (Klein 1993). Collisions with aircraft and manmade structures have resulted in pelican deaths, although none have been documented on the Washington coast. Entanglement in fishing gear has been a significant cause of death in the southeastern United States (Schreiber and Mock 1988), but is not considered a major threat on the California coast (U.S. Fish and Wildlife Service 1983, Jehl 1984) and has not been investigated specifically in Washington State.

Studies of disturbance, prey relationships, and other potential impacts to brown pelicans in San Juan County have not been conducted. No records of the direct killing of pelicans by humans exist for San Juan County.

Protection and Conservation

The California Brown Pelican Recovery Plan (U.S. Fish and Wildlife Service 1983) recommended offshore protection zones to buffer birds from human disturbance and limit or regulate impacts from fishing, oil development, dredging, contaminants, and sea and air traffic. While the intention was largely to protect breeding colonies, it was suggested that such areas might also protect food resources. For non-breeding birds, protection of natural roosting sites and estuarine habitat from disturbance was recommended, although assumed to be of less importance than breeding-bird roosts. Regulation of public access to known roost locations and hunting in roost vicinities has helped to reduce disturbance in California (Jaques et al. 1996). Isolation of roosting sites is recommended as a means of preventing disturbance.

San Juan County Conservation Recommendations

Published information regarding brown pelicans in San Juan County is limited to the occurrence accounts above. Use of marine waters off San Juan County by the species excludes breeding and rearing, and non-breeding habitat use in the County has not been recorded in the literature. Winter habitat use in other areas, specifically California and the southeastern U.S., demonstrates the importance of islands, breakwaters, spits, offshore rocks, piers, and sandbars for resting and roosting. Protection of these and similar potential perches and roosts from human disturbance, particularly hunting activities and more passive recreation, would benefit pelicans by reducing flushing and fleeing. Foot traffic may be particularly disruptive; protection of onshore perch and roost sites should include limiting human foot access.

Much of the available information regarding non-breeding foraging is speculative (Briggs et al. 1983) and based on breeding bird forage habits. Commercial fishing activity has, however, impacted non-breeding pelicans, although the extent of the species' dependence on commercially harvested fish is not clear for wintering birds. Because brown pelican abundance off the Washington coast has been associated with ocean productivity and water temperature, the protection of forage fish populations in San Juan County may enhance foraging success of pelicans in winter. This might be most effectively accomplished through water quality improvements via effective stormwater management in shoreline areas, and through enhancement of fish habitat both in the shoreline and marine environments. Small, surface-schooling species are likely of greatest importance, although information specific to Washington birds is lacking.

Past impacts of organochlorines on brown pelicans are evident from the large body of literature on the subject. These contaminants are present in Puget Sound fish (West et al. 2008), although most pesticide sources are no longer registered for use in the U.S. and Canada. There is probably no need to address this potential source of contamination in pelicans, as it is no longer considered a threat to the species and the presence of banned contaminants in pelican eggs declined after banning (U.S. Fish and Wildlife Service 1983). Offshore oil from refineries continues to be a direct threat to pelicans; avoiding spills from refineries, commercial movement, and storage would help to protect wintering birds in San Juan County waters. Enhancement of wetlands adjacent to potential oil contamination sources (such as roads and parking areas) would also act to protect marine waters from water quality issues related to oil.

Common Loon

San Juan County Occurrence

Christmas Bird Counts consistently report common loons in the marine waters of the San Juan Islands (National Audubon Society 2002). There are no recent records of breeding birds in San Juan County (Richardson et al. 2000, Wahl et al. 2005). A single confirmed sighting of two feathered young at Sportsman Lake was recorded in 1948 (Richardson et al. 2000). A peak count of 275 individuals was recorded at San Juan Island in 1995 (Wahl et al. 2005).

Habitat

Wintering, migrating and non-breeding common loons occur on coastal and inland marine waters of Washington State, and subadult birds often spend the summer in the marine environment. They are most commonly found in shallow, clear, sheltered waters close to shore. The species most often feeds within five meters of the surface but will dive to at least 60 meters (McIntyre and Barr 1997). Daub (1989) found loons wintering off of Rhode Island to forage most frequently at depths of 1.5 to 5.5 m, and to performing drifting and preening activities at greater depths (5.5 to 9.0 meters). These winter congregations were consistently within 180 meters of shore. Common loons spent a disproportionately high amount of time in depths up to 19 meters depths during winter on the continental shelf of the southeastern United States; individuals were observed as far as 100 meters from shore in this location as well (Haney 1990). Rafting was recorded in deeper waters than daytime activities off the tip of Assateague Island, Virginia (McIntyre 1978). During migration, birds have been observed up to 100 km offshore of the Washington coast (Wahl et al. 2005). These and other studies (see Prey and Foraging below) suggest that winter habitat use is at least partially dictated by prey populations.

Prey and Foraging

Common loons require abundant prey (Richardson et al. 2000), and marine habitat use is largely determined by prey availability. Time spent in the shallower zone by the Rhode Island wintering birds was greater in 1991 and 1992 than in 1989, and researchers theorized that the birds were spending more time foraging in shallow water for bottom-dwelling prey such as crab as fish abundance declined in the area. Haney (1990) suggested that higher concentrations of common loons were supported by fertile estuarine waters than the less rich waters of the continental shelf. Other studies (Daub 1989, Ford and Gieg 1995) also show evidence that common loons respond to shifting abundance of small fish.

Common loons feed primarily on live fish, obtained opportunistically with some evidence of preferences. Salmon may be eaten, although preference was exhibited for other species in lakes where salmon occur (Evers et al. 2004), possibly because salmon escape methods make them difficult prey. The limited knowledge of marine prey species in Washington comes from two specimens prepared at the Slater Museum; prey included Pacific staghorn (*Leptocottus armatus*), big skate (*Raja binoculata*), tidepool sculpin (*Oligocottus maculosus*), flounder (Pleuronectidae), and sole (Soleidae) (Richardson et al. 2000). Wintering Rhode Island loons preyed heavily on crabs, but it is assumed that much prey is consumed below the water surface and not observed (Daub 1989, Ford and Gieg 1995).

Threats

Predominant threats to loons in marine waters include boat disturbance, loss of prey, fishing line entanglement, and fishing lure and line ingestion (Richardson et al. 2000). Other factors potentially impacting the birds in the marine environment are oil spills, toxins, disease, predation, and hunting or other persecution (Richardson et at 2000).

Alexander (1991) suggested that mercury-induced toxicity may have contributed to winter mortality in common loons in Florida, but suspected that mercury was acquired on breeding grounds. Monomethylmercury is present in Puget Sound, possibly the result of atmospheric deposition of mercury, influxes of which were correlated with precipitation (Brandenberger et al. 2010). Mercury bioaccumulates in fish, as well as in birds, including common loons. Mercury levels in common loons have been correlated with those in their preferred prey species (Burgess and Hobson 2006, Burgess and Meyer 2008). However, no studies indicating that wintering grounds are a significant source of mercury in loons were found during this literature search, and winter sampling has shown lower levels of mercury then those found on breeding grounds (Evers et al. 1998, Evers 2004, Burgess et al. 2004, Evers et al. 2008, Evers et al. 2009).

The greatest cause of winter mortality in Florida coastal waters was emaciation syndrome, likely due to interacting effects of food resource changes and the energetic costs of migration, molt, weather, and other physiological and environmental factors (Alexander 1991, Forrester et al. 1997). Similarly, emaciation syndrome was the primary cause of death among wintering loons in the Pacific, but specific factors leading to this condition (presumably including flightlessness during molt), are largely unknown (Spitzer 1995).

Oil spills have a well-documented impact on common loons and occur most commonly in the marine environment, most often in response to a spill incident (Forrester et al. 1997, Day et al. 1997). Fouling of plumage can lead to hypothermia, starvation and drowning, and ingestion compromises a number of physiological pathways and functions in both the long- and short-term (Burger and Fry 1993). The winter flightless period increases the species' vulnerability to oil contamination, as the resultant loss of the feathers' waterproofing qualities leads to hypothermia and inability to forage when the birds are unable to leave the contaminated area, preen, or dive effectively (Richardson et al. 2000). Both direct oiling of eggs and ingestion of oil affect reproductive success, and common loon is one of several species that can experience long-term population impacts from oil spills (Sperduto et al. 2003). As well, they appear to avoid oiled habitat for unknown lengths of time (Day et al. 1997).

Effects of DDT on common loons are evident in thinned eggshells but records of a significant impact to populations were not located. DDT reported in at least one Minnesota loon was at a lethal level for other bird species (Ream 1976).

Avian botulism has been the cause of death in substantial proportions of dead common loons collected from breeding grounds (Brand et al. 1983, 1988; Frason and Cliplef 1993, Evers 2004). Little information is available pertaining to sources of the disease in the species, and no evidence that the disease has been spread on wintering grounds. Botulism was not found in dead loons collected off the Florida coast in winter (Forrester et al. 1997).

Lead from fishing equipment is a relatively common form of poisoning in common loons (Pokras et al. 1993, Richardson et al. 2000). Most incidences of loons ingesting fishing tackle are recorded on breeding grounds, where shallower waters allow easier and more frequent access to substrate, where it is often picked up by the birds. Birds may also ingest lead tackle still attached to gear during active fishing.

Human disturbance impacts on common loons, including habitat loss to development, noise and physical disturbance, recreational activities, point-source pollution, and illegal hunting are prevalent on breeding grounds but limited in winter habitat.

Protection and Conservation

Effective restoration of a loon population following impacts from an oil spill on the coast of Rhode Island was found to depend on protection of future productivity through nest site protection from development (Sperduto et al. 2003), and numerous recommendations for breeding habitat protection and restoration are presented in the literature. No recommendations regarding winter habitat restoration are in place or under consideration in Washington State (Richardson et al. 2000), although some wintering areas are protected by NOAA and NMFS programs (Evers 2004).

General conservation recommendations for North America include expansion of surveys to identify wintering concentrations and track migrating birds. This may be achieved by protecting the winter population, particularly where they are at risk of oil spill impacts; developing regulations that minimize by-catch of loons during commercial fishing operations in coastal waters; and developing geographic linkages between breeding and wintering populations (Evers 2004).

San Juan County Conservation Recommendations

Nesting bird protections are not necessary in San Juan County. Wintering, migrating, and other non-breeding common loons in the nearshore waters of the County would benefit from enhancement of small fish populations in shallow marine waters, although knowledge of prey species and foraging locations is very limited in the area.

Water quality controls designed to remove contaminants from stormwater could be an effective means of protecting the species in San Juan County waters, although most contamination impacts are observed on breeding grounds. Again, little documentation of toxicity from contaminants in non-breeding birds is available. Removing lead fishing gear from nearshore areas might be the most direct and effective way of preventing poisoning.

Finally, steps to prevent oil fouling from spills and leaks will both protect molting (such as flightless) birds in the County and prevent habitat avoidance by the species. Enhancement of wetlands for water quality functions near potential spill and leak sites would further protect the species in the event of oil contamination.

Marine Natural Area Preserves, Natural Resource Conservation Areas, and Wildlife Areas

MARINE BIOLOGICAL PRESERVE

The waters of San Juan County and Cypress Island were established as a Marine Biological Preserve (MBP) in 1923 (Chap. 74, House Bill 68, RCW 28.77.230, 1969 Revision RCW 28B.20.320). This status as a MBP prohibits the unlawful collection of biological materials from the marine waters except for approved scientific purposes and food for human consumption (RCW 28B.20.320).

MARINE PROTECTED AREAS

In 1994, the British Columbia/Washington Marine Science Panel recommended that marine protected areas (MPAs) be established in Puget Sound and Georgia Basin to protect marine habitat and resource populations (Copping 2005). Marine Protected Areas, since then, have come to include a wide range of protected areas that are managed by various local state and federal agencies. Examples in San Juan County include numerous state parks, national parks and wildlife refuges, and natural resource conservation areas; and include the MBP described above and the protected areas described in the following sections.

Washington State currently contains 127 MPAs that are managed by eleven federal, state, and local agencies (Van Cleve et al. 2009). Slightly different naming conventions are used by the various agencies that establish and manage MPAs. Various levels of protection (and therefore different management policies) apply to different MPAs within San Juan County.

In addition to government managed MPAs, San Juan County Land Bank has several preserves with shoreline present that are managed primarily to protect nearshore ecological functions and wildlife as well as provide passive recreational opportunities. These include the Judd Cove, Crescent Beach, Deer Harbor and Orcas Village Tidelands Preserves on Orcas Island, Fisherman Bay Spit, Tombolo, Weeks Wetland and Watmough Bay Preserves on Lopez Island, and the Deadman Bay, West Side, Lime Kiln, and Third Lagoon Preserves on San Juan Island.

Due to different management objectives, MPAs provide various levels of protection and have varying success in conserving the county's HCAs. Various management objectives, limited monitoring, and limited data make the effectiveness of MPAs uncertain and difficult to assess (Stewart et al 2009). Identifying additional MPAs to be managed by the county, potentially in collaboration with agencies, may provide opportunities for additional conservation and protection of species and habitats that are associated with the county's HCAs. Designated areas in need of conservation or restoration could also provide mitigation opportunities for unavoidable development impacts.

MARINE PRESERVE AREAS

In addition to the designation as MBP and numerous other protected areas, portions of the San Juan County marine environment have been designated as a Marine Preserve Area for special management. Washington State designated the San Juan Marine Preserve Area in response to the Marine Science Panel's recommendation in 1994. Marine Preserve Areas are one type of Marine Protected Area described above, that receives special management under Washington State law. Marine Preserve Areas are areas specially managed to protect species, habitats and ecosystems. They are marine areas set aside from otherwise unrestricted human activities (Murray and Ferguson 1998), and represent high value ecosystems important to species and habitat biodiversity. Washington Administrative Code defines the San Juan Islands Marine Preserve Area as the following (WAC 220-16-440):

> False Bay: The tidelands and bedlands of False Bay on San Juan Island, including all University of Washington-owned tidelands beginning at a marker 400 feet east of the east entrance of False Bay and extending to the entrance of False Bay, all University of Washington-owned tidelands and bedlands within a line beginning at the University of Washington marker on the shore at the east entrance of False Bay, projected 500 yards offshore, thence northwesterly to a point 500 yards offshore along a line projected from a University of Washington marker on the shore at the west side of a small peninsula at the west entrance of False Bay, thence to shore along said line to the marker, and all University of Washington-owned tidelands west of the marker to a University of Washington marker 600 feet west of the small peninsula.
>
> Friday Harbor: Those tidelands and bedlands adjacent to San Juan Island within a line beginning on the shore 500 yards west of Point Caution, thence 500 yards offshore, thence south and east following the shoreline to the intersection with a line projected from a University of Washington marker located 100 feet north of the north entrance of the floating breakwater of the Port of Friday Harbor and projected towards Reid Rock Buoy, thence along said line to shore on San Juan Island.
>
> Argyle Lagoon: Those University of Washington-owned tidelands and all bedlands enclosed by the inner spit of Argyle Lagoon on San Juan Island.
>
> Yellow and Low Islands: All tidelands and bedlands within 300 yards of Yellow Island and 300 yards of Low Island.
>
> Shaw Island: Those tidelands and bedlands within a line beginning at a University of Washington marker on the shore at Hicks Bay, 122 degrees, 58 minutes, 15 seconds west longitude, thence due south 500 yards, thence north and west at a distance of 500 yards from shore to the intersection with a line projected 261 degrees true from a University of Washington marker on the shore of Parks Bay, which line passes just south of the unnamed island at the north end of Parks Bay, thence along said line to the shore of Shaw Island, including all tidelands and bedlands of Parks Bay south of said line.

MARINE STEWARDSHIP AREA

More recently, in 2004, the San Juan Marine Stewardship Area (MSA) was established by the San Juan County Commissioners (now County Council) to protect marine habitats and species as well as for sustainable socio-economic uses such as thriving livelihoods and enjoyment and preservation of cultural traditions (Van Cleve et al. 2009). San Juan County designated the entire county as a Marine Stewardship Area in 2004 , making its boundaries similar to those of the original MBP of 1923 (which is still designated), minus Cypress Island.

When the San Juan County Commissioners established all marine waters in the county as an MSA they directed the County Marine Resources Committee (MRC) to develop a plan for achieving goals to protect marine resources in the MSA. Using a structured analytical conservation planning approach developed by The Nature Conservancy (Van Cleve et al. 2009), the MRC worked with community partners, marine managers, stakeholders, and others over three years to produce a plan (Evans and Kennedy 2007) that is centered around six principal marine protection strategies. In 2007 the County Council adopted a resolution to use the management plan to guide its operations and policies (Van Cleve et al. 2009). This MSA plan was adopted with the requirement that it be consulted by all county departments in carrying out their work. Because the plan's basis includes a structured analysis of the status of and threats to specific species assemblages and habitats that collectively describe the marine ecosystem, the MSA plan and its supporting documentation are important BAS resources for land use and development planning and management.

NATURAL RESOURCE CONSERVATION AREAS

San Juan County contains several areas that are managed by state and federal agencies. Areas having special protection or management include numerous state parks throughout the county, and federally managed San Juan Islands National Wildlife Refuge lands.

The Critical Areas Assistance Handbook (Ousley et al. 2003) recommends designating Natural Resource Conservation Areas (NRCAs) owned by the Department of Natural Resources (DNR) as Fish and Wildlife HCAs. These areas represent unique or high quality undisturbed ecosystems and habitats for endangered, threatened and sensitive plants and animals, and scenic landscapes (DNR 2010b).

San Juan County has one NRCA located at Cattle Point at the south end of San Juan Island. It consists of 112 acres with waterfront on the Strait of Juan de Fuca and Griffin Bay, a freshwater wetland, grasslands, gravel beach, dunes, a mature conifer forest and steep bluffs. Wildlife is abundant and includes eagles and other birds of prey.

San Juan County has one Natural Area Preserve owned by DNR. Natural Area Preserves protect the best remaining examples of many ecological communities including rare plant and animal habitat. These are high quality, ecologically important sites, intended to preserve the state's diverse natural ecosystems. Natural areas serve as baseline reference sites to guide the management and restoration of less pristine lands (DNR 2010c). This preserve is located at Point Doughty on the coast of Orcas Island and includes 57 acres of forest dominated by Douglas-fir and ocean spray, a plant community representative of the "rain shadow" micro-climate which occurs in parts of San Juan County. Bald Eagles feed and nest on the preserve, and seals haul out on the rocky shoreline (DNR 2010d).

EFFECTS OF DEVELOPMENT AND OPTIONS FOR PREVENTING OR MINIMIZING IMPACTS ON MARINE FISH AND WILDLIFE HABITAT CONSERVATION AREAS

Nearshore marine habitats around the San Juan Islands are considered relatively healthy and are generally assumed to perform the functions needed to support fish and wildlife populations (SSPS 2007). However, coastal regions are continuing to experience changes as a consequence of global climate change and the associated acidification of marine waters, as well as local pressures from fishing, direct habitat destruction, contamination, and alteration of the hydrological cycle (Johannessen and Macdonald 2009) that may degrade San Juan County shoreline resources over time. Although dealing with fishing pressure and the water quality aspects of climate change are outside the scope of land use and development impacts that are the focus of this literature review, they add additional stress to marine species and habitats, which may exacerbate the effects associated with land use impacts. Planning for potential sea level rise is however, something that can be incorporated into land use regulations, particularly those that pertain to the siting of roads and shoreline structures in areas prone to wind and wave erosion. In these locations, it is likely that some will be threatened by rising waters and potentially greater intensity storms, resulting in additional construction of bulkheads which are known to harm marine species and ecological functions.

Stressors on habitat and the protected or sensitive species that use that habitat are commonly associated with development activities on a local scale as well as a regional (or cumulative) scale. Locally, the San Juan Islands has experienced a population growth of 80 percent over the last 20 years, and the projected growth rate is estimated at 35 percent over the next 20 years (SSPS 2007). Most land and shoreline development in the County occurs through incremental single-family residential development. Because many of the undeveloped land parcels in the islands are along shorelines, the impacts associated with shoreline development are likely to continue and cumulative effects would concurrently increase, absent effective protection and conservation efforts.

This section focuses on common types of development and associated anthropogenic impacts that affect fish and wildlife HCAs. It is not a comprehensive or exhaustive analysis but provides a brief summary of best available science on each of the identified topics including:

Bulkheads
Over- and in-water structures
Stormwater
Shoreline vegetation
Discharge of water from individual desalination systems.

It is important to recognize that numerous other sources of impacts may be common in San Juan County. In the San Juan County Marine Stewardship Area Plan, Evans and Kennedy (2007) identified top ranking threats to the marine environment as the following:

Rank	Threat	Overall Threat Rank
1	Large oil spills	**High**
2	Climate change	**High**
3	Shoreline modification due to docks, shoreline armoring, boat ramps, jetties, etc.	**High**
4	Non-local sources of salmon decline	**High**
5	Invasive species	**Medium**
6	Persistent organic pollutants from current industrial and historical sources	**Medium**
7	Polluted stormwater runoff	**Medium**
8	Septic systems and wastewater discharge	**Medium**
9	Predation by marine mammals	**Medium**
10	Historical harvest of rockfish, lingcod & greenling until 1999	**Medium**
11*	Disturbance by other wildlife	**Medium**
12*	Fishing/harvesting activities	**Medium**

Rank	Threat	Overall Threat Rank
13	Derelict fishing gear	**Medium**
14	Small chronic fuel and oil spills	**Medium**
15	Human disturbance on shore	**Low**
16	Sediment loading resulting from upland construction activities, logging, clearing and livestock	**Low**
Overall Threat Status for MSA		**High**

*denotes tied ranking
(Source: Evans and Kennedy, 2007)

Many of the threats to HCAs identified here are parallel to commonly cited threats, such as shoreline modifications including docks, shoreline armoring, boat ramps, and other shoreline development or disturbance; and pollutants and sediment loading associated with stormwater runoff in conjunction with land use activities such as agriculture, septic systems, and increased roads, driveways and other impervious surfaces. These threats are generally addressed within the following discussion as outlined in the beginning of this section.

Bulkheads

With population increasing and suitable building sites becoming less available for residential development, the construction of bulkheads is likely to become a greater concern (Zelo et al. 2000) in San Juan County, particularly if shoreline armoring is viewed as a necessary and acceptable approach to property protection. Most of the beaches throughout the County are composed of sand and gravel derived from the erosion of feeder bluffs (MacLennan et al, 2010). The process of bluff erosion and subsequent deposition on beaches is important to numerous HCAs (Johannessen and MacLennan 2007). Some forms of shoreline protection can adversely affect this process.

Riprap, retaining walls (such as bulkheads), groins, and other forms of shoreline armoring can have a number of adverse impacts on the marine shoreline environment (Herrera 2007a, b, c). The construction of these types of structures in most cases results in loss of terrestrial, shallow-water, and benthic habitat.

This section is primarily focused on bulkheads as the effects of these structures are considered the highest risk for San Juan County. This determination is based on the relatively high percentage of unaltered shoreline currently present, recent increases in the number of permitted hard shoreline protection structures, the potential for future construction of bulkheads, the limited length of shoreline containing feeder bluffs found in San Juan County, and projected population growth.

Numerous documents have suggested a link between armoring (particularly by bulkheads), accelerated beach and marsh erosion, and the burying, loss or disruption of nearshore habitat of adjacent shorelines (Mulvihill et al. 1980, Thom and Shreffler 1994, Spaulding and Jackson 2001, Williams and Thom 2001, Sobocinski 2003, Herrera 2005, Finalyson 2006, Rice 2006, Herrera 2007a&b, Toft et al. 2007, Bilkovic and Roggero 2008, Sobocinski et al. 2010, and Mattheus et al. 2010). While there have been some studies that argue certain aspects of these linkages (such as the role of wave reflection in producing sediment erosion: Kraus et al. 1998), all of these authors document some array of the negative ecological impacts of bulkheads, particularly when the bulkhead is seaward of MHHW (Toft et al. 2007). While many of these studies have been performed outside of the Pacific Northwest (Kraus et al. 1998, Spaulding and Jackson 2001, Bilkovic and Roggero 2008, and Mattheus et al. 2010), a significant number were based on studies conducted within western Washington (Sobocinski 2003, Herrera 2005, Rice 2006, Finlayson 2006, Herrera 2007a&b, Toft et al. 2007, Sobocinski et al. 2010).

The physical disturbance and damage to fish and wildlife habitat caused by the construction of bulkheads can vary, and is dependent on several factors including:

- Type of habitat present prior to construction
- Location and elevation (along the beach profile) of the structure on the shoreline
- Design (size and configuration) of the structure
- Construction materials used
- Methods used to construct it

Bulkheads and other shoreline structures have been shown to alter substrate conditions, wave energy, and beach conditions (Herrera 2005). These factors are discussed below and include related, direct or indirect impacts on habitat conditions such as shade, air temperature, and water quality.

There are several additional mechanisms through which shoreline armoring can impact the nearshore environment, and they can be complex in nature. Many of these impacts can be minimized through proper design, but rarely avoided entirely. In addition, the cumulative impacts from multiple shoreline armoring projects are potentially significant. Where extensive shoreline armoring has resulted in significant cumulative impacts, it may be difficult or impossible to maintain desirable ecological functions. These factors must be considered when reviewing proposed projects, and when developing mitigation requirements (EnviroVision et al. 2007).

Bulkheads can take many different forms. They are typically riprap slopes, but vertical walls constructed of wood and concrete are also common. Not all bulkheads produce the same magnitude of environmental impact. Well-designed bulkheads that do not extend below extreme high water, do not replace shoreline vegetation, and incorporate some form of beach nourishment are expected to have a modest impact on the nearshore environment. However, there are many instances when this is either not feasible or impacts have already caused modifications to the overall landscape that have compromised the habitat functions of a particular site.

It should be noted that relative to Puget Sound, much of San Juan County's coastlines are extremely steep and comprised of exposed bedrock. However, a considerable portion of the coast is also unconsolidated sediment. These areas function as feeder bluffs supplying sediment to beaches (feeder bluff maps for the County were recently completed in 2010). Due to the lack of rivers in San Juan County, most beaches depend solely on bluff erosion for sediment.

Drift cells are comprised of three basic components: (1) a sediment source (usually an eroding bluff); (2) a transport zone where sediments are moved along the shoreline over time; and (3) a depositional area. For the situation described above where bedrock formations block most of the nearshore deposition, the depositional area would be offshore. When a drift cell carrying sediment encounters a bedrock formation or a particularly steeply sloping area along the shoreline, the sediment carried by the drift cell is transported offshore and is permanently "lost" to the nearshore environment.

Armored areas increase wave energy at their base (Spaulding and Jackson 2001, Finlayson 2006) and trigger greater offshore transport as compared to a similar unarmored shoreline. These effects could also result in the loss of nearshore habitat such as forage fish spawning areas (Herrera 2005). Though not a part of a drift cell, the County also has many pocket beaches which would be similarly affected by shoreline armoring. As a consequence it is important to consider to the specific characteristics of shoreline segments where armoring may be proposed.

SUBSTRATE

Shoreline bulkheads that are hard structures can alter wave energy in the surrounding area. Regardless of the specific type of structure (or nature of shoreline hardening) the altered relationship between topography and wave energy results in a shoreline that is out of equilibrium with natural shoreline processes (Komar 1998; Williams and Thom 2001). Transformation of a shoreline from its natural state by installing some form of shoreline hardening would change the way waves interact with the shoreline and thus alter the natural equilibrium. For example, this may change the way substrates move along the shoreline or it may change the rate of erosion processes on or adjacent to the altered site. As a result, wave energy artificially accumulates in some areas and is diminished in others. This redistribution of wave energy can have a number of interrelated indirect and direct effects on sensitive habitat and species by altering conditions of the substrate and water column. The alterations can affect the movement of spawn and larvae, increase shear stress and burial, alter water column stratification, and alter the distribution of aquatic vegetation (Herrera 2007).

Surf smelt, for example, require a specific substrate composition and depend on wave action to cover their eggs with a fine substrate layer (Thom et al. 1994). Other species such as Pacific sand lance also require a specific beach profile and substrate composition for spawning (Penttila 2004). Pacific sand lance spawn in the high intertidal zone on substrates varying from sand to sandy gravel. Increased wave energy intensifies bed shear stress; if some of the coarsest material is not mobilized, a generally coarser substrate results (Komar 1998). This can alter the substrate so as to be unsuitable for forage fish spawning. Invertebrates that cannot tolerate high shear stress or burial may also be affected by altered wave energy and sediment transport. It is important to recognize these indirect substrate disturbances caused by the placement of bulkheads or other similar structures, particularly when considering the cumulative effects of shoreline hardening structures.

WAVE ENERGY

Wave energy plays a role in the distribution of aquatic vegetation used by salmonids and other nearshore fishes, particularly in energetic environments. San Juan County exhibits the full range of exposures to wave energy (Johannessen 2009). Parts of the county are exposed to high energy waves from the Strait of Georgia and the Strait of Juan de Fuca, while other reaches in more sheltered areas exhibit moderate and low wave energy conditions (see also Section 3.1, for a more complete description of San Juan County's waves and current characteristics).

Altered wave energy resulting from shoreline structures can affect habitat suitability for salmonids, forage fish, kelp, eelgrass, and other species. Forage fish depend on tidal currents for feeding and for avoiding predation. Several studies in the San Juan Islands have documented the relationship between tidal currents and predation on herring and other forage fish (Zamon 2001, 2003), or food availability for forage fish (Zamon 2002). Because some shoreline structures can alter tidal current flow patterns, food availability for forage fish, or species that depend on forage fish, may be impacted. The distribution and behavior of schooling fish is important, and perhaps more important than abundance, in determining prey availability and predator success (Zamon 2001). Increased wave energy could impact vegetation communities, and has been shown to dislodge kelp (Kawamata 2001) and inhibit the colonization and growth of seagrass including eelgrass (Fonseca et. al. 1983, Fonseca and Bell 1998, Mumford 2007).

The construction of bulkheads and associated activities also cause local erosion, new sediment deposits in the vicinity of the structure, turbidity, and hence water quality degradation. New sediment deposits are often silty and thus can degrade spawning areas, smother benthic organisms, and reduce bottom habitat diversity, negatively affecting the prey base for other species (Herrera 2007).

EROSION AND BEACH CONDITIONS

In addition to altering shoreline substrate conditions, bulkhead hardened shores can cause beach erosion. Bulkheads and shoreline structures can isolate natural feeder bluffs from sediment receiving beaches. Bulkheads promote erosion of the foreshore because waves can reflect off the face of these structures with sufficient energy to transport sediments, particularly fine sediments, along the shoreline or offshore. Erosion of finer sediments can lead to coarsening of the beach substrate (Spaulding and Jackson 2001), and can be severe in many cases, leading to downcutting of the beach and the eventual loss of the higher elevation portion of the intertidal zone. Downcutting may eventually undermine the bulkhead itself, leading to its eventual failure. Bulkheads can also interfere with the recruitment of sediment from bluffs and the transport of sediment within drift cells, starving adjacent beaches of sediment. These two mechanisms can lead to the gradual loss of fine sediments in the nearshore environment and lowering of the beach profile, leading to a loss of shallow water habitat.

The recent development of "soft" erosion protection techniques, such as vegetated berms and natural wood structures designed to emulate natural drift wood accumulations are preferable to vertical bulkheads because they effectively attenuate wave energy and reduce beach erosion. But even soft structures can reduce sediment recruitment by limiting feeder bluff erosion. Over time, decreased loading of sand and gravel size sediment within an active drift cell can result in coarsening of nearshore substrates, potentially degrading forage fish spawning habitat and requiring sediment nourishment in order to sustain these habitats. Repeated nourishment can have impacts to the benthic environment, but benthic communities are adapted to natural disturbance and can weather occasional placement of appropriate material (Herrera 2007a). However, the placement of a bulkhead may require continual and frequent nourishment, which may exceed the frequency of natural disturbance effects; thus adversely affecting benthic communities over time. This is particularly the case if the nourishment events have the potential to interfere with annual recruitment cycle of benthic species.

The altered wave energy, sediment transport, and beach conditions discussed above can adversely affect sensitive species and their habitat. Rice (2006) examined the effects of shoreline modifications on surf smelt mortality and compared microclimate parameters at a Puget Sound beach with bulkheads and no overhanging riparian vegetation to those at an adjacent unmodified site with extensive riparian vegetation. He documented significant differences in light intensity, air temperature, substrate temperature, and humidity levels at the modified site. Differences in peak substrate temperatures were particularly striking, averaging nearly 20°F (11°C) higher at the modified site. Temperature plays an important role in determining the distribution, abundance, and species' survival in the upper intertidal zone. Results of the study show that anthropogenic alteration of the shoreline typically makes beaches less suitable for surf smelt embryo survival when compared with unmodified shores.

Shoreline armoring, or other shoreline modification or development (including upland development), can impact natural erosion and increase sediment grain size (Spaulding and Jackson 2001). Development along the shoreline can change surface water runoff patterns and result in increased soil erosion and risk of landslides (EnviroVision et al. 2007). Bulkheads, in combination with roads along the backshore and other development that reduces shoreline vegetation, may affect shoreline conditions important to sensitive species. Shoreline armoring may reduce the ability for forage fish to use the 63 currently documented surf smelt and sand lance spawning sites throughout San Juan County (SSPS 2007), or to use an estimated 80 miles of potential spawning habitat that represents 20 percent of local shorelines (Friends of the San Juans 2004a).

Though in some cases well constructed bulkheads can protect trees and vegetation from erosion, their construction can also remove riparian vegetation, impacting the numerous functions afforded by vegetated shoreline conditions. Impacts related to riparian vegetation disturbance are discussed later in this document.

DISCUSSION AND DATA GAPS

Analysis of shoreline permit activity indicates that a total of 318 shoreline permits for bulkheads were issued between 1972 and 2005 (Friends of the San Juans 2007). This represents nine percent of developed shoreline parcels in San Juan County. The annual rate of bulkhead development increased to nine permits per year (between 2000 and 2005) from five per year (before 2000). One study (MacLennan and Johannessen 2008) examined areas representing a range of nearshore characteristics and development patterns found within San Juan County. The study found that approximately 30 percent of 4.5 miles of feeder bluffs in the study area (within 34 miles of shoreline) were modified. Primary modifications were rock bulkheads or armoring that interfere with numerous processes (described above), and prevent sediment supply to the nearshore.

Considering the increased rate of bulkhead related permit activity and projected growth rate of San Juan County (35 percent over the next 20 years; SSPS 2007), the impacts of bulkhead development will likely be significant for San Juan County's marine HCAs. This is particularly true given the predominance of shoreline modifications along not just feeder bluffs but also along transport zones, accretion shoreforms, and pocket beaches, all of which provide habitat for important marine species (MacLennan and Johannessen 2008). (Transport zones are part of a drift cell. They are shoreline areas in which sediments are predominantly moving along the shoreline. However, at the same time, these transport zones also provide some sediment supply from shoreline erosion processes, and may include temporary depositional areas. As such, transport zones are important for habitat development and geormorphic processes).

Based on the literature review, the specific localized effects of bulkheads have not been thoroughly identified in San Juan County. To address data gaps important to regulations on bulkheads and the consequential impacts, Johannessen (2009) recommends incorporating a drift cell management approach to shoreline regulation and development planning. Such an approach would likely require continued mapping of shoreline structures, feeder bluffs, and drifts cells, as well as site-specific assessments for alternative shoreline protection methods during development planning.

Based on current available science, alternative soft shoreline protection and stabilization methods can be considered reasonable alternatives to bulkhead construction as long as it can be shown that the location, design, materials and construction methods would not significantly impact coastal processes, functions, and intertidal conditions.

A comprehensive survey and characterization of marine shorelines (that includes feeder bluffs, bedrock bluffs, beach and substrate conditions, vegetation, and development types), and analysis of sediment transport, would help inform appropriate shoreline development and minimize impacts on sensitive species and habitat. More comprehensive shoreline characterization (for example, MacLennan et al. 2010) can improve regulatory and permitting decisions at both a planning level and for individual projects. However, requiring site specific analysis on a project site basis is also recommended to assist the County in applying appropriate conservation measures to protect nearshore marine habitat processes and functions. In this regard, an assessment of cumulative impacts from shoreline modifications would provide the context needed for the County to identify areas where allowing shoreline modifications would further degrade shoreline functions and adversely impact neighboring properties.

MANAGEMENT OPTIONS

Buffers to protect marine riparian vegetation can be a key factor to minimize the need for bulkheads. This is because bulkheads are most likely to become a preferred alternative where narrow buffers and high shoreline erosion rates occur (Johannessen 2009). Siting a structure away from the hazard area would likely be less impacting on species, habitat and sediment transport, and potentially be more cost-effective, particularly given the range of potential impacts including damage to neighboring properties.

Options for reducing the construction of new bulkheads include limiting their use to those situations where a structure is documented to be threatened from wind and wave erosion. Several recent guidance documents have outlined the different technical methods for assessing and evaluating the level of risk from erosion from various shoreline armoring schemes and their impacts to the environment and nearshore habitat (US Army Corps of Engineers 2006, Herrera 2007a, b, 2008a, Johannessen 2009).

Finally, when a shoreline stabilization structure is necessary, soft shore options can be a feasible alternative with fewer negative effects on neighboring properties, and shoreline processes and habitats (US Army Corps of Engineers 2006).

Over- and In-water Structures

The following sections describe impacts associated with over-water and in-water structures. In addition to bulkheads discussed above, over-water and in-water structures typically associated with shoreline development can have subsequent impacts on fish and wildlife HCAs (Fresh et al. 2004, Thom et al. 2005, Mumford 2007, Sobocinski et al. 2010, Brennan et al. 2009).

In an inventory of major shoreline modifications, Friends of the San Juans found that forty percent of shoreline parcels in San Juan County already have at least one beach structure. Nearly 4,000 modifications were documented on local shorelines, including over 700 bulkheads, 472 docks, 32 groins, 55 marine railways, 70 boat ramps, 1,914 mooring buoys and floats, 425 pilings (not associated with a dock or marina), 50 marinas/jetties/breakwaters, and 191 “other” intertidal man made beach structures. Stairs and stormwater outflow pipes were not included in the survey (Friends of the San Juans 2010).

For this report over-water and in-water structures are categorized into the following; marinas and ferry terminals, boat launches, and mooring buoys. Individual docks and piers are considered within the section describing marinas. Docks and piers typically result in similar impacts as marinas (a collection of docks and piers), albeit the impacts of a single dock may be comparatively less due to the cumulative nature of impacts that would result from a more expansive marina development. However, multiple individual docks or other shoreline structures developed across a geographic area would also result in cumulative impacts and potential threats to marine HCAs. Other in-water structures which are not specifically addressed in this summary, but are noted as having similar impacts on marine HCAs, include jetties and breakwaters.

MARINAS, DOCKS, AND PIERS

Public and private marinas are found on most of the large islands in San Juan County, the largest of which include the Port of Friday Harbor and Roche Harbor Marinas on San Juan Island, West Sound and Deer Harbor Marinas on Orcas, and Island Marine Center, Lopez Islander Bay, and

Spencer's Landing Marinas on Lopez Island. San Juan County currently has four ferry terminals; at Friday Harbor on San Juan Island, Lopez Island, Orcas Island, and Shaw Island.

These marinas and ferry terminals are well established and not likely to be a priority concern with respect to further degradation of shoreline functions. However, ongoing maintenance practices and proposals for facility upgrades and expansion should be carefully evaluated to ensure protection and conservation of HCAs.

The placement and operation of structures associated with recreational, transport, and shipping vessels affect aquatic ecosystems through a variety of mechanisms including the resuspension of benthic sediments, substrate and shoreline erosion, vehicle emissions, stormwater pollution, traffic-related disturbance, and direct mortality of sea life from collisions with vessels (Herrera 2007b).

Marinas (as a collection of individual piers), and shipping or ferry terminals are known to affect light availability and the aquatic habitats upon which sensitive species depend. A considerable body of literature provides evidence that shading from these structures reduces the ambient daytime aquatic light available to levels below the light threshold levels required for aquatic plant photosynthesis and fish feeding and movement (Herrera 2007b). Marina and ferry terminal facilities can also alter ambient nighttime light through the use of artificial light. For terminals that berth large vessels, documented shading includes the reflective effects of sediment resuspension and bubbles generated by high propulsion propeller wash in shallow environments (Thom et al. 1996, Haas et al. 2002, Blanton et al. 2001). Boat propeller wash and benthic disturbance by ferries are well documented for ferry terminals (Haas et al. 2002; Blanton et al. 2001; Thom and Shreffler 1996), and has the potential to alter substrates and reduce habitat for numerous species dependent on specific substrate types.

Nutrient and contaminant loading from vessel discharges, engine operation, prop scouring, bottom paint sloughing, boat wash-downs, haul-outs, boat scraping, painting, and other maintenance activities pose risks such as sediment contamination and water quality degradation (Herrera 2007b). Increased vessel use that may result from new or expanded ferry terminals, marinas, docks, or boat access structures increases the potential for toxic substances to enter the water due to accidental spills.

More vessel traffic in the marine environment increases the potential for underwater noise and disturbance of sensitive species, particularly marine mammals. Recent studies have shown that vessel activity can alter the behavior of whales, including foraging behavior (Lussea et al. 2009; Williams and Ash 2007; Williams et al. 2002, 2009).

MANAGEMENT OPTIONS

Minimization of both size and quantity of over-water structures can be an effective management tool to reduce potential impacts to the aquatic environment. Measures to reduce shading include:

- Use of permitted mooring buoys in lieu of piers/docks (see below)
- Avoid installing over-water structures or mooring buoys on eelgrass beds
- Minimization of pier width
- Orientation of structures in as much North-South direction as feasible
- Installation of light transmitting decking (such as grated decking) (see Figure 3-1)
- Use elevated walkways as high above the water surface as feasible
- Preference for joint-use or multi-use structures over single-use over-water structures.

Measures to reduce substrate impacts include:

- Use of float stops on pilings to prevent floats from resting on the substrate during low water
- Locate moorage far enough off-shore to prevent substrate disturbance from prop wash and potential grounding
- Minimize pile size and quantity to the minimum necessary to support the structure.

Figure 3-1. Examples of grated decking.

BOAT LAUNCHES

Boat ramps, riprap, and other shoreline hardening structures that may be constructed in association with marinas and boat launches can function in a similar manner as described for bulkheads. Depending on the design and location, these shoreline hardening structures can alter wave energy in the surrounding area (Komar 1998), and alter sediment transport (Williams and Thom 2001), with subsequent impacts on habitat conditions and species. Regardless of the nature of the alterations, the modified relationship between topography and wave energy results in a shoreline that is out of equilibrium with natural shoreline processes (Komar 1998). As a result, wave energy artificially accumulates in some areas and is diminished in others. As previously noted, this redistribution of wave energy can have a number of interrelated indirect and direct effects on sensitive species by altering substrate and water column characteristics. These alterations can affect the movement of spawn and larvae, increase shear stress and burial, alter water column stratification, and alter the distribution of aquatic vegetation (Herrera 2008a). The effects of these disturbances can cascade to upper trophic species including salmon and marine mammals, as a consequence of impacts to marine crustaceans and beach and sediment dwelling invertebrates that are lower trophic organisms (Sobocinski et al 2010).

MOORING BUOYS

Mooring buoys can differ significantly in design. Washington State DNR provides guidance for the construction of mooring buoys and requires that all mooring buoys be registered with them (DNR 2008e). Since mooring buoy design effectively determines whether or not specific impacts occur, design is an important consideration for minimizing impacts on sensitive species and habitat. For instance, mid-line float buoys tethered to a well-designed helical anchor (that anchors into the bed) do not have significant construction, maintenance or operational impacts aside from encouraging vessel traffic (Betcher and Williams 1996; DNR 2010e).

The disturbance of primary importance caused by mooring buoys in marine environments is related to eelgrass (Betcher and Williams 1996). Because mooring buoys are usually placed in shallow coastal settings, typical of the location of eelgrass meadows (Phillips 1984), impacts to these areas from mooring buoys are common (Betcher and Williams 1996). Mooring buoys are also often placed in more rural settings (as compared to marinas or other major shoreline development) (JCDCD 2008), and therefore have a higher potential for being within or near an intact eelgrass meadow. Mooring buoys should not be placed in known eelgrass meadows, where possible. Even where eelgrass does not occur, design recommendations for anchoring (PADI 2005) and tethering systems (DNR 2008) should be followed to ensure that adjacent areas are not impacted. If a mooring buoy anchor is placed in or near a known eelgrass meadow it is likely that some impact to this habitat type might occur, the degree of which will depend on the type of anchor and tether.

DISCUSSION AND DATA GAPS

San Juan County has experienced a notable increase in the number of permits related to dock development and other in-water and over-water structures (Friends of the San Juan 2007). Due to the widely recognized impacts of in-water and over-water structures discussed above, analysis of dock design details, such as float size and proximity to eelgrass, conducted through the various permit phases (project proposal, permitting review, and implementation) could improve eelgrass protection. Such analysis would assist County-wide planning decisions, as well as site-specific shoreline development regulation or mitigation decisions that have implications for other species and habitats as well, and would likely lend toward better protection of HCAs.

The cumulative and synergistic effects of multiple docks and other over-water structures is an information need. Because the majority of shoreline development in San Juan County occurs through incremental single-family development and individual shoreline alterations (Friends of the San Juans 2007, SSPS 2007), and because most development is likely to occur within close proximity of the shoreline, the cumulative impacts of multiple individual actions is of particular importance in San Juan County. Although a single dock structure may have minimal direct impacts beyond localized disturbance and altered conditions, numerous structures (and their continued use and maintenance) will likely have more severe impacts on a cumulative scale. For example, beach composition that is determined in part by wave energy (MacLennan et al, 2010) and sediment transport into drift cells (MacLennan and Johannessen 2008) would be highly susceptible to alteration when the presence of multiple docks alter wave energy along the shoreline.

To minimize impacts on HCAs it is recommended that the County's permit process require that proposals meet in-water and over-water structure siting and design standards. Design standards could be based on existing requirements such as those established by the US Army Corps of Engineers for residential docks (USACE 2005), or could be developed and tailored to meet specific local conservation goals based on identified HCAs and/or based on land use designations throughout the county. Siting standards should include an evaluation of potential cumulative impacts that considers the presence of other over-water structures. More stringent siting and design criteria would likely provide better conservation, particularly on a cumulative scale and could be based on the potential and likely contribution to threats identified by Evans and Kennedy (2007) as having local significance.

The development and maintenance of ferry facilities in San Juan County is managed by Washington State, and there are regulations and policies in place to ensure minimization of impacts on HCAs important to San Juan County. Proposed changes to ferry and marina facilities, and their potential impacts on threatened and endangered species, are typically described and reviewed in a biological assessment or other documentation prepared for the project. San Juan County should ensure review of the project's documentation for adequate inclusion of all HCAs identified for the county, and request additional analysis or reporting if information is absent or inadequate to inform development decisions.

Stormwater Synopsis

Washington State Department of Ecology estimates that about one third of all the polluted waters on the Section 303(d) list of impaired waters are degraded due to stormwater runoff (PSAT 2005). Though San Juan County does not have any closed shellfish areas, thousands of acres of shellfish growing areas in other parts of the Puget Sound Region are closed to harvest due to stormwater runoff and other pollutant sources. Scientists have cited loss of habitat due to development and stormwater runoff as a primary concern contributing to the decline of ESA listed species (PSAT 2005, Sandahl et al. 2007).

The physical processes associated with land cover, runoff and water quality have been extensively studied over the past thirty years. Recently, the City of Seattle completed a compilation and review of literature that is representative of the best available science regarding stormwater management for the protection of environmentally critical areas (Seattle 2005, 2009). Though impacts are greater in highly urbanized areas, hydrologic and water quality changes can be identified beginning with the conversion of forest to meadow and agricultural land, and significant impacts are observed when impervious areas comprise as little as 5 – 10% of the watershed (Booth and Jackson 1997). Chapter 7 of this report reviews additional studies on stormwater management and their applications for conditions in San Juan County. The report chapter provides a summary of impacts associated with stormwater runoff related to flow rates and water quality and a review of scientific literature related to alternatives that can be used for stormwater management, focusing on best management practices for flow control and water quality treatment.

From work done in southern California, stormwater has been shown to be a human health risk to visitors of the nearshore because of fecal coliform bacteria levels, particularly in protected embayments (e.g., Newport Bay: Pednekar et al. 2002, He and He 2008). High velocities and intense mixing in the various tidal channels that separate islands in the County (e.g., President Channel, San Juan Channel, Upright Chanel, Rosario Strait and Haro Strait) means that stormwater pollution there can be rapidly conveyed away to deeper water where significant dilution can occur, minimizing the impact of contamination on the nearshore ecosystem (Fischer et al. 1979). At creek mouths, runoff is concentrated. Often in the County, the larger streams that produce significant runoff are associated with agricultural lands, which can be a source of fecal coliform and sediment. From an extensive study of Orange County coastal drainages, Dwight et al. (2002) found stormwater contamination at creek mouths was concentrated and persisted for significant periods after initial contamination.

A study of water quality in San Juan County was completed by Huxley College of the Environment at Western Washington University (Wiseman et al., 2000). The study evaluated water quality at selected freshwater and marine sites for use in the County Watershed Action Plan that was being developed. Freshwater sites were selected that were a) geographically representative of the different County watersheds, b) identified in previous studies as having elevated fecal coliform counts, or c) identified as a concern by the County Watershed Management Committee. Site selection was also limited to streams that could be accessed and had enough drainage area to flow most of the year. Marine sites were selected based on presence of high boat traffic, low flushing rates, and sensitive marine resources.

All freshwater sites (sites 1-24) were sampled monthly during the wet season (November through June), Most streams were dry from July through October 1999, and as a result only seven freshwater sites were sampled during that period. Water quality parameters that were monitored for fresh water sites included temperature, dissolved oxygen, conductivity, pH, turbidity, total phosphorus, ammonia, nitrate/nitrite, and fecal coliform. When possible stream discharge was also measured.

Marine sites (25-33) were sampled during June – October, which encompassed the period of maximum recreational activity by boats. Marine samples were collected at 6 ft. below the halocline, and analyzed to determine temperature, dissolved oxygen, conductivity, pH, turbidity, soluble reactive phosphorus, nitrate/nitrite, fecal coliform bacteria and secchi depths.

This study identified several locations with impaired or marginal water quality compared to State standards. Anthropogenic sources and, in some cases, natural upwelling were suggested as possible causes. Results are summarized below:

OBVIOUSLY IMPAIRED WATER QUALITY

Site 1, Lopez north end, near Port Stanley Road and Ferry Road: high fecal, chronically low DO, high nutrients

Site 4, Lopez southwest, intersection of Richardson Road & Davis Bay Road: high fecal coliform, occasional low DO high nutrients in late fall

Site 9, Orcas stream draining Crow Valley: high fecal coliform, low DO, high nutrients, high TSS

Site 11, Orcas Eastsound stormwater culvert: high fecal coliform, low DO, high conductivity

Site 16, Orcas Doe Bay: high fecal coliform, low DO, high nutrients

Site 17, Friday Harbor Spring Street stormwater outfall: high fecal coliform, high nutrients, high TSS

Site 19, San Juan Island stream draining Sportsman's Lake: chronically low DO, high nutrients

Site 24 San Juan Island creek near False Bay: chronically high fecal, high temperatures, chronically low DO, high nutrients, high turbidity.

MARGINAL WATER QUALITY

Site 2, Lopez Hummel Lake drainage: high fecal coliform, low DO, high nutrients

Site 3, Lopez near wetlands north of Lopez Village: high fecal coliform, low DO, high nutrients

Site 5, Lopez east side by Elliot Road: high fecal coliform, occasional low DO, high nutrients in late fall

Site 6, Lopez near Port Stanley Road and Lopez Sound Road: high fecal coliform, low DO, high nutrients in fall

Site 7, Lopez west side by intersection of Davis Bay Road and Richardson Road: high nutrients
Site 14, Orcas near Olga at mouth of Cascade Creek: high fecal
Site 15, Orcas by intersection of Buoy Bay Road and Horseshoe Hwy: low DO
Site 18, San Juan stream draining Beaverton Valley by University Drive: high fecal, variable DO
Site 22, San Juan stream draining Garrison Bay watershed by intersection of Yacht Haven & Mitchell Bay Road: high fecal, high temperature, low DO
Site 23, San Juan Valley Creek near intersection of Wold Road and San Juan Valley Road: high fecal coliform, high temperature, low DO

More recently, the San Juan County Conservation District with a grant from Ecology conducted a volunteer-based monitoring program from March 2002 to December 2005 (SJCD 2005). The study consisted of data collection on an approximate 4 to 6 week interval from 24 sampling locations including both marine and freshwater. Samples were analyzed for temperature, pH, dissolved oxygen, turbidity, and fecal coliform. A summary of the data results by site is provided below:

San Juan Island

- Site BV-1, Halverson Rd near Roche Harbor Rd – low DO
- Site BV-2, Barn Swallow Way near Beaverton Valley Rd. – low DO
- Site BV-3, University Rd. near Tucker Rd. – no issues
- Site FB-1, Julie Rd. near Kiehl Rd. – slightly low DO
- Site FB-2, Club Mud Rd. near Wold Rd. – high fecal coliform
- Site FB-3, Valley Farm Rd. near San Juan Valley Rd. – high fecal coliform
- Site FB-4, Bailer Hill Rd at False Bay Drive – high turbidity and fecal coliform
- Site FB-6, Bailer Hill Rd. 0.7 miles from False Bay Drive – high turbidity and fecal coliform

Lopez Island

- Site SB-1, Cross Rd. near Port Stanley Rd. – high turbidity and fecal coliform
- Site FM-2, Outfall north of Lopez and Weeks Rd – elevated turbidity, low DO
- Site FM-3, Outfall in Fisherman's Bay 100 ft south of Erisman Dr. – elevated turbidity
- Site DB-4, Davis Bay Rd. near Burt Rd. – no issues
- Site DB-5, Richardson Rd. near Davis Bay Rd. – no issues
- Site LS-6, Lopez Sound Rd near School Rd. – no issues

Orcas Island

- Site O1, Willow Creek Ln and Killebrew Lake Rd. – low DO
- Site O2, Deer Harbor Rd. – high temperatures
- Site O3, Deer Harbor Rd near Crow Valley Rd. – low DO
- Site O4a, near Nordstrom Ln. and Crow Valley Rd. – high fecal coliform
- Site O5, Main St. near Orcas Rd. – low DO
- Site O6, Rosario Rd. near Orcas Rd. – no issues
- Site O7, Pt. Lawrence Rd. at head of Buck Bay – no issues
- Site O8, Doe Bay Resort parking lot – low DO and very high fecal coliform
- Site O9, Forest Lane near Eagle Lake Community – low DO

Local studies by Barsh et al. (2008, 2009, 2010) suggest that pyrethroid pesticide use is contributing to the contamination of lakes, streams, ponds and freshwater sediments in the San Juan Islands (Barsh et al. 2008) and may be accumulating in nearshore trophic webs where they could affect sensitive fish and wildlife including local human food supplies (Barsh et a. 2009). Drainage from the town of Eastsound appears to contribute to pyrethroid pesticide contamination of bivalves in Fishing Bay (Barsh 2009), resulting in levels above current federal food safety standards, and suggesting that pesticide contamination of Fishing Bay is continuing. Barsh et al. (2010) examined multiple parameters in False Bay Creek, including water quality and toxins in fish and invertebrate samples. Contaminants were found at levels that could have biological effects, including loss of fertility in salmonid eggs. In this study, water quality issues were worsened by negligible summer instream flows, use of the riparian corridor as cattle pasture, outdoor use of spray pesticides, and untreated runoff from county roads (Barsh et al. 2010).

It should be noted that none of these sampling programs included targeted storm sampling. Since the majority of surface water pollutants are elevated in storm flow relative to base flow, it is likely that the monitoring that has been conducted in San Juan County to date has underestimated average annual pollutant concentrations.

As discussed throughout this chapter, maintaining water quality is a major requirement for protecting marine HCAs, for the habitats and their dependant species. Chapter 7 notes that the effect of runoff on a particular habitat is related to several variables, including the quantity and composition of contaminants washed into runoff, the effectiveness of any stormwater treatment systems, and the sensitivity of receiving waters and habitat. Even when discharged into areas with good mixing, where localized impacts might be negligible, contaminants still add to the overall pollutant load to inland marine waters). Preventing contamination of stormwater is probably the most effective approach to maintaining good water quality. This can be accomplished through a variety of mechanisms, including better management of road and driveway runoff, proper use and maintenance of septic systems, use of roofing materials that are not susceptible to growth of moss and which do not contain copper or zinc, and reduced use of pesticides especially near drainageways, streams, wetlands and the marine shoreline. Preventing or minimizing contamination at the source can reduce the need for wide buffers intended to protect water quality. Effective flow control and treatment of stormwater runoff, including runoff from residential properties, will substantially prevent further degradation of marine water quality.

DISCUSSION (DATA GAPS AND LOCAL IMPORTANCE)

The unincorporated urban areas of Eastsound on Orcas Island and Lopez Village on Lopez Island lack adequate stormwater treatment systems, and both are in close proximity to potential forage fish spawning beaches (Friends of the San Juans 2004a). Additional treatment for these areas is important as both developed areas drain to important embayments in the County.

The discharges from stormwater and septic systems, likely primary pollutant sources in marine areas (Brennan et al. 2009), requires further study and continued improvement in San Juan County. A county-wide assessment of both stormwater and septic influence on marine waters and riparian areas is necessary to fully understand the impacts on marine HCAs, and to guide local development (including upland development) policies.

To address environmental concerns related to stormwater, the *Low Impact Development Technical Guidance Manual for Puget Sound* (PSAT 2005) provides stormwater managers and site designers with guidance for goals and specific practices that are applicable to the Puget Sound region. The manual provides extensive background information on related impacts and data to help managers make informed decisions.

Additional information regarding stormwater flow control and treatment alternatives is provided in Chapter 7 *Stormwater Management Alternatives* of this report.

Shoreline Vegetation

HABITAT FUNCTIONS

Shoreline or marine riparian vegetation is an important component of nearshore habitat throughout the Puget Sound region (Herrera 2007, Lemieux et al 2004, Levings and Jamieson 2001, Redman et al. 2005) including San Juan County. Marine riparian vegetation includes both upland forested plant communities occurring on the shoreline that function similarly to freshwater riparian communities, as well as unique vegetation found only in the marine nearshore (Lemieux et al 2004). Marine riparian areas contain elements of both aquatic and terrestrial ecosystems which mutually influence each other (Knutson and Naef, 1997, Fresh et al. 2004, Lemieux et al 2004). For example, juvenile salmon consume terrestrially derived carbon which can extend into the low intertidal zone (Romanuk and Levings 2010), and salmon are well known conduits for returning marine derived nutrients into freshwater systems (Chaloner et al. 2002, Wipfli 2003). Beach wrack and detritus accumulated in driftwood and tree fall in the nearshore zone, provide both terrestrial and marine derived food sources for invertebrates, fish, birds, and other organisms (Lewis 2007, Brennan et al. 2009).

These interactions between riparian vegetation and the nearshore marine environment, for example the conveyance of organic debris and nutrient cycling, are important to the survival and population success of numerous species that depend on marine habitats. Conservation efforts that preserve the natural processes of detritus and nutrient conveyance, and organic debris accumulation, are therefore important in the marine environment. The establishment of buffers (discussed in the *Marine Riparian Buffers* section) is likely to be an important management strategy for protecting marine HCAs.

MacLennan and Johannessen (2008) conducted geographically-focused research in the San Juans and found an average 25 percent loss of marine riparian forest cover on San Juan, Orcas, Lopez and Stuart islands between 1977 and 2006. Marine riparian mapping completed for four case study areas found a range of shoreline conditions that included dunes, marshes, prairie grasslands, shrubs, forest, lawn, and impervious surface (San Juan Initiative 2008). Shoreline condition and vegetation type can influence the filtering of pollutants from runoff and the amount of water runoff that is introduced into the marine environment (Lemieux et al. 2004). Additional shoreline mapping may be useful to inform conservation efforts related to marine HCAs in San Juan County.

Marine riparian areas can be directly impacted by vegetation removal or alteration, or indirectly impacted by changing the physical conditions required by plants that make up the community. Indirect impacts can occur as a result of shoreline armoring or development in buffer areas and the back shore zone. By disturbing riparian vegetation directly, or by altering the physical conditions that determine the type of plants that grow in the nearshore zone, shoreline modifications can affect numerous protected or sensitive species and their habitat.

In literature reviews conducted to evaluate the potential impacts of riparian vegetation modifications on numerous sensitive species, several mechanisms of impact were identified (Herrera 2007b, 2008b). The degree of impact to the aquatic environment depends upon the magnitude of the vegetation removal or alteration (such as size and number of trees affected, and total area cleared of vegetation). At more severe levels, riparian vegetation modification could result in the following impacts, which would have subsequent implications for species survival and overall habitat condition:

Altered shade and temperature regime: Caused by direct removal of vegetation.

Reduced bank and shoreline stability: Caused by degradation of riparian vegetation, loss of vegetative cover and root cohesion, and reduced resistance to erosion. This may, in turn, affect aquatic habitat by increasing suspended sediments and altering riparian habitat structure.

Altered organic material contributions: Caused by reduced source of leaf litter, woody debris, terrestrial insects, and other biota.

Altered habitat complexity and increased habitat fragmentation: Caused by removal of native vegetation and creating habitat favored by invasive species

There are geologic constraints on the type and density of vegetation that can establish on some areas of marine shoreline in San Juan County. For example, many bedrock shorelines, especially those exposed to swell and the stress of sea spray are limited in the development of functional densities of vegetation and even shrub species may be precluded, particularly where shores are composed of ultramafic bedrock.

SHADE AND TEMPERATURE

The effects of modifications to riparian vegetation on shade and temperature have not been well studied in marine systems (Herrera 2007b). The majority of research on the effects of modification of riparian vegetation, particularly temperature impacts on aquatic species, has focused on salmonids in stream environments (Herrera 2008b), where optimal shading and temperature regulation have been associated with mature forest cover and a high degree of canopy closure near the stream (Kleinschmidt 1999). Altered water temperatures (particularly temperature increases) can adversely affect habitat for marine species (Rice 2006). This can have direct or indirect effects on fish health and survival, and can include mortality as well as sublethal or behavioral effects.

While the removal of stream, lake, and wetland riparian vegetation may at first be perceived as irrelevant to the marine ecosystem, indirect impacts are actually likely, particularly in areas where freshwater streams mix with saltwater and the freshwater contributions play a major role in nearshore ecology. This includes areas such as Westcott Bay on San Juan Island and East Sound on Orcas Island. Hence, consideration should be given to potential impacts associated with development taking place throughout the stream-based watersheds. These considerations include, for example, avoiding riparian vegetation removal by establishing regulated buffer areas, and maintaining pre-development flow regimes to the extent possible (such as infiltrating runoff from impervious surface areas) to help maintain base flow to streams, lakes, and wetlands.

Implementing actions that are aimed to protect water temperature will also help to avoid the impacts associated with turbidity and sedimentation in the nearshore environment (see related discussion in the Shoreline Stability section). The same is likely applicable to pollutants that may originate throughout the watersheds. This includes moss control chemicals (such as zinc strips, detergent, and chemical mixtures), deicing chemicals, and pesticides used on lawns, gardens and around house foundations (such as spray for ants and termites). Hence, although it is outside the main scope of this chapter, it is important to understand the relevance of stream riparian vegetation, within the context of how it can moderate the water temperature and pollutant concentration of nearshore areas with limited mixing of marine water.

Marine riparian shade influences microclimate conditions in the upper intertidal zone. Loss of riparian shade is correlated with increased substrate temperatures and reduced humidity (Rice 2006), which in turn affect the survival of many upper intertidal organisms, including summer spawning forage fish species, specifically sand lance and surf smelt (Brennan and Culverwell 2004, Penttila 2001, Rice 2006). Approximately 1,000 survey sites in San Juan County, including potential forage fish spawning areas, were documented with shading of less than 50 percent (Friends of the San Juans 2004a). Shade values of less than 50 percent were noted for 42 documented forage fish spawning beaches. It is also likely that juvenile salmon and other species sensitive to temperature (for example, some shellfish species discussed in this document) are adversely affected by reduced shade to the extent that it impacts water temperature in the nearshore zone. This would particularly be the case in areas with limited water circulation, mixing, or exchange.

SHORELINE STABILITY

Marine riparian vegetation clearly plays a role in stabilizing marine shorelines, particularly bluffs and steep slopes (Brennan and Culverwell 2004; Desbonnet et al. 1994; Lemieux 2004; Myers 1993), but the specific impact mechanisms are not as well understood as they are in freshwater environments. Along marine shorelines, stability and erosion rates are affected by site-specific factors including soil type and depth, surface and below ground hydrologic conditions, and whether the location is susceptible to wind and wave erosion. Vegetation removal and other development can lead to destabilization of bluffs and shorelines, and accelerated erosion and sedimentation levels that are out of equilibrium from natural bluff erosion processes.

While natural sediment input from bluff erosion is an important physical process that gives rise to beaches and productive nearshore habitat, accelerated erosion due to riparian vegetation removal or poor stormwater management can often increase the rate of sediment production as well as produce sediment with a more fine-grained, silt, and clay character that can degrade water quality and habitat.

Sedimentation and siltation impacts resulting from destabilized shorelines can affect the distribution of eelgrass beds or other organisms which are dependent on specific substrate compositions (Finlayson 2006). Siltation thus reduces habitat complexity and may reduce or eliminate habitats (Steneck et al 2002, Mumford 2007) that are important sources of food (prey) and refuge for salmon and marine fish, and are important spawning habitat for forage fish. Due to their dependence on specific water quality conditions, eelgrass beds and kelp forests that provide important habitat for forage fish and other sensitive species may be affected by updrift development activities which affect water quality. In addition, upstream impacts on water quality within freshwater systems discharging to marine waters can affect the nearshore environment if the activities result in the discharge of sediment-laden water or excessively warm and/or contaminated water to nearshore areas that have limited mixing potential.

ORGANIC MATERIAL CONTRIBUTIONS

Marine riparian vegetation, and vegetation along streams and wetlands draining into marine waters, are a known source of organic matter, nutrients, insects (e.g. midges, mayflied, blackflies, and net spinning caddisflies) and macroinvertebrate prey for numerous sensitive species (Murphy, 1995; Duffy et al. 2010). In aquatic systems there are two sources of energy, primary production from photosynthesis associated with aquatic plants (e.g. diatoms), and leaves and needles deposited from trees and shrubs which are then consumed by aquatic organisms (Murphy, 1995). Leaves from deciduous trees and shrubs are consumed relatively quickly, while those from coniferous trees take longer to decompose and be consumed. Productivity associated with photosynthesis peaks in the summer, and that associated with deposition of leaves peaks in the fall.

Along streams, mature conifer forest (which allows in some light and provides large woody debris) mixed with some deciduous trees and shrubs has been found to provide optimal, year round food sources for fish and aquatic invertebrates (Murphy, 1995; Knutson and Naef, 1997). In well functioning stream systems, sediment, water and nutrients are slowly metered out over time. When supplies of woody debris are inadequate, stream energy during storm events is not adequately dissipated, there is less storage capacity for sediment and organic material, and these materials are quickly flushed out of the system resulting in a reduction of food sources and habitat for aquatic invertebrates (Murphy, 1995).

Riparian areas also provide driftwood to the nearshore zone, which then accumulates detritus from both marine and upland sources. The detritus is subsequently consumed by invertebrates, birds, and other organisms (Brennan et al. 2009). Also, terrestrial insects have recently been shown to be a large component of the diet of juvenile salmonids (Romanuk and Levings 2010). Sobocinski (2003) documented the importance of insect communities and benthic organisms that are either directly or indirectly associated with riparian vegetation. These lower trophic organisms serve as the basis of the food web for sensitive fish species that use the upper nearshore environment (Romanuk and Levings 2010, Williams and Thom 2001). In addition, some fish and invertebrates feed directly on vegetative detritus (Brennan et al 2004, Fresh 2007).

The recruitment of organic matter, nutrients, and macroinvertebrate prey items can be reduced when riparian vegetation is removed (Brennan et al. 2004, Sobocinski 2003, Williams et al. 2001). Reduction of organic material contribution into the marine environment, in turn, reduces the availability of food for sensitive species. Studies suggest that the delivery of leaf and other organic matter declines at greater distances away from the water's edge, and that most contributions are made within 100 to 200 ft (30-60 meters) of the shoreline (Brennan et al. 2009). Finally, in freshwater systems it has been shown that detritus feeding organisms may not be adapted to the leaf fall patterns or the chemical characteristics of leaves from non-native trees suggesting that riparian areas are most effective when comprised of native vegetation (Karr and Schlosser 1977). This is likely the same for marine riparian areas. In addition, native plant species have adapted to local physical conditions such as soil, geology, and climate and therefore require less maintenance, are resistant to most pests and diseases, and require little or no irrigation or fertilizers, once established. Thus maintaining native plant species in marine riparian areas can have consequent benefits on maintaining water quality.

HABITAT STRUCTURE AND COMPLEXITY

By maintaining bank stability and contributing large wood to the aquatic environment, riparian vegetation forms and maintains habitat complexity. As described above, riparian vegetation and large wood improve beach stability and contribute to roughness and sediment trapping (Brennan and Culverwell 2004, Gonor et al. 1988, Herrera 2005). Riparian vegetation also provides contributions of organic matter, moisture, and nutrients that assist in the establishment and maintenance of estuarine marsh plants (Eilers 1975, Williams and Thom 2001).

