Best Available Science for Wetlands of Island County, Washington: Review of Published Literature

A Report Prepared in Response to Critical Areas Ordinance Updating Requirements for Wetlands

by

Paul R. Adamus, Ph.D.

Adamus Resource Assessment, Inc.

and College of Oceanic and Atmospheric Sciences, Oregon State University

prepared for:

Island County Department of Planning and Community Development

November 2007

Foreword

Island County has embarked upon an exciting and progressive approach to critical area protection. While many jurisdictions have chosen to simply rely upon wetland regulations that are based upon data collected elsewhere, Island County has instead developed a program that is tailored specifically to your very special and unique islands. Information compiled in this document, *Best Available Science for Wetlands of Island County,* has been used in Island County's updated wetland regulations proposal.

Over the past two and one-half years I have served as the lead scientist, advising Island County throughout the process of modernizing its wetland protection program. This process included:

- Evaluation of the functions and health of wetlands in Island County. We visited a statistical sample of over one-hundred wetlands on Camano and Whidbey Islands. The vegetation, soils, and land use data we collected allowed us to draw conclusions about the sensitivity, functions, and health of the County's wetlands as a whole. This characterization also provided an essential foundation for the County's new Surface Water Monitoring Program.
- Review of existing scientific literature developed primarily in the United States and Canada. After reviewing the literature I made a determination as to its applicability specifically to Island County wetlands.
- Development of a draft protection program that considers best available science, as defined by existing laws and policies. Because science doesn't suggest just one solution for protection, the draft program provides a range of options that can be customized to protect a wetland when it is potentially affected by a development proposal, to protect wetlands with fairness to the landowner.

It has been my distinct pleasure to participate in the development of this program, to work with the fine professionals who represent you in Island County, and to participate in the many public meetings where you shared your knowledge and perspectives.

Paul Adamus, Ph.D.

Wetland Scientist and Wildlife Biologist

Coupeville, Washington - November 2007

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Acknowledgments

Assistance in the compilation and presentation of data used in this report was provided by Anthony Boscolo, Kim Bredensteiner, Kirsten Harma, Mike Kershner, and Jeff Tate of the Island County Department of Planning and Community Development (ICPCD). We express our gratitude to Teresa Lewis, Margaret Clancy, and Teresa Vanderburg for their technical peer review of this draft document.

For questions or comments regarding intended use of information in this report, please contact Jeff Tate (Director, ICPCD). For technical questions, the principal investigator (Dr. Paul Adamus) may be contacted by email at: adamus7@comcast.net

1.0 Introduction

1.1 Background

The Washington State Growth Management Act (GMA, RCW 36.70A.172) requires that cities and counties review, and if necessary revise, their development regulations as reflected most commonly in a Critical Areas Ordinance (CAO), at least once every seven years. This document addresses the Wetlands component of Island County's CAO (ICC 17.02.050.A). As described at: http://www.islandCounty.net/planning/caoupdates.htm, the others are:

- Critical Aquifer Recharge Areas
- Frequently Flooded Areas
- Geologically Hazardous Areas
- Fish and Wildlife Habitat Conservation Areas

Changes to CAO provisions have already been adopted for the first three of the above components, and the fourth will be addressed later this year. For the Wetlands component, the County agreed at a early stage that the most effective and reliable way to make recommended changes to the wetland CAO is to (1) evaluate aspects of the present health (natural ecological condition)[1] of wetlands within the County by visiting and collecting data from a statistical sample of individual wetlands, and then (2) complement that information with information from peer-reviewed studies from mostly outside of Island County, i.e., a review of the technical literature. With these two sources of information, judgment as to the likely effectiveness of the current wetland regulations can be made and changes implemented if necessary. Details of the wetland health assessment conducted in 2005 by the ICPCD were presented in a previous document informally termed the "Phase I report" (Adamus et al. 2006b) and have been integrated, when appropriate, with the review of technical literature presented in this report, termed the "Phase II report."

In addition, Washington law (RCW 36.70A.172(1)) states that special consideration must be given to "measures necessary to preserve or enhance anadromous fisheries," which refers to those species that reproduce in fresh water and migrate to salt water for some portion of their life, returning to fresh water. The term "fisheries" commonly refers to stocks of fish that are managed for commercial, recreational, cultural, or ceremonial uses. Only three Island County streams contain anadromous fisheries. However, the Island's shorelines are important to many anadromous and marine fish. Measures to protect Island County's wetlands are important to the goal of giving special consideration to anadromous fisheries partly because (a) salmon and other anadromous fish are believed to forage frequently in accessible parts of the County's estuarine wetlands, and (b) some wetland types potentially help filter and remove pollutants before they contaminate streams and nearshore waters used by anadromous fish.

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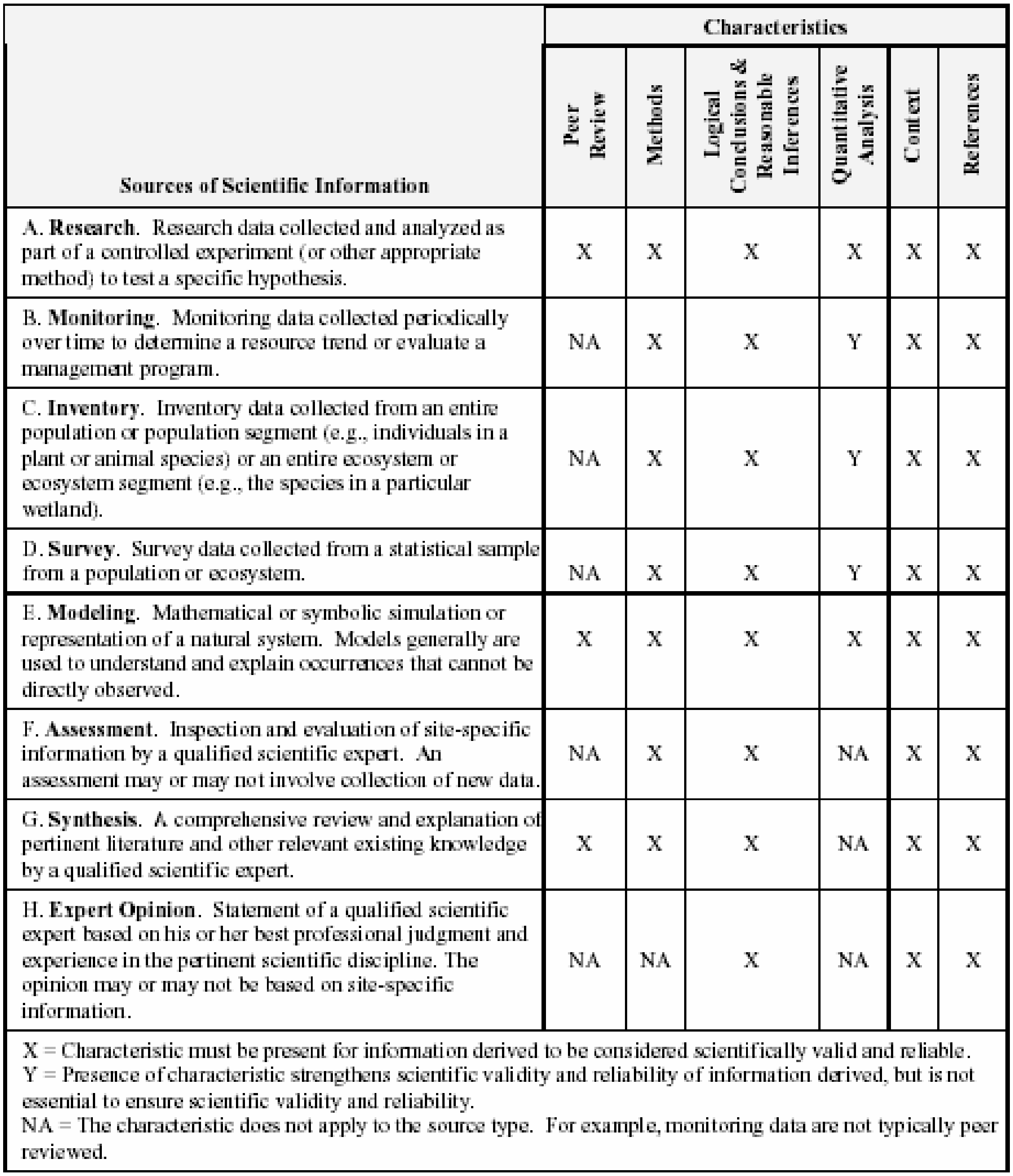
[1] As discussed in the Phase I report, there is no clear agreement among wetland scientists as to how to assess wetland health. A predominance of native wetland plants, normal water level fluctuations, and good water quality are commonly used as indicators of a healthy wetland. Indicators of wetland health should not include potential stressors, e.g., extent of ditches and dikes, or proximity to pollution sources (Young & Sanzone 2002).

1.2 Compliance with the Best Available Science Requirement

The State of Washington requires that Best Available Science (BAS) be ~~used~~ considered by jurisdictions in the CAO updating process. WAC 365-195-900 through 925, and the *Critical Areas Assistance Handbook* (WaCTED 2003), describe in detail the types of scientific information and sources that may be considered to be BAS (Table 1). The table is hierarchical. That is, items listed higher in the table (e.g., Research) are generally to be given greater credibility and priority than items lower in the table (e.g., Expert Opinion).

Table 1. Sources and characteristics of scientific information that may comprise Best Available Science



	Characteristics					
Sources of Scientific Information	**Peer Review**	**Methods**	**Logical Conclusions & Reasonable Inferences**	**Quantitative Analysis**	**Content**	**References**
A. **Research**. Research data collected and analyzed as part of a controlled experiment (or other appropriate method) 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.	NA	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).	NA	X	X	Y	X	X
D. **Survey**. Survey data collected from a statistical sample from a population or ecosystem.	NA	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.	NA	X	X	NA	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	NA	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.	NA	NA	X	NA	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.
NA = The characteristic does not apply to the source type. For example, monitoring data are not typically peer reviewed.

Information derived from among the potential sources (items A-H in Table 1) can be considered scientific information if it possesses the required characteristics marked in the columns of Table 1. These characteristics are defined by WAC 365-195-905 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.*

The Phase I report (Adamus et al. 2006b) coupled with the present Phase II report together comprise Best Available Science (BAS) for Island County wetlands as defined by the above. Specifically, the *Phase I report* presents and summarizes detailed data from the County's **Assessments** (item F in Table 1). Those assessments were done in a statistical sample of the County's wetlands (a **Survey**, item D in Table 1) by professional wetland scientists during 2005. In some cases, additional quantitative data were compiled from all mapped wetlands, rather than just a sample, using a Geographic Information System (GIS). Herein, the Phase II report presents some **Synthesis** (item G) of pertinent knowledge by a qualified scientific expert (the author), as well as that person's **Expert Opinion** (item H). In this document, text accompanied by citation contributes to Synthesis, whereas text not so accompanied comprises Expert Opinion. Issues concerning limitations of the technical literature used for Synthesis are described mainly in Section 3.1.2. **Peer review** (characteristic #1 above) has been integral throughout this project. Peer reviews were conducted of the original design of the Survey, the Assessment data forms, and drafts of both the Phase I and Phase II documents. Suggestions of the peer reviewers (national experts from universities, natural resource agency representatives, and professional wetland consultants) were routinely incorporated. **Methods** used in the Survey and Assessments are described extensively in Appendix A of the Phase I report, and in Appendix D of this Phase II report. **Conclusions and inferences** are provided and placed in **Context** throughout both reports, and inconsistencies with other pertinent studies are explained when applicable. About 60 technical publications were reviewed in the preparation of the Phase I report, and over 200 for this Phase II report.

1.3 Purposes of This Document

This document is primarily a review of BAS applicable to Island County wetlands, as needed for categorizing wetlands for regulatory actions and determining widths for **buffers**[2] that protect the functions of wetlands. The number of technical papers and reports published on these topics is enormous, and none of the available reviews on these topics claims to have reviewed all of them. Similarly, we have not attempted to review all or even most such studies, but rather have emphasized information published since the review prepared by the Washington Department of Ecology (WDOE, Sheldon et al. 2005), up until April 2007. Although this document provides some discussion of habitat functions of wetlands, this topic will be covered primarily in a future document pertaining to Fish and Wildlife Habitat Conservation Areas of Island County.

1.4 What Are Wetlands?

In designating wetlands for regulatory purposes, jurisdictions are required to use the following definition of wetlands from RCW 36.70A.030 (20):

> *"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.*

A perception is often voiced that if an area doesn't contain 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 and they meet the other criteria above. Wetlands include many -- but not necessarily all -- areas known locally as wet farmed pastures, wet prairie, subirrigated pasture, alder thickets, swales, riparian areas, aquatic weed beds, and kettles. However, not all of these are subject to the same legal requirements. The determination of whether an area legally qualifies as "wetland" and therefore is subject to specific agency regulations (i.e., a "jurisdictional wetland") must be made by a qualified wetland professional.

When multiple wetlands are connected by streams, ditches, other non-wetland surface water, or shallow (>12 inches) ground water, they are termed *associated* wetlands and their total area is considered as constituting a single wetland for purposes of regulation. This is generally similar to the concept of a wetland complex or mosaic, which is a group of wetlands located very near each other.

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[2] Defined as a generally terrestrial area surrounding a wetland and measured a specified distance outward from the wetland-upland boundary. The distance (width) may depend on wetland type, size, intensity of adjacent land uses, and other factors. Buffers are intended to reduce impacts from adjacent land uses. Related terms are vegetated filter strip, wetland setback, riparian strip.

1.5 General Characteristics of Island County Wetlands

As mentioned previously, the County's Phase I report analyzed about 100 wetlands that comprised a probabilistic (statistical) sample of all wetlands mapped in the County. Thus, information on their characteristics can be reliably inferred and reported. Island County differs from other counties in that none of its wetlands occur along rivers or in river flood plains. This has important implications for wetland functions (e.g., Richardson et al. 2005a, 2005b, Moore & Wondzell 2005, Feller 2005). For example, traditional concerns about anadromous fish spawning areas, and the need to supply enough large woody debris and an optimal thermal regime to support anadromous fish rearing, may be less important for Island County wetlands because none are on rivers and only a small number are close to anadromous fish streams. Although few County wetlands are connected to streams directly, many likely are connected to aquifers, streams, or estuaries by subsurface flow. More than 75% are located in watersheds that drain into distinct estuaries. While few in number, the largest wetlands are the estuarine wetlands located on the shoreline. Most non-estuarine wetlands are on slopes or in depressions surrounded by sloping land (average slope within 100 ft is 10%), potentially making them more susceptible to the quality of runoff from their contributing area[3]. A large number of the wetlands are man-made ponds or are associated with man-made ponds. Slightly more than half of the County's non-estuarine wetlands completely lack year-round surface water. When not shadowed by a forest canopy, such wetlands may be at highest risk of invasion by non-native plant species. About 87% of the County's wetlands host some non-native species of plants. However, non-native plants dominate (i.e., cover most of the vegetated area within) in only 20% of the wetlands. At least 19% of the County's non-estuarine wetlands are dominated by trees or shrubs.

2.0 Wetland Regulatory Categories

2.1 Introduction

By intent, when wetlands are regulated, not all wetlands are treated the same. That is appropriate because wetlands differ with regard to their sensitivity to impact, levels of functions, and importance to society (Kusler 1992). Jurisdictions attempt to reflect the differences among wetlands by assigning different wetlands to different regulatory categories. A jurisdiction then requires different levels or types of protection for the different regulatory categories. Most jurisdictions in Western Washington are using, or plan to use, a four-category scheme recommended by the WDOE. Since 1984 Island County has used a different three-category scheme (Table 2).

Wetland *classification* is similar to wetland *categorization,* because it assigns wetlands to groups. However, the classes are mainly scientific and have no regulatory implications, whereas with categorization, the categories reflect regulatory differences. At a national scale, two systems are widely used for *classifying* wetlands and they have been applied to many Island County wetlands. They are the Cowardin et al. (1979) classification and the less-detailed hydrogeomorphic or HGM (Brinson 1993) classification. In British Columbia, a classification system for wetlands based on their vegetation, geomorphic, and regional setting was described generally by MacKenzie & Shaw (2000). Also, a colloquial classification of Island County wetlands (coastal lagoon, salt marsh, depression,

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[3] A wetland's contributing area is the land and water area that drains to that wetland, as illustrated in the Phase I report.

slope, lake fringe, artificial) has been suggested. None of these classification schemes reflect differences in the relative sensitivity, levels of functions, or importance of wetlands.

Table 2. Regulatory categories of Island County wetlands included under the existing Critical Areas Ordinance, their associated buffer prescriptions, and approximate area protected

Category	Criteria	Zone	Minimum Size	Approx. % of all wetlands (number)[4]	Approx. % of all wetlands (acres)	Required Buffer Width	Approx. acres (wetlands + buffer)[5]	Approx. % of County land area (wetlands + buffer)
A	Estuarine wetland	any	any	3.34%	7.68%	100 ft	1307	0.99%
	Native vegetation dominates, OR protected species[6] habitat or presence	Rural	1/8 acre	54.49%	51.65%		9466	7.18%
		any other	¼ acre	26.30%	39.26%		6814	5.17%
B	Non-native[7] vegetation dominates	Rural	¼ acre	4.18%	4.88%	50 ft	388	0.29%
		any other	1 acre	5.64%	8.38%	25 ft	526	0.39%
C	Wetlands that were purposefully created where no wetland previously existed. Includes most farm ponds.			(no data)		None required	(no data)	

2.2 Wetland Sensitivity and Importance as a Basis for Regulatory Categories

With regard to establishing regulatory categories for wetlands, the State of Washington, in its *Critical Areas Assistance Handbook* (WaCTED 2003), encourages jurisdictions to consider use of a **rating system**. In such rating systems, counties and cities may include the following, in no particular priority order:

1. Ability to compensate for destruction or degradation (re-creation difficulty)
2. Degree of a wetland's *sensitivity* to disturbance
3. *Functions* of the wetland

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[4] These are only estimates because categories cannot be assigned to non-estuarine wetlands without an onsite visit to determine if its plant cover is dominated by non-native species, and such an inspection has been made in all or part of only 54% of the County's wetlands. The remainder were *assumed*, only for purposes of this table, to be dominated by native plants.

[5] Excluding marine waters or lakes that fall within the buffer. Note that different parts of a single wetland may be assigned to different categories

[6] "Protected" species are those on the County's list of Species of Local Importance and Protected Species, plus species listed by WDFW as Threatened, Endangered, or Sensitive. Those that are likely to have a primary association with County wetlands include great blue heron, bald eagle, peregrine falcon, osprey, 3 anadromous salmonid species, and 5 plants: *Agoseris elata, Cicuta bulbifera, Fritillaria camschatcensis, Morella (Myrica) californica, Puccinellia nutkaensis*

[7] Over 61 non-native species (17% of the County's wetland flora) occur in Island County wetlands) but the 1984 Ordinance lists only the following: *Iris pseudocorus repens, Juncus effusus* (erroneously), *Myriophyllum spicatum, Ranunculus repens, Phalaris arundinacea.* Our field data show that the following additional non-native wetland species (at a minimum) can dominate in non-estuarine wetlands of Island County: *Agrostis capillaris, Agrostis gigantea, Holcus lanatus, Solanum dulcamara*. Many non-native upland plants also invade portions of drier wetlands.

4. *Rarity* of the wetland type

The first two of the above items can be grouped under the general term ***Sensitivity*** and the last two under the term ***Importance***. Whichever factor or factors are used, the type and relative intensity of current or proposed uses within the buffer can also be considered (Section 3.5).

With regard to wetland *sensitivity*, wetlands that are most sensitive are those that are most likely – based on their inherent physical, chemical, and biological characteristics -- to respond to natural or human-associated stressors 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.

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.

With regard to wetland *importance,* the most important wetlands are generally considered to be those that are of a type that is rare, and/or which perform one or more functions to a large degree, and/or which because of their location or other factors are especially valued for whatever degree they perform a particular function, such as trapping suspended sediment in headwaters before it reaches marine eelgrass beds. Note that not all sensitive wetlands are important, and not all important wetlands are sensitive. This approach to prioritizing wetlands -- considering both their sensitivity and functional importance -- has been implemented previously in Colorado, Minnesota, and elsewhere, e.g.: www.co.larimer.co.us/planning/planning/master_plan/chapter_6.htm .

The WaCTED Handbook specifically references the WDOE "four-tier wetlands rating system" as a possible tool for helping assess wetland sensitivity and importance. That rating system is described in *Washington State Wetland Rating System for Western Washington (Revised).* The *Rating System* is a revision of a similar one that the WDOE developed in 1993. The two main features of the *Rating System* are (a) a field-based method for rapidly scoring the relative potential levels of three broadly-defined functions (Hydrologic Functions, Water Quality Functions, and Habitat Functions) of a particular wetland (#3 above), and (b) regulatory categories (the four tiers, #1 above) based partly on the scores a user assigned to the wetland's functions by using the method, and partly from criteria intended to reflect a wetland's relative sensitivity (#2), significance, and replacement difficulty (#1). The categories range from I (most protective) to IV. The *Rating System* requires a site visit by a trained wetland professional. It is one of dozens of relatively rapid methods developed throughout North America to assess wetland functions, values, and/or sensitivity The wetland and landscape characteristics used by such methods are well-supported by peer-reviewed studies. As part of this

CAO update, the part of the Rating System used to assess habitat was adapted for use by landowners in Island County.