Herrera (2005) suggested that driftwood and tree fall at the top of the beach may also stabilize the upper beach area by slowing littoral drift and reducing wave-induced erosion). It has been suggested that estuarine wood can affect water flow and the subsequent formation of bars and mudbanks (Gonor et al. 1988). The contribution to habitat complexity along marine shorelines may be maximized if trees that fall to beaches remain in place (Herrera 2005).

Marine shorelines that have been modified by human activities tend to have less large woody debris and driftwood than unmodified beaches (Herrera 2005; Higgins et al. 2005). In particular, shoreline development including marinas, jetties, and bulkheads, redistribute large woody debris such that it concentrates in certain areas and is absent in others (Miller et al. 2001, Herrera 2007a).

Direct disturbance of shoreline vegetation can also alter habitat complexity. Disturbance by pedestrian traffic and kayaks can impact intertidal plant communities as well as the species that rely on the vegetation. The impacts of trampling on rocky intertidal beaches is well documented (Brosnan and Crumrine 1994; Irvin 2005; Jenkins 2002; Pinn and Rodgers 2005). On San Juan Island, Jenkins et al. (2002) showed that experimental trampling of 250-steps, three times per week reduced seaweed species (*Fucus* spp.) cover by 70 percent after six weeks with continued loss of cover for at least three months after the end of trampling. *Fucus gardneri* populations at Cattle Point on San Juan Island were exposed to trampling, and the study by Irvine (2005) showed increased loss of biomass with increased trampling, and reduced cover ranging between 10 percent cover in a 100-step plot up to 85 percent loss in a 200-step plot (Irvine 2005). Trampling has also been shown to result in loss of mussels (*Mytilus spp.*) and significantly reduced barnacle cover (Brosnan and Crumrine 1994), loss of larger, branching species of algae, and an increase in ephemeral (short-lived) and smaller, non-branching species (Pinn and Rodgers 2005).

SCIENTIFICALLY BASED OPTIONS FOR MARINE RIPARIAN BUFFERS

Due to the importance of riparian vegetation in freshwater and marine systems, the establishment of buffers is commonly regarded as having a key role in protecting aquatic habitat. In general, the term **buffers** refers to terrestrial areas surrounding a wetland, stream, water body or other area of high ecological, geological, or hydrological importance, and whose purpose is to reduce or prevent impacts to the functions of the protected resource, such as may occur from adjacent land uses. In comparison, **setbacks** are regulatory tools used to protect land from encroachment by structures, but do not generally specify how the setback area must be managed. Like setbacks, buffers are measured a specified distance between a development and the resource being protected. Unlike setbacks, buffers usually are considered off-limits to some activities and land uses which themselves may impact the functions of the resource being protected. Buffers are often (but not necessarily) configured to completely encircle a wetland , lake or other resource, whereas setbacks are confined to just a direct path between the development and the resource being protected.

Although information on the application and effectiveness of marine buffers is more limited than for freshwater systems, many of the same physical processes occur, particularly with regard to transport of pollutants, organic material, and food and nutrients from the land to the water (Lemieux et al. 2004). Because riparian buffers in both stream and marine environments can have implications for water quality in the marine ecosystem, some references to freshwater buffers are included in this section. Best available science for freshwater and marine riparian environments, particularly related to safeguarding the processes that protect riparian functions, remains an active field of research.

Nonetheless, an extensive body of research and literature has emerged over the last three decades which documents the importance of riparian areas in providing ecological functions related to waters of the state. These functions include the following (Romanuk and Levings 2010, Brennan et al. 2009, Lemieux et al. 2004):

- Water quality maintenance
- Fine sediment control
- Large woody debris delivery and retention
- Microclimate moderation
- Nutrient delivery and retention
- Terrestrial carbon source to nearshore food webs
- Fish and wildlife habitat creation and maintenance
- Direct food support for juvenile salmonids
- Hydrologic based slope stability

There is consensus in the scientific community that marine riparian area buffers are critical to sustaining many ecological functions (Desbonnet et al. 1994, Brennan and Culverwell 2004, Lemieux et al 2004, Brennan et al. 2009) however few studies were found addressing marine riparian buffer functions and identifying and proposing specific distance requirements. As for freshwater stream riparian areas, these are commonly grouped into three primary categories: water quantity, water quality, and habitat. Development and human activities can adversely affect water bodies by impacting the hydroperiod (extent, duration, and timing of flow), or by impacting water quality and habitat either directly or indirectly. This is especially true when structures and land uses that discharge generate and discharge pollutants are located in areas that are most likely to flush pollutants into the water (see discussion in Chapter 2). Buffers adjacent to water bodies are therefore key to providing functional benefits related to water quality and habitat. For example, vegetation in buffers can improve water quality through capture and uptake, and buffers provide a complex transitional zone between upland and aquatic environments that is important habitat for many species.

Other factors relevant to the effectiveness of marine buffers, or of a given buffer width, include the type and intensity of surrounding land development; influence of groundwater; stability of slopes or bluffs; types of pollutants and their sources; vegetation dynamics (such as type and density); susceptibility of the buffer to wind throw, which may require buffers in excess of one site potential tree height (e.g. in areas with high winds, particularly when prevailing winds are perpendicular to the buffer (Murphy, 1995); whether some tree removal will be allowed in the buffer; and geomorphic functions of driftwood or other habitat features that might affect the functions and values of the buffer (Brennan et al. 2009). For example, slopes that are more susceptible to massive failure may require a larger buffer, particularly if existing development is contributing to an increased rate of erosion such as from poor stormwater management or lack of stabilizing vegetation. Likewise, feeder bluffs contributing to spawning beaches may require a larger buffer in order to protect future development while also decreasing the need for shoreline armoring. In some cases, steep slopes comprised of bedrock may allow for a narrower buffer as slope stability and sediment sources would not be impacted by development. For example, in the San Juan Islands, there can be a nearly vertical slope in basalt that can be very stable. However, water quality and habitat protection may warrant additional buffer width. Regarding effects of limited tree removal within buffers, Wenger (1999) suggests that after the first 25 – 50 feet some removal of trees can occur. Kleinschmidt Assoc. (1999) recommends an increase in buffer width for areas with less than 75% canopy closure and recommends that no tree removal be allowed in the first 35 feet, with limited tree removal allowed in the outer portions of the buffer. Murphy (1995) found that more than 58% of potential large woody debris must be maintained to support stream functions. Finally, in areas with high winds, particularly if prevailing winds are perpendicular to the buffer, tree removal may increase the potential for blow down of the remaining trees. (Note: canopy closure and basal area are often used to describe the coverage of trees on a site, with basal area being the cross sectional area of the timber at a point 4 ½ feet from the ground surface).

Sustaining habitats and species requires protection of the ecological functions and processes that support survival and population success, in addition to the direct protection of the habitats themselves. Without adequate habitat protection, the functions listed above and key natural processes become degraded. In response to this risk, scientifically based recommended buffer widths and site-specific methods for determining buffers have been established in several sources.

Because much of the existing riparian and buffer literature is related to freshwater systems, WDFW established a panel of scientists in 2008 to assess the freshwater riparian scientific literature to establish its applicability to marine shoreline systems. The result of the literature review, and the Marine Riparian Workshop Proceedings conducted by the scientific panel in 2008 was a common consensus that freshwater riparian buffer research was generally applicable to marine shorelines (Brennan et al. 2009). The scientific panel determined the functions listed in Table 3-3 were the most critical to marine shorelines and they identified a range of applicable studies that provided recommendations to protect these functions.

The data provided by the scientific panel (Brennan et al. 2009) suggest that necessary buffer widths vary considerably depending on the site-specific functions and characteristics. For example, in order to achieve at least 80 percent effectiveness at removing pollutants from stormwater runoff, the recommended buffer varied from as little as 16 feet to as large as 1,969 feet depending on the slope, depth and type of soil, surface roughness, density of vegetation and the intensity of the land use (see Table 3-3) reflecting the breadth of water quality issues. The panel found that studies of recommended buffer widths required for organic matter contributions (such as plant litter and terrestrial insects) were limited for the marine environment, however buffer widths ranging from between 16 to 328 feet from the shoreline depending on site conditions were recommended by Bavins et al. (2000) for providing this function. Buffers recommended to protect the large woody debris function (important to habitat structure as described in the previous section) were between 33 and 328 feet. However, given that trees located 300 feet landward from the edge of a bluff or bank would not immediately be recruited on the nearshore, consideration should be given to the site's potential tree height and the current and expected rate of bluff or bank retreat when establishing buffers for providing large woody debris.

The panel found that buffer widths to support a number of specific riparian functions were identified by May (2003) and Knutson and Naef (1997). May recommended 98 feet for fine sediment control, and shade and microclimate control and 164 feet for the LWD function. Knutson and Naef recommended 138 feet for fine sediment control, 90 feet for temperature moderation, and 147 feet for LWD and litter fall functions. The panel's review indicated that recommendations for wildlife habitat protection ranged from 50 feet (specific to rural areas) to 328 feet.

Riparian buffer widths necessary for protecting functions have also been based on a site's potential mature tree height called the FEMAT Curves Method (FEMAT 1993). Several other site specific methods of sizing buffers for freshwater systems have been developed and are discussed later in Section 3.5.

FEMAT CURVES METHOD

The panel found that the FEMAT curves method is applicable to marine nearshore environments (Brennan et al. 2009). The FEMAT curves method is based on the effectiveness of a mature forest at supporting a riparian function at various buffer widths. For example, the FEMAT curve for large woody debris (LWD) indicates that an approximately 131-foot buffer width achieves 80% effectiveness of the LWD function (Table 3-3). In some cases, the FEMAT function curves illustrate several parameters, such as the water quality FEMAT curve, which shows recommended buffer widths to achieve 80 percent removal of pollutants from 82 feet for sediment, 197 feet for nitrogen to 279 feet for phosphorous removal. In this case, the range of widths reflects recommendations addressing each parameter of concern. FEMAT curve based recommendations were not provided for wildlife functions

Table 3-3. Riparian buffers functions and width recommendations in the literature.

Riparian function	Scientific Recommendations for Marine Shorelines Range of buffer widths (feet) to achieve ≥ 80% effectiveness and literature cited	FEMAT Curve Method Minimum buffer width (approximate) based on curve to achieve ≥ 80% effectiveness[1]
Water quality	Lowest: 16 ft: Schooner and Williard (2003) for 98% removal of nitrate in a pine forest buffer	82 ft: sediment 197 ft: TSS 197 ft: nitrogen 279 ft: phosphorus
	Highest: 1969 ft: Desbonnet et al (1994/1995) for 99% removal	
Fine sediment control	Lowest: 82 ft: Desbonnet et al (1994/1995) for 80% removal	82 ft: (sediment) 197 ft: (TSS)
	Highest: 299 ft Pentec Environmental (2001) for 80% removal	
Shade/Microclimate	Lowest: 56 ft: Belt et al 1992 IN Eastern Canada Soil and Water Conservation Centre (2002) for 90% effectiveness	121 ft (0.6 SPTH*)
	Highest: 125 ft: Christensen (2000) for 80% temperature moderation	
LWD	Lowest: 33 ft: Christensen (2000) for 80-90% effectiveness	131 ft (0.65 SPTH*)
	Highest: 328 ft: Christensen (2000) for 80-90% effectiveness	
Litterfall & Insects	16 to 328 ft: Bavins et al (2000)	80 ft (0.4 SPTH)
Hydrology/slope stability	Consensus is that for steep slopes affecting critical areas such as feeder bluffs, a site specific analysis by a qualified professional is necessary to determine a specific buffer width.	Recommendations are based on protecting property. Buffers widths are provided for a range of slope conditions but do not consider underlying geology or adjacency to critical areas.

[1]FEMAT data in this table are based on one SPTH as equal to 200 ft. This typical mature tree height will vary based on site conditions. For San Juan County, the height of mature conifers is estimated to be 80 – 90 feet.

Figures 3-2 and 3-3 illustrate buffer function compared to buffer width from Murphy, 1995.

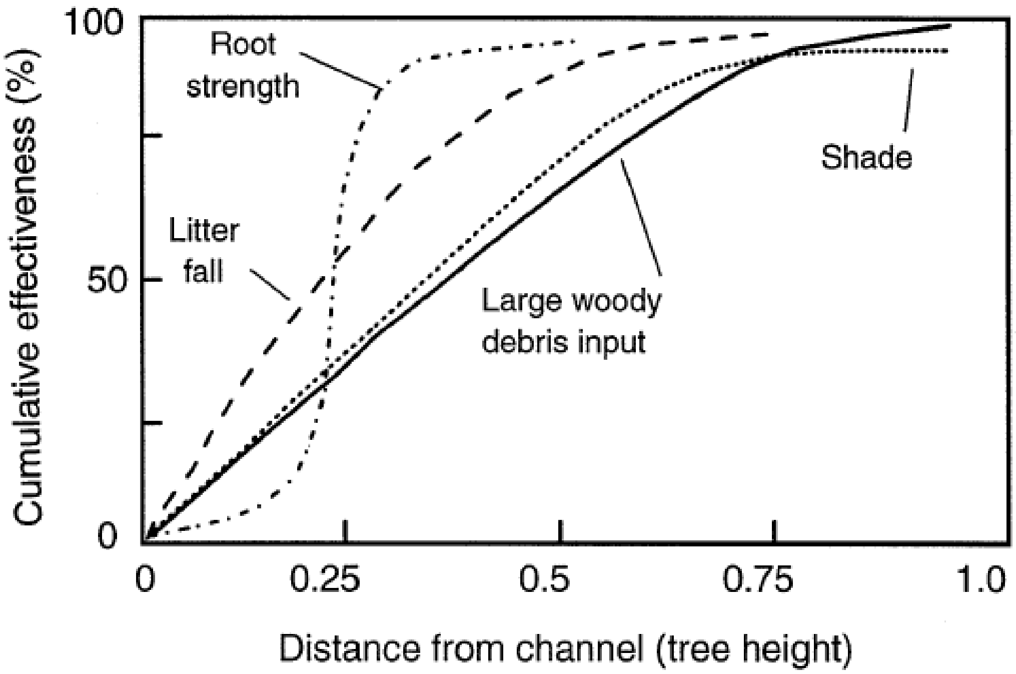

Figure 3-2. The cumulative effectiveness of various functions of riparian vegetation in relation to distance from the streambank in western Oregon. [Murphy (1995) after FEMAT 1993]. For San Juan County, the height of mature conifers is estimated to be 80 – 90 feet.

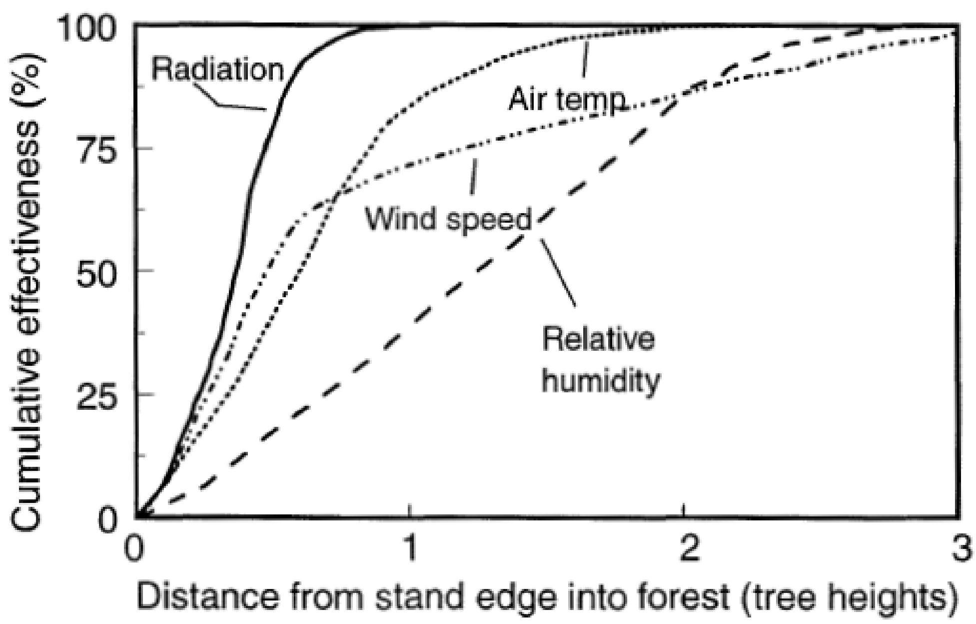

Figure 3-3. The cumulative effectiveness of various functions of forest vegetation in relation to distance from the edge of adjacent clearcuts in western Oregon. [Murphy (1995) after FEMAT 1993].

Regardless of which approach or combination of approaches is adopted, to increase the effectiveness of the buffer, additional considerations should be applied. These include allowing driftwood accrual on beaches, and protecting, restoring and enhancing marine riparian forests for long-term future wood recruitment. These measures will help to prevent or slow shoreline retreat, and reduce landslide potential. Using natural stabilization designs to protect shores (if shoreline protection is needed) will further help to protect nearshore ecosystem processes.[18] A need for shoreline protection may become more frequent with increased wave energy (predicted for some portions of the County), and sea level rise that are anticipated as a result of global climate change.

Activities that pose a higher risk of adverse effects on marine HCAs may require additional "setbacks" with limitations on uses. Other measures may allow for reduced buffers, such as effective on-site pollution control measures, low impervious surface, and minimizing breaks (or gaps) in buffers (Wenger 1999). Similarly, encouraging preservation and restoration of native vegetation may contribute to increased habitat complexity and improved functional benefits compared to non-native landscapes, which typically result in a homogenous habitat structure. This could lead to allowing a narrower buffer in such circumstances. As mentioned previously, shoreline stability and/or the presence of a feeder bluff may dictate a larger buffer or additional setback, based on the observed and anticipated erosion rates (determined by a qualified professional).

Finally, although minimally discussed in this report, the County may wish to consider measures to protect rocky intertidal communities from degradation due to human trampling. An example would be to adapt Oregon's territorial sea management plan (OCMP 2010) to local circumstances (Irvine 2005). Irvine (2005) recommends the plan because it includes realistic considerations for several of the main issues related to human use of the shoreline. More specifically, the evaluation of human use and disturbance trends in order to minimize impacts from human trampling may provide long-term benefits for the conservation of important habitats.

DISCUSSION AND DATA GAPS

The importance of terrestrial contributions to the marine environment has been documented (Romanuk and Levings 2010), however, there have been no quantitative assessments describing the contribution (rate and volume) of litter fall and allochthonous inputs specific to the county's marine riparian zone. Therefore, the extent of impacts from local shoreline development in this regard remains uncertain. Similar uncertainties are present with regard to other functional benefits potentially provided by the marine riparian area for a range of habitats.

Much of the existing buffer literature addressing water quality maintenance describes buffer effectiveness based on a percentage of pollutant removal, without recognizing that the quantity of pollutants exported from a site is actually the product of both the quantity of incoming pollutants and the removal effectiveness of the buffer either standing alone, or in conjunction with other treatment mechanisms. If this is not considered, a particular percentage reduction may be excessive for a given situation (with a buffer that is larger than necessary) , or the buffer may not provide sufficient treatment to comply with water quality standards or protect biological resources. More focused studies that apply to marine shorelines and are specific to

[18] Natural stabilization designs to protect shores include:

- Using stable large wood pieces without the use of cables or ecology block,
- Nourishment with sediment types appropriate for the site, and
- Revegetation (using, for example, inoculation with beneficial microorganisms and other treatments to expedite growth) with plants that respond well to site-specific conditions.

the shoreline conditions and typical land uses of San Juan County would better inform the broad range of recommendations found in the literature for removing pollutants. In addition, as discussed in the *Stormwater Synopsis* section of this chapter, more effective stormwater management methods could result in reduced buffer requirements for certain types of development and shoreline conditions.

Based on review of available literature, information on specific conditions of San Juan County shoreline vegetation is limited. This represents an opportunity for further surveying and mapping similar to the characterization completed by MacLennan and Johannessen (2008) in order to appropriately plan development, maximize the effectiveness of buffers, and minimize related impacts on marine HCAs including waters of the state, kelp and eelgrass vegetation communities, and areas important to sensitive fish and wildlife. In establishing buffer requirements, consideration could include the shoreline type, amount of and quality of existing vegetation, surface roughness, slope steepness and composition, type of land use, effectiveness of engineered stormwater treatment systems for the situation, as well as the marine HCAs needing protection.

It is important to recognize that buffers are a tool for conserving a wide array of functions and values, and that each function may require different buffer sizes. Due to highly variable conditions of shoreline structure and functions throughout San Juan County coastlines, many factors influencing the effectiveness of a buffer depend on site-specific characteristics and the functions desired for conservation.

Additional Site Specific Methods for Buffer Width Determination

The following material was primarily compiled by San Juan County with assistance from Paul Adamus and the Watershed/ Herrera team.

As discussed above, the WDFW scientific panel (Brennan et al. 2009) consensus was that freshwater literature is generally applicable to the establishement of buffers needed to protect marine shorelines. As such, several other site specific methods different from the FEMAT curves method are discussed below. Some were developed primarily for sizing buffers to protect water quality functions (the Nieswand and Mayer models), while others were designed to protect both water quality and aquatic habitat (the Kleinschmidt and Wenger models). In crafting a scientifically supported approach for San Juan County, it may be necessary to draw from several of these models. For example, for water quality functions, the Mayer model is more current, and appears to be based on a more rigorous scientific analysis than the other models. It is not however, designed to protect aquatic habitat functions, so additional parameters would need to be added to fully protect San Juan County's marine Critical Areas.

Nieswand

Table 3-4 below presents recommendations for sizing water quality buffers for lakes and perennial streams developed by Nieswand et al. (1989 and 1990) using a modified Manning's equation and the procedures presented in NRCS Publication TR-55, *Urban Hydrology for Small Watersheds.* This assumes additional stormwater treatment BMP's are installed as part of upslope development, runoff enters the strip as overland, sheet flow, and areas exceeding 15 percent slope and strip impervious surfaces (such as roads) are not counted toward the required buffer width.

Table 3-4. Site Specific Water Quality Buffers to Protect Lakes and Perennial Streams (Nieswand, et al. 1989 and 1990)

Slope	**Forest with heavy ground litter and hay meadow (feet)**	**Short grass pasture (feet)**
1%	50	140
3%	87	242
5%	112	313
7%	132	370
9%	150	420
11%	166	464
13%	180	505
15%	194	542

Mayer et al. 2005 and 2007

The water quality buffer guidance developed by this team is more current and scientifically defensible than the above approach developed by Nieswand. They performed a sophisticated analysis using statistical procedures (meta-analysis) to synthesize results from previously published studies. For the 2007 paper, they analyzed over 89 individual buffer studies included in 45 peer-reviewed reports on nitrogen removal.

Results from the 2007 paper are shown below *(Note: The report presents buffer widths in meters, which are converted to feet by multiplying them by 3. 28)* :

Table 3-5. Percent Effectiveness of Riparian Buffers at Removing Nitrogen (Mayer et al., 2007)

Buffer Characteristics	Buffer widths necessary to achieve given percent effectiveness (in feet)		
	50%	75%	90%
All buffers	13	161	489
Surface Flow dominates	89	266	430
Herbaceous Vegetation (including grass)	56	167	276
Herbaceous Vegetation/ Forest	10	59	144

The following Figures also illustrate nitrogen removal in percent when compared to buffer width.

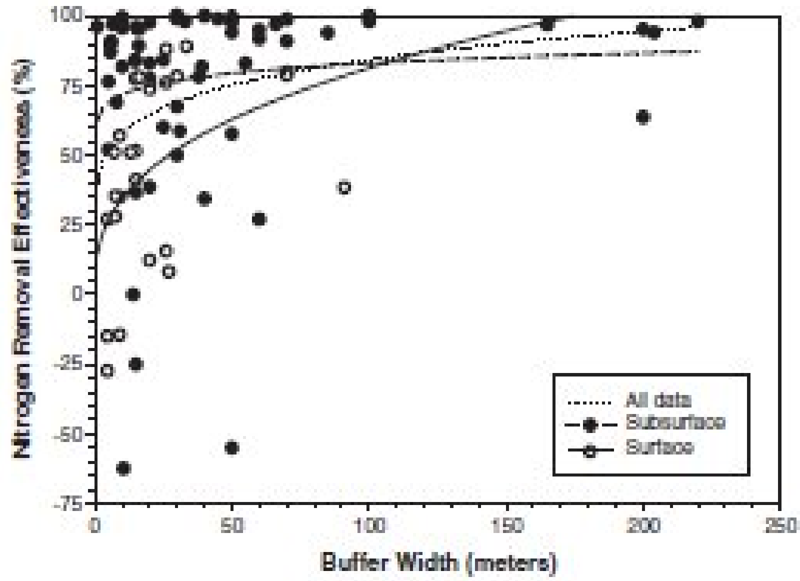

Figure 3-4. Relationship of nitrogen removal effectiveness to riparian buffer width over all studies and analyzed by water flow path. Lines are fitted to model y = ax b . (Mayer et al., 2007)

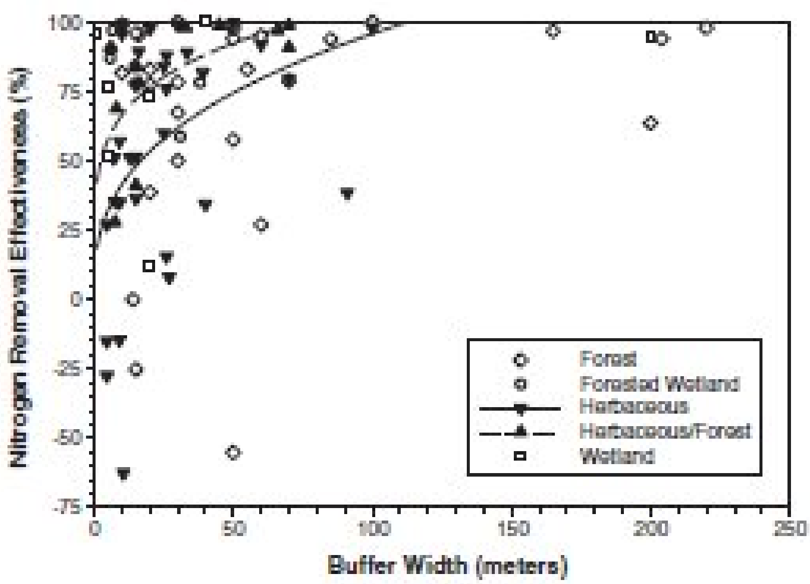

Figure 3-5. Relationship of nitrogen removal effectiveness to riparian buffer width analyzed by vegetation type. Lines are fitted to model y = ax b/ Only the regression lines for herbaceous and herbaceous/ forest vegetation types are shown because model results for other vegetation types were not significant (P>.3). (Mayer et al., 2007)

Significant findings discussed in the 2007 paper include:

- Increased width improves the effectiveness of buffers comprised of herbaceous vegetation.
- Subsurface nitrogen removal is more efficient than removal from surface flow.

- Factors affecting nitrogen removal include type of vegetation, depth of root zone, hydrologic flow paths that favor denitrification (saturated, anaerobic soils, adequate carbon supplies, floodplain connections).
- Subsurface processes may be directly influenced by soil type, soil saturation, groundwater flow paths, and subsurface biogeochemistry.
- Buffers are especially important around stream headwaters.
- Riparian zones have limited capacity to process nitrogen, so it is also important to control point and non-point source inputs of nitrogen into buffers.
- The following should be avoided to protect buffer integrity:
    - Soil compaction.
    - Construction of impervious surfaces.
    - Practices that reduce soil saturation.
    - Activities that reduce available carbon rich organic matter (raking, tree trimming, introduction of invasive species.

The following figures from the 2005 report also illustrate nitrogen removal effectiveness (in percent) for several different situations, including all studies combined (Fig. 3-5), subsurface vs. surface flow path (Fig. 3-6), and type of vegetation (Fig. 3-7).

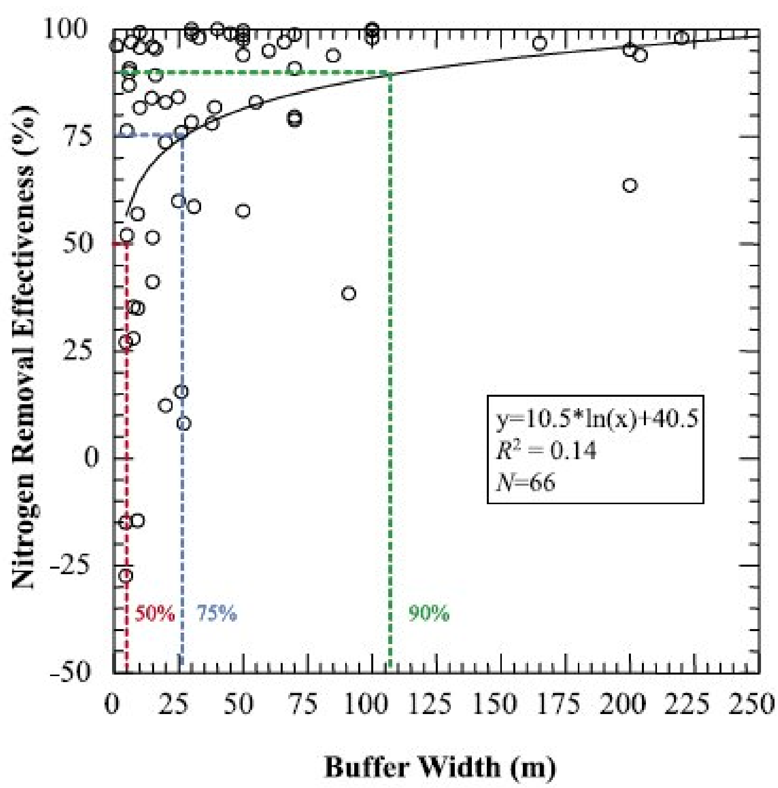

Figure 3-6. Relationship of nitrogen removal effectiveness to riparian buffer width. All studies combined. Lines indicate probably 50%, 75% and 90% nitrogen removal efficiencies based on the fitted non-linear model (Mayer et al., 2005).

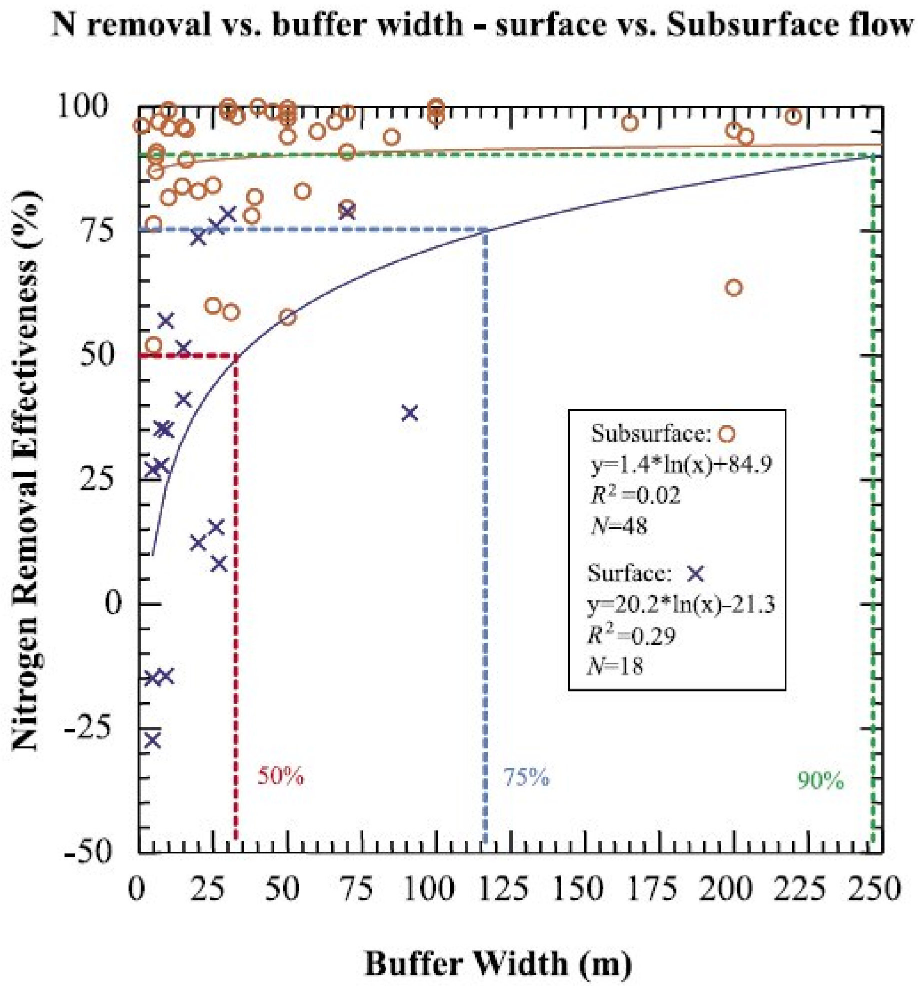

Figure 3-7. Relationship of nitrogen removal effectiveness to riparian buffer width by flow path. Lines indicate probable 50%, 75% and 90% nitrogen removal efficiencies in the surface flow path based on the fitted non-linear model (Mayer et al., 2005).

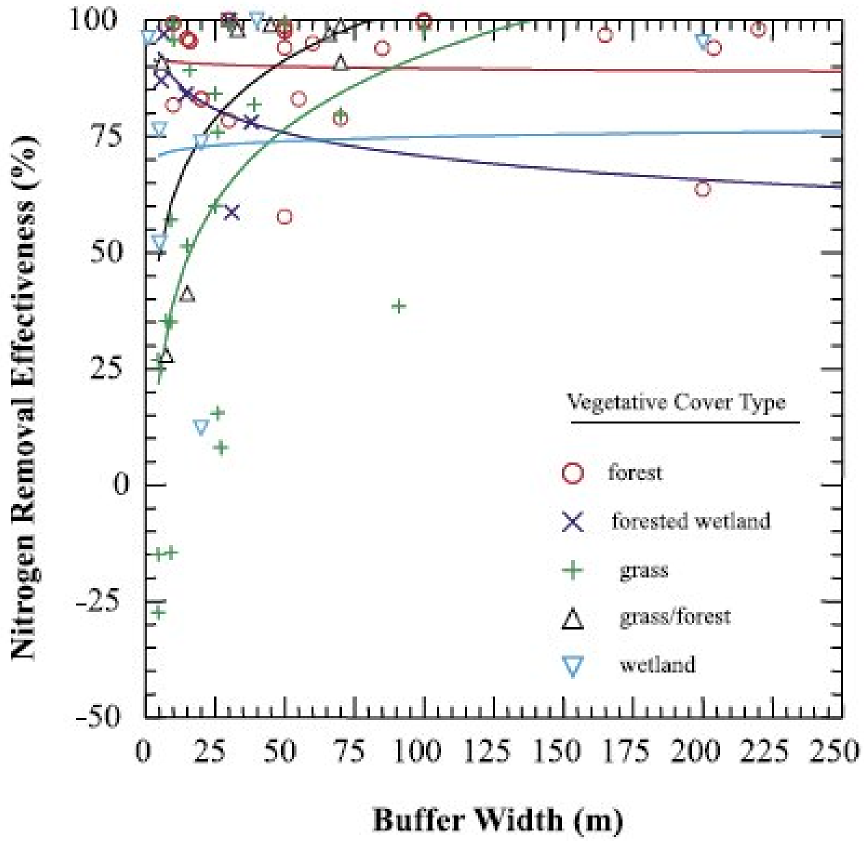

Figure 3-8. Relationship of nitrogen removal effectiveness to riparian buffer width by riparian vegetation type. Curves are fitted to non-linear model: y = a * ln(x) + b. (Mayer et. al , 2005).

Kleinschmidt Associates

Table 3-6 presents buffers to protect stream and pond functions as recommended by Kleinschmidt Associates (1999). Though this scientifically based approach was designed for freshwater environments, many of the principles are applicable to marine buffers (e.g. bank stability; filtration of pollutants; shade and temperature regulation; supply of wood, leaves, insects and organic debris to the land and water).

Recommended buffers are broken into two zones:

- Zone I is located closest to the water and is a fixed width of 35 feet (as recommended by Kleinschmidt (1999) in which there should be no disturbance to the soils or vegetation. The buffer is measured from the normal high water mark, or if flood plains or wetlands are present, from the landward edge of those areas. The primary function of this portion of the buffer is to provide shade, temperature regulation, bank stabilization, and inputs of organic debris, and to act as a final barrier to potential water quality degradation. This nearshore zone is also the most critical for nearshore aquatic and terrestrial habitats.

- Zone 2 is a variable width extending from 35 feet to the landward edge of the buffer. Zone 2 is ideally made up of a well distributed, multi-age forest stand, with the primary objectives being to filter sediment, provide water quality functions, and to protect Zone 1 from higher than natural rates of wind throw. Additional functions of Zone 2 include attenuation of peak stream flows and maintenance of base flows. Activities that can occur within Zone 2 include light recreational use and light tree harvesting that does not jeopardize water quality or wind-firm conditions. Activities that cannot occur within this zone include the creation of impervious surfaces, removal of the organic soil horizon, use of fertilizer or chemicals, significant alteration of the infiltration capacity of the soil, and tree removal sufficient to jeopardize-wind firm conditions. Stocking levels for trees ≥six inches in diameter at breast height (DBH) should be at least 80 square feet per acre for primarily softwood stands, 70 square feet per acre in mixed wood stands, and 50 square feet per acre in primarily hardwood stands, and no more than 40% of the volume over 6" DBH should be removed in any 10 year period. (The stocking levels discussed here are the "basal area" which is the cross sectional area of the timber at a point 4 ½ feet from the ground surface). Uses that would compromise the function of Zone 2 include residential and commercial development, septic disposal systems, roads, and agricultural uses.

- Additional factors are discussed which allow modification of these buffers based on site specific conditions (e.g. surface roughness and the presence of wetlands, surface water features, springs, significant sand and gravel aquifers, and very steep slopes (>25%).

Table 3-6. Site Specific Buffers to Protect Stream and Pond Functions (Kleinschmidt 1999)

Buffers for Slopes 0-8%

Canopy Closure in Percent	Hydrologic Soil Group		
	A & B (feet)	C (feet)	D (feet)
76-100%	70	90	110
51-75%	80	100	120
26-50%	90	110	130
0-25%	100	120	140

Buffers for Slopes 8-15%

Canopy Closure in Percent	Hydrologic Soil Group		
	A & B (feet)	C (feet)	D (feet)
76-100%	**100**	**120**	**140**
51-75%	**110**	**130**	**150**
26-50%	**120**	**140**	**160**
0-25%	**130**	**150**	**170**

Buffers for Slopes 15-25%

Canopy Closure in Percent	Hydrologic Soil Group		
	A & B (feet)	C (feet)	D (feet)
76-100%	130	150	170
51-75%	140	160	180
26-50%	150	170	190
0-25%	160	180	200

Buffers for Slopes > 25%

Canopy Closure in Percent	Hydrologic Soil Group		
	A & B (feet)	C (feet)	D (feet)
76-100%	160	180	200
51-75%	170	190	210
26-50%	180	200	220
0-25%	190	210	230

Wenger and Fowler This model was developed for streams and rivers, but as previously discussed, marine riparian areas have many of the same functions as freshwater riparian areas. In order to protect aquatic habitat, Wenger determined that the most effective buffers are at least 100 feet wide and are composed of native forest. He also determined that for aquatic habitat, no buffer under 50 feet can be considered effective. He presented two variable buffer approaches which are summarized below, and provided additional guidance on crafting buffer regulations (Wenger, 1999; Wenger and Fowler, 2000).

Option One (provides greatest level of protection):

- Base width: 100 ft. plus 2 ft. per 1% slope (of the stream valley).
- Extend buffer to edge of flood plain.
- Slopes over 25%, impervious areas, and wetlands do not count toward the required buffer width.Option Two (provides good protection under most circumstances, although severe storms, floods or poor management of contaminant sources could easily overwhelm the buffer):
- Base width: 50 ft. plus 2 ft. per 1% slope (of the stream valley).
- Entire floodplain in not necessarily included in buffer, although potential sources of severe contamination should be excluded from the floodplain.
- Slopes over 25%, impervious areas, and wetlands do not count toward the required buffer width.

Synopsis

1. Well functioning streams are an important source of organic material, food and nutrients which support the marine food web, eventually providing food to salmon, rockfish, Marbled murrelet, Orca and other listed species. To provide for these functions, vegetative buffers are necessary along streams and associated wetlands.
2. Marine riparian vegetation is an important component of nearshore terrestrial and aquatic habitat providing structure, shade, and temperature moderation (e.g., for forage fish

spawning beaches); providing nutrients and organic inputs (leaf litter, woody debris, terrestrial insects) that support the food web; maintaining bank stability; and helping to maintain good water quality. There are different methods of describing the density of trees in riparian areas including percent canopy coverage.

3. Bank stability is highly site specific and dependent on a number of factors including surface and sub-surface hydrology, the presence of a geologically hazardous area, whether the shoreline is susceptible to erosion from wind and waves, whether drainage from upslope is resulting in erosion, and the lithology of underlying or exposed bedrock. These factors and necessary mitigation actions are best determined on site by a licensed geologist.
4. The majority of organic inputs (large woody debris, litterfall, insects) comes primarily from the area of buffer closest to the critical area it protects (range from literature 33 feet to 328 feet). .6 Site Potential Tree Height (SPTH) is a common recommendation for this function (Murphy 1995; May 2004). SPTH in San Juan County is estimated to be approximately 80-90 feet.
5. Limited tree removal and harvest of timber within buffers can occur without significant negative effects to habitat conditions under certain conditions.
6. In terms of protecting water quality, buffers alone may not always provide the best protection for streams, wetlands, and marine waters. Managing stormwater and other pollution at its known or likely sources, especially before it reaches ditches and drainages, is also important.
7. The effectiveness of buffers for protecting water quality is attributable in part because well-configured buffers can passively exclude development – with its concomitant removal of vegetation, increase in impervious surfaces, erosion and compaction of soils, installation of drains and ditches, and introduction of new pollutants -- from areas where development impacts, due to on-site hydrologic factors, are most likely to be magnified (see Chapter 2, section 2.4.5). Research also shows that the effectiveness of riparian buffers for maintaining water quality is strongly influenced by the type of underlying soils and geologic formations. However, these are difficult to assess. Buffer width is nearly the only characteristic relevant to protecting water quality that can be measured objectively and at reasonable cost, and so has commonly become the basis for regulations.
8. The necessary width or distance to remove or retain pollutants depends partly on the *intensity and extent of the development activity or land use*. The most intensive activities require higher percent-removal rates in order to maintain quality of receiving waters. There are limits -- both technical and financial -- as to what improved engineering for stormwater treatment can accomplish. Nonetheless, as detailed in Chapter 7, more could be done to improve the management and treatment of stormwater throughout the county in ways that will minimize changes to the water regimes of wetlands, streams and marine waters and reduce the load of pollutants reaching them. For stormwater treatment systems that are designed to increase the infiltration of runoff after it is treated, an appropriate setback will still be needed to allow that infiltration to occur.
9. The buffer width or distance also depends on whether soluble pollutants are transported mainly via *subsurface seepage* (e.g., high water table), *sheet flow* (diffuse surface runoff), or channelized *surface runoff* (ditches, gullies, subsurface pipes). The latter require larger buffers. A determination of which transport route prevails at a particular location cannot legitimately be based only on county soil maps, topography, and one-time field observations; it requires an expensive geohydrological investigation at each location. Results would vary seasonally and sometimes even hourly as water tables rise after a storm and sheet flow

channelizes for indeterminate periods. In lieu of requiring such investigations for each permit application, the County could assume that water quality buffers for marine shorelines be wider wherever slopes are steep. Together, these are termed *transport and sensitivity* factors.

10. Under ideal conditions, buffers of only a few feet width can remove most coarse sediment that is carried towards a water body by diffuse sheet flow. However, for the removal or retention of finer sediments as well as some *soluble* substances that can harm aquatic life, buffers of between 10 and 810 feet are generally necessary.
11. Depending on the terrain and local surficial geological formations, infiltration of stormwater can sometimes be increased by implementing particular LID (Low Impact Development, see Chapter 7) measures, thus potentially converting surface flow to less harmful subsurface seepage. When that is feasible, consideration could be given to reducing a buffer width requirement provided riparian habitat functions are also adequately maintained and the LID measures do not require maintenance over the long term. However, there are no data quantifying the amount of buffer reduction that could be allowed if LID or other mitigating measures were implemented to varying degrees.
12. Large loads of many soluble substances such as nitrate potentially threaten aquatic life in semi-confined marine waters.

Discharge of Water from Individual Desalination Systems

Adapted by San Juan County from Richard R. Strathmann's 2009 addendum to The Current Status of Desalination Systems by Mayo et al. (unpublished, 2009).

Reverse Osmosis Desalination Systems

Reverse Osmosis (RO) plants pump seawater or other feedwater at high pressure through permeable membranes that allow the passage of water molecules while blocking the passage of salt, other dissolved minerals, and contaminants. Few coastal areas in the Pacific Northwest have the limited supply of freshwater and proximity to seawater that occur in San Juan County, and there is likely to be increased demand for these systems. Potential impacts on sea life from desalination plants have been identified. Minimizing those impacts will protect marine resources.

Potential Impacts of Desalination Systems

Potential impacts from RO desalination plants have been noted (Tularum & Ilahee 2007; Einav et al. 2002; Lattemann and Höpner 2008). These include:

- **Discharge of brine to receiving waters.** Water of greater density because of its greater salinity sinks below water of lower salinity. If denser, more saline water sinks to the seafloor, the denser water can, in some circumstances, form a stable pool on the seafloor that resists mixing. This can result in decreased oxygen, increased salinity, and associated changes that can negatively effect or kill marine plants and animals.

- **Chemicals used in water treatment and cleaning of membranes.** Some RO facilities use chemicals to clean membranes and prevent scaling (due to impurities in the water), biological growth and clogging of membranes. Membranes can however, be replaced or sent off site for cleaning, and in the future it is unlikely that facilities in San Juan County will use these chemicals (D. Drahn, A. Evers, personal communication).

Examples of chemicals used in RO desalination plants (not necessarily in this County) include:

- Sodium hypochlorite or other forms of chlorine to prevent growth of organisms;
- Ferric or aluminum chloride for flocculation (to form larger masses that are easier to filter out of the water);
- Sulfuric or hydrochloric acid to adjust pH;
- Sodium bisulfite to neutralize remaining chlorine;
- Polymaleic acid and phosphonates to inhibit scale;
- Cleaning chemicals for membranes (enzymes to remove bacterial slimes, detergents, biocides to kill bacteria, chelators such as EDTA to remove scale, acids to dissolve inorganics, and caustics to dissolve organic material and silica).

- **Impingement** (marine animals killed or injured as they collide with screens at the intake).
- **Entrainment** (marine life sucked into the system with seawater).
- **Noise from pumps.**
- **Energy** required for generating the pressure differences required for desalination by reverse osmosis.
- **Leaking of brine from pipes or other spills on land into groundwater.**
- I**nstallation of the desalination plant near the shoreline**, including potential impacts from impervious surfaces and removal of vegetation to allow for construction of a building to house equipment or road access to the site.
- **Other impacts of development or water intensive uses** in areas that otherwise could not support them.

Potential Impacts on Sea Life

LARGE DESALINATION PLANTS IN OTHER LOCATIONS

The studies of marine impacts found in a literature search were for RO desalination plants that discharge larger volumes of brine at higher salinities than those in San Juan County. A study in Spain tracked substitution of an assemblage of animals characterized by Polychaeta, Crustacea, and Mollusca for another dominated by nematodes (Del Pilar Ruso et al. 2007). The plant was large with high initial salinity (68 parts per thousand) and discharge of 65,000 m^3 per day. The changes were correlated with greater salinities near the discharge and also with differences in organic matter, depth, and sediment sizes. They also found changes in abundance of polychaetes (a group of animals living in and on the sea floor sediments) (Del Pilar Ruso et al. 2008). At the site of another large plant in the Canary Islands (discharge of 17,000 m^3/day of water of 90 parts per thousand salinity), a seagrass was less abundant near the outfall (Pérez Talavera and Quesada Ruiz 2001).

At another site in Spain with discharge of high salinity (60 parts per thousand) water, there was however, no detectable effect on benthic animals or fishes, and the lack of detectable effect was attributed to rapid dilution of discharged brine and high variability of abundances in the habitat (Raventos et al. 2006).

LOCAL DESALINATION PLANTS

Studies for a marine biota more similar to that in San Juan County and for smaller desalination plants with discharges at lower salinity, like those presently in San Juan County, would be useful. A literature search has thus far revealed no similarly detailed studies from desalination plants in California or from small desalination plants. Ideally such studies would include before and after sampling at control and impact sites. Megan Dethier (unpublished observation) found no apparent change in sea life on rocks near a desalination plant outfall on Haro Strait, where tidal currents are fast and mixing is rapid.

Two studies in the San Juan Islands, following installation of desalination plants, indicated rapid mixing of water near the discharge pipes. In each case salinities were reduced to concentrations near or not detectably different from that of the surrounding water within a few feet of the discharge pipe. A discharge into Griffin Bay near San Juan Island is described in Mayo (2009, Appendix 4, communicated by Dan Drahn and Chris Betcher). The mixing occurred in slow currents (speeds of 0 to 3 feet per minute). The volume flow of discharged water was unstated. At a discharge into Lopez Sound, measurements indicated rapid mixing to salinities near that of the receiving water but the volume flow of effluent and the current velocities in the receiving water were unstated (Andrew Evers, personal communication).

Ongoing modeling of mixing of discharged water may provide improved predictions of mixing of discharged water under a range of conditions (Dan Drahn and Tom Boydston, personal communication).

The sites expected to be most vulnerable to impacts from small desalination plants are sheltered bays in which currents and mixing are slow, especially those with basins that could accumulate sinking effluent water. In such cases the effect of denser (higher salinity) water on mixing of water near the seafloor would be the possible source of impacts on sea life. Small bays with low flushing would also be the sites where volume pumped could remove a greater proportion of slow swimming planktonic animals.

No studies of effects or lack of effects of desalination plant discharges on juvenile salmon or other fish moving along shore were found in a literature search. In the study by Raventos et al. (2006), some fish, instead of avoiding the discharge site, aggregated near the discharge pipe, as can happen at artificial reefs where there are no natural rock reefs. In a laboratory study with artificial seawater, Iso et al. (1994) observed that juvenile sea bream spent less time in water at high salinities, but the salinities with this effect were very high, with avoidance at 45 ppt salinity.

Avoiding or Minimizing Impacts in the San Juan Islands

MIXING AT OUTFALLS

Impacts from effluent water from desalination plants are expected to be reduced where the brine is rapidly dispersed by currents or waves and greater in environments where mixing is slow (Höpner and Windelberg 1996; Höpner 1999; Lattemann and Höpner 2008).

Salinities in the waters of the San Juan Islands commonly vary by several parts per thousand and the plants and animals in the San Juans are likely to tolerate the increased salinities observed near outfalls of small desalination plants after some mixing has occurred.

Pooling of denser water at the seafloor is most likely to occur where discharges are into sheltered bays where currents are often slow and into basins that would retain denser water. If, even with mixing, the water was dense enough to sink to the sea floor and form a stable layer that retards further mixing, then the impacts on sea life would be substantial. Bottom water and sediments would become hypoxic or anoxic. This situation occurs naturally in some basins, such as Saanich Inlet, where less saline water overlies more saline water.

However, for a small desalination plant, pumping about 50,000 gallons per day and with brine mixed to within one part per thousand close to the outfall, under most circumstances the currents from tides and winds are expected to be adequate to further mix the water. A total capacity of 50,000 gallons per day is a small fraction of the volume at low tide in many of the bays. The vertical salinity difference would be within the range that commonly occurs with lowered surface salinities from freshwater runoff. Impacts may be more substantial in small bays in which discharged water could enter a basin. For such situations, useful studies would include direct observations of the movement of the discharged plume of mixing water under a variety of current conditions, with known rates of discharge and measured salinities of discharged and receiving water. The discharged water could be marked by a dye such as fluorescein mixed with the brine. This dyed discharge plume would indicate whether or not the mixing effluent water was sinking to the seafloor.

Where accumulation of denser, more saline water near the seafloor is suspected, monitoring of oxygen and pH (acidity) are indications of impacts from reduced mixing. Monitoring sulfide in sediments could reveal a history of low oxygen. Sediment cores could show the level at which black anoxic sediment occurs. Finally, if necessary, an Acoustic Doppler Current Profiler (ADCP) could be used to characterize currents and mixing of receiving waters. This is a sonar device that records water current velocities for a range of depths. The devices can be rented for approximately $2,000 per month, which is what would be needed to reasonably characterize currents. Hiring a consultant to install the device, interpret the data and write a report would cost in the range of $10,000 (communication from Amanda Azous).

Design of effluent pipes varies. In some plants the intake and discharge pipes are designed with intakes screened to exclude organisms and discharge pipes configured solely to enhance mixing. In other systems, intake and discharge are switched at intervals to avoid fouling of pipes, and both then have similar screens. A comparison of mixing with these two arrangements and demonstration of best design for each will help to minimize impacts.

While uncertainty about mixing and sinking of water remains, impacts could be avoided by not siting outfalls in waters with slow currents and in basins in which denser water could accumulate. Such sites could be identified and listed. Locating an outfall in such an area could require demonstration that mixing effluent water does not sink even when currents are slowest and mixing least.

Impingement and Entrainment of Marine Animals

Slow moving marine animals are killed when they are sucked against a filtering screen at the intake or sucked into a desalination plant with the seawater. A present standard for intakes is a screen size less than 1/8" to exclude larger organisms (D. Drahn, personal communication). A screen of this size excludes juvenile fish but not small larvae, like those of clams, mussels, oysters, and sea urchins.

The capacity of 12 desalination plants in San Juan County is 124,000 gallons per day (Mayo 2009, Table 5). That amount of freshwater is expected to require a 4 to 1 ratio of seawater to freshwater (Mayo, personal communication) and thus pumping of about 496,000 gallons per day of seawater (2456 cubic yards). Measured face velocities at several intake screens were approximately 0.1 feet per second (Mayo 2009), which is about 3 centimeters per second. Many small larvae (of sea urchins, clams, mussels, oysters, some crustaceans, etc.) do not swim that fast. (F.-S. Chia, et al. 1984). If this face velocity is representative, at full capacity slow swimming animals would be removed from a volume equal to about 1.4 miles by 1 square yard each day. Average production is about 1/5 of this volume flow (R. Mayo, personal communication).

As a proportion of a local population, however, losses from impingement and entrainment are expected to be low if the volume pumped is a small fraction of the volume of a bay. For many bays, the proportion of water pumped is low, even with a low rate of flushing. As an example, 50,000 gallons per day is about 250 cubic yards per day; soundings and area from a chart indicate about 500,000 cubic yards at low tide in Mitchell Bay. In three weeks, the volume of water pumped would be equivalent to about 1% of the volume of the bay. The small expected effect depends on scale. If desalination capacity were greatly increased within a small bay in which larvae were retained, then losses from impingement and entrainment could impact animals within that bay.

Intakes below the sediment surface have been recommended as a means of avoiding impingement and entrainment of animals, but mussels have settled within a system supplied by in this manner (Andrew Evers, personal communication), which indicates that larvae were drawn into the gravel used as a filter.

The first stage filters in an RO desalination plant are back flushed to clear the filter (D. Drahn and Tom Boydston, personal communication). A filter of 20 to 25 microns excludes animal embryos and larvae. Few planktonic eggs are less than 50 microns. Those that survive the impingement between flushings of the filter would be returned to the plankton. A study could demonstrate survival and mortality of small animals caught on the filter and then washed away when the filter is flushed. Survival presumably depends on the type of filter, frequency of backflushing, and swimming speeds and vulnerability of small animals.

Inclusion in permit applications of face velocity at filters and a calculation of volume pumped at capacity relative to volume of an embayment would give one indication of probable losses from impingement and entrainment.

ENERGY USE

Ron Mayo (personal communication) gives the energy requirements for three desalination plants on San Juan Island as 38, 29, and 26 gallons per kilowatt hour. If production were at the current capacity of 124,000 gallons per day for the 12 desalination plants in San Juan County and at 30 gallons/kWh, then production would require 4133 kilowatt hours daily, which is about 0.7% of the 560,000 kWh per day average energy consumption in San Juan County. The average production is much less than full capacity: 23,500 gallons per day with an energy requirement of about 800 kWh per day. Additional desalination capacity will increase energy demand, as will other development in the County. Ron Mayo (pers. comm.) estimates the present energy use for desalination in the County as equivalent to the energy use of 15 housing units. Another way of estimating energy for desalination is from the 16 connections, 5500 gal/day (summer), 3000 gal/day (other seasons), and 38 gal/kWh for desalination at Cattle Point, and the 50.7 kWh/day per average household in the County (Ron Mayo 2009, Table 6, and personal communication). From these estimates, desalination would be 4.8% of an average household's energy use. These estimates could be improved for accuracy by including other desalination plants, and by comparison with costs for water from other sources, such as wells, cisterns, or hauling.

CHEMICALS USED IN OPERATION

Lattemann and Höpner (2008) say that various metals from corrosion are in low concentrations and that dechlorination with sodium bisulfite is done to protect membranes. They nevertheless mention discharge of chemicals used in cleaning as potentially harmful to aquatic life.

Information from the operators of desalination plants in San Juan County is that most, possibly all, future desalination plants in the County will not be using these chemicals. Most small RO plant operators replace membranes or send them away to be cleaned. There are several procedures that can minimize impacts of cleaning chemicals:

1. Off-site cleaning of membranes could be required.

2. If there is on-site cleaning, a requirement for chemicals used in cleaning to be known to be harmless.

   Of chemicals used for cleaning membranes, acid and alkaline treatments (low and high pH) can be rendered not toxic from pH effects if pH is subsequently adjusted before the cleaners are discharged, but some cleaners are proprietary mixes of unknown composition. The second requirement would eliminate on site use of proprietary cleaners of unknown composition. Operators prefer hydrochoric acid to sulfuric acid because it is gentler on equipment and because the chloride present after neutralizing the acid is already present in seawater at a high concentration (D. Drahn, personal communication).

   The MSDS (material safety data sheet) for polymaleic acid (a scale inhibitor) says that it is no more than slightly toxic if absorbed or swallowed, that it is moderately irritating to eyes and skin, and that significant health effects are not expected if less than a mouthful is swallowed (indicating low toxicity for this scale inhibitor).

   Some cleaners also occur in household products. These are enzymes that remove bacterial slimes, biocides that kill bacteria, and detergents. These cleaners are therefore part of a more extensive environmental and regulatory issue. Quantities used in desalination plants could be evaluated in relation to quantities entering the sea from other sources and any effects from those other sources.

   The EDTA that removes scale occurs in household products. It is a chelator of divalent positive ions. EDTA is a component of algal culture medium and thus is introduced to cultures of marine larvae at low concentrations with no known ill effects. The MSDS indicates (for health effects) that EDTA is a mild irritant.

   Flocculents are generally used in very large plants that remove the material and dispose of it in land fills (D. Drahn, personal communication).

3. Latteman and Höpner (2008) suggest prefiltration, and UV disinfection as means of reducing the need for chemical treatments.

Subsurface sources of water, such a beach wells, have also been recommended as means of reducing chemical treatments (Campbell and Jones 2005). However, beach wells are not a possibility on all shores and require more extensive disturbance to the sea floor during construction.

There is also a "pickling" process for keeping membranes when they are not in use. The chemical used is sodium metabisulfite and may not present problems of toxicity in the concentrations discharged. The MSDS for sodium metabisulfite indicates irritation to eyes or skin and recommends dilution as the treatment, with no known or anticipated mutagenic effect. Toxicity at low concentrations is not expected.

Operators and installers of desalination plants in San Juan County can provide advice on practical means of minimizing impacts from chemicals used with desalination plants. A recommendation for minimizing marine impacts is that sodium metabisulfite solutions be allowed as a membrane preservative and that no other chemicals be allowed without evaluation (D. Drahn, personal communication). A potential problem with permitting on-site cleaning is the difficulty of assuring proper disposal of cleaning chemicals.

SALT WATER LEAKS ON LAND

Leaks of seawater on land can be prevented by:

1. Use of pipes unlikely to fail, such as high density polyethylene; and

2. A design for buildings so that overflows or spills within the building go into a drain that leads to the effluent outflow pipe.

The polyethylene pipe for the Friday Harbor Labs seawater system has been in use for many years without a break in the pipe. The spills that have occurred were because of design features that can be avoided in desalination plants. Also, RO desalinaton is often installed to halt the intrusion of seawater into groundwater that can be associated with withdrawal of water from wells.

IMPERVIOUS SURFACES AND OTHER IMPACTS OF CONSTRUCTION NEAR SHORELINES

Design, siting, and construction are or can be managed under the regulations for other shoreline development.

CUMULATIVE IMPACTS

One difficulty in detecting impacts of desalination plants in San Juan County is that the plants are small but will likely be numerous. Thus impacts may be cumulative but not large at any one site. Minimizing reliance on desalination for water supplies until more experience is gained on impacts (or lack of impacts) for sea life is one way to avoid undesired impacts. Also, this discussion has addressed potential impacts of small desalination plants, not larger desalination plants, as might be anticipated for towns like Friday Harbor or East Sound.

PERMIT REVIEW

Marine impacts could be reduced by changes in the criteria for permit review.

Permit applications in San Juan County have included data on currents distant from and quite different from the site of the desalination plant outfall. The County review process does not appear to consider the impacts that could occur where currents are slow and where basins could accumulate denser water. Also, developments in the County may still be permitted where water supplies are uncertain and later application for RO desalination likely.

Criteria for sites of outfalls and other best practices that would guide permitting of desalination plants would be useful. Such information is available for other kinds of shoreline development. Criteria for best practices could minimize impacts by guiding appropriate design, construction, and operation.

Threshold volumes could be stated such that above a given capacity and recovery rate additional analysis of marine impacts would be required to inform a decision on the permit application.

Also, sites in bays with slow currents and basins could be identified as sites at which a permit would not be issued before a site-specific study indicated that there would be adequate mixing and no accumulation of denser water at the sea floor. Methods of analysis are discussed previously in this section. Information that should be required to properly evaluate a proposed facility include:

1. On or off-site membrane cleaning;
2. Type of intake, capacity;
3. Type of effluent discharge;
4. Volume to be pumped/ discharged per unit time at maximum capacity;
5. Salinity of the brine produced at the outfall;
6. Useful detail on the characteristics of intake screens or filters and their flushing;
7. Type and position of the diffuser at the outfall;
8. If available, information on bottom topography and currents at the outfall;
9. Face velocity at filters (this could be estimated from the flow and area of the intake); and

Reported currents should be relevant to the outfall site and include currents at times of slack water on calm days.

A general requirement after installation could be measurement of salinities at and near the outfall when currents in the receiving water are minimal to assess mixing of discharged water. That would create a data base that would aid improved design for outfalls from future desalination plants.

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APPENDIX 3.A

State Listed Priority Habitat and Species in San Juan County

		Species/ Habitats	State Status	Federal Status
1	Habitats	Aspen Stands		
2		Biodiversity Areas & Corridors		
3		Herbaceous Balds		
5		Old-Growth/Mature Forest		
6		Oregon White Oak Woodlands		
7		West Side Prairie		
10		Riparian		
11		Freshwater Wetlands & Fresh Deepwater		
12		Instream		
15		Puget Sound Nearshore		
16		Caves		
17		Cliffs		
18		Snags and Logs		
19		Talus		
25	Fishes	Pacific Herring	Candidate	Species of Concern
31		Longfin Smelt		
32		Surfsmelt		
33		Bull Trout/ Dolly Varden	Candidate *	Threatened *
34		Chinook Salmon	Candidate	Threatened (Upper Columbia Spring run is endangered)
35		Chum Salmon	Candidate	Threatened
36		Coastal Res./ Searun Cutthroat		Species of Concern
37		Coho	Candidate	Threatened – Lower Columbia Species of Concern – Puget Sound
38		Kokanee		
39		Pink Salmon		
41		Rainbow Trout/ Steelhead/ Inland Redband Trout	Candidiate **	Threatened **
42		Sockeye Salmon	Candidate	Threatened – Ozette Lake Endangered – Snake River
44		Pacific Cod	Candidate	Species of Concern
45		Pacific Hake	Candidate	Species of Concern

		Species/ Habitats	State Status	Federal Status
46		Walleye Pollock	Candidate	Species of Concern
47		Black Rockfish	Candidate	
49		Brown Rockfish	Candidate	Species of Concern
50		Canary Rockfish	Candidate	Threatened
51		China Rockfish	Candidate	
52		Copper Rockfish	Candidate	Species of Concern
53		Greenstriped Rockfish	Candidate	
54		Quillback Rockfish	Candidate	Species of Concern
55		Redstripe Rockfish	Candidate	
56		Tiger Rockfish	Candidate	
57		Widow Rockfish	Candidate	
58		Yelloweye Rockfish	Candidate	Threatened
59		Yellowtail Rockfish	Candidate	
60		Lingcod		
62		Pacific Sand Lance		
63		English Sole		
64		Rock Sole		
73	Amphibians	Western Toad	Candidate	Species of Concern
76	Reptiles	Sharptail Snake	Candidate	Species of Concern
80	Birds	Brandt's Cormorant	Candidate	
82		Cassin's Auklet	Candidate	Species of Concern
84		Common Murre	Candidate	
85		Marbled Murrelet	Threatened	Threatened
86		Short-tailed Albatross	Candidate	Endangered
87		Tufted Puffin	Candidate	Species of Concern
88		Western Grebe	Candidate	
89		W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids		
90		W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids		
94		Great Blue Heron		
95		Brant		

		Species/ Habitats	State Status	Federal Status
96		Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser		
97		Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead		
98		Harlequin Duck		
100		Trumpeter Swan		
102		Waterfowl Concentrations		
103		Brown Pelican	Endangered	Species of Concern
105		Common Loon	Sensitive	
108		Bald Eagle	Sensitive	Species of Concern
116		Golden Eagle	Candidate	
122		Peregrine Falcon	Sensitive	Species of Concern
123		Sooty Grouse		
124		W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae		
128		Band-tailed Pigeon		
131		Yellow-billed Cuckoo	Candidate	Candidate
134		Vaux's Swift	Candidate	
135		Pileated Woodpecker	Candidate	
140		Oregon Vesper Sparrow	Candidate	Species of Concern
143		Purple Martin	Candidate	
145	Mammals	Dall's Porpoise		
146	Mammals	Gray Whale	Sensitive	
147	Mammals	Harbor Seal		
149	Mammals	Southern Resident Orca (Killer Whale)	Endangered	Endangered
153	Mammals	Pacific Harbor Porpoise	Candidate	
154	Mammals	Steller (Northern) Sea Lion	Threatened	Threatened
155	Mammals	Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat		
172	Mammals	Townsend's Big-eared Bat	Candidate	Species of Concern
186	Mammals	Keen's Myotis	Candidate	
189	Mammals	Columbian Black-tailed Deer		
190	Invertebrates	Pinto (Northern) Abalone	Candidate	Species of Concern
191	Invertebrates	Geoduck		
192	Invertebrates	Butter Clam		

		Species/ Habitats	State Status	Federal Status
193		Native Littleneck Clam		
194		Manila Clam		
196		Olympia Oyster	Candidate	
197		Pacific Oyster		
208		Dungeness Crab		
209		Pandalid shrimp (Pandalidae)		
216		Great Arctic	Candidate	
219		Island Marble	Candidate	Species of Concern
220		Sand-verbena Moth	Candidate	
222		Valley Silverspot	Candidate	Species of Concern
		Taylor's Checkerspot	Endangered	Candidate
		Red Urchin		

** Important Note **

These are the species and habitats identified for San Juan County. This list of species and habitats was developed using the distribution maps found in the Priority Habitat and Species (PHS) List (see http://wdfw.wa.gov/hab/phslist.htm). Species distribution maps depict counties where each priority species is known to occur as well as other counties where habitat primarily associated with the species exists. Two assumptions were made when developing distribution maps for each species:

1) There is a high likelihood a species is present in a county, even if it has not been directly observed, if the habitat with which it is primarily associated exists.

2) Over time, species can naturally change their distribution and move to new counties where usable habitat exists.

Distribution maps in the PHS List were developed using the best information available. As new information becomes available, known distribution for some species may expand or contract. WDFW will periodically review and update the distribution maps in PHS list.

CHAPTER 4

BEST AVAILABLE SCIENCE
UPLAND HABITAT CONSERVATION AREAS

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CHAPTER 4 CONTENTS

Appendices

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UPLAND HABITAT CONSERVATION AREAS

4.1 Overview

The first part (4.2) of this chapter provides definitions and a general overview of **streams and lakes** of San Juan County (SJC) and then describes impacts to these water bodies and strategies for determining widths of buffers[20] that protect their functions. The second part (4.3) of this chapter provides definitions and a general overview of SJC **upland (terrestrial) habitats**, describes impacts to these, and suggests options for enhancing their protection or management. Except where supported by citation of specific literature, all statements in this chapter are either commonly-accepted, science-based knowledge among ecologists or are the interpretation of the chapter author who is a wetland scientist and wildlife biologist.

The State of Washington requires San Juan County, as well as other counties and cities, to identify and protect the functions and values of "Fish and Wildlife Habitat Conservation Areas" (FWHCA's). This is one of the five types of "Critical Areas" identified in the Growth Management Act (WAC 365-190-080). In WAC 365-190-030(6a), FWHCA's are defined as:

> "areas that serve a critical role in sustaining needed habitats and species for the functional integrity of the ecosystem, and which, if altered, may reduce the likelihood that the species will persist over the long term. These areas may include, but are not limited to, rare or vulnerable ecological systems, communities, and habitat or habitat elements including seasonal ranges, breeding habitat, winter range, and movement corridors; and areas with high relative population density or species richness.

"Fish and Wildlife" is intended to include some plants and invertebrates, as well vertebrates (birds, mammals, amphibians, reptiles, fish). Virtually every square inch of the planet provides habitat for some organism, so priorities must be established. At a state level, the Washington State Department of Fish and Wildlife recommends species and habitat types they consider to be priorities for extraordinary protection or management in each county. The Washington State Department of Natural Resources (Natural Heritage Program) recommends ecosystems and rare plants they consider to be of highest priority in each county. Not all species and areas recognized or recommended by either department must be singled out and designated by counties and cities for extraordinary protection or management (WAC 365-190-040 4b).

[20] In general, the term buffer refers to terrestrial areas surrounding a wetland, stream, water body or other area of high ecological, geological, or hydrological importance, and whose purpose is to reduce or prevent impacts to the functions of the protected resource, such as may occur from adjacent land uses. In comparison, **setbacks** are regulatory tools used to protect land from encroachment by structures, but do not generally specify how the setback area must be managed. Like setbacks, buffers are measured a specified distance between a development and the resource being protected. Unlike setbacks, buffers usually are considered off-limits to some activities and land uses which themselves may impact the functions of the wetland. Buffers are often (but not necessarily) configured to completely encircle a wetland, lake or other resource, whereas setbacks are confined to just a direct path between the development and the wetland being protected.

At a minimum, the State of Washington requires counties and cities to protect the following natural resources:

- Shellfish Areas (commercial and recreational)
- Kelp and Eelgrass Beds
- Herring, Smelt and Other Forage Fish Spawning Areas
- Waters of the State as Defined in RCW 90.48.020
- Lakes, Ponds and Streams Planted With Game Fish
- Naturally Occurring Ponds Less Than 20 Acres
- Areas Important to Threatened, Endangered, or Sensitive Species
- Habitats of Local Concern
- State Natural Area Preserves, Natural Resource Conservation Areas and Wildlife Areas

Although this chapter has attempted to include all important data directly relevant to fish and wildlife habitat of streams, lakes, and uplands in San Juan County, there are few or no data describing the locations, abundance levels, local habitat preferences, and trends of nearly all of the County's plants and animals. Even for species and habitats believed to be locally rare, few countywide systematic surveys have been done because of the difficulties of accessing private lands and the time and costs of conducting such work. Despite these limitations, within SJC there regularly occur at least 988 species of vascular plants, 7 amphibians, 7 reptiles, 216 birds, 35 mammals, close to a dozen fish species, and perhaps over a thousand of species of invertebrates (Appendix 4-A).

Despite the county's relatively small area, its vertebrates (amphibians, reptiles, birds, and mammals) comprise more than 26% of those occurring regularly in Washington.
Most have a unique set of environmental requirements but those are poorly known for most species (but see Appendix 4-B for a catalog of general habitats used by each terrestrial vertebrate species). For some species, SJC probably supports the largest or only populations or densities in the Puget Sound region, the Pacific Northwest, or the entire United States. These include but are not limited to Black Oystercatcher, Golden Eagle (breeding, formerly), Island Marble Butterfly, Vesper Sparrow (Oregon subspecies, breeding), Sharp-Tailed Snake, Marbled Murrelet (wintering), and several plant species. The following data sources are particularly useful in understanding the status, locations, and needs of individual plant and wildlife species in San Juan County:

- *Floristic Atlas of the San Juan Islands* http://biology.burke.washington.edu/herbarium/resources/sanjuanatlas.php
- *Wild Plants of the San Juan Islands.* (Atkinson & Sharpe 1993).
- *Birding in the San Juan Islands*. (Lewis & Sharpe 1987).
- *Checklist: Birds of the San Juan Islands*. (Jensen 2010).
- *Local Conservation Priorities for Western Washington: Suggestions for Effective Conservation Actions for County, City, and Private Landowners and Managers: San Juan County.* (Cassidy & Grue 2006).
- *Landscape Planning for Washington's Wildlife: Managing for Biodiversity in Developing Areas (A Priority Habitats and Species Guidance Document)*. (Washington Department of Fish and Wildlife 2009)

Relative to its size, the county contains a wide variety of habitats. Many areas by now have recovered from disturbances that occurred within the past 150 years, while others continue to be altered, and still others exist in relatively unaltered condition. The effect of this habitat variety and quality on the richness of species in the greater Puget Sound – Georgia Strait Region is unquestionably positive. This is true despite the fact that, in contrast to many mainland parts of western Washington that are of similar size, SJC's fauna overall is naturally less diverse. That happens for several reasons. The topography of the county spans less than 3000 feet of elevation, creating less climatic diversity than in many mainland counties, and that in turn constrains the diversity of plants and animals. Perhaps more significantly, the island environment limits the ability of many terrestrial species to colonize from adjoining mainland, and to persist in otherwise suitable habitats in the county. That same factor makes the decline of any species in the county potentially a greater concern than a similar decline occurring in mainland counties, because recovery via immigration of new individuals from the mainland is likely to be slower or not occur at all. Species that primarily inhabit extensive forests also may be absent, or are relatively vulnerable to extirpation, partly because historically forested areas in many parts of the county have been fragmented by roads and urban and agricultural development, as well as by natural phenomena. Large mammals such as elk, gray wolf, cougar, and bison were perhaps among the first animals to disappear entirely from the county (probably before the 1900's), if they were present at all, and have never recovered. Species possibly present at one time but now apparently extirpated (absent) include one native game bird (e.g., ruffed grouse), spotted frog, Pacific giant salamander, western pond turtle, and many plant species. A lack of credible and comprehensive countywide surveys, especially during the early years of island occupation by humans, makes it difficult to confirm the disappearance of many plants and animals formerly reported from the county or suspected to have occurred here based on the types of habitats they are known to associate with.

Protecting a broad range of habitats is the first step to protecting biodiversity (the number of species and their genetic variation). Protecting biodiversity is important not only for legal and aesthetic reasons, but also because of the services that myriads of obscure but irreplaceable species silently perform for humans (Cardinale et al. 2006, 2009, Chivian & Bernstein 2008). Yet, thousands of species are now being irreversibly lost from counties, regions, and the planet, at perhaps a faster rate than at any time during co-existence with modern humans.

4.2 Review of Information: Freshwater FWHCA's Requiring Protection

4.2.1 Classification of Fresh Waters

As noted at the beginning of this chapter, the following features are among habitats on a list of Fish and Wildlife HCAs that the State of Washington requires be protected:

- Waters of the State as Defined in RCW 90.48.020
- Lakes, Ponds and Streams Planted With Game Fish by Public Agency
- Naturally Occurring Ponds Less Than 20 Acres With Fish and Wildlife Habitat

These are now discussed in individual sections.

4.2.1.1 Waters of the State as Defined in RCW 90.48.020

This includes "lakes, rivers, ponds, streams, inland waters, underground waters, salt waters, and all other surface waters and water courses" (RCW 90.48.020). It includes areas where surface water is present only seasonally or intermittently, as is the case with many wetlands, ditches, drainageways, and headwater streams. Although this definition is extremely broad, counties and cities have the latitude to assign different levels of protection to different types of water. They may do so by considering the following (for example) as listed in WAC 365-190-130 4f(iii):

- Species present which are endangered, threatened or sensitive, and other species of concern;
- Species present which are sensitive to habitat manipulation (e.g., as listed by WDFW's priority habitats and species program);
- Historic presence of species of local importance;
- Existing surrounding land uses that are incompatible with salmonid habitat;
- Presence and size of streamside ecosystems;
- Existing water rights; and
- The intermittent nature of some waters.

Counties and cities, as a starting point for assigning different levels of protection (e.g., buffer widths) to streams and other surface waters, commonly use the classification system established in WAC 222-16-030 and -031. Three types of flowing waters defined by that classification are present in San Juan County: Type F, Type Np and Type Ns. These have been mapped for Orcas and San Juan Islands, and mapping is currently underway for Lopez Islands. These maps are included in Chapter 8.

Type F. **Fish Bearing Streams** (also called Types 2 and 3). Segments of natural waters which are within the bankfull widths of defined channels and periodically inundated areas of their associated wetlands (or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water) and which in any case contain fish habitat, or fall into at least one of the following four categories:

(1) Waters diverted for domestic use by more than 10 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and the only practical water source for such users. Such waters shall be considered to be Type F Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(2) Waters diverted for use by federal, state, tribal or private fish hatcheries. Such waters shall be considered Type F Water upstream from the point of diversion for 1,500 feet, including tributaries if highly significant for protection of downstream water quality;

(3) Waters within a federal, state, local, or private campground having more than 10 camping units under certain conditions specified in the WAC;

(4) Riverine ponds, wall-based channels, and other channel features that are used by fish for off-channel habitat, as evidenced by a seasonal or perennial fish-accessible connection to a fish habitat stream.

If fish use has not been documented, two characteristics may be considered indicative of highly significant fish populations (Type 2):
-- Stream segments having a defined channel 20 feet or greater within the bankfull width and having a gradient of less than 4 percent; or
-- Lakes, ponds, or impoundments having a surface area of 1 acre or greater at seasonal low water.
Also, if fish use has not been documented, additional characteristics may be considered indicative of Type 3 in western Washington:
-- Stream segments having a defined channel of 2 feet or greater within the bankfull width and having a gradient of 16 percent or less; or
-- Stream segments having a defined channel of 2 feet or greater within the bankfull width and having a gradient greater than 16 percent and less than or equal to 20 percent and having a contributing area greater than 50 acres; or
-- Ponds or impoundments having a surface area of less than 1 acre at seasonal low water and having an outlet to a fish stream; or
-- Ponds or impoundments having a surface area greater than 0.5 acre at seasonal low water.

Type Np. Non Fish-bearing Perennial Streams (also called Type 4) Perennial streams are flowing waters that do not go dry any time of a year of normal rainfall and include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.

Type Ns. Non Fish-bearing Seasonal Streams (also called Type 5). These are nonfish habitat streams in which surface flow is absent for at least some portion of a year of normal rainfall and which are not located downstream from any stream reach that is a Type Np Water. For brief periods at least, Type Ns Waters must be physically connected by an above-ground channel system to the ocean or to channels with perennial flow (Type S, F, or Np Waters).

Figure 2. Examples of Type Ns streams, with measuring rod (photos courtesy of Wild Fish Conservancy).

An additional term used only in this report is **drainageway**. This is a scientific term (not a regulatory term) used to denote networks of linear topographic depressions whose existence or flow regime has not been field-verified, but which are readily discernable using laser-based LiDAR aerial imagery (fine-resolution topographic data that screens out the vegetation). As part of this project this imagery was analyzed automatically to delineate "high certainty drainageways" and "low certainty drainageways." Many or most of the former are believed to include all currently mapped streams qualifying as Type F, Type Np, and Type Ns Streams. Many or most of the latter include Type Ns Streams but also include many (but not all) additional areas expected to convey surface or shallow subsurface water for short periods. A new spatial data layer resulted from that LiDAR analysis. Although other investigators have used such analyses to identify unmapped intermittent streams important to fish (Mouton 2005, Wild Fish Conservancy unpublished), our purpose was different. We used LiDAR imagery mainly *to identify approximate paths that runoff and shallow subsurface flow (and the pollutants they potentially carry) are more likely to take* while moving downhill towards streams, lakes, wetlands, and the marine shoreline during the most intense or prolonged storms. Our drainageway maps should be integrated with those from SJC Public Works that provide more detail on locations of drainage lines and culverts along public roads on the major islands. The Public Works maps have been ground-checked to a greater extent, although not comprehensively.

The importance of using GIS and topographic analysis to delineate intermittently-flowing drainageways for the analysis of water quality problems and protection of receiving waters has been demonstrated by Baker et al. 2006, Walsh & Kunapo 2009, and many other scientists during the past few years. The spatial layer (map) we created showing high and low certainty drainageways has not been field checked, but should be. That is because LiDAR imagery, although sensitive to slight (less than 1 ft) differences in ground elevation, is coarser with regard to horizontal precision. Thus, this new layer, although better documented and more complete than any unverified streams layer the County currently has, should (for most uses) be "registered" manually against channels that are visible in color imagery, as well as by using ground-level observations and GPS readings (when satellite reception is sufficient to use GPS to pinpoint locations better than the LiDAR imagery does). If the County is unable to do this comprehensively, then it might be done on a case-by-case basis by building permit applicants or their qualified consultants.

There are four year-round (perennial) streams in San Juan County. Two are found on Orcas Island -- Cold and Cascade creeks. Cold Creek is fed by a large spring and Cascade Creek has Mountain Lake as its source. Two streams on San Juan Island also run all year. These are San Juan Valley Creek, which begins at Trout Lake on Mt. Dallas and converges with the drainage system for the wetlands of the False Bay watershed, and a small creek that begins at the back of Mt. Cady and drains into Garrison Bay. Streams on the remaining islands in the county flow only intermittently (SJC *Water Resource Management Action Plan* 2000).

While few would argue that surface waters as a whole are important to many forms of life, less well known and valued is the role of surface waters that are present only intermittently throughout the year, such as Type Ns streams. Yet, many studies -- both in SJC (Barsh 2010) and in other parts of the Pacific Northwest (e.g., Brown & Hartman 1988, Nickelson et al. 1992, Steiner et al. 2005, Colvin 2005, Wigington et al. 2006) -- have demonstrated routine and perhaps crucial use of such intermittent (also called ephemeral) streams, ponds, and wetlands by some wildlife species and salmonid fish, at least in places where seasonal access is not blocked by impassible culverts or extremely steep gradients.

Especially where intermittent streams exist in ravines, they concentrate fallen leaves, fish foods (terrestrial insects), and wood. Instream wood usually helps maintain pools important to fish, particularly during extremely dry or wet periods. Accumulations of wood and leafy material comprise important shelter for amphibians and for invertebrates important to downstream fish, as well as providing one of several energy sources for marine food webs. Intermittent streams and drainageways also provide sheltered humid environments where amphibians and other wildlife can conduct essential dispersal movements, moving from pond to pond (or wetland to wetland) with less risk of desiccation (Colvin 2005, Olson & Chan 2005, Freeman et al. 2007, Meyer et al. 2007, Olson et al. 2007, Welsch & Hodgson 2008).

In addition, where vegetation along intermittent streams has not been extensively cleared, a relatively large amount of leaf litter, insects, woody debris, and other particulate carbon -- all important to marine food chains -- is transported during storms from headwaters to estuaries via these flow paths (Wipfli et al. 2007, Rykken et al. 2007, Progar & Moldenke 2009). Nonetheless, although large wood and other natural organic matter from intermittent streams is clearly beneficial to individual fish and to salmonid food webs, the degree to which a reduction in its supply or transport might, relative to other factors, limit salmonid *populations* in SJC or regionally is unknown.

In addition to their habitat benefits, low-gradient Type Ns streams and drainageways appear to be among the most important areas (with the exception of wetlands) for treating excess nitrate and some other pollutants from lawns, gardens, crops, and malfunctioning septic systems, before that nitrate can pollute groundwater and other surface waters (Dieterich & Anderson 1998, Peterson et al. 2001, Alexander et al. 2007, Creed et al. 2008, O'Driscoll & DeWalle 2010). They perform that function through a microbially-mediated process called denitrification. That occurs when dissolved nitrogen comes in contact with moist, organic, anoxic sediments, such as where decaying leaves or wood are buried in the bed of a low-gradient drainageway or intermittent stream (Craig et al. 2008). Levels of moisture in the sediment should be at least 70% for optimal denitrification (Hefting et al. 2006). Even when water flows through intermittent drainageways or ditches, if those are well-vegetated it helps maintain the temperature and clarity of downstream waters (Duncan et al. 1987, Gomi et al. 2006).

Resources of Streams and Lakes in SJC

It is estimated that 31 streams countywide are potentially fish-bearing. Surveys of at least parts of most of these streams have been completed in the last several years. There are no known natural Chinook spawning areas in the county. Chum salmon spawn near tidewater but if they still occur in the county, they are barely hanging on. Coastal cutthroat trout are currently well-documented in four streams, and probably occur in several additional streams that have not yet been fully surveyed. Most are landlocked, but anadromous runs exist in at least two streams. Whether these salmonid populations are "natural," as opposed to being planted or introduced, is not a legal requirement for habitat protection. Available information is shown in Table 4-1.

Table 4-1. Distribution of native salmonids in SJC intermittent and perennial streams

sources: SJC Dept. of Health and Community Services 2000, Barsh 2010, Barsh (pers. comm.).

Salmonid Species	**Island**	**Stream** (unofficial names)	**Comment**
Chum salmon	Orcas	Crow Valley stream	only one juvenile reported from 2004-2010 surveys
	San Juan	San Juan Valley creek/ False Bay	recent anecdotal reports, but none found in 2004-2010 surveys
Coho salmon	Orcas	Cascade Creek	seen in sea-accessible reach; most likely planted
	Orcas	Pickett Springs creek	one juvenile seen
Coastal cutthroat trout	Orcas	Cascade Creek	widespread spawning
	Orcas	Doe Bay stream	landlocked and persisting
	Orcas	West Beach stream	small numbers of sea-run
	Orcas	Victorian Valley (Bayhead) stream	apparently extirpated by pond construction, seen until 2007
	San Juan	Garrison Bay- Mitchell Hill	numerous sea-run and landlocked, genetically distinct from others in islands

Aside from salmonids, native freshwater fish that depend on perennial or intermittent streams in SJC include three-spined stickleback (*Gasterostreus aculeatus*), reticulated sculpin (*Cottus perplexus*), and shiner perch (*Cymatogaster aggregata*). Surveys of SJC streams and lakes have found more non-native fish stocks than native ones. Introduced species with populations that may be self-sustaining in SJC include rainbow trout (*Oncorhynchus mykiss)*, brook trout (*Salvelinus fontinalis*), fathead minnow (*Pimephales promelas*), bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), and probably others. Most of these are" warm water" fish native to the eastern United States. Aquatic invertebrates have also been collected in studies by Barsh (2010) and others, but no comprehensive survey has been conducted to quantify their diversity among SJC's streams, lakes, and wetlands. Two crayfish are known to be present in the county: signal crayfish (*Pacifastacus leniusculus*) on Orcas and Lopez Islands, and white river crayfish (*Procambarus acutus*) on northwestern Lopez (S. Rosenbaum, wetland scientist, pers. comm.).

San Juan County has 11 bodies of fresh water larger than 20 acres, which are traditionally defined as lakes (e.g., Cowardin et al. 1979, and WAC 173-2). In decreasing order of area, the lakes are Mountain, Cascade, Sportsmans, Horseshoe, Spencer, Trout, Zylstra, Roche Harbor, Hummel, Martin, and Woods Lake. The county also has over 1000 ponds, of which at least 27 are larger than 5 acres. San Juan Island has the most ponds and lakes. Relatively little biological or water quality information has been published on the county's 11 lakes. Probably all support both native fish and the introduced (exotic) fish species that compete with them. The WDOE, based on a single visit to Cascade Lake in 1997, categorized it as oligo-mesotrophic, meaning its fertility is poor to moderate. Large seasonal growths of algae, indicative of eutrophic (high fertility) conditions, are apparent in shallow Hummel Lake on Lopez Island, and significant fish kills as a result of the subsequently low dissolved oxygen levels have been reported. However, lakes in SJC have generally been spared the problem of summertime blooms of toxic blue-green algae that many western Washington lakes have suffered. All the county's lakes are important to waterbirds, especially when severe storms and high tides batter the marine shoreline.

4.2.1.2 Lakes, Ponds, and Streams Planted With Game Fish by Public Agency

Neither WDFW nor any other public agency stocks game fish in the county's streams. During 2010, rainbow trout (a game fish) were stocked in four SJC lakes: Cascade, Egg, Hummel, and Mountain. Non-native fish of unknown origin have been reported from Sportsman Lake and the Lakedale Lakes on San Juan Island, and probably have been stocked in dozens of private ponds by landowners.

Stocking of ponds and lakes, especially with predaceous non-native warmwater fish such as bass and bluegill, whether done by agencies or private individuals, can be extremely detrimental to salmonids and native amphibian populations – far more than the presence of predatory bullfrogs (Adams et al. 2003, Pearl et al. 2005). Many introduced fish species prey voraciously on native fish as well as on sub-adults of locally uncommon frogs, salamanders, and turtles. They also may introduce fungal diseases, compete for food, and at the very least reduce the abundance of native species and average size of individuals (Hoffman et al. 2004, Hirner & Cox 2007). Unfortunately, bass have been found in Killebrew Lake, Hummel Lake, Sportsman's Lake, and perhaps elsewhere. Wetlands along these lakes would otherwise provide some of the physically best habitat for native amphibians in the county.

4.2.1.3 Naturally-occurring Ponds Less Than 20 Acres with Fish and Wildlife Habitat

Nearly all such areas in San Juan County are considered to be wetlands in whole or part. Accordingly, measures to conserve the habitat functions of ponds are described in Wetlands (Chapter 2).

4.2.2 Impacts to Freshwater FWHCAs

Home construction and associated impervious surfaces and storm drains, even when occurring at low densities but near drainageways that lead to the same stream or wetland, can dramatically alter the amount, timing, frequency, and duration of flow in streams and water level in lakes and wetlands (Booth et al. 2002, Schuster et al. 2005; Konrad et al. 2005, Poff et al. 2006, Shields et al. 2008); increase pollutant loads and concentrations (Chadwick et al. 2006; Morgan et al. 2007, Cunningham et al. 2009); disrupt channel configurations (McBride & Booth 2005, Colosimo & Wilcock 2007); shift local air and water temperature regimes (Delgado et al. 2007); introduce chronic noise, predators, and other disturbances (Hepinstall et al. 2008); and as a consequence of these and related factors, alter the abundance, diversity, and species composition of fish and wildlife communities (Miltner et al. 2004, Hansen et al. 2005, Alberti et al. 2007, Walsh & Kunapo 2009, Cookson & Schorr 2009). Many studies from other regions have correlated a reduced occurrence of fish and wildlife with increased housing density (even at low densities), without specifying the specific causes (e.g., water pollution, hydrologic alteration from impervious surfaces, vegetation removal, noise, disturbance). For example, a study of multiple watersheds in Tennessee found reduced occurrence of native fish where housing densities exceeded 1 unit per 4 acres (Cookson & Schorr 2009).

These impacts are discussed below, first for areas near streams (riparian habitat) and then for relatively dry uplands.

4.2.2.1 Impacts of Stormwater, Septic Systems, and Water Diversions on Water Quality and Quantity

Over 63,000 synthetic chemicals are in common use in the United States, many of them in households with septic systems incapable of detoxifying them completely. Nationwide, more than 200 of these chemical substances have been found in groundwater, but only where someone has checked (and monitoring most of these chemicals is rare due to high costs for laboratory analysis). Only a tiny fraction of these synthetics has been tested for their possible effects on humans, let alone on the thousands of species of plants and animals occurring in SJC. When testing has been done, it most often has focused only on direct toxicity rather than effects on reproduction and behavior which can be almost equally damaging to populations over the long term. Moreover, common pollutants can arrive simulataneously in the same waterway and the effects of the enormous number of possible *combinations* on aquatic life has only rarely been investigated. Many organisms that are able to physiologically tolerate or adapt behaviorally to a single stress such as low dissolved oxygen are unlikely to survive multiple simultaneous stresses, such as mildly elevated levels of turbidity, pesticides, and metals. Multiple pollutants are common in stormwater runoff.

Potential or actual sources of waterborne pollution within San Juan County include:
- on-site septic systems (bacteria, nutrients, household chemicals)
- ditching of "poorly drained" low spots (sediment, reduced capacity to process runoff)
- soil erosion, as natural vegetation is converted to residential and commercial developments
- dirt roads and unpaved driveways (sediment, hydrocarbons)
- household, garden, and agricultural chemicals including those used for killing moss (zinc roof strips), ants, termites, mice, rats, and weeds.
- untreated stormwater runoff from residential and commercial developments, roads, parking lots, and vehicles (metals, hydrocarbons, nutrients)
- wild and domestic animals (nutrients and bacteria from waterfowl, dogs, livestock)
- agricultural practices (e.g., fertilizer, pesticides, drainage, pond creation, plowing, irrigation)
- forestry practices (e.g., soil disturbance, shade removal, concentrations of decaying vegetation, facilitation of alder establishment)
- marinas and boating activities (hydrocarbons, metals, bacteria, shade)
- excavated ponds (warmed and oxygen-poor outflows)
- golf courses (warmed runoff, nutrients, herbicides)
- solid waste/hazardous waste
- rain carrying pollutants from outside the county (even from across the Pacific Ocean)

Partly as a result of these sources, water quality issues of greatest potential or actual concern, generally or in limited portions of the county, include:
- surfactants (laundry and dishwasher detergents such as nonyl phenols) in all surface waters
- pesticides (especially pyrethroids) and their wetting agents in all waters
- other hydrocarbons (PCB, PAH, etc.)
- other household chemicals and pharmaceuticals from septic system outflows
- excessive nitrate and ammonium in surface and groundwater, from septic system outflows, residential yards, golf courses, gardens, large stands of alder, and lands with domestic animals
- excessive phosphorus from fertilizing of residential lawns and gardens

- excessive sediment (turbidity) in intermittent streams, wetlands, and marine waters with limited circulation
- naturally high levels of arsenic (a potent carcinogen), fluoride, barium, and sodium in aquifers
- intermittently elevated temperature and low dissolved oxygen in the county's few fish-bearing streams
- increasing salinity in aquifers used domestically

Any of these water quality issues can be aggravated when water is diverted for human use from streams and groundwater, or when stream flows and pond levels are regulated by dams or other control structures. Because of the county's lack of snowpack derived water, capturing and storing water during the rainy season for domestic or agricultural use during the dry months has long been practiced by individual landowners and groups in San Juan County. Yet even a simple reduction in the amount of water reaching portions of a stream or wetland can have important ecological consequences. An artificiallly-caused water deficit, rather than polluted water, may be the single most important factor limiting productivity of freshwater habitat in many parts of SJC.

Approximately 40% of the county's population receive their drinking water from surface water systems. On the main islands these areas include the Town of Friday Harbor, Roche Harbor, Eastsound (54% surface water), Doe Bay, Olga, Rosario Resort, Rosario Highlands, and Spring Point. These water systems serve the majority of the high-density growth areas in the county. Trout Lake and Briggs Pond supply domestic water for the Town of Friday Harbor and Roche Harbor, respectively. Rosario Resort draws water from Cascade Lake; the Olga and Doe Bay water systems depend on Mountain Lake; and Eastsound uses Purdue Reservoir as a backup for well water sources (SJC *Water Resource Management Plan* 2004). Orcas Island has the county's largest lakes, and Lopez Island has the least amount of perennial surface water. Roche Harbor and Eastsound are in the process of increasing their storage capacity. There are also many instances of private pond water being used for irrigation, which is illegal under Washington law unless a water right is legally held (San Juan County, *2004 Water Resource Management Plan*).

With lower remaining flows or shallower waters during the late spring and summer, some pollutants become concentrated as water temperatures rise, water evaporates, and networks of pools, ponds, and ditches become disconnected from each other earlier in the spring than usual. This can be lethal for any aquatic life remaining in those areas, especially when accompanied by heat-induced loss of oxygen dissolved in the water. Keeping domestic animals far from ponds and their input channels is additionally important because the nutrients they add tend to rob the receiving waters of dissolved oxygen. In some cases, the natural wetlands that existed where many ponds now occur also may have tended to raise stream temperatures, but probably to a much lesser degree. Artificial ponds have much greater sun exposure than most natural wetlands and probably have less subsurface interflow, resulting in higher water temperatures.

The life cycle of coastal cutthroat trout in SJC necessitates that hatchlings remain in a stream for their first summer. Summer pool conditions therefore determine the survival of each cutthroat generation (Barsh 2010). Many SJC streams remained functionally disconnected for four to eight months after midsummer, which includes most or all of the period within which adult cutthroat trout return in the autumn. Streams in which flow does not begin until late in the autumn had no salmonids or only resident salmonids (Barsh 2010). Thus, concerns about the effects of impervious surfaces, water diversion, and ponds on waters of SJC are not limited just the quality and quantity of water, but also the timing, frequency, and duration of its occurrence in the most ecologically important locations. A guiding principle is that the water regimes that exist in wetlands, streams, and aquifers after development or other regulated actions occur should resemble as closely as possible the pre-development water regimes.

The placement of small dams to create ponds at several points on intermittent streams, or the enlargement of existing instream ponds, has been shown to sometimes diminish the water available to downstream areas during certain seasonal periods. Impoundments also can cause warming of whatever water is present in downstream portions of many receiving streams. Instream ponds that must fill completely before they can spill over into the channel downstream delay flows required by fish during critical periods in the autumn. Some instream ponds also cause stream flows to stop abruptly in early summer, potentially stranding fish in de-watered sections. Pond owners who wish to minimize this problem can modify the control structures on their ponds to provide at least 0.25 cfs (cubic feet per second) summer instream flow, which usually maintains enough water to keep instream pools connected (Barsh 2010). Despite sometimes adverse impacts to native fish, the excavation of many instream ponds in SJC has probably facilitated the expansion of local populations of some native waterbirds that typically shun heavily vegetated wetlands, and has perhaps also provided additional breeding habitat for some salamanders and frogs. Depending partly on their outlet characteristics, instream ponds can either improve or degrade the chemical quality of runoff they receive.

The productivity of estuarine habitats also can be compromised if less fresh water from upland systems (streams and groundwater seeps) is available at critical times, having been diminished by domestic water consumption and increased evaporative losses from ponds. In those estuarine areas, maintaining intermediate salinities during at least part of each day, as well as normal water temperatures and turbidity levels, is essential to salmonids and some other estuarine animals and plants.

Large portions of the county are at a point where water right allocations for groundwater by the State exceed local recharge, and in some areas current use of water exceeds aquifer capacity. Among the major islands aquifer recharge may range from 1.44 inches per year (5% of rainfall) on Shaw to 2.49 in/yr (9% of rainfall) on Lopez (San Juan County, *2004 Water Resource Management Plan*). When groundwater is not adequately recharged, and stormwater runoff is routed to the ocean more quickly through ditches and pipes rather than through natural wetlands, this shortens the duration of flooding or saturation in wetlands as well as the duration of flows in intermittent streams, with major consequences for water quality and aquatic life. On the other hand, in possibly a few densely-populated areas that still have septic systems, water seepage from these systems collectively may extend seasonal flow duration somewhat in drainageways or intermittent streams. Areas designated for high-density growth in the county's comprehensive plan which also may have limited groundwater include Eastsound, Orcas Landing and Deer Harbor. In addition, when groundwater is extracted on landforms such as peninsulas and isthmuses with limited acreage for recharge, this may pose the greatest threat to wetlands and intermittent streams in those areas.

Another problem arises when groundwater is extracted from aquifers for domestic use. At many locations a potential exists for the vacated underground soil/rock pore space to be filled with salty marine waters which can seep laterally into the fresher aquifers, especially when infiltration of surface waters has been reduced by developments accompanied by impervious surfaces that speed the overland movement of water. The result, termed seawater intrusion, can render water in some aquifers unfit for human consumption for long periods. All SJC groundwater is vulnerable to this threat, and there are several places throughout the county where wells have become undrinkably saline or a rising trend in groundwater salinity has been detected. As aquifers become more saline, the wetlands that depend on groundwater discharging naturally to the wetlands may also become more saline, and significant changes are likely to occur in their species and functions. The threat is greatest in areas within 1000 feet of shoreline, glacial underlying deposits, and where nearby wells already have chloride levels greater than about 100 mg/L (San Juan County, *2004 Water Resource Management Plan WRIA 2*).

Compared with contributions from other counties, the contribution of San Juan County to pollution loads in Puget Sound as a whole has been suggested as being *relatively* small because of the county's low population density, low-intensity agriculture, and few commercial or industrial facilities. Indeed, several ecological studies have chosen areas in San Juan County as the least altered benchmark or reference site when compared with other areas in the Puget Sound. However, even low concentrations of some pollutants can interfere significantly with aquatic life.

By State law, all unclassified surface waters that are tributaries to Class AA marine waters are classified as Class AA, meaning they must meet State standards for water quality. Because nearly all runoff in San Juan County flows into marine waters, all SJC streams and drainageways must meet the State standards, and this has been shown to be difficult in some bays with limited water circulation. Except in those areas with limited marine water circulation, once pollutants enter the county's marine waters, there usually is a potential for rapid dilution by the large volume of typically cleaner water associated with local tides and currents. This reduces pollutant concentrations and, perhaps in some cases, the threat to coastal resources from non-persistent contaminants. Nonetheless, before runoff reaches marine waters, evaporation and low summer flows potentially concentrate pollutants in wetlands, deeper pools of intermittent streams, and in ponds, lakes, and lagoons that lack persistent outflows. Animals that live in these areas, drink this water, or find refuge there from summer drought are likely to be exposed to these concentrated pollutants (e.g., Barsh et al. 2010).

In 1997-1999 the County ranked individual watersheds with regard to likely pollution sources (SJC *Watershed Management Action Plan*, 2000) but that effort has not been updated. "Conversion of natural land cover" was ranked as the highest potential source of pollution for Deer Harbor, a small watershed with steep terrain that in the past decade has experienced perhaps the most clearing of forest lands for residential development. Potential contamination from marinas ranked highest for Roche Harbor, the smallest priority watershed, with an extensive resort and marina complex. Potential pollution from stormwater runoff ranked highest for the Friday Harbor watershed, which is the most urbanized part of the county. Agricultural practices ranked highest as a potential source of contaminants in the False Bay and Westsound watersheds. The threat to water quality of failing on-site septic systems was ranked highest for the Westcott/Garrison, East Sound, Fisherman Bay, and Mud/Hunter watersheds. Contamination had been documented or reported in these areas (SJC *Watershed Management Action Plan,* 2000) but more recent monitoring has not found high levels of bacterial contamination.

Currently, no government agency conducts systematic, ongoing, countywide monitoring of critical pollutants in SJC surface water. The County Stormwater Utility is now establishing such a program. Between 1997 and 2008 the County monitored water quality in several gauged streams. This included sampling that was contracted to Huxley College (Wiseman 2000) in 1999 and 2000. The County's monitoring from 2002 to 2008 adhered to a WDOE-approved quality assurance plan, and was done jointly with the San Juan Conservation District and University of Washington Marine Labs . Some water quality measurements have also been made by individuals or organizations supported by short-term grants from state, federal, or private institutions. For the last 3 years the SJC Department of Health and Community Services has managed 2 networks for monitoring groundwater. Overall, knowledge is least complete regarding the concentrations and loads of "emerging" pollutants (new synthetic substances whose toxicity to SJC organisms is uncertain), including pharmaceuticals and some household chemicals. Also, few of the county's wetlands have been sampled.

Little has been documented regarding any actual harm caused by pollutants to SJC's native plants and animals. However, harm (other than sudden acute mortality) is extremely difficult to demonstrate. Harm can be presumed where contaminants are known to exceed legal standards, but harm can occur nonetheless for several reasons. First, dozens of studies have shown that some combinations of chemicals are more harmful together than individually, and chemical-by-chemical legal standards do not recognize this. Second, for most contaminants, the effects on many organisms and life stages, under diverse background environmental conditions, have not been studied at all. Third, no legal standards exist for hundreds of untested household chemicals whose use has become commonplace in recent decades. Because most native species have not had time to gradually adapt their physiology or behavior for coping with these chemicals, it is reasonable to anticipate some adverse effects on reproduction, behavior, and growth – and ultimately on survival as a species.

The following discussion focuses mainly on water quality impacts associated with residential development and public roads (rather than agriculture or forestry), only because those are the impacts which the County is legally most capable of addressing. The discussion also focuses mainly on the substances most likely to harm aquatic life due to their known or presumed extent of occurrence and/or toxicity.

Figure 3. Single-family homes on small lots.
(photo from Camano Island)

Septic Systems

About 75% of the SJC population relies on onsite septic systems; the rest relies on sewage treatment plants serving the communities of Friday Harbor, Roche Harbor, Eastsound, Orcas Village, Rosario, and a portion of Lopez Village. Soil ratings established by the NRCS indicate that very little area in San Juan County is suitable for conventional on-site septic systems, so alternative septic systems designed to provide an additional level of treatment are often used. However, these systems require regular maintenance to insure that they are functioning properly. The County maintains a database of locations of over 8000 septic systems (not all of them active), but the County estimates that locations of perhaps 1000 septic systems are unknown. Even for the known locations, the County does not have sufficient resources to monitor all systems to ensure they are performing as designed. The lack of a septage disposal facility on San Juan Island increases the cost for pumping a septic tank, thus discouraging many people from routinely servicing their systems as often as required. Improperly functioning septic systems can result in high levels of some **viruses and bacteria**, as indicated by coliform bacteria, in surface or ground water. This can harm human health. Consequently, legal standards exist to protect drinking water, shellfish areas, and swimming areas.

Even when functioning as designed, the ability of septic systems to effectively treat almost anything other than bacteria and excessive nutrients (nitrate and phosphorus) is limited or unknown (Staples et al. 2004, Klaschka 2008, Caliman & Gavrilescu 2009). Knowledge is particularly limited concerning the effectiveness of SJC septic systems for treating common household substances such as shampoo, odorants (whether labeled as "natural" or not), and pharmaceuticals. Despite not being widely viewed by the public as serious pollutants, these inescapable substances can damage aquatic life and contaminate aquifers (see discussion below, "Surfactants").

Other Contaminants Associated With Residences or Commercial Developments

Vehicles and machinery at residences, especially when parked outdoors, are a source of hydrocarbon (oil, grease, gasoline) and metal pollutants. Domestic animals, including pets, are a source of nutrients and bacterial contamination, adding to natural sources of such contamination such as deer and waterfowl. Many homeowners use herbicides to control weeds in gardens and lawns, and some use insecticides to control bothersome animals (e.g., spiders, mosquitoes, ants, termites, slugs) in homes and gardens. Also, fertilizers rich in phosphorus are sometimes applied to commercial and residential lawns and gardens, and can trigger blooms of algae that rob surface waters of dissolved oxygen essential to aquatic life. Precipitation running off zinc strips, zinc-based powders or detergents applied to building roofs for moss control moss can contaminate waterways and wetlands.

At least during the construction phase, the potential exists for increased erosion of soil around homes. This often continues if there is concentrated use of yards by people or animals. The movement of sediment and other substances associated with residences into downslope water bodies is accelerated by the increased runoff of stormwater that occurs from (a) roofs and paved surfaces around homes, (b) features that concentrate runoff, such as ditches and foundation/curtain drains placed to dry wet spots around homes, residential yards, athletic fields, golf courses, and driveways, and (c) clearing of vegetation (see section 4.2.2.3 Impacts of Removing Streamside Vegetation).

Roads

Most construction and widening of hard-surface roads in SJC occurred decades ago and such activities are currently very limited in the county. However, driveways to private homes are constructed all the time without a significant review of their environmental impacts, which can be substantial. Traffic along SJC roads, although light compared with mainland counties, introduces some amount of hydrocarbons and metal pollutants. Herbicides are not generally used along public roads, but are used by property owners along private roads and driveways.

The greatest impact of roads on surface water quality comes from their associated ditches. These can raise water temperatures, concentrate runoff, and cause water to move downslope so rapidly that vegetation and soil biological communities have less opportunity to process the waterborne pollutants before they reach waters considered most important for aquatic life. This impact is exacerbated when landowners illegally connect their private ditches and drainage tile to public ditches along roads.

Pesticides and Hydrocarbons

Research on the important risks posed to salmonids by pesticides was recently reviewed by Macneale et al. (2010). Although pesticide use in SJC is probably less than in many mainland areas with more extensive and intensive agriculture, pesticides are still used on crops and around homes. Pyrethroids (e.g., Bifenthrin, Cyfluthrin, Cyhalothrin, Esfenvalerate, Deltamethrin) are one of the most-often used groups. The most extensive data on pesticides in non-tidal waters of SJC are the data collected by Barsh et al. (2008) in collaboration with scientists at the University of Washington Friday Harbor Laboratories. They sampled 32 lakes, streams, and ditches throughout the county to determine concentrations of widely-used pyrethroid pesticides which people use to control carpenter ants and fleas (among other uses). They reported the following:

> Pyrethroid pesticides in excess of 1.0 part per billion (ppb) were found in at least one water specimen or one sediment specimen from 22 of 32 sampling sites. More than 10 ppb pyrethroid pesticides were found in water from three sites and sediments from two sites, with some results as high as 18 ppb. Only one site had no detectable pyrethroid pesticides in either water or sediments at the 0.1 ppb limit of detection.. It can safely be said that pyrethroid pesticide levels of 1-2 ppb are widespread in San Juan County waters. ... Six pyrethroid pesticides in local use are each toxic to rainbow trout at less than 2 ppb; thirteen pyrethroid pesticides in local use are each toxic to rainbow trout at 18 ppb or less.

Although remote, a possibility exists that a small portion of the measured pyrethroids may have been carried to the islands in rain clouds that previously had passed over more developed areas outside the county. For most pollutants, fish and other aquatic life are harmed at much lower concentrations than are humans. Some commonly-used pesticides such as pyrethroids are not effectively treated by most wastewater treatment systems. Pesticides often contain undeclared wetting agents such as alkyl phenyl ethoxylates (APEOs) which are believed to disrupt endocrine systems and may pose greater risks to aquatic ecosystems than the declared active ingredients (Barsh et al. 2010).

Another highly toxic hydrocarbon of potential concern is a coal-tar based substance used to seal parking lots and driveways. Extent of use in the county is unknown. Many cities and counties have recently enacted laws requiring use of an asphalt emulsion-based alternative.

Another study sampled just 6 nearshore locations on San Juan Island, and focused on soils. Concentrations of non-pyrethroid pesticides, herbicides, and some other potentially toxic substances were analyzed (Earth Solutions 2010a-b). At all locations, the sample points were less than 100 ft from both a single-family residence located uphill and the shoreline located downhill. At two of these locations, samples were also collected from undeveloped land near the residences. A common herbicide (MCPP) was detected at half the locations. Although levels of this herbicide were not found by that study at levels believed to be acutely toxic to some animals, the levels that are safe for all local aquatic life are unknown. No other manmade chemicals (phthalates, several insecticides) that were analyzed were detected. Many factors, including several unrelated to the presence or absence of residences, could explain the lack of detection of some of these substances in the samples at the time of sampling.

Pesticides are a potential threat to SJC amphibians as well as salmonids, butterflies, and other non-target species. Although adequately-sized wetland buffers can lessen somewhat the threats to pond-breeding amphibians from aerial spraying (Thompson et al. 2004), many species are highly sensitive to even low concentrations of herbicides (Solomon et al. 2008) or their wetting agents (see next paragraph). Lower amphibian hatching rates have been documented in several agricultural areas in the Pacific Northwest where pesticides and fertilizers are used (e.g., de S et al. 2002, Bishop et al. 2010), even where water quality guidelines for these have been met (Westman et al. 2010).

<u>Surfactants, Antibacterial Soaps, Pharmaceuticals</u>

Surfactants (from shampoo, laundry and dishwasher detergents), pharmaceuticals (including many with hormonal compounds), and antibacterial soaps (e.g., triclosan) can be expected to occur chronically in the effluent from many households. These are potentially disruptive to aquatic life, and in some cases are not removed completely by septic systems (e.g., Swartz et al. 2006, Standley et al. 2008, Wilcox et al. 2009, Conn et al. 2010, Dougherty et al. 2010, Sanford & Weinberg 2010, Sanford et al. 2010). The most extensive data on this group from SJC pertains to surfactants. Samples were analyzed for nonylphenol surfactants in samples collected by Barsh et al. (2008 and 2010). In 2008 they sampled 32 lakes, streams, and ditches throughout the county and reported the following:

> Anionic surfactants of 1.0 part per million (ppm) or greater were found in at least one water specimen from 8 of 32 sampling sites. The highest concentration observed was 1.6 ppm. Anionic surfactants were detected at all 32 sampling sites at our 0.2-ppm limit of detection. Indeed, only a single specimen from one site had no detectable surfactants. Variation was low between sampling sites and very low within sites as well. This family of surfactants appears to be nearly ubiquitous in San Juan County freshwater systems at a level of roughly 0.5 parts per million (500 parts per billion). This is currently the EPA's national secondary drinking water standard for surfactants—the maximum recommended for water consumed by humans.

The incompleteness of septic systems for processing surfactants, or the persistence of surfactants applied with herbicides, is hinted at by the discovery of surfactants in every one of

32 lakes, ponds, and streams sampled in July-August 2008 in SJC (three replicate sets of samples were collected from each site). In addition, in the False Bay watershed in 2010 they found nonyl phenol (an ingredient of many surfactants) at levels which they said the technical literature shows being high enough to result in loss of fertility in salmonid eggs. The USEPA is considering an aquatic life toxicity standard of 5.9 micrograms per liter for nonylphenol ethoxylates (Staples et al. 2004). The incompleteness of septic systems for processing surfactants, estrogenic pharmaceuticals, and other household substances that may be ecologically hazardous is also suggested by many peer-reviewed studies from other regions, as cited above.

Phosphorus, Nitrate, and Ammonia

Phosphorus and nitrate are essential for plant growth. However, in high concentrations these nutrients are widely known to be significant “nonpoint source” pollutants that can cause shifts in species composition and habitat structure that are detrimental to rare plants, aquatic food chains, and valued species (Carpenter et al. 1998, Anderson et al. 2002). High concentrations of nitrate in well water also are a human health hazard, and some levels of ammonia impair aquatic life. No numeric standards for nutrients in surface waters have been legally adopted at the federal, state, or SJC level. However, the USEPA (2000) recommended 2.62 mg/L as a maximum level for nitrate in fresh surface waters of the Puget Lowlands, and 1.8 mg/L for total phosphorus. A survey of freshwater locations in SJC in 2000 (Wiseman et al. 2003) found levels of nitrate and phosphorus averaged less than those EPA levels at all but one of 24 locations sampled on a semi-monthly basis. Ammonia toxicity depends on species but generally is around 0.2 to 2.0 ppm. The true extent of water quality impairments or lack thereof will remain uncertain until a sustained countywide monitoring program (including sampling during the largest runoff events) is implemented.

For groundwater intended for domestic use, the EPA’s maximum allowable nitrate level is 10 mg/L. As of 2007 no SJC wells were known to be regularly exceeding this level. However, dozens of domestic wells in SJC have nitrate concentrations above 1 mg/L, indicating the initial stages of aquifer pollution due to human activities (San Juan County Health and Community Services 2007).

Inputs of phosphorus and nitrate to SJC wetlands, lakes, streams, and nearshore waters were possibly at least as great during early periods of the county’s development as they are now. During those times wildfire, mining, and the drainage of wetlands (especially peatlands and forested wetlands) were more prevalent and would have increased nutrient and sediment export, as organic soils were oxidized and eroded soils were freely washed into lakes, streams, and estuaries. Much of the ditching and clearing occurred in the early 1900’s. Although the paucity of streams in the county means that salmon runs were never as dominant an event as elsewhere, when salmon occurred more widely than now, they probably introduced nutrients of marine origin to headwaters of the county’s few perennial streams. The large concentrations of waterfowl that occurred prior to the extensive regional wetland losses likely had a similar effect.

High levels of dissolved inorganic nitrogen have been mentioned as a possible cause of severe growths of algae in marine areas of relatively restricted circulation, such as near the southern end of Hood Canal (Redman 1998, Paulson et al. 2006). However, some analyses have suggested that nitrogen loading may not pose an immediate threat to biological communities in most of Puget Sound, and "the least sensitive sub-regions are the Strait of Juan de Fuca and the tidally-mixed passages linking it to Puget Sound and the Strait of Georgia" (Mackas & Harrison 1997).

When the excessive algal growths occur on marine rocks and sediments, aquatic invertebrates important to the food chain can be smothered. Excessive algal growths also can temporarily deprive the water of oxygen needed to sustain marine fish. When excessive algal growths are triggered by abnormally high levels of nutrients in the tidal or marine water column, they block light needed by eelgrass (Williams & Ruckelshaus 1993), a submersed plant very important to fish and wildlife. Discharge of unusually warm and/or contaminated water occurs in several of the county's nearshore areas that have limited circulation, such as Westcott Bay. That area has experienced a complete and unexplained die-off of its eelgrass within the last 10 years. Also, East Sound is listed by the WDOE as an impaired water body due to low dissolved oxygen, and discharge of sediment and excess nutrients could be partially creating that oxygen deficit. On the other hand, when nitrate makes salt marsh plants more productive and the dead material of those plants is washed into estuaries by tides, the material can help sustain important food chains.

In fresh water, excessive nitrate concentrations or the presence of correlated land uses have been associated with changes in species composition of plant communities in wetlands (Adamus et al. 2001) and in some other habitats. Increased invasion by weeds such as reed canary grass has especially been noted in wetlands with low organic content in their sediments (Perry et al. 2004) and with widely fluctuating water levels (Magee & Kentula 2005). Nitrate concentrations as low as 1 mg/L can change the structure of freshwater algae communities of streams (Pan et al. 2004) and contribute to blooms of toxic algae in lakes and wetlands. Streams receiving heavy nutrient loads from septic tank leakage have aquatic invertebrate communities that are significantly altered, especially where storm drains are commonplace (Walsh & Kunapo 2009). Nitrate loading has been shown to increase exponentially in response to increases in impervious surface in watersheds, even at low levels (5-10%) of imperviousness (Cunningham et al. 2009).

New research is helping define thresholds for defining "excessive" nitrate concentrations or loading rates for amphibians as well. Two components of many fertilizers -- ammonium nitrate (NH_3NO_3) and ammonium sulfate (NH_3SO_4) – are known to kill tadpoles at concentrations lower than typical application levels, which are lower than USEPA water quality criteria[21]. A study of farm ponds determined that to maintain species richness of amphibians, the nitrate concentration needed to be less than 2.5 mg/L (Knutson et al. 2004).

[21] From Hayes et al. (2008): "The 7-day median lethal concentration (LC50) for *R. aurora* [red-legged frog] larvae was 4.0 mg/L NH_3NO_3, whereas the 15-day LC50 was 1.2 mg/L. In studies using *R. aurora* embryos, the 16-day LC50 for NH_3NO_3 was 71.9 mg/L; but the 16-day LC50 for sodium nitrate ($NaNO_3$) was 636.3 mg/L, which pointed to ammonium rather than nitrate ions producing the toxic effect. Moreover, significant decreases in the length and weight of *R. aurora* embryos were observed at NH_3NO_3 concentrations ≥ 13.2 mg/L, and at concentrations of $NaNO_3$ > 29.1 mg/L (Schuytema and Nebeker 1999). In similar work, concentrations of ammonium sulfate (NH_3SO_4) ≥ 134 mg/L impaired *R. aurora* larval growth."

Metals

Copper, lead, zinc, mercury, and cadmium are part of a group of metals commonly known as "heavy metals." Especially when soluble or attached to suspended sediment or organic matter in concentrations that are much higher than natural background levels, they can be toxic to many forms of aquatic life. Potential sources in SJC are both human-related (abandoned gravel pits, road cuts, vehicle tires and emissions, zinc compounds used for moss control, discarded batteries) and natural geologic formations.
Sampling and analysis of surface and well water for heavy metals has not been comprehensive in SJC, but limited data suggest that despite the current absence of major industrial facilities, heavy metals do sometimes occur at levels potentially harmful to aquatic life.

A recent study at 6 nearshore locations on San Juan Island (Earth Solutions 2010a-b) sampled copper, lead, zinc, and mercury in soils next to the shoreline. At all locations, the sample points were less than 100 ft from both a single-family residence located uphill and the shoreline located downhill. At two of these locations, metals were also sampled on undeveloped land near the residences. Levels of copper in the soil ranged from 4 to 30 mg/Kg (ppm), zinc from 4 to 96 mg/Kg, and lead from 3 to 12 mg/Kg. Many factors, including several factors unrelated to the presence or absence of residences, could explain the lack of excessive levels of these metals in the San Juan samples, and spatial differences in their concentrations, at the time of collection. None of these samples exceeded government standards on the particular day of sampling. However, an unrelated study found that a short-term (30 minute) exposure to only 20 ppm copper dissolved in water can reduce the ability of coho to smell a natural odorant by 82%, thus potentially impairing their homing ability; increasing the water hardness or alkalinity only slightly diminished the inhibitory effects of copper (McIntyre et al. 2008).

Sediment

Fine sediments suspended in water are a concern because they block the sun from reaching underwater plants, thus reducing aquatic productivity. Excessive suspended sediment can interfere with the respiration and reproduction of larval amphibians (Knutson et al. 2004) and important fish. Sediment also serves as a carrier for heavy metals, phosphorus, and some toxic household chemicals, which routinely bind to surfaces of suspended clay particles (Hoffman et al. 2009, Kronvang et al. 2009). When deposited, sediments can smother bottom-dwelling aquatic life, as well as eventually fill in small isolated wetlands, or at least reduce the duration of time they are saturated, thus reducing their suitability as habitat for some dependent species. Suspended sediments concentrations are expressed as turbidity or total suspended solids. Extensive year-round sampling in neighboring Island County determined that background levels in streams of relatively unaltered watersheds there are about 15 NTU (a unit of measurement typically applied to turbidity). Sampling of several streams throughout SJC by the County in 1997-1998 found several exceedences of the turbidity standard (San Juan County Dept. of Health and Community Services 2000). A survey freshwater locations in SJC in 2000 (Wiseman et al. 2003) found average turbidity levels to be within the standard at all but 4 of 24 locations sampled on a semi-monthly basis. Also, the San Juan Islands Conservation District (2008) between 2005 and 2007 found the turbidity standard being exceeded (during at least part of the year) at 6 of about 23 sites. Although there is a State standard for turbidity (which only grossly represents the level of suspended sediments), there are no standards useful to defining "excessive" sediment deposition rates in streams, wetlands, or estuaries. Turbidity results largely from soil erosion, and susceptibility to erosion is the dominant hazard or limiting factor in components of soils that comprise 34% of the land area of SJC (calculated from NRCS 2009). However, most such soils have slopes in excess of 30 percent and thus are unlikely to be developed or cultivated. Logging or road building on such slopes may nonetheless increase sediment in runoff. Suspended sediment also originates from eroding stream banks. Although bank erosion is a normal geologic process, it is greatly accelerated when vegetation in or near the channel is cleared and the extent of impervious surfaces in adjoining uplands is increased by development (Segura & Booth 2010).

Bacteria, Viruses, and Fungi

Microbial communities are diverse and essential to well-functioning ecosystems, but they also contain some organisms that are pathogenic to humans, other animals, and plants. Pathogens found in surface waters are overwhelmingly ones associated with human waste, but can also originate from waterfowl, dogs, and some other mammals. Septic systems are designed to reduce populations of harmful bacteria (indicated mainly by the presence of coliform bacteria, *Escherichia coli*) before they reach surface or groundwater and contaminate shellfish. However, a potential exists for some bacterial releases when systems in geologically sensitive areas exceed their designed lifespan. In Australia, concentrations of *E. coli* in streams were best predicted by the number of septic systems per square mile, weighted by septic system distance to streams measured along drainageways that led to the streams. At that location, subsurface stormwater drains were not found to be an important conduit for bacteria in septic leakage (Walsh & Kunapo 2009).

State standards exist for the bacterial group most often associated with animal waste, the coliforms. Examples of streams and lakes where very high levels of fecal coliform bacteria have been reported on at least one date in the last 10 years, in some cases exceeding state standards, are Horseshoe Lake (Blakely Island), an unnamed stream flowing southeast from Hummel Lake, Cascade Creek at Olga, an unnamed stream next to Cascade Creek, and streams or drainageways flowing into marine waters at East Sound, West Sound (Crow Valley), Doe Bay, Buck Bay, False Bay, Friday Harbor, Westcott Bay, Garrison Bay, and at numerous Lopez Island locations. Where failing septic systems are a likely contributor, the County has been working with homeowners to correct these issues. Most of the septic systems associated with newer construction of homes in the County are of a relatively advanced design that incorporates both aerobic and anaerobic processing of wastes.

4.2.2.2 Impacts of Channel Alterations

Although mostly small and flowing only seasonally, many SJC streams have been excavated and re-aligned (channelized), in some cases disconnecting productive wetlands from streams. Sometimes this was done to increase the productivity of crops growing in wetlands or to make wet soils suitable for home construction or roads. This inevitably results in overall simplification of the stream networks, meaning that rainfall now travels more quickly from uplands where it lands to places where water intercepts the ocean. Research elsewhere indicates that this can result in less infiltration, less recharge of aquifers, less processing of pollutants before they reach the ocean, stream flow that is warmer and more murky, and significant degradation of aquatic life except, perhaps, in places where channels and pools have been deepened sufficiently to improve fish access and perhaps the summer survival of fish.

The cross-sectional shape of some channels also changes when vegetation near the channel is cleared, especially when replaced by impervious surfaces. The larger volumes of runoff that result can cause channels to become more incised, depending on the slope and soil erodibility. Areas farther downstream where the eroded sediments are deposited can become shallower and wider, potentially restricting fish access and impairing aquatic life in many other ways.

The county's roads and private driveways have cut off historic fish passage to significant portions of many intermittent streams (for examples, see Barsh 2010). At some locations no culverts were installed perhaps because seasonal flows were judged too small and brief to matter. At other locations culverts were installed but are inadequately positioned or improperly sized to allow passage of fish, wood, and leaves. Although small numbers of coastal cutthroat trout in some SJC streams seem able to survive despite being landlocked and confined to scattered relict pools during late summer (Barsh 2010), this may be a precarious adaptation for local populations of the species in the long term (Gresswell et al. 2006).

4.2.2.3 Impacts of Removing Streamside Vegetation

Effects of Removal of Streamside Vegetation on Aquatic Life

The importance of streamside vegetation, especially trees, for sustaining the health of aquatic systems has been documented hundreds of times over the past 50 years, especially in the Pacific Northwest (e.g., Gregory et al. 1991, Naiman et al. 2000, Richardson et al. 2005, Wipfli et al. 2007). The scientific basis for protecting streamside vegetation as "buffers[22]" is also discussed extensively in Chapter 2 (Wetlands) of this document. A key finding is that *the primary water quality reason for protecting vegetated buffers in SJC is not to increase infiltration or filtering of overland runoff (buffers are often ineffective for that), but rather to prevent potential sources of pollution and runoff (i.e., development) from being placed on top of hydrologic source areas, which are the areas most responsible for rapidly transporting any pollution to sensitive water bodies downslope or downstream* (Creed et al.2008a,b; Qiu 2009a,b).

As one hydrologist (Walter et al. 2009) puts it:

"Riparian buffers are commonly promoted to protect stream water quality. A common conceptual assumption is that buffers "intercept" and treat upland runoff. As a shift in paradigm, it is proposed instead that riparian buffers should be recognized as the parts of the landscape that most frequently generate storm runoff. Thus, water quality can be protected from contaminated storm runoff by disassociating riparian buffers from potentially polluting activities."

Few if any studies have been done on the effects of buffers along *intermittent* streams on the abundance and diversity of aquatic life in those types of streams. The effects of buffers and/or tree canopy closure on aquatic life in *perennial* streams are varied, with some studies showing little effect on native fish (Roy et al. 2005, Fischer et al. 2009) and others a positive effect especially when buffer width was at least 100 ft (Frimpong et al. 2005, Horwitz et al. 2008). A

[22] **Buffers** are generally-terrestrial areas surrounding a wetland or bordering a stream or shoreline, whose purpose is to reduce impacts to the functions of that protected water body, such as may occur from adjacent land uses. Like **setbacks**, buffers are measured a specified distance between a development and the water body being protected. Unlike setbacks, buffers usually are considered off-limits to some activities and land uses which themselves may impact the functions of the water body.

30-ft wide buffer along perennial streams in British Columbia was found to be insufficient to protect stream invertebrate communities from clear-cut logging, although the terrestrial insects the buffer provided were noted as a potentially important food source for fish using the streams (Hoover et al. 2007). Another study of BC perennial streams found uncut riparian buffers of at least 30 ft were needed to limit changes from clear-cut logging to aquatic life in headwater forested watersheds; those changes included increase abundance of aquatic invertebrates and algae (Kiffney et al. 2003). In Maryland, agricultural streams with extensive buffers had greater diversity of aquatic invertebrates than urban streams. Perennial urban streams, even when impervious surfaces were extensive in their watersheds, had high diversity of invertebrates in places where a riparian forest canopy had been preserved (Moore & Palmer 2005). And the conversion of streamside cropland to natural vegetation resulted in more diverse stream aquatic communities within one year of the riparian planting (Teels et al. 2006).

Variation among the results found by some studies of buffer effects on aquatic life is perhaps due to the fact that *intensity of land use* and forest fragmentation in a stream's watershed often has a greater influence than buffer width (e.g., Shandas & Alberti 2009, Stephenson & Morin 2009). The effects of buffer width or proportion of forest in the watershed can also be overshadowed by differences in stream substrate type and flow duration (Roy et al. 2005). In Georgia, where the proportion of the riparian zone occupied by forest was great, only the perennial streams with coarse bed sediment and low bed mobility (vs. sites with high amounts of fine sediment) had greater richness and abundance of sensitive fish species (Roy et al. 2006). Comparing data from multiple regions, Utz et al. (2009) reported that aquatic invertebrates sensitive to impervious cover were generally lost when impervious cover was in the range of 3% (most sensitive taxa) to 23%. Agricultural land cover seemed less impacting than impervious cover. Most organisms were capable of tolerating high levels of agricultural land cover, but a few disappeared when agricultural land cover exceeded 21% of the watershed area. Once urbanization in a watershed reached 60%, all taxa remaining responded either neutrally or positively with respect to continued urbanization. Most were harmed at much lower levels. The degraded physical condition of urban perennial streams of the Puget Lowlands was best explained statistically by the extent of high-intensity land use and grassy urban land in the contributing area, and percent grassy urban land within about one-quarter mile of the stream. Stream physical condition was also much worse near road crossings, but conditions improved after a stream flowed through a forested buffer or a wetland (McBride & Booth 2005). A study in Australia found that sensitive aquatic invertebrate taxa rarely occurred in streams whose contributing areas had greater than 4% total imperviousness. However, within sites of similar imperviousness, those with more riparian forest cover were more diverse in terms of some insect groups. Canopy cover along the streams did not explain invertebrate community composition strongly (Walsh et al. 2007).

Changes in aquatic life caused by vegetation clearing near streams and wetlands are usually the result of changes in a series of interrelated factors that are affected by canopy removal, including stream temperature, dissolved oxygen, suspended and deposited sediment, channel morphology, flow duration, type and extent of replacement vegetation, and the abundance and instream retention times of woody material, terrestrial insects, and leaves (McBride & Booth 2005, Poff et al. 2006, Alberti et al. 2007, Roberts et al. 2008, Segura & Booth 2010).

As is widely known, one function of streamside vegetation is to help maintain regimes of **water temperature and dissolved oxygen** favorable to local fish and other aquatic life. Water temperature in smaller streams and wetlands is usually influenced the most by shade from the vegetation closest to these waters, and from the capacity of plant roots to open up soil pores that allow for greater subsurface interflow. Overall vegetation patterns in a watershed frequently have an equal or greater influence on stream temperature and aquatic productivity than vegetation just within buffer areas adjoining a stream (Brosofske et al. 1997, Sridhar et al. 2004, Stephenson & Morin 2008). This may also be true of air temperatures: maximum within one 100-ft wooded buffer was only slightly cooler than in a 16-ft wide wooded buffer (Meleason & Quinn 2004).

Streams whose contributing areas have a greater extent of roads (road density) have higher temperatures. A study of 104 streams in British Columbia found there is a 6-in-10 chance that the summer maximum weekly average water temperature will increase by 2.3 °F if road density in the contributing area exceeds 27 ft of road per acre and by 5.8 °F if road density exceeds 53 ft of road per acre (Nelitz et al. 2007). GIS analysis of County data indicates that road densities on most of the SJC islands exceeds these thresholds (Table 4-2).

Table 4-2. Densities of roads (excluding driveways) by island.

Island	**Island Acres**	**Road Ft**	**Ft/Acre**
Center	168	16430	98
Crane	226	14640	65
Obstruction	220	12108	55
Decatur	2237	112693	50
Orcas	36991	1385984	37
Lopez	18995	698871	37
San Juan	35503	1287438	36
Shaw	4889	141376	29
Stuart	1823	47170	26
Henry	999	22958	23
Blakely	4302	52821	12
Waldron	2905	32764	11

Besides shade and other thermal effects from vegetation, factors controlling temperature in streams of the Pacific Northwest include groundwater discharge (springs), stream orientation (buffers along north-south streams in British Columbia are more effective, Gomi et al. 2006), channel depth, presence of instream ponds (Rayne et al. 2008), and other factors reviewed by Moore et al. (2005).

The importance of water temperature is recognized by legal standards that have been adopted for streams. Cool waters (less than 68°F, ideally less than 60°F) are particularly important to salmonid fish because at higher temperatures less of the dissolved oxygen necessary for their survival (a minimum of 5 ppm is needed by most local fish) is able to remain in the water. It should be noted, however, that local populations of some fish in SJC may have adapted to somewhat higher temperatures (Barsh 2010). For example, coastal cutthroat (*Oncorhynchus clarki clarki*) have been observed in San Juan County streams at temperatures that were as high as 66.2 °F for at least short periods and even higher temperatures in deep ponds (Barsh 2010).

Being highly mobile, fish can of course avoid channel segments with excessive temperatures or pollutants, unless trapped in pools by rapidly dropping water levels. However, when fish avoid areas due to pollution or physical barriers, this reduces the extent of useable habitat and thus the number of fish that can exist in an area.

Also, researchers in some parts of the Pacific Northwest have discovered that populations of a few species of native frogs, pond-breeding salamanders, and aquatic invertebrates sometimes *in*crease following partial removal of shading vegetation. That may be related to a subsequent increase in water temperatures and algae, provided that sediment inputs to streams do not increase greatly at the same time (Murphy et al. 1981, Hawkins et al. 1983).

A study by Pollock et al. (2010) of 40 small forested watersheds in the Olympic Peninsula found that mean daily maximum temperatures averaged 58.1°F and 53.8°F in logged and unlogged watersheds, respectively, even 40 years after logging. Diurnal fluctuations also were greater in the harvested watersheds, averaging 3.0 °F compared to 1.6 °F in the unharvested. Average daily maximum temperature depended on the amount that had been cut in both the watershed as a whole and in just the parts of the watershed near the streams. The amount of recently clear-cut riparian forest (<20 year) within ~2000 ft upstream ranged from 0% to 100% and was not correlated to increased stream temperatures. The probability of a stream exceeding the temperature standard increased with increasing amount of the watershed harvested. All unharvested sites and five of six sites that had 25-50% harvest met the temperature standard. In contrast, only nine of eighteen sites with 50-75% harvest and two of nine sites with >75% harvest met the standard. Many streams with extensive canopy closure still had higher temperatures and greater diurnal fluctuations than the unharvested basins, indicating that that the impact of past forest harvest activities on stream temperatures cannot be entirely mitigated through the reestablishment of riparian buffers. A study in Oregon found that thinning a forest to a density of 80 trees/acre did not affect soil temperature in streamside areas nor the water temperature of the stream (Olson & Chan 2005).

Riparian vegetation is also important for its ability to provide energy (mainly in the form of carbon) to aquatic food chains, and to add physical structure (downed wood) valued as habitat by many stream and lake species. Carbon is added in the form of leaves, logs, and large numbers of terrestrial insects that fall into streams. In the Pacific Northwest, the clearing of forests for home construction and roads has promoted a shift from coniferous or mixed vegetation to deciduous vegetation; this contributes 54% more nitrate and 40% more phosphorus to streams and alters the seasonal timing of the inputs and light availability (Roberts & Bilby 2009). Consequences for aquatic life in streams and perhaps estuaries are probably significant, but cannot be assumed to be positive or negative from a perspective of human values. A similar vegetation shift occurred as a result of clear-cutting near streams in British Columbia (Kiffney & Richardson 2010).

In some streams and at some times of the year, large quantities of insects fall from terrestrial vegetation into streams and the ocean, providing substantial food for fish. A study in Oregon found quantities were greater when streamside vegetation was deciduous shrubs and trees rather than conifers (Progar & Moldenke 2009). A study in Georgia found that, paradoxically, more terrestrial insects fell into open-canopy streams than forested streams. However, the insects were generally smaller and less often consumed by the fish, whereas insects falling into densely forested streams were larger and more often used (Roy et al. 2005). In the Pacific Northwest, some uncertainty remains regarding the relative importance of different land cover types and tree species as contributors of insects consumed by salmonids at different seasons. The dominant type of vegetation, both near a stream and in a watershed generally, undoubtedly has the potential to strongly influence aquatic productivity (Ball et al. 2010).

Although leaves from riparian vegetation ("litter fall") increase the abundance of aquatic invertebrates, they also take up oxygen from the water as they decompose (due to microbial respiration). When they accumulate in isolated pools, as in intermittent streams that slowly dry up each spring, this could be detrimental to any fish remaining in those pools.