2.2.1 Characteristics That Predict Wetland Sensitivity

As noted above, wetland sensitivity is one of two themes used to define wetland regulatory categories. Sensitive wetlands are:

> (a) wetlands whose physical, chemical, and biological features are the least able to resist impacts from alteration of surrounding uplands, and/or
> (b) wetlands in which those impacts tend to be the most severe, and/or
> (c) wetlands that recover the slowest from those impacts once they have occurred, and/or
> (d) wetlands that are the most difficult to recreate once destroyed, and/or
> (e) wetlands that are susceptible or vulnerable -- because of their position relative to highly erodible soils -- to major sediment inputs if surrounding land is altered.

Several characteristics were identified by Adamus & Stockwell (1983) as being especially relevant to defining which wetlands are the most sensitive. These include:

1. Water residence time, as partly indicated by:
    - presence/absence of a year-round surface water outlet
    - flatness of the wetland
    - size relative to size of contributing area
2. Size and configuration
3. Water hardness and alkalinity
4. Vegetation and soil organic matter
5. Soil type and slope of adjoining uplands

2.2.1.1 Water Residence Time

Other factors being equal, wetlands with long water residence times (slow flushing rates) tend to be more sensitive because this implies that incoming pollutants are also retained longer, increasing the risk of damage to the wetland. Thus, depressional wetlands that lack permanent outlets, or which spill into downgradient streams only seasonally, are likely to have long water residence times (Leibowitz 2003) and thus be more *sensitive* (Whited 2001, Whigham & Jordan 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). Also, wetlands that are large relative to the size of their contributing area (e.g., headwater wetlands) tend to be more sensitive, because (a) inputs of pollutants that are small in an absolute sense are proportionally larger and less diluted by runoff than if the contributing area was larger (Diamond 1989), and (b) the hydrologic balance in such wetlands tends to be the most precarious, often reflecting shallow lateral flows, springs, or artificially-routed inputs, all of which are highly susceptible to change (Fitzgerald et al. 2003). This runs counter to the water quality *values* of such wetlands, which tend to be greater where contributing areas are large, because larger contributing areas imply increased opportunity for pollutants to enter a wetland for processing (Hruby et al. 1999). Finally, wetlands on slopes (Cole et al. 1997) and estuarine wetlands may be the least sensitive to water pollution because they typically have the shortest water residence times, so are least subject to accumulation of waterborne pollutants. Slope wetlands, which typically have saturated soils with little or no persistent surface water, may also tend to be least 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 Pennsylvannia study confirmed that slope wetlands are driven mainly by the discharge of groundwater, tend to have the lowest sediment accretion rates of any wetland type (HGM class), and have moderate to high rates of organic matter accretion (Wardrop & Brooks 1998).

2.2.1.2 Size and Configuration

Other factors being equal, wetlands that are small and 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 3.4.2). Some evidence also suggests that predation rates on nesting birds are higher in narrow strips of vegetation than in wider ones (Hansen et al. 2004). 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. If a threshold must be established for practical reasons related to wetlands regulation, consideration should also be given to a small wetland's proximity to other wetlands, i.e., wetland "mosaics."

2.2.1.3 Water Hardness and Alkalinity

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 Island County, bogs[8] are perhaps the most sensitive because of their typically low chemical buffering capacity (as implied by low hardness and alkalinity), whereas estuarine wetlands are the least chemically-sensitive, this being due to their higher hardness and alkalinity. Data on hardness of Island County water in wetlands and streams is being collected by the County's Surface Water Quality Monitoring Program, and averages about 80-90 mg/L, which is considered moderately hard water. Such data may be interpreted in the context of expected stream chemical processes in the Pacific Northwest (e.g., Feller 2005). For groundwater, existing data from Island County wells show a median hardness of 156 mg/L and median alkalinity of 166 mg/L, implying a moderate-to-high capacity to buffer extreme chemical conditions.

2.2.1.4 Vegetation and Soil Organic Matter

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 may be more resistant to further change (Werner et al. 2002, Wigand 2003). 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).

Soil organic matter that is essential to wetland functions also can take many years to recover, if it is oxidized by prolonged drops in wetland water tables such as from ditching (Shaffer & Ernst 1999). Thus, native plant communities in wetlands that are on organic soils (such as bogs) might be particularly sensitive to slight drops in wetland water tables. Some studies suggest that soils low in organic content are more vulnerable to invasion by non-native plants (Perry et al. 2004).

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[8] Bogs are low-nutrient, acidic wetlands with organic soils and extensive cover of characteristic mosses and shrubs.

2.2.1.5 Adjoining Soil Type and Slope

Other factors being equal, 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 (see section above) which is best evaluated on-site, but sometimes is represented partly by land use intensity, i.e., the degree to which various land uses clear natural vegetation. Studies that have specifically linked increased slope in a watershed or buffer strip to increased delivery of pollutants to surface waters include the following, for example: Trimble & Sartz (1957), Dillaha et al. (1988, 1989), Phillips (1989), and Nieswand et al. (1990). See also page 31.

In Island County, data from the NRCS (Natural Resource Conservation Service) suggest the soil map units shown in Table 3 may be among the most prone to erosion from water. These could be mapped, and finer spatial resolution could be achieved by overlaying LiDAR imagery (for better slope estimation) with the soil and wetlands maps, and by application of the NRCS's Revised Universal Soil Loss Equation (RUSLE) to soils data collected onsite. The total area of soils in Island County that are potentially susceptible to erosion from water or wind is estimated to be 35,431 acres (Table 4), of which 1457 acres (4%) is estimated to be located within 100 ft of wetlands in the County (Table 5).

Table 3. Soil map units potentially most prone to erosion according to NRCS data for Island County

Note: "Kf" stands for "k factor" and is a coefficient used by NRCS to indicate the susceptibility of a soil to sheet and rill erosion from water, based primarily on percentage of silt, sand, and organic matter and on soil structure and permeability. Values of Kf potentially range from 0.02 to 0.69, with higher values indicating greater erosion susceptibility. There are potentially 5 wind erosion groups. Onsite inspection of soils is encouraged to verify accuracy of mapped units and their erosion ratings. *Areas whose soils are not included on the list below may nonetheless experience equal or greater erosion if their soils are frequently tilled, compacted, and/or intermittently flooded.* The suggested widths in the last column are based on a review of studies of forested riparian buffers in the eastern U.S. (Welsch 1991) and take into account slope and erosion potential, as represented by NRCS land capability class.

Soil Map Unit	Slope %	Kf	Road/trail erosion potential	US Forest Service suggested maximum buffer width (ft)
Alderwood fine sandy loam (Ab)	5-15	.32	severe	118
Alderwood fine sandy loam (Ac)	15-30	.32	severe	170
Alderwood gravelly sandy loam (Af)	>15	.24	severe	170
Bow loam (Bc)	>5	.28	severe	118
Bozarth fine sandy loam (Be)	>5	.32	severe	118
Carbondale muck (Ca)	>0	varies	very severe	95
Casey fine sandy loam (Cc, Cd)	>5	.37	severe	118
Casey loam (Cf, Cg)	>5	.43	severe	170
Coveland loam (Cn, Co)	>5	.43	severe	118
Everett gravelly sandy loam (Ee)	>15	.24	severe	170
Greenwood peat (Ga)	>0	varies	very severe	?
Hovde sand (Ha)	>0	.10	severe	?
Hoypus coarse sandy loam (Hd)	>15	.24	severe	170

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[9] Erodibility is influenced by the texture, stability, infiltration capacity, cohesiveness, organic content, and chemical composition of the soil.

Soil Map Unit	Slope %	Kf	Road/trail erosion potential	US Forest Service suggested maximum buffer width (ft)
Hoypus gravelly loamy sand (Hg)	>15	.24	severe	170
Indianola loamy sand (Ib,Ic)	>5	.17	severe	170
Keystone loamy sand (Kd, Ke)	>5	.17	severe	170
Mukilteo peat (Mb, Mc)	>0	varies	very severe	95
Pondilla fine sand (Pa)	>0	.15	severe	170
Rifle peat (Ra, Rb)	>0	varies	severe	95
Semiahoo muck (Sc, Sd)	>0	varies	very severe	95
Swantown loam (Sm)	>5	.32	severe	170
Tanwax peat (Tb)	>0	varies	very severe	95
Townsend sandy loam (Tf)	5-15	.24	severe	118
Townsend sandy loam (Tg)	>15	.24	severe	170

Table 4. Erodible soil, by slope and land use category, for all of Island County

Land Use Category	Slope 6-15%	Slope 16-30%	Slope >30%	sum
Agriculture	7.03%	1.54%	0.67%	18%
Developed	**7.26%**	2.18%	0.91%	17%
Natural	**24.81%**	11.06%	6.17%	60%
Timber Harvest Areas	**2.34%**	0.91%	0.41%	5%

Table 5. Acres of erodible soil within 100 ft of wetlands of various slope classes, by zoning category

Note: Includes all Island County wetlands. Large water bodies within the buffer were excluded from acreage sums. Data for individual wetlands also are available.

Zoning Designation	Slope 6-15%	Slope 16-30%	Slope >30%	sum
Commercial Agriculture	16.32	1.94	1.11	71.57
Federal Land	74.32	4.98	0.00	236.67
Municipality	13.01	0.14	3.56	49.96
Park	25.08	5.84	4.58	42.65
Review District	0.28	0.00	0.00	2.04
Rural	374.26	102.97	42.75	757.80
Rural Agriculture	35.02	4.55	4.20	82.67
Rural Center	1.05	0.28	0.00	2.63
Rural Forest	48.40	27.36	8.28	96.96
Rural Residential	39.79	25.54	7.21	102.27
Rural Service	1.74	1.21	0.00	3.07
Rural Village	5.01	0.03	0.00	9.06
sum	634.28	174.87	71.70	1457.37

2.2.1.6 Other Factors Related to Wetland Sensitivity

Wetlands that are difficult to replace using conventional wetland construction techniques, or which take decades or centuries to return to their former state, also may be considered to be highly sensitive.

These include mature forested wetlands and bogs. Some spring-fed slope wetlands also can be difficult to recreate.

2.2.2 Characteristics That Predict Wetland Importance

As noted above, wetland importance is one of two themes used to define wetland regulatory categories. A major component of wetland importance is the levels of a wetland's Functions (WaCTED 2003). Examples of functions that are commonly attributed to some wetlands are shown in Table 6. The reasons for protecting some of the functions shown in Table 6 *in Island County specifically* are not always apparent. Evidence for the general occurrence of some functions also is highly uncertain. Therefore, assumptions behind the importance of each function will now be discussed. Evidence for and against the existence of these wetland functions is presented in much more detail in Adamus et al. (1992), Mitsch & Gosselink (2000), and Sheldon et al. (2005).