Although **large wood** (fallen trees) can sometimes block fish access to parts of streams, the importance of large wood to aquatic life has been widely documented in perennial streams (literature reviewed by Murphy 1995, May 2003, Wenger 2000, Knutson and Naef 1997) and in lakes (Roth et al. 2007). A study in Montana found that channels having wider wooded buffers had more instream wood (McIlroy et al. 2008). During storms in-channel wood shelters fish from severe flow velocities, and at other times wood shelters fish from predators. Wood also provides shade and additional attachment surfaces for aquatic invertebrates that fish feed upon. By detaining leaves that fall into channels, wood lengthens the time that leaf decay occurs before leaves are washed downstream into the ocean. In doing so, this enriches the leaves and the invertebrates that feed on them, thus potentially supporting more fish, both in the stream and in nearshore waters. Adding large wood to a stream appeared in at least one instance to increase the stream's capacity to remove excessive nitrate (Roberts et al. 2007). Large wood that partially blocks flow can force more stream water into the underlying sediments (hyporheic flow), thus potentially cooling the water temperature and enhancing the processing of soluble pollutants. During the most severe storms, debris flows in streams nearest the marine shore can provide wood to coastal bays, with consequent benefits to marine forage fish and invertebrates. Treefall directly into marine waters from adjoining cliffs can serve the same purpose as large wood entering marine waters via streams , and because of the county's long shoreline relative to its total stream lengths, shoreline treefall is probably a larger source of marine wood.

Information from studies in the Pacific Northwest (FEMAT 1993) suggests that most large wood in streams is provided by trees that are within a horizontal distance of 0.5 (50% effectiveness) and 0.8 (90% effectiveness) tree-height of water, and that most leaf litter originates from trees that are within 0.2 (50% effectiveness) and 0.4 (90% effectiveness) of the water. In the soils and climate present in the San Juan Islands, most trees grow to about 85 feet tall. Thus, most large wood in SJC streams is likely to originate within 43-68 feet of water, and most leaf litter within 17-34 feet.

As contrasted with its role in perennial streams and rivers, the importance of large wood in narrow intermittent streams has not been firmly established. However, it would appear that most of the same principles should apply. A lack of wood in intermittent streams could force fish to use deeper pools for shelter. This might increase the risk of fish being stranded by rapidly receding water levels. Also, deeper pools often have less dissolved oxygen, thus potentially increasing the risks associated with greater physiological stress. Large wood falling into steep intermittent channels could also help minimize downcutting and head-cutting of those channels, which can be detrimental to aquatic habitat.

Effects of Removal of Riparian Vegetation on Wildlife
Few or no wildlife species in SJC reside in or depend directly on streams or their adjoining vegetation exclusively, perhaps because so few of the county's streams flow perennially and because stream networks historically present have been disrupted. Some of the county's wildlife species may occur disproportionately near fresh water (e.g., wetlands, lakes), but being located along perennial or intermittent streams per se may not be critical to the vegetation structures or food sources that comprise habitat for local species. No scientific evidence suggests that any SJC songbird or amphibian species prefers vegetated areas close to the marine shoreline over similarly vegetated areas located further inland, and the importance of a contiguously wooded corridor connecting the marine shoreline with habitats closer to the center of islands has not been demonstrated. It seems at least equally likely that many species would favor the warmer, more sheltered interior environments over the harsher conditions often found along shorelines.

The affinities of some wildlife species with streamside or shoreline vegetation may have less to do with the fact of the vegetation being along a stream or shoreline as with the plant species and structure of the vegetation that occurs disproportionately there (Shirley 2004), the microclimate which the vegetation creates, or to the fact that there often is a greater concentration of downed wood and snags valued by wildlife in the areas closer to shorelines, streams, and other topographic depressions (Martin et al. 2007). In British Columbia, activity levels of bats were more than 40 times greater in riparian than in upland areas, due to greater abundance of emerging aquatic insects, and were significantly greater where stand complexity and extent of forest edges was greater; bat activity levels were not correlated with forest stand age (Grindal et al. Brigham 1999, Grindal et al. 1999).

Although some studies (almost entirely from the eastern United States) have found more wildlife *species and individuals* in wider strips of vegetation, such as in buffers of increasing width along streams, this is an obvious outcome. Any time any sort of vegetation is added to the landscape, most wildlife species will respond positively because vegetation adds vertical complexity to the landscape in ways that buildings, roads, lawns, and croplands do not. Even if wide buffers were placed along every stream and shoreline and around every wetland in a county or large island, this will still not be wide enough to meet the habitat needs of all the county's indigenous wildlife species. Ecologically, more is always better, but *the key issue really is: How much is "enough?"* There are few if any SJC species for which this question can be answered confidently with the existing data. And as noted earlier, it isn't only the width of the buffer that matters – it's also the quality of the habitat within it and the intensity of land use behind it.

Mammals in SJC that probably use stream and shoreline riparian areas and wetlands disproportionately include muskrat, beaver, river otter, mink, raccoon, and all bats (Appendix 4-B). They all use upland habitats as well, and their buffer width requirements, if any, are not reliably known. A study in British Columbia compared abundance of small mammals in a 100-ft wooded buffer there with those in a clearcut and an unlogged forest (Cockle & Richardson 2003). No dramatic differences were noted. Two species (shrew-mole, montane shrew) were less numerous in the 100-ft buffer, but only slightly so. At increasing distances from streams, creeping voles increased and deer mice (during 1 of 2 years) decreased. In southwestern Washington, a 200-ft wetland buffer appeared adequate to protect small mammals in the wetland from effects of logging nearby forests (MacCracken 2005). Similarly, near an Oregon clearcutting operation, only one of 17 small mammal species declined in riparian buffers that were 10-50 ft wide (Wilk et al. 2010). Some published literature syntheses have made the mistake of assuming that the distance a species has been recorded from a stream or wetland is the same as the size of buffer it would require.

Among SJC birds, those that are likely to occur disproportionately near streams, based on knowledge of their habitat preferences in Washington (WDFW 2009) or adjoining states and provinces (e.g., Kinley & Newhouse 1997, Shirley 2006) include Willow Flycatcher, Olive-sided Flycatcher, Swainson's Thrush, Varied Thrush, Warbling Vireo, Yellow Warbler, Wilson's Warbler, and perhaps Western Screech-Owl, Pacific-slope Flycatcher, Pacific (Winter) Wren, and Black-throated Gray Warbler. In Ohio, 20 of 27 migrant bird species were *more* abundant (by 58 - 75%) in upland forest than in riparian forest. Migrant bird abundance was statistically unrelated to either percent urbanized land or percent forest cover within 0.6 mile (Rodewald & Mathews 2005). Also in Ohio, migrant songbirds had the strongest positive correlation with natural land cover near streams when it was measured within ~820 ft of streams, rather than in areas closer or farther. Some migrant songbirds were much less likely to occur where there were many buildings within that distance of streams (Pennington 2008).

4.2.2.4 Impacts of Human Presence Along Streams

The frequent and/or persistent presence of humans and domestic animals (particularly dogs and house cats) can discourage some wildlife species from using streamside areas (or any habitat area) where those species otherwise would be present. Noise, night-time outdoor lighting, large picture windows (a collision hazard for birds), trash dumping, and a host of other things associated with humans contribute to avoidance of residential areas by some riparian wildlife species. See section

4.3.2.2 Impacts of Human **Presence** for additional description.

4.2.2.5 Development Intensity

Because of the complexity in assessing the potential for each of the above-mentioned impacts in each development permit application, planners often just create a limited number of categories intended to reflect the likely cumulative intensity of pollution, vegetation alteration, hydrologic disruption, and other disturbance associated with particular land use types. For example, the WDOE (Granger et al. 2005, in Table 8C-3) rates various proposed expansion or creation of particular land uses as High, Moderate, or Low Intensity as follows:

> HIGH: Residential (if more than 1 unit/acre); industrial; commercial; high-intensity recreation (e.g., golf course, athletic field), or conversion to high-intensity agriculture (dairies, nurseries, greenhouses, growing and harvesting crops requiring annual tilling and raising and maintaining animals, hobby farms, etc.).
> MODERATE: Residential (if 1 unit per multiple acres); logging roads, driveways, paved trails; right-of-way or utility corridor shared by several utilities; or conversion to moderate-intensity agriculture (e.g., orchards, hay fields).
> LOW: Forestry (tree-cutting only), unpaved trails, utility corridor without a maintenance road and little or no vegetation management.

An alternative approach is to base the intensity categories on the proportion of vegetation cleared, impervious surface created, or other measurable features.

4.2.3 Data Gaps and Expanding the Knowledge Base

1. Significant uncertainty remains regarding the degree to which conclusions from studies of perennial streams can be extended to accurately describe many of the ecological relationships and processes in intermittent streams. It is unclear, for example, whether the abundance of many wildlife species is greater along SJC's intermittent streams than in uplands, or whether the supply of large wood in SJC's intermittent channels significantly limits fish populations.

2. Although most of SJC's streams are intermittent, the County lacks a comprehensively ground-truthed spatial data layer (map) that shows their locations accurately, particularly as regards their headwater points of origin. Creating such a map is as essential for water quality planning as for analysis of salmonid Habitat Conservation Areas. Observable geomorphic characteristics can be used to delimit headwater points of origin in many cases. Also, the size of a contributing area that results in channel formation or flow initiation needs to be computed for SJC streams, in the context of specific local geologic, topographic, land cover, road density, and climate factors that cause variation in this relationship.

3. Recent water quality studies of limited scope have identified potentially harmful levels of pollutants of human origin in SJC streams and nearshore areas. To adequately protect aquatic Habitat Conservation Areas, a monitoring program that is geographically and chemically comprehensive is needed to portray the true scope of this issue, identify pollutant sources, and initiate remedial actions. The Stormwater Utility and Marine Resources Committee is currently

developing a monitoring program which could, if adequately funded and staffed over the long term, provide such data.

4. Although Wild Fish Conservancy and other groups have discovered much about fish use of some SJC intermittent streams, funding should be provided to determine fish use of the remaining unsurveyed streams that have some potential to support fish, and to identify all natural or artificial barriers to fish passage.

5. More information is needed regarding minimum flows necessary in SJC streams during each month of the year to allow fish passage and support other aquatic life.

6. More information is needed regarding effects of non-native fish in SJC lakes and streams on native fish and amphibian populations. In the interim, effects should be assumed to be adverse based on studies elsewhere, and intentional stocking of ponds and lakes with bass, bluegill, and other non-native species should be strongly discouraged.

7. Despite the above data gaps and information needs, the County's efforts to protect aquatic Habitat Conservation Areas should not be put on hold until more information is available. State laws, the public trust, and popular concern for protecting natural resources from long-lasting harm dictate that both voluntary and regulatory efforts proceed with urgency using the best available science, whatever its current limitations.

4.2.4 Synopsis and Science-based Options

Synopsis

1. Buffers are not always the best way to protect the water quality of streams and other water bodies. Stopping stormwater and other pollution at its known or likely sources, especially before it reaches ditches and drainageways that connect to streams and wetlands, is often a better strategy.

2. The effectiveness of buffers for protecting water quality is attributable less to their vegetation's active role in filtering and taking up pollutants, than to the simple fact that well-configured buffers can passively exclude development – with its concomitant removal of vegetation, increase in impervious surfaces, erosion and compaction of soils, installation of drains and ditches, and introduction of new pollutants -- from areas where development impacts, due to on-site hydrologic factors, are most likely to be magnified (see Chapter 2, section 2.4.5). Research also shows that the effectiveness of riparian buffers for maintaining water quality is strongly influenced by the type of underlying soils and geologic formations. However, these are difficult to assess. Buffer width is nearly the only characteristic relevant to predicting water quality that can be measured objectively and at reasonable cost, and so has commonly become the basis for regulations.

3. The necessary width or distance to remove or retain pollutants depends partly on the *intensity and extent of a proposed development activity or land use*. The most intensive activities or uses require higher percent-removal rates in order to maintain quality of receiving waters. There are limits -- both technical and financial -- as to what improved engineering for

stormwater treatment can accomplish in SJC. Nonetheless, as detailed in Chapter 7, more could be done to improve the management and treatment of stormwater throughout the county in ways that will minimize changes to the water regimes of wetlands and streams and reduce the load of pollutants that reach wetlands. For stormwater treatment systems that are designed to increase the infiltration of runoff after it is treated, an appropriate setback will still be needed to allow that infiltration to occur.

4. The buffer width or distance also depends on whether the soluble pollutants commonly transported to streams and lakes are transported mainly via *subsurface seepage* (e.g., high water table), *sheet flow* (diffuse surface runoff), or channelized *surface runoff* (ditches, gullies, subsurface pipes). The latter require larger buffers. A determination of which transport route prevails at a particular location cannot legitimately be based only on county soil maps, topography, and one-time field observations; it requires an expensive geohydrological investigation at each location. Results would vary seasonally and sometimes even hourly as water tables rise after a storm and sheet flow channelizes for indeterminant periods. In lieu of requiring such investigations for each permit application, the County could assume that water quality buffers for streams and lakes be wider wherever slopes between the channel or lake and the proposed development activity are steep, or (b) the lake lacks a persistent surface water outlet and is thus more likely to accumulate pollutants to the detriment of its aquatic life. Together, these are termed *transport and sensitivity* factors. Depending on the terrain, soils, and local surficial geological formations, infiltration of stormwater can sometimes be increased by implementing particular LID (Low Impact Development, see Chapter 7) measures, thus potentially converting surface flow to less hazardous subsurface seepage. When that is feasible, consideration could be given to reducing a buffer width requirement provided riparian habitat functions are also adequately maintained and the LID measures do not require maintenance over the long term.

5. Under ideal conditions, buffers of only a few feet width can remove most coarse sediment that is carried towards a stream or lake by diffuse sheet flow. However, for the removal or retention of finer sediments as well as some *soluble* substances that can harm aquatic life, buffers of between 10 and 810 feet are generally necessary.

6. Depending on the terrain and local surficial geological formations, infiltration of stormwater can sometimes be increased by implementing particular LID (Low Impact Development, see Chapter 7) measures, thus potentially converting surface flow to less hazardous subsurface seepage. However, there are no data quantifying the amount of buffer reduction that could be allowed if LID or other mitigative measures were implemented to varying degrees.

8. Large loads of many soluble substances such as nitrate potentially threaten aquatic life in lakes, perennial streams, wetlands, and semi-confined marine waters. However, the impact of these substances on mobile aquatic organisms that temporarily inhabit *intermittent streams* is largely unknown. In such habitats, exposure is more likely to be brief than chronic, and may occur chiefly at times when flowing water dilutes some substances. Compared with the situation in perennial streams and lakes, in intermittent streams large growths of oxygen-depriving algae may be of less concern, and therefore the nutrients that trigger their growth may be of less concern, because surface water is mainly present during seasons when light, rather than soluble nutrients, limits the growth of such algae. Oxygen deficits that occur in

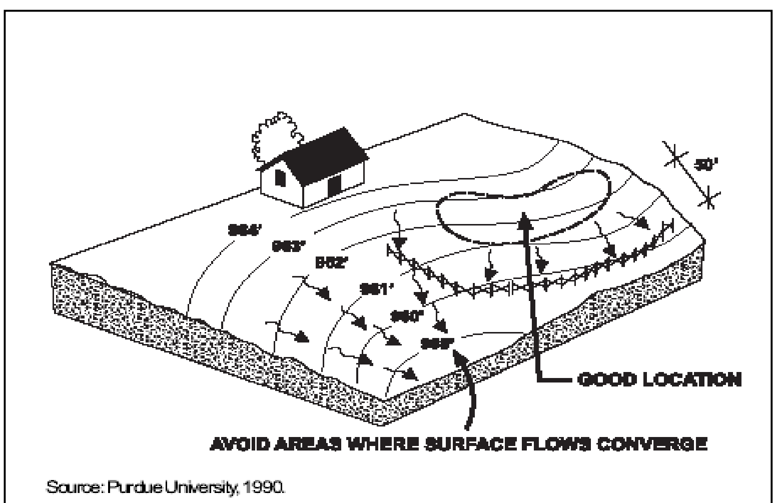
pools that persist seasonally in some intermittent streams may be due more to the decay of accumulated leaves and wood than to growths of algae triggered by excessive concentrations of soluble nutrients.

Options

Based on the Best Available Science, the County could do the following to protect the freshwater HCA's and their functions[23]:

1. For **fish habitat** protection, adopt the stream typing maps that have been prepared and ground-truthed by the Wild Fish Conservancy, as they are completed. For County-regulated development activities within streams shown on this map, landowners would need to request a permit from the County.

2. For assisting in the protection of **surface water quality**, adopt as well the countywide map titled "Possible Drainageways" (that was developed as part of this project using LiDAR imagery). This map has not been ground-truthed and the County does not intend to regulate activities in drainageways. Rather, this map is intended to alert landowners to parts of their property that often are most responsible for transporting possible pollutants, and to alert permit applicants and the County to areas where implementation of Low Impact Development (LID) practices would be most important. Buffers around lakes, streams, and wetlands could also be widened (perhaps with a "buffer width averaging" process) where mapped drainageways intersect those water bodies, once the existence and location of those drainageways on a parcel has been field-verified. Some of the areas shown on this map do not meet legal definitions for "streams" but are important nonetheless to the transport of pollutants into protected water bodies, as well as serving as corridors for amphibian movements.



Source: Purdue University, 1990.

3. Support [illegible]wide, as well as its integration with the drainageways map. Also support surveys of fish and fish habitat in all of SJC's intermittent streams that might be accessed by fish. Regularly monitor those streams where spawning salmonids have been reported, to verify anecdotal reports and determine the

[23] Note that because section 4.2.4 is a synopsis, literature supporting many of the statements in this section is generally not cited here, but rather in preceding parts of this HCA chapter.

persistence of salmonid populations as a basis for remedial action, especially if declining use is noted.

4. Continue to support the On-site Sewage System Operation and Maintenance Program with annual inspections of septic systems near sensitive marine waters, and if possible expand to also include annual inspections of systems closest to streams, lakes, and wetlands and those on soils least suitable for effective waste treatment. If necessary, consider requiring costlier septic systems with more advanced treatment capabilities for new home construction in the most sensitive areas, as well as implementation of Low Impact Development practices for maintaining stormwater quality.

5. Use buffers along streams as one tool to help keep pollutants out of these HCA's as well as marine waters. Rather than requiring the same width for all buffers, the County could require the application of simple, standardized decision rules to identify the scientifically appropriate buffer widths applicable to each stream, and apply these rules on a permit-by-permit basis. The rules would account for (a) the intensity of the proposed activity or land use, as well as the stream's (b) sensitivity as determined by adjoining slope and other factors, (c) the relative importance of the stream for salmonids, other aquatic life, and ecosystem processes. The widths of buffers to protect water quality of streams could be determined site-specifically using a standardized procedure.

6. The County could choose to apply the same buffer width criteria to lakes as to wetlands (as described in section 2.7).

7. An alternative approach to buffers might involve *adaptive management*, wherein larger buffers would be required only where monitoring indicated ground or surface water quality conditons are not in compliance with standards. There are several problems with such an approach. First, by the time a violation of standards is discovered, aquatic life may already have been harmed, perhaps irreversibly, and a new development that caused the problem cannot realistically be removed to make way for a buffer that is being widened in response. In particular, time lags of years are common between when a development occurs and when resulting pollution plumes reach groundwater and are discovered (Meals et al. 2010). Second, unless monitoring occurred in every stream and wetland and analyzed every potential pollutant at every season and storm event, there would be no assurance that aquatic life was not being harmed. Third, for the reasons detailed in section 4.2.2.1, even if no violations of water quality standards were found, this would not necessarily mean aquatic life was unharmed by development. Finally, protecting water quality is not the only reason buffers are necessary; they are also essential for maintaining habitat of many fish and wildlife species. Annual monitoring of the populations of all those species, as would be necessary under an adaptive management approach, would be an extremely costly endeavor, and it might be impossible to attribute population declines to development in a specific area, as opposed to pollution carried from afar, or climate change, predators, or other factors.

4.3 Review of Information: Terrestrial FWHCA Requiring Protection

4.3.1 Terrestrial Classifications

4.3.1.1 State Natural Area Preserves, Natural Resource Conservation Areas, and Wildlife Areas

Counties and communities must consider the manner in which activities they regulate might adversely impact the State Natural Area Preserves and Natural Resource Conservation Areas managed by the Washington State Department of Natural Resources, and the Wildlife Areas managed by the Washington State Department of Fish and Wildlife. These areas represent an investment of public funds to conserve habitat within specific areas that are often of outstanding importance to populations of animals and plants. Natural Area Preserves are intended to protect the best remaining examples of many ecological communities including rare plant and animal habitat. Natural Resource Conservation Areas are intended to represent unique or high quality undisturbed ecosystems and habitats for endangered, threatened and sensitive plants and animals, and scenic landscapes.

Biological resources within these areas are assumed to be generally more secure than on most private lands.

The following such areas are in San Juan County:

1. Point Doughty Natural Area Preserve: Located on the coast of Orcas Island, this 57-acre forested preserve protects a natural forest community dominated by Douglas-fir and ocean spray (a shrub), representing the "rain shadow" vegetation which occurs in the San Juan Islands.

2. Cattle Point Natural Resource Conservation Area: Located along the southeastern shore of San Juan Island, this 112-acre area includes freshwater wetlands, grasslands, gravelly beaches, dunes, mature conifer forest, and steep bluffs along waterfront on the Strait of Juan de Fuca and extending across Mount Finlayson to Griffin Bay.

There are no State Wildlife Areas in San Juan County.

Extensive additional areas of habitat are protected from severe impacts by being in public or conservation ownership, e.g., lands owned and managed by the National Park Service (San Juan National Historic Site), US Fish and Wildlife Service (San Juan Islands National Wildlife Refuge), Bureau of Land Management (see USDI BLM 2010), State Parks (Moran State Park and 14 others) and County Parks (e.g., Eastsound County Park). In addition, San Juan County is the only county in the state that has passed a real estate excise tax for purchasing and setting aside significant amounts of land for permanent protection from intensive development. As documented by island in Appendix 4F-1.10, the County's parks and Land Bank programs and the San Juan Preservation Trust have together protected 9% of SJC's area primarily for conservation, and an additional 10% of the county's area is owned by State, Federal, and private conservation groups.

4.3.1.2 Areas Important to Threatened, Endangered, or Sensitive Species

Both Federal and State agencies, through a public listing process, have designated particular species as Threatened, Endangered, or Sensitive. Under the GMA, cities and counties must adopt measures to protect habitat for populations of these species. Table 4-5 and Appendix 4-A indicate animal species that are currently listed as Threatened, Endangered, or Sensitive *and* which occur regularly in San Juan County.

Table 4-5. Species currently listed by Federal or State agencies as Endangered, Threatened or Sensitive and which occur regularly in San Juan County.

Group and Species:	**Status***	**General Habitat (breeding)**	**General Habitat (non-breeding)**
FISH:			
Chinook Salmon (Puget Sound)	FT	(not in SJC)	Marine
Chum Salmon (Summer)	FT	Streams	Marine
Steelhead	FT	(not in SJC)	Marine
Rockfish (Boccacio)	FE	Marine	Marine
Rockfish (Canary and Yelloweye)	FT	Marine	Marine
MAMMALS:			
Killer Whale (Southern Resident Orca)	FE, WE	Marine	Marine
Humpback Whale	FE, WE	(not in SJC)	Marine
Steller Sea Lion	FT, WT	(not in SJC)	Marine
Sea Otter	WE	(not in SJC)	Marine
Gray Whale	WS	(not in SJC)	
BIRDS:			
Marbled Murrelet	FT, WT	Mature Forest	Marine
Bald Eagle	WS	Large trees	all
Peregrine Falcon	WS	Cliffs	all
Common Loon	WS	(not in SJC)	Marine & large lakes
Brown Pelican	WS	(not in SJC)	Marine
INSECTS:			
Taylor's Checkerspot Butterfly	WE	Grassy Shorelines	Grassy Shorelines

* F= Federal listing, W= State listing; listed as E= Endangered, T= Threatened, S= sensitive. See also Appendix 4-A and 4-B.

Note that Common Loon (another species considered Sensitive, but only when breeding) has not nested in San Juan County since around 1948 (Lewis & Sharpe 1987; Cassidy & Grue 2006) and currently breeds at only one location in western Washington. Forage fish are a principal food. Significant numbers are present in SJC primarily during the fall, winter, and spring in marine waters. The species deserves the same habitat protections as dozens of other waterbird species, many of which are unlisted but are equally or more sensitive, e.g., Western Grebe, Brant, Greater Scaup.

Similarly, Brown Pelican is listed as Endangered at the State level. Small numbers regularly visit marine waters surrounding the islands during warmer seasons. However, the species does not breed here and is not known to be present in significant concentrations. Forage fish are a principal food.

4.3.1.2.1 Marbled Murrelet

Life History and Preferred Habitat: This seabird with federal Threatened status has the unusual habit (for seabirds) of nesting high in the canopy of mature evergreen forests (Burger 1995). Because of this, nesting is nearly impossible to confirm, generally requiring at least 20 visits by experienced biologists during at least 2 consecutive years. Hamer and Nelson (1995) described characteristics of 36 murrelet nest stands in the Pacific Northwest. Nest stands in the Pacific Northwest averaged 510 acres. The smallest was 7 acres and the largest was 2725 acres. Because it is difficult to locate murrelet nests, a 1.5-mile radius circle mapped from the point where murrelets were observed flying within the forest canopy or circling above the forest canopy (occupied behavior) is used to delineate occupied murrelet habitat in Washington (WAC 222-16-080 (j)). All suitable murrelet habitat located within a contiguous stand from the point of observation within the 1.5-mile radius circle is considered to be occupied habitat. Because murrelets require only a single tree with suitable nest platforms surrounded by other trees to provide some cover for nesting, suitable habitat that occurs in patches smaller than 7 acres in size could be occupied by murrelets.

Adults fly between the nest and sheltered marine waters to feed on small forage fish and tiny swimming marine invertebrates. Those are most abundant where marine waters have been enriched by nutrients or where ocean currents concentrate these foods.

Status, Threats, and Protection in San Juan County: No nests have been confirmed in the county, but nest survey efforts have been minimal. Nesting here is very likely, as suggested by presence of mature forest (though of limited extent) and observations of many adults and young along shorelines during the breeding season. Murrelets nesting on Vancouver Island make regular round trips of 120 miles to feed in the San Juans. Possibly suitable nesting habitat, as determined by the USDA Forest Service, is shown in Chapter 8.

Especially during winter, the highest densities in Washington are found in the San Juan Islands and adjoining Strait of Juan de Fuca. Areas of concentration are the south shore of Lopez Island and Obstruction and Peavine Passes between Orcas and Blakely Islands in the San Juan Islands (Seattle Audubon Society: http://www.birdweb.org).

One potential threat that might be reduced through regulation is the fragmentation of older forests by scattered homebuilding, roads, or other clearing. The creation of even small clearings in larger blocks of unfragmented forest, as a result of home construction or timber harvest, would be expected to facilitate the invasion of murrelet nest predators such as ravens and crows. Increases in those species can also be triggered by increased availability of food debris that accompanies human settlement. Nelson and Hamer (1995b) found that successful murrelet nests were significantly further from edge than unsuccessful nests, and cover directly around the nest was significantly greater at successful nests. However, Zharikov et al. (2007) commented that habitat fragmentation *per se* need not have a negative effect on this species beyond that as a result of habitat loss, unless associated with increased abundance of such predators, which is not inevitable. The adverse effects of large clearings might be reduced somewhat by maintaining “soft” edges, i.e., a gradual spatial transition from open field to young forest to mature forest (Malt & Lank 2009).

Another potential concern is the permitting of new docks (and thus boats) within about 160 ft of key foraging areas for this and other local seabird species (Chatwin 2010). Boat traffic that is concentrated by docks might, to a small degree, adversely affect feeding activities of this and other seabird species (Bellefleur et al. 2009), though the cumulative effect of that on breeding success and population stability is unknown. There already is heavy boat traffic (both ferries and private recreational boats) near potential feeding areas at certain times of year, and the incremental effect of any additional increase is unknown.

Regulations that prevent harm to the marine habitats (e.g., eelgrass) and local populations of forage fish and other marine organisms that depend on them will benefit murrelets, eagles, and many other species.

4.3.1.2.2 Bald Eagle

Life History and Preferred Habitat: Eagles forage over areas that encompass a wide variety of open habitats, covering up to about 5 square miles on a daily basis. They are particularly attracted to marine and lake shorelines where dead or live fish or waterfowl are present or where colonies of nesting seabirds are nearby. Eagles also feed on rabbits, other small mammals, and carrion in open country. They nest in tall (>85 ft) trees, whether isolated or in forests. They typically use the same nest sites from year to year, but sometimes change as the supply of the most desirable nest trees changes. Nests are most often within about 0.25 mile of marine or lake shorelines. Some eagles are resident while others do not breed locally.

Status, Threats, and Protection in San Juan County: Until recently this species was listed as Threatened, but was delisted federally while its Washington status was changed to Sensitive. It also receives special protection under WAC 232-12-292 and RCW 77.12.655. Despite the concern for this iconic species at the national and state levels, eagles are quite common throughout SJC and the County hosts one of the largest nesting concentrations of this common species in the lower 48 states, numbering at least 125 pairs, or about one-quarter of the nesting population in Washington. Locations of many nest sites are known but change periodically, thus causing maps of locations to quickly become outdated.

Many individual eagles grow accustomed to being near people as they forage along settled shorelines and farmlands. Nonetheless they usually are highly sensitive to human activities around nest sites, especially while incubating their eggs during late winter and early spring. For this reason the WDFW recommends avoiding disturbances at that time from loud machinery within ~800 feet of known nest sites. Other activities that might be disruptive within about 400 feet of communal roosts (regularly-used clusters of trees where eagles sleep) also should be avoided, especially where visually screening vegetation is sparse or absent (WDFW 2004). A study of one eagle nest in SJC found that noise produced by pile driving seemingly had little effect on eagle behavior beyond 1300 ft (Bottorff et al. 1987).

To maintain productivity of eagle populations, prey must be abundant and uncontaminated by pollutants (see section 4.2.2.1 Impacts of Stormwater, Septic Systems, and Water Diversions on Water **Quality and Quantity**). Stormwater pollution, shade removal, expansion of ditches, and other actions likely to adversely affect fish and waterfowl or their availability to eagles will ultimately affect productivity of eagle populations by affecting the quality and quantity of food items. Land management practices that reduce the long-term supply of tall trees and facilitate more foot traffic near nesting and roosting areas may also be harmful in the long run. At the same time, the creation of ponds attractive to waterfowl, and the stocking of these with fish, might expand some types of feeding opportunities.

In accordance with WAC 232-12-292 and RCW 77.12.655, whenever activities are proposed that alter habitat near a nest or communal roost, landowners or their consultants must prepare a WDFW-approved site management plan, or submit an existing generic one for approval. Requirements apply to (a) all subdivisions; (b) projects within 800 feet of a nest; and (c) to sites that are within 250 ft. of the shoreline and are within a half mile of a nest. Custom plans are required for subdivisions, for lots within 400 feet of a nest, and for projects that cannot meet the requirements of a generic plan.

4.3.1.2.3 Peregrine Falcon

Life History and Preferred Habitat: Like the preceding species, Peregrine Falcons feed over a wide variety of open habitats, covering several square miles on a daily basis, and are particularly attracted to marine and lake shorelines where waterfowl concentrate or nesting seabird colonies are present. Nest sites are most often located on ledges on large (>45 ft) cliffs within sight of lakes or the marine shoreline, and are used consistently from year to year.

Status, Threats, and Protection in San Juan County: At a state and national scale, this species has rebounded from a sharp decline in the mid-1900's which prompted its initial listing as Threatened. It was recently delisted federally and its Washington status was then changed to Sensitive. As nesting birds Peregrines returned to the San Juans in 1980/ At least 20 pair are now known to regularly nest in the county, probably the highest nesting concentration in Washington if not the entire Pacific Northwest (see http://www.frg.org/SJI_project.htm). In addition, during the fall and winter individuals from other regions commonly forage along the county shorelines. As is true for Bald Eagle, stormwater and other pollution sources potentially threaten its fertility and available foods, but no recent toxicological data specific to this raptor are available from SJC, and the high productivity of the local population suggests no major problems currently. Avoidance of foot traffic and construction activities near active nests during the springtime may increase nest success further.

4.3.1.2.4 Taylor's Checkerspot Butterfly

Life History and Preferred Habitat: This Endangered butterfly is a subspecies of Edith's checkerspot, a medium-sized butterfly. Preferred habitat is various types of unmowed grasslands and rocky outcrops (even some forested ones), especially those with a dominance of native grasses and located near shorelines. It is a relatively sedentary species which remains year-round and rarely disperses more than 2 miles. Host plants include harsh paintbrush (*Castilleja hispida*), and possibly golden paintbrush (*Castilleja laevisecta*), which has been found in only 3 locations in the county. Some populations in other parts of its range appear to be dependent on the non-native English plantain *(Plantago lanceolata)*, a weedy introduced species. Local populations of this butterfly are prone to large year to year fluctuations.

<u>Status and Threats in San Juan County</u>:
Known from only one location on private land; its current status there is unknown. The species could potentially occur in grasslands on San Juan Island (e.g., American Camp) and possibly Lopez Island, but has not been reliably documented. Use of specific locations can vary from year to year. Key host plants for this species could be threatened by some exotic plants (e.g., Scotch broom, blackberry), altered fire regimes (allowing grasslands to be invaded by rose, blackberry, Douglas-fir, and other woody species), and overgrazing by a proliferation of deer and rabbits. Adults and larvae are vulnerable to pesticides and changes in habitat size and connectivity (e.g., by planting trees in particular abandoned fields, replacing grasslands with developments). Direct threats to the butterfly include trampling, fire, inappropriately timed grazing and mowing, and in some cases tidal inundation.

4.3.1.3 Locally Significant Habitat Conservation Areas

As noted at the beginning of this chapter, counties and cities may designate, through a public process, habitats and species they consider to be "locally significant" and thus worthy of a level of protection that is somewhat greater than accorded other private lands. Many counties in Washington have done so. Until now San Juan County has not, but some local citizens have recently made a strong case for recognizing three important habitats, while not nominating any particular species. Those three have also been noted as **Priority Habitats** by Cassidy & Grue (2006) and are described below. It may not be necessary to subject all private lands containing these habitats to an extraordinary level of regulation. Perhaps only those containing some of the highest quality representatives of their type, as evaluated by professional field ecologists and considering multiple ecological factors, are in need of greater protection or management.

1. West Side Prairie. These are uncultivated areas, including some meadows and fallow fields, that are mostly treeless and ideally have a significant presence of native forbs (e.g., *Camas* spp.) and grasses (e.g., *Danthonia californica, Festuca rubra*). Most seasonally wet prairies also qualify as wetlands. The WDFW recognizes West Side Prairie as a Priority Habitat and has mapped some such areas in SJC, e.g., parts of Mount Constitution, the southern slopes of the Turtleback Range on Orcas Island, the west side of San Juan Island, Iceberg Point on Lopez Island, Yellow Island, and a few other locations. Information on their prevalence and locations in SJC is not comprehensive. In SJC they support many plant species that are rare or that grow in few other land cover types. Their plant communities generally are described by Dunwiddie et al. (2006). In most places their native plants have been replaced by non-natives, so the highest level of protection should be given to those prairies that retain the highest cover of native plants, especially native wildflowers and other forbs. Areas as small as 1000 square feet should be protected. Mowing, brief light grazing, or burns may help maintain the native forbs when such activities are conducted sporadically. Machinery and off-road vehicles can damage this habitat.

2. Oak Woodlands and Savannas. These are grasslands containing numerous Garry oak (Oregon white oak) trees, especially those with >50% cover of oak and at least 1 acre in extent. This habitat often grades into West Side Prairie and/or Herbaceous Balds and Bluffs. In SJC this habitat supports several plant species that are rare or that grow in few other land cover types, as well as rare butterflies such as the Duskywing (*Erynnis propertius*). Mast from the oaks provides a key food for gray squirrels, many birds, and other wildlife. The WDFW recognizes "Oregon white oak" as a Priority Habitat and has mapped some such areas at, for example, English Camp, Point Disney, Turtleback Mountain, Cady Mountain, West Sound, and patches in the east, south and west edges of the San Juan Valley and west side of San Juan Island. A naturalist who explored the valley in 1859 found Garry oaks in the False Bay watershed extending for a square mile between the ridge and the wetland soils that comprised the southern two-thirds of the valley (Barsh 2010). See Larsen & Morgan 1998, Murphy & Barsh 2006 for management information. Consideration should be given to broadening the definition to include not only oak, but young stands of **other broadleaf shrubs and trees** (e.g., maple, alder, willow). Some of the Pacific Northwest's most eminent ornithologists (Betts et al. 2010) have noted that the bird species that are strongly associated with that habitat type are showing more declines in the Pacific Northwest than are birds typically associated with mature and old growth forests, for example.

3. Herbaceous Balds and Bluffs. These are native plant areas with few or no trees, with sparse herbaceous vegetation growing on steep exposed slopes, not usually bordering the shoreline. In SJC this habitat supports many plant species that are rare or that grow in few other land cover types. Most sites encompass fewer than 12 acres. They are a preferred habitat of the Taylor's Checkerspot butterfly, a species officially listed as Threatened. In SJC they also have been the subject of several botanical studies, including those of Rapp (1981), Salstrom (1989), Rust (1992) and Peterson & Hammer (2001). Their plant communities are generally described by Chappell (2006) and factors related to their conservation in the Gulf Islands are described by Sadler & Bradfield (2010). The WDFW also recognizes cliffs, caves, and talus as Priority Habitats; they often co-occur with herbaceous balds and bluffs.

Distributions of these habitats in San Juan County have been mapped approximately, but the maps have not been ground-truthed and no comprehensive survey of these habitats on private lands has been conducted.

All three of these habitats are relatively rare at this latitude, and their area regionally has diminished dramatically in the past century. Avoiding or minimizing impacts to these habitats now will lessen the likelihood of their component species being legally listed as Threatened or Endangered in the future. In some places these habitats could be threatened by future construction of homes and roads, as well as by natural vegetational succession (which may have historically and beneficially reduced the extent of tree canopy, but tree canopy is no longer removed as often by fires), by invasion of exotic plants (e.g., Scotch broom), and by conversion of abandoned fields to lawns or gardens. Potentially, the quality of these habitats could be impacted by off-road vehicle use, road construction, powerlines, and trampling of vegetation by people and domestic animals.

Other SJC habitats that WDFW has stated are Priority Habitats in SJC are Cliffs, Caves, Talus, Old Growth and Mature Forest, and Snags and Logs. An estimated 12 caves are present in the county (T. Domico, pers. comm.). In addition, Freshwater Wetlands, Riparian (Streamside) Habitat, and Instream Habitat are listed as Priority Habitats, but are discussed in other chapters or sections. Locations that meet definitions of Old Growth and Mature Forest have not been mapped in SJC. Such areas would most likely exist within existing public preserves. Snags and Logs are omnipresent throughout the county and no particular areas are known to deserve elevated attention. Cliffs, caves, and talus often occur together and in association with

Herbaceous Balds and Bluffs. Cliffs in SJC were mapped by this study based on LiDAR topographic imagery. In the interior parts of the islands, several species of bats and reptiles depend highly on cliffs and/or caves, as do some rare plants. Due to the sensitivity of many of these species to human disturbance, trails should not be routed near cave entrances or cliffs. Protection of cliffs near the marine shoreline falls partly under the Shoreline Management Act.

4.3.1.4 Other Species

The WDFW maintains a list of "Priority Species and Habitats." That list includes all the legally-designated Threatened and Endangered species described in section 4.3.1.2 Areas Important to Threatened, Endangered, or Sensitive Species). It also includes species with no extraordinary legal protection but which are considered to deserve some level of elevated conservation or management due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance in Washington State. And it also includes Priority Habitats with unique or significant value to a diverse assemblage of species. A priority habitat may consist of a unique vegetation type, dominant plant species, a successional stage, or a specific habitat feature.

Although comprising only about 17% of Washington's entire list of vertebrates (and 42% of those in SJC), the 113 WDFW-designated **Priority Species** that occur in SJC contribute disproportionately to regional biodiversity. The list for SJC (Appendix 4-A) contains 44% of the county's birds, 46% of the mammals, 14% of the amphibians, and 17% of the reptiles in SJC. The list contains a disproportionately high number of waterfowl, shorebird, and seabird species, only a single amphibian, and no songbirds. WDFW has published management recommendations for some of these species (e.g., Larsen et al. 2004). Avoiding or minimizing impacts to these species and their habitats now will lessen the likelihood that these and other species associated with similar habitats will need to be legally listed as Threatened or Endangered in the future, with increased restrictions on what landowners may do.

<u>Wildlife</u>
WDFW's Priority Species found in SJC are indicated in Appendix 4-A, and their habitats are noted in Appendix 4-B.

Also, the WDFW (2009) has rated the relative sensitivity to development of all wildlife species in Washington. Confirmed or probable breeding species in SJC which WDFW has classified as being the most sensitive to development are:

> Chipping Sparrow, Golden Eagle, Hermit Thrush, Long-eared Owl, Merlin, Olive-sided Flycatcher, Pileated Woodpecker, Short-eared Owl, Sooty (Blue) Grouse, Townsend's Warbler, Turkey Vulture, Vaux's Swift, and Western Toad.

Separately, two wildlife biologists at the University of Washington (Cassidy & Grue 2006) analyzed wildlife information statewide for the purpose of recommending additional species in each county that might not meet WDFW criteria for Priority Species status, but which local governments and landowners might wish to take additional steps to protect due to their sensitivity to development and important contribution to regional biodiversity. They recommended that heightened local conservation attention be given to the needs of the following SJC species not currently listed by WDFW as Priority Species:

Birds: Cooper's Hawk, Golden Eagle, Sandhill Crane, Barn Owl, Western Screech-owl, Short-eared Owl, Northern Saw-whet Owl, Common Nighthawk, Vaux's Swift, Rufous Hummingbird, Red-breasted Sapsucker, Hairy Woodpecker, Olive-sided Flycatcher, Willow Flycatcher, Purple Martin, Tree Swallow, Brown Creeper, Swainson's Thrush, Varied Thrush, Yellow Warbler, Chipping Sparrow, Vesper Sparrow, Western Meadowlark, Red Crossbill
Amphibians: Long-toed Salamander
Mammals: River Otter, Silver-haired Bat

A review of all the above lists, as well as information in Lewis & Atkinson (1987), Jensen (2010) and other local sources, indicates that breeding locations of several species from these lists warrant heightened local attention due to one or more of the following:

(a) small local breeding population or infrequent recent sightings during breeding periods suggest they are likely to be in near-term (5-50 years) danger of disappearing as breeders from one or more of the islands in SJC, if they are not already gone;
(b) apparently declining breeding population on the mainland or on at least one of the main islands in the region, combined with a relatively small population throughout their continental or Puget Sound range;
(c) potentially slow recolonization rates due to strong aversion to crossing marine waters;
(d) particular aversion to breeding near residential and other developed areas, or
(e) rapid changes now occurring or anticipated to soon occur in much of their preferred local habitats.

These species are:

Sharp-tailed Snake (a, b, c)
Western Fence Lizard (a, c)
Northwestern Salamander (a)
Black Oystercatcher (b)
Wilson's Snipe (b)
Short-eared Owl (a, b, d)
Sooty (Blue) Grouse (a, b, c, d)
Common Nighthawk (b, e)
Western Bluebird (a, b, e)
Chipping Sparrow (b)
Vesper Sparrow (a, b, e)
Fox Sparrow (a)
Golden-crowned Sparrow (a)

Additionally, there have been reports of the following species in SJC during the breeding season, but breeding has not been confirmed in recent years, either because many potential breeding sites were on inaccessible private lands, or because the species has disappeared locally:

Western Toad (a, b, c), Western Pond Turtle (a, b, c, d, e), Rubber Boa (a, c), Northern Goshawk (a, b), Golden Eagle (a, b, d), Merlin (a), American Dipper (a, b, e), Long-eared Owl (a, c), Northern Pygmy-owl (a, c), Northern Harrier (a, b), Red-breasted Sapsucker (a), Hammond's Flycatcher (a), Horned Lark (a, b, e), Western Meadowlark (a, b, e).

If, in the future, any of these are confirmed to breed successfully and repeatedly in SJC, they and their habitat should be protected or managed as necessary to maintain species presence. Information on gross habitat preferences and general locations of all the above is given in Appendix 4-B. Also, trends in marine birds that don't breed locally but spend much of the winter in SJC should be evaluated, as studies elsewhere in the region have pointed to major declines in Western Grebe, Brant, and Greater Scaup (Anderson et al. 2009).

Consideration of species of local significance – not just habitats of local significance and species that are important at a state or national scale – is suggested by the decision Clark County Natural Resource Council et al. v. Clark County et al. (WWGMHB #96-2-0017 FDO 12-6-96) which stated, "The failure of the County to also include **species of local** importance results in noncompliance with the [Growth Management] Act." For some of these species, protecting specific locations where they are or were found is no guarantee that populations will be conserved or recover, because individuals may shift the local breeding locations from year to year. However, locations that receive consistent use over many years deserve attention. Also, Washington law (365-190-080(5) WAC) states that jurisdictions must work cooperatively to ensure that isolated subpopulations of a species are not created. Many such subpopulations exist in nature, especially in island environments where they are particularly vulnerable to adverse effects of further fragmentation.

The status and distribution of potentially thousands of ground beetles, freshwater mollusks, snails, and other invertebrate species has been little-studied in SJC. For example, little is known about status, trends, habitat needs, and vulnerabilities of the specific insects responsible for pollinating gardens, crops, and native vegetation in SJC. Some of these insects may not adapt to the replacement of native vegetation with non-native plant species, and are highly sensitive to fragmentation of some types of land cover (Aguilar et al. 2006). Some information on SJC butterflies and moths is documented in Hinchliff (1996) and in some local sources. Those with status as WDFW (2008) Priority Species include Island Marble, Great Arctic, Valley Silverspot, and Sand Verbena Moth. Additionally, very little is known about the status, distribution, and specific habitat needs of most of the small mammals and bats that would be expected to occur in SJC.

Plants

In addition to plant species recognized as Threatened or Endangered (Appendix 4-C), high-quality examples of several plant communities (Appendix 4-D) appear to be so limited in SJC that they may deserve consideration at least locally for heightened protection or management. This also is true of most of the dozens of species of native forbs and grasses that are described as "rare" in SJC by Atkinson & Sharpe (1993), as well as native species that have been documented only once in the county according to the online *Floristic Atlas of the San Juans* and from Dr. David Giblin's recent surveys of the smaller islands. Local botanists should be consulted. As well, several species of mosses, lichens, and fungi should be considered, although their distribution countywide has not been well documented. Mosses and lichens, where they were studied in neighboring coastal British Columbia (Coxson & Stevenson 2007, Sadler & Bradfield 2010), were found to be both functionally important and highly sensitive (Berglund et al. 2009). They are sensitive, for example, to the carving out of clearings amid blocks of forest, e.g., by single-family home construction, driveways, timber harvests. Their sensitivity is in response to changes to microclimate (temperature, moisture) and host vegetation initiated by forest thinning or clearing. See also the synopsis of literature in section 4.3.2.1 Impacts of Upland Vegetation Removal, Alteration, and Habitat Fragmentation).

4.3.1.5 Biodiversity Areas and Corridors

When classifying and designating FWHCAs, jurisdictions are required by WAC 365-190-130 to consider "Creating a system of fish and wildlife habitat with connections between larger habitat blocks and open spaces, integrating with open space corridor planning where appropriate." In addition, the WDFW (2008) recognizes "Biodiversity Areas and Corridors" as a Priority Habitat and suggests jurisdictions consider using systematic approaches for identifying and protecting them. Additional guidance (CTED, WDOE) recommends that counties and cities not limit their protection of habitat to specific habitat types, but also identify and protect the connections between patches of important habitat ("connectivity"). Connectivity is important to maintaining the diversity of native plants and animals because reconnecting habitat patches amplifies biodiversity conservation both within and beyond areas already set aside as natural preserves (e.g., Damschen et al. 2006).

Corridors and large blocks of suitable habitat are important not only to some of the species already discussed in section 4.3.1.2 Areas Important to Threatened, Endangered, or Sensitive Species), but also as a safety net for maintaining the thousands of species whose local status, distribution, and specific needs were judged by WDFW to be too poorly understood to justify their listing as Endangered, Threatened, or Sensitive and to receive the additional protections incumbent therein. Many of those species are unlikely to survive if the only areas protected from development are those in public ownership or which local jurisdictions designate as Locally Significant (e.g., prairies, oak woodlands, herbaceous balds) for other reasons. Many of these poorly-known or common species, which together comprise "biodiversity," cannot survive without species-focused efforts at a countywide or islandwide scale to identify areas in which they are likely to feed, reproduce, and travel. The problem in identifying which such areas are most important to wildlife in general is that *there is no such thing as "generally good" habitat characteristics*. Landscapes that are too fragmented for one species are ideal for another. Habitat patches that are too small or narrow for one species are optimal for others. "Corridors" and "landscape connectivity" that facilitate movements of some species often facilitates movements of their predators or competitors as well (e.g., Rogers 1997, Novotny 2003, Hilty & Merenlender 2004, Sinclair et al. 2005). And planning for the specialized and sometimes-conflicting needs of each of the 264-plus wildlife species that occur regularly in the county – not to mention the needs of thousands of invertebrates and plants – quickly becomes an overwhelming task.

In response, one strategy is to protect areas that science suggests will support *the most* species. Such areas are often those along the edges where multiple habitat types converge (i.e., not large blocks of homogeneous vegetation), vegetation structure is often more complex, and downed wood and snags are more abundant and will continue to be so (e.g., Harper & MacDonald 2001). However, not all species can be considered equal. Many "edge" species are adaptable generalists that will survive under a wide variety of conditions. Simply maintaining a large variety of species in one's yard, property, or other localized area (termed "alpha diversity") does not ensure that a full suite of species will be maintained at an island or county scale (termed "gamma diversity"). In some cases, it may be better to maintain conditions supporting fewer species on one particular parcel, if those few species that are maintained contribute more to overall island or county biodiversity by virtue of their occurring at few other locations.

Similarly, simply maintaining patches of each priority habitat type – while being a relatively promising way of protecting some of the most imperiled species – will not protect all or even most of the rare or sensitive species. As can be seen in Appendix 4-B in SJC, the habitat type hosting the most wildlife species is "Herbaceous Wetlands, Ponds, and Lakes" followed by "Wooded Wetlands & Streams," "Residential," and "Oak Woods & Balds" while the habitats hosting the fewest are "Open Marine Waters" and "Rocky Shore." If one focuses just on WDFW Priority Species, the richest habitat is again "Herbaceous Wetlands, Ponds, and Lakes" but is followed by "Sheltered Marine Waters" and "Beaches & Tidal Flats." However, many species do not prefer any of these habitat types. Also note that a ranking of these habitat types based on plants, invertebrates, fish, or other taxa might differ from a ranking based only on wildlife richness. Moreover, these habitat types are seldom homogeneous, and within each there are areas of greater and lesser quality that have significantly greater or fewer numbers of species, due to habitat features present only at a finer or broader scale. This internal heterogeneity was quantified by our LiDAR analysis.

Another strategy is to focus on maintaining areas important to the species which are least able to breed successfully around buildings and roads and the edges they create. To some degree, this can be achieved by assigning highest levels of protection to lands farthest from these features, and perhaps connecting those lands with blocks of natural vegetation not bisected by roads or driveways. Many (but not all) of the species that are rare and contribute the most to gamma diversity are ones that are most productive in secluded areas.

A third strategy, also compatible with the other two, is to assign highest priority to habitats of species which disperse the slowest over marine waters. Those are relatively sedentary species least likely to recolonize if anything should happen that eliminates their populations on one or more islands, and which (unlike most plants) do not become reestablished easily after being reintroduced to an area.

A fourth strategy would involve actually conducting a countywide or islandwide all-species biological inventory, building upon species data already collected by Kwiaht and others, and from those data identifying areas having the most species, or the most species that are rare, sensitive, sedentary, or whatever. However, many private landowners would not allow access for species surveys, unfortunately making this option infeasible in any comprehensive sense. Concentration areas and other key habitats of some species also change frequently over time.

At least two systematic attempts have been made to incorporate some of the above ideas into countywide analyses of biodiversity areas and corridors, addressing more that just those lands already in public reserves or conservation easements or receiving some degree of protection as wetlands, oak woodlands, or other locally significant habitats. One attempt, called a "Local Habitat Assessment," was made by Jacobson (2008) on behalf of the WDFW. The other was conducted as part of analyses needed to support this chapter.

Without considering the vertical habitat structure or needs of individual species, the WDFW approach assumed that the most important habitat areas were simply those with the lowest intensities of land use (70% of the weighting) and with low road densities (30% of the weighting). This resulted in a draft "landscape biodiversity map" which rated each 98 ft by 98 ft cell across the entire county. One of its many limitations is that land use intensity scores were based on a small number of broad land use categories that had been determined from interpretation of aerial images from the 1990's, and have since been shown by our LiDAR analysis to be vast oversimplifications. Several other limitations are described by the author (Jacobson 2008).

The other attempt, conducted as part of developing this FWHCA chapter, did not result in a new map of important biodiversity areas and their corridors. Rather, it has provided spatial data layers (maps) that could quickly be assembled in various ways for that purpose, along with other map themes. Habitat structure in each 30 ft by 30 ft cell in SJC is described in terms of average and maximum vegetation height, as well as height variation. Also, from our LiDAR analysis, statistics on the contiguity of the landscape with regard to tree or shrub canopy across each island have been compiled for this project. Thus, these spatial data layers describe the vertical vegetation structure and horizontal habitat connectivity in every vegetation height class within each cell. This can be interpreted to identify areas likely to support the most species, or to support particular species whose vegetation height and patch size preferences are known. This information was the result of a state-of-the art computer analysis of the most current (2008) LiDAR aerial imagery, a new high-resolution systematic approach for quantifying habitat structure that is rapidly gaining in popularity among wildlife biologists (e.g., Genc et al. 2004, Seavy et al. 2009, Goetz et al. 2010).

4.3.2 Potential Impacts to Upland Habitats and Species

4.3.2.1 Impacts of Upland Vegetation Removal, Alteration, and Habitat Fragmentation

<u>Overview</u>

Vegetation is essential for meeting the food, shelter, and other habitat needs of most upland and wetland animals that occur in SJC. Vegetation is removed permanently whenever buildings, roads, or driveways are built, and this diminishes wildlife habitat permanently or for long periods.

Habitat suitability for a given species is determined largely by the type of plants that together comprise "vegetation" (e.g., species of grass, forb, shrub, tree; evergreen vs. deciduous, native vs. non-native), their structure (e.g., height, age class) and their arrangement relative to other plants of the same or different type and structure. These largely determine which particular wildlife species will be present and persist at various spatial scales. Context is important: the spatial scales important to a given species can be local (less than a few acres), "landscape" (many acres or square miles), or regional (larger areas). And the arrangement of vegetation, especially at a landscape scale, is often defined in terms of:

- Matrix: the prevailing vegetation type or land cover.
- Patch: a mostly nonlinear area that is less prevalent than, and different from, the matrix.

• Corridor: a special type of patch that links other patches in the matrix. Typically, a corridor is somewhat linear or elongated in shape, such as a stream corridor.
• Mosaic: a collection of patches, none of which is prevalent enough to connect with others of its type throughout the landscape.

"Habitat" for a species can exist within any or all of the above. When, through either natural processes or human actions, a species' preferred habitat becomes less prevalent within a landscape (i.e., switching from a matrix to a patch, corridor, or mosaic), this is termed habitat **fragmentation**, and is described in terms of the sizes of the remaining habitat patches, the distances between them, and the character of the new land cover matrix. Protection of wooded corridors facilitates movements of many forest species across openlands that separate large blocks of forest. To sustain most forest-dwelling species, driveways and other linear clearings should cause no gap in the forest canopy wider than about 100 feet (Belisle & Desrochers 2002, Tremblay & St. Clair 2010). Ideally, no clearing should result in a forest being fragmented into an isolate smaller than about 100 acres or narrower than 150 feet, and definitely not smaller than 2 acres or narrower than 100 feet (Donnelly & Marzluff 2004).

Habitat fragmentation and its effects must always be defined in terms of particular species and regions, because what comprises fragmentation for one species often comprises improved habitat for another, because different species have different needs. Although the removal of small areas of tree canopy and substitution with roads, buildings, and lawns fragments the habitat for tree-nesting songbirds and will cause them to disappear locally at some point, at the same time it creates habitat for songbirds that characteristically nest only around open areas. Creating or maintaining wooded corridors can potentially fragment the landscape for species such as Northern Harrier and Western Meadowlark that depend on large well-connected patches of open grassland distant from tall trees. Thus, decisions about where to maintain wooded corridors must consider all indigenous species, not just forest-dependent ones.

Within most landscapes, creation of moderate amounts of "edge" between tall and short patches of vegetation supports the largest number of species of both plants (McKinney 2008) and animals. Although this diversity of species confined within a relatively small area is appealing to many people, it does not necessarily promote the conservation of many species that can't tolerate the fragmentation of their habitat that results from creating edges. In developing landscapes, species that require large nearly uninterrupted (or well-connected) patches of vegetation of a particular type – whether that be forest, grassland, or something else – are often the species that are rarest and threatened with extirpation (total disappearance from an entire county or region). If the policy goal is to maintain nearly all species indigenous to a landscape or region, then needs of those habitat area-sensitive species must come first, and emphasis placed on conserving large blocks of well-connected habitat having the types of internal features they need.

Many species also respond to particular features occurring at a finer scale within vegetation patches and the landscape generally. For example, large numbers of wildlife species require (or at least benefit from) downed wood and standing deadwood (snags). Downed wood is often the result of natural windthrow, which also creates small patches of semi-open canopy within blocks of forest and in so doing can support a larger number of wildlife species, despite the temporary loss of nest trees (Zmihorski 2010). Unfortunately, the needs of wildlife for an abundance and diversity of standing and downed wood run counter to human desires to keep yards manicured and "clean," both for aesthetic perceptions and to reduce hazards to people and property from fires and treefall. Other fine-scale elements that provide habitat for relatively large numbers of species within relatively small areas include but aren't limited to cliffs, caves, animal burrows and dens, nectar plants, tall perching trees, seeps and springs, mast (acorns), unusual soil types, dry sandy plains, mountaintops, and cool moist shady areas.

Vegetation Dynamics and Habitat

Regulations to protect wildlife habitat should recognize that even without the direct actions of humans, landscapes are not static. Fires, windstorms, drought, and other natural phenomena periodically re-set the natural succession of vegetation, especially along shorelines and on steep slopes where storm damage occurs most easily and recovery, if it occurs at all, is slowest. There are many species whose persistence depends on particular types of vegetation disturbance (not necessarily the types of disturbance associated with houses and roads), so protection of large unfragmented blocks of habitat must be balanced against the needs of those species as well. Indeed, many of the rarer species in SJC are ones associated with "disturbance-dependent" habitats, such as prairies, cliffs, and balds (see 4.3.1.3 Locally Significant Habitat Conservation Areas). Changes in the type, structure, arrangement, and extent of vegetation will occur periodically with or without direct intervention by people. No statistics have been compiled in SJC regarding long term trends in forest or openland patch sizes and proximities, road density, corridor connectivity, and other indicators of habitat fragmentation, but doing so would not be difficult and could provide a stronger basis for making decisions about building permits in various places throughout the county.

By creating disturbances that may or may not adequately mimic natural ones, human actions can accelerate habitat changes. For example, beavers have been intentionally eliminated from most parts of the county, and historically they were a key factor in sustaining wetlands and perhaps summertime stream flows. Logging practices and fires wrought massive destruction of old-growth forests and probably resulted in severe sedimentation of streams and bays in parts of the county in the 1800s and early 1900s. Vegetation and cleaner waters have mostly returned, but superficial appearances may fail to reveal the likely disappearance from the county of dozens of species .

Resilience appears high in formerly farmed lands that have been abandoned, as they are naturally replaced by shrubland and forest. Partly as a result, a small number of species has increased. Especially noticeable are increases in populations of species like deer, rabbits, and raccoons that adapt readily to human presence and are most productive in semi-open landscapes (Chamberlain et al. 2007). Since the elimination of large predators (other than humans) from the county during early settlement, populations of deer and European rabbits have prospered and have reduced the biomass and often the diversity of native forbs -- and consequently the butterflies, other insects, and birds that depend on them (Bassett-Touchell 2008, Martin et al. 2010). However, evidence from elsewhere suggests that rabbit warrens might provide beneficial microhabitats to some other wildlife (Gálvez Bravo & Belliure 2009). Damages to native ecosystems from abnormally high deer density have been documented in the San Juans (Martin et al. 2010) and on an island in British Columbia (Allombert et al. 2005). Such damage to shrubs and ground cover occurs in places where fragmentation of forests by scattered residential development or agriculture has created deer densities of more than about

1 per 25 acres (Thiemann et al. 2009, Martin et al. 2010). Overbrowsing of native shrubs often facilitates invasion by non-native shrubs such as Himalayan blackberry. Many of the non-native plants are less palatable to most wildlife. Reduced ground cover also means there may be less vegetation capable of taking up and processing polluted runoff, and greater potential for erosion and rapid runoff.

With increasing numbers of people and vehicles, an increasing number of non-native plants and animals also have incidentally "hitchhiked" or been intentionally introduced into one of more of the islands, to the point where non-native plants now comprise about one-third of the county's plant species. Removal of the forest canopy, creation of habitat edges around homes, and increasing vehicle and foot traffic have probably facilitated this increase (Parendes & Jones 2000), especially within 50 ft of the created edges (Watkins et al. 2003). Some of the new plants are aggressive invaders that eliminate manyfold more native species (Perkins & Willson 2005, Magee et al. 2008). Non-native plants are typically the first to respond to the disturbed conditions caused by home and road construction, and those disturbances are often ones that simultaneously constrain other important ecosystem functions. Non-natives also tend to have broad environmental tolerances, so areas dominated by them frequently are more resistant to further change (Werner et al. 2002, Wigand 2003, Stohlgren et al. 2002), which has both benefits and costs in terms of wildlife habitat. Non-native plants may also affect wildlife habitat, pollination, and other ecosystem functions (see section 4.3.2.1). For example, research from Oregon suggests that one of the most common invasive species in SJC – Himalayan blackberry – uses far more water than the closely related salmonberry (Caplan & Yeakley 2010).

A study in Alberta found that non-native plants within forests there were most abundant between 15 and 50 ft from the edge, and some of those species were found up to 130 ft from the edge. Although larger patches of forest generally supported more non-natives species than smaller fragments, the smallest fragments had the greatest number of non-native species per square meter (Gignac & Dale 2007). Wooded buffers with dense vegetation tend to restrict wind-driven dispersal of seeds of non-native plants into the area protected by a buffer (Cadenzas & Pickett 2001). However, wider riparian buffers in North Carolina were no less prone to invasion by non-native plants than narrow buffers (Vidra & Shear 2008), perhaps emphasizing the importance of considering individual species traits rather than relying on general paradigms.

As the area of a patch of natural habitat increases within a landscape, so does the diversity of plant species. A leveling off of the plant species-area accumulation curve in Alberta forests appeared at a forest patch size of about 27 acres (Gignac & Dale 2007), while on Prince Edward Island in eastern Canada, the small mammal species accumulation curve appeared to level off at a forest patch size of about 22 acres (Silva et al. 2005). Blocks of forest smaller than about 9 acres may be less capable of supporting the expected array of mosses in British Columbia (Baldwin & Bradfield 2007), although a study in Washington found that forest patches as small as 2.5 acres, if not narrow, may be large enough to have a microclimate supportive of most plants and animals (Heithecker & Halperin 2007). In Wisconsin forests that were studied over a 55-year period, larger patches of forest and those with more surrounding forest cover lost fewer plant species and were more likely to be colonized by new native species than smaller forests in more fragmented landscapes. Nearby urbanization further reduced the diversity of plants in the forest understory, and plant community composition was better explained by the amount of surrounding forest than by environmental factors within the studied forests (Rogers et al. 2009). In Ontario, forested wetlands with the most plant species were those with the largest areas and the largest proportion of upland forest within ~ 800 ft of the wetlands (Houlahan et al. 2006).

In agricultural landscapes, maintaining hedgerows of natural vegetation helps sustain populations of many species. In Quebec, wider hedgerows and those with more intact forest nearby had greater abundance and diversity of native forest-dwelling plant species (Roy & de Blois 2008). On Prince Edward Island, the abundance of most small mammals was greater in hedgerows longer than about 750 ft, but was unrelated to a hedgerow's length when the hedgerow was shorter. Most small mammals needed hedgerows with diverse shrubs, ground cover with vines and much leaf litter, and few non-vegetated gaps (Silva & Prince 2008).

Snags, Blowdowns, and Downed Wood as Habitat

As noted above, there often is a greater concentration of downed wood and snags in areas closer to streams and other topographic depressions. This may be true especially if wooded buffers are narrower than ~ 50 ft and thus more prone to wind damage (Lopez et al. 2006, Martin et al. 2007, Anderson & Meleason 2009). Along a lakeshore, the amounts of downed wood were greater from the lake edge up to at least 130 ft into the lakeside forest (Harper & MacDonald 2001). A study in Oregon found that the amount of downed wood in riparian buffers was unaffected by thinning operations in the adjoining upland forest unless the buffer was narrower than about 50 ft (Anderson & Meleason 2009). The amount of downed wood also depends on orientation of the cleared edge relative to wind, edge contrast (size differential of vegetation), the size of nearby clearings, tree species and age distribution, and local topography (Laurance & Curran 2008). Most instream wood originates in the parts of the riparian areas that are within 100 ft of a stream (McDade et al. 1990, Van Sickle & Gregory 1990, Robison & Beschta 1990, Meleason et al. 2003).

Where minimizing the loss of timber due to blowdown is a concern, a wooded buffer of 75 ft width may be adequate according to a literature review by Pollock and Kennard (1998). In California, researchers found that 100-ft buffers were inadequate to protect trees from windthrow (Reid & Hilton 1998). Tree fall rates were abnormally high for a distance of at least 656 ft from clearcut edges. Within riparian buffers that adjoined clear-cuts in Washington, tree fall rates were 26 times higher than normal for 3 years after logging, and may have caused the eventual replacement of coniferous trees with deciduous hardwoods. Trees tended to fall towards channels regardless of the channel orientation relative to the wind (Liquori 2006). It has not been proven that the deciduous vegetation that typically grows back after riparian trees are blown down (and persists for several years or decades) is less effective for purifying runoff. Such vegetation may, however, provide less shade and load the stream with more organic matter and nutrients if conifers were the vegetation being replaced (Roberts & Bilby 2009).

Microclimate and Habitat

Microclimate is a term that includes the humidity, soil moisture, and temperature within zones of between a few square feet and several acres in size. Microclimate is particularly important to the survival of amphibians, insects, and plant species. Microclimate within closed-canopy forests is the result of vegetation buffering of wind and direct sunlight. Microclimate can be altered by clearings created for home construction or roads, as well as by timber thinning, natural phenomena (blowdowns, landslides, streams), and overgrazing of shrub and understory vegetation by deer and domestic animals. Much of the forested land in SJC is near the ocean, and the associated humidifying effect might help counter the drying effect of a diminished ground cover and of clearings created in forested areas – at least as compared with similar clearings in forests in non-coastal areas. This has not been tested. Overgrazing is rampant in localized areas within SJC, and sometimes is greatest near streams. Requiring wider buffers for protecting the microclimate of streams and wetlands could be less effective unless excessive browsing of understory vegetation is first controlled. Streams and wetlands could be fenced where risk of overbrowsing by livestock is greatest.

Microclimate is influenced not only by the density, height, type, and configuration of vegetation (Wuyts et al. 2008), but also by elevation, wind exposure, aspect (solar exposure), proximity to surface waters (particularly marine waters), and distance from impervious surfaces. In some instances the topography (e.g., steep-sided ravine protected from wind and sun) may have far greater influence on microclimate than vegetation density, structure, and type. The influence of adjoining fields or clear-cuts on microclimate within a forest normally extends about 160 ft into the forest, but in extreme cases can extend as far as 500 ft (Dignan & Bren 2003, Ries et al. 2004, Moore et al. 2005, Hennenberg et al. 2008). Where forests are thinned rather than clear cut, buffers as narrow as 55 ft may be enough to offset changes in riparian microclimate that would otherwise have occurred from the thinning (Olson & Chan 2005). A modeling simulation suggested that air temperature in a forest might sometimes be affected up to 230 ft from an edge; a warming of only 7° F could change relative humidity exponentially from 94% to about 77% (Dong et al. 1998) with consequent effects on mosses, lichens, amphibians, and other organisms which require vaporized water during certain phases of their development.

In the Pacific Northwest, early studies in western Washington found the light regime on the forest floor was affected ~100-200 ft from the edge, while humidity and air circulation were affected as far as ~800 ft into the forest (Chen et al. 1990, 1995). A second study of riparian areas in western Washington suggested a wooded buffer of about 150 ft might be necessary to approximate the natural microclimate gradients around streams (Brosofske et al. 1997).

A third study, in Oregon, examined buffers with widths of about 20, 55, 200, and 400 ft, and found buffers averaging as narrow as 55 ft could offset changes in microclimate that otherwise would occur as a result of thinning upland forests. Thinning to a density of 80 trees/acre within the buffer did not affect soil temperature in streamside areas or the water temperature of the stream (Olson & Chan 2005).

A fourth study from the region reported that most changes in light and temperature occurred within ~60 ft of an edge, and soil temperature reached normal levels ~100 ft from edges (Heithecker & Halperin 2007). The distance from edge within which the microclimate of a forested buffer was altered depended on forest structure and aspect, especially those conditions within ~50 ft of the edge of dense stands on steep terrain. When 15% of the forest canopy was retained, it did little to protect the remaining forest from microclimatic changes , with mean and maximum air temperatures being significantly warmer than at higher retention levels (Aubrey et al. 2009). When canopy retention reached 40%, mean air temperature was significantly cooler than when the canopy was totally removed, but maximum air temperature did not differ. Mean and maximum soil temperatures differed only between 0 and 100%

retention, and different levels of canopy retention had no detectable effect on minimum air and soil temperatures and late-summer soil moisture. Light conditions within the forest did not differ significantly between 40 and 100% canopy retention (Heithecker & Halperin 2006). For most biological responses, the total amount of canopy was more important than how it was distributed horizontally (clumped or dispersed) (Aubrey et al. 2009).

Although the science showing the importance of riparian areas to streams is strong, the converse – the influence of intermittent streams on the adjoining uplands – is less certain. Because most of SJC's streams flow only during winter and early spring, their waters probably influence the humidity and other aspects of the microclimate primarily within a limited area of the narrow adjoining zones of vegetation. Removal of vegetation in some cases will temporarily bring the water table closer to the surface as water loss from transpiration diminishes, thus creating a more moist microclimate despite the absence of a vegetation canopy. But when new rapidly-growing vegetation takes hold a few years later, soil moisture losses and drier conditions may be higher than originally and will prevail for several years. And of course, if removed vegetation is supplanted by houses, roads, and other impervious surfaces, streamside humidity and temperature may never return to the original conditions necessary to support many frogs, salamanders, insects, plants, and birds.

Creating clearings and more edges also is potentially bad for water conservation, as vegetation water losses from evapotranspiration in some cases are increased; only in smooth-edged blocks of forest larger than about 250 acres are the typically greater water losses from the forest edge likely to be compensated for by water conserved by the interior forest (Herbst et al. 2007).

In Oregon, selective thinning of forests that adjoined riparian buffers did not affect the herbaceous or shrub cover in the buffers when they were wider than ~50 ft (Anderson & Meleason 2009). Thinning can increase the distance seeds disperse into the forest and the number that disperse successfully (Cadenasso et al. 2001). Lichens and mosses have been affected by edge-induced microclimate changes extending at least 50 ft into forested areas (Hylander et al. 2002, Boudreault et al. 2008) and as far as ~150 ft from the forest edge (Baldwin & Bradfield 2005). The orientation of the edge that is created can influence its impact on lichens (Johansson 2008). The negative effects on some lichens of removing the forest canopy also can be reduced by making the forest edge a spatially "soft" transition that shifts gradually from dense forest to shrubs to short open vegetation (Stevenson & Coxson 2008).

Upland Habitat for Amphibians and Reptiles

Frogs, toads, salamanders, and turtles may be the most demanding of all SJC upland wildlife in terms of the type and area of habitat they need. While it might seem that frogs could spend their entire life in a pond and along its shores as they mature from tadpoles to adults, in reality they and several other amphibians cannot and do not. As they mature, they instinctively disperse long distances from their natal ponds and wetlands, attempting to cross roads and fields that put them at high risk of predation and road-kill, and seeking accessible sheltered areas (burrows, logs, boulders) with a favorable microclimate and abundant invertebrates. In some cases, their times traversing uplands are short, intended only as direct movements to less crowded aquatic breeding sites. In other cases, many months are spent away from ponds and wetlands, and therein lies a major hindrance to preserving their populations: while wetlands and other aquatic habitats are to some degree protected from development, the poorly-defined types of upland areas that some amphibians require for lengthy periods seldom are.

Requirements of some amphibians and reptiles for large areas of terrestrial habitat have been noted both generally (e.g., Jehle & Arntzen 2000, Lemckert 2004, Regosin et al. 2005, Cushman 2006, Rittenhouse & Semlitsch 2007, Harper et al. 2008, Ficetola et al. 2009) and to a perhaps lesser extent, for species in the Pacific Northwest (Fellers & Kleeman 2007, Hayes et al. 2008). Unexpectedly, some analyses suggest that particular frog and salamander species may make less use areas directly adjoining a wetland or stream than of areas more than 300 ft away (Rittenhouse & Semlitsch 2007). Western Toad, Red-legged Frog, Rough-skinned Newt, and Northwestern Salamander are SJC species that, at least on the mainland, are known to disperse long distances overland from their natal wetlands, and/or to spend significant time in uplands during part of the life cycle. In Idaho, toads spent almost 60% of their time in terrestrial areas farther than 33 ft from the pond where they were born, which dried up late in the season. On a daily basis individuals traveled 127 ft, and seasonally they typically moved at least 0.36 (females) to 0.69 miles (males) from the pond, generally favoring shrublands and open forest (Bartelt et al. 2004). In Montana, toad movements follow stream corridors (Adams et al. 2005) and clearcuts may not be a major barrier (Deguise & Richardson 2009). Habitat characteristics measured within 300 ft of natal sites explained much of the variation in toad abundance in part of Alberta (Browne et al. 2009). When a forest patch was more than 150 ft from a wetland, only 15% of the toads moved successfully between the wetland and forest (Rothermel & Semlitsch 2002).

Northern Red-legged Frogs that were radiotracked were found to use areas as far as 1.7 miles from their natal sites, and when released frogs moved primarily toward the nearest riparian area (Fellers et al. 2007). Migration movements to and from breeding sites invariably extend over 1000 ft, and frequently over 3300 ft (Hayes et al. 2008). When radiotracked frogs on Vancouver Island were released inside clusters of trees amidst otherwise unsuitable habitat (clearcuts), the proportion of frogs abandoning the tree cluster was greater the smaller the cluster. Frogs were less likely to leave tree patches intersected by a running stream or where neighborhood stream density was high. Scattered tree patches of 2.0 to 3.7 acres, preferably in stream locations, were the minimum needed to allow successful overland passage of this frog species (Chan-McLeod & Moy 2007).

Radiotracked newts in France migrated with strong directionality up to 480 ft from their breeding sites, but most stayed within ~65 ft of the wetland edge. Burrows of small mammals were among their favored refuges while moving across uplands (Jehle et al. 2000). In Oregon, the occurrence of newts among 85 wetlands was greater where forest cover within 3281 ft was greatest (Pearl et al. 2005). However, the other species studied (red-legged frog, Pacific treefrog, long-toed salamander, northwestern salamander) were uncorrelated with surrounding forest cover, or were correlated to a lesser degree. Structural characteristics of individual wetlands were believed to be more important than landscape characteristics in predicting presence of those species (Pearl et al. 2005). Among Puget Sound wetlands (Ramos & Lawler 2010), those occupied by northwestern salamander and red-legged frog were near permanent water that was also occupied by bullfrogs, and tended not to be near deciduous or mixed forest. Wetlands with red-legged frog also had a greater proportion of shallow areas and had less high-density urban development, at least historically. Wetlands with bullfrogs were deeper and had more of the surrounding land cleared for development. Long-toed salamander occurred less often where the distance to the nearest forest patch was greater. Wetlands with Pacific treefrog had a greater proportion of emergent vegetation, had less medium-density surrounding development, and did not have fish. Another study found Pacific treefrog populations were best predicted by habitat characteristics within ~1800 ft of wetlands (Price et al. 2004). In the northeastern U.S., wetlands surrounded by less than 40% forest cover within a half-mile tend to have fewer amphibian species (Herrmann et al. 2005). In Ontario, the correlation of amphibians with surrounding land cover was greatest when land cover was measured in a radius of about 656 ft from a wetland (Houlahan et al. 2003).

Wetland buffers of 538 ft (Semlitsch 1998) or even more than 1000 ft (Semlitsch & Bodie 2003) have been recommended for amphibians. However, these are mostly for species found in the southeastern United States, not in the Pacific Northwest. And a study that recommended buffers of 150 ft along Oregon Coast Range streams was based mainly on stream salamanders that do not occur in SJC (Vesely & McCombs 2002). Also, Lemckert (2004) noted: "With distance values varying greatly, movement for an average species was difficult to predict. Individual movement within studies also varied widely, resulting in wide scatter of study populations...The wide scatter of data indicated that protective measures [e.g., typical wetland buffers] are uncertain to protect all or even most of a target population." On the other hand, based on computer modeling, Bauer et al. (2010) commented: "In landscapes dominated only by low-density residential housing, if there is a high density of ponds and wetlands, then buffers around these may be all that is necessary to maintain populations of amphibians, and preserving large patches of undeveloped non-buffer habitat is less cost-effective as an amphibian conservation measure. This is especially true if more than 80% of the suitable amphibian habitat is occupied by the target species."

Amphibian requirements for large upland areas may be less if the uplands have "stepping stones" or corridors of suitable habitat, as well as few roads and driveways. In Oregon, thinned forest stands with adjoining headwater stream buffers were not a significant barrier to amphibian movements, especially where adequate amounts of rocky or fine substrate were present to maintain microclimate conditions (Kluber et al. 2008). In Washington, a 100-ft buffer was found to be sufficient, at least in the short term, to maintain the relative abundance and richness of terrestrial amphibians at levels close to pre-logging conditions (Hawkes 2007). In Maine, amphibians (none which occur in SJC) were more abundant in 35-50 ft forested riparian buffers than in adjacent clear cuts two years following harvest, indicating at least some benefit to retaining buffers of this size (Perkins et al. 2006). In Pennsylvania, the abundance of 12 species of salamanders (including 4 wetland species) dropped where tree basal areas were below about 40 sq.ft./ acre (or approximately 50% to 60% canopy cover)(Ross et al. 2000). Based mainly on a synthesis of studies from eastern and central U.S., Semlitsch et al. (2009) recommended that no more than 40-50% of the canopy within a forest be cleared, especially in ravines, north-facing slopes, and uplands within a radius of about 300 ft from wetlands where amphibian abundance is likely to be greatest. Additional data on thresholds of amphibian tolerance of natural and artificial forest gaps is provided by Strojny & Hunter (2010).

Most clearcuts, grazed grasslands, croplands, and lawns are avoided whenever possible by dispersing amphibians, and when forced to move through such areas, fewer amphibians may survive (Rittenhouse & Semlitsch 2006, Patrick et al. 2006, Todd et al. 2009). To an unknown extent, the harshness of these areas to amphibian movements can be mitigated where they are intersected by drainage ditches (Mazerolle 2005), detention ponds or natural ponds (Knutson et al. 2004, Birx-Raybuck & Price 2010), streams, ravines, seeps, woody debris piles, tree or dense shrub stands of at least a few acres, or abundant logs, leaf litter, or boulders (Rittenhouse et al. 2008). These features can act as stepping stones or corridors for dispersing amphibians. Heavily grazed lands and ponds or ditches used frequently by horses and cattle are much less suitable (Knutson et al. 2004, Chandler et al. 2009).

Roads and/or traffic are a significant barrier to dispersing amphibians (Mader 1984, Fahrig et al. 1995, and see review by Fahrig & Rytwinski 2009). Although some amphibian populations are limited mainly by microclimate and indirectly by a lack of forest cover, for others (or for the same ones in other regions) the main limitation is roads and traffic. In Ontario (Eigenbrod 2008a) and Virginia (Marsh 2007), the presence of roads and traffic were the more significant limitation for amphibians, and "accessible habitat" -- defined as the habitat available to pond-dwelling amphibians without individuals needing to cross a major road -- was a better predictor of amphibian species richness than simply the amount of habitat within some distance of breeding ponds (Eigenbrod 2008b). Narrow roads gated to exclude traffic were crossed more often than roads with traffic by terrestrial salamanders in Virginia (Marsh 2007). Very high traffic volumes harmed amphibian populations even for species that were less prone to getting run over (Eigenbrod & Hecnar 2009). Most amphibians freeze at the approach of vehicles (Mazzerole et al. 2005).

Remarkably, even some narrow logging roads that had long been abandoned continued to impair movements and densities of salamanders in North Carolina; the road effect appeared to extend about 115 ft into the adjoining woods on both sides of the road (Semlitsch et al. 2007). If this research is applicable to SJC species, this finding may have implications for the effects of driveways on amphibians. For example, if a wetland buffer would intercept an existing driveway or road before the buffer's required width is met, land on the other side of the driveway or road should perhaps not count towards meeting the width requirement, and instead a comparable buffer width increase might be advisable on the opposite side of the wetland, i.e., buffer averaging, as suggested by Zanini & Klingemann (2008).

<u>Upland Habitat for Birds and Mammals</u>

The occurrence of most upland bird and mammal species is influenced both by the type and structure of vegetation and by its extent (total area and average patch size), connectivity, and configuration. Theoretical and limited empirical data suggest that 30% or more forest cover across a large area is the threshold value above which landscapes might provide sufficient habitat and connectivity for many forest species, allowing those species' populations to survive even in small remaining patches (Andren 1994). Minimum patch sizes required for breeding by those forest songbirds (e.g., Brown Creeper) which may be the most sensitive to forest fragmentation in the Pacific Northwest may be about 25 acres (Donnelly & Marzluff 2004, Poulin et al. 2008). However, a study in British Columbia found patch size had little to do with the abundance or diversity of birds in patches of old growth forest (Schieck et al. 1995). Parasitism of songbird nests by cowbirds studied in Montana was no less in large than in small patches (Fletcher & Hutto 2008).

A Montana study found the rates of predation on breeding songbirds were actually higher in forested landscapes than in landscapes that were dominated and fragmented by agriculture, which is contrary to what has been shown in other regions (e.g., Hobson & Bayne 2000) and by some computer models (e.g., Vergara & Hahn 2009). Patch size and distance to habitat edge did not influence predation rates, and predation of nests by crows and ravens increased only at very high levels of forest fragmentation (Tewksberry et al. 1998). Other studies have found that nests of forest-interior species located closer to forest edges are not necessarily less successful than nests placed in the forest interior (Argent et al. 2007), and in one case nestlings grew faster along edges than in forest interiors (Kaiser & Lindell 2007). The type of edge may matter: nest failure due to predation was greater around clearcut edges than logging road edges in Pennsylvania (Yahner & Mahan 1997).

Some mammals and perhaps birds follow edges during their daily travels. Because streams (at least perennial ones), lakes, and shorelines often form edges of contrasting vegetation heights and types with the surrounding landscape, they may to some degree concentrate and focus wildlife movements (e.g., Machtans et al. 1996, Shirley 2006). However, in an Alberta study, small mammals were found to be no more common (except at the immediate shoreline) near edges created by lakeside forests than in forests farther than ~160 ft from lakes (MacDonald et al. 2006). A review of 33 studies on the effects of forest edges and area on site occupancy patterns for 26 long-distance migrant forest songbirds in eastern North America showed that there was sufficient evidence only to show that 1 of 12 studied species avoided small patches and edges (Parker et al. 2005).
Forest gaps caused by placement of roads, driveways, or homes – as well as by natural features such as rockslides and wide tidal channels -- can impact movements of mammals and birds (Trombulak & Frissell 2000, Ortega & Capen 2002). This is especially true when the gaps are wider than about 100 feet (Rich et al. 1994, Rail et al. 1997, St. Clair et al. 1998, Belisle & Desrochers 2002, Laurance et al. 2004, Tremblay & St. Clair 2010), and definitely when wider than 200 ft (Creegan & Osborne 2005, Bosschieter & Goedhart 2005, Awade & Metzger 2008, Lees & Peres 2009). Species that prefer low vegetation may be particularly reluctant to cross forest clearings. The presence of small clusters of trees scattered within very wide forest gaps may be sufficient to enhance willingness of some forest bird species to cross those gaps (Robertson & Radford 2009). However, roads add additional risks (Forman et al. 2002, Clevenger et al. 2003, Massey et al. 2008, Minor & Urban 2010, Tremblay & St. Clair 2010, and see reviews by Fahrig & Rytwinski 2009, Benitez-Lopez et al. 2010). These include of direct collision (road-kill) and traffic noise that potentially interferes with reproductive success. In Quebec, traffic volume seemed to have a greater impact on birds than traffic noise (Tremblay & St. Clair 2009), but chronic noise has been shown to impair reproductive behaviors in songbirds (Wood & Yezerinac 2006, Slabbekoorn & Ripmeester 2008, Barber et al. 2010) and restrict habitat use by bats (Schaub et al. 2008).

A study in northern Alberta found no evidence that 330-ft wide wooded corridors that were preserved between forested patches improved the likelihood of most breeding bird species occurring in the connected patches after surrounding timber was cut (Schmiegelow et al. 1997, Hannon & Schmiegelow 2002). After clearing of the adjoining upland forest, forest-interior species were less often found in a forested buffer around a lake despite the buffer being 656 ft wide. Thus, effects of large-scale forest clearing are not fully compensated for simply by using of buffers and corridors. Nonetheless, the use and maintenance of high-quality buffers can lessen the impacts to wildlife when clearing or thinning of forests is less extensive or intensive.

Data relevant to choosing **buffer widths for species occurring in SJC** are limited. Birds associated with wider buffers in the Portland metropolitan area were Pacific (Winter) Wren, Brown Creeper, and Pacific-slope Flycatcher (Hennings & Edge 2003). A study in the Oregon Coast Range that compared buffers of 0 to 246 ft width found that the same three species, plus Chestnut-Backed Chickadee, were more likely to be present in wider riparian buffers, and even the widest buffers (131-230 ft) failed to support Hammond's Flycatcher, Varied Thrush, and Golden-crowned Kinglet (Hagar 1999). Pacific-slope Flycatcher was mostly absent from streamside buffers narrower than 145 ft in logged watersheds of British Columbia (Shirley & Smith 2005), and in clearcut areas in Southeast Alaska, the species peaked in riparian buffers of 820 ft (Kissling et al. 2008).
That study also reported that Brown Creeper and Hairy Woodpecker might have been sensitive to buffer width, and it found few other nesting songbirds whose presence was correlated with buffer width, but it did not examine buffers narrower than ~330 ft.

In the Seattle metro area, Pacific (Winter) Wren occurred mostly in areas with less than 20% surrounding urban cover and forest patch size of more than 3 acres (Donnelly 2004, Donnelly & Marzluff 2006). That wren, as well as Golden-crowned Kinglet, Townsend's Warbler, and Varied Thrush, were found more often in wider buffers in a study in British Columbia that compared buffer widths of 46, 121, and 230 ft (Kinley & Newhouse 1997). In Quebec, Golden-crowned Kinglet, and Swainson's Thrush were seldom found in buffers narrower than 65 ft (Darveau et al. 1995). Surveys in the forested landscape of the Cedar River watershed east of Seattle also found Golden-crowned Kinglet and Brown Creeper, as well as Black-throated Gray Warbler, more often in wider buffers or uncut forest. Riparian buffer widths of ~150 ft were needed for these species in order to attain equivalence with numbers found in unlogged areas, and occurrence of most other species was associated with buffers of 100 ft but not 50 ft (Pearson & Manuwal 2001). In British Columbia, even buffers of 472 ft failed to support several species at densities equivalent to those in extensive uncut forests: Brown Creeper, Pileated Woodpecker, Golden-crowned Kinglet, Varied Thrush, and Red-breasted Sapsucker; however, at least 2 species -- Warbling Vireo and Swainson's Thrush – were more common in buffers than in uncut forest (Shirley & Smith 2005). Based on bird data from the Oregon Cascades, stream buffers of 200 ft were deemed adequate to support corridor and refuge functions for birds in clearcut areas (Lehmkuhl et al. 2007). In Alberta, the narrowest riparian buffers in which several species nested were as follows (Hannon 2002):

66 ft = Yellow Warbler, Song Sparrow, Black-capped Chickadee, Western Wood-Pewee, Yellow-rumped Warbler, Dark-Eyed Junco;
328 ft = Swainson's Thrush, Common Yellowthroat, Hairy Woodpecker, Brown Creeper;
656 ft = Western Tanager, Purple Finch.

Buffers in the range of 328-656 ft were not surveyed so precise recommendations for widths in that range cannot be made from this study.

In other regions, particular bird species or a majority of species have been shown to occur more often in riparian buffers with widths of 100 ft (Hanowski et al. 2006 – MN) or widths in the range of 100-150 ft (King et al. 2009 – MA; Mason et al. 2007 – NC, Minor & Urban 2010 –

NC; Conover et al. 2009 - MS), compared with narrower buffers or with uncut upland forested areas of the same extent. Overall, however, most studies have not shown that forest interior bird species prefer natural forest more than buffers, and wider buffers do not result in greater similarity between reference forest and buffer sites (Marczak et al. 2010).

Some studies have reported more *individual birds per unit area* in wider buffers (Kinley & Newhouse 1997 in BC). In fact, most studies of birds and insects have found higher densities of birds in buffers than in areas of comparable size in the middle of extensive forests (Marczak et al. 2010). This could be because *most buffer studies have been of buffers next to vast clearcuts*, not small patch-cuts associated with single-family home construction in a large matrix of forest. Several studies (e.g., Betts et al. 2006) have noted how recent clearcutting can crowd individual birds (presumably those that formerly nested in the now-clearcut forest) into remaining patches of forest, e.g., buffers, for at least a year or two post-harvest.

Among buffers of different widths, wider buffers are more likely than narrow buffers to have higher bird and insect densities simply because they are more likely to contain a variety of vegetation types and size classes, which generally leads to higher avian abundance (Marczak et al. 2010). However, these findings do not apply to amphibians; the majority of those studies show lower densities of adult amphibians in buffers than in comparable areas of interior forest, perhaps highlighting the importance of microclimate to amphibians (Marczak et al. 2010).

The **density of vegetation** (e.g., basal area or percent canopy closure) in a buffer, corridor, or patch -- or in the landscape generally -- also influences habitat value for some species, perhaps as much or more than buffer width, corridor width, or patch size. A study in Minnesota found that when trees within riparian buffers were thinned to a basal area average of 17–25 sq.ft/acre, the number and variety of sensitive forest interior bird species declined in those buffers (Hanowski et al. 2005). In the Seattle metro area, the variety of breeding birds declined as forest canopy closure increased over the range of 45% to 100% (Donnelly & Marzluff 2006). That study found greater retention of native breeding birds where forests retained a tree density of at least 25 trees per acre.

Of particular concern in the Pacific Northwest are declining numbers of birds that are strongly associated with broadleaf deciduous shrubs and trees (chiefly maple, alder, oak). There are more such bird species than there are species associated with mature and old growth forest and currently in decline (Betts et al. 2010). Depending on the species and scale of measurement (distance of 500 ft or 1640-6560 ft around nest site), between 1.35% and 24.5% cover of broadleaf trees should be maintained to sustain particular songbirds with declining populations in this region (Betts et al. 2010). Wider riparian buffers in British Columbia supported a greater density of deciduous trees (Shirley 2004). Deciduous leaves often have higher nutrient levels (Roberts & Bilby 2009) and can support greater abundance and functional diversity of stream invertebrates (Piccolo & Wipfli 2002, Allan et al. 2003).

Changes in forest cover can cause changes to populations of some wildlife species that are long-lasting (Pavlacky & Anderson 2007). For example, both timber-harvested lands and lands burned by a natural fire had few forest-interior breeding bird species until 76–125 years after their respective disturbances (Schieck & Song 2006).

The cover of **non-native plants,** especially highly invasive ones, may also influence buffer use by some wildlife species positively or negatively, and would be expected to be greater in narrower buffers. Some studies have inferred a reduction in productivity or diversity of wildlife populations where non-native plants have invaded, but no studies in the Pacific Northwest have yet proven this. The assumption is well-founded, being based on the fact that the most common invasive plants typically simplify the physical structure and reduce the diversity of the plant community by outcompeting more diverse assemblages of native plant species. To varying degrees, native fish and wildlife species have come to depend on native plants (or their leaf litter) being available for food and/or cover at specific times of year. Thus, any significant simplification of vegetation structure, or shifts in the seasonal timing of food availability (due to different maturation, flowering, or fruiting times of non-native plants, or different times of leaf-fall, leaf decay, and nutrient release) is likely to adversely impact many fish and wildlife species (Burghardt et al. 2009, Rodewald et al. 2010). However, the likely effects of non-native plants on wildlife are probably very species-specific and region-specific, with some invasive plants benefiting particular native species of wildlife and others being detrimental or neutral (e.g., Kennedy et al. 2009). There is near-universal agreement among biologists that lawns and overgrazed grasslands are the poorest of the vegetated habitats for wildlife overall.

In some cases, bird and mammal use of riparian buffers and other small patches of vegetation is influenced less by buffer width than by the proportional extent and intensity of development (or natural areas) in the surrounding landscape, e.g., within a radius of 0.5 – 2 miles (Bolger et al. 1997, Melles et al. 2003, Rodewald & Bakermanns 2006, Oneal & Rotenberry 2009). Other studies have found the opposite, i.e., birds correlated more with riparian vegetation characteristics measured at a local scale (0.5 to 22 acres) than with land cover characteristics over a broad geographic area , e.g., Luther et al. 2008 and Nur et al. 2008, Seavy et al. 2009, Fletcher & Hutto 2008).

<u>Upland Habitat for Invertebrates</u>

In Oregon, a riparian buffer width of ~100 ft was needed to create an invertebrate community comprised of nearly the same species as nearby mature forests (Rykken et al. 2007). Ground beetles are particularly sensitive to roads, alteration of vegetation, and changes in microclimate. In Australia, a riparian buffer ~130 ft wide did not fully protect native ground beetle assemblages from impacts of upslope logging (Baker et al. 2009). In Scottish grasslands, wider buffers along streams actually had fewer species of ground beetles, but the species they supported were found in few other areas and so contributed heavily to regional biodiversity (Cole et al. 2008). In New Zealand, the abundances of many forest beetle species were affected as far as ~850 ft from forest edges, compared to the forest interior, but distance from forest edge was less important in predicting occurrence than size of the forest patch (Ewers et al. 2007, Ewers & Didham 2008). Based on studies of spider diversity in Quebec forests, Larrivee et al. (2008) recommended riparian buffers there be at least 330 ft in order to maintain the same species composition of spiders as found in forest interiors.

Butterflies and other pollinators are also known to be highly sensitive to fragmentation of their habitat, and research on this theme was reviewed by Dover & Settele (2009). Amid Iowa farmlands, butterflies were most diverse and abundant in riparian buffers that were wider and had more forbs (Reeder et al. 2005). Studies of an endangered butterfly in Oregon prairies found that habitat patches for that species should be within ~1600 ft of each other and should be larger than ~5 acres (Schultz & Crone 2005). Models of butterfly dispersal suggested that butterflies are more successful where uncut grassy margins are left around agricultural fields (Dellatre et al. 2010). The optimal configuration was predicted to be six ~70-ft wide grassy margins for meadows ~800 ft apart, and four ~82-ft wide margins for meadows ~1000 ft apart. Another model simulation, of pollination services, indicated that optimal conditions occurred when the *size* of remnant habitat patches was equal to half the mean foraging and dispersal distance of pollinators and the *spacing* between remnant patches was equal to the mean foraging and dispersal distance. However, maximization of pollination services was predicted to be generally incompatible with conservation of wild pollinator-dependent plants (Keitt 2009).

Butterflies and other insects are also highly sensitive to plant species. In some studies, native butterflies have used non-native plants extensively (Matteson & Langellotto 2010) whereas other studies have documented lower butterfly or insect diversity in association with non-native than native plants (Burghardt et al. 2009, 2010, Tallamy & Shropshire 2009).

4.3.2.2 Impacts of Human Presence

The simple presence of humans and especially their pets can dissuade many wildlife species from using productive habitat areas around single-family homes, wetlands, and shorelines. Monitoring the behaviors of citizens and their domestic animals is impractical, so restrictions on locations of buildings are typically necessary to protect wildlife indirectly from human disturbance.

For most upland species, biologists from WDFW (2009) have identified building densities (dwelling units per acre), ranging from none to more than 7 per acre, which they believe might be tolerated by particular wildlife species. Those densities are summarized in Figure 4-2, and details are given by species in Appendix 4-B. A study in rural Massachusetts found lower abundances of sensitive forest-dwelling birds where housing densities were 1 per acre as contrasted with 8 per acre (Kluza et al. 2000).

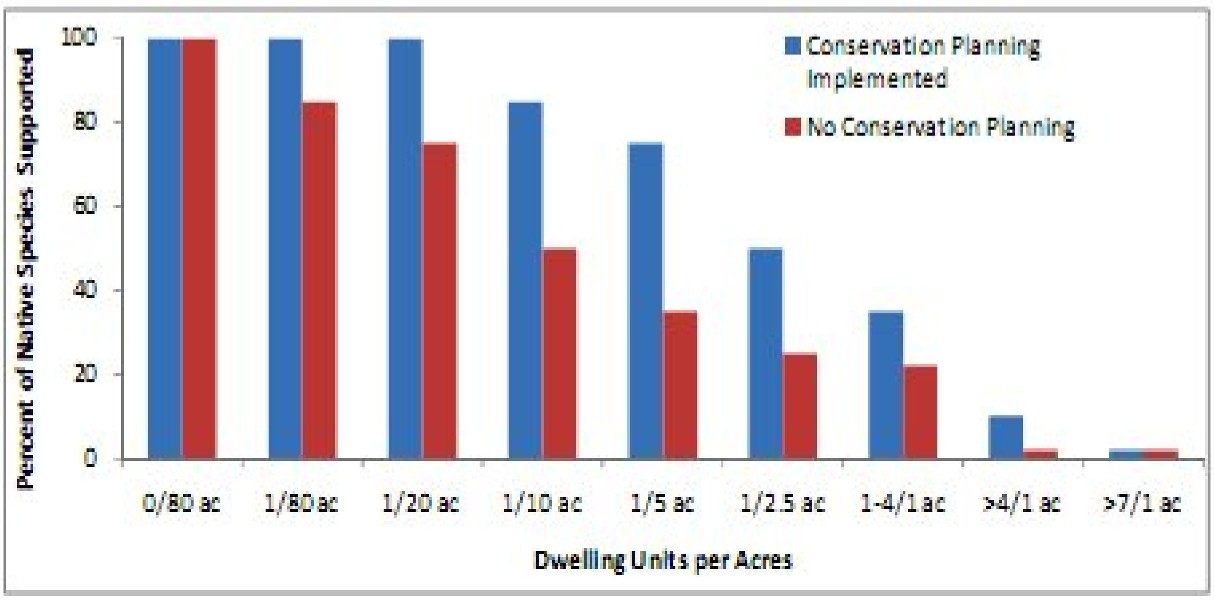


Figure 4-2. Impacts of different housing densities on richness of upland wildlife species in western Washington (from WDFW 2009).
"Conservation planning" refers to the measures described in the WDFW (2009) habitat manual, such as retaining dead wood and placing homes as far as possible from important habitat areas within a property.

In addition to disturbing wildlife, the dogs and cats that almost inevitably accompany human settlements prey directly on individuals of many species and can reduce local bird populations, not just kill individual birds (Kays & DeWan 2004, Baker et al. 2008, Barber et al. 2010, van Heezik et al. 2010, Dauphiné & Cooper 2010). Many songbirds arriving on the islands after exhausting overwater flights probably land first in shoreline vegetation where many homes and pets happen to be located. Songbirds there are more vulnerable to predation (Sperry et al. 2008). Where vegetation has been thinned or mowed by homeowners or by overbrowsing by deer and rabbits, songbirds become even more vulnerable to predators.

Almost as inevitably, human settlements are accompanied by an increase in refuse, whether it be illegally dumped trash, recklessly contained household garbage, or well-intended compost piles. These serve as a food for at least three species – raccoons, crows, and ravens – that prey extensively on native songbirds, frogs, and other wildlife (Chace & Walsh 2006). Crow populations have been shown to increase as a result of urbanization in areas up to at least 0.5 mile from the new urban areas (Oneal & Rotenberry 2009). Buildings provide useable habitat, but only for a few species, e.g., rats, bats, barn swallows, starlings (Marzluff & Ewing 2001). Collisions with picture windows are also a new hazard for many birds. Where homeowners put up bird nest boxes and feeders and maintain them annually over many years, this can help support populations of some species, especially in places where natural foods and nest sites (e.g., snags of suitable dimensions) are scarce. However, only a tiny proportion of all wildlife species are potentially benefited by such management actions (McKinney 2008). Declines in insects and some other natural foods preferred by many migratory songbird species are perhaps as likely to occur with development, especially if properties are landscaped with exotic plants, and insectivores are often the first to decline with increasing urbanization (Chamberlain et al. 2009).

Increased noise and light also accompany settlements and disturb some wildlife species, especially along roads, ATV trails, and in harbors. Artificial outdoor lighting alters the behaviours of some animals, and is particularly dangerous to birds along shorelines. During dark foggy nights, seabirds can be drawn to high-intensity shoreline lights, like a moth to a flame, and some are killed when they collide with hard objects. Also, research has demonstrated that many songbirds and frogs alter their vocalizations along roads and other environments with moderate but chronically present noise. This can reduce reproductive success if the noise is prolonged during critical breeding times. Even temporarily loud noises, such as from heavy equipment, blasting, and pile driving may disturb species for up to a quarter mile beyond the source of the noise, even causing nest abandonment (Watson and Rodrick 2002; Kennedy 2003).

Distances at which birds will or won't be disturbed by humans, pets, or noise vary depending on species, habitat, time of year, flock size, amount of visual screening by vegetation, and other factors (Dahlgren and Korschgen 1992). A buffer of 100 to 300 ft may be required to reduce disturbance of most waterbirds, and a few species sometimes take flight when humans or pets approach from as far as 800 ft away. Based on visits to a number of wetlands with various buffer widths, Cooke (1992) commented that buffers narrower than 50 feet seemed insufficient for the purpose of minimizing physical impacts to the vegetation within those mostly urban wetlands, e.g., by trampling, vandalism, non-permitted clearing. For the purpose of minimizing noise that could disturb some wildlife species, Shisler et al. (1987) found that "low-intensity" land uses could be effectively screened with vegetated buffers of 50-100 ft and "high-intensity" land uses required buffers of 100-150 feet. Neither study measured wildlife response to various buffer widths, and such information is crucial to making correct inference and extrapolation.

When humans on foot or their domestic animals approach individuals of some wildlife species, those species sometimes abandon their young or at least flee (termed "flushing") or interrupt their activities. When these disturbances occur regularly over periods of time, it reduces the food intake and weight of animals, eventually making their populations less competitive or putting individuals at greater risk of predation or disease. The energy balance may be especially delicate for bird species that characteristically have annual migrations spanning multiple continents, such as many of the warbler and flycatcher species. Large waterbirds (herons, swans) and perching hawks and eagles tend to be the most wary. However, as long as they are not shot at or chased by pets, over time many individuals of these species habituate to the presence of humans. Open habitats frequented the most by herons, waterfowl, and perching raptors probably deserve the widest visual/ noise separation from human activities. Based on extensive data collected on bird responses to boats in nearby marine waters off Vancouver Island, Chatwin (2010) recommended boats keep a distance of ~160 to 230 ft from foraging seabirds. In contrast, where the only objective is to visually screen birds inhabiting forested habitats from humans, a densely forested buffer of only about 25 ft width may be adequate as a visual screen. Much wider buffers could be necessary to reduce wildlife impacts where chronic noise is a potential concern. Where sensitive habitat areas are fenced or surrounded completely by a very dense thicket of vegetation (e.g., rose, blackberry, meadowsweet), such features might reduce disturbance by excluding humans and some predators of the wildlife species using those areas.

4.3.3 Data Gaps and the Need to Expand the Knowledge Base

1. Perhaps the greatest informational data gap that hinders planning for biodiversity in SJC is the lack of data on the patch sizes of suitable habitat, and dimensions of movement corridors, that are needed to sustain each indigenous species of terrestrial plant and animal.

2. Simultaneously, it is important to know which species the county harbors and where they are located. While this is relatively well-known for the more common species of birds, next to nothing is known of the locations favored by hundreds of species of breeding reptiles, amphibians, mammals, and uncommon birds, not to mention the potentially thousands of species of invertebrates and plants.

3. In addition, information is needed on the widths of noise buffers and general disturbance buffers that are needed to provide adequate seclusion to waterbirds and other sensitive wildlife.

Many other data gaps exist that pertain to upland habitat, but these are perhaps the ones that most limit attempts to base land use decisions on sound science. Despite the above data gaps and information needs, the County's efforts to protect habitats and biodiversity should not be put on hold until more information is available. State laws, the public trust, and popular concern for protecting natural resources from long-lasting harm dictate that both voluntary and regulatory efforts proceed with urgency using the best available science, whatever its current limitations.

4.3.4 Synopsis and Science-based Options for Protecting Terrestrial FWHCA's

1. Planning for biodiversity should be based on needs of individual species, not focus *only* on conserving areas containing priority habitat types, or on some perceived notion of "generally good habitat structure" as is the case with many of the currently used methods for rapidly

assessing habitat quality. Habitat planning and assessment methods must recognize that research findings on a particular species or species group in one region can not always be applied validly to different species in different landscapes and regions. As Zuckerberg & Porter (2010) note:

> "incorporating ecological thresholds in environmental planning should be species-specific and focus on populations on the verge of rapid ecological change."

And Schmiegelow et al. (2002) explain:

> "the magnitude of the fragmentation effects we documented is small compared with those observed elsewhere. Birds breeding in the boreal forest, where frequent small- and large-scale natural disturbances have occurred historically, may be more resilient to human-induced habitat changes, such as those caused by limited forest harvesting. "

And Tewksbury (1998) comments:

> "the effects of fragmentation are dependent on the habitat structure, the landscape context, the predator community, and the impact of parasitism. All of these factors may differ substantially in western ecosystems when compared to previously studied forests, making generalizations about the effect of fragmentation difficult."

Based on their extensive data from Vancouver Island, Schieck et al. (1995) concluded:

> "Most species of birds that occur in the Pacific Northwest may be less susceptible to adverse effects of forest fragmentation."

And finally, in a synthesis on this topic, Kremsater & Bunnell (1999) observed:

> "In the east and midwest many studies document increased predation and parasitism near edges; in the Pacific Northwest researchers have found little effect of patch area or negative edge effects"

These warnings to focus on species and be conservative in the application of popular landscape conservation paradigms, especially when dealing with regions and species different from the regions and species upon which those paradigms were based, are echoed by Pavlacky & Anderson 2007, Shanahan & Possingham 2009, McWethy et al. 2009, and many others. Even the applicability to SJC of the few habitat fragmentation studies conducted in the Pacific Northwest may be limited because virtually all such studies have been conducted on *mainland* environments, most often around clearcuts or in heavily urbanized landscapes.

2. On islands, the minimum patch areas and widths of natural land cover that would be required for sensitive species to persist might need to be larger. That is because of the severe inhospitably to many species of part of the matrix habitat (marine waters), as compared to mainland matrix habitats which typically are interspersed with some marginally suitable habitat patches (Cassidy & Grue 2006). On islands, recolonization of vegetation patches which have lost individuals of various species, due to humans or natural processes, is likely to occur slowly if at all because of the severe barrier posed by marine waters (Russell et al. 2006, Trevino et al. 2007). The availability of temporary "refuges" from humans or predators is far more constrained on islands. Many other factors that make SJC significantly different from the rest of western Washington are outlined in Chapter 2 (Wetlands).

Based on the Best Available Science, the County in amending current regulations could do the following[24]:

3. Adopt immediately as Locally Significant Habitats those habitats described in section 4.3.1.3. Also solicit information on species listed in section 4.2.1.4. If sufficient information exists (or can be easily generated by field surveys), take steps to protect their preferred habitats and locations.

4. Consider and possibly adopt or expand incentives to landowners to voluntarily and permanently set aside natural lands and open space for species and habitat protection. Highest priority could be given to habitat on islands that currently have the lowest proportion of lands permanently set aside for conservation, as well as to habitat elsewhere that is known to support Priority Habitats, Priority Species, and other species identified as rare or sensitive in section 4.3.1.4 of this chapter. Higher priority could also be given to patches of these habitats that are larger and/or are in the best condition, and are most likely to be self-sustaining over the long term.

5. Provide information to private landowners describing voluntary measures, consistent with the BAS presented here in sections 4.3.1.5 and 4.3.2.1, which they can take to recognize and avoid impacting sensitive species and habitats on their lands, as well as to enhance habitat for sensitive species in a self-sustaining manner.

6. Encourage and help fund the centralized compilation, databasing, and synthesis of much species and habitat distributional information already collected by SJC citizens and various private groups, but not yet in the public domain. Without disclosing exact locations of the most sensitive species, continue to use these data to help refine priorities for the San Juan County Land Bank and other open space and conservation efforts.

7. Facilitate and help fund a countywide biological inventory that builds upon Appendix 4B and #6 above, and catalogs where all uncommon species breed or otherwise occur in SJC.

8. Consider restricting the placement or widening of driveways, roads, and linear clearings in situations where doing so would "lop off" part of a contiguous forest currently larger than 100 acres and create a non-continguous "forest island" smaller than 100 acres, especially if the driveway or road is wider than 100 ft. When new structures are built, encourage their placement such that any existing forest "islands" are not narrowed.

9. Support waste management programs and enforce littering regulations to ensure that all garbage remains as inaccessible as possible to raccoons, crows, and other songbird nest predators.

10. To minimize illegal harassment of sensitive shorebirds, enact and/or ensure strict enforcement of leash laws in known shorebird concentration areas (e.g., Westcott Bay, False Bay) along marine and lake shorelines.

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[24] Note that because section 4.3.4 is a synopsis, literature supporting many of the statements in this section is generally not cited here, but rather in preceding parts of this HCA chapter.

11. Wherever landscaping of County property is needed or desired, use native plants and minimize the creation of new lawns. Continue supporting programs for noxious weed control throughout the county. Use herbicides only when no practical alternatives exist.

12. For Threatened, Endangered, and Sensitive species, the County could support -- through regulations, policies, and/or public education -- the actions shown in Table 4-6.

Table 4-6. Proposed protective actions for listed Threatened, Endangered, and Sensitive species.

See section 4.3.1.2 for background information on these species.

Species or Group	Proposed Protections
Bald Eagle	Require landowners to have a site management plan prepared in collaboration with WDFW, or by a professional wildlife biologist and approved by the WDFW, whenever regulated activities that alter habitat are proposed near a nest or communal roost. This requirement could apply to proposed projects within 800 feet of a nest and to projects that are within 250 ft of the shoreline and are within 0.5 mile of a nest. This is in accordance with WAC 232-12-292 and RCW 77.12.655. The plan could specify, in part, that the landowner maintain 50% of all trees in representative size classes and all trees ≥24 in. dbh within 250 ft of the shoreline for ½ mile on either side of a nest. Monitor compliance with the approved plan. Adopt and enforce buffer regulations for streams, lakes, wetlands, and the marine shoreline that help protect these surface waters from contamination. Identify pollution sources, partly through a countywide monitoring program, and remediate them. Adopt and enforce regulations and policies that protect habitat of salmonids and other fish.
Peregrine Falcon	Restrict or discourage public access to areas within 250 ft of nest cliffs during active nesting periods (generally spring and early summer). Require landowners to have a site management plan prepared in collaboration with WDFW, or by a professional wildlife biologist and approved by the WDFW, whenever regulated activities that alter habitat are proposed near nesting cliffs. Adopt and enforce buffer regulations for streams, lakes, wetlands, and the marine shoreline that help protect these surface waters from contamination. Identify pollution sources, partly through a countywide monitoring program, and

Species or Group	**Proposed Protections**
	remediate them.
Marbled Murrelet	Adopt and enforce regulations and policies that support populations of forage fish and swimming marine invertebrates. Protect the oldest coniferous forests having the greatest extent, especially any which currently have trees at least 32" in diameter and cover more than 7 acres. Support efforts of murrelet biologists to determine current nesting status of the species in SJC and identify more accurately locations of potential nesting habitat. If a nest is found, require landowners to have a site management plan prepared in collaboration with WDFW, or by a professional wildlife biologist and approved by the WDFW, whenever regulated activities that alter habitat near the nest are proposed. Adopt and enforce buffer regulations for streams, lakes, wetlands, and the marine shoreline that help protect these surface waters from contamination. Identify pollution sources, partly through a countywide monitoring program, and remediate them. Adopt and enforce regulations intended to keep recreational motorized boats and new docks at least 200 ft from seasonal concentration areas in marine waters.

Fish Salmon Chinook Chum Coho Pink Sockeye Cutthroat Steelhead	Adopt and enforce buffer regulations for streams and the marine shoreline that help protect these surface waters from contamination while supporting vegetation which supplies terrestrial insects to feeding fish. Identify pollution sources, partly through a countywide monitoring program, and remediate them. Adopt and enforce regulations and policies that protect forage fish spawning areas, eelgrass and kelp beds, and the dynamic complexity of nearshore habitat. Disallow construction of ponds that empty to streams and marine waters. Require properly sized culverts for all driveways and roads that cross fish-accessible streams. (For marine waters, see also Chapter 3)
Taylor's Checker-spot butterfly	In privately owned grasslands with potential for this species, actively seek landowner permission for annual surveys by a qualified entomologist. Even in grasslands not known to currently host this species, discourage use of herbicides, insecticides, intensive grazing, and vegetation clearing. This is especially applicable in areas where one of its host plants -- plantain (*Plantago* spp.) -- is common. Require landowners to have a site management plan prepared in collaboration with WDFW, or by a professional entomologist and approved by the WDFW, whenever regulated activities that alter habitat are proposed near a known site.

4.4 Literature Cited

Note: Peer reviewed references and documents that local, state or federal natural resource agencies have determined represents the best available science consistent with the criteria set out in WAC 365-195-900 through 365-195-925 are shown in bold.

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Appendices

4-A. Occurrence of SJC Wildlife Species by Island

4-B. Occurrence of SJC Wildlife Species by Habitat Type

4-C. Plant species considered to be rare in SJC by the Washington Natural Heritage Program (September 2010)

4-D. Plant communities for which high-quality examples are considered rare in SJC by the Washington Natural Heritage Program (September 2010)

4-E. Quality of SJC surface waters (from WDOE's WQA database)

4-F. Environment Summary Tables from GIS Compilation of Existing Data
    4F-1. Environment by Island

Appendix 4-A. Occurrence of SJC Wildlife Species by Island

Sources: Jensen (2010), WDFW (2009), Cassidy & Grue (2006), Lewis & Sharpe (1987), R. Barsh (pers. comm.), R. Myhr (pers. comm.), Adamus (personal observations)

Legend:
Native to WA: Y= yes, N- no
Times Present: R= resident; N= nesting season only; MW= migration/ wintering only; ? = nesting unconfirmed
Distribution by Island: C= confirmed by reliable report, P= probable based on known habitat preferences, ? = unknown but possible based on habitat
Listing Status:
Fed (Federal): E= Endangered, T= Threatened, SC= Species of Concern
State: M= species of potential concern whose status should be determined or monitored, C= Candidate (species that will be reviewed by WDFW for possible listing as Endangered, Threatened, or Sensitive according to the process and criteria defined in WAC-232-12-297), E= Endangered, T= Threatened
State PS (Priority Species): 1= state-listed species, 2= protect vulnerable aggregations, 3= species of recreational or commercial importance
Building Densities Tolerated (du/ac = dwelling units per acre): Based on scientific literature analysis by WDFW biologists (WDFW 2009). Blanks indicate lack of information, not insensitivity to impact. "Conservation Planning" refers to the measures described in the WDFW (2009) habitat manual.

				Distribution by Island				Listing Status			Building Densities Tolerated	
Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Northwestern Salamander	Ambystoma gracile	Y	R	P	C	C	?				1du/10	1du/ac to 4du/ac
Long-toed Salamander	Ambystoma macrodactylum	Y	R	?	C	P	C				1du/5	>4du/ac to 7du/ac
Rough-skinned Newt	Taricha granulosa	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Western Toad	Bufo boreas	Y	R	?	P	?	P	SC	C	1	1du/40 to 1du/80	1du/5
Pacific Treefrog	Hyla regilla	Y	R	C	C	C	C				1du/5	>7du/ac
Northern Red-legged Frog	Rana aurora	Y	R	P	C	C	C				1du/20	1du/5
Bullfrog	Rana catesbeiana	N	R	C	C	C	C					
Western Painted Turtle	Chrysemys picta	Y	R	C	P	C	?					
Northern Alligator Lizard	Elgaria coerulea	Y	R	C	C	P	?				1du/5	>4du/ac to 7du/ac
Western Fence Lizard	Sceloporus occidentalis	Y	Y	C								
Rubber Boa	Charina bottae	Y	R	C	C	?	?				1du/10	1du/ac to 4du/ac
Sharptail Snake	Contia tenuis	Y	R	C	C	?	?				1du/10	1du/ac to 4du/ac
W. Terrestrial Garter Snake	Thamnophis elegans	Y	R	P	P	C	?				1du/10	1du/ac to 4du/ac
Northwestern Garter Snake	Thamnophis ordinoides	Y	R	P	P	C	?				1du/5	>7du/ac
Common Garter Snake	Thamnophis sirtalis	Y	R	P	P	C	?				1du/10	1du/ac to 4du/ac
Red-throated Loon	Gavia stellata	Y	MW	C	C	C	?			2		
Common Loon	Gavia immer	Y	MW	C	C	C	C		S	1,2		
Yellow-billed Loon	Gavia adamsii	Y	MW	P	P	C	?			2		

				Distribution by Island				Listing Status			Building Densities Tolerated	
Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Pacific Loon	Gavia pacifica	Y	MW	C	C	C	C			2		
Pied-billed Grebe	Podilymbus podiceps	Y	R	C	C	C	C			2		
Horned Grebe	Podiceps auritus	Y	MW	C	C	C	C		M	2		
Red-necked Grebe	Podiceps grisegena	Y	MW	C	C	C	C		M	2		
Eared Grebe	Podiceps nigricollis	Y	MW	C	P	P	?			2		
Western Grebe	Aechmophorus occidentalis	Y	MW	C	C	C	C		C	1,2		
Brown Pelican	Pelecanus occidentalis	Y	M	C	C	C		E	E	1,2		
Double-crested Cormorant	Phalacrocorax auritus	Y	R	C	C	C	C			2		
Brandt's Cormorant	Phalacrocorax penicillatus	Y	MW	C	C	C	C		C	1,2		
Pelagic Cormorant	Phalacrocorax pelagicus	Y	R	C	C	C	C			2		
American Bittern	Botaurus lentiginosus	Y	R?	C	P	P	P					
Great Blue Heron	Ardea herodias	Y	MW	C	C	C	C		M	2		
Green Heron	Butorides virescens	Y	N?	C	P	P						
Tundra Swan	Cygnus columbianus	Y	MW	C		P				2,3		
Trumpeter Swan	Cygnus buccinator	Y	MW	C	C	C	P			2,3		
Greater White-fronted Goose	Anser albifrons	Y	MW	C	C	P				2,3		
Brant	Branta bernicla	Y	MW	C	P	C	P			2,3		
Canada Goose	Branta canadensis	Y	R	C	C	C	C			2,3		
Cackling Goose	Branta hutchinsii	Y	MW	C	P	P				2,3		
Wood Duck	Aix sponsa	Y	R	C	C	P	P			2,3		
Green-winged Teal	Anas crecca	Y	R	C	C	C	C			2,3		
Mallard	Anas platyrhynchos	Y	R	C	C	C	C			2,3		
Northern Pintail	Anas acuta	Y	R?	C	C	C	P			2,3		
Blue-winged Teal	Anas discors	Y	R	C	C	P	P			2,3		
Cinnamon Teal	Anas cyanoptera	Y	R	C	C	P	P			2,3		
Northern Shoveler	Anas clypeata	Y	R?	C	C	C	P			2,3		
Gadwall	Anas strepera	Y	R	C	C	C	P			2,3		
Eurasian Wigeon	Anas penelope	Y	MW	C	C	C	P			2,3		
American Wigeon	Anas americana	Y	MW	C	C	C	C			2,3		
Canvasback	Aythya valisineria	Y	MW	C	C	P	P			2,3		
Redhead	Aythya americana	Y	MW	C	P	P	P			2,3		
Ring-necked Duck	Aythya collaris	Y	R	C	C	P	P			2,3		

				Distribution by Island				Listing Status			Building Densities Tolerated	
Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Greater Scaup	Aythya marila	Y	MW	C	C	C	C			2,3		
Lesser Scaup	Aythya affinis	Y	R?	C	P	P	P			2,3		
Harlequin Duck	Histrionicus histrionicus	Y	MW	C	C	C	C			2,3		
Long-tailed Duck	Clangula hyemalis	Y	MW	C	C	C	C			2,3		
Black Scoter	Melanitta nigra	Y	MW	C	C	P	P			2,3		
Surf Scoter	Melanitta perspicillata	Y	MW	C	C	C	C			2,3		
White-winged Scoter	Melanitta fusca	Y	MW	C	C	C	C			2,3		
Common Goldeneye	Bucephala clangula	Y	MW	C	C	C	C			2,3		
Barrow's Goldeneye	Bucephala islandica	Y	MW	C	C	C	C			2,3		
Bufflehead	Bucephala albeola	Y	MW	C	C	C	C			2,3		
Hooded Merganser	Lophodytes cucullatus	Y	R	C	C	C	C			3		
Common Merganser	Mergus merganser	Y	R	C	C	C	C			2,3		
Red-breasted Merganser	Mergus serrator	Y	MW	C	C	C	C			2,3		
Ruddy Duck	Oxyura jamaicensis	Y	R?	C	P	C	P			2,3		
Turkey Vulture	Cathartes aura	Y	R	C	C	C	C		M		0du/ac	1du/10
Osprey	Pandion haliaetus	Y	R	C	C	C	P		M		1du/20	1du/ac to 4du/ac
Bald Eagle	Haliaeetus leucocephalus	Y	R	C	C	C	C	SC	S	1	1du/20	1du/2.5
Northern Harrier	Circus cyaneus	Y	R?	C	C	C	C				1du/10	1du/ac to 4du/ac
Sharp-shinned Hawk	Accipiter striatus	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Cooper's Hawk	Accipiter cooperii	Y	R	C	C	C	P				1du/5	>4du/ac to 7du/ac
Northern Goshawk	Accipiter gentilis	Y	R?	C	C	C	C	SC	C	1	1du/5	>4du/ac to 7du/ac
Red-tailed Hawk	Buteo jamaicensis	Y	R	C	C	C	C				1du/20	1du/2.5
Rough-legged Hawk	Buteo lagopus	Y	MW	C	P	P	P					
Golden Eagle	Aquila chrysaetos	Y	R	C	C	C	P		C	1	0du/ac	1du/10
American Kestrel	Falco sparverius	Y	R	C	C	P	P				1du/5	>4du/ac to 7du/ac
Merlin	Falco columbarius	Y	R?	C	C	C	P		C	1	0du/ac	1du/10
Peregrine Falcon	Falco peregrinus	Y	R	C	C	C	P	SC	S	1	1du/10	1du/ac to 4du/ac
Gyrfalcon	Falco rusticolus	Y	MW	C	P	P	P		M			
Ring-necked Pheasant	Phasianus colchicus	N	R	C	C	C	P			3		
Blue Grouse	Dendragapus obscurus	Y	R		C					3	0du/ac	1du/10
Wild Turkey	Meleagris gallopavo	N	R	C						3		
California Quail	Callipepla californica	N	R	C	C	C	C					

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Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Virginia Rail	Rallus limicola	Y	R	C	C	C	C					
Sora	Porzana carolina	Y	R	C	C	P	C					
American Coot	Fulica americana	Y	R	C	C	C	P			2,3		
Sandhill Crane	Grus canadensis	Y	MW	C	P	P			E	1		
Black-bellied Plover	Pluvialis squatarola	Y	MW	C	C	C	P			2		
American Golden-Plover	Pluvialis dominica	Y	M	C		P				2		
Pacific Golden-Plover	Pluvialis fulva	Y	M	C		P				2		
Semipalmated Plover	Charadrius semipalmatus	Y	MW	C	P	C	P			2		
Killdeer	Charadrius vociferus	Y	R	C	C	C	C			2		
Black Oystercatcher	Haematopus bachmani	Y	R	C	C	C	C		M	2		
Greater Yellowlegs	Tringa melanoleuca	Y	MW	C	C	C	C			2		
Lesser Yellowlegs	Tringa flavipes	Y	M	C	P	C	P			2		
Solitary Sandpiper	Tringa solitaria	Y	M	C	P	P	P			2		
Wandering Tattler	Heteroscelus incanus	Y	M	C	P	P	P			2		
Spotted Sandpiper	Actitis macularia	Y	R?	C	C	C	C			2		
Whimbrel	Numenius phaeopus	Y	MW	C	P	P	P			2		
Ruddy Turnstone	Arenaria interpres	Y	MW	C	P	P	P			2		
Black Turnstone	Arenaria melanocephala	Y	MW	C	C	C	C			2		
Surfbird	Aphriza virgata	Y	MW	C	P	C	P			2		
Sanderling	Calidris alba	Y	MW	C	C	C	C			2		
Semipalmated Sandpiper	Calidris pusilla	Y	M	C	P	P	P			2		
Western Sandpiper	Calidris mauri	Y	MW	C	C	C	C			2		
Least Sandpiper	Calidris minutilla	Y	M	C	P	C	P			2		
Baird's Sandpiper	Calidris bairdii	Y	M	C	P	C	P			2		
Pectoral Sandpiper	Calidris melanotos	Y	M	C	P	P	C			2		
Dunlin	Calidris alpina	Y	MW	C	C	C	C			2		
Short-billed Dowitcher	Limnodromus griseus	Y	M	C	P	P	P			2		
Long-billed Dowitcher	Limnodromus scolopaceus	Y	M	C	P	C	P			2		
Wilson's Snipe	Gallinago delicata	Y	R	C	C	C	C			2		
Red-necked Phalarope	Phalaropus lobatus	Y	M	C	C	C	C			2		
Parasitic Jaeger	Stercorarius parasiticus	Y	M	C	C	C	C					
Franklin's Gull	Larus pipixcan	Y	M	P	P	P	P					

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Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Bonaparte's Gull	Larus philadelphia	Y	MW	C	C	C	C					
Heermann's Gull	Larus heermanni	Y	MW	C	C	C	C					
Mew Gull	Larus canus	Y	MW	C	C	C	C					
Ring-billed Gull	Larus delawarensis	Y	MW	C	P	P	?					
California Gull	Larus californicus	Y	MW	C	C	C	C					
Herring Gull	Larus argentatus	Y	MW	C	C	C	C					
Thayer's Gull	Larus thayeri	Y	MW	C	C	C	C					
Western Gull	Larus occidentalis	Y	MW	C	P	P	P					
Glaucous-winged Gull	Larus glaucescens	Y	R	C	C	C	C					
Glaucous Gull	Larus hyperboreus	Y	MW	P	P	P	P					
Caspian Tern	Hydroprogne caspia	Y	MW	C	C	C	C		M	2		
Common Tern	Sterna hirundo	Y	MW	C	C	C	C			2		
Common Murre	Uria aalge	Y	NB	C	C	C	C		C	1,2		
Pigeon Guillemot	Cepphus columba	Y	R	C	C	C	C			2		
Marbled Murrelet	Brachyramphus marmoratus	Y	R	C	C	C	C	T	T	1,2		
Ancient Murrelet	Synthliboramphus antiquus	Y	MW	C	C	C	?			2		
Cassin's Auklet	Ptychoramphus aleuticus	Y	R	C	P	C	P	SC	C	1,2		
Rhinoceros Auklet	Cerorhinca monocerata	Y	NB	C	C	C	C			2		
Tufted Puffin	Fratercula cirrhata	Y	R	C	P	C	P	SC	C	1,2,3		
Rock Dove	Columba livia	N	R	C	C	C	C					
Band-tailed Pigeon	Columba fasciata	Y	R	C	C	C	C			3	1du/5	>4du/ac to 7du/ac
Eurasian Collared-dove	Streptopelia decaocto	N	R	C	C	C	C					
Mourning Dove	Zenaida macroura	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Barn Owl	Tyto alba	Y	R	C	C	C					1du/5	>4du/ac to 7du/ac
Western Screech-owl	Otus kennicotti	Y	R	C	C	C	?				1du/10	1du/ac to 4du/ac
Great Horned Owl	Bubo virginianus	Y	R	C	C	C	P				1du/10	1du/ac to 4du/ac
Snowy Owl	Nyctea scandiaca	Y	MW	C	P	P			M			
Northern Pygmy-owl	Glaucidium gnoma	Y	R?	C	C	P	?				1du/20	1du/2.5
Barred Owl	Strix varia	Y	R?	?	P	C	?				1du/5	>4du/ac to 7du/ac
Long-eared Owl	Asio otus	Y	R	C	C	C	C				0du/ac	1du/10
Short-eared Owl	Asio flammeus	Y	R?	C	P	C					0du/ac	1du/10
Northern Saw-whet Owl	Aegolius acadicus	Y	R	C	P	C					1du/20	1du/2.5

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Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Common Nighthawk	Chordeiles minor	Y	N	C	C	C					1du/10	1du/ac to 4du/ac
Black Swift	Cypseloides niger	Y	NB	C	C	C		SC	M			
Vaux's Swift	Chaetura vauxi	Y	N?	C	C	C	?		C	1	1du/40 to 1du/80	1du/5
Anna's Hummingbird	Calypte anna	Y	R	C	C	C	C				>7du/ac	
Rufous Hummingbird	Selasphorus rufus	Y	N	C	C	C	C				1du/5	>4du/ac to 7du/ac
Belted Kingfisher	Ceryle alcyon	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Red-breasted Sapsucker	Sphyrapicus ruber	Y	MW?	C	C	C	?					
Downy Woodpecker	Picoides pubescens	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Hairy Woodpecker	Picoides villosus	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Northern Flicker	Colaptes auratus	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Pileated Woodpecker	Dryocopus pileatus	Y	R	C	C	C	C		C	1	1du/40 to 1du/80	1du/5
Olive-sided Flycatcher	Contopus borealis	Y	N	C	C	C	C				1du/40 to 1du/80	1du/5
Western Wood-pewee	Contopus sordidulus	Y	N	C	C	P	P				1du/20	1du/2.5
Willow Flycatcher	Empidonax traillii	Y	N	C	C	P	?				1du/10	1du/ac to 4du/ac
Hammond's Flycatcher	Empidonax hammondii	Y	N?		P						1du/20	1du/2.5
Pacific-slope Flycatcher	Empidonax difficilis	Y	N	C	C	C	C				1du/20	1du/2.5
Say's Phoebe	Sayornis saya	Y	M	C	C	C					1du/5	>4du/ac to 7du/ac
Western Kingbird	Tyrannus verticalis	Y	M	C	P	P					1du/40 to 1du/80	1du/5
Horned Lark	Eremophila alpestris	Y	M	C	P	P						
Purple Martin	Progne subis	Y	N	C	C	C			C	1	1du/10	1du/ac to 4du/ac
Tree Swallow	Tachycineta bicolor	Y	N	C	C	C	C				1du/20	1du/2.5
Violet-green Swallow	Tachycineta thalassina	Y	N	C	C	C	C				1du/20	1du/2.5
N. Rough-winged Swallow	Stelgidopteryx serripennis	Y	N	C	C	C	C					
Cliff Swallow	Hirundo pyrrhonota	Y	N	C	C	C					1du/10	1du/ac to 4du/ac
Barn Swallow	Hirundo rustica	Y	N	C	C	C	C				1du/5	>4du/ac to 7du/ac
Steller's Jay	Cyanocitta stelleri	Y	R		C						1du/5	>4du/ac to 7du/ac
American Crow	Corvus brachyrhynchos	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Common Raven	Corvus corax	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Chestnut-backed Chickadee	Poecile rufescens	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Bushtit	Psaltriparus minimus	Y	R	C	C	C	?				1du/10	1du/ac to 4du/ac
Red-breasted Nuthatch	Sitta canadensis	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Brown Creeper	Certhia americana	Y	R	C	C	C	C				1du/20	1du/2.5

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Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Bewick's Wren	Thryomanes bewickii	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
House Wren	Troglodytes aedon	Y	N	C	C	C	C				1du/5	>4du/ac to 7du/ac
Pacific (Winter) Wren	Troglodytes troglodytes	Y	R	C	C	C	C				1du/20	1du/2.5
Marsh Wren	Cistothorus palustris	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
American Dipper	Cinclus mexicanus	Y	R?		C							
Golden-crowned Kinglet	Regulus satrapa	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
Ruby-crowned Kinglet	Regulus calendula	Y	MW	C	C	C	C					
Western Bluebird	Sialia mexicana	Y	R	C	C	C						
Mountain Bluebird	Sialia currucoides	Y	M	C								
Townsend's Solitaire	Myadestes townsendi	Y	MW	C	C	C	C					
Swainson's Thrush	Catharus ustulatus	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Hermit Thrush	Catharus guttatus	Y	MW	C	C	C	C					
American Robin	Turdus migratorius	Y	R	C	C	C	C				>7du/ac	
Varied Thrush	Ixoreus naevius	Y	R	C	C	C	C				1du/20	1du/2.5
American Pipit	Anthus rubescens	Y	MW	C	C	C	P					
Cedar Waxwing	Bombycilla cedrorum	Y	R	C	C	C	P				1du/10	1du/ac to 4du/ac
Northern Shrike	Lanius excubitor	Y	MW	C	P	C	?					
European Starling	Sturnus vulgaris	N	R	C	C	C	C					
Hutton's Vireo	Vireo huttoni	Y	R	C	C	C	C				1du/20	1du/2.5
Warbling Vireo	Vireo gilvus	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Cassin's Vireo	Vireo cassinii	Y	N	C	C	C	C				1du/20	1du/2.5
Orange-crowned Warbler	Vermivora celata	Y	N	C	C	C	C				1du/20	1du/2.5
Yellow Warbler	Dendroica petechia	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Yellow-rumped Warbler	Dendroica coronata	Y	R	C	C	C	C				1du/20	1du/2.5
Black-throated Gray Warbler	Dendroica nigrescens	Y	N	C	C	C	C				1du/5	>4du/ac to 7du/ac
Townsend's Warbler	Dendroica townsendi	Y	R	C	C	C	C				1du/40 to 1du/80	1du/5
MacGillivray's Warbler	Oporornis tolmiei	Y	N	C	C	P	?				1du/20	1du/2.5
Common Yellowthroat	Geothlypis trichas	Y	N	C	C	C	C				1du/20	1du/2.5
Wilson's Warbler	Wilsonia pusilla	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Western Tanager	Piranga ludoviciana	Y	N	C	C	C	C				1du/20	1du/2.5
Black-headed Grosbeak	Pheucticus melanocephalus	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Spotted Towhee	Pipilo maculatus	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac

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Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
Chipping Sparrow	Spizella passerina	Y	N	C	C	P	?				0du/ac	1du/10
Vesper Sparrow	Pooecetes gramineus	Y	N	C	P	P					1du/20	1du/2.5
Savannah Sparrow	Passerculus sandwichensis	Y	N	C	C	C	C				1du/10	1du/ac to 4du/ac
Fox Sparrow	Passerella iliaca	Y	R?	C	C	C	C				1du/20	1du/2.5
Song Sparrow	Melospiza melodia	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Lincoln's Sparrow	Melospiza lincolnii	Y	MW	C	P	P						
White-throated Sparrow	Zonotrichia albicollis	Y	MW	C	P	P						
Golden-crowned Sparrow	Zonotrichia atricapilla	Y	MW	C	C	C	C					
White-crowned Sparrow	Zonotrichia leucophrys	Y	R	C	C	C	C				1du/ac to 4du/ac	>7du/ac
Dark-eyed Junco	Junco hyemalis	Y	R	C	C	C	C				1du/ac to 4du/ac	
Red-winged Blackbird	Agelaius phoeniceus	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Western Meadowlark	Sturnella neglecta	Y	NB	C	P	P					1du/20	1du/2.5
Brewer's Blackbird	Euphagus cyanocephalus	Y	R	C	C	C	?				1du/10	1du/ac to 4du/ac
Brown-headed Cowbird	Molothrus ater	Y	N	C	C	C	C				1du/5	>4du/ac to 7du/ac
Purple Finch	Carpodacus purpureus	Y	R	C	C	C	C				1du/10	1du/ac to 4du/ac
House Finch	Carpodacus mexicanus	Y	R	C	C	C	C				>7du/ac	
Red Crossbill	Loxia curvirostra	Y	R	C	C	C	C				1du/20	1du/2.5
Pine Siskin	Carduelis pinus	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
American Goldfinch	Carduelis tristis	Y	R	C	C	C	C				1du/5	>4du/ac to 7du/ac
Evening Grosbeak	Coccothraustes vespertinus	Y	R	C	C	P	C				1du/5	>4du/ac to 7du/ac
House Sparrow	Passer domesticus	N	R	C	C	C	C					
Vagrant Shrew	Sorex vagrans	Y		C	P	C	C				1du/ac to 4du/ac	>4du/ac to 7du/ac
Little Brown Myotis (Bat)	Myotis lucifugus	Y		C	P	P	?			2		
Yuma Myotis	Myotis yumanensis	Y		P	P	P	?			2		
Keen's Myotis	Myotis keenii	Y		P	P	P	?		C	1,2		
Long-eared Myotis	Myotis evotis	Y		P	P	P	?	SC	M	2		
Long-legged Myotis	Myotis volans	Y		C	P	P	?	SC	M	2		
Californian Myotis	Myotis californicus	Y		C	P	P	?			2		
Silver-haired Bat	Lasionycteris noctivagans	Y		P	P	P	?					
Big Brown Bat	Eptesicus fuscus	Y		P	P	P	?			2		
Hoary Bat	Lasiurus cinereus	Y		P	P	P	?		M			
Townsend's Big-eared Bat	Corynorhinus (Plecotus) townsendii	Y		P	P	C	?	SC	C	1,2		