Table 6. Examples of functions potentially associated with some wetlands

(Adapted from Adamus & Stockwell 1983, Adamus et al. 1992, Hruby et al. 1999)

Category	Function	Definition	Example of Quantification
Hydrologic Function	Water Storage & Delay	capacity to store or delay the downslope movement of surface water for long or short periods	cubic feet of water stored or delayed within a wetland per unit time
Hydrologic Function	Water Infiltration & Aquifer Recharge	capacity to serve as a conduit, at least seasonally, for movement of surface waters into underlying aquifers	cubic feet of water infiltrated within a wetland per unit time
Water Quality Function	Detoxification of Toxic Organic Compounds	capacity to remove these substances from the water column and sediments and render them non-toxic to aquatic life	percent of the grams of total, incoming, waterborne toxins that are removed per unit wetland area, during a single typical growing season
Water Quality Function	Sediment Stabilization & Retention of Phosphorus & Heavy Metals	capacity to intercept suspended inorganic sediments, reduce current velocity, resist erosion of underlying sediments, minimize offsite erosion, and/or retain any forms of phosphorus or heavy metals (e.g., zinc, lead)	percent of the grams of total, incoming, waterborne phosphorus and/or inorganic solids (sediment) that are retained in substrates or plant tissue, per unit wetland area, during a single typical growing season
Water Quality Function	Thermoregulation	capacity to maintain or reduce water temperature	decrease in temperature of water exiting a site via surface flow or infiltration, compared with temperature of the water when it enters the site via surface flow
Water Quality & Habitat Function	Primary Production and Export	capacity to use sunlight to create particulate organic matter (e.g., wood, leaves, detritus) through photosynthesis, and to export that organic matter	grams of carbon gained (from photosynthesis) and then exported to other waters or uplands, per unit area of wetland per year
Habitat Function	Resident Fish Habitat Support	capacity to support the life requirements of most of the non-anadromous (resident) species that are native to the region	sum of native non-anadromous fish recruited annually from within the site
Habitat Function	Anadromous Fish Habitat Support	capacity to support some of the life requirements of anadromous fish species	sum of native anadromous fish using the site annually for spawning, feeding, and/or refuge

Category	Function	Definition	Example of Quantification
Habitat Function	Invertebrate Habitat Support	capacity to support the life requirements of many invertebrate species characteristic of such habitats in the region	number of invertebrate species and guilds (functional feeding groups) per unit of sediment, soil, water, and colonizable vegetation within a wetland area
Habitat Function	Amphibian & Turtle Habitat	capacity to support the life requirements of several of species of amphibians and turtles that are native to the region	sum of native amphibians and turtles that use the site annually for feeding, reproduction, and/or refuge
Habitat Function	Breeding Waterbird Support	capacity to support the requirements of many waterbird species during their reproductive period in the region	sum of waterbirds that use the site during breeding season for nesting, feeding, and/or refuge
Habitat Function	Wintering & Migratory Waterbird Support	capacity to support the life requirements of several waterbird species that spend the fall, winter, and/or spring in the region.	sum of waterbirds that use the site during fall, winter, and/or spring for feeding, roosting, and/or refuge
Habitat Function	Songbird Habitat Support	capacity to support the life requirements of many native non-waterbird species that are either seasonal visitors or breeders in the region	sum of native songbirds that use the site at any time of the year for breeding, feeding, roosting, and/or refuge
Habitat Function	Support of Characteristic Vegetation and Native Plant Richness	capacity to support the life requirements of many plants and plant communities that are native to the region	dominance (relative to non-native species) of native herbs and woody plants that are characteristic of the region’s wetlands

2.2.2.1 Importance of Wetland Hydrologic Functions in Island County

For the species that occur in and around the wetlands, **storing water** is very important 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. Also, partly by delaying runoff from rain events, wetlands potentially allow time for the runoff to **slowly infiltrate** (recharge) into underlying aquifers when and where conditions permit this, rather than quickly running off into coastal waters. In Island County, aquifers (underground areas where water naturally accumulates) supply nearly all water for domestic use. Areas of the County where such infiltration is most likely to occur have been mapped. Fresh water in aquifers is important not only for domestic and agricultural use, but also because it potentially deters the influx of contaminating seawater into the aquifers (Jones 1985). When some of the aquifer water discharges naturally near the land surface (e.g., springs, seeps, and via wetlands that discharge groundwater at other seasons), it can help sustain stream flow, dilute estuarine salinity, and maintain soil moisture. Of course, if all of a wetland’s water infiltrated rapidly there would be no wetland. What is believed to typically happen is that infiltration and subsequent aquifer recharge is partial, occurring just during brief periods of the year and around the margins of wetlands rather than through their less permeable center.

The ability of most wetlands to store **surface outflow** has been judged by the WDOE to be relatively unimportant in maintaining low flows in receiving streams (Hruby et al. 1999). Wetland vegetation in some cases promotes the loss of water via transpiration and consequently reduces stream outflow, although the vegetation’s shading effect somewhat counters this (Line et al. 2000). Also, a value commonly attributed to the hydrologic functions of wetlands, i.e., the protection of downstream areas from flood damage and shoreline erosion – is much less a consideration in Island County than elsewhere because flooding from streams and rivers is not a widespread problem due to their scarcity. Although flooding often damages property in nearshore areas, estuarine wetlands along the County's shoreline are seldom located in front of structures or eroding cliffs where they otherwise could protect these from damaging erosion caused by waves.

2.2.2.2 Importance of Wetland Water Quality Functions in Island County

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, and/or estuaries. 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 hydrologic inputs and outputs, and simultaneously measuring their contaminant concentrations. Water quality functions of wetlands potentially include (a) altering loads of contaminants, (b) altering the loads of nitrogen, (c) altering the concentrations of harmful bacteria, (d) altering stream temperatures, and (e) filtering out and stabilizing fine sediments that are suspended in the water column. Each will now be discussed as it applies to Island County, whose non-estuarine wetlands cumulatively comprise about 4% (range= 0.2 to 40%) of the watersheds in which they occur, and individually comprise about 8% (mean= 16%) of their contributing area.

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 occurrence of this function depends on the substance being detoxified. For example, under specific conditions some wetlands may actually cause particular contaminants (e.g., mercury) to become more toxic and/or more likely to be consumed by people or taken up by aquatic life (Helfield & Diamond 1997, Stamenkovic et al. 2005). Contamination of the food chains of Puget Sound fish and wildlife, especially by petroleum hydrocarbons, has become a concern (Redman 1998, Long et al. 2001). However, the contribution to pollutant loading of Puget Sound specifically from Island County is likely less than that of counties with more urban or intensive agriculture land uses, and indeed, several studies (e.g., Cobb et al. 2003) have used reference sites in the County's nearshore to compare with more degraded urban estuaries.

When particular wetlands are able to **remove nitrate**, the effects could be positive, negative, or neutral depending on the species and environments that are potentially affected. 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), mainly by a microbial process known as denitrification. No scientific studies of the nitrogen removal function, or of its effect on plants and animals, have been done specifically in the wetlands of Island County, so its potential occurrence is inferred from studies done elsewhere.

A 1997 study of the County's aquifers found slightly elevated levels of nitrate were correlated with, but were not necessarily caused by, agricultural uses in the overlying lands. This was possibly due to livestock and fertilizer applications, but might partly have been the result of natural sources. Nutrient loading rates have been estimated countywide by Ruddy et al. (2006). It is important to note that time delays between when the nitrate is introduced at the land surface and when it enters an aquifer could be on the order of years in some instances, complicating the identification of sources. However, the

County's data so far suggest declining rather than increasing interannual trends in nitrate in wells (Douglas Kelly, ICHD, personal communication), which may correspond with a projected decreasing trend in nitrate inputs within the County (Rudy et al. 2006). Brief occurrences of levels capable of harming infants have been noted in a few wells, but health effects have not been monitored consistently. Where overlying wetlands remove nitrate, they could be helping protect aquifers from such contamination.

In some of the County's non-estuarine wetlands, lakes, and streams, slightly elevated levels of nitrate also have been found. The causes are not known definitively and the impacts probably vary. Nitrate is a nutrient that is essential to all plant life. However, excessive nitrate concentrations, or the presence of correlated land uses, have been documented elsewhere to be associated with changes in species composition of wetland plant communities (Adamus et al. 2001), especially, increased invasion by weeds such as reed canary grass in wetlands with low sediment organic content (Perry et al. 2004) and 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. Such blooms have resulted in closure of Lone Lake to swimming during some recent summers. 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[10]. 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). There currently are no legal standards for nitrate concentrations in wetlands or other surface waters, although the USEPA (2000) recommended 2.62 mg/L as a maximum level for nitrogen in the Puget Lowlands.

Limited sampling of surface waters in Island County has shown concentrations of up to 69 mg/L nitrate (but median of only 0.57 mg/L) and groundwater concentrations of up to 68 mg/L nitrate (but median of only 0.50 mg/L) (Adamus et al. 2006a). More comprehensive data are currently being collected by the County's new Surface Water Monitoring Program. Samples from the County's extensive well monitoring program serve as indicators of groundwater quality, and have shown exceedence of the human health standard of 10 mg/L in just 1.6% of samples, exceedence of 5 mg/L in 6.2% of samples, and exceedence of the possible ecological threshold (if these had been surface water samples) of 2.5 mg/L in 14.9% of samples. Groundwater discharge to wetlands is probably a typical occurrence throughout Island County (Doug Kelly, Island County Health Dept., pers. comm.).

In the County's estuarine wetlands and nearshore waters, and in Puget Sound, the impacts of nitrate also vary. Elsewhere, studies have shown nitrate deficiencies to be one of many factors potentially limiting the productivity of some estuarine algae and higher plants (Anderson et al. 2002), but the effects can be either positive or negative, depending in part on the species, the loading rates, weather conditions, and on how well-flushed the receiving waters are. Experiments in a brackish marsh and a fresh marsh in Louisiana found that fertilization caused a drop in plant species diversity, but only if herbivory (e.g., densities of grazing animals) was low. The reduced diversity may have been partly

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[10] From Hayes et al. (*in press*): "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."

attributable to a buildup of dead plant litter, which was caused by the low density of plant consumers (Gough & Grace 1998). Dissolved inorganic nitrogen has been mentioned as a possible cause of severe growths of algae in waters with relatively restricted circulation, such as in parts of the southern end of Hood Canal (Redman 1998, Paulson et al. 2006). When the excessive algal growths occur on marine rocks and sediments, aquatic invertebrates important to the food chain can be smothered. When excessive algal growths are triggered by nitrate in the estuarine or marine water column, they block light needed by eelgrass (Williams & Ruckelshaus 1993), a submersed plant very important to fish and wildlife. Excessive algal growths also can temporarily deprive the water of oxygen needed to sustain marine fish. 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. No scientific studies of this function, or of effects on food chains, have been done specifically in the wetlands or nearshore areas of Island County, so its potential occurrence is inferred from studies done elsewhere.