				Distribution by Island				Listing Status			Building Densities Tolerated	
Common Name	Scientific Name	Native to WA	Times Present	SJ	Orcas	Lopez	Shaw	Fed	State	State PS	Without Conservation Planning	With Conservation Planning
European Rabbit	Oryctolagus cuniculus	N	R	C	P	C	?					
Townsend's Chipmunk	Neotamias townsendii	Y	R	C	?	C					1du/ac to 4du/ac	>4du/ac to 7du/ac
Eastern Gray Squirrel	Sciurus carolinensis	Y	R			C						
Eastern Fox Squirrel	Sciurus niger	Y	R	P	C	P						
Douglas' (Red) Squirrel	Tamiasciurus douglasii	Y	R	?	C	?					1du/ac to 4du/ac	>4du/ac to 7du/ac
Northern Flying Squirrel	Glaucomys sabrinus	Y	R	C	P	?	?					
American Beaver	Castor canadensis	Y	R		C						1du/10	1du/ac to 4du/ac
Deer (White-footed) Mouse	Peromyscus maniculatus	Y	R	C	C	C	C				1du/ac to 4du/ac	>7du/ac
Townsend's Vole	Microtus townsendii	Y	R	C	C	C	?		M			
Muskrat	Ondatra zibethicus	Y	R	C	C	C	?				1du/ac to 4du/ac	>7du/ac
Black Rat	Rattus rattus	N	R	C	P	P	?					
Norway Rat	Rattus norvegicus	N	R	C	P	P	?					
House Mouse	Mus musculus	N	R	P	P	P	?					
Killer Whale (Orca)	Orcinus orca	Y		P	P	P	P	E	E	1,2		
Harbor Porpoise	Phocoena phocoena	Y		P	P	P	P		C	1,2		
Dall's Porpoise	Phocoenoides dalli	Y		P	P	P	P		M	2		
Gray Whale	Eschrichtius robustus	Y		P	P	P	P		S	1,2		
Red Fox	Vulpes vulpes	Y	R	C								
Steller's Sea Lion	Eumetopias jubatus	Y		P	P	P	P	T	T	1,2		
Raccoon	Procyon lotor	Y	R	P	P	C	C				>4du/ac to 7du/ac	
Mink	Mustela vison	Y	R	P	P	C	P			3	1du/10	1du/ac to 4du/ac
Northern River Otter	Lontra canadensis	Y	R	C	P	C	P				1du/20	1du/2.5
Harbor Seal	Phoca vitulina	Y	R	P	P	P	P		M	2		
Black-tailed Deer	Odocoileus columbianus	Y	R	C	C	C	C			3	1du/40 to 1du/80	1du/5

Appendix 4-B. Occurrence of SJC wildlife species by habitat type

Sources: WDFW (2009), Cassidy & Grue (2006), Lewis & Sharpe (1987), and author's experience.
Legend: State PS (Priority Species): 1= state-listed species, 2= protect vulnerable aggregations, 3= species of recreational or commercial importance

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Northwestern Salamander		X	X									
Long-toed Salamander		X		X	X	X	X					X
Rough-skinned Newt		X	X		X	X						X
Western Toad	1	X	X	X		X	X					
Pacific Treefrog		X	X	X	X	X	X		X			X
Northern Red-legged Frog		X	X	X	X	X						X
Bullfrog		X	X				X					
Red-throated Loon	2									X	X	
Common Loon	1,2	X								X	X	
Yellow-billed Loon	2									X	X	
Pacific Loon	2									X	X	
Pied-billed Grebe	2	X	X							X	X	
Horned Grebe	2	X								X	X	
Red-necked Grebe	2									X	X	
Eared Grebe	2	X								X	X	
Western Grebe	1,2	X								X	X	
Brown Pelican	1,2									X	X	
Double-crested Cormorant	2	X	X						X	X	X	
Brandt's Cormorant	1,2									X	X	
Pelagic Cormorant	2								X	X	X	
American Bittern		X										
Great Blue Heron	2	X	X				X	X	X	X		
Green Heron		X	X									
Tundra Swan	2,3	X						X				
Trumpeter Swan	2,3	X	X				X	X				
Greater White-fronted Goose	2,3						X	X		X		
Brant	2,3							X	X	X		
Canada Goose	2,3	X					X	X		X		X
Cackling Goose	2,3						X	X		X		

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Wood Duck	2,3	X	X									
Green-winged Teal	2,3	X					X	X		X		
Mallard	2,3	X	X				X	X		X	X	X
Northern Pintail	2,3	X						X		X	X	
Blue-winged Teal	2,3	X					X	X		X		
Cinnamon Teal	2,3	X					X	X		X		
Northern Shoveler	2,3	X					X	X		X		
Gadwall	2,3	X					X	X		X		
Eurasian Wigeon	2,3	X						X		X		
American Wigeon	2,3	X	X				X	X		X	X	
Canvasback	2,3	X								X		
Redhead	2,3	X								X	X	
Ring-necked Duck	2,3	X								X		
Greater Scaup	2,3	X								X	X	
Lesser Scaup	2,3	X								X		
Harlequin Duck	2,3								X	X	X	
Long-tailed Duck	2,3									X	X	
Black Scoter	2,3									X	X	
Surf Scoter	2,3									X	X	
White-winged Scoter	2,3									X	X	
Common Goldeneye	2,3	X	X							X		
Barrow's Goldeneye	2,3	X								X		
Bufflehead	2,3	X	X		X					X		
Hooded Merganser	3	X	X							X		
Common Merganser	2,3	X	X							X		
Red-breasted Merganser	2,3									X	X	
Ruddy Duck	2,3	X								X		
Turkey Vulture		X	X	X	X	X	X	X	X	X		X
Osprey		X	X							X		
Bald Eagle	1	X	X	X	X	X	X	X	X	X	X	X
Northern Harrier		X					X	X				
Sharp-shinned Hawk		X	X	X	X	X	X	X	X			X
Cooper's Hawk		X	X	X	X	X	X			X		X
Northern Goshawk	1		X	X	X							

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Red-tailed Hawk		X	X	X	X	X	X	X	X			X
Rough-legged Hawk		X					X	X				
Golden Eagle	1	X		X	X		X	X				
American Kestrel		X	X	X		X	X					
Merlin	1	X	X	X	X		X	X	X	X		X
Peregrine Falcon	1	X	X		X		X	X	X	X	X	X
Gyrfalcon							X	X	X	X		
Ring-necked Pheasant	3	X		X		X	X					X
Blue Grouse	3		X	X	X	X						
Wild Turkey	3		X	X	X	X						
California Quail		X		X		X	X					X
Virginia Rail		X										
Sora		X										
American Coot	2,3	X						X				
Sandhill Crane	1	X					X	X				
Black-bellied Plover	2							X				
American Golden-Plover	2	X					X	X				
Pacific Golden-Plover	2	X					X	X				
Semipalmated Plover	2							X				
Killdeer	2	X					X	X				X
Black Oystercatcher	2								X			
Greater Yellowlegs	2	X						X	X			
Lesser Yellowlegs	2	X						X				
Solitary Sandpiper	2	X										
Wandering Tattler	2											
Spotted Sandpiper	2	X						X	X			
Whimbrel	2							X				
Ruddy Turnstone	2							X	X			
Black Turnstone	2							X	X			
Surfbird	2							X	X			
Sanderling	2							X				
Semipalmated Sandpiper	2							X				
Western Sandpiper	2	X						X				
Least Sandpiper	2	X						X				

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Baird's Sandpiper	2	X						X				
Pectoral Sandpiper	2	X						X				
Dunlin	2	X					X	X				
Short-billed Dowitcher	2							X				
Long-billed Dowitcher	2	X										
Wilson's Snipe	2	X	X									
Red-necked Phalarope	2									X	X	
Parasitic Jaeger										X	X	
Franklin's Gull								X		X		
Bonaparte's Gull								X	X	X	X	
Heermann's Gull								X	X	X	X	
Mew Gull		X					X	X	X	X		
Ring-billed Gull		X						X	X	X	X	X
California Gull		X						X	X	X	X	
Herring Gull		X						X	X	X	X	
Thayer's Gull		X						X	X	X	X	
Western Gull		X						X	X	X	X	X
Glaucous-winged Gull		X						X	X	X	X	X
Glaucous Gull								X	X	X	X	
Caspian Tern	2	X						X	X	X	X	
Common Tern	2								X	X	X	
Common Murre	1,2										X	
Pigeon Guillemot	2								X	X	X	
Marbled Murrelet	1,2									X	X	
Ancient Murrelet	2										X	
Cassin's Auklet	1,2											
Rhinoceros Auklet	2									X	X	
Tufted Puffin	1,2,3									X	X	
Rock Dove							X					X
Band-tailed Pigeon	3		X		X	X						X
Eurasian Collared-dove							X					X
Mourning Dove	3	X	X	X		X	X					X
Barn Owl		X					X	X	X	X		X
Western Screech-owl		X	X	X		X						X

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Great Horned Owl		X	X	X	X	X	X					X
Snowy Owl		X					X	X				
Northern Pygmy-owl			X		X							
Barred Owl		X	X		X	X						
Long-eared Owl		X	X	X	X	X	X					
Short-eared Owl		X					X	X				
Northern Saw-whet Owl			X	X	X	X						X
Common Nighthawk		X	X	X		X	X					
Black Swift		X						X	X			
Vaux's Swift	1	X	X	X	X	X	X	X	X			X
Anna's Hummingbird						X	X					X
Rufous Hummingbird		X	X	X	X	X						X
Belted Kingfisher		X	X					X	X	X		
Red-breasted Sapsucker			X	X	X	X						X
Downy Woodpecker			X	X		X						X
Hairy Woodpecker			X	X	X	X						
Northern Flicker			X	X	X	X	X					X
Pileated Woodpecker	1		X	X	X	X						
Olive-sided Flycatcher			X		X							
Western Wood-pewee			X	X	X	X	X					X
Willow Flycatcher			X			X						
Hammond's Flycatcher			X		X	X						
Pacific-slope Flycatcher			X	X	X	X						
Say's Phoebe							X					X
Western Kingbird							X					X
Horned Lark												
Purple Martin	1	X						X		X		
Tree Swallow		X	X	X		X	X	X	X	X		X
Violet-green Swallow		X		X		X	X	X	X	X		X
N. Rough-winged Swallow		X					X	X	X	X		X
Cliff Swallow		X					X	X	X	X		X
Barn Swallow		X					X	X	X	X		X
Steller's Jay			X		X							X
American Crow		X	X	X	X	X	X	X	X			X

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Common Raven		X	X	X	X	X	X	X	X			X
Chestnut-backed Chickadee			X		X							X
Bushtit			X	X		X						X
Red-breasted Nuthatch			X	X	X	X						X
Brown Creeper			X	X	X	X						X
Bewick's Wren		X	X			X			X			X
House Wren					X	X						
Pacific (Winter) Wren			X	X	X							
Marsh Wren		X										
American Dipper			X						X			
Golden-crowned Kinglet			X	X	X	X						
Ruby-crowned Kinglet		X	X	X	X	X						X
Western Bluebird				X		X	X					
Mountain Bluebird				X	X	X	X					
Townsend's Solitaire			X	X	X	X						
Swainson's Thrush			X	X	X	X						
Hermit Thrush			X	X	X	X						
American Robin		X	X	X	X	X	X	X	X			X
Varied Thrush					X	X						X
American Pipit		X					X	X				
Cedar Waxwing		X	X	X	X	X						X
Northern Shrike		X					X					
European Starling		X	X	X	X	X	X	X	X			X
Hutton's Vireo			X	X	X	X						X
Warbling Vireo			X	X		X						X
Cassin's Vireo				X		X						
Orange-crowned Warbler			X	X		X						X
Yellow Warbler			X	X								
Yellow-rumped Warbler		X	X	X	X	X						X
Black-throated Gray Warbler			X			X						
Townsend's Warbler			X	X	X	X						X
MacGillivray's Warbler			X	X	X	X						
Common Yellowthroat		X	X			X	X					
Wilson's Warbler			X		X	X						

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Western Tanager			X	X	X	X						
Black-headed Grosbeak			X	X		X						X
Spotted Towhee			X	X		X						X
Chipping Sparrow				X		X	X					X
Vesper Sparrow							X					
Savannah Sparrow		X					X					X
Fox Sparrow			X	X	X							X
Song Sparrow		X	X	X	X	X	X	X	X			X
Lincoln's Sparrow		X					X					
White-throated Sparrow												X
Golden-crowned Sparrow		X	X	X		X						X
White-crowned Sparrow		X				X	X					X
Dark-eyed Junco			X	X	X	X						X
Red-winged Blackbird		X					X	X	X			X
Western Meadowlark		X					X					
Brewer's Blackbird		X	X	X		X	X					X
Brown-headed Cowbird		X	X	X	X	X	X					X
Purple Finch			X	X	X	X						X
House Finch							X					X
Red Crossbill			X		X							
Pine Siskin			X	X	X	X						X
American Goldfinch		X	X	X		X	X					X
Evening Grosbeak			X		X							X
House Sparrow												X
Vagrant Shrew		X	X	X	X	X	X	X	X			X
Little Brown Myotis (Bat)		X	X	X	X	X	X	X		X		X
Yuma Myotis		X	X	X	X	X	X	X		X		X
Keen's Myotis		X	X	X	X	X	X	X		X		X
Long-eared Myotis		X	X	X	X	X	X	X		X		X
Long-legged Myotis		X	X	X	X	X	X	X		X		X
Californian Myotis		X	X	X	X	X	X	X		X		X
Silver-haired Bat		X	X	X	X	X	X	X		X		X
Big Brown Bat		X	X	X	X	X	X	X	X	X		X
Hoary Bat	1,2	X	X	X	X	X	X	X		X		X

Common Name	State PS	Herbaceous Wetlands, Ponds, Lakes	Wooded Wetlands, Streams	Aspen Woods	Conifer & Mixed Forest	Oak Woods & Balds	Dry Grassland, Cropland	Beaches & Tidal Flats	Rocky Shore	Sheltered Marine Waters	Open Marine Waters	Resi-dential
Townsend's Big-eared Bat	1,2	X	X	X	X	X	X	X		X		X
European Rabbit	2						X					X
Townsend's Chipmunk	1,2		X		X	X						
Eastern Gray Squirrel						X						X
Eastern Fox Squirrel	1,2					X						X
Douglas' (Red) Squirrel					X							
Northern Flying Squirrel	3		X	X	X	X						
American Beaver		X	X	X								X
Deer (White-footed) Mouse	2	X	X	X	X	X	X	X	X			X
Townsend's Vole	3	X	X			X	X	X	X			
Muskrat		X	X									
Black Rat												X
Norway Rat												X
House Mouse												X
Killer Whale (Orca)											X	
Harbor Porpoise											X	
Dall's Porpoise	2										X	
Gray Whale	1,2										X	
Red Fox		X	X	X		X	X					X
Steller's Sea Lion	1,2									X	X	
Raccoon		X	X	X	X	X	X	X	X			X
Mink	3	X	X	X	X	X	X	X	X			X
Northern River Otter		X	X	X	X	X		X	X		X	
Harbor Seal	2								X	X	X	
Black-tailed Deer	3	X	X	X	X	X	X	X	X			X
Western Painted Turtle		X	X									
Northern Alligator Lizard				X		X		X	X			X
Rubber Boa			X	X	X	X	X					
Sharptail Snake	1			X		X	X					X
W. Terrestrial Garter Snake		X	X	X		X	X	X	X	X		X
Northwestern Garter Snake		X	X	X		X	X	X	X			X
Common Garter Snake		X	X	X	X	X	X	X				X

Appendix 4-C. Plant species considered to be rare in SJC by the Washington Natural Heritage Program (September 2010)

Note: These are mainly species which are rare statewide*, nationally, or globally. Dozens of species not listed here are believed to be rare just in SJC as reported in Atkinson & Sharpe (1985), and could disappear entirely from the county's flora, thus losing an important regional subpopulation.
State Status: E= Endangered, T= Threatened, S= Sensitive, X= no longer present?
Federal Status: LT= Threatened, SC= Species of Concern

Scientific Name	Common Name	State Status	Federal Status	Habitat
Carex pauciflora	few-flowered sedge	S		Wetlands (acidic bogs) at Mt. Constitution
Castilleja levisecta	golden paintbrush	E	LT	Native grasslands
Crassula connata	erect pygmy-weed	T		shorelines
Eurybia merita	Arctic aster	S		near summit of Mt. Constitution
Isoetes nuttallii	Nuttall's quillwort	S		Wetlands (seasonally dry)
Lepidium oxycarpum	sharpfruited peppergrass	T		Wetlands (seasonally dry)
Liparis loeselii	twayblade	E		Wetlands (acidic bogs)
Lobelia dortmanna	water lobelia	T		Wetland, pond, and lake margins
Meconella oregana	white meconella	T	SC	Native grasslands, moist meadows
Microseris bigelovii	coast microseris	X		open moist dunes and damp shaded bluffs
Ophioglossum pusillum	Adder's-tongue	T		Wetlands (acidic bogs)
Orthocarpus bracteosus	rosy owl-clover	E		Native grasslands
Oxytropis campestris var. gracilis	slender crazyweed	S		Native grasslands, open woodlands
Potamogeton obtusifolius	blunt-leaved pondweed	S		Wetlands, ponds, lakes
Ranunculus californicus	California buttercup	T		Native grasslands and bluffs
Sericocarpus rigidus	white-top aster	S	SC	Native grasslands
Symphyotrichum boreale	rush aster	T		Wetlands (acidic bogs)
Utricularia minor	lesser bladderwort	R1		Wetlands, ponds, lakes

* In addition, *Centaurium (Zeltnera) muehlenbergii* is currently under consideration for State listing as Threatened.

Appendix 4-D. Plant communities for which high-quality examples are considered rare in SJC by the Washington Natural Heritage Program (September 2010)

Note: Communities in bold are particularly uncommon or threatened in SJC (R. Barsh, pers. comm.) and are not entirely within protected preserves. A significant omission from this list is quaking aspen (*Populus tremuloides*) which also is uncommon and threatened.
Context: FW= freshwater wetland, SW= saltwater wetland, G= native grassland, U= other upland

Common Name of Plant Community	Dominant Form	Context	Scientific Name
Red Alder / Salmonberry	shrub	FW	Alnus rubra / Rubus spectabilis
Sitka Sedge	herbaceous	FW	Carex aquatilis var. dives
Cusick's Sedge - (Sitka Sedge) / Sphagnum moss	herbaceous	FW	Carex cusickii - (Carex aquatilis var. dives) / Sphagnum spp.
Bighead Sedge	herbaceous	FW	Carex macrocephala
Slough Sedge	herbaceous	FW	Carex obnupta
Coastal Spit with Native Vegetation		G	
California Oatgrass Valley Grassland	herbaceous	G	Danthonia californica
Saltgrass - (Pickleweed)	herbaceous	SW	Distichlis spicata - (Salicornia virginica)
Roemer's Fescue - Field Chickweed - Prairie Junegrass	herbaceous	G	Festuca roemeri - Cerastium arvense - Koeleria macrantha
Red Fescue - Great Camas - Oregon Gumweed	herbaceous	FW	Festuca rubra - (Camassia leichtlinii, Grindelia stricta var. stricta)
Red Fescue - Silver Burweed	herbaceous	G	Festuca rubra - Ambrosia chamissonis
Lagoon: Hyperhaline and Euhaline	herbaceous	SW	
Common Marestail	herbaceous	FW	Hippuris vulgaris
Bog Labrador-tea - Bog-laurel / Sphagnum moss	shrub	FW	Ledum groenlandicum - Kalmia microphylla / Sphagnum spp.
Low Elevation Freshwater Wetland	herbaceous	FW	
Low Elevation Sphagnum Bog	herbaceous	FW	
Lagoon, Mesohaline and Oligohaline	herbaceous	SW	
North Pacific Herbaceous Bald and Bluff	herbaceous	G	
Yellow Pond-lily	herbaceous	FW	Nuphar lutea ssp. polysepala
Lodgepole Pine - Douglas-fir	forest	U	Pinus contorta - Pseudotsuga menziesii cover type
Lodgepole Pine Forest	forest	U	Pinus contorta cover type
Shore Pine - Douglas-fir / Salal	forest	U	Pinus contorta var. contorta / Gaultheria shallon
Shore Pine / Bog Labrador-tea / Sphagnum moss	shrub	FW	Pinus contorta var. contorta / Ledum groenlandicum / Sphagnum spp.
Douglas-fir - (Grand Fir, Western Red-cedar) / Dwarf Oregon-grape - Salal	forest	U	Pseudotsuga menziesii - (Abies grandis, Thuja plicata) / Mahonia nervosa - Gaultheria shallon
Douglas-fir - Grand Fir	forest	U	Pseudotsuga menziesii - Abies grandis cover type

Common Name of Plant Community	Dominant Form	Context	Scientific Name
Douglas-fir - Pacific Madrone / Salal	forest	U	Pseudotsuga menziesii - Arbutus menziesii / Gaultheria shallon
Douglas-fir - Pacific Madrone / American Purple Vetch	forest	U	Pseudotsuga menziesii - Arbutus menziesii / Vicia americana
Douglas-fir - Oregon White Oak / Common Snowberry	forest	U	Pseudotsuga menziesii - Quercus garryana / Symphoricarpos albus
Douglas-fir - Western Hemlock / Salal / Swordfern	forest	U	Pseudotsuga menziesii - Tsuga heterophylla / Gaultheria shallon / Polystichum munitum
Douglas-fir - Western Hemlock / Salal	forest	U	Pseudotsuga menziesii - Tsuga heterophylla / Gaultheria shallon
Douglas-fir - Western Hemlock / Oceanspray / Swordfern	forest	U	Pseudotsuga menziesii - Tsuga heterophylla / Holodiscus discolor / Polysticum munitum
Douglas-fir - Western Hemlock / Dwarf Oregongrape	forest	U	Pseudotsuga menziesii - Tsuga heterophylla / Mahonia nervosa
Douglas-fir / Salal - Oceanspray	forest	U	Pseudotsuga menziesii / Gaultheria shallon - Holodiscus discolor
Douglas-fir / Baldhip Rose - Oceanspray	forest	U	Pseudotsuga menziesii / Rosa gymnocarpa - Holodiscus discolor
Douglas-fir / Common Snowberry - Oceanspray	forest	U	Pseudotsuga menziesii / Symphoricarpos albus - Holodiscus discolor
Oregon White Oak / Long-stolon Sedge - Common Camas	forest	G	Quercus garryana / Carex inops - Camassia quamash
Pickleweed	herbaceous	SW	Salicornia virginica (depressa, maritima)
Low salt marsh, sandy, high salinity	herbaceous	SW	
Hard-stem Bulrush	herbaceous	FW	Schoenoplectus acutus
Douglas' Spirea / Sphagnum moss	shrub	FW	Spiraea douglasii / Sphagnum spp.
Western Redcedar - Grand Fir / Swordfern	forest	FW	Thuja plicata - Abies grandis / Polystichum munitum
Broad-leaf Cattail	herbaceous	FW	Typha (latifolia, angustifolia)

Appendix 4-E. Surface water quality from from WDOE's WQA database

Some additional data from the County and other sources is not included in this summary. Data were not based on temporally or geographically systematic sampling. Query the online WDOE database for details on locations, dates, and methods.

Parameter	# of samples	Average	Minimum	Maximum
Ammonia (mg/L)	36	3.05	0.05	5.43
Arsenic (µg/L)	4	0.17	0.10	0.26
Arsenic III (µg/L)	4	0.06	0.03	0.09
Cacodylic acid (µg/L)	4	0.05	0.05	0.05
Chlorophyll (µg/L)	5	8.52	0.92	32.40
Conductivity (µmhos/cm)	53	139.47	46.00	245.00
Dissolved Oxygen (mg/L)	323	8.78	0.20	19.30
Fecal Coliform (# of colonies/ 100 ml)	209	85.34	0.00	2000.00
Hardness as CaCO3 (mg/L)	3	45.00	36.00	58.00
Monomethylarsonic acid (MMA) (µg/L)	4	0.03	0.01	0.05
Nitrate (mg/L)	36	0.35	0.01	0.81
Ortho-phosphate (mg/L)	61	5.03	0.00	30.00
pH	323	7.83	6.20	10.10
Phosphorus (µg/L)	2	10.00	10.00	10.00
Total Inorganic Arsenic (µg/L)	4	0.06	0.04	0.08
Total Persulfate Nitrogen (mg/L)	8	0.48	0.03	1.20
Total Phosphorus (µg/L)	8	49.84	1.30	219.00
Turbidity (NTU)	217	6.23	0.00	38.90
Water transparency, Secchi disc (feet)	4	16.50	3.00	30.00

Appendix 4-F. Environment Summary Tables from GIS Compilation of Existing Spatial Data

Compiling the Best Available Science involves compiling information not only from published literature, but also from the best available spatial data (digital maps) that are available for a county or city and relevant to understanding the particular type of critical area being addressed. Accordingly, we used GIS to quantify (in tables) several environmental themes from existing maps. This is useful for understanding the gross structure in SJC of habitat and land use, and potential impacts to species. Available environmental data have been tabulated below by major island. At project completion tables will also be available compiling data by watershed and protected vs. non-protected lands. As with all such efforts, the reliability of the compiled information is no better than the quality of the original data. Much of that has significant constraints, many of which (when known) are noted in metadata files provided to the CD&P.

4F-1. Environment by Island

Appendix 4F-1.1 Land acres and shoreline length by island

Island	Acres	Shoreline Length (ft)
Shaw	4889	136276
Lopez	18995	334607
Decatur	2237	65704
Center	168	10576
Blakely	4302	64427
James	117	12332
Waldron	2905	58998
Jones	187	15802
Orcas	36991	407963
Crane	226	14214
Patos	208	19911
Little Sucia	15	4752
Sucia	552	62261
Matia	152	17980
Obstruction	220	15290
Stuart	1823	78597
Henry	999	57380
San Juan	35503	393849
Spieden	505	32467
Johns	222	22078
TOTAL	111214	1825465

Appendix 4F-1.2. Elevation by island

	Maximum	Average
Shaw	384	122
Lopez	534	137
Decatur	550	167
Center	172	77
Blakely	1040	435
James	272	103
Jones	197	66
Orcas	2409	488
Crane	155	68
Obstruction	255	113
Henry	311	84
San Juan	1075	195

Appendix 4F-1.3. Area (acres) in various slope categories by island

Islands not shown lacked LiDAR data used in this analysis.

PERCENT SLOPE	Shaw	Lopez	Decatur	Center	Blakely	James	Jones	Orcas	Crane	Obstruction	Henry	San Juan
0 percent	44	216	24	2	23	5	3	119	2	11	16	101
0-1 %	55	408	23	1	34	0	1	393	2	0	15	727
1-2 %	134	1042	58	3	63	0	2	765	5	1	33	1691
2-3 %	195	1402	82	5	71	1	3	962	7	2	42	2159
3-4 %	239	1523	96	6	70	1	4	1060	9	3	48	2317
4-5 %	263	1484	103	7	67	1	5	1102	10	4	52	2287
5-7 %	550	2603	209	16	131	3	12	2211	22	10	107	4149
7-10 %	779	2961	290	25	207	6	20	3173	32	20	146	5037
10-15 %	978	3068	375	34	389	12	31	4664	44	39	184	5807
15-20 %	582	1625	249	22	418	11	24	3862	29	37	113	3570
20-30 %	538	1368	291	23	779	18	30	5816	29	43	107	3659
>30 %	541	1322	440	23	2056	59	53	12914	35	48	135	4048

Appendix 4F-1.4. Number of buildings by island

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases.

	Blakely	Center	Crane	Decatur	Lopez	Obstruction	Orcas	San Juan	Shaw	Stuart	Waldron	Total
Commercial	24	4			101	2	249	78	6			464
Residential	142	133	57	2	2060	41	3497	3749	238	2	1	9922
Town								1255				1255
Other	89	60	5	1	799	17	2088	2218	156	2		5435
Total	255	197	62	6	2960	60	5834	7302	401	4	1	17082

Appendix 4F-1.5. Length (miles) of road by island

Raw data provided by San Juan County, August 2010. No guarantee is made of its comprehensiveness or accuracy in all cases.

	Blakely	Center	Crane	Decatur	Henry	Lopez	Obstruction	Orcas	San Juan	Shaw	Stuart	Waldron	Total
Private roads	10.00	3.11	2.77	13.78	4.35	63.62	2.29	175.36	133.94	12.55	5.74	1.67	429.18
Public roads	0.00	0.00	0.00	7.57	0.00	68.75	0.00	87.13	109.89	14.23	3.20	4.54	295.30

Appendix 4F-1.6. Length (ft) of driveway by island

	Blakely	Center	Crane	Decatur	Lopez	Obstruction	Orcas	San Juan	Shaw	Stuart	Waldron	Total
Total	119916	21326	15227	981	772649	10609	1318354	1456265	130102	347	410	3846185

Appendix 4F-1.7. Estimated length (ft) of perennial and possible intermittent streams by island

Based on automated interpretation of LiDAR topographic imagery. Not field-verified.

	Blakely	Center	Crane	Decatur	Henry	James	Jones	Lopez	Obstruction	Orcas	San Juan	Shaw	Total
Perennial or Higher Confidence Intermittent	138404	2116	4036	50909	9633		2156	494449	1771	1262696	1106616	121511	3194298
Low Confidence Intermittent	102277	361	3399	58315	17092	1474	1372	520875	285	1097802	1041787	105039	2950079
Total	240682	2478	7435	109224	26725	1474	3528	1015324	2057	2360498	2148403	226550	6144377

Appendix 4F-1.8. Acreage of mapped ponds and lakes by size category and island

Raw data provided by San Juan County, August 2010. Many small ponds are known to be missing from these data.

	All ponds and lakes			Ponds 5-20 acres			Lakes (>20 acres)		
	Count	Sum of Acres	Average Acres	Count	Sum of Acres	Average Acres	Count	Sum of Acres	Average Acres
Blakely	3	144	48				2	70	140
Crane	1	0	0						
Decatur	6	6	1						
Henry	4	2	0						
Lopez	117	81	1				1	34	
Orcas	305	663	2	9	11	96	4	105	34
San Juan	503	668	1	13	10	133	6	46	421
Shaw	44	32	1	2	7	13			278
Stuart	4	1	0						
Waldron	20	19	1	1	12	12			
Grand Total	1007	1616	2						

Appendix 4F-1.9. Lithology of major islands (acres, by type of rock or deposit)

Raw data provided by San Juan County, August 2010.

Type of Rock or Deposit	Blakely	Decatur	Henry	Lopez	Orcas	San Juan	Shaw	Spieden	Stuart	Sucia	Waldron
advance continental glacial outwash, Fraser-age				116.9			50.27				
alluvium						71.46					17.65
artificial fill, including modified land						5.48					
basalt flows		51.25		783.28							
beach deposits	23.6	60.84	42.96	135.42	65.68	35.71	28.88		83.9		88.62
chert-rich marine sedimentary rocks					4549.39		316.52				
continental glacial drift, Fraser-age	292.06		130.68	1692.69	5322.09	8132.24	309.24		9.61	100.63	1889
continental glacial outwash, Fraser-age				725.24							
continental glacial outwash, marine, Fraser-age					1343.84	477.41					
continental glacial till, Fraser-age	64.03	818.08	46.55	6517.98	1289.09	4102.33	530.96				
continental sedimentary deposits or rocks										399.91	
dune sand				7.55		21.02					
glacial and non-glacial deposits, undivided		5.51									
glaciomarine drift, Fraser-age		188.73		4542.58		3096.91	91.46				
intrusive rocks, undivided	3681.18	60.12	7.09		8335.58	137.83					
marine metasedimentary rocks			12.22	31.76	784.89	13725.46					
marine sedimentary rocks	55.18	1026.3		1356.57	9670.34	729.07	3408.12			34.39	
mass-wasting deposits, mostly landslides		6.92									
metasedimentary and metavolcanic rocks, undivided			1.1		476.44						
metasedimentary rocks, chert-bearing			742.83		20.13	2921.16	129.79				
metasedimentary rocks, cherty						763.22					
metavolcanic rocks				2750.91		505.91					
nearshore sedimentary rocks					164.18	75.34		496.61	1700.86		877.29
peat deposits				164.28		23.98					
schist, low grade						159.81					
tectonic zone	30.7			29.13	190.62						
tonalite				14.43		8.56					
volcanic and sedimentary rocks					4080.35						
volcanic rocks					131.7						
water	134.48	2.16		41.4	476.17	373.74					
Total	4281.23	2219.91	983.43	18910.12	36900.49	35366.64	4865.24	496.61	1794.37	534.93	2872.56

Appendix 4F-1.10. Public and other lands protected for conservation

Raw data provided by San Juan County, August 2010.

	Blakely	Crane	Decatur	Henry	Johns	Lopez	Orcas	San Juan	Shaw	Stuart	Sucia	Waldron	others	Total
Land Bank - Fully Built Out Conservation Easements				20.59		100.46	248.85	310.49				218.86	0	899.25
Land Bank Preserve						171.35	2184.53	762.46					0	3118.34
San Juan County Parks						44.64	1	19.23	17.63				0	82.5
San Juan Preservation Trust - Fully Protected Conservation Easement	60.35	16.74	11.76	32.14		809.41	1468.35	899.29	474	77.97		55.92	0	3905.93
San Juan Preservation Trust Preserve			112.74	41.18		140.14	281.66	474.32	256.86	115.4		437.72	0	1860.02
WDNR							76.39						0	76.39
WDFW	0	0	0	0	0	5.07	145.1	0	0	0	0	0	0	150.17
Washington Parks & Rec	0	0	0	0	5.75	58.26	672.46	40.11	0	0	0	0	0	776.58
State Lands DIvision	195.46					259.27	4811.51	437.54		85.13	551.95		136.58	6477.44
The Nature Conservancy												476.78	0	476.78
US Coast Guard						23.97							0	23.97
US-BLM						368.79							0	368.79
US government (other)				62.14		64.17		1706.36		74.12			546.8	2453.59
Univ. Washington								365.1					0	365.1
Protected Acres	255.81	16.74	124.5	156.05	5.75	2045.53	9889.85	5014.9	748.49	352.62	551.95	1189.28	683.38	21034.85
Island Acres	4302.13	225.68	2236.53	999.11	221.81	18995.22	36990.63	35503.29	4888.69	1822.68	551.96	2904.99	846.62	110489.34
% protected	6%	7%	6%	16%	3%	11%	27%	14%	15%	19%	100%	41%	81%	19%

Appendix 4F-1.11. Landscape disturbance scores assigned by Jacobson (2008) based mainly on maps of 1990's land use and current road density

See section 4.3.1.5 for description of Jacobson's Local Habitat Assessment for SJC. Units shown in this table are number of pixels (equal-sized land units) having that disturbance score. Disturbance scores were calculated based only on road density and assumed intensity of land use.

Potential Disturbance	Blakely	Center	Crane	Decatur	Henry	Johns	Jones	Lopez	Obstruction	Orcas	Patos	San Juan	Shaw	Spieden	Stuart	Sucia	Waldron
1 MOST								2		21		226					
2								76		210		462	1				
3	19			145				795		1505		1858	72		20		13
4	61	35	20	107	10			737	1	1610		1008	186		61		83
5	59	8	9	3	15	1		1706	3	663		1915	81	37	5		80
6	48			9	25	5	0	2766		923		4777	29		4	1	2
7	3		5	181	3	2		661		1562		1959	128	13	53		11
8	83	1	4	850	25	8		5245		10376	0	8414	1439	257	351	2	423
9	1945	121	184	837	590			5820	203	13965		11701	2117		979		1043
10	1911			62	306	197	183	952	2	5437	200	2526	747	188	308	537	1229
1 1 LEAST	139		0	4	1			61		549		499	13				
	4267	165	222	2198	975	212	183	18822	209	36821	200	35345	4812	495	1782	539	2885

CHAPTER 5

BEST AVAILABLE SCIENCE
Frequently Flooded Areas

CHAPTER 5 CONTENTS

FREQUENTLY FLOODED AREAS: REVIEW OF THE SCIENTIFIC LITERATURE

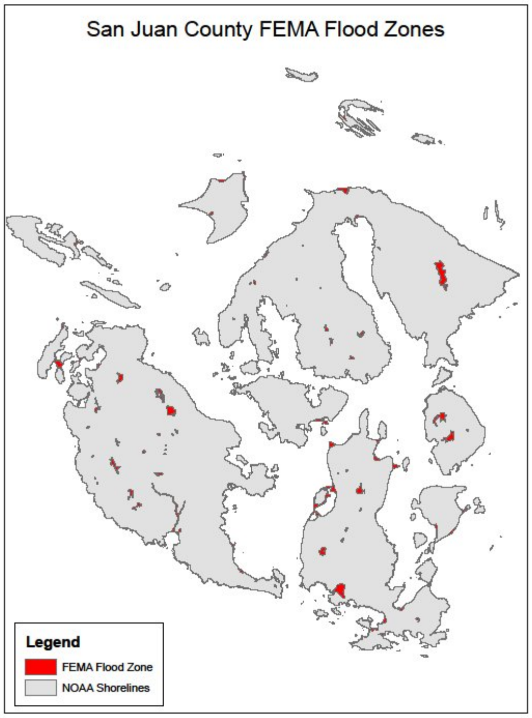
5.1 Frequently Flooded Areas in San Juan County

Floodplains and areas subject to flooding provide important hydrologic and habitat functions. This is especially true of large riverine floodplain areas. Most flood science existing today is focused on the management of large floodplains, channel migration, the transport of large woody debris through watercourses, and severe stream-related flooding events. San Juan County lacks the major fresh water riverine systems of mainland Washington counties and therefore has less severe stream-related flood events. San Juan County's primary threat in regard to flood danger is coastal flooding, which occurs throughout the county on shorelines with low-lying developments.

Coastal flooding usually occurs when large storm systems bring heavy precipitation and high winds, especially when such storms occur during high tide (Mofjeld 1992). The entire shoreline of San Juan County is currently designated as a "Zone A" (Special Flood Hazard Area) because tidewaters rise above the ordinary high water mark (OHWM) during storm events of this type. In addition to the flooding of shoreline properties, flooding can occur throughout the inland areas of the County on lands adjacent to lakes, ponds, wetlands, swales, and any other low-lying areas where water accumulates. This is especially true for areas with undersized or inadequately maintained drainage structures. There are very few mapped Frequently Flooded Areas in the inland of San Juan County. Those that are mapped are shown in Exhibit A.

Frequently Flooded Areas present a risk to persons and property, and historically, regulations for these areas have focused on safety. Increased awareness of the ecological value provided by Frequently Flooded Areas (*i.e.*, the habitat functions performed by both the floodwaters and floodplains) has led to regulations that recognize and better protect those functions. The San Juan County Comprehensive Plan, which guides all land use regulations in the County, includes policies for Frequently Flooded Areas that explicitly protect "*the important hydrologic role of frequently flooded areas*." These functions include: groundwater recharge, the safe conveyance of floodwaters, transport of woody debris, temporary alteration of habitat, and moderating the salinity of water for eelgrass. The protection of these functions can be accomplished through identification and designation, avoidance (when possible), and otherwise mitigating the impacts of development in these hazard areas. Frequently Flooded Areas are regulated under the San Juan County Unified Development Code in Sections 18.30.130 (Critical Areas, Frequently Flooded Areas), 13.04 (Stormwater Utility), 15.04 (Construction Codes Adopted), and 15.12 (Flood Hazard Control Regulations).

Exhibit A: FEMA Flood Zones. Source: San Juan County GIS 2010. (Note: this graphic is for illustrative purposes only. Please refer to the Community Development & Planning Department for large-scale, detailed maps. The FEMA-designated coastal flood zones may not be visible due to the scale of the map).



5.2 Flood Hazard Area Mapping

The Washington Administrative Code (WAC 365-190-110(1)) directs that critical areas designated as Frequently Flooded Areas include, at a minimum, those lands located within the 100-year floodplain as shown on Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs). (The 100-year flood is commonly referred to as the "base flood.") San Juan County has complied with this directive and uses these maps as the basis for designating Frequently Flooded Areas. Those areas shown as "Zone A" (Special Flood Hazard Area) on the FIRMs are regulated to protect the public health and safety from flooding. FEMA generated a set of FIRMs for San Juan County on June 7, 1977. These maps illustrate the extent of the base flood and are used in the implementation of the National Flood Insurance Program (NFIP).

Development of the first FIRMs relied heavily on information provided by the U.S. Geological Survey, U.S. Army Corps of Engineers, and private engineering firms. Many inaccuracies and errors have been found in the FIRMs for San Juan County, and they have not been comprehensively ground-tested. Despite these deficiencies, no other set of maps covers the area for which the FIRMS do for San Juan County, nor is there any more detailed flood data available from another source (with the exception of highly-localized, site-specific studies undertaken by individual property owners). Further, San Juan County's participation in the NFIP requires the use of these maps. Therefore, although the FIRMs are often erroneous, they are the most comprehensive source of inundation data available at this time and are the county's primary resource in determining flood hazard areas. For the purposes of developing an individual property, site-specific studies (as opposed to the FIRMs) yield the most accurate and detailed data; this is due to technological advances in surveying, bathymetry, hydrology, and hydraulics since the 1977 mapping effort.

The National Flood Insurance Program was established as part of FEMA in 1968 following the passage of the National Flood Insurance Act. The NFIP provides three flood-related services to participating communities: the identification (and mapping) of areas subject to flooding, the provision of federally-backed flood insurance, and the administration of floodplain management regulations that reduce flood damage. Communities are not required to participate in the NFIP; however, more than 20,000 communities in the United States currently participate in the program (FEMA 2010). Participation requires that the jurisdiction adopt and enforce floodplain management ordinances that reduce future flood damage and that they adhere to the minimum requirements of the NFIP as described in 44 CFR 60. The NFIP also requires that each jurisdiction meet all the requirements of the state in which it is located, even if the state standards are more restrictive than federal standards. (For Washington, these are found in RCW 86.16.) In communities that elect not to participate, the NFIP prohibits federally regulated banks, lenders, or federal agencies from providing mortgages or loans for the acquisition or development of properties within designated flood hazard areas.

5.3 Additional Considerations

The Washington Administrative Code (WAC) directs jurisdictions to consider the following in the designation and classification of Frequently Flooded Areas:

• Effects of flooding on human health and safety, and to public facilities and services;
• Available documentation including federal, state, and local laws, regulations, and programs, local studies and maps; and federal flood insurance programs, including the provisions for urban growth areas in RCW 36.70A.110;
• The future flow floodplain, defined as the channel of a stream and that portion of the adjoining floodplain that is necessary to contain and discharge the base flood flow at build-out; and
• Greater surface runoff caused by increasing impervious surfaces.

Coastal hazards within Frequently Flooded Areas are also specifically addressed in the WAC, with direction given to consider the effects of tsunami waves, high tides with strong winds, sea level rise, and extreme weather events, including those potentially resulting from global climate change (WAC 365-190-110(2)(d)).

5.3.1 Increased Impervious Surfaces

The impacts of impervious surfaces related to commercial and residential development affect Frequently Flooded Areas by facilitating the rapid accumulation of large volumes of water in concentrated areas. Ponding and flooding can occur in any low-lying area with poor drainage, which can lead to habitat alteration or damage, hazards to humans, and the transport of pollutants through the environment.

The conversion of natural land to developed land decreases the amount of land available for the infiltration of precipitation. However, stormwater runoff from impervious surfaces is not considered a major contributor to flood hazards in San Juan County, as the greatest hazard exists in areas prone to coastal flooding. In those areas where uncontrolled stormwater does accumulate and therefore exacerbates the impacts of other sources of flooding, the effects can be minimized by the use of Low Impact Development (LID) practices and installation and maintenance of adequate drainage, treatment, and flow control facilities. LID combines the use of on-site natural features and engineered systems to re-create pre-development hydrologic functions. Primary goals of this practice include minimized site disturbance and decreased reliance on Best Management Practices (BMPs) for the mitigation of impacts. The most comprehensive source of LID techniques appropriate for implementation in the Puget Sound region is the *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Action Team 2005). (LID is more completely discussed in Chapter 7, Alternatives for Stormwater Management.) It should be noted that the site-specific implementation of LID practices does not compensate for the cumulative adverse impacts of road networks, parking areas, and development, but LID can and should be included as part of a local, comprehensive stormwater program due to its cumulative benefits on a watershed scale (Puget Sound Action Team 2005).

5.3.2 Tsunami Waves

San Juan County boasts over 400 miles of coastline, with much of the islands' development situated in these areas. Although the most significant impacts of tsunami waves would be borne by communities along the outer coast of Washington, the waves from a subduction earthquake would also enter the inland waters of the Puget Sound through the Strait of Juan de Fuca (although at a diminished intensity). There is also some potential for a tsunami to originate within the interior waters of Washington: from smaller earthquakes in one of the small surface faults in San Juan County or one of the two large faults that exist just outside the County (the Devils Mountain and South Whidbey Island faults). Tsunami waves from these smaller, local sources would be larger and more damaging to San Juan County, due to the proximity of its point of origin to the County. The anticipated inundation from such a wave therefore warrants special consideration in the designation and protection of Frequently Flooded Areas.

A tsunami is a series of long-wavelength, long-period sea waves generated by abrupt vertical displacements of large amounts of water, typically following seismic movement of the ocean floor. These waves usually result from subduction earthquakes of a magnitude of 7.5 or greater on the Richter scale (USGS 2010). In the Puget Sound region, this would likely take the form of a Cascadia subduction zone earthquake (SJC/FH DEM 2004). Tsunami waves can also result from large, sudden disturbances to the surface of a semi-enclosed body of water, such as a deep-seated bedrock landslide in San Juan County. In the open ocean, the wave heights of tsunamis are typically small and can have large distances between crests. Because of these distances, they can reach the shore in wave periods ranging from five minutes to one hour. Tsunami waves do not usually manifest in a singular wave but rather are generated in sets (or "trains"), the first of which is usually not the biggest (especially if the tide is rising at the time the tsunami approaches the shore). These waves can travel across the open ocean at speeds of approximately 600 miles per hour (WMD 2010). As tsunami waves approach the coast and less distance exists between the ocean floor and the surface of the water, the waves slow and compress, causing the swell to greatly increase in height before landfall. For this reason, a wave that was only a few inches in height at sea may grow to dozens of feet by the time it meets the shore.

Computer models indicate that a Cascadia-generated tsunami could reach nearly 30 feet in height and affect the entire ocean coast of Washington. The first wave would likely reach coastal communities within 30 minutes after the earthquake, and communities along the Strait of Juan de Fuca in 90 minutes (WMD 2010). A tsunami would endanger people, homes, marinas, and other types of development along the majority of the County's low-lying coastlines. Due to the protected nature of Puget Sound, a tsunami originating from geologic movement in the Pacific Ocean would likely result in a surge of approximately ten feet above mean high tide in San Juan County, to a maximum of 20 feet at the head of long inlets (SJC/FH DEM 2010). This wave would resemble a sudden surge of the tidal waters rather than a large cresting wave. The San Juan County/Town of Friday Harbor Department of Emergency Management (SJC/FH DEM) characterizes such an event as the tide coming in over a series of minutes rather than hours (2010). The surge would have a different appearance and impacts if it occurred during high tide, during a wind storm with heavy precipitation, or both.

Earthquakes in the Pacific Ocean that can generate tsunamis that sweep through the Pacific basin occur at a frequency of about six per 100 years. The National Oceanic and Atmospheric Administration (NOAA) maintains a notification system (the Emergency Alert System), that is tied into the West Coast Tsunami Warning Center. The data is gathered in Hawaii and Alaska and disseminated throughout the Pacific region. This system can issue a tsunami warning within 15 minutes of an earthquake. Within the Puget Sound, the likelihood of a tsunami resulting from an earthquake of at least a 9.0 magnitude in the next 50 years is estimated at about 10-14 percent (WMD 2010). In A.D. 900-930, the Seattle Fault caused uplift that triggered a tsunami within the Sound. Both above-water and underwater landslides can also trigger tsunamis; in 1949, a landslide into the Tacoma Narrows set off a tsunami several days after an earthquake in Olympia (WMD 2010). Landslides in the subaqueous Fraser River delta in Canada could trigger tsunamis that would primarily affect San Juan County islands that have northwestern exposure to the Salish Sea (Rabinovich et al. 2003). Johnson et al. (1996) has found evidence that significant strain has accumulated on the South Whidbey Island Fault, which could produce a large tsunami (*i.e.*, several dozen feet in height) in the Puget Sound.

Although other counties in the Puget Sound region maintain an official tsunami hazard map, San Juan County does not currently have one. The San Juan County/Town of Friday Harbor Department of Emergency Management utilizes information from the 1977 FIRMs in planning for evacuations, augmented with selected information from other map sources. This evacuation map is not considered a comprehensive tool for tsunami hazard planning. For example, the map does not include bathymetric data for the shorelines, which help to determine the "run-up" zones for tsunami hazard areas (run-up zones are the areas that would be inundated to any degree during a tsunami). The Washington State Department of Natural Resources has produced a soils liquefaction map for San Juan County, which identifies areas of solid earth that can shake so intensely during seismic events that the soil loses its structural cohesion and behaves like a liquid. This type of map, when used in concert with Light Detection and Ranging (LiDAR) graphic information (available within the San Juan County's Geographic Information System), can be a useful tool for identifying areas of both seismic and tsunami risk. The LiDAR graphics can illustrate the full extent of low elevation areas that would be inundated during a tsunami event. Tsunami hazard area maps should also include the full tsunami run-up zone.

A tsunami would most intensely affect those coastal areas already designated as Special Flood Hazard Areas on the FIRMs. As such, development and infrastructure should be avoided in these locations, where possible. However, development can and does occur in these areas when floodplain management standards can be properly adhered to. Essential public facilities (where practicable) and any structure where the primary purpose is congregation should not be sited within these hazard areas, particularly due to the need for safe, operational emergency facilities in the recovery period following a tsunami.

5.3.3 Sea Level Rise

On a global scale, it is widely accepted throughout the scientific community that global climate change is occurring. Climate change has been shown to increase stream temperatures (particularly in the summertime: Mantua et al. 2010), compromise habitat restoration success (Battin et al. 2010), increase wave energy (Allan and Komar 2006) and increase sea level (Canning 2005, Mote et al. 2008). Sea level rise is the result of several factors, including: the thermal expansion of ocean waters, vertical land deformation (*e.g.*, tectonic movements), and melting glaciers and ice fields (Glick et al. 2007), as well as seasonal water surface elevation changes due to local atmospheric circulation effects (Mote et al. 2008).

Thermal expansion is a process that occurs when seawater expands as it is warmed. The source of this added warmth affecting the oceans is increased global temperatures. Rising global temperatures are largely attributable to increased carbon emissions into the Earth's atmosphere. Human activities are responsible for the majority of the carbon emissions currently being released into the atmosphere (IPCC 2007). Among the variables contributing to sea level rise, the thermal expansion of seawater accounts for approximately one-half of the projected sea level rise in the 21st century (Mote et al. 2008). Considering this, changes in global carbon emissions can ultimately impact the amount of sea level rise. Global climate change and the associated rise in sea level may affect Critical Areas in the long-term by exacerbating seawater intrusion into groundwater and changing shoreline habitat.

5.3.3.1 Temperature Changes

The application of simple physics, as well as observation of geological evidence, dictates that increased greenhouse gases in the atmosphere leads to an increased air temperature on the Earth's surface (Mote et al. 2005). During the 20th century, the Earth's average air temperature rose approximately 1.1°F; an unprecedented change within the last 1,000 years (Mann et al. 2003. von Storch et al. 2004, and Moberg et al. 2005; as cited in Mote et al. 2005).

Based on historical temperature data collected throughout the Puget Sound region during the 20th century, average annual temperatures in this region have risen more rapidly (1.5°C [2.3°F]) than temperatures during the same time period for the entire Pacific Northwest region of the United States (0.8°C [1.4°F]) (Mote et al. 2005). This is partly due to meteorological influences of El Niño and the Pacific Decadal Oscillation. El Niño and the warm phase of the Pacific Decadal Oscillation (PDO, a pattern of inter-decadal climate variability, characterized by changes in sea surface temperature, sea level pressure, and wind patterns) bring warmer winters to the Pacific Northwest. The three warmest winters on record in the Puget Sound have been during El Niño years (Mote et al. 2005). The combined influence of El Niño and the PDO must be accounted for in order to accurately assess the temperature trends in the Puget Sound region over the 20th century; to do so, Mote et al. (2003) performed a regression analysis using the North Pacific Index (NPI), which reflects the variability of both the PDO and El Niño and their influence on atmospheric circulation in the region. The analysis showed that the NPI accounts for about 40% of the 20th century warming trend in winter months, but has very little influence over the trends observed in other seasons (all of which contribute to the average annual temperature). Regarding future increases in Pacific Northwest temperatures, climate models have predicted an average rise of 0.6 °F per decade for the period of 1990 to 2040 (Mote et al. 2005).

Historical data from the NOAA Friday Harbor water level station observed between 1934 and 2006 has shown a local average increase of 1.13 mm/year, with a confidence interval of ±0.33 mm. Using only these numbers and assuming a linear relationship, this would result in an increase of 0.37 feet in 100 years (NOAA 2010).

5.3.3.2 Projections for Sea Level Rise

The 2007 *IPCC Fourth Assessment Report* (also referred to as "AR4") is a good foundational overview of the science, impacts, and mitigation of climate change. However, since its publication, its predictions have been bolstered and refined by other research, including but not limited to clarifying the link between fossil fuel emissions and global climate change, and the accelerated speed of melting of the Greenland ice sheet and warming of Antarctica (Pew 2009). The overall anthropogenic contribution to climate change has also become better understood. In the years following the 2007 IPCC report, scientific research has improved methodologies and produced varying estimates of sea level rise that are higher than predicted in AR4. Additionally, technological advancements, such as improved satellite observations, have enhanced the scientific community's understanding of polar ice sheet processes. The estimates of the IPCC report are discussed here, with additional information from some later studies.

According to the IPCC, the factors of thermal expansion, geologic movement, and melting glaciers and ice fields contributed approximately 3.1 mm (±0.7 mm) of sea level rise globally per year between 1993 and 2003 (IPCC 2007). Estimates of future global sea level rise are primarily determined through tide gauge records, considered with either numeric models or actual measurements of the Earth's tectonic movement. The long-term projections for sea level rise are given as ranges. These estimates incorporate such a multitude of factors that, given a sudden, dramatic change in any of the variables, the far estimate (on either end of the spectrum) may become more accurate. The projections reflect various scenarios illustrating human actions such as reduced, increased, or unchanged carbon dioxide levels.

By the year 2100, the IPCC projected that global sea levels will rise 7.1" (inches), 13.4", or 23.2" (provided as low, intermediate, or high estimates, respectively) (IPCC 2007). Later studies have built upon these numbers by considering additional variables for global sea level rise, such as accelerated ice sheet loss or different future emission scenarios. Cayan et al. (2008) is perhaps the most widely referenced refinement of the IPCC's global sea level rise projections; this study added an important element to the body of knowledge for sea level rise modeling, taking into account the volumes of water stored in the world's dams. This is a potential (and somewhat "masked") contributor of water to the oceans (i.e., if not diverted, this water would have added to the volume of surface water bodies). This study also included "low" and "high" greenhouse gas emission scenarios, as did the IPCC. The study yielded two levels of projection: low and high estimates of 19.7" and 55.1," respectively. (It should be noted that other models, namely those extrapolating a linear relationship over time, have provided much higher rates of sea level rise than the 2007 IPCC projections [Rahmstorf, 2007; as cited in Mote et al., 2008]. However, linear models are much more sensitive to changes in variables; meaning, small changes in the contributing factors can yield large changes in final conclusions; therefore, caution should be exercised when interpreting the results of such models.)

The model employed by the U.S. Army Corps of Engineers uses some global projections as its foundation (namely, the IPCC numbers and the modified curves and equations from the 1987 National Research Council's *Responding to Changes in Sea Level: Engineering Implications*), and it also is tailored to local conditions by the addition of historic data from local tide gauges and local vertical land movement estimates (USACE 2009). Table 1, below, compares the projections from the IPCC 2007 study, USACE model, and Cayan 2008 study. (Note that the Cayan study does not include an "intermediate" figure because the study yielded only two levels of projection.)

Table 1. Comparison of Global Sea Level Rise Projections for the Year 2100			
	LOW	**INTERMEDIATE**	**HIGH**
IPCC "AR4" (2007)	18 cm (7.1 in)	34 cm (13.4 in)	59 cm (23.2 in)
USACE (2009)	Historic (tide gauge)	34 cm (13.4 in)	150 cm (59 in)
Cayan et al. (2008)	50 cm (19.7 in)	-	140 cm (55.1 in)

* This table adapted from Clancy et al. 2009.

In the Puget Sound region, there are additional local factors that influence sea levels. These include: subduction of tectonic plates, isostatic rebound, oceanic winds, coastal winds, and local atmospheric pressure patterns.

Another local factor in assessing sea level rise is interannual sea level variability, including the meteorological impacts associated with El Niño. In Washington, northward-driven winds along the outer coast (which are common in winter) combine with the Earth's rotation to push ocean water toward the shore, elevating sea levels regionally (Mote et al. 2008). In El Niño years, this effect on sea level is intensified (Mofjeld 1992). This results in average winter sea levels that are 20 – 32" higher than in the summer, for a duration of several months (Ruggiero et al. 2005; as cited in Mote et al. 2008). Global climate change also has the potential to increase the intensity of storms and weather systems; considering this, the wintertime northward winds could increase in strength over future decades. (However, it is important to note that the intensity of storms does not always equate to increased precipitation levels; Mote et al. [2005] states that the human influence on precipitation is less predictable than the human influence on temperatures and that there is little indication that precipitation in the 21st century will vary significantly from precipitation in the 20th century.)

Various models in the scientific literature account for the local contributing factors in different ways. Many recent studies have based their modeling on the IPCC estimates although they are considered to be somewhat low (this must then be accounted for in the modeling). The later models include other improvements, such as local atmospheric dynamics. It is also important to note that the meanings of the labels "very low," "low," "medium,' "intermediate," "high" and "very high" vary by study and model. In some cases these labels refer to the levels of emissions assumed ("scenario"); in others, they refer to the possible range, or likelihood of outcome. Generally, it is best not to rely upon any one model or study in assessing the risks of sea level rise, but rather to consult various sources due to the inherent weaknesses of any one model.

The local estimates for the Puget Sound region vary. The Washington State Department of Ecology uses an assumption of one to five inches per decade for regional sea level rise (WSDOE 2006). Mote et al. (2008) defined two projections of likely sea level rise for coastal waters of Washington State: "very low" and "very high." This model began with the IPCC estimates as a foundation and then added two local factors, local atmospheric circulation and local tectonic contributions. A "medium" estimate was also included, as the arithmetic mean of the six central values from the IPCC. Table 2, below, shows the sea level rise estimates for the Puget Sound region from the Mote study (2008).

Table 2. Mote et al. (2008) – Puget Sound Region Sea Level Rise Estimates for the Year 2100			
	VERY LOW	**MEDIUM**	**VERY HIGH**
GLOBAL sea level rise	18 cm (7.1 in)	34 cm (13.4 in)	93 cm (36.6 in)
Contribution of local atmospheric dynamics	-2 cm (0.8 in)	0 cm (0 in)	15 cm (5.9 in)
Contribution of local vertical land movement	0 cm (0 in)	0 cm (0 in)	20 cm (7.9 in)
Total LOCAL sea level rise	16 cm (6.3 in)	34 cm (13.4 in)	128 cm (50.3 in)

* This table adapted from Mote et al. 2008.

Clancy et al. factored in the influence of the unique, local, Puget Sound atmospheric dynamics as provided in the "very high" estimates from Mote et al. (2008) with the "very high" global sea level estimate given in the 2008 Cayan et al. study (the "medium" scenario from Mote et al. included the local variables as zero, and the Cayan study did not include a "medium" level, so the "very high" estimate is used for the purposes of comparison). This yielded a locally-applicable version of Cayan's estimates; a projected rise of 68.9" by the year 2100 (Clancy et al. 2009).

Changes in wave action, as a result of meteorological changes, must also be considered in estimating and planning for future sea level rise. Heightened wave setup, a physical process by which wave energy raises the mean level of the sea, can increase extreme wave heights. Because this effect is dependent on large open-ocean-derived waves, average sea levels during storm events would only likely increase where swell is present (swell is the result of large waves produced in the open ocean). However, the potential for this increase in wave heights could be particularly hazardous in areas where increased sea levels are impacting development and habitats. This is discussed in more detail in Chapter 3, Marine Fish and Wildlife Habitat Conservation Areas.

While tectonic movement is a consistent and measurable factor in other parts of the state (*e.g.*, tectonic uplift in the Olympic Peninsula) it is inconsistent in the Puget Sound basin and its net effect on sea level rise is negligible in the northern part of the sound. This may be why the Mote et al. study expressly excludes tectonic movement from consideration in the "very low" and "medium" sea level rise estimates. This is because the subsidence in the Puget Sound region somewhat exacerbates the impacts of the sea level rise (Verdonck 2006, Canning 2005, and Mote et al. 2008).

5.3.3.3 Planning for Sea Level Rise

Much of the science regarding sea level rise focuses on marine habitat impacts, such as the loss of estuarine beaches, tidal flats, inland and tidal fresh marshes and swamps, and brackish marsh (Glick 2007). However, regarding Frequently Flooded Areas, the hazards to developments and infrastructure from inundation of coastal areas are the primary considerations.

Both public and private entities should consider the effects of sea level rise on coastal developments and public infrastructure projects (IPCC 2007, and others). In July 2009, the U.S. Army Corps of Engineers (USACE) issued circular EC 1165-2-211, which provides federal guidance on incorporating the physical impacts of projected sea level rise into federal civil works projects. This guidance document directs that, during the planning phase of projects, alternatives be evaluated against a comprehensive range of local sea level rise projections (USACE 2009).

Although the timeline is distant for appreciable sea level changes, even small changes in sea level can cause serious impacts, particularly to low-lying coastal developments. Infrastructure sited within these flood hazard areas are of particular concern; for example, one recent multi-agency report noted that, in the Gulf of Mexico region, 27 percent of the major roads and other critical transportation infrastructure will be below projected sea levels for the region within the next 50 to 100 years. The increased storm surges and consequent coastal flooding would potentially damage more than half of the region's major highways, almost half of its rail miles, 29 airports, and all ports (CCSP 2008; as cited in NOAA 2010). San Juan County contains more shoreline than any other county in the contiguous United States. Thus, planning and regulations for development (both public and private) should consider coastal flooding hazards and, if possible, avoid areas identified as coastal flooding hazard zones. Regardless of the magnitude of any future rise in sea level, these are the areas where the effects will be realized.

5.4 Options for Protecting Frequently Flooded Areas

Both coastal and inland Frequently Flooded Areas often coincide with other Critical Areas, such as wetlands, streams, and marine shoreline areas, and are subject to the regulations that protect those areas. Considering the low threat of severe stream- or river-related flood events in San Juan County, the protection afforded by the County's flood hazard control regulations, and the common overlap with other critical areas, it is reasonable to assume that the buffers and other protections that apply to other critical areas (which are generally based on protecting habitat functions), should be sufficient to protect most floodplain functions and public safety.

Ponding or flooding of stormwater runoff, however, can occur in almost any location, not always coinciding with other critical areas. In order to allow for the proper conveyance of these waters, collection and drainage infrastructure throughout the County must be maintained and/or retrofitted so that they meet the standards of the *Stormwater Management Manual for Western Washington* (WSDOE 2005).

As mentioned previously, the most effective approach to the management of flood hazards is to keep development out of flood hazard areas. However, even when development avoids the designated Special Flood Hazard Area, essential public facilities and land uses where congregation is the primary purpose (or where large numbers of people would regularly be present) could gain additional protection by being sited at least 15 vertical feet above the mean high tide. (This figure is an estimate, based on recent tsunami modeling; see description below under "Data Gaps" [Cowan 2011].) This additional safety would minimize a development's risk of tsunami inundation resulting from a large subduction earthquake. Seismic events of a smaller magnitude and closer proximity (within the Puget Sound) are more likely and would require even more vertical distance because tsunamis produced at a closer distance could have taller wave heights than those originating in the open ocean. Improved tsunami hazard maps can help determine this distance, given a property's land features and topography.

LiDAR technologies and the State's (WDNR) soils liquefaction map should be used in developing the tsunami hazard zone map, which should include the full extent of the run-up zone. This map should incorporate bathymetric information, to help identify where likely hazard areas would exist during tsunamis or storm events. In addition, the map should show future sea level rise, illustrating areas of predicted inundation and estimated changes to the Ordinary High Water Mark. This mapping effort would yield important information, at the parcel scale, for planning to accommodate Frequently Flooded Areas.

5.5 Data Gaps

It has been noted that San Juan County's Flood Insurance Rate Maps (FIRMs) are inaccurate; for example, in some areas the FIRMs show the floodplain present at elevations more than 40 feet above the ordinary high water mark. The maps were created in 1977 and are in need of updating. The County Council has included this identified need in their 2011 Legislative Priorities. Specifically, the County Council will be requesting that the State Legislature recognize the problems with the current FIRMs and engage federal legislators to secure adequate federal funding to update the FIRMs throughout Washington State.

San Juan County does not have an official tsunami hazard map. In the absence of such a map, the San Juan County Department of Emergency Management has referred to the modeling done for Port Townsend, which has the most similar physical attributes to San Juan County. The modeling for a large subduction earthquake yielded a forecast of a ten-foot wave (above mean high tide), to which a five-foot measure of safety was added for hazard planning (due to the uncertainty of the modeling). Combining bathymetric data and LiDAR information, future projections for sea level rise, and changes to the Ordinary High Water Mark (OHWM) would produce a map that could be used for evacuation and hazard planning.

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CHAPTER 6

BEST AVAILABLE SCIENCE
Geologically Hazardous Areas

CHAPTER 6 CONTENTS

GEOLOGICALLY HAZARDOUS AREAS: REVIEW OF THE SCIENTIFIC LITERATURE

The geological history of the San Juan Islands is discussed in detail in the Overview section of this synthesis document, and is not repeated here.

6.1 Geologically Hazardous Areas in San Juan County

The purpose of this chapter is to identify the geologic hazards that exist in San Juan County and review the best available science pertaining to these hazards, in order to create a technical foundation to inform possible amendments to SJCC 18.30.120. This section also provides an overview of management tools for dealing with these hazards. Amendment of this section of the critical area regulations is required, in part, by language in the Washington Growth Management Act that specifies that "Best Available Science" shall be included in the process of designating and protecting critical areas (WAC 365-195-900(2)).

Geologically Hazardous Areas are "*those areas that are susceptible to erosion, sliding, earthquake, or other geological events and are not suited to the siting of commercial, residential, or industrial development consistent with public health and safety concerns*" (RCW 36.70A.030 (9)). These areas are subject to periodic events that can result in injury, loss of life or property, disruption of governmental services, and unexpected public expenditures. Geologic hazards can be exacerbated by human actions in sensitive areas. The risk of these hazards can be reduced through the careful consideration of development within or adjacent to the hazard.

Regulations for Geologically Hazardous Areas should protect both the public and other critical areas from the impacts of development, particularly that which does not properly account for the hazards. Geologically Hazardous Areas pose a threat to safety when incompatible development is sited on them. The impacts of such development can also extend to adjacent properties. The availability of coastal properties has decreased in recent decades; therefore, there is increased pressure to develop difficult properties which may contain erodible features. This can result in risks to people and damage to natural resources.

The use of engineered mitigation measures to enhance safety in these areas is addressed in the GMA Guidelines: *"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, there is a limit to the use of such engineered solutions, as described later in the same section of the Code: *"When technology cannot reduce risks to acceptable levels, building in geologically hazardous areas is best avoided."* Some engineered solutions for shoreline erosion (*e.g.*, shoreline armoring) can have unintended, adverse, cumulative environmental impacts such as reduced beach nourishment, beach lowering and coarsening (Canning & Shipman 1995).

(Note: More information about the habitat impacts of shoreline armoring can be found in Chapter 3, Marine Fish and Wildlife Habitat Conservation Areas.)

6.2 Types of Hazard Areas

The Washington Growth Management Act establishes four different types of Geologically Hazardous Areas: erosion hazard areas; landslide hazard areas (which are a type of erosion hazard); seismic hazard areas; and areas subject to other geological events such as coal mine hazards and volcanic hazards. Varying levels of risk are associated with each type of hazard area. Only a negligible amount of potential mine hazard areas are present in San Juan County; as such, no regulations for these areas are necessary. San Juan County contains no identified volcanic hazard areas; however, there is some risk associated with the potential for tephra deposition (fragmental material including ash, cinders, or blocks) in this region of the State, which would result from the eruption of North Cascade volcanoes (Gardner et al. 1995, Hoblitt et al. 1998).

Erosion and landslide hazard areas are the most common Geologically Hazardous Areas in San Juan County.

Surface erosion and landslides are both considered types of mass wasting events. They often occur close in time and have shared contributing factors, both natural and man-made. Erosion hazard areas are the most prevalent geologic hazard in San Juan County. It is estimated that the County has approximately 13 miles of unstable bluffs (Downing 1983; as cited in Shipman 2001a). Lopez Island has the most coastal bluffs, relative to the other islands in the County. Coastal cliffs and bluffs are relatively recent landforms. They vary in size, elevation, and morphology, and in San Juan County, can reach heights exceeding 120 feet. The toe of the bluff is usually shaped by wave attack, undercutting and allowing the bluff to "passively" erode. The shores of San Juan County are exposed to the full range of wave energy, with the strongest waves originating from the Strait of Juan de Fuca and the Georgia and Rosario Straits, and moderate to low wave action in the more sheltered waters.

The stability of coastal cliffs and bluffs is influenced by variables such as upland relief, geologic composition and stratigraphy, hydrology, orientation and exposure, erosion rates, mass wasting mechanisms, and the amount and quality of vegetation (Shipman 2004). Bluff stability can also be directly affected by human actions that lead to unintended consequences. Development of a property can include structures that can overload the top of a bluff, grading and removing topsoil, removing vegetation, or adding water (*i.e.*, changing hydrologic conditions) (Emery and Kuhn 1982, Shipman 2004; as cited in Johannessen and MacLennan 2007). These actions can result in "active" (human-induced) erosion. Common sources of "added water" resulting from development include lawn watering, improperly installed drainage systems, and septic system drainfields. A less direct development-related source of water to bluff soils is the increase in impervious surfaces, which collects and directs water to concentrated discharge points, rather than allowing drainage to disperse across the land.

In the San Juan Islands, shorelines with erosion-resistant, exposed bedrock far exceeds those with erodible soils; however, a geologic inventory of the islands shows that unstable, steep, and erodible features and/or soils appear in many locations.

Feeder bluff on north Waldron Island. (Photo credit: Friends of the San Juans 2010)

Exposed bedrock along the coastline. (Photo credit: Friends of the San Juans 2010)

The location and distribution of these features are as follows, based on the information found in the *Washington Coastal Zone Atlas* (Washington State Department of Ecology 2010). "Unstable Bluffs" are primarily found on Lopez Island, with the majority of occurrences on the west and south coastlines. Bluffs also make up a large portion of the western coast of Blakely Island. Some isolated unstable bluffs also exist (in order of prevalence) on Orcas, San Juan, Shaw, and Waldron islands, and to a lesser degree on several other islands. "Unstable Slopes" are somewhat more common and are scattered throughout the County on large stretches of coastline, although they primarily occur on Orcas, Lopez, Decatur, and Sucia islands. The most unstable among these are found on Lopez, Blakely, Decatur, and Waldron islands, and the southeast tip of San Juan Island (near Cattle Pt. Road and on Mt. Finlayson). "Erosion Soils" are common, with the greatest amounts on Orcas, Blakely, San Juan, Waldron, and Stuart islands. These are found in both the coastal and inland areas. Additionally, "Steep Slopes" (those exceeding 15%) are found throughout, with the majority occurring on Orcas, Blakely, San Juan, Stuart, Speiden, Waldron, and Sucia islands.

Erosion and landslide hazard areas are discussed in more detail below.

6.2.1 Erosion Hazard Areas

Erosion hazard areas include areas likely to become unstable (such as bluffs, steep slopes, and areas with unconsolidated soils), as well as coastal erosion areas, as identified in the *Washington State Coastal Atlas* (see WAC 365-190-120(5)). Cattle Point on San Juan Island is characterized by erodible soils and is a good example of an area of coastal erosion. Although coastal erosion is typically associated with hazards to shoreline properties, it is also a driver for natural geomorphic processes that build beaches and maintain coastal habitats upon which various terrestrial and marine species rely. Throughout the inland, other potential erosion areas (like steep hillsides) are less obvious but still pose hazards.

Erosion hazard areas can present significant threats to life and safety and are primarily identified by their soil type. The soil type can reveal a great deal of information about the soils on a site. Soil types are grouped by their attributes, which serve as predictors for how the soil will respond to certain environmental factors. The likelihood of soil loss can be better understood by considering the soil's attributes, particularly the soil structure and permeability. The structure affects the soil's susceptibility to detachment and the rate of infiltration (percolation). Permeability affects its exposure to water and, ultimately, impacts runoff.

Erosion is not solely determined by the soil type but also by environmental factors. These include the quality and amount of vegetative cover, landform shape, slope gradient and length, rainfall quantity and duration, drainage and watershed conditions, and land use and development. Erosion can range from small rills to events moving massive amounts of earth. Small amounts of erosion, over time, can cause situations that can eventually become dangerous to people and property. Long-term erosion rates in the Puget Sound are relatively slow, but also tend to be highly episodic, often driven by storm events (Shipman 2010). Erosion rates (or "bluff recession" rates) in this region most commonly range between one and three inches per year (Keuler 1988; as cited in Johannessen 2009).

Erosion from a bluff in the San Juan Islands. (Photo credit: Friends of the San Juans, 2010)

The rate, quantity, and intensity of erosion are dependant upon multiple variables. These can be formally accounted for in calculating the erosion rate through the Revised Universal Soil Loss Equation ("RUSLE" or "RUSLE2" [updated version]: USDA 2010). This USDA-developed equation is the professional standard for predicting soil loss from sheet or rill erosion. The equation yields a product which is the estimated rate of erosion in tons per acre per year. Several factors are considered, such as slope length and average rainfall, but the "K Factor" is the most informative about the soil. The K Factor is a measure of soil erodibility that represents the soil's susceptibility to erosion and the amount and rate of runoff. This factor is influenced by the soil's texture, structure, amount and type of organic matter, and runoff potential (based on permeability). Soils high in clay content have low K values because they are resistant to detachment and therefore do not easily erode. On the opposite end of the spectrum, soils high in silt content are highly erodible and have high K values. They crust readily and have high rates of runoff; in other words, they are easily detached and transported.

(Note: The transport of sediment with stormwater runoff is addressed in Chapter 7, Alternatives for Stormwater Management, and in the Western Washington Stormwater Manual and will not be discussed here.)

6.2.2 Landslide Hazard Areas

Landslide hazard areas are susceptible to landslides based on a combination of geographic, geologic (and stratigraphic), topographic, and hydrologic factors, which show evidence of movement within a certain period of time (see WAC 365-190-120(6)). These hazard areas not only include known, existing landslides, but areas at risk of future failure. Landslides are a type of mass wasting event, which is broadly defined as the downward and outward movement of slope-forming materials that includes rock, soil, artificial fill, or a combination of these (Gray and Sotir 1996). More specifically, landslides involve the sliding, toppling, falling, or spreading of relatively large and often fairly intact masses along a failure surface or combination of surfaces (Gray and Sotir 1996). Although bedrock is generally resistant to erosion, it is still susceptible to landslides, particularly the highly deformed and fractured bedrock found throughout the County (especially on Orcas Island). Bedrock landslides can range from small bedrock topples to large, deep-seated landslides. Landslides are caused by wave attack at the toe of a coastal slope, hydrologic processes, and [the impacts of] land use and development (Tubbs 1974; as cited in MacLennan, Johannessen, & Williams 2009).

The majority of landslides in the Puget Sound region occur where permeable sand and gravel units lie directly on top of less permeable silts and clays, which creates a condition commonly referred to as "perched water." The layer of locally saturated soils eventually gives way to the forces of gravity in the form of slumps, earthflows, and debris avalanches (Manashe 1993). This happens more readily on steep slopes. Steep slopes exist throughout the County, overlain with varying types and depths of sediment and soils. When water accumulates in these soils, the steep slopes become vulnerable to landslides (as described above). There are also areas where the topography has been modified by terra-forming or engineering, which can expose vulnerable layers of the stratigraphy to weather and precipitation, thereby increasing the risk of landslides. Landslides in the Puget Sound region are typically very limited in their extent and are characterized as shallow slides (large landslides are considered rare). In San Juan County, landslides also have a long recurrence interval, with erosion rates that are generally fairly low (Johannessen 2009).

A recent landslide on San Juan Island. (Photo credit: Gregory Simon 2011)

The dense vegetation typical to this region usually limits significant erosion to situations where runoff has been concentrated by human actions or to locations where vegetation has been removed from easily erodible soils (Shipman 2004). Ground-clearing atop steep slopes is a common practice that should be carefully considered early in the site planning process. The retention of healthy vegetation is one of the most effective ways to retain soil onsite and reduce the damaging impacts of erosion. Clearing the vegetation from a property removes the soil-binding benefits of roots, decreases evapotranspiration rates, and concentrates surface water flow concentration (Gray and Sotir 1996). This ultimately modifies the natural hydrology and can exacerbate unstable conditions or even trigger landslides (Menashe 1993, Shipman 2004).

Vegetation, decomposed organic material, and small depressions in the soil help to anchor the soils and infiltrate runoff, effectively reducing erosion. The roots from vegetative cover provide not only mechanical reinforcement of the bluff, but also alter moisture content through root uptake, which changes and stabilizes the slope hydrology (May 2003; as cited in Brennan and Culverwell 2004). Vegetation intercepts and allows for the evaporation of precipitation, thereby reducing the absorption of shallow groundwater by decreasing the rate and volume of infiltration of rainfall into the soils below. On a subsurface level, vegetation also helps remove water that has percolated into the soil as live, deep roots help anchor the soil structure on slopes and remove excess water through transpiration.

Considering these potential impacts, the presence of a vegetated buffer along the top of a bluff or bank can significantly benefit slope stability (Menashe 1993). In most cases, retaining the natural vegetative cover does this effectively. Although the complex subterranean and above-ground structure of a sites' natural vegetation and anchoring cannot be exactly reproduced, in cases where the native vegetation has been removed prior to development, the installation and proper ongoing maintenance of a vegetative buffer can yield nearly the same benefits.

6.2.3 Seismic Hazard Areas

Seismic hazard areas include areas subject to severe risk of damage due to earthquake-induced ground shaking, slope failure, settlement or subsidence, soil liquefaction, surface faulting, or tsunamis (see WAC 365-190-120(7)). All of western Washington is generally at risk of earthquake damage resulting from the subduction of the Plate of Juan de Fuca beneath the North American [continental] Plate. San Juan County also contains several small surface faults, particularly on Orcas Island and the south end of Lopez Island. Additionally, two large faults exist outside the County but within close proximity: the Devils Mountain and South Whidbey Island faults. The complex to which the Devils Mountain fault belongs could be more active and extend farther west than previously assumed. It extends westward for over 125 kilometers from the Cascade foothills to Vancouver Island, passing approximately five kilometers south of Lopez Island (Johnson et al. 2010). While a large subduction earthquake within the main Cascadia trench would cause shaking that could be felt in San Juan County, seismic activity within one of the aforementioned smaller (but active) local faults would likely be more damaging. An earthquake along the Devils Mountain Fault could reach a magnitude of 7.5 on the Richter scale. The cumulative slip rate on the three main faults of the complex northern Puget Lowland structural zone (which includes the Devils Mountain fault) is approximately 0.5 mm/year, with the potential to be much larger (Johnson et al. 2010). In addition to the regional risk of ground shaking from seismic activity, the San Juan Islands (with 408 miles of shoreline and a large number of developed coastal properties), are at particular risk of encountering a tsunami wave resulting from such an event.

A tsunami is a series of long-wavelength, long-period sea waves generated by abrupt vertical displacements of large amounts of water, typically following seismic movement of the ocean floor. The wave crests of a tsunami can have large distances between them and, subsequently, reach the shore in wave periods ranging from five minutes to one hour. As tsunami waves approach the increasingly shallow waters of the shoreline, the wave can greatly increase in height. A wave that was only a few inches in height at sea may grow to dozens of feet by the time it meets the shore.

Tsunami waves usually result from subduction earthquakes of a magnitude of 7.5 or greater on the Richter Scale (USGS 2010). Tsunami waves can also result from large, sudden disturbances to the surface of a semi-enclosed body of water, such as a deep-seated bedrock landslide in San Juan County. Terrestrial landslides are a primary cause of tsunami waves in the Puget Sound region (Parsons and Nittrouer 2004). Historical evidence shows that landslide-generated tsunamis have occurred in the Puget Sound and in Lake Washington (Shipman 2001b). Additionally, there is potential for tsunami waves occurring in Puget Sound resulting from subaqueous landslides in the Fraser River delta front (Rabinovich et al. 2003), which would most impact those islands of San Juan County with open northwestern exposure. Although a large subduction earthquake within the main Cascadia trench or from the Seattle Fault could produce a dangerous tsunami, the above-mentioned local faults experience activity more frequently. Thus, these smaller faults represent the most immediate threat of tsunami to the County (Johnson et al. 1996).

Due to the protected nature of Puget Sound, a tsunami originating from geologic movement in the Pacific Ocean or along the ocean coastline would likely result in a surge of water approximately ten feet above mean high tide, to a maximum of 20 feet at the head of long inlets in San Juan County (SJC/FH DEM 2010). In the Puget Sound, a tsunami wave would more closely resemble a surge of the tidal waters than a cresting wave. The San Juan County/Town of Friday Harbor Department of Emergency Management (SJC/FH DEM) describes the appearance of the potential event as the tide coming in over a series of minutes rather than hours (2010). The surge would have a different appearance and impacts if it were to occur during high tide, during a storm, or both. A tsunami in San Juan County would create a safety hazard to people, homes, marinas, and other types of development along the County's low-lying coastlines.

(Note: Although tsunami waves are induced by geologic events, the WAC identifies them as more closely associated with Frequently Flooded Areas (WAC-190-080 [3]). Please see Chapter 5, Frequently Flooded Areas, for a more detailed discussion on this topic.)

6.3 The Locations of Geologically Hazardous Areas

The management of Geologically Hazardous Areas begins with the location, identification, and designation of hazardous areas.

In San Juan County, the primary source of information on Erosion Hazard Areas is the *Soil Survey of San Juan County, Washington* (Regan 2009). The soil survey provides detailed mapping of soil types throughout the County. Based on the soil survey, the soils in San Juan County identified as having a high water-erosion hazard potential (and listed in the Unified Development Code as such) are: the Pickett Soil portion within the Pickett-Rock Outcrop Complex (including PrD and PrE) and the Roche Soil portion within the Roche Rock Outcrop Complex (including Roche gravelly loam) (see UDC Article 18.30.120(A)(1)(2)(a)). The *Soil Survey of San Juan County, Washington* was updated in 2009. Prior to this, the 1962 soil survey (Schlots 1962) was the authoritative reference resource. Some of the names of soil types have changed in the 2009 survey, and this will need to be accounted for in revising the language in SJCC 18.30.120.

The primary source of information on Landslide Hazard Areas in San Juan County is the *Washington State Coastal Atlas* (Washington State Department of Ecology 2010). This is a collection of color maps of relative slope stability and past landsliding (as evident at the time of study). The volumes are organized by county and were published between 1977 and 1980. The maps were compiled using aerial photography interpretation, field observations from the water, and existing maps of geology and soils. Unstable slopes are identified by factoring together the geological composition, slope, and geomorphological expressions of historic landslides (Shipman 2001a). Slopes are classified into categories based on the associated risk, and in San Juan County, the following slope types are considered the highest risk, "Category 1": U (Unstable), UB (Unstable Bluff), URS (Unstable Recent Slide), and UOS (Unstable Old Slide). The maps use a 1:24,000 scale, which does not provide a high level of detail. This scale precludes the use of the atlas for site-specific assessment of geological hazard; rather, they are to be used as a screening device or a tool for assessing general landslide risk areas that warrant further study.

The practice of identifying landslide areas often relies on evidence of previous slides or environmental conditions that, when considered together, present a higher risk of future mass failures. The importance of slope gradient in determining stability must be assessed in conjunction with other factors such as soil characteristics, stratigraphy, topography, and watershed characteristics. Steep slope gradient is the primary factor of consideration, as steep slopes are more likely to fail than gentle slopes. Sand and gravel banks are typically stable at a slope gradient of approximately 30 to 40 degrees. If the bank is modified by either natural (*e.g.*, wave attack) or engineered means (*e.g.*, vegetation removal, terra-forming), it will seek a new equilibrium to return to the optimal degree of slope. This is achieved through events of mass soil movement.

Studies have indicated that a large proportion of landslides [in some areas of the Puget Sound] are associated with human actions (Tubbs 1974, Shannon & Wilson 2000; as cited in Shipman 2001a). This occurs through: vegetative clearing; increased surface water runoff; changing rates and locations of precipitation infiltration; the construction and operation of small (i.e. residential) and large (i.e., urban infrastructure) drainage systems; and the excavation and fill of material (Shipman 2001a). It should also be noted that landslides are more frequently noticed in densely populated areas. Subsequently, more reports are received from these areas. This may be perceived as an indication that they are more frequent in urban areas; however, at least one study (Palmer 1998; as cited in Shipman 2001a) found that extensive landsliding had occurred along bluffs in rural parts of Puget Sound, where little to no development is present. A recent study found evidence of both recent and historic landslides in San Juan County on San Juan Island, Orcas Island, and Waldron Islands (MacLennan, Johannessen, & Williams 2010). Although development can and does exacerbate erosion problems and increase the likelihood of landslides, they also occur naturally throughout the Puget Sound region.

6.4 Options for Protecting Geologically Hazardous Areas

The most effective management approach for Geologically Hazardous Areas, especially landslide areas, is complete avoidance. However, this is not always an option. Slopes seek equilibrium, which is achieved through erosion and mass wasting events. The slope will erode until the forces upon it are balanced. Based on consideration of all the site-specific characteristics, it is possible to estimate the angle at which a given slope will achieve stability. The slope's stability relates to the internal friction of the soil, which is a function of the soil's angle or slope, the soil and/or bedrock strength, and the depth to groundwater. Understanding the angle at which the slope will be stable can help identify the area atop the slope that is most likely to erode away in the process. For example, a 45° slope of coarse talus will likely become stable at approximately 26°. Similarly, a 35° slope of sandy mantle should become stable at about 9°. (This angle is even lower for clay soils. [Skempton 1964; as cited in Ritter et al. 1978]) The area atop the slope that would no longer exist once the slope's angle has stabilized is the most hazardous and it is advisable to limit development in this area. Use of such a methodology is site-specific and requires assessment by a qualified professional in order to determine the angle at which a given slope would become stable.

Other effective approaches for land development in Geologically Hazardous Areas include: limiting the types of land uses that can be sited in these areas, requiring building setbacks (where no structure could be located), requiring buffers (where no improvements could be located), and vegetation management practices. Physical stabilization (such as retaining walls) is an active form of management for hazard areas. Stabilization can be expensive, labor-intensive, and impactful to natural resources, whereas some geologic problems can be overcome by simply siting development further from the edge of the bluff. Stabilization practices typically include: drainage collection and/or diversion, bulkheads, and slope stabilization engineering, which are described below.

6.4.1 Drainage Collection

This is typically the cheapest engineered solution to removing water that can cause stabilization problems. It can be accomplished through various means, such as vertical dewatering wells and the collection and direct discharge of surface runoff from gutters, drives, and other impervious surfaces. Although this effectively reduces surface erosion and the saturation of the top soil layers, if not managed properly, it can also concentrate and deposit runoff water and associated pollutants (*e.g.*, zinc and surfactants from moss control products, sediments) directly into the aquatic environment without the benefit of filtration through vegetative cover or soils.

In situations where the source of the water and the subsurface conditions are compatible, vertical dewatering wells divert water without some of the typical problems of other drainage options (*e.g.*, horizontal wells). In recent years, directional drilling (which is used in drilling vertical dewatering wells) has taken the place of short horizontal wells drilled into the bluff face.

Horizontal wells have proven expensive to construct and maintain due to equipment access to the shore, access to the pipe for regular cleanouts, and long-term maintenance of the drainage system. Directional drilling allows the well to be drilled from several hundred meters landward of a bluff, travelling under structures and daylighting at the bluff face (Shipman 2004). This method reduces the environmental impacts of heavy machinery access during construction and eases access for ongoing maintenance. This preferred technique of drilling does, however, necessitate consideration of some additional factors. First, the source of the runoff water should be identified because water from some sources (e.g., roofs, driveways) can have different chemical contents than excess water from a natural area (e.g., a vegetated, rocky hill). Also, variability in subsurface conditions and flow are dictated by the water-bearing strata, which can only be accurately analyzed through site-specific geologic study.

6.4.2 Bulkheads

Bulkheads are common throughout the Puget Sound region as a means of preventing wave-induced toe erosion of slopes, bluffs, and cliffs. These typically take the form of long mounds of basalt rocks placed near the toe of the slope, up to about two meters in height. Armoring types present in San Juan County include: large rocks, small rocks, wood, creosote wood, concrete, and gabion basket construction. The majority (approximately 80%) of shoreline in San Juan County is rocky. The remaining shoreline is "soft," comprised of sand and gravel, and includes feeder bluffs, transport zones, accretion shoreforms, and pocket beaches. This type of beach is particularly important because it provides habitat for marine species (such as forage fish spawning habitat) and also provides for habitat-forming processes.

In some situations, bulkheads can be an effective tool for protecting against wave attack and, if designed properly, can add to beach nourishment. However, bulkheads have been broadly implemented throughout the Puget Sound to address all types of erosion, including stability problems not directly related to wave action. Bulkheads have also been found to prevent sediment transport, which is a necessary process to "feed" adjacent beaches. This can result in adverse environmental and safety impacts.

The impacts of shoreline modification, including bulkheads, are not yet completely understood. Disagreement within the literature drives ongoing research in the Puget Sound region and beyond (Pilkey and Wright 1988, Kraus and MacDougal 1996; as cited in Johannessen and MacLennan 2007). It is noted that while some artificial structures of this type have been successful, many have failed and have been left in place, derelict, resulting in further beach erosion (Bird 2008). Much is known about the changes bulkheads cause to local sediment transport, particularly because most of the impacts are the intended results of a properly-functioning armor structure. Shoreline armoring is intended to contain both "passive" (natural) and "active" (human-induced) erosion.

Waves breaking against a solid structure such as a sea wall or bulkhead are reflected back to the sea and carry sediments with them away from the foot of the wall (Bird 2008). This is sometimes referred to as beach lowering. These reflected waves can also increase erosion on adjacent properties. A successful bulkhead can, therefore, reduce the amount of sediment from a bluff that is deposited along the coast through net-shore drift. This is commonly referred to as "sediment starvation," which can have serious implications for beaches fed by bluff erosion including: changes to beach profile and substrate (such as burial of the back beach), modification of riparian vegetation and beach hydrology, and reduction of the upper beach as the shoreline retreats in front of the fixed structure (Shipman 2004).

San Juan County contains no large river systems, which are usually the primary source of sediment for beaches. Because of this, the County's beaches are fed by bluff erosion and rely upon drift cells to move the sediment along the coastline. These natural erosion processes are essential to San Juan County's beaches. It has been estimated that beaches in San Juan County are composed of more than 90% bluff-derived sediment (Friends of the San Juans 2010). The top of the bluff, face of the bluff, beach, and nearshore aquatic environment are all interrelated and interdependent. Bulkheading has the potential to disrupt the balance of this system. Over time, changes to the sediment-deposition cycle gradually change the structure of the beach and its associated habitat.

The impacts of these changes on habitats include: reduced beach width, conversion to gravel beaches (*i.e.*, loss of fine-grained sand, also known as "beach sediment coarsening"), loss of organic debris (*e.g.*, wood, algae), reduced epibenthic prey, and the potential for increased predation of salmonids (MacDonald et al. 1994, Thom et al. 1994, Brennan 2007; as cited in MacLennan et al. 2009). (Impacts to the nearshore habitat are more fully discussed in Chapter 3, Marine Fish and Wildlife Habitat Conservation Areas.) The aforementioned impacts are magnified when the bulkhead is placed lower on the beach (Pilkey and Wright 1988; as cited in MacLennan et al. 2010).

Regarding safety impacts, sediment starvation has several implications. First, spits that would naturally form in front of shoreline homes will shrink in height and length and eventually disappear. As the spit retreats, this would allow storm waves to overtop the land feature. When the spit completely disappears, so does its protection as a barrier, and shoreline development is exposed to the full force of storm waves. The beach directly in front of bulkhead structures also diminishes over time. Without the protection of a beach, stormwaters must only overtop the bulkhead itself to gain access to the structure. Hence, bulkheads can lead to increased wave-induced erosion and coastal flooding of low-lying structures (MacLennan et al. 2009).

A recent feeder bluff mapping study found that approximately 22.5% of the "soft" shore shoreline in the County is armored in some way. According to this study, the percentage of current (active) feeder bluffs is greatest on Lopez Island (33%), followed by Orcas Island (16%), San Juan Island (15%), and Waldron (9%). Additionally, most of the shoreline modifications that exist in the County have been installed on Lopez Island (38%), followed by Orcas Island (23%), San Juan Island (19%), and Shaw Island (8%) (Friends of the San Juans 2010).

6.4.3 Slope Stabilization Engineering

Slope stabilization engineering includes the use of machinery and structural retention techniques to prevent the further erosion of a slope. Common types of slope stabilization engineering include: multi-level retaining walls, reinforced soil embankments, and terra-forming. In the Puget Sound region, these techniques are sometimes employed when other types of shoreline armoring have failed.

Slope stabilization engineering is often viewed as a last resort for reigning in erosion; however, these techniques have the potential to dramatically alter the geometry of the landform, intensifying the instability problem by causing the slope to seek a new equilibrium through mass wasting events. When such engineered measures fail, it can typically be attributed to the underestimation of slope processes and/or the absence of proper geotechnical engineering evaluation and site assessment (Shipman 2001, Burns 2007).

One alternative to the use of rock, concrete, or steel stabilization is the implementation of biotechnical stabilization techniques. This involves the use of living materials (*i.e.*, plants) paired with other living or non-living reinforcement materials such as geotextiles or geogrids to reduce the erosive forces of water and stabilize the soil against such erosion. Although biotechnical stabilization techniques have been well-known since at least the 1930s, they have increased in popularity in recent years because of their efficacy, cost-effectiveness, and applicability in sensitive habitats or scenic areas. It should be noted, however, that biotechnical stabilization is not effective in all situations. This is especially true for very steep slopes and arid soils. Also, the newest reinforcement materials have not been commercially available for very long and their long-term efficacy is somewhat unknown.

6.4.4 LiDAR

Light Detection and Ranging (commonly referred to as "LiDAR") topographical mapping is a relatively recent technology that can be used to identify areas of historic mass ground movement. The refined imagery it provides makes it possible to better determine the full extent of landslide areas, whereas previous technology identified only the areas of largest volume lost. LiDAR technology can identify or confirm the presence of large and/or historic landslide features in close proximity to mapped faults and give graphic information regarding bluff morphology and slope processes (Shipman 2004). This level of information has not previously been available and can greatly enhance the identification of hazard areas. It should be noted, however, that there is essentially no amount of imagery that can take the place of in-depth, site-specific, geotechnical engineering review (Burns 2007, Shipman 2001, and others).

6.5 Data Gaps

Overall, more geological information is needed about the shoreline evolution of the Puget Sound, particularly in regard to the impacts of human development in recent times. Not enough is known about the biological and geological interaction of bluffs and the nearshore environment. It has been noted that geologic mapping throughout the entire Puget Sound (not exclusive to the San Juan Islands) is outdated and potentially inaccurate, particularly in reference to shoreline stratigraphy (Shipman 2004). No detailed longitudinal data on bluff erosion is currently available. The erosion rates of some specific locations are known, but no in-depth study for the entire county has been undertaken. This information would provide valuable information about bluff morphology and slope processes.

The *Washington State Coastal Atlas* continues to be the primary source of information for landslide hazardous areas. It has been noted that the shortcoming of these maps lies primarily in the inability to address erosion rates, long-term bluff retreat, or run-out zones at the base of steep slopes (Shipman 2001). Additionally, the mapping does not extend very far inland and it is incomplete in that certain types of coastal lands (such as military property and tribal lands) have been excluded from review.

Although many small faults exist within the County (especially on Orcas Island and the south end of Lopez Island), not enough is known about the likelihood of a seismic event from each of these faults.

6.6 Literature Cited*

*Peer reviewed references and documents that local, state or federal natural resource agencies have determined represents the best available science consistent with the criteria set out in WAC 365-195-900 through 365-195-925 are shown in bold.

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CHAPTER 7

BEST AVAILABLE SCIENCE

Stormwater Management Alternatives

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7 STORMWATER MANAGEMENT ALTERNATIVES

7.1 Stormwater Runoff Effects[25]

Changing land cover and land use from natural conditions, and the construction of drainage networks, roads and impervious surfaces profoundly affects how water moves above and below ground during storm events, the quality of that stormwater, and the ultimate condition of streams, lakes, wetlands and estuaries. Nearly all the associated problems result from one underlying cause: loss of the water retaining and evapotranspirating functions of the soil and vegetation. When combined with the introduction of pollutants that accompany people and their development, these changes lead to water quality and habitat degradation (National Research Council, 2009). This chapter discusses how human activities and changes to the landscape affect runoff and options for preventing and reducing associated impacts.

7.1.1 Impacts on Hydrology

Before modern settlement in San Juan County, the tree canopy, vegetative cover, and forest duff layer slowed stormwater runoff and limited damaging high stream flows through interception, evapotranspiration, absorption and infiltration of rainfall. However, as population and development increased, the nature of the landscape was changed resulting in associated impacts to streams, wetlands, water quality and habitat. Though the County remains predominantly rural and forested, historically trees were logged, land was cleared, soil was compacted, buildings and roadways were built, and drainage pipes, trenches and ditches were constructed to collect surface water, intercept groundwater, and speed the flow of runoff from developed areas. These activities continue today. Even converting land from forest cover to pasture or developing small impervious areas, such as driveways and small buildings can have significant cumulative effects on surface hydrology. These land use changes are associated with the following hydrologic impacts:

- Increased flow rates of runoff
- Increased volume of runoff
- Decreased time for runoff to reach local streams and bays
- Reduced ground water recharge
- Increased frequency and duration of high stream flows and wetlands inundation during and after wet weather
- Reduced stream flows and wetlands water levels during the dry season
- Greater instream velocities.

Schueler (1987) provides a graph illustrating the relationship between predevelopment and post-development stream flow rates (Figure 1).

[25] Portions of this section are from the *City of Seattle Environmentally Critical Areas Best Available Science Review for Stormwater Code and Grading Code* (June 30, 2009) and are used by permission.

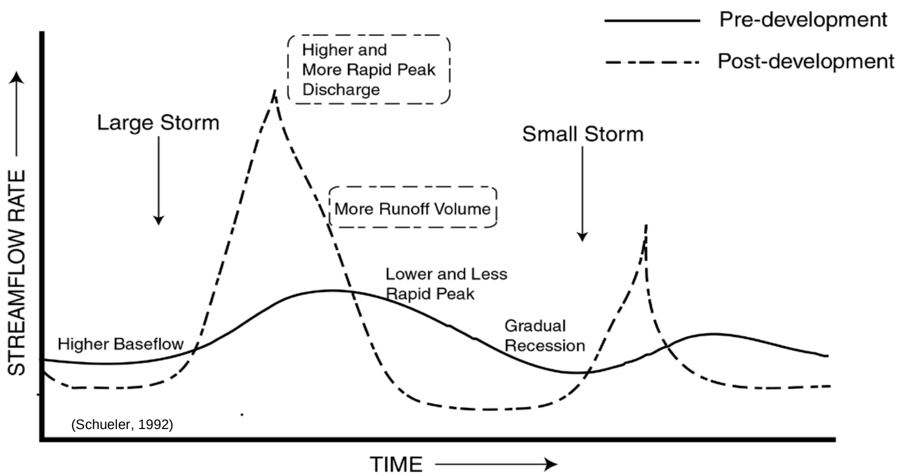

Figure 1. Changes in hydrology after development (Schueler 1987).

The relationship between changes in effective imperviousness (such as driveways, parking lots, streets, roofs, and other impermeable surfaces that are hydraulically connected with local streams) and stream quality is well documented (see, for example, Dunn and Leopold 1978, Booth and Jackson 1997, Arnold and Gibbons 1996, McMahon and Cuffney 2000, USGS 2009). Increased stormwater runoff, caused by increases in imperviousness in a catchment or watershed, can have negative effects on physical processes in creeks, including channel erosion and streambank instability (Booth and Henshaw 2001, Castro and Jackson 2002, Konrad 2000, Moscrip and Montgomery 1997). Booth and Jackson (1997) showed that increased instream flows can occur even when the catchment has undergone small changes in the percent of effective imperviousness. Figure 2 illustrates the relationship between percent imperious cover in a catchment and relative channel stability, as well as comparisons between current and historical flow patterns (Booth and Jackson 1997). In summary, stream channels begin to show signs of instability at approximately 10 percent impervious area in a watershed. Likewise, when the relatively frequent 2-year storm event discharge rates in a developing watershed exceeds the flow rates that are estimated for a larger 10-year event under historic or forested condition, stream channels begin to show signs of instability (Booth and Jackson 1997). These trends highlight the impacts of land cover change on hydrology, and thus stream condition.

Residential density and lot size have been discussed as factors affecting stormwater runoff. However, other factors also influence stormwater quantity and quality. For example, a small parcel with a modest size home constructed with a sod roof, a short driveway constructed to drain and infiltrate runoff, and native vegetation landscaping will produce less runoff and fewer contaminants than an identical parcel with a large home, long driveway, accessory structures, and a manicured lawn requiring the use of weed killer and insecticide.

Impervious area in San Juan County watersheds and basins generally ranges below 10 percent based on GIS analysis. However, more highly developed basins such as Friday Harbor on San Juan Island and Eastsound on Orcas have much higher percentages of impervious area at 49 percent and 31 percent respectively. The majority of stormwater runoff from developed properties in rural San Juan County either flows directly into surface water bodies, is dispersed in surrounding land, or flows into the many miles of private or County owned and maintained ditches and swales. In addition, curtain and foundation drains commonly discharge to roadside ditches without permission (although approval is required), and this can contribute additional flow to surface water bodies. The infiltration and water quality treatment functions provided by vegetated ditches and swales will be discussed in a subsequent section. As development activity increases it will be important to minimize the addition of impervious surfaces, maximize infiltration of stormwater from impervious surfaces where possible, and to mitigate areas of existing impervious area wherever feasible.

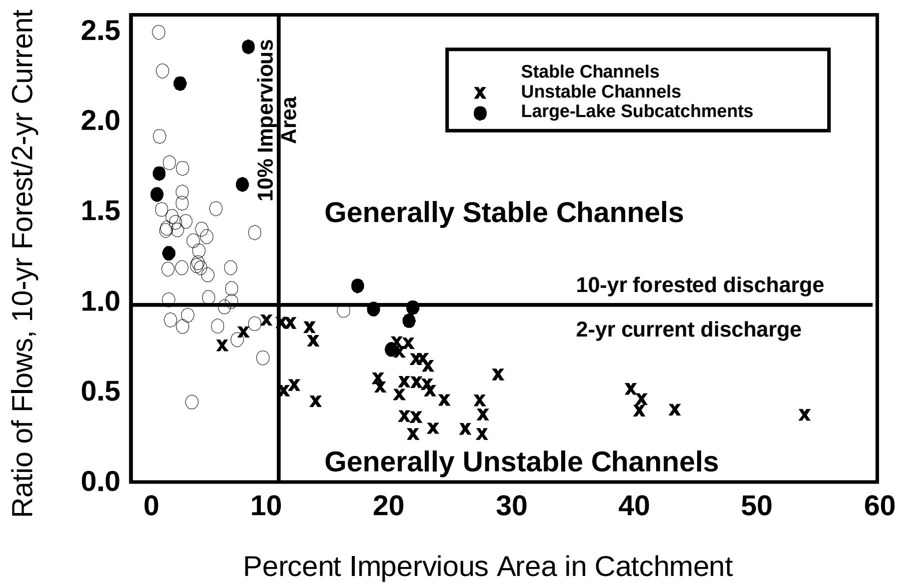

Figure 2. Channel stability and land use: Hylebos, East Lake Sammamish, and Issaquah Basins (Booth and Jackson 1997).

Stormwater runoff from developed areas has also been shown to impact aquatic life. When increased flows change a stream's physical configuration and substrate (such as stream stability elements highlighted in Figure 2), habitats are altered. Associated detectable changes in the biological community of streams can begin early in the watershed development process. May (1996) and May et al. (1997) reported observable negative biotic changes with only 5-10 percent total impervious area coverage in a watershed. Using the Benthic Index of Biotic Integrity (B-IBI) developed by Karr (1991) and Kleindl (1995), May et al. (1997) evaluated the relationship between B-IBI and the extent of watershed development as estimated by the percentage of total impervious area (Figure 3). The B-IBI is a stream-health grading system based on aquatic insects found at stream monitoring sites. Figure 3 also displays data on the ratio of coho salmon to cutthroat trout (Lucchetti and Fuerstenberg 1992), which is another indicator that can be used to measure stream quality. Coho are more sensitive to degradation, thus a higher Coho: cutthroat ratio is indicative of higher stream quality. This salmonid data further indicates that watershed development degrades the biological health of streams. While this figure is based on studies of Puget Sound lowland streams, its relevance for San Juan County is to illustrate how research has confirmed the correlations between increased watershed development and decreased health and diversity of the aquatic insect and fish communities found in local streams. The biological communities in wetlands, bays and estuaries can also be impacted and altered by watershed development. In wetlands, small changes in the natural water elevation fluctuations can cause dramatic shifts in the composition of vegetative and animal species.

Maintaining natural hydrology and predevelopment flow regimes are of high importance in San Juan County, particularly due to the low summer precipitation and limited groundwater supplies. Preserving native landscapes, limiting the quantity of impervious surfaces, and encouraging infiltration of stormwater throughout the County can help recharge groundwater supplies, maintain stream baseflow, maintain flow to wetlands and minimize impacts to marine bays and estuaries.

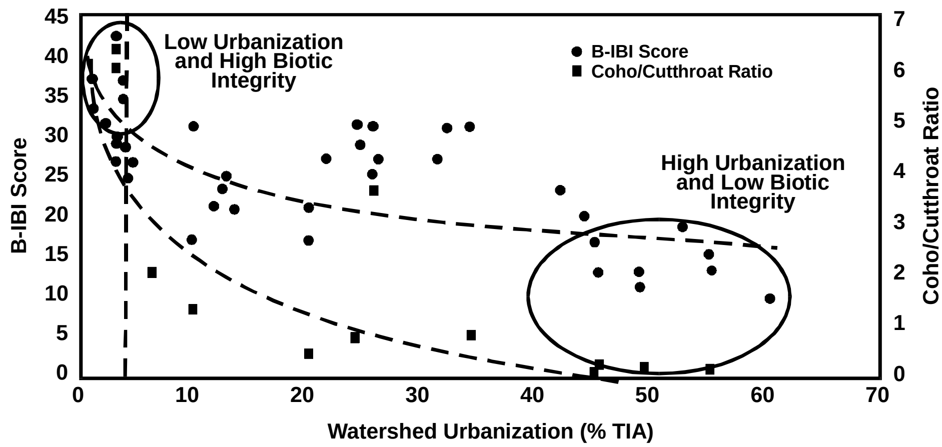

Figure 3. Relationship between basin development and biologic integrity in Puget Sound lowland streams (May et al. 1997).

7.1.2 Impacts on Water Quality

Stormwater runoff and associated contaminants from developed areas has been identified as one of the leading threats to aquatic life and human health supported by the Puget Sound ecosystem (Puget Sound Partnership 2010). Reducing surface water runoff pollutant loading and runoff from the built environment is a key priority action for the restoration of Puget Sound (Puget Sound Partnership 2010).

Stormwater is conveyed to marine waters through drainageways, ditches and pipes, carrying with it the pollutants that are present in the watershed. Although marine systems require a certain amount of sediment to maintain nearshore ecosystem processes, sediment from roads and developed areas typically contains adsorbed toxins, and is dominated by fine clay and silt, which can smother benthic organisms. Heavy metals (such as zinc, copper and cadmium) which are often present, and which do not degrade over time are toxic to phytoplankton and other marine organisms. Pesticides enter runoff from lawns, gardens, structures, and agricultural lands. They, too, are water soluble, mobile, and highly toxic to marine organisms. Other contaminants of concern include Polycyclic Aromatic Hydrocarbons (PAHs) which are found in fuel, oil, asphalt abrasion dust, and deposits from automobile exhaust; surfactants such as nonylphenol ethoxylates, which are used as detergents, wetting agents, and emulsifiers, and Polychlorinated Biphenyls (PCBs) which are extremely toxic, extremely stable, and which have been extensively released into coastal waters (Levinton 2001).

Typical sources of pollutants include:

- **Roads**: Runoff from roads is typically contaminated with pollutants from vehicles. However, the drainage systems associated with roads act as conduits for exporting pollutants from surrounding land uses, and it is frequently difficult to separate pollutant sources in these systems. Oil, grease, polynuclear aromatic hydrocarbons (PAHs), lead, zinc, copper, cadmium, sediments (soil particles), associated nutrients, and road salts are all typical pollutants present in road runoff (Zawlocki et al. 1981, Mar et. al. 1982, Davis et al. 2001, Horner 1994). Vehicles are the primary source of all of these pollutants. Most oil and grease comes from vehicle leakage, while PAH's are primarily from exhaust. Lead is most commonly associated with wear of metallic parts, wheel balance weights (wearing and falling from wheels), and battery leakage due to car accidents. The primarily source of zinc is wear from tires, and copper primarily comes from brake pad wear.

- **Commercial/Industrial areas**: Runoff from commercial and industrial areas typically can contain heavy metals, sediments, and a broad range of man-made organic pollutants including phthalates, PAHs, and other petroleum-based hydrocarbons (National Research Council 2008). Vehicles and pavement sealants are two common sources of pollutants from these areas. Other sources depend on the types of operations that are present on the property.
- **Residential areas**: Runoff from residential areas can include the same road-based pollutants outlined above, as well as insecticides, herbicides, rodenticides, surfactants (found in pesticides, lubricating oil, detergents, shampoo, paint, and moss control products), metals such as copper and zinc (from wear of automobile parts, galvanized flashing and building materials, pressure treated wood, moss control products, copper/zinc impregnated shingles, copper/zinc roofing strips), chlorine (from moss control products), deicers, nutrients (such as phosphorus and nitrogen from fertilizers and detergent), bacteria and viruses (from animal waste) (Engstrom 2004), as well as sediment from dirt and gravel driveways. Residential areas can also contribute nutrients, viruses, bacteria and chemicals from septic systems, which can enter stormwater when ponded or inadequately treated effluent flows into surface runoff. Finally, curtain and foundation drains that are common in areas with a perched or high water table, often discharge to drainageways and roadside ditches. This exacerbates the hydrologic changes that accompany development, and adds to the quantity of runoff flushing pollutants into wetlands, streams and marine waters.
- **Dirt and Gravel Roads**: Many large parcels in San Juan County have very long gravel and dirt driveways. These roads are often former logging roads that are not graded properly or made of fine grained soils, so they contribute total suspended solids (TSS) and sediment to roadside drainage systems (Figure 4). There are currently no driveway standards in San Juan County, which adds to the problem. These roads also sometimes have poorly maintained culverts that plug, overtop roads, and cause additional undercutting, erosion and sedimentation.
- **Construction sites**: Runoff from construction sites can include sediments and other suspended material, which can increase turbidity or cloudiness in downstream receiving waters and can be deposited over the natural sediments of the receiving water and affect streams and wetlands (Barrett et al. 1995, Ecology 2005a, Horner et al. 2002a). In addition to sediment, construction sites can also be sources of typical construction-related pollutants, such as phosphorus, petroleum products, and products that can affect pH (Ecology 2005b).

- **Ferry Terminals**: The primary pollutant generating surfaces associated with ferry terminals are the parking and waiting lots. Consequently, stormwater runoff from ferry terminals is similar to what is found in runoff from heavily-used commercial parking lots. The most intensive study of ferry terminals in Western Washington (Herrera 2009a) found that high-traffic terminals export total suspended solids (TSS), total phosphorus, total petroleum hydrocarbons, copper, and zinc at levels similar to those found in runoff from Western Washington highways. This indicates that ferry terminals can be a significant source of aquatic pollution in the nearshore.
- **Agriculture and Forestry**: Stormwater pollutants from agricultural practices can be highly varied and extensive. Cultivating soil and leaving bare soils can result in increased erosion and TSS loads to receiving waters. The TSS can carry large amounts of nutrients and pesticides (Welch and Jacoby, 2004). These same pollutants can be discharged to receiving waters through irrigation runoff, in addition to during storm events. Farm equipment can generate oil, grease, and metals. Common pollutants from pastures include TSS that can result from erosion due to over grazing (i.e. disturbance of the soil and denuding of ground surfaces). Livestock enclosures can have even more severe impacts, contributing high amounts of TSS and sediment if there is significant erosion, as well as bacteria, nutrients, antibiotics, and growth hormones if concentrated animal waste is allowed to flow offsite comingled with stormwater. Forest practices commonly disturb soil and increase erosion resulting in delivery of TSS and sediment to receiving waters. Log sorting and handling areas typically generate oil and grease (from equipment), sediment, TSS, heavy metals, pesticides, and wood-based debris (Ecology 2005a).

Typical annual pollutant loading rates for common stormwater constituents found by Horner (1992) to be associated with the above land uses in a study of Covington in King County are listed in Table 7-1, below.

Stormwater pollutants resulting from development can be dissolved in the water column or can be attached to particulates that settle in streambeds, lakes, wetlands, or marine estuaries, where they can have both immediate and long-term impacts (Baldwin et al. 2003; Hansen et al. 2002). Pesticides are designed to kill plants and animals and can have significant negative effects on aquatic life. Nitrogen can pose a problem for marine waters because they are nitrogen limited and adding nitrogen results in increased growth of algae, decreasing the clarity of the water and potentially reducing oxygen levels. Phosphorus can have the same effect on fresh water bodies, which are phosphorus limited. Metals have long been recognized as having a negative effect on aquatic organisms, and copper is a common component of marine bottom paint.

While effective removal can be obtained through biological processes that occur in soil and vegetation (Brown et al. 2009), detergent and surfactant by-products such as 4-nonylphenol are endocrine disrupters that can accumulate and persist in aquatic sediments, resulting in acute and chronic effects on aquatic organisms. These compounds can cause feminization of organisms, decreased in male fertility, and altered growth, development and reproduction which may be passed on to future generations. Due to the harmful effects of these compounds, nonylphenol ethoxylate surfactants have been banned in EU countries (Soares et al., 2008; Isidori et al., 2006).

Table 7-1 Typical Pollutant Loading Ranges for Various Land Uses in Covington, WA

Land-Use Category		TSS	TP	TN	Pb	Zn	Cu	FC
Road	Minimum	281	0.59	1.3	0.49	0.18	0.03	7.1E+07
	Maximum	723	1.5	3.5	1.1	0.45	0.09	2.8E+08
	Median	502	1.1	2.4	0.78	0.31	0.06	1.8E+08
Commercial	Minimum	242	0.69	1.6	1.6	1.7	1.1	1.7E+09
	Maximum	1369	0.91	8.8	4.7	4.9	3.2	9.5E+09
	Median	805	0.08	5.2	3.1	3.3	2.1	5.6E+09
Single Family Low Density	Minimum	60	0.46	3.3	0.03	0.07	0.09	2.8E+09
	Maximum	340	0.64	4.7	0.09	0.2	0.27	1.6E+10
	Median	200	0.55	4	0.06	0.13	0.18	9.3E+09
Multifamily Residential	Minimum	133	0.59	4.7	0.35	0.17	0.17	6.3E+09
	Maximum	755	0.81	6.6	1.05	0.51	0.51	3.6E+10
	Median	444	0.7	5.6	0.7	0.34	0.34	2.1E+10
Pasture	Minimum	103	0.01	1.2	0.01	0.02	0.02	4.8E+09
	Maximum	583	0.25	7.1	0.03	0.17	0.04	2.7E+10
	Median	343	0.13	4.2	0.02	0.1	0.03	1.6E+10
Forest	Minimum	26	1.1	1.1	0.01	0.01	0.02	1.2E+09
	Maximum	144	2.8	2.8	0.03	0.03	0.03	6.8E+09
	Median	86	2	2	0.02	0.02	0.03	4.0E+09

Notes: Abbreviations: TSS-total suspended solids, TP-total phosphorus, TN-total nitrogen, Pb-lead, Zn-zinc, Cu-copper, FC-fecal coliform. Pollutant loadings are listed as kg/ha/year, except FC is no./ha/year.
Source: Horner, 1992

In addition to the toxic effects of contaminated runoff, development can increase water temperatures by heating stormwater runoff as it passes over exposed surfaces, before being discharged to receiving waters (Foulquier et al. 2009). A rise in water temperature can have direct lethal effects on aquatic organisms by reducing the available dissolved oxygen, and potentially causing algae blooms that further reduce water clarity and the amount of dissolved oxygen in the water (McCullough et al. 2001).

Some local monitoring of water bodies has occurred over the years, including six years of stream monitoring conducted using an Ecology approved quality assurance plan. A water quality study completed by Western Washington Universities Huxley College of the Environment identified several areas with impaired or marginal water quality when compared to State standards. Anthropogenic sources and natural upwelling were identified as potential sources of identified substances. Following are some of the findings from this study (Wiseman et al, 2000):

Obviously Impaired Water Quality

- Site 1, Lopez north end, near Port Stanley Road and Ferry Road: high fecal, chronically low DO, high nutrients
- Site 4, Lopez southwest, intersection of Richardson Road & Davis Bay Road: high fecal coliform, occasional low DO high nutrients in late fall

- Site 9, Orcas stream draining Crow Valley: high fecal coliform, low DO, high nutrients, high TSS
- Site 11, Orcas Eastsound stormwater culvert: high fecal coliform, low DO, high conductivity
- Site 16, Orcas Doe Bay: high fecal coliform, low DO, high nutrients
- Site 17, Friday Harbor Spring Street stormwater outfall: high fecal coliform, high nutrients, high TSS
- Site 19, San Juan Island stream draining Sportsman's Lake: chronically low DO, high nutrients
- Site 24 San Juan Island creek near False Bay: chronically high fecal, high temperatures, chronically low DO, high nutrients, high turbidity.

Marginal Water Quality

- Site 2, Lopez Hummel Lake drainage: high fecal coliform, low DO, high nutrients
- Site 3, Lopez near wetlands north of Lopez Village: high fecal coliform, low DO, high nutrients
- Site 5, Lopez east side by Elliot Road: high fecal coliform, occasional low DO, high nutrients in late fall
- Site 6, Lopez near Port Stanley Road and Lopez Sound Road: high fecal coliform, low DO, high nutrients in fall
- Site 7, Lopez west side by intersection of Davis Bay Road and Richardson Road: high nutrients
- Site 14, Orcas near Olga at mouth of Cascade Creek: high fecal
- Site 15, Orcas by intersection of Buoy Bay Road and Horseshoe Hwy: low DO
- Site 18, San Juan stream draining Beaverton Valley by University Drive: high fecal, variable DO
- Site 22, San Juan stream draining Garrison Bay watershed by intersection of Yacht Haven & Mitchell Bay Road: high fecal, high temperature, low DO
- Site 23, San Juan Valley Creek near intersection of Wold Road and San Juan Valley Road: high fecal coliform, high temperature, low DO

The San Juan County Watershed Management Action Plan and Characterization Report also identified problem areas including the following (SJCWMC 2000):

- Site L26, Lopez, Fisherman Bay north: fecal, TSS
- Site L18, Lopez west side by Johnson lane: fecal, TSS
- Site L32, Lopez near Hunter Bay: fecal
- Site L33, Lopez near Mud Bay: fecal
- Site O1, Orcas, Buck Bay: fecal, TSS
- Site O2, Orcas Buck Bay, TSS
- Site O9, Orcas stream from Crow Valley near West Sound: fecal, TSS
- Site 0 13, Orcas stream from Crow Valley by Horseshoe West Creek: fecal, TSS
- Site O19, Orcas West Sound by Milk and Honey Cove: fecal, TSS
- Site SJ2, San Juan stream draining to False Bay: fecal, TSS
- SJ5, San Juan Westcott Bay north outlet: TSS
- Site SJ6, San Juan Westcott Bay south outlet: fecal, TSS
- Site SJ8, Friday Harbor Spring Street outfall: fecal

- Site SJ15, San Juan Westcott Bay south Mitchell Bay road culvert: TSS

In addition, studies by Barsh et al. (2008, 2009, 2010) suggest that pyrethroid pesticide use is contributing to the contamination of lakes, streams, ponds and freshwater sediments in the San Juan Islands (Barsh et al. 2008) and may be accumulating in nearshore trophic webs where they could affect sensitive fish and wildlife, and local human food supplies (Barsh et a. 2009). Drainage from the town of Eastsound may contribute to pyrethroid pesticide contamination of bivalves in Fishing Bay (Barsh 2009). As an important food source for many other species covered under the marine HCAs, oyster and clam health, and population success will likely have implications for higher trophic species (Sobocinski et al. 2010).

Barsh et al. (2010) examined multiple parameters in False Bay Creek, including water quality and toxins in fish and invertebrate samples. Contaminants were found at levels that could have biological effects, including loss of fertility in salmonid eggs. In this study, water quality issues were worsened by negligible summer instream flows, use of the riparian corridor as cattle pasture, outdoor use of spray pesticides, and untreated runoff from county roads (Barsh et al. 2010).

Figure 4. Example of eroding dirt road contributing sediment to the County drainage system (Sutton Road, San Juan Island).

7.1.3 Effects on Groundwater Quality and Quantity

The County's reliance on groundwater as the primary source of fresh water has implications for the management of stormwater. Because the many small aquifers in the County are recharged by the infiltration of precipitation, land use and stormwater management practices that affect runoff, infiltration, and pollutant loading can impact the quality of groundwater resources throughout the County. Runoff and infiltration rates on steep topography underlain by thin soils or sedimentary deposits on shallow bedrock may be more sensitive to changes in land use and vegetative cover than gently sloping topography underlain by a thick sequence of sedimentary deposits. Likewise, the low water-bearing capacity of the many bedrock aquifers may not be able to buffer water quality impacts from pollutant loading related to roads, and commercial and residential areas. Thus, an understanding of the hydrogeology of the County is important for assessing which areas are more sensitive to various land-use practices and stormwater management alternatives. Careful management of stormwater to promote infiltration and maintain high surface and groundwater quality is essential.

7.1.4 Climate Change Considerations

Significant research on climate change impacts has been conducted by the Climate Impacts Group at the University of Washington. This research projects the local impacts of global climate change using 20 global climate models and two emissions scenarios. Local climate impacts were analyzed by downscaling the model results and by using regional climate models. The results indicate that future temperatures will increase by approximately 5.9°F by 2080 (range: 2.8 °F to 9.7 °F) (Littell et al. 2009). Therefore evaporation and transpiration are likely to increase in the future, reducing the amount of water that is available to recharge groundwater during the summer months. However, climate change impacts on precipitation are much more uncertain. Model results vary widely, but the average projected increase in precipitation is 4% by 2080 (range: -10% to +20%) (Littell et al. 2009). Some models show significant seasonal shifts, especially towards wetter autumns and winters and drier summers, and at least one regional model indicates that fall precipitation will increase less in the San Juans that elsewhere in Western Washington (Littell et al. 2009). Average projected winter increases in precipitation are not large relative to interannual variability (Littell et al. 2009). Projections of extreme precipitation events also vary significantly, but generally indicate increases in extreme rainfall magnitudes throughout the state in the future (Littell et al. 2009). The potential changes increase the importance of stormwater management practices that control flows, promote infiltration during the wet season, and preserve water quality. Infiltration of stormwater and groundwater recharge will also become increasingly important as population grows, groundwater demand increases (due to higher temperatures and greater population), and water resources become more scarce (due to the potential for greater seasonality of precipitation events, including reduced summer precipitation, and due to increased temperatures, which could affect the overall quantity of water that is available for groundwater recharge).

7.2 Alternatives for Stormwater Management[26]

7.2.1 Purpose

To protect critical areas including "Waters of the State," wetlands, streams, eelgrass beds, kelp forests, shellfish, and forage fish spawning habitat, stormwater runoff must be effectively managed. This section synthesizes the best available science for stormwater management alternatives. References provided in this section were primarily selected for their applicability to development in San Juan County. Stormwater alternatives were selected to illustrate an array of stormwater techniques that are used around the Puget Sound region, and are expected to be feasible at sites found within San Juan County to control flow rates and/or to improve stormwater runoff quality from developed areas.

Effective stormwater management prevents or minimizes disruption of natural site hydrology and preserves the quality of stormwater that leaves the site. The *Stormwater Management*

[26] Portions of this section are from the *City of Seattle Environmentally Critical Areas Best Available Science Review for Stormwater Code and Grading Code* (June 30, 2009) and are used by permission.

Manual for Western Washington (Ecology 2005a) includes the following 10 elements that can be implemented to effectively manage stormwater:

- Site planning via preparation of a stormwater site plan
- Prevention of pollution from construction sites through erosion and sediment control and other best management practices (BMPs)
- Control of pollution sources
- Preservation of natural drainage systems and outfalls
- On-site stormwater management through BMPs that include basic infiltration of roof runoff, dispersion, and preservation of soil quality
- Treatment of runoff, including more advanced treatment BMPs for pollutant generating surfaces
- Flow control using BMPs such as infiltration systems and ponds to mimic natural hydrology of the site
- Wetlands protection
- Basin/watershed planning
- Operation and maintenance of the site and stormwater management BMPs.

7.2.2 Best Management Practices for Stormwater Flow Control

Initial Site Planning

Proper planning for stormwater management at development sites helps to ensure that the most effective and efficient stormwater BMPs are implemented in order to preserve site hydrology and minimize impacts to water quality. A properly documented plan enables local authorities to efficiently review the proposed design for conformance with requirements. Many regional stormwater manuals prescribe a site planning process for stormwater management, in addition to providing guidance for BMP design. The *Stormwater Management Manual for Western Washington* (Ecology 2005a) is one of the most widely used stormwater guidance manuals in the region. The site planning process contained in his Manual includes the following steps (Ecology 2005a):

Collect and Analyze Information on Existing Conditions
Prepare Preliminary Development Layout
Perform Off-site Analysis (at local government's option)
Determine Applicable Minimum Requirements
Prepare a Permanent Stormwater Control Plan
Prepare a Construction Stormwater Pollution Prevention Plan
Complete the Stormwater Site Plan
Check Compliance with All Applicable Minimum Requirements.

A stormwater site plan should provide a comprehensive report containing all of the technical information and analysis necessary for designers and regulatory agencies to evaluate a proposed new development project relative to requirements (Ecology 2005a).

Perhaps more important, implementing a comprehensive stormwater site plan can help minimize impacts to stormwater quantity and quality through a holistic and thorough approach to site assessment, site layout, and stormwater planning. The Low Impact Development Technical Guidance Manual for Puget Sound (Puget Sound Action Team/Washington State University 2005) highlights the benefits of a comprehensive inventory and assessment of on-site and adjacent off-site conditions as the initial steps for implementing effective stormwater management plans. Evaluation of the existing hydrology, topography, soils, vegetation, and water features at a site will identify how stormwater moves through the site prior to development, providing valuable information necessary to implement proper stormwater site planning and layout as part of development (Puget Sound Action Team/Washington State University 2005).

Low Impact Development

The term "low impact development," or LID, refers to a range of development options and stormwater management measures that can help mimic predevelopment hydrologic processes. LID focuses on minimizing disturbance of the natural environment and engineering the built environment to maintain ecosystem and hydrologic functions. The result is a hydrologically functional and environmentally sensitive landscape (Prince George's County 1999a).

Ecology (2007) defines LID as follows:

> *Low Impact Development means a stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions.*

The *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Action Team/Washington State University 2005) is the most widely used local LID design manual in Washington. It contains information on site assessment, site planning and layout, vegetation protection and maintenance, clearing and grading, and flow control and treatment methods. It also contains information on hydrologic modeling parameters for LID flow control measures; this same information is also contained in the *Stormwater Management Manual for Western Washington* (Ecology 2005a). An increasing body of literature is promoting LID as the preferred means for managing stormwater from development (Booth 2007, Horner 2006, Horner 2007a, Horner 2007b, and Holz 2007). As with traditional stormwater management, it should be noted that the LID approach seeks to minimize disturbance and protect native vegetation as the first step, prior to resorting to BMPs to mitigate unavoidable stormwater impacts (Puget Sound Action Team/Washington State University 2005). Washington State University is currently working on an update to the 2005 *Low Impact Development Technical Guidance Manual for Puget Sound*, anticipated to be completed in 2011. Similarly, Ecology has organized a technical advisory committee and an implementation advisory committee to assist in developing statewide guidance and requirements for future application of LID (including through future municipal National Pollutant Discharge Elimination Permit [NPDES] requirements).

Best Management Practices for Flow Control

The following sections present information on a selection of stormwater management options that can help mitigate the hydrologic impacts of development in San Juan County. The facilities discussed include:

1. Bioretention

Permeable Pavement
Infiltration Facilities
Dispersion and Soil Amendment

Green Roofs
Cisterns
Trees
Downspout Dispersion.

Bioretention

Bioretention is the practice of retaining stormwater in depressions or structures that incorporate specific soils and plants. Common names for bioretention BMPs include bioretention swales, bioretention cells, rain gardens, and bioretention planters (also called planter boxes*)*. The healthy soil structure and vegetation associated with bioretention BMPs store water, promote infiltration and evapotranspiration, and slowly release stormwater flows in a way that mimics the hydrology of a natural landscape. Bioretention can provide stormwater flow control benefits through the following processes:

- **Infiltration** (routing stormwater flow to groundwater)
- **Evapotranspiration** (stormwater flow reduction through loss to atmosphere)
- **Attenuation** (reducing stormwater peak flows by slow release later in the event)

Early hydrologic performance of a bioinfiltration system in Maryland is discussed by Davis et al. (1998), and some of the initial bioretention design information was provided by Prince George's County (1999a and 1999b). More recent design guidance is provided in the *Low Impact Development Technical Guidance Manual for Puget Sound* (2005). Washington State University, Pierce County Extension has published the *Rain Garden Handbook for Western Washington Homeowners* that provides guidance for planning, design, and construction of small-scale bioretention installations. The San Juan Islands Conservation District also provides information on LID alternatives for land owners (http://www.sanjuanislandscd.org/Land_Use_Programs/Land_Use_Programs.html).

Bioretention systems are becoming one of the most widely used LID stormwater BMPs in the region and generally can be expected to be effective in many areas of the Pacific Northwest, including San Juan County. Several bioretention performance monitoring efforts have been conducted in the Pacific Northwest, Bioretention can be effective in all types of soils. Under drains or weep walls may be necessary in areas with impermeable soils or rock and in paved areas bioretention planters constructed of concrete may be used. Though these types of bioretention do not infiltrate as much water as facilities constructed in highly permeable soils, they still attenuate flows and remove contaminants.

In one of the more high-profile regional applications, in the late 1990s the City of Seattle constructed a bioretention system in a North Seattle street right-of-way. The underlying soil is mostly glacial till but there is some sand as well. Approximately 2.3 acres of road and residential development drains to the swale. During the period between January 2000 and January 2001, the system retained all of the dry-season runoff and 98 percent of the wet-season runoff, and was capable of fully attenuating approximately 0.75 inches of rainfall on the catchment area (Horner et al. 2002b). In Portland, Oregon, "Green Streets" Bioretention systems on SW 12th Avenue have been shown to reduce the peak flow of a 25-year storm event by 70 percent (BES 2006). In areas with glacial till or other low permeable soils, soils can be amended to improve infiltration effectiveness.

Permeable Pavement

Permeable pavement includes a wide range of technologies—including asphalt, carbonate-cement, paver blocks, and grass or soil-filled geogrids—that stabilize a surface while still allowing water to infiltrate into the ground. The feasibility and effectiveness of permeable pavement is limited by the long-term hydraulic capacity of the paving material (based on material, use, and long-term maintenance), the infiltration capacity of the underlying soil, and other factors such as depth to groundwater and slope of the finished grade. Permeable pavement may be an effective stormwater management measure in roadway, parking, and pedestrian access areas of San Juan County.

Booth and Leavitt (1999) compared the hydrologic performance of four types of permeable pavement to standard asphalt pavement at a municipal building parking lot in Renton, Washington. The native soil at the site was deep and very permeable sand, such that overall infiltration capacity of the pavement/soil system would be limited by the pavement. Booth and Leavitt (1999) observed no surface runoff from the permeable pavement. Brattebo and Booth (2003) reevaluated the hydraulic performance at the same location during 15 storms in the winter of 2001-2002. Virtually all water infiltrated for every observed storm; the most significant surface runoff event occurred during a 4.8 inch/72-hour storm, in which only 0.2 inch of surface runoff was generated from one type of pavement. St. John and Horner (1997) reported that porous asphalt shoulders installed on a two-lane highway in Redmond, Washington significantly reduced wet-season storm volumes, relative to runoff generated by standard asphalt shoulders. Similar to bioretention systems, extensive design and performance evaluation for permeable pavement continues throughout the Puget Sound region and nationwide, with any lessons learned being reflected in regional design guidelines and requirements. Applications in San Juan County should be sure to reference the very latest design and construction methods to assure optimal performance and longevity.

Infiltration Facilities

Infiltration is a technique used in many BMPs (including bioretention), typically incorporating constructed trenches, depressions, or systems of pipes or chambers to detain water, allowing time for it to soak into the surrounding soils. Properly designed and constructed infiltration facilities can be one of the most effective flow control (and water quality treatment) BMPs, and should be encouraged where conditions are appropriate (Ecology 2005a). The primary limitations for infiltration include poor soils, high groundwater elevations, sensitive groundwater resources, and long-term operation and maintenance sometimes necessary to maintain design infiltration performance. In particular, long-term performance of infiltration systems may be limited by clogging, due to sediment input or biological fouling as described by Warner et al. (1994) based on experiments conducted in a laboratory. Given the importance of groundwater quality protection in San Juan County, if infiltration facilities are used to reduce stormwater rates and volumes from pollution generating impervious areas, the design and construction must be carefully scrutinized to ensure appropriate water quality treatment is achieved and maintained.

Research has shown that it is important to conduct field infiltration tests in order to accurately estimate the design infiltration rate and appropriately size infiltration BMPs, rather than basing design infiltration rates on laboratory analysis of soils or other methods for approximating infiltration rates. Massman (2003) conducted full-scale *in situ* "flood tests" at four infiltration facilities in western Washington and found very large discrepancies when infiltration rates derived from these flood tests were compared with infiltration rate estimated from air conductivity or grain size measurements. On-site flood test based infiltration rates, which are considered to be the most accurate measure of infiltration, differed by up to two orders of magnitude (higher and lower) from infiltration rates developed using other (non-flood test) methods. These results show that infiltration rates cannot be reliably estimated on the basis of soil properties alone. Large scale field testing should be performed whenever possible prior to designing infiltration facilities to accurately design for site conditions.

Dispersion and Soil Amendment

Infiltration and treatment of runoff by directing unconcentrated flow through vegetated areas can also be a highly effective means of managing stormwater runoff. Naturally occurring undisturbed soil and associated vegetation provide important stormwater management functions, including: slowing runoff as it encounters dense ground level vegetation; capturing runoff in shallow depressions in the soil and organic duff; infiltration; nutrient, sediment, and pollutant adsorption and biofiltration; water interflow storage and transmission; and pollutant decomposition. Unfortunately, in addition to the reduction in available infiltration area caused by construction of impervious surfaces, development typically results in the smoothing, compaction and/or removal of the upper soil layers, reducing the infiltration capacity of the remaining soil (Booth et al. 2002, Chollak and Rosenfeld 1997, Kosti et al. 1995). This effect also significantly reduces the ability of the soil to remove dissolved metals (Minton 2002). Moreover, not only are important stormwater management functions lost, but such landscapes themselves can become pollution-generating pervious surfaces. Pollutants can include pesticides, fertilizers, waste from pets and other domesticated animals, and other landscaping and household/industrial chemicals. Given the relatively undeveloped conditions prevalent in San Juan County, it will be important to protect existing undisturbed soils and vegetation to help buffer important natural resources as part of planned future development.

Where soil and vegetation cannot feasibly be protected or retained on site, soil amendment approaches should be used to restore the hydrologic and other related functions of site soils. Studies by Chollak and Rosenfeld (1997) developed guidelines for amending soils with compost in landscaping practices. Several regional stormwater manuals also include guidelines for amending soil for improved stormwater functions (such as the Ecology, Seattle, and PSP/WSU manuals mentioned previously). Kosti et al. (1995) measured surface runoff and subsurface runoff from seven test plots of glacial till soil containing differing amounts of compost in Seattle, Washington. During storms from December 1994 to June 1995, two plots containing compost generated 53 percent and 70 percent of the total runoff volume generated by a control plot with no compost. The surface runoff hydrographs were attenuated in the compost plots as well. In addition to flow control benefits, amended soils in lawns can also have the benefit of reduced fertilizer requirements and reduced dry-season irrigation requirements (US EPA 1997).

Green Roofs

Green roofs have received significant national and local attention in the past several years and are being used in new construction with increasing frequency in San Juan County due to their stormwater management benefits. In Philadelphia, runoff monitoring was conducted for a nine-month period at a pilot-scale vegetated roof with a thickness of less than three inches (US EPA 2000). In this period there were 44 inches of rain and less than 16 inches of runoff. In Portland, Oregon, monitoring of four storms (two in March 2001 and two in August 2001) at a full-scale commercial building vegetated roof showed between a three-fold and nine-fold reduction in per-storm runoff volume (Portland 2001). Beyerlein et al. (2004) modeled the performance of a hypothetical ten-acre flat green roof with eight inches of soil using Washington State's Western Washington Hydrologic Model (WWHM) and long-term rainfall and pan evaporation data for five northwest cities: Vancouver, Bellingham, Seattle, Olympia, and Port Angeles. They predicted how green roofs could result in reductions in required stormwater detention storage volumes using the detention sizing module of WWHM. The results showed detention volumes, based on flow control requirements of the *Stormwater Management Manual for Western Washington* (Ecology 2005a), were reduced between 17 percent and 31 percent as compared with the volumes required for a standard impervious roof. Beyerlein et al. (2004) attributed the difference between the model results and the results of studies in Portland and Philadelphia to the fact that detention storage volume as determined by WWHM is typically controlled by winter storms that occur when potential evapotranspiration is lowest in western Washington.

Other local studies of green roof performance have been conducted by the City of Redmond (Herrera 2010a) and the City of Seattle (MKA 2007). Annual runoff volume reductions in these studies ranged from 47 percent to 70 percent depending upon the site and year.

Cisterns

Cisterns are tanks used to store stormwater runoff. Typically used to store runoff from roofs or other impervious surfaces for later use, cisterns can also be used for stormwater detention by capturing and then slowly releasing the water to an approved discharge point. Like other detention facilities, cisterns can help reduce peak flows and flow durations. In San Juan County many residences use roof runoff collection and cistern storage for potable water supply and for irrigation as an alternative to or in addition to well sources.