Although data are lacking, nutrient inputs to Puget Sound from Island County were possibly at least as great during early periods of the County's development as they are now. During those times the drainage of wetlands, especially peatlands and forested wetlands that typify the County, would have increased nutrient export as organic soils were oxidized and eroded soils were freely washed into lakes, streams, and estuaries. Ditching and clearing were extensive in the early 1900's. Although the paucity of streams in the County means that salmon runs were never a dominant event, when salmon occurred more widely than now, they probably introduced nutrients of marine origin to headwaters of the County's streams. The large concentrations of waterfowl that occurred prior to the extensive regional wetland losses probably had a similar effect.

In summary, many if not most Island County wetlands probably are capable of retaining or removing nitrate, with resulting beneficial effects on the quality of aquifers and downslope streams and lakes. The significance of this function to estuaries and Puget Sound is unclear.

When particular wetlands are able to **alter the levels of harmful bacteria**, it improves the potential for human use of waters for drinking and bathing. Levels exceeding State standards have been documented in parts of Island County. 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 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.

When particular wetlands are able to alter **water temperature**, it potentially affects many aquatic species and biochemical processes. Declining salmonid populations can benefit from relatively cool temperatures that sometimes result from shade provided by densely-vegetated wetlands (e.g., Monohan 2004). On the other hand, thermal requirements of some native frogs and pond-breeding salamanders may be higher, such that too much shade can be detrimental. As noted above, some 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. In summary, it is not possible to determine in advance which wetlands will provide a thermoregulatory function that is ecologically beneficial. Studies of factors controlling temperature in streams of the Pacific Northwest are reviewed by Moore et al. (2005).

When particular wetlands are able to filter and/or stabilize **fine sediments** that are suspended in the water column**,** as well as the **phosphorus** and **heavy metals** typically adsorbed to them, this also can have benefits. That is because excessive amounts of these substances often have negative impacts on plants and animals, and once they are transported by wind or runoff from developed lands into wetlands, a dilemma is whether to allow their continued retention in wetlands (with impacts to wetland life) or to have wetlands serve as filters that delay the entry of these substances into downslope streams, lakes, estuaries, and Puget Sound. One reason that fine suspended sediments are a concern is they block the sun from reaching underwater plants, thus reducing aquatic productivity, but such sediments also commonly contain adsorbed phosphorus, which can stimulate aquatic productivity, sometimes to the point of supporting nuisance blooms of algae especially in non-estuarine waters (Anderson et al. 2002). Excessive suspended sediment can interfere with the respiration and reproduction of larval amphibians (Knutson et al. 2004) and important fish. Excessive deposition of sediments in wetlands can prevent the germination of some wetland plants (Wardrop & Brooks 1998, Mahaney et al. 2005) and 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 channels. Although there are State standards for turbidity (which only grossly represents the level of suspended sediments), there are no standards useful to defining “excessive” sediment deposition rates.

There currently are no legal standards for phosphorus concentrations in wetlands or other surface waters, but the USEPA (2000) suggested 1.8 mg/L total phosphorus as an appropriate level. Based on very limited surface water data, the median phosphorus concentration in Island County streams may only be about 0.14 mg/L, with a maximum of 13.9 mg/L (Adamus et al. 2006a).

Heavy metals (e.g., zinc, lead, copper) are a concern because of their toxicity, especially to fish, and State standards do exist. Although surface water data are very limited, the County’s extensive well monitoring program, an indicator of groundwater quality, has shown exceedence of the 0.005 mg/L threshold for cadmium in 2.5% of the locations, the 0.05 mg/L threshold for arsenic in 1.6% of the locations, 0.02 mg/L threshold for lead in just 0.7% of the locations, the 1 mg/L threshold for copper in just 0.5% of the locations, and the 5 mg/L threshold for zinc in just 0.5% of the locations.

In summary, although many wetlands are very capable of retaining sediments, phosphorus, and heavy metals at least temporarily, the potential benefits of that function do not accrue equally across a watershed. The benefits depend on whether higher priority is given to protecting aquatic life in wetlands, or in downslope streams, lakes, estuaries, and Puget Sound.

2.2.2.3 Importance of Habitat Functions in Island County

All of the County’s wetlands provide **habitat** for plants and wildlife, and some also provide habitat for fish. The effect of this habitat function on regional biodiversity (the number of species and their genetic variation) is unquestionably positive. This is especially true for species that have an *obligate* or *primary* association with wetlands[11]. In contrast to other areas of Western Washington that are of similar area, Island County's fauna overall is naturally less diverse for several reasons. The topography of Whidbey and Camano Islands spans only 580 feet of elevation, creating less climatic diversity which 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 mainlands, 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 inhabit only extensive forests also may be absent, or are relatively vulnerable to extirpation, because of fragmentation of historically forested areas by roads and urban and agricultural lands in many parts of the County. Large mammals such as elk, gray wolf, and cougar were among the first animals to disappear entirely from the County (in the mid-1800's) and have never recovered. Also apparently gone are two native gamebirds (e.g., ruffed and blue grouse), spotted frog, and western pond turtle (R. Milner, WDFW, pers. comm.). A number of other species that are still found in similar habitat in mainland counties appear to now be gone from the County. However, a lack of credible and comprehensive surveys (except for most types of birds) makes this difficult to confirm. In some cases, the species may never have inhabited the County. Also, note that conversion of forest cover to more open lands during the past century has created or improved habitat for open-land species that formerly may have been absent from the County or much less common.

Although comprehensive biological surveys have not been conducted, wetlands as a whole, based on their complex and varied vegetation structure, are likely to host more species per unit area than any other habitat type present in Island County. About one-third of the County's plant species have a primary association with wetlands. About 18% of the bird, mammal, amphibian, and reptile species that regularly occur in Island County have a primary association with wetlands, that is, they use wetlands disproportionate to other habitat types and may be dependent upon them. Many upland species forage in wetlands but do not require wetlands in any absolute sense. Although all wetlands are important as habitat, some types may be considered more important than others because (a) they support a wider array of species, or (b) they are a rare type, or (c) the species they support are considered especially important (see Table 9). One example is estuarine wetlands and wetlands in coastal lagoons. Many such wetlands are important to salmon listed officially as threatened species (Beamer et al. 2004). They provide critical habitat for rearing, shelter from predators and high wave energy, and physiological transition for young salmon (Salmon Technical Advisory Group for WRIA 6 (2005). Estuarine wetlands have low energy regimes, high productivity, and seasonally diluted salinity regimes.

Data are mostly lacking on fish use of the County's non-estuarine wetlands. Even when these wetlands are not accessible to fish, their outflow can help support fish populations in downslope waters that are (e.g., Wipfli & Gregovich 2002).

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[11] **Obligate** species are those that require wetlands for some part of their life cycle, and would disappear if wetlands 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 Island County. In this report, obligate and primarily-associated species together are termed **wetland-dependent** species. However, the degree of wetland dependence (as opposed to dependence on undeveloped land generally) is uncertain for some species, partly because in some regions where habitat affinities were investigated, the only undeveloped land remaining happens to be predominantly wetlands, so that was where wildlife was found to concentrate. It also is important to understand that 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. Many species require both wetland and non-wetland habitats to survive. Also, many wetland species infrequently use non-wetlands if local wetlands become degraded, but the productivity of such species will suffer over the long term.

Among the types of non-estuarine wetlands that are recognized as being especially important as habitat are (a) bogs, (b) mature forested wetlands, (c) wetlands that contain more than about 5 acres of shallow standing water (water without visible flow) and throughout most of the growing season, (d) wetlands located just upslope of bogs or streams hosting anadromous fish or resident salmonids, (e) wetlands in the delta estuary of the Skagit River, (f) wetlands with shallow water that are situated within a large block of contiguously wooded uplands (especially contiguous woodlands of >100 acres, with few or no roads), and (e) wetlands not dominated by exotic (non-native) plant species. Bogs and mature forested wetlands host unusual and often rare assemblages of native plants. Wetlands with relatively large areas of shallow water are especially important for waterbirds and aquatic plants. Wetlands in large blocks of forest are important to at least three wetland-dependent amphibians.

2.2.2.4 What Predicts the Habitat Functions of Island County Wetlands?

For most species, "suitable habitat" is predicted by characteristics such as water quality; the type and structure of vegetation; size of a patch of vegetation or water; proximity and connectivity to other patches of natural habitat; the depth, duration, and flow rate of water; and soil type. There are two common approaches to assessing the Habitat Functions of a region's wetlands. One, called the "species approach," involves using technical literature and expert opinion to summarize the habitat characteristics associated with use by most of the most sensitive wetland-dependent species that occur in a region -- identifying wetlands in which those characteristics occur, and then compiling the information as species lists, counts of species for which a wetland is likely to be suitable, and species distribution maps. Another approach is to identify characteristics believed to be important to wetland-dependent wildlife, fish, and plants "in general," and use that information to score and map wetlands anticipated to support the most species. This assumes that maximizing the number of "niches" in an individual wetland, and thus the wetland's number of species, is a desirable objective because as the number of species potentially supported by a wetland increases, the needs of several species whose buffer needs are unknown are more likely to be accounted for. This latter approach and objective have been adopted by the WDOE in their *Rating System* (Hruby 2004).

2.2.2.5 Summary of Evidence for Wetland Functions

The best-documented function of wetlands is their ability to provide habitat to plants and animals. The hydrologic and water quality functions are generally supported, but many exceptions exist, depending on a wetland's setting, type, and many other factors. The *value* of a wetland performing some of the water quality and hydrologic functions also varies by setting and other factors.

2.2.2.6 Importance Defined by Rarity of Wetland Type and Species

Regulatory categories could potentially be based on rarity of a wetland type or its species, because these partly determine wetland importance. Because rarity is a relative rather than absolute concept, the designation of a wetland type as rare depends partly on the size of the geographic area being assessed. For example, a wetland type that is present in only a few acres of Island County may be present in thousands of acres in adjoining counties. A determination of the rarity of a particular wetland type also depends on the system being used to classify wetlands. The more detailed the classification system, the greater is the tendency for it to identify some wetlands as being unique or rare. For example, if a resource (e.g., wetlands) is divided into 100 classes (types), there is a higher probability that one of those classes will be rare than if the resource is grouped into just 4 classes. As noted earlier, the two most common systems for classifying wetlands are the Cowardin et al. (1979)

classification and the less-detailed HGM (Brinson 1993) classification system. Although neither has been applied to all wetlands in the County, where they have been applied the data show that all the wetland types are ones that are found routinely, although not always commonly, elsewhere in the region.

Considering the rarity of *species* as a basis for assessing wetland or stream importance, the presence of anadromous fisheries is currently used by several jurisdictions as a basis for wider buffers of protective riparian vegetation. Rarity of many species is reflected partly by their designation by the County as species as Species of Local Importance, or as Species of Special Concern designated by the WDFW (Washington Department of Ecology). Because neither the County's wetlands nor those of the region have been the subject of a comprehensive species inventory, it is not possible to tell if there are other animals and/or other plants that are truly rare in the County and/or region and are equally or more deserving of enhanced protection as Species of Local Importance.

2.3 Island County's Existing Regulatory Categories and Their Relationship to Wetland Sensitivity and Importance

Existing Ordinance: All *estuarine* wetlands are assigned to Category A (the most protective of 3 categories).
Assumption: Estuarine wetlands are more sensitive, rarer, have higher levels of functions, and/or their functions are more highly valued.
Findings: No scientific studies in the Pacific Northwest have directly compared multiple functions of estuarine wetlands with those of otherwise-similar non-estuarine wetlands, to determine if levels of functions of estuarine wetlands are greater or more sensitive to impacts. For some functions (e.g., habitat for wintering waterfowl) estuarine wetlands are probably more effective than most non-estuarine wetlands, whereas for other functions (e.g., aquifer recharge) their role would be expected to be negligible. Estuarine wetlands are valued highly due to their relative scarcity (3% of the number of wetlands in Island County), large historical losses, and potential role in supporting anadromous fisheries and marine resources. However, with specific regard to wetland sensitivity, estuarine wetlands and the species they typically host have not been shown to be more sensitive to impacts than non-estuarine wetlands. Indeed, the opposite may be true. Because estuarine wetlands are hydrologically open systems, flushing rates are relatively high and pollutants tend not to accumulate rapidly. However, large loads of sediment from eroding uplands can reduce moisture, nutrients, and salinity in adjoining tidal marshes (Byrd & Kelly 2006). Many plants and animals that inhabit estuarine wetlands are adapted to large and rapid fluctuations in water levels (from tide), salinity, temperature, and sediment loads. Plant communities are relatively simple, with high redundancy among estuarine wetlands (e.g., Phillips 1977, Burg et al. 1980, Lefstad & Fonda 1995).

Existing Ordinance: Wetlands dominated by *native plants* are assigned to Category A (the most protective of 3 categories) if they are larger than 1/8 acre in the Rural Zone, or larger than ¼ acre in other zones.
Assumption: Wetlands dominated by native plants are more sensitive to impacts, or are more important because they are rarer, have higher levels of functions, or their functions are more highly valued.
Findings: 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-native plants also tend to invade wetlands

as a result of disturbances. Non-natives tend to have broad environmental tolerances, so wetlands dominated by them may be more resistant to further change (Werner et al. 2002, Wigand 2003). With regard to wetland importance (scarcity, function, and value), the statistical sample of wetlands inspected in summer 2005 indicated that in Island County, wetlands dominated by native plants are not rarer than ones dominated by non-native plants, so their assignment to Category A cannot be supported based only on scarcity. However, native-dominated Category A wetlands are *valued* more highly – at least by ecologists -- because they often are typified by more-natural (unaltered) water regimes, better water quality, and more diverse plant communities[12]. Alternatively, it could be argued that wetlands dominated by non-native plants (Category B wetlands) should be *valued* to a greater degree because they tend to occur in agricultural and urban areas, where they are given more opportunity to process pollutants. With regard to wetland *functions,* wetlands dominated by native plants are *assumed* to provide higher levels of most functions because of their relatively unaltered state, but this has not been shown by any published scientific studies in the Pacific Northwest. For Water Quality function, reed canary grass (the most common invasive wetland plant in Island County) was shown in experiments elsewhere to retain no more added nitrogen than native plant assemblages (Herr-Turoff & Zedler 2005).

Existing Ordinance: Wetlands that were purposefully *created* where no wetland previously existed are assigned to the least protective category (Category C).
Assumption: Naturally-occurring wetlands, as compared to artificial ones created in uplands, are more important because they are rarer, have higher levels of functions, or their functions are more highly valued than those of created wetlands.
Findings: In Island County, naturally-occurring wetlands are not rarer than created wetlands, so on that basis alone should not be assigned to a higher category. In western Washington generally, wetlands created in uplands tend to fall short of expectations with regard to hydrologic sustainability and functions (Johnson et al. 2002). Because their flora is often dominated by generalist species with broad tolerances (Magee et al. 1999), created wetlands may tend to be more resistant (less sensitive) to further impacts, but lack of data prevents firm conclusions about their overall sensitivity. Thus, the status of a wetland as created vs. naturally-occurring is often not the best predictor of wetland function, but may indirectly tend to reflect wetland sensitivity.

Conclusions: The County's three existing categories address to only a limited degree the differences among wetlands in level of function, values, scarcity – which collectively define "importance" – and sensitivity. Among the criteria the County uses to define the three wetland categories, perhaps the best indicator of a wetland's *value* is its status as an estuarine wetland. Perhaps the best indicator of its *sensitivity* is its size and predominance of native vs. non-native vegetation. Perhaps the best indicator of its *functions* is its status as a naturally-occurring (vs. created) wetland.

2.4 Minimum Size Thresholds for Wetland Regulation

Currently, the County's CAO specifies that the County regulate wetlands no smaller than one-eighth acre (5438 square feet), or in some cases no smaller than one-quarter acre (10,875 sq. ft) or one acre. For regulated timber harvest operations around wetlands, the Washington Department of Natural Resources uses 0.25 acre (10,875 sq. ft) as the minimum. In Island County, wetlands occur at a

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[12] Abundant non-native species such as reed canarygrass (*Phalaris arundinacea*) typically invade wetlands whose water, vegetation, nutrient, and/or sedimentation regimes have been disturbed, especially by human activities (Mahaney et al. 2005, Guzewell 2005). Their invasion causes the disappearance of many native plant species (Werner & Zedler 2002). Reed canarygrass tends to invade and spread in wetlands that remain shallowly flooded for long periods annually.

density of approximately 7 wetlands per 1000 acres (or 1 acre of wetland per 10 acres of land). Figure 1 shows their size frequency distribution, but is limited by the fact that many very small wetlands remain unmapped.

Although some wetlands are too small to encompass the daily home range of many animals, they may nonetheless support rare wetland plants, as well as serve as corridors[13] or 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.

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 (as the County currently does), 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. As related to this, Figure 1 illustrates the current size frequency distribution of mapped Island County wetlands.

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 much 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 wooded corridors. The WDOE currently encourages consideration of whether a small wetland (<4000 sq. ft., and especially, <1000 sq. ft) is part of a wetland "mosaic" when deciding whether it should be exempt from certain provisions. Similarly, Island County's existing CAO recognizes the importance of wetland mosaics by considering individual wetlands to constitute a single wetland for purposes of regulation when the wetlands are connected by streams, ditches, other non-wetland surface water, or shallow (>12 inches) groundwater (the County uses the term *associated* wetlands to describe these, ICC 17.02.30)

Patches of natural vegetation that are too small 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.

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[13] **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.

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 in a population study of song sparrows nesting in wetlands of coastal British Columbia (Rogers et al. 1997). This highlights the importance of considering wetland mosaics when establishing minimum sizes for regulated wetlands.

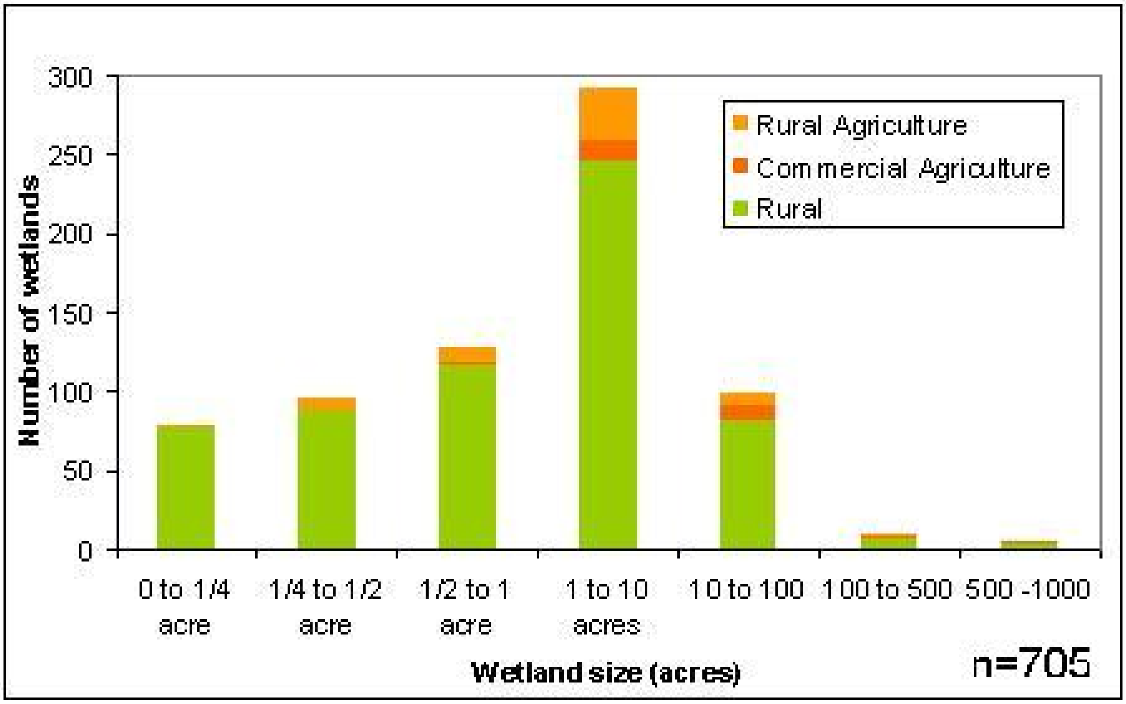

Figure 1. Size frequency distribution of non-estuarine wetlands in Island County's major zoning designations

3.0 Buffer Widths and Best Available Science

3.1 Introduction

Undeveloped or lightly-developed upland buffers around wetlands can do much to protect the functions and natural ecological condition (health) or wetlands. Buffer requirements for wetlands under the County's existing CAO are shown in Table 2, with estimates of the area affected. The County's wetland categories and associated buffer width requirements have not been changed since they were adopted in 1984. They feature a variable-width approach, with three wetland categories (and thus, buffer widths) defined by wetland size, zoning classification, and wetland type (see the first four columns of Table 2). The three regulatory categories and the associated buffer requirements are not explicitly linked to wetland functions, rarity, or sensitivity, either conceptually or site-specifically.

The following are often cited as potential benefits of upland buffers:

- 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 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 windthrow loss of trees within forested wetlands.
- Exporting wood and other organic matter to streams and wetlands as required by some of their animals.
- Maintaining vegetated "permeable" 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.