Cisterns are more likely to be aboveground than other detention facilities. The detention performance of cisterns is a function of contributing area, cistern size, and orifice size. The *Low Impact Development Technical Guidance Manual for Puget Sound* (2005) provides design guidelines and performance information for cisterns. In addition, there are online tools available to aid in sizing cisterns, such as the Rainwater Harvesting Calculator from the Washington State Department of Ecology (2010a). The City of Seattle has performed several pilot projects (including projects in Fremont, Ballard, and Lakewood) to demonstrate the feasibility of using cisterns for flow control on residential properties. These studies showed that cisterns can effectively control peak flows from residential roofs if cistern size and flow control orifice size is adequate relative to the contributing drainage area (Herrera 2008). The City of Seattle also provides design guidance for using cisterns as flow control.

Trees

Trees provide flow control via interception, transpiration, and increased infiltration, although the hydrologic benefits (particularly transpiration) can vary with seasonality (Xiao et al. 1998). Trees also provide improved air quality, reduced heat island effect, pollutant removal and habitat preservation or formation (McPherson et al. 2002). Some jurisdictions (such as Portland, Austin, San Jose, Seattle) give "flow control credits" for retaining or planting trees anywhere on a development site, with higher credit applied when trees are near impervious surfaces. The degree of flow control provided by a tree depends on the tree type, canopy area, and whether or not the tree canopy overhangs impervious surfaces. The City of Seattle has produced a literature review on the effects of trees on stormwater runoff (Herrera 2008). Key findings of this review were that evergreen trees in the Pacific Northwest can reduce flows through interception of 18 to 25 percent of annual rainfall and transpiration of up to 10 percent of annual rainfall. Deciduous trees are typically about half as effective as evergreens. The results of this review include recommendations for flow control credits, which may not be applicable in San Juan County, but exemplifies a model that indicates the level of flow control benefits that are provided by trees. A similar model could be developed for San Juan County based on local conditions.

In general, tree protection and retention would be a valuable stormwater management strategy throughout San Juan County and could be performed through designating native growth protection areas. A native growth protection area is a parcel of land, usually wooded, that may have a stream or wetland on it, which is permanently protected from any human disturbance or alteration and development or destruction. It is either dedicated to the local government, owned jointly by all the private landowners that have property adjacent to the parcel and otherwise protected in perpetuity.

Downspout Dispersion

Downspout dispersion BMPs include splash blocks, gravel-filled trenches (e.g. drip line trenches, and gravel trench level spreaders), or perforated pipes that spread runoff over vegetated pervious areas to minimize concentrated flow facilitate infiltration, attenuate peak flows and slow the entry of the runoff into the conveyance system (Hinman 2009; Hunt et al. 2010). Downspout dispersion BMPs require areas of vegetated ground cover, which is often available on larger parcels in San Juan County. However, downspout dispersion is not as effective and may not be appropriate near steep slopes, areas with little soil or vegetation, or where they may cause erosion or flooding problems on the site or on adjacent lots (Ecology 2005a).

7.3 Best Management Practices for Water Quality Treatment

The quantity of pollutants exported from a site, and the effect of those pollutants on a particular resource, can vary significantly depending on the amount of impervious area particularly roads, driveway and parking areas; the use of pesticides and chemicals on the site (e.g. moss control products, deicers, fertilizer, herbicides, insecticides, rodenticides); the effectiveness of stormwater dispersion, treatment and infiltration practices and any associated maintenance; and the sensitivity of the wetland or receiving water. Where stormwater flows into marine waters, bays and areas with limited mixing will experience more significant localized effects. In areas with good mixing, local impacts will be less significant, but discharged pollutants still add to pollutant background levels found in the Puget Sound and Salish Sea.

This section describes Best Management Practices that can be employed to prevent and reduce the quantity of pollutants flowing from roads and residential and commercial properties. To be most effective, these types of practices should be established for all development throughout the County. It should be recognized however, that while the systems and practices outlined can reduce the impacts of development on water quality and hydrology, they cannot replicate the natural hydrologic functions that existed before development, nor can they remove sufficient pollutants to replicate the water quality of pre-development conditions. This is because land development, as typically practiced today, is incompatible with the achievement of sustainable ecosystems. To effectively prevent additional impacts, and protect Critical Areas that rely on clean water, development methods that cause significantly less disruption of the hydrologic cycle must be utilized. (Ecology 2005a).

7.3.1 Construction Site Stormwater Pollution Prevention

Soil erosion from construction sites and grading activities has long been identified as a significant source of sediment and other suspended solids in runoff (Ellis 1936, Hagman et al. 1980, Yorke and Herb 1976, Becker et al. 1974). (US EPA 2007). Sediment from construction and grading sites with poor stormwater control can harm aquatic environments, adjacent properties, public and private roadways, and drainage systems.

Numerous studies at large sites (greater than five acres) have shown that the amount of sediment transported by stormwater runoff is significantly greater from sites with no erosion control practices than from sites with erosion controls (US EPA 1999; Owens et al. 2000). Similarly, results of a USGS/Dane County Land Conservation study (Owens et al. 2000) indicate that small sites can also be significant sources of sediment. Sediment loads in stormwater runoff from two monitored construction sites were 10 times greater than that which is typical from rural and urban land uses in Wisconsin. Total and suspended solids concentration data indicate the active construction phase produced concentrations that were orders of magnitude higher than pre- and post-construction periods.

The best way to stop erosion on typical construction sites is to employ BMPs that keep the soil in place using existing vegetation, erosion control blankets, or other methods which will prevent the soil from becoming dislodged during rain events (Ecology 2005a). Erosion and sediment control BMPs can be grouped according to three broad practice categories:

1) **Cover practices** – temporary or permanent cover that are designed to stabilize disturbed areas
2) **Erosion control practices** – physical measures that are designed and constructed to prevent erosion at the project site
3) **Sediment control practices** – temporary measures designed to prevent eroded soils from leaving the project site by trapping them in a depression, filter, or other barrier.

Ecology has developed a training program to design and inspect BMPs to assure they are reducing erosion and sedimentation from construction sites, including all sites subject to NPDES requirements (sites generally over one acre in size). BMPs must be inspected by a Certified Erosion and Sediment Control Lead (CESCL) (Ecology 2005c).

In addition to sediment, construction sites can also be sources of other pollutants, such as phosphorus, petroleum products, and products that can affect pH (Ecology 2005b). Source control practices designed for construction sites can reduce the use of these potential pollutants and/or prevent them from contaminating stormwater (Ecology 2005b). Pollutants other than sediment are primarily controlled using good housekeeping practices (such as maintaining vehicles and checking them regularly for leaks, keeping a spill kit on site, controlling concrete washout onsite) and other operational methods to reduce both the risks of pollutants contacting stormwater and the risks and impacts of accidental spills. Extensive information on stormwater BMPs for construction sites can be found in the *Stormwater Management Manual for Western Washington* (Ecology 2005a). For example, work can be phased to minimize the amount of soil that is exposed and subject to erosion at any given time. In Washington State it is practical to follow different procedures in the wet season when rain is frequent than in the dry season. West of the Cascade Mountains, Ecology (2005c) defines the wet season as October 1 to April 30 and the dry season as May 1 to September 30.

7.3.2 Permanent Stormwater Quality Treatment Best Management Practices

The following sections present information on a selection of stormwater facilities that may be most effective at mitigating the water quality impacts of development in San Juan County. The facilities discussed include:

1. Bioretention

    Permeable Pavement

Infiltration and Bioinfiltration Facilities
Wet Pool Facilities
Stormwater Treatment Wetlands
Sand Filtration
Media Filtration
Biofiltration Swales
Filter Strips
Water Quality Buffer Strips
Oil Control Facilities
Enhanced Treatment
Emerging Stormwater Technologies
Flexible Water Bars

Each of these alternatives has particular site and design requirements and limitations that must be considered when selecting BMPs for a particular location. An important consideration for facilities requiring periodic maintenance (e.g. removal of sediment or cleaning of oil control facilities) is whether the responsible party (homeowners association, private landowner) will be capable of providing facility maintenance required to maintain facility effectiveness. Another issue, particularly with runoff from lawns and driveways, is whether it is possible to collect the runoff so that it may be directed to a treatment facility, and after treatment, whether it is possible to infiltrate or otherwise dispose of excess runoff in a manner that does not result in it being recontaminated. Combining BMPs in series called "treatment trains" can be particularly effective at preventing problems commonly associated with some facilities.

The Metropolitan Washington Council of Governments (MCOG 1992) and California Department of Transportation (Caltrans 2008) studied the effectiveness and limitations of several commonly used stormwater practices, and identified a number of concerns addressing specific BMPs. The Ecology 2005 stormwater manual provides guidance on these concerns by specifying selection criteria, siting limitations, design considerations, and operation and maintenance procedures to address the following issues:

- Not all BMPs can reliably provide high levels of removal for both particulate and soluble pollutants, and treatment efficiencies vary widely. Infiltration BMPs can be effective in removing pollutants, but are only effective if sited properly and routinely maintained. Other BMPs, such as grassed swales, filter strips and water quality inlets, provide reliable levels of pollutant removal when designed for site-specific conditions including considering soil type, providing adequate treatment area, and periodic inspection and maintenance to prevent erosion or short circuiting.
- The longevity of some BMPs can be limited depending on site conditions, use patterns and maintenance frequency. Of particular concern are infiltration practices such as basins, trenches and porous pavement where success depends heavily on soil type, water table, and regular maintenance.
- In general, where poor longevity of BMPs is reported it is typically attributed to: lack of pretreatment, poor construction practices, improper site selection, and lack of regular maintenance. The life spans of these BMPs can be increased to acceptable lengths if communities adopt enhanced designs and commit to strong maintenance and inspection programs.
- Bioretention systems, green roofs, and any BMP that filters stormwater through a growing media have been shown to export nutrients. Care should be taken when designing these systems in basins that has are sensitive to nutrient loading.

- No single BMP option can be applied to all development situations and all BMP options require careful site assessment prior to design.
- Poorly designed BMPs can have significant negative environmental impacts. Careful site assessment and design are required to prevent stream warming, destruction of natural wetlands, export of pollutants, and modification of riparian habitat (MCOG, 1992).

Bioretention

In addition to flow control benefits discussed in the previous section, bioretention facilities provide water quality treatment through sedimentation, soil filtration, adsorption, and filtration and uptake by plants. Studies in Maryland (Davis et al. 2001, Davis et al. 2006, Davis et al. 2003) and Minnesota (Tornes 2005) have shown that rain gardens remove 74, 73, and 88 percent of influent TSS, total phosphorus, and total zinc, respectively. Davis et al. (2001, 2006, and 2003) also examined the effect of the mulch layer on system performance. The effect of mulch on total zinc removal was drastic, as only 65 percent of the influent zinc was removed by the low mulch rain garden, compared with 95 percent removal in the high mulch system. A minimum two-inch mulch layer on the surface of the BMP is essential for optimal performance (Davis et. al. 2001). Davis et al. (2001) states that "laboratory and pilot studies have implicated the surface mulch layer as the most important component of the bioretention facility for metals removal." Bioretention is becoming an increasingly common and preferred BMP for achieving both flow control and water quality goals in San Juan County and much of the Puget Sound region.

Permeable Pavement

Booth and Leavitt (1999) documented the pollution removal capability and long-term hydraulic performance of four types of commercially available permeable pavement compared to standard (impervious) asphalt pavement at a municipal building parking lot in Renton, Washington. Total copper and total zinc concentrations in the sampled infiltrate were significantly lower than corresponding concentrations in runoff from the asphalt. Motor oil was detected in 89 percent of the samples from the asphalt runoff, but not in any water sample infiltrated through the permeable pavement. Brattebo and Booth (2003) reevaluated pollution removal at the same pavement system during nine storms in the winter of 2001-2002. Again, infiltration had a dramatic effect on water quality. Toxic concentrations of copper and zinc were present in 97 percent of the asphalt runoff samples, and in 14 percent of the infiltrate samples.

St. John and Horner (1997) reported that porous asphalt shoulders installed on a high-traffic highway removed over 90 percent of the solids and total metals in runoff generated from standard asphalt shoulders installed in adjacent locations. Nationwide, numerous studies have shown similar results (Fach and Geiger 2005; Gilbert and Clausen 2006; Legret et al. 1996; Pratt et al. 1989).

Not only does permeable pavement reduce pollution in stormwater, but even a simple permeable pavement layer over an impervious road surface has been shown to improve runoff water quality. In this method, a porous top course, known as an open graded friction coat (OGFC), is laid over a standard impervious asphalt base. While the primary reasons for using an OGFC are traffic noise reduction and visibility improvement through spray reduction, the porous surface layer filters particles and attached pollutants from stormwater, which can be periodically removed by vacuum sweeping. OGFC has been used in Europe, by the Oregon State Department of Transportation (ODOT), and by the Washington State Department of Transportation (WSDOT). Barrett (2005) found that OGFC was associated with concentration reductions for TSS (92 percent), total lead (91 percent), total copper (47 percent), and total zinc

(75 percent). WSDOT has installed test sections of OGFC, but has not conducted any water quantity or quality monitoring associated with these installations.

Notably, despite these and other study results confirming the water quality treatment benefits of permeable paving, the 2005 Ecology stormwater management manual does not give water quality treatment credit for permeable pavement surfaces used for stormwater management (without a specific treatment layer designed beneath the pavement layer). Regardless, given the importance of groundwater quality protection in San Juan County, if permeable pavement facilities are used to manage runoff from pollution generating areas, the application should be carefully scrutinized to ensure appropriate water quality treatment is achieved and maintained. In some cases, a dedicated treatment layer beneath the pavement layer, or a collection system beneath the pavement layer that routes water to a separate downstream treatment facility may be prudent.

Infiltration and Bioinfiltration Facilities

Infiltration and bio-infiltration systems remove pollutants primarily via physical filtration as stormwater passes through the underlying soil, but also via chemical adsorption and precipitation reactions, as well as by microbial decomposition. Biological uptake by plants may also occur. In addition, some pollutants (such as nutrients) may also be utilized by microbes present in the soil. A study of several stormwater infiltration system designs in Pierce County, Washington showed that infiltration of stormwater through a biofiltration swale underlain by six inches of imported topsoil reduced total copper concentrations by 47 percent, total lead concentrations by 79 percent, and total zinc concentration by 50 percent (Tacoma-Pierce County Health Department/Pierce County Public Works Department 1995). Nineteen storm events were monitored over four years in the study. In contrast to these results, the study also found elevated concentrations of these metals in groundwater under infiltration systems that discharged directly to the gravelly native soils without any other treatment (such as a specific soil treatment layer). These results together demonstrate the importance of properly absorptive soil or treatment medium, but also the efficacy of a relatively shallow layer of such soil in removing metals. The treatment properties of soils are particularly important in wellhead protection areas and aquifer recharge areas.

Additional local biofiltration studies include Goldberg et al. (1993), Kulzer and Horner. (1992), King County (1995), and Horner (1988). These studies generally showed that TSS and total metals are removed in biofiltration swales, with phosphorous removal possible to a more variable degree. Field inspection of thirty-nine biofiltration swales in King County, Washington found only nine to be in ‘good’ condition; that is, having complete and uniform vegetation cover (King County 1995).

Davis et al. (2001) studied the characteristics and performance of bioretention systems for the removal of several heavy metals (copper, lead, zinc) and nutrients (phosphorus, Total Kjeldahl Nitrogen [TKN], ammonia [NH_4^+-N], and nitrate [NO_3^--N]) using synthetic urban storm water runoff based on batch and column adsorption studies, and pilot scale laboratory systems. Reduction in concentrations of all metals exceeded 90 percent, with specific metal removals of 15 to 145 milligrams per square meter (mg/m^2) per event. TKN, ammonium, and phosphorus levels were reduced by 60 to 80 percent. Little nitrate was removed and nitrate production was noted in several cases. Davis et al. (2003) evaluated pollutant removal in pilot-plant laboratory bioretention systems and two existing bioretention facilities. Removal rates of lead, copper, and zinc were close to 100 percent under most conditions; with effluent copper and lead levels mostly less than 5 micrograms per liter (µg/L) and zinc less than 25 µg/L. Somewhat less removal was noted for shallow bioretention depths. Runoff pH, duration, intensity, and pollutant concentrations were varied, and all had minimal effect on removal. The two field investigations generally supported the laboratory studies.

Kim et al. (2003) evaluated nitrate removal by denitrification in test columns and a pilot-scale bioretention system that were designed to promote nitrate removal through the use of a continuously submerged anoxic zone with an overdrain. The pilot-scale facility achieved nitrate plus nitrite mass removals of up to 80 percent.

Studies of conventional infiltration trenches in Maryland indicate that up to half of recently constructed (5-years old or less) facilities failed to operate as designed do to clogging or inflow problems (Galli 1992). Lifespan can be increased by proper design of pretreatment systems, use of a sand layer rather than filter fabric at the bottom of the trench, and rototilling the trench bottom to preserve infiltration rates (Galli 1992).

Studies in the mid-Atlantic region indicate that infiltration basins also have high failure rates within five years of construction due to clogging (Galli 1992, Maryland Depatment of Environment 1991, Maryland Department of Environment 1986). Facility performance can be increased by constructing facilities with adequate pretreatment, shallow water depths, bypass systems for large storms, careful geotechnical investigations, sand surfacing for the trench bottom, and installation of underdrains (Schueler 1992).

Hathhorn and Yonge (1996) investigated the potential for groundwater pollution from stormwater infiltration systems using bench-scale systems containing soils found in Washington State and organic soil amendments. They found that copper and zinc tended to be removed by association with organic material, while adsorption onto soil minerals due to cation exchange was the dominant removal mechanism for cadmium and lead. Extensive reviews of the potential for and confirmation of groundwater contamination are provided in Minton (2002) and Pitt (1996). As noted previously, given the importance of groundwater quality protection in San Juan County, if infiltration facilities are used to manage runoff from pollution generating areas, the design and construction must be carefully scrutinized to ensure appropriate water quality treatment is achieved and maintained.

Wet Pool Facilities – Wet Ponds, Wet Vaults, and Combined Detention and Wet Pool Facilities

Water quality facilities built as wet pool facilities contain a permanent pool of water designed to dissipated energy and improve the settling of particulate pollutants. Example wet pool facilities include wet ponds, wet vaults, and combined detention and wet pool facilities. A wet pond is a constructed stormwater pond that retains a permanent pool of water ("wet pool") at least during the wet season. A wet vault is an underground structure similar in appearance to a detention vault, except that a wet vault includes a permanent pool of water (that dissipates energy and improves settling of particulate pollutants). A combined detention and wet pool facility has the appearance and design features of a detention facility, but contains a permanent pool of water.

The primary design factor that determines a wet pool's treatment efficiency is its volume relative to the volume of stormwater that enters the BMP; the larger the ratio, the greater the potential for pollutant removal (Ecology 2005a). These facilities provide runoff treatment by allowing settling of particulates during quiescent conditions (sedimentation) and, for aboveground facilities, by biological uptake, bacterial decomposition, and vegetative filtration.

Because the wet vault is underground, it lacks much of the biological pollutant removal mechanisms, such as algae uptake, that would be present in surface wet ponds (Ecology 2005a.). Studies of pollution removal in wet pool facilities in the Puget Sound region include King County (1995), Comings (1998), and Kulzer (1989). Other useful studies include Driscoll (1986), Gain (1996), Kantrowitz and Woodham (1995), Lawrence et al. (1996), Stanley (1996), Walker (1987), Whipple (1979), and Wu et al. (1996). These studies show that wet pool facilities can remove TSS, total nitrogen, metals, and phosphorous. However, some of the studies showed a net release of some of these pollutants. Wet pools can also remove dissolved pollutants. In particular, national data indicate that wet pools are one of the most effective BMPs for dissolved metals removal (Barrett 2005; Strecker et al. 2004). Sediment removal typically ranges from 50 to 90%, total phosphorus removal ranges from 30 to 90%, removal of soluble nutrients ranges from 40 to 80%, and removal of trace metals, coliform, and organic matter is frequently moderate to high (Schuler et al. 1992). However, like many BMPs, performance can decline in the long term if maintenance is inadequate or if contaminant levels become highly concentrated in the facility sediment, particularly with respect to dissolved phosphorus (Minton 2004, 2005). .

A Florida study of the migration of soluble metals through sediments accumulated in the bottom of highway-runoff wet ponds showed that most of the metals are retained in the top 15-25 centimeters, and that removal of accumulated bottom sediments approximately every 25 years would be sufficient to minimize the potential of groundwater contamination (Yousef and Yu 1992). The implications of this result can be applied to many BMPs; metals removed by BMPs will accumulate in the BMP and must be periodically removed if long term performance is to be optimized. Other potential negative factors associated with wet pond facilities include waterfowl use (Schuler et al. 1992) and associated pollutants including bacteria and nutrients.

Stormwater Treatment Wetlands

Water quality treatment in wetlands is achieved through sedimentation, filtration, soil adsorption, chemical precipitation, biological uptake by plants, and microbial transformation of nutrients. Wetland hydroperiod is the primary driver of these processes because hydrology is the most important factor for sustaining wetland processes and plant communities (Mitsch and Gosselink 1986). Hydroperiod of a wetland includes the water depth, flow, and duration and frequency of flooding. The hydroperiod affects species composition and richness, primary productivity, organic accumulation, and nutrient cycling.

Wetlands constructed for water quality treatment generally provide high quality treatment similar to the effectiveness of bioretention and infiltration, however with a lower risks of groundwater quality impacts. Constructed wetland designs that incorporate long residence times and low velocities are typically the most effective at treating stormwater. Kadlec and Knight (1996) give the following expected pollutant removal performance (listed with constituent concentration) for parking lot runoff treated by constructed wetlands:

- TSS: 88 – 98 percent (2-10 mg/L)
- Fecal coliform: 60-90 percent (20-500 colonies/100 mL)
- Total zinc: 25 to 95 percent
- Total Phosphorus: 89-95 percent (0.02-0.05 mg/L)

The processes that occur in wetlands make them particularly capable of significant metals removal (Kadlec and Knight 1996). These metals removal processes include:

- Binding to soils, sediment, particulates, and soluble organics

- Precipitation as insoluble salts, principally sulfides and oxyhydroxides
- Uptake by plants, including algae and bacteria.

Wetland studies indicate that stormwater treatment wetlands are effective at removing between 21 percent and 95 percent of copper (by mass), with a median of 73 percent for all studies (Feijtel et al. 1989, Hendry et al. 1979, Schiffer 1989, CH2M Hill 1994, Harper et al. 1986, Sinicrope et al. 1992, Noller et al. 1994, Gladden et al. 2002, Walker and Hurl 2002). Similarly, wetlands can be very effective at removal of zinc, with documented removal rates of 33 percent to 96 percent (by mass), with a median of 79 percent for all studies (Feijtel et al. 1989, Hendry et al. 1979, Schiffer 1989, CH2M Hill 1994, Harper et al. 1986, Edwards 1993 [unpublished Tennessee Valley Authority data], Sinicrope et al. 1992, Walker and Hurl 2002).

Hydrocarbons in wetlands are removed through volatilization, photochemical oxidation, sedimentation, sorption, and biological (microbial) degradation (Kadlec and Knight 1996). Most studies on hydrocarbon removal focused on biological and chemical oxygen demand for municipal waste, but studies do indicate that wetlands are also effective for hydrocarbon removal (Litchfield and Schatz 1989, Litchfield 1993, Tang and Lu 1993, Knight et al. 1994, Fountalakis et al. 2009, Terzakis et al. 2008). Nonetheless, specific values are not presented in this report because of limited applicability to stormwater runoff.

Sand Filtration

Sand filtration is a water treatment technology that has frequently been applied to stormwater. A typical sand filtration facility consists of a pretreatment system, flow spreaders, a sand bed, and underdrain piping (Ecology 2005a). Studies of sand filters have been conducted by Austin (1990), Horner and Horner (1995), Bell et al. (1995), the California Department of Transportation (2004), and Minton (2005). These studies show that sand filters can be effective at removal of TSS, metals, biochemical oxygen demand (BOD), petroleum, total nitrogen, and phosphorous.

Minton (2002) cites various studies showing the positive pollution removal effectiveness of sand coated with iron oxide and sand mixed with iron wool or calcitic lime. Wanielista and Cassagnol (1981) demonstrated that various amended sand media reduced BOD and TSS concentrations in detention pond effluent, and that some nitrogen removal took place in the filters as well.

Stormwater filtration using peat mixed with sand is effective at removing metals (Clark et al. 1998). Severe clogging in a sapric peat/sand filter in Minnesota demonstrated the importance of using hemic or fibric peat (Tomasek et al. 1987).

Basic sand filters are expected to achieve average pollutant removals of 80 percent TSS at influent event mean concentrations of 300 mg/L (King County 1995, Chang 2000). Basic sand filters are also expected to reduce oil and grease to below a daily average of 10 mg/L and 15 mg/L, with no ongoing or recurring visible sheen in the discharge (Ecology 2005a). Large sand filters are expected to remove at least 50 percent of the total phosphorous compounds (as total phosphorus) by collecting and treating 95 percent of the runoff volume (ASCE and WEF 1998).

Sand filters should be located off-line before or after detention (Chang 2000). Pretreatment is necessary to reduce velocities to the sand filter and to remove debris, floatables, large particulate matter, and oils. A sand filter vault is similar to an open sand filter except that the sand layer and underdrains are installed below-grade in a vault that consists of presettling and sand filtration cells. A linear sand filter is a long, shallow, two-celled and rectangular vault, with the first cell designed for settling coarse particles and the second cell containing the sand bed (Ecology 2005a).

Media Filtration

Media filtration systems typically consist of a vault or catch basin housing a dedicated stormwater treatment material through which stormwater passes. The pollutant removal capacity is dependent on the type of media. Leif (1999) and CSF Treatment Systems (1994) demonstrated that filtration using mature processed leaf compost effectively removes TSS and total metals. Phosphorous concentrations were higher in the effluent than in the influent in the tests by Leif (1999), probably due to degradation of vegetative material washed onto the filter and bird manure deposited on the filter bed. Since compost serves as a cation exchange medium, one would expect metals removal by adsorption, but not removal of phosphorous or nitrate, which are anions. Minton (2002) cited various studies showing the effectiveness of zeolite minerals as a filtration medium to remove metals by cation exchange and phosphorous by anion exchange in cases where the zeolites were amended to improve anion exchange capability. Minton (2002) also cited the studies on the use of activated alumina, cationic and anionic polymers, synthetic resins, and other media. The performance of a media filtration facility depends on many factors, including the type of media (such as diatomaceous earth, leaf compost, perlite, sand, zeolite, etc.), and the physical properties of the granular media, including size, size distribution, sphericity, porosity, density, and hardness (Minton 2005).

There are two proprietary cartridge-based media filters that have been approved for TSS treatment in Washington by Ecology: the Contech StormFilter and the KriStar Perk Filter. Both of these systems utilize a media mix of perlite, zeolite, and granulated activated carbon. The systems have been shown to remove greater than 80 percent of influent TSS concentrations. The Perk Filter has also been shown to remove greater than 50 percent influent total phosphorus (Herrera 2010b). Another proprietary system that takes advantage of media filtration is the Filterra system. The Filterra system uses a proprietary media mix placed in a vault and planted with a small tree or shrub. The Filterra system has been shown to effectively remove dissolved metals, oil and grease, and TSS (Herrera 2009b). Future research on the Filterra system will determine if the system is effective at removing total phosphorus.

Another media filtration option that is appropriate for San Juan County is the media filter drain. The WSDOT *Highway Runoff Manual* (2008) provides guidance for design and construction of media filter drains. Studies conducted by WSDOT have indicated that this system is effective at removing TSS, total phosphorus, and dissolved metals (Herrera 2006; Herrera 2009c). The media filter drain consists of a roadside embankment constructed with a wedge of media (aggregate, perlite, dolomite, and gypsum) that dispersed runoff must pass through before entering an underdrain system. The system has been shown to be effective to remove greater than 80 percent of influent TSS, greater than 50 percent of total phosphorus, and approximately 50 percent of dissolved copper and zinc (Herrera 2006).

Biofiltration Swales

Basic biofiltration swales typically have a trapezoidal or parabolic shaped cross-section and are typically designed to be an in-line treatment facility. These facilities are designed as water quality treatment facilities to remove low concentrations of pollutants such as TSS, heavy metals, nutrients, and petroleum hydrocarbons (Ecology 2005a). Flow-through grass swales function as treatment devices if vegetation remains sufficiently erect to reduce the shear stresses in the channel, thereby reducing its capacity to carry sediment (Carollo et al. 2002). The performance of biofiltration swales is highly variable (Ecology 2005a, Minton 2005) and can be significantly affected by improper design, construction, and/or maintenance.

A wet biofiltration swale is a variation of a basic biofiltration swale and used where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. This condition is often found in flat roadway areas in the agricultural valleys of San Juan County. Vegetation specifically adapted to saturated soil conditions is needed, which in turn requires modification of several of the design parameters for the basic biofiltration swale (Ecology 2005a). A continuous inflow biofiltration swale is used in situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head. This type of facility requires an increased swale length to achieve an equivalent average residence time (Ecology 2005a).

Filter Strips

Filter strips are vegetated treatment systems (typically grass) designed to remove low concentrations and quantities of TSS, heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as linear strips that receive dispersed sheet flow from roads or other surfaces. A basic filter strip is flat with no side slopes. Contaminated stormwater is distributed as sheet flow across the inlet width. A narrow area filter strip is a filter strip designed for impervious areas with flow paths of 30 feet or less that can drain along their widest dimension to grassy areas (Ecology 2005a).

Newberry and Yonge (1996) found that a vegetated strip removed significant amounts of TSS and metals from simulated stormwater. WSDOT developed a compost amended vegetated filter strip (CAFVS) and found that the system infiltrated more water than a standard roadside embankment. However, the effluent concentrations were not lower in the CAVFS system compared with the unimproved control (Herrera 2009d).

In a separate study, WSDOT monitored the performance of unimproved filter strips along Interstate 5 (Herrera 2009e). They found that even 42-year old embankments that were not designed for stormwater treatment removed 94, 83, and 71 percent of influent TSS, total zinc, and total copper, respectively. Results like this indicate that filter strips may be some of the most effective BMPs for treating runoff from roadways.

Water Quality Buffer Strips

Water quality buffer strips are typically undisturbed areas of native vegetation next to streams, wetlands and marine areas. These strips can be very effective in protecting water quality by removing dissolved and particulate contaminants, reducing bank erosion, and displacing activities from the water's edge that would otherwise be a source of pollution. Buffer strips to protect water quality as well as habitat functions of Critical Areas are discussed in detail in Chapters 2, 3 and 4.

Oil Control Facilities

Oil control facilities are designed to remove oil and other water-insoluble hydrocarbons and settleable solids from stormwater runoff. These facilities typically consist of three bays: forebay, separator section, and afterbay. The American Petroleum Institute (API) separator, also called a baffle type separator, contains two baffles. The sludge retaining baffle rises from the floor of the oil/water separator chamber and settled solids are trapped behind this baffle. The oil retaining baffle descends from the top of the chamber and extends at least 50 percent below the depth of the oil/water volume. The floating oil and other hydrocarbons are trapped behind this baffle as the cleaner water flows under and exits the facility (American Petroleum Institute 1990, Ecology 2005a). The coalescing plate (CP) separator consists of a series of parallel and inclined plates that provide quiescent conditions for settling and a depth separation to trap oils at the surface (Ecology 2005a). Oil control facilities are primarily effective at removing relatively high concentrations of oil in runoff, and typically are only applied to sites that generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil (Ecology 2005a). In San Juan County, this would be limited to only the highest used roadway intersections, ferry terminals, and targeted commercial or industrial areas.

Emerging Stormwater Treatment Technologies

Ecology approves BMPs and technologies that can be used for several types of water quality treatment, including pretreatment, oil treatment, basic treatment, enhanced treatment, phosphorus treatment, and treatment at construction sites. Ecology has published guidance for evaluating emerging stormwater treatment technologies, Technology Assessment Protocol – Ecology (TAPE) and publishes a list of approved technologies on the Ecology website (2010b). Technologies that have received General Use Level Designation (GULD) status are approved for general use in the given application. The Ecology list includes both generic technologies that can be constructed by the general public (such as WSDOT Media Filter Drain) and proprietary treatment technologies that must be purchased from the manufacturer (such as Americast Filterra system). These technologies can be implemented in San Juan County in accordance with local regulations to target specific water quality goals and/or to expand the available suite of stormwater BMPs for site development or retrofitting.

BMPs for Management of Dirt and Gravel Roads

San Juan County has significant problems with sediment and TSS in stormwater due to erosion of gravel driveways and dirt roads. The County currently does not have standards for driveway construction and maintenance and driveways are often not constructed with proper drainage, which can contribute to excessive erosion of the driving surface during storm events. Studies of forest roads in southwestern Washington and western Oregon have found that dirt roads with steep gradient, heavy use, fine soils, and that drain directly to surface water bodies have the highest potential to deliver sediment to the environment (Bilby et al. 1989, Luce and Black 1999). Thus, abatement and management efforts should at minimum address similarly steep road sites in order to achieve the most benefit for the least effort. Effective approaches to manage sediment from roads include: directing ditches onto the forest floor where possible, crowning the road, increasing the frequency of cross culverts or road dips to minimize the amount of flow that is directed into the forest in any one location, increasing the amount of road ballast used, and surfacing the road with harder rock (Bilby et al. 1989). Sediment production can also be reduced by minimizing the frequency of ditch cleaning, allowing for vegetation to become established in ditches, and encouraging vegetation on cut slopes (Bilby et al. 1989, Luce and Black 1999).

The USDA Forest Service (2000) has developed a water quality management guide that contains BMPs that are applicable for use on dirt roads. The guide was developed for use on forest system lands in California, but is very applicable for roads in San Juan County. The BMPs contained in the guide would need to be evaluated on a site by site basis to ensure appropriate application because a number of treatment options may be feasible at each site. The following BMPs could be considered to minimize erosion on dirt roads:

- Construction of properly spaced cross drains, water bars, or rolling dips
- Installing energy dissipaters, aprons, gabions, flumes, oversized drains, and debris racks
- Armoring of ditches, drain/culvert inlets and outlets
- Removing or adding berms to control runoff.

Runoff can also be dispersed from the road surface by constructing the road with rolling grade, outsloping, or crowning the road, and installing water-spreading ditches or contour trenching to disperse water after it leaves the road surface. This dispersion can reduce downstream peak flows by allowing water to infiltrate into the surrounding soils. Additionally, sediment filters or settling ponds can be used to reduce sediment loads by treating the runoff. Road surface treatment including sealing, aggregate surfacing, chip-sealing, or paving may also be considered to reduce erosion. Though infiltrative capacity of dirt roads is typically quite limited, pervious surfacing options would typically result in less runoff from the road.

Flexible water bars (i.e. rubber razor blades) are one example of a BMP that can be installed in the roadway to ensure that precipitation and surface flow is directed off the roadway and into vegetation or ditches (Figure 5). These water bars can be constructed from conveyor belt material sandwiched between timbers and buried in the road. They should be installed at an angle to direct water off the road and into the drainage system.

Source: (www.edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=00038T)

Figure 5:Example of flexible water bars

Ditches

San Juan County owns and operates miles of roadside ditches that make up the majority of the drainage infrastructure in the County. Ditches can collect a wide range of pollutants from fecal coliform bacteria to petroleum hydrocarbons to heavy metals from roads, parking lots, and construction sites and transfer them to watersheds. Vegetated ditches can be effective at removing sediment and TSS from stormwater when flow depths are low (2 to 4 inches or less) and velocities are low (less than 1 foot per second) (WSDOT 2008). Maintenance of ditches should focus on preserving the condition and capacity for which they were originally constructed and minimizing bare or thinly vegetated ground surfaces. Cleaning should be performed in spring or early fall, vegetation removal should be avoided if possible, and ditches should be reseeded when vegetation is removed (Seattle 2009). The King County Department of Transportation Roads Maintenance Section is experimenting with stormwater treatment BMPs for retrofitting these ditches. The BMP they are using is similar to a large rock checkdam with an amended soil filter in the center. Thus far in experimentation, the BMP has been effective at reducing TSS, turbidity, PAH's, and zinc in stormwater runoff and also increasing infiltration, particularly during small storms and earlier in the rainy season before the surrounding ground becomes saturated (Jim Crawford, King County engineer, personal communication on September 22, 2010).

7.4 Literature Cited*

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CHAPTER 8

BEST AVAILABLE SCIENCE
Maps

(Please refer to the accompanying PDF for map images.)

8 Maps

This chapter contains the maps that were compiled and/or developed as part of the compilation of the Best Available Science for San Juan County. Following is a brief description of each map along with the sources of the data presented.

San Juan County Wetlands – This map was created by Earth Design Consultants Inc. working with Dr. Paul Adamus. The methodology for creating the information shown on the map is described in Chapter 2, Appendix 2A-1.

San Juan County Tidal Wetlands – The data in this map came from two sources, the National Wetlands Inventory, and a map layer provided by Jim Slocomb, a local GIS expert and member of the San Juan County Marine Resources Committee.

San Juan County Streams – This map was developed by Earth Design Consultants Inc. and Dr. Paul Adamus using the County LiDAR maps. It shows the approximate path that runoff and shallow subsurface flow (and potentially pollutants) are likely to take during the most intense and/or prolonged storms, and may be helpful in protecting water quality.

San Juan County Vegetation Height – This map was also developed by Earth Design Consultants Inc. and Dr. Paul Adamus using the County LiDAR maps. It can be used in conjunction with other data to identify areas likely to support the most species, corridors connecting areas with high diversity, or to identify the habitat of particular species.

Shoreline Fish and Wildlife Habitat Conservation Areas – The map layers presented were provided by the Washington Department of Fish and Wildlife, Washington Department of Natural Resources, National Marine Fisheries Service (salmon map), and Friends of the San Juans (who worked with DNR and WDFW to produce maps of forage fish spawning beaches and kelp and eelgrass beds).

Marbled Murrelet Habitat – This map was provided by the U.S. Forest Service.

Potential Upland Fish and Wildlife Habitat Conservation Areas – The layers included on these maps were provided by the Washington Department of Fish and Wildlife, Washington Department of Natural Resources, and the Wild Fish Conservancy who prepared the stream type maps using State protocols.

Flood Zones – The layers included on these maps were provided by the Federal Emergency Management Agency and the Department of Ecology (Coastal Zone Atlas).

Slope – Slopes are from the County maps (based on United States Geological Survey 1:24,000 quads?). Hazardous slopes are from the Washington Department of Ecology Coastal Zone Atlas.

Erosive Soil Map – Erosive soils are from the County soil survey (prepared by the United States Department of Agriculture).

Cliffs and Protected Areas - This map was also developed by Earth Design Consultants Inc. and Dr. Paul Adamus, using information provided by the County GIS department. Protected areas are those owned (or with management oversight?) by a conservation organization such as the County Land Bank and the San Juan Preservation Trust. The source of the cliffs layer needs to be confirmed, but is likely the Washington Department of Fish and Wildlife.

CHAPTER 9

BEST AVAILABLE SCIENCE

Responses to Comments from Scientific Experts and Agencies

CHAPTER 9 CONTENTS

9 Expert Comments and Responses

This chapter contains responses to comments from scientific experts which were received during the review period for the draft document, which was part of the peer review process for this report. Original copies of the expert comments and, where available, information on the qualifications of the expert, are included at the end of this chapter. (Those submitting expert comment were asked to provide a summary of their educational background and experience to determine their areas of expertise, and most did so. Some experts included the description of their professional qualifications within the text of their submittals. Please refer to the expert comment letters at the end of this chapter for these descriptions. Comments were also received from staff and committees associated with governmental agencies, and it was assumed that they are experts within the scope of their duties and positions. In evaluating the comments, the particular expertise of the individual or individuals was considered (i.e., they were considered to be experts only in their field; comments outside of their area of expertise were considered as general public comment).

9.1 Introduction and Overview

1. Section 1.4, pg. 15, Scott Rozenbaum, a local wetlands professional, provided rainfall data for Lopez Island which was included.

2. Section 1.9, pg. 22, Barbara Rosenkotter, Lead Entity for Salmon Recovery, provided several quotes from the Salmon Recovery plan and suggested additions to this section to better characterize salmon use of the nearshore. To avoid duplication and maintain consistency with the approach for other types of Critical Areas which were not discussed in the introductory chapter, this section was relocated and combined with related sections in Chapter 3, and additional information was included on salmon habitat in the San Juans.

3. Discussion provided by Janet Alderton, a local biologist (BA Zoology, MS Biology with many published papers) on how science works. Discussion added to this chapter.

4. Ed Kilduff, a local geologist and hydrogeologist with expertise in contaminant fate and transport, submitted the comments which are summarized here (original attached):

a) Additional study is needed to better characterize agents of environmental impact and model the pathways and mechanisms giving rise to effects;

b) The quality of data is important;

c) Suggested a framework for evaluating scientific evidence;

d) Pointed out that the Dept. of Ecology encourages local jurisdictions to tighten their Critical Area requirements without taking actions to deal with environmental problems within their jurisdiction (e.g., enforcement of sediment antidegradation standards);

e) Suggested that there needs to be more discussion of potential alternatives to buffers and provided some LEED guidance on buffers and a paper prepared by Entrix; and

f) Disagreed with a statement made by Dr.Adamus regarding wetlands being limited in their ability to remove contaminants.

Responses follow:

a. The type of modeling and risk assessment described in Mr. Kilduff's submission is not required, would take years to complete and the cost would be prohibitive (likely several million dollars). With the resources we have we are doing our best to summarize what is known about San Juan County's Critical Areas and to present options for protecting them. It is likely that additional options will be identified and discussed in the coming months. Though not perfect, the BAS Synthesis and underlying scientific reports provide an adequate foundation for decision making.

b. It is agreed that quality data is important. The scientists and planners who compiled the Synthesis evaluated the reports and information that is cited and determined that it meets the WAC standard for BAS.

c. The Council may wish to consider the suggested evaluation framework. Again, the scientists and planners who compiled the Synthesis evaluated the reports and information that is cited and determined that it meets the WAC standard for BAS.

d. The action or inaction of other governmental organizations does not relieve San Juan County of its legal obligation to protect Critical Areas.

e. As discussed in the report, buffers provide for a variety of functions, including different components of wildlife habitat (food, shelter, cover). It is agreed that there are a variety of options for preventing contaminants from getting into runoff and for removing contaminants before they reach wetlands and waterways. A treatment train, with multiple treatment/ infiltration features in sequence, is a well recognized and effective approach and this is mentioned in Chapter 7 .

The LEED guidance that was provided by Mr. Kilduff does not state that points are given for buffers of 10 feet, and it does not recommend the use of a 50 foot buffer. It reads:

*As buffer width increases, improved riparian functions are gained.

- < 50 feet: Minimal protection of streams and wetlands.
- 51-100 feet: Protection from human disturbance, protection of aquatic habitat.
- 101-200 feet: Protection of water quality.
- 201-300 feet: Protection of wildlife habitat.
- 301 feet or greater: Protection of wildlife migration corridors and habitat for threatened, endangered and sensitive species.

Regarding EPA recommended buffers, a 100 foot buffer has historically been a common recommendation for a one size fits all approach that is appropriate for average conditions.

The Entrix paper which was provided appears to have limited applicability. There is no information on the qualifications of the authors, the paper was not peer reviewed, the literature review focused on conditions in southeastern Pennsylvania, and the authors state that they did not consider the habitat functions of buffers. As with many papers on buffers and stormwater treatment, this one does not delve into the site specific factors that result in different study results (e.g. slope; type and quality of vegetation; soil depth, permeability and quality; surface roughness). This paper cites but does not adequately explain the Neiswand study, which resulted in a model for sizing water quality buffers based on site specific conditions (though it should be noted that the Mayer approach presented in Chapters 2 and 4 represent more current science). Using the Neiswand model for streams and lakes, at the lower end (1% slope with either hay meadow or forest with heavy ground litter) the model recommends a 50 foot buffer, but at 10% slope the recommended buffer is over 100 feet and it continues to increase with slope. In applying the model, slopes over 15% and roads are not counted toward the specified buffer width.

Additional discussion was added to Chapter 3 regarding treatment trains, the Neiswand model and water quality buffers.

9.2 Chapter 2: Best Available Science for Wetlands

Summarized comments (full text available in the original submittal letter, attached) from Paul Anderson and Tom Hruby from the Washington Department of Ecology (Ecology):

1. Ecology has requested the inclusion of additional information regarding buffer widths in regard to different levels of risk.

Dr. Adamus' response: Before any changes are made in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.

2. Ecology suggested adding the following reference to the wetlands discussion: O'Neil, T.A. and D.H. Johnson. 2001. *Oregon and Washington wildlife species and their habitats*. Chapter 1, p. 1-21 in D.H. Johnson and T.A. O'Neil (eds.), Wildlife-Habitat Relationships in Oregon and Washington. Corvallis, OR: Oregon State University Press.

Dr. Adamus' response: Not done because WDFW has a more comprehensive and newer (2009) reference with the same type of information, and we used that.

3. Ecology suggested changing the definitions included for mitigation types to those used by the U.S. Army Corps of Engineers and the Department of Ecology.

Dr. Adamus' response: We changed those to comply as suggested.

4. Section 2.1.1, p.1, para. 2: Ecology recommended adding text regarding the Water Pollution Control Act (RCW 90.48).

Dr. Adamus' response: Done.

5. Section 2.4.3, p.30, para. 2: Ecology recommended stating that the use of the state *Rating System* is required for state wetland authorizations and is also used by the Corps Seattle District office.

Dr. Adamus' response: Modified the sentence in response to this comment and subsequent phone conversation with Stockdale.

6. Section 2.2.3.2, p.22, para. 3: Ecology requested clarification about the interpretation of habitat scoring.

Dr. Adamus' response: Although true, this statement does not add anything useful so was deleted.

7. Section 2.4.3.A.5, p.33, para. 1: Ecology recommends stating that bogs are also sensitive because they are irreplaceable and notes that the literature clearly indicates that mitigation science has not evolved sufficiently to create or restore bogs.

Dr. Adamus' response: Elsewhere in the BAS report the sensitivity of bogs is mentioned.

Regarding the article suggested by Ecology entitled "Setting Buffers for Wetlands When the Science is Not Specific," Dr .Adamus responded that this information was helpful when the BAS was revised to address relative risk.

Comments from Scott Rozenbaum, a local wetlands professional, are included below. These comments have been summarized from their original length and detail. We encourage the reader to refer to the full text available in the original submittal letter, attached):

1. Appendix 2B-1: Add a statement in Chapter 2 that mentions that any national updates will be automatically adopted and supersede designations of this January 2011 draft list.

Dr. Adamus' response: Addition made.

2. List *Crataegus monogyna* with its assigned Region 9 indicator status, until it is formally changed.

Dr. Adamus' response: Correction made.

3. Add *Salix lucida* var. *lasiandra* (Pacific willow) and *Salix alba* (white willow, or also called golden willow) to the species list.

Dr. Adamus' response: Correction made.

4. Add a statement at the top of the plant list that mentions that other species, including drier facultative upland (FACU), upland (UPL), and nonlisted (NL) species can occur in wetlands.

Dr. Adamus' response: Addition made.

5. I have not observed *Acer glabrum* growing in wetlands in San Juan County. Common snowberry (*Symphoricarpos albus*) can and often is a common or dominant shrub in numerous seasonal wetlands in San Juan County. Pacific or trailing blackberry (*Rubus ursinus*) is another drier species that can occur broadly in seasonal wetlands.

Dr. Adamus' response: True, but must stick with the official Federal designations of these species, at least for now.

6. The plant list did not include many non-native species.

Dr. Adamus' response: If they are wetland indicators and have been documented locally they were included.

7. I agree with Dr. Adamus' approach in generating a new possible wetlands map, although some of those data planes have inherent weaknesses. And ultimately, nothing trumps actual site visits and evaluations.

Dr. Adamus' response: Agree.

8. The Possible Wetlands map omits many wetlands [for several possible reasons].

Dr. Adamus' response: Essentially all of the[se] w[ere] explained in several places.

9. Does the Tidal Wetlands Map agree with the numbers on page 35?

Dr. Adamus' response: It should.

10. The San Juan County Tidal Wetlands Map is very conservative and shows significantly less than 50% of the saltwater fringe, tidal wetlands (by area) in the county.

Dr. Adamus' response: Would appreciate knowing where those are. May only be an issue with the legibility/ scale of the map.

11. Scientific literature and Dr. Adamus' discussion on minimum sizes of wetlands for regulatory purposes do not ultimately distinguish a threshold under which a small wetland is non-functional or unimportant. I encourage the Council to adopt a minimum size threshold. My recommendation to the Council is to work with Dr. Adamus or the State Department of Ecology to devise a logical minimum size threshold.

Dr. Adamus' response: Before any changes are made in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.

12. Pg. 37, fifth sentence: the large, impressive aspen wetland occurring on northern Lopez Island is located in the Odlin Park drainage watershed, not the Swifts Bay watershed.

Dr. Adamus' response: Correction made.

13. Suggested additions to Appendix 2B-2: western toad, long-toed salamander, red-legged frog, Pacific Treefrog, Rough-skinned newt, bullfrog, barred owl, Townsend's vole, muskrat, raccoon, mink, river otter, signal crayfish [*Pacifastacus leniusculus*], white river crayfish [*Procambarus acutus*], and beaver. Suggested deletion: northwestern salamanders.

Dr. Adamus' response: The above information was helpful and changes are reflected in the final BAS.

14. I would recommend that a landowner or applicant contract with a qualified wetland scientist for a reconnaissance-level wetland study to identify any wetlands within several hundred feet of a

proposed project. If bogs were located within 500 feet of a project clearing, then they should be identified and inventoried, and adequate protective buffers established. Otherwise, most other wetland types have more resiliency and looking out 500 or 800 feet is probably not necessary, given the smaller-scale types of development that occur in most of San Juan County. If the qualified wetland scientist identified, through a wetland reconnaissance, that certain wetlands occur within 200 feet of a project clearing or proposed foundation site, then consider requiring the more expensive, more thorough wetland delineation. Perhaps a hybrid wetland study could also serve the needs of San Juan County citizens, where a reconnaissance-level onsite wetland study is done, and a few, strategic boundary flags are established closest to the proposed project area, so the landowner could adjust the building plan to adequately avoid the wetland and avoid its assigned buffer.

15. Recommend editing the statement: "At the discretion of CD&P staff, a professional wetland delineation could be required for some areas not shown as wetlands on this map, especially if they are along streams, in drainageways, or in areas dominated by hydric or partially hydric soils according to the NRCS (2009) soil survey" to possibly require a wetland reconnaissance (instead of wetland delineation), and perhaps add that a professional wetland delineation may be required if a wetland is found within XXX feet (150 feet or 200 feet, etc.) of the proposed project site. Or making the delineation requirement also consider the rating category of the nearby wetland. If it is a small, marginally functioning wetland, or it is situated upslope of any proposed development, perhaps requiring a formal delineation within 200 feet is not necessary.

Dr. Adamus response: Before any changes are made in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.

16. Suggest adding the words "soils and" as: "Depending on the terrain and local soils and surficial geological formations, infiltration of stormwater can sometimes be increased by implementing particular LID (Low Impact Development) measures, thus potentially converting surface flow to less hazardous subsurface seepage."

Dr. Adamus response: Correction made.

17. I generally agree with the multi-facetted, variable-width buffer approach. However, the distinction among "low," "moderate," or "high" intensity of proposed development is unclear. How will the County administer this approach? Regarding micro-climate, many wooded wetlands may have lost adjacent wooded areas long ago and some naturally lack surrounding woodland stands. Point 17 makes sense from a standpoint that some wetlands are not supporting diverse habitat, sensitive species, or large varieties of native species. However, the occurrence of open, grass-forb dominated fields do support certain animal species not found in other SJC habitats.

Dr. Adamus' response: Before any changes are made in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.

18. Some tidal and lakeside wetlands in SJC have been highly modified by humans and/or contain dense adjacent development. To implement especially broad buffers on partially- or mostly-

developed lakes seems counterintuitive. However, if the lake has additional sensitive habitat, such as a bog, that would warrant broader buffers.

Dr. Adamus' response: Despite disturbance, all provide important refuge for waterbirds during rough seas, and also are a rare feature in the island landscape.

19. I do not support an all-out prohibition on future "new" agricultural uses or expansion.

Dr. Adamus' response: Before any changes are made in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.

Dr. Adamus' responses to comments from Steven Neugebauer, licensed geologist and hydrogeologist (full text available in the original submittal letter, attached):

Pg. 1, Comments Section, para. 1: This is a commonly known phenomenon, at least as regards phosphorus. The BAS report for example cites a study by Mukherjee et al. 2009. Many substances such as lead quickly bioaccumulate in wetlands without being effectively processed or detoxified.

Pg. 1, Comments Section, para. 2: This is a commonly known phenomenon, at least as regards phosphorus. The BAS report for example cites a study by Mukherjee et al. 2009. Many substances such as lead quickly bioaccumulate in wetlands without being effectively processed or detoxified.

Pg. 1, Comments Section, para. 2: The Rating System lumps all pollutants under one heading called Water Quality, when in fact it depends on the particular substance whether that substance is processed effectively or not by a wetland.

Pg. 1, Comments Section, para. 3: The Rating System lumps all pollutants under one heading called Water Quality, when in fact it depends on the particular substance whether that substance is processed effectively or not by a wetland.

Pg. 2, para. 1: True, when introduced to wetlands in small amounts under optimal conditions. But some form even more toxic substances when they compound with organic matter naturally present in wetlands.

Pg. 2, para. 1: Again, it all depends on the amount and rate and toxicity of the substance being introduced. Too much of anything is detrimental because it will overwhelm natural detoxification processes which are not infinite.

Pg. 2, para. 2: Has the effluent entering and leaving that wetland been monitored for all potentially toxic pollutants? Without such information we can only speculate.

Pg. 2, para. 2: Has the diversity of native aquatic life at the outfall been shown to not be harmed?

Pg. 2, para. 3: The BAS notes that wildlife are a common source, but certainly not the only source. Adding more from human sources does not improve the problem.

Pg. 2, para. 4: The BAS report does not say these systems leach into ground water.

Pg. 2, para. 4: The County's codes are probably adequate for the majority of systems. But not every system can be checked all of the time. And some pollutants are not effectively processed by septic systems, e.g., some pharmaceuticals.

Pg. 2, para. 5: Quite the contrary, the BAS report documents that wetlands do perform these functions -- but at a high cost to other aquatic life within the wetland in some cases.

Pg. 3, para. 1: see prior comments

Pg. 3, para. 2: addressed by prior comments

Pg. 3, para. 3: not required to show this for Puget Lowlands specifically, and the report does not imply this is not a function of wetlands.

Pg. 3, para. 4: But wetlands regulations require that habitat functions be protected, and excessive levels of some natural and human-sourced substances can impair those functions.

Pg. 4, para. 2: Regardless, the County may choose to enact laws with provisions that are more restrictive or less restrictive.

Pg. 4, para. 4: That is why the BAS report plainly states that it will not be used for regulation, and that conditions on the ground will always rule.

Pg. 8, para. 4: This has not been determined for all pollutants under all conditions.

Pg. 8, para. 5: Mukherjee et al. 2009 is cited, and is one of many that document this.

Pg. 9, para. 4: Adsorption sites for phosphorus on clay particles can become saturated over time, leading to reduced retention capacity.

Pg. 11, para. 2: That statement is untrue, as nearly all wetland biologists know.

Pg. 12, para. 6: No County is legally required to prove this, and the health of a wetland certainly is not limited to whether or not it is merely surviving on the landscape.

Pg. 13, para. 1: Agreed! Which is why the County is proposing to use a tailored site-specific approach that is practical enough to implement with limited County budgets and resources.

Response to letter from Scott Rozenbaum on second draft of BAS Synthesis.

Comment 1. There are many wetlands not depicted on the "possible wetlands" map, and there are some shown that do not meet state or federal designation criteria. On site evaluations are the most accurate way to confirm the presence or absence of jurisdictional wetlands. *We agree and this is discussed in the text.*

Comment 2. More tidal wetlands occur in the County than are shown on the map. *The draft map contains the data that is available. On-site evaluations are needed to more accurately determine the presence or absence of wetlands.*

Comment 3. Concern expressed that "Synopsis and Options" were deleted from the text. *The specific examples of scientifically defensible actions for protecting wetlands were deleted from the BAS Synthesis document, but will be discussed with recommendations and options for the regulations.*

Comment on second draft received from Janet Alderton.

Buffer width guidance was eliminated from text. Concern about open ended flexible buffers individually determined for each site, and with the inadequacy of man made stormwater treatment systems. *Though the buffer examples were removed from the text, they will be presented as part of the discussion of regulations and options for protecting wetlands.*

Comment on second draft received from Paul Anderson, Dept. of Ecology.

Comments generally supportive of document. *Some edits of text to address specific concerns identified in the letter.*

Comment on second draft submitted by Steven Neugebauer.

States that the WA wetland delineation manual has been repealed and replaced with the federal manual. *Text was edited to reflect this.*

States that on site studies are necessary to identify saturated soil conditions and to properly delineate wetlands. *This is discussed in the text.*

States that neither wetland delineation manuals nor BAS Synthesis provide detailed information on unsaturated flow zones and suggests additional references. *At this point in the process the BAS Synthesis is nearing completion and additional references are not being considered.*

States that a license to practice geological science is required to conduct wetland and stream studies. *The definition of what constitutes a qualified professional for wetland and stream studies can be considered with the upcoming review of the regulations.*

Disagrees with suggestion that wetland areas cannot be naturally filled in. States that there is no established time frame for aquic conditions to develop.

States that the federal codes do not discuss setbacks and buffers. *This effort is focused on meeting Washington State requirements to protect the functions and values of wetlands, not federal requirements.*

States that the Critical Area maps are not accurate enough for regulating development. *The regulations will make it clear that the maps are simply a guide and that with regard to application of the regulations, conditions in the field control.*

9.3 Chapter 3: Best Available Science for Marine Fish and Wildlife Habitat Conservation Areas

1. Janet Alderton submitted general comments on bulkheads and specific comments on toxicity and break down of surfactants. Additional discussion on surfactants was added to this chapter and chapter 7 and the section on bulkheads was reviewed for consistency.

2. In response to comment from Vicki Heater, San Juan County Health and Community Services, a reference to the Huxley water quality study was corrected and discussion on the conclusions of this study clarified.

3. Section 3.3.5, pg. 77. SJ County Water Resource Committee provided comment related to discharge from desalination systems and suggested alternate language including a threshold volume of 33,000 gpd of potable water as a trigger for analysis of marine impacts. Some changes were incorporated based on their comment and subsequent communication with Dr. Strathmann. The 33,000 gpd trigger was not, however, included because a scientific basis for the number was not provided (it appears to be based on requirements for NPDES permits). This could be considered as a policy decision when the Council considers this issue.

4. Ken Sebens, Director of Friday Harbor Labs, submitted both general and specific comments. General comments are summarized below (numbers correspond to those in his letter):

1) There are important species that are not discussed in the Synthesis.

2) Protection should be directed at entire communities of organisms rather than focused on individual species; rocky intertidal ecology is not discussed.

3) More discussion should be included on the effects of increasing sea surface temperatures and ocean acidification which may act synergistically with impacts from local land use.

4) The role and importance of long term monitoring should be emphasized.

5) Sediment samples should be collected and archived as a baseline.

Responses to the general comments follow:

1) This effort and the BAS Synthesis are focused on meeting a legal requirement to protect certain species and habitats that are called out in State laws and regulations – those that meet the definition of a Critical Area. That doesn't mean that other species are not important – and some may eventually need additional protection measures under the updated Shoreline Master Program. For now though, our focus is on those species and habitats that are defined as Critical Areas.

2) Critical Areas include both habitat for individual species (e.g., Peregrine falcon) and habitat used by many species (wetlands, eelgrass, kelp) and both are addressed in the Synthesis. Rocky intertidal habitat is not a designated Critical Area, though it often contains kelp beds and shellfish areas that are. In most cases protection measures for the designated Critical Areas should be adequate to protect intertidal habitat.

3) Discussion added on increasing sea surface temperatures, ocean acidification and synergistic effects on habitat and species.

4 and 5) While it is a good idea, the County is not required to monitor impacts unless the effectiveness of Critical Area protection strategies is questionable. A discussion of long term monitoring is beyond the scope of this document.

Response to specific comments follow:

1) Pg. 7, para 2. Paragraph on aquatic vegetation clarified as suggested.

2) Pg. 10, para 3. Paragraph on abalone clarified.

3) Pg. 27, para 5. River otters are not a species that must be protected. Controlling predation of river otters on marine organisms is outside of County jurisdiction. Discussion related to river otters is beyond the scope of this document.

4) Pg. 33. At this time the County is only required to protect the habitat of rockfish species that are listed as endangered, threatened or sensitive. Discussion of the other species is beyond the scope of this document.

5) Pg. 44. Again, this document focuses on the species that are listed as endangered, threatened or sensitive. Others could potentially be added as species of local importance, but that is a policy decision for the County Council.

6) Pg. 67, para 2. Additional discussion added.

7) Pg. 72. Additional discussion added.

8) Site specific buffers and buffer averaging are options that can be considered when regulations are discussed.

9) Pg. 77. Remarks are in agreement with draft Synthesis. No response necessary.

10) List of published studies provided. No response necessary.

5. SJ County Marine Resources Committee requested that discussion and BAS references be expanded to include data from three several previously submitted papers (Hanson et al. 2010, Duffy et al. 2010 and (Koski, 2009). They were all included.

6. Revisions included based on comment from Barbara Rosenkotter, Lead Entity for Salmon Recovery (described under Chapter 1, above).

7. Tina Whitman (Friends of the San Juans) submitted both general and specific comment on the second draft of the BAS Synthesis. Responses follow. Numbers refer to those in her letter.

1. Climate change. *Additional narrative added to address comment.*

2. Marine habitat areas mitigation and submission of position paper from MRC. *Additional narrative was added to address this comment.*

3. General comment on need for more discussion of cumulative impacts. *Existing text was felt to be adequate.*

4. Fish utilization of nearshore habitat and submission of two presentations. *Existing text was felt to be adequate. Not all marine fish habitat must be protected as a Critical Area. Presentations do not constitute BAS. The study by Beamer et al. that was referenced has not been finalized.*

Remainder of letter includes specific comments, many of which were addressed with additional or amended text. This includes clarification or additions on the following topics:

- *Correction to the percentage of shoreline with documented eelgrass and kelp.*
- *Mitigation for potential impacts to kelp.*
- *Added narrative noting that observations of forage fish spawning areas likely underestimates the amount of spawning that occurs throughout the County.*
- *Added narrative regarding potential direct impacts to forage fish habitat and indirect impacts to rockfish.*
- *Added narrative discussing importance of pocket beaches that may occur outside of a designated drift cell.*

8. Richard Stathmann submitted comments on the second draft. *Some edits incorporated to address comments.*

9. Tim Hyatt (Skagit River System Cooperative) submitted comment on the second draft. He stated that they did a brief review of the document, that several recent and relevant studies were not included, and that the papers they submitted were not considered. *Of those specifically mentioned in the letter, the only one that was not cited in the BAS Synthesis was a study that does not appear to have been completed. Their list of suggested references were provided to and considered by the team that prepared the BAS Synthesis.*

9.4 Chapter 4: Best Available Science for Upland Fish and Wildlife Habitat Conservation Areas

Comments from Vicki Heater, San Juan County Health and Community Services:

1. Page 11 ends with a bullet list titled: Water quality issues of greatest potential or actual concern . . . On the top of page 12 the last bullet: "increasing salinity in aquifers used domestically" should be revised to say that "some areas of the county are at risk of seawater intrusion".

Dr. Adamus' response: Both statements are true, according to available sources of information.

2. On the rest of page 12 there is a discussion of the diversion of "scarce existing surface water". It is important to recognize that capturing and storing water during the rainy season for use during the dry months has long been practiced in San Juan County and is a valuable source of water for habitat, irrigation, and municipal use.

Dr. Adamus' response: That information has been added.

3. The sentence at the end of the last paragraph on page 12 is incorrect: "There are also many instances of private pond water being used for irrigation, which is illegal under Washington law (San Juan County, *2004 Water Resource Management Plan*)". Irrigation using surface water requires a water right, but is not illegal.

Dr. Adamus' response: That statement has been modified.

4. On page 14, second paragraph leads with the statement that "Large portions of the county are at a point where extraction of groundwater exceeds local recharge" and references the *Water Resource Management Plan*. The Plan states: water right allocations by the state exceed water available, and, that there are <u>areas</u> where current use of water exceed aquifer capacity.

Dr. Adamus' response: Correction made.

5. Also on page 14, third paragraph, there is a discussion of seawater intrusion. The statement is made that this condition is irreversible, which is not correct, and that, "All SJC groundwater is vulnerable to this threat", which is not physically possible.

Dr. Adamus' response: Correction made.

6. And a final comment on page 20, second paragraph. To my knowledge, it has not been determined by Ecology that the low DO in East Sound is due to sediment and nutrients, nor has the cause of the eel grass decline in Westcott Bay been identified.

Dr. Adamus' response: This has been modified.

Comments from Terry Domico, a local Conservation Biologist. Those addressed by Dr. Adamus are summarized below (numbers correspond to those in his letter):

1) Pg. 9: Lake Chub are present. (Dr. Adamus corrected as suggested.)

2) Pg. 35, item 9: suggests the inclusion of a caveat regarding the range and a practical suggestion for interpretation. (Dr. Adamus states that prior to any changes in the County's current regulations, more details will be provided to the public on a procedure for determining the width of a buffer appropriate for protecting the wetlands, streams, lakes, and shoreline of any particular parcel.)

3) Pg. 45: no mention of the Island Marble Butterfly. (Was it delisted?) (Dr. Adamus' response: Yes.)

4) I conducted a 10-year-long study of this species in the Puget Basin and have concluded that it is indeed rare and rapidly waning. It should be listed as a San Juan County "Species of Local Concern." (Dr. Adamus' response: Useful information. It is up to the County to decide whether to include it. That is why the BAS report recommends that local botanists be consulted on rare plant species.)

Comments from Jamie Glasgow, Director of Science and Research, Wild Fish Conservancy

1. Pg. 6, last paragraph: Question regarding the number of perennial streams, especially depending on which definition of 'perennial' is used. (Dr. Adamus' response: This will be made clearer in the final regulations the County may adopt.)

2. Pg. 9, first paragraph: The author states that "Surveys of SJC stream and lakes have found **more** non-native fish stocks than native." As written, the statement implies abundance. (Dr. Adamus' response: Not intended that way. "Stocks" are often treated like species, e.g., legal listings of salmonids.)

3. Pg. 44, Table 4-5: Clarify that the presence of Chinook and Chum salmon in San Juan County has been documented and that these areas need additional protection. (Dr. Adamus' response: The statement in the BAS applies only to streams, and elsewhere it is stated that there is considerable potential habitat for these species if barriers were removed.)

4. Pg. 84: Why aren't cutthroat trout included in this list? (Dr. Adamus' response: An accidental oversight; correction made.)

5. Page 84 – (fifth sentence) – Culverts should be properly sized **and placed**. (Dr. Adamus' response: Corrected.)

Comments from Tim Hyatt (Skagit River System Cooperative) on the second draft of the BAS Synthesis.

He stated that they did a brief review of the document and were concerned about the papers they submitted not being considered, and that the discussion of streams and freshwater impacts was not complete.

Response from Dr. Adamus: Nothing in those documents is contrary to the statements made in Chapter 4. At least 2 of their citations were used, but the others were a low priority because (a) they did not appear to address processes in intermittent streams (which are the vast majority of SJC streams), or (b) were published prior to 2005.

9.5 Chapter 5: Best Available Science for Frequently Flooded Areas

1. The Technical Advisory Group for Salmon Recovery in San Juan County (TAG) submitted comments on the sea level rise estimate used in the BAS synthesis. The TAG noted that they consider sea level rise in prioritizing funding for salmon recovery projects. They also noted that the sea level rise estimate cited from the Clancy 2009 study is consistent with their current working hypothesis.

9.6 Chapter 6: Best Available Science for Geologically Hazardous Areas

1. Brendan Cowan, Director of the San Juan County Department of Emergency Management commented that he is not aware of any evidence of activity in the fault lines running through the San Juan islands and that we should clarify that the islands' seismicity is not completely understood. The County's consultant (Chris Brummer) responded to this comment explaining that most of the faults within the County are cretaceous and inactive, but there are also other local faults that are considered active by the USGS. For example, the Devil's Mountain fault passes just five kilometers south of Lopez Island and has mapped strands projecting onto the islands. Staff has since included the following report into the expanded discussion of the County's seismicity: "Devils Mountain Fault - Online professional paper: Active Tectonics of the Devils Mountain Fault and Related Structures, Northern Puget Lowland and Eastern Strait of Juan de Fuca Region, Pacific Northwest. U.S. Geological Survey professional paper #1643."

9.7 Chapter 7: Stormwater Management Alternatives

1. Additional discussion added in response to comments submitted by Janet Alderton on toxicity and break down of surfactants.

2. Jack Bell provided a list of reports related to monitoring and monitoring plans in San Juan County, and provided input on chemicals of highest concern in Puget Sound. Additional discussion was added related to chemicals associated with land use and development.

9.8 Chapter 8: Critical Area Maps

1. Brendan Cowan, Director of the San Juan County Department of Emergency Management commented regarding the FEMA flood zone map for San Juan Island: the failure inundation map for Trout Lake should not be included in the flood zone because it gives the impression that there is only one dam in the County, and, in actuality, there are many. Staff has since removed this polygon from the map.