3.1.1 Types of Buffer Regulations

Regardless of whether wetland sensitivity or importance is used to categorize wetlands, there are three basic types of buffer regulations: variable-width, fixed-width, or some combination:

Variable-Width Buffer Approach

The variable-width approach is a case-by-case strategy that probably is the most consistent with what scientific literature says about buffer effectiveness. This approach usually 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. By taking into consideration 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. However, this approach is time-consuming, costly to implement, and provides a less predictable outcome. It requires either that the applicant hire a consultant to conduct the necessary analysis, or that County staff conduct the analysis. In either event, the staff must have appropriate training and expertise to conduct or review the analysis. In addition, this approach requires considerable effort up front to select and appropriate formula and measurement protocol. This approach also does not provide much predictability. Applicants have no idea how large a buffer may be required until considerable time and money are invested in the analysis. Using a case-by-case, variable-width approach can also result in attempts to manipulate the site-specific data, lead to frequent haggling with applicants, and create the perception that buffer widths are determined in an arbitrary and capricious manner.

Fixed-Width Approach

By contrast, a fixed-width approach provides predictability and is less expensive to administer. Such buffers are often intended to protect just one feature or function of a wetland. 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 includes the best available science since the scientific literature clearly recommends different buffer widths based on a variety of different factors.

Combined Variable- and Fixed-Width

There are several ways to modify a standard, fixed-width approach to incorporate some of the varying factors that contribute to buffer effectiveness. In theory, some drawbacks of the fixed-width approach can be lessened by utilizing a wetland rating system that assigns wetlands into different categories (or assigns scores across a continuum) based on specific characteristics. Then, different buffer width standards can be assigned to each category or score range. This approach provides predictable widths, yet allows some tailoring of buffer widths to characteristics of a specific wetland.

Another way to tailor a fixed-width approach to address site-specific factors is to have different standard widths based on the likely intensity of adjacent land use (as sometimes represented by its zoning designation, see Section 3.5). A buffer regulation could require a larger buffer width for adjacent land uses with intense impacts and a smaller buffer width if the impacts from adjacent land uses are low. This approach can be combined with a wetland rating system to provide a more scientifically defensible regulatory approach. However, it must be recognized that land uses often change. If a land use requiring only a narrow buffer is subsequently converted to another more-intensive use, some structures just outside the original narrow buffer might need to be removed and/or vegetation may need to be planted to widen the buffer, and this is generally not practical.

Other critical factors, such as the characteristics of the buffer itself and the desired buffer functions, can be addressed by establishing criteria and procedures for varying from a standard width. This approach allows for some site-specific tailoring of the standard buffer width on a case-by-case basis without the need for developing a detailed formula or protocol for determining site-specific widths. In this approach, criteria for increases or reductions from the standard buffer width are developed, and the applicant or any other interested party is given the option of “making a case” as to why the standard buffer width should be increased or decreased. County staff would then evaluate the proposal for deviation from the standard buffer width against the criteria, and decide if such a deviation is warranted. The criteria for allowing a deviation from the standard buffer width should address the various site characteristics such as slope, soil type, vegetative cover, and/or the habitat needs of particular wildlife species. For reducing standard buffer widths, an applicant should have to demonstrate that a smaller buffer will protect the functions of the wetland. This would generally require hiring a qualified expert and preparing a site-specific report for the review and approval. It is also important to have a minimum buffer width below which the buffer cannot be reduced.

3.1.2 Applying Best Available Science to Buffer Width Requirements

Section 1.2 noted that one component of Best Available Science (BAS) is “Synthesis.” For updating critical areas regulations pertaining to wetlands, some jurisdictions in Western Washington 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 in Western Washington 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[14]. It suggests that local jurisdictions 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. For updating of Island County’s wetland CAO, we began our consideration of BAS by reviewing these documents.

The determination of buffer widths necessary to protect sensitive and/or important wetlands, their species, and functions is a complex endeavor. The difficulty lies primarily in the paucity of applicable scientific studies of buffers. 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 Island County 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:

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[14] 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 Phase II document (Adamus et al. 2001: *Indicators for Monitoring Biological Integrity of Inland Freshwater Wetlands: A Survey of North American Technical Literature, 1990-2000*).

> "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, attempts must be made to base critical area regulations – including buffer widths -- on "best available" science while realizing that it 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?"

3.1.2.1 BAS Limitations Related to Choice of Literature

Like all science, the science behind 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. Moreover, the WDOE document intentionally excluded estuarine and other tidal wetlands. Thus, before drafting the material in this document, we identified and read an additional 180 references (approximately) that are pertinent to wetland buffers. This expanded by 16% the number that were cited in the WDOE's document.

3.1.2.2 BAS Limitations Related to Research Designs in Published Studies

To credibly determine the effects of buffers of various widths, an experimental approach is needed. 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 the same key parameters are monitored. Together, these two common research designs are termed BACI (Before-After, Control-Impact), yet very few published studies that are 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."

3.1.2.3 BAS Limitations Related to Measured Response Variables

For representing the water quality of wetlands, studies of the effects of buffers of various widths generally measure the surface water directly. In contrast, 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 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 at considerable distance from a wetland are helpful for documenting complementary *use* of multiple habitats, the criticality of such complementary areas to the species' survival remains unanswered.

Moreover, although a common assumption is that buffers must be wooded, few studies have documented the specific types and intensities of land use ("landscape permeability") that will render a buffer inhospitable to movement of individuals of a given species. For example, there are no data from the Pacific Northwest that demonstrate avoidance of hayfields and lightly-grazed pastures by dispersing amphibians, mammals, or birds. There also are no regional studies that show populations of any wetland species being harmed by occasional flushing of individual non-breeding birds as a result of humans approaching wetlands on foot (as opposed to disturbance from motorboats). Thus, data comprised only of 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 remotely-relevant data that are available. In addition, species richness (c) is a poor way to represent the value of buffers. This is partly because 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. Moreover, wetlands supporting only a few species may be critically important to regional biodiversity if those species are specialized wetland obligates that occur in few other wetlands.

3.1.2.4 BAS Limitations Related to Extrapolating from Study Environments

Much subjectivity is involved in deciding when it is appropriate to extrapolate from published research to conditions present in a specific wetland. For example:

- If the study was done in an urban or forested landscape, are the results valid for agricultural areas in Island County?
- If the study was done in an agricultural area of North Dakota, are the results valid for agricultural areas in Island County?
- 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 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 Island County?

The reality is that no area where buffer studies have been done is an exact match for Island County wetlands in terms of species, wetland types, and wetland settings. Even within Island County, wetlands show a great degree of variation. To minimize having to extrapolate from the literature, then, the best approach would be to study Island County wetlands and their buffers directly, and indeed that is what the County did in 2005. However, it was infeasible to sample water quality or to conduct comprehensive surveys of wildlife and plant species that reproduce successfully in (or simply use) the County's wetlands and their buffer areas, and nearly all the studied wetlands had buffers of at least 100 ft (the usual legal requirement for most County wetlands), thus not allowing for comparisons with narrower buffers.

3.2 Buffers for Protecting Wetland Water Quality

3.2.1 Background

Where natural vegetation is allowed to dominate an upland area next to a wetland, that not only reduces 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. 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 2006). 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, and the resulting levels of the pollutant in the receiving wetland are quantified relative to some standard.

3.2.2 Key Considerations

Although discussions of buffer design typically focus mainly on the buffer's width, several other buffer characteristics can be equally or more influential with regard to the buffer's effectiveness. These include vegetation type, water source, flow pattern, slope, soil type, 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:

Vegetation Type: Many studies have compared grass vs. wooded buffers. Some have found grass filters (buffers) to be more effective whereas others have found wooded to be more effective, and some have found mixtures of both to be most effective (Sovell et al. 2004, Schultz et al. 2004, Lowrance & Sheridan 2005). Thus, no general conclusions can be drawn. The differences are probably explained by underlying differences in vegetation patterns, species, root structures, season, pollutant type, and/or characteristics described below that correlate with vegetation type. There are no data that indicate buffers dominated by non-native plant species are less or more effective than ones dominated by native plants. 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. A statistical sample of Island County wetlands visited in 2005 found that 69% contained some amount of alder. That sample also found that approximately 90% of the wetlands had vegetated ground cover within 150 ft of their wetland-upland boundary, and about half had a tree or shrub canopy within 150 ft.

Water Source: Vegetated buffers are more effective in protecting the quality of wetlands whose primary water source is shallow subsurface lateral flow or discharging groundwater, rather than channel flow or surface runoff. That is because pollution transported towards the wetland via 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). A large proportion of the non-estuarine wetlands in Island County are believed to be fed primarily by subsurface seepage rather than by flooding from streams, which are few in the County. Thus, wetland buffers are expected to be particularly effective in Island County.

Flow Pattern: Flow pattern is perhaps the most important factor influencing buffer effectiveness. Vegetated buffers are most effective in protecting the quality of wetlands in which the largest portion of incoming water enters the wetland as diffuse flow (surface sheet flow or subsurface lateral flow) rather than as flow concentrated in rills and gullies (Dillaha et al. 1989, Dosskey et al. 2002, 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), man-made alterations, 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). Field surveys of a statistical sample of Island County wetlands and their buffers during 2005 found very little evidence of gullying or channel headcutting in the buffers, which could reduce their effectiveness. 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.

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 also 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.

Various rules-of-thumb have been proposed for increasing required buffer widths to compensate for the effects of slope (Table 7). It is unclear how these rules were derived (field data, model simulations, or professional judgment). The average slope of Island County wetlands is 3%, and within 100 ft surrounding the County's wetlands, the average slope is about 10%. This is further broken down by zoning category and distance in Table 8. Within 100 ft of wetlands, the slope exceeds a gradient of 30% in about 5% of the County's 958 wetlands.

Table 7. 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)

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

Table 8. Mean slope of surrounding land at various distances from Island County wetlands, by zoning category

Zoning Category	Within 50 ft	Within 100 ft	Within 150 ft	Within 300 ft
Commercial Agriculture	5	5	5	5
Federal Land	6	7	6	6
Light Manufacturing	5	5	4	5
Municipality	6	5	5	6
Park	10	12	12	11
Review District	5	6	5	4
Rural	10	10	10	10
Rural Agriculture	7	7	7	7
Rural Center	7	8	8	8
Rural Forest	11	12	12	11
Rural Residential	11	12	12	11
Rural Service	13	13	12	13
Rural Village	9	8	9	10

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 (Polyakov et al. 2005). Finer-textured soils may quickly become saturated, allowing incoming pollutants to simply "float" over the root zone where most pollutant processing otherwise occurs. But if soils are so coarse that water infiltrates very rapidly through the root zone, there also may be too little time for pollutants to be fully processed. In one study, buffers with widths of 82 to 577 ft (much larger than usual) were required to remove 90% of nitrate due to a geologic confining layer situated beneath very coarse soils (Vidon & Hill 2004). Due to their associated physical and chemical properties, coarser-textured soils – especially those with minimal organic content – also tend to be less effective in retaining pollutants. On this basis, for removing nitrate in Island County runoff, the most effective buffers (and wetlands) may be those located on the following soil types. Bellingham, Carbondale, Coupeville, Greenwood, Lummi, Mukilteo, Norma, Rifle, Semiahoo, Tacoma, and Tanwax. This list is based on the assumption that soils having less than 65% silt and clay have only minimal 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 other soil map units can have high denitrification (nitrate removal) rates as well, if the soils are not too acidic.

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 down and *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 the statistical sample of County 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.

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). 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). Although that particular measurement has not been made for Island County wetlands, a rough approximation might be made by considering the size of the County's *wetlands* relative to *their* contributing area. On the average, the County's non-estuarine wetlands comprise 16% of their contributing area (median = 8%). Across the County, the ratio of wetland to contributing area decreases slightly with decreasing elevation, suggesting a possible need to increase width requirements for buffers lower in a watershed, although slopes around wetlands tend to be steeper higher in a watershed, thus suggesting a possible need to increase buffer widths there as well.

Pollutant Type, Amount, Dosing Rate, and Duration: Scientists agree that buffers are no panacea for treating runoff that is polluted severely. Wetland buffers, as well as wetlands themselves, are capable of effectively processing polluted water, but this capacity is not infinite. Wetlands and their buffers probably cannot process some types of pollutants at all. Buffer effectiveness is greatest when incoming polluted runoff or groundwater arrives in small doses (low loading rates). To some degree this can be estimated from the above ratio, with smaller doses being associated with buffers that have relatively small contributing areas. Zoning categories and their usually-associated land uses are sometimes used as a rough surrogate for pollutant loading rates, as is described in Section 3.5. There is some evidence (e.g., Daniel & Moore 1997) that vegetated buffers that have received pollutants (especially phosphorus) for many years may lose their effectiveness, thus jeopardizing the water quality of their associated wetland. However, studies of this phenomenon are too few to predict situations (loading rates and wetland types) where it is likely to occur.

3.2.3 Buffer Widths Needed to Process Pollution: Current BAS

Dozens of secondary sources (review papers) have been published on the topic of vegetated buffers for water quality improvement (Castelle et al. 1992, Desbonnet et al. 1994, Wenger 1999, McMillan 2000, Melcher & Skagen 2005, Sheldon et al. 2005, Polyakov et al. 2005). Many or most pertain to studies of buffers used to protect streams from urban development or timber harvest activities.

In a review of buffer effectiveness literature, Desbonnet et al. (1994) simply took the average of the buffer widths indicated by several studies, and concluded that buffers of 150 ft would protect water quality in most instances. Some of the sources cited by that report showed as much as 70% pollutant removal with buffers as narrow as just 3 ft (for sediment) or 13 ft (for nutrients).

Another review of literature on riparian buffers, by 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 "100 ft buffer should provide good control [of excessive nutrients], and 50 ft buffers should be sufficient under many conditions." An earlier review by Fennessy & Cronk (1997) also suggested that 100-ft buffers would remove nearly 100% of nitrate inputs. Reflecting a concern for potable groundwater, in Island County new wells for individual residences are required to have a pollution control radius of 100 feet inside of which a variety of activities are restricted. This corresponds to the minimum 100-ft distance using the calculated fixed-radius method as described by WAC 246-290-135 (Source Water Protection, Sanitary Control Area).

A literature review by Castelle et al. (1994) indicated that effective retention of runoff-borne sediment requires buffers of between 30 and 200 ft (300 ft for nutrient retention). The same range was noted by Melcher & Skagen (2005), and Sheldon et al. (2005) indicated a range of 66 to 328 ft. However, our review found that when papers or reports recommended buffers wider than about 100 ft, the suggestion most frequently was based on (a) opinions of authors, not actual data, (b) studies that were not peer-reviewed (e.g., Gilliam & Skaggs 1987), (c) studies of runoff from cattle feedlots, which would be expected to require a wider buffer due to much higher nutrient concentrations than are found in Island County, (d) studies in geologic settings dissimilar to those in Island County (e.g., Vidon & Hill 2004), and/or (e) studies where the unusually wide buffer was needed to achieve a percent-removal level (e.g., 95%) that may not be necessary, given the apparently low loading of nutrients and sediment in Island County. None of these reviews indicated whether the measured percent-removal of pollution was sufficient to reduce the pollutant's concentration in the receiving water body to a level that complied with water quality standards. Most reviewers suggested that buffers be wider where sediment or nutrient loads in runoff are large (e.g., more intensive land uses such as feedlots), nearby soils have a large clay component, and/or runoff flows are concentrated and extreme. Water quality data from Island County streams, although limited, suggests that sediment and nutrient loads are mostly well below levels expected to harm resources (see Section 2.2.2.2 and Adamus et al. 2006a). Although some of Island County's highly compacted glacial till has a high clay content, County soils are mainly sandy or loamy, with very few having a large clay component. There appears to be little gullying or other flow-concentrating features within most of the County's wetland buffers, based on examination of a statistical sample of County wetland buffers in 2005 (Adamus et al. 2006b). However, extreme flows can occasionally be expected in wetlands surrounded by relatively steep (>5%) slopes, as many County wetlands are.

The NRCS office for the State of Washington has a BMP (i.e., Conservation Practice Standard, or EFOTG) called "Filter Strip" which it defines as a strip or area of herbaceous vegetation situated between… grazing land… or disturbed land and environmentally *sensitive* areas." For Island County 24-hour storm events whose intensity occurs on the average of once every 10 years, it recommends minimum widths for filter strips (i.e., vegetated buffers) of 20 ft to 40 ft to control sediment and nutrients. This assumes all storm runoff enters the wetland's buffer as diffuse sheet flow, and that stormwater outputs to and within the buffer from ditches, gullies, subsurface drains, and pipes are negligible. It assumes that gullies created by storms are promptly repaired. The suggested widths also assume that grazing within the buffer is allowed only when a grazing management plan is being implemented and in particular, when animals are excluded from the buffer when soil is so wet that compaction or other damage would occur. This BMP also requires that mowing, livestock, and vehicle traffic be excluded from the buffer during nesting season (in Island County, this is approximately April 15 through July 15).

Timber harvest rules (WAC222-30-010) in Washington specify the use of forested buffers that average 100 ft (range= 50 to 200 ft) wide around bogs larger than 5 acres and around non-forested wetlands that have more than 0.5 acre of standing water (for at least 7 consecutive days, April-October). They specify an average buffer width of 50 ft (range= 25-200 ft) around smaller bogs and most other non-forested wetlands. Width is measured from the point where the nonforested part of a wetland becomes forested wetland.

Many studies have shown that sediment retention is greatest in the first 10-20 ft of a buffer, that is, the most uphill portion, which is closest to potential inputs of runoff-borne sediment (Polyakov et al. 2005). The same has been shown with nutrient retention (Bedard-Haughn et al. 2004).

It is apparent from the above that some uncertainty still surrounds the question of minimum buffer widths needed for water quality protection. As noted by Parkyn (2004), "The width required to optimize nutrient removal has been debated with little systematic study of the issue." Also, in their similar review of buffer studies Polyakov et al. (2005) concluded, "…there is still a lack of a comprehensive relationship between buffer width and its sediment removal potential" and a similar conclusion was reached by Hickey & Doran (2004). Thus, although the dozens of buffer studies together may be considered "Best Available Science," as a whole they may fall short of yielding the types of specifications needed to define buffers that are effective under all circumstances. To address this uncertainty, an adaptive management approach could be taken, wherein buffer width extensions might be considered site-specifically or generally across the County if surface water quality data suggest chronic exceedence of standards for turbidity and nitrate. This is, in fact, what Island County has implemented with its new long-term Surface Water Monitoring.

Limitations of buffer BAS as relates to water quality are as follows:

1. 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. The number of published studies generally is so large and their test conditions so vaguely documented, that it is not practical to attempt matching them, case by case, with conditions most similar to those found in Island County.

2. 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. 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.

3. 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 minimize ecological damage. A 95% pollutant removal efficiency means nothing if the incoming runoff is polluted severely, and a 10% pollutant removal efficiency can be outstanding if the incoming runoff is polluted only minimally. Also, for some pollutants such as sediment and phosphorus, removal efficiency may decline with increased loading. Thus, actual concentrations of incoming pollutants, as inferred very approximately from land use intensity (Section 3.5), must primarily be taken into account.

4. No published studies have examined, for all major pollutants, the full array of buffer widths under a variety of conditions of slope, soil type, vegetation type, contributing area size, and dosing rates. One option for making such essential comparisons may be to use a modeling approach, with local calibration. Potentially, the use of numeric models provides more realistic estimates of appropriate buffer widths than can summaries of published studies that covered a wide range of often-poorly-defined test conditions, and which tend to report "percent removal" without regard to pollutant levels in the receiving waters. Water quality models specifically intended to identify appropriate buffer widths have been developed and/or applied elsewhere by Wong & McCuen 1982, Qiu 2003, Wissmar et al. 2004, Yang & Weersink 2004. Popular models with broader water quality purposes, such as the NRCS's Revised Universal Soil Loss Equation (RUSLE) could also be used. The modeling approach is no panacea and would

involve making several assumptions, but that is also the case with use of published literature. Before stronger conclusions can be drawn regarding whether the output flow from various types and sizes of buffers is (or would be) clean enough to meet standards before it reaches and impacts wetlands, it may be important to collect additional data[15] and/or to conduct additional analysis of existing topographic data using established models (pollutant runoff equations).

5. Buffers surrounding estuarine wetlands have not been shown to protect water quality of those wetlands in situations even remotely analogous to Island County. Tidally-driven water exchanges that occur in the lower parts of estuaries, independent of the presence of upland buffers, are expected to be the main driver of changes in temperature, sediment, and nutrients in most estuarine wetlands with unrestricted tidal flow. In the absence of major rivers, marine inputs of nutrients and suspended sediment are expected to far overshadow the loading of most estuarine wetlands as a result of runoff and groundwater inputs from the County's adjoining uplands. However, there may be local exceptions if soils are sandy and tidal circulation is somewhat confined. Then, large loads of sediment from eroding uplands may reduce moisture, nutrients, and salinity in adjoining tidal marshes, as demonstrated in California by Byrd & Kelly (2006).

6. 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 grazed areas buffers may, however, continue to be useful for retaining sediment and supporting wildlife habitat.

3.2.4 Summary: Buffer Widths for Protecting Water Quality of Island County Wetlands

From the perspective only of maintaining wetland water quality, we found no definitive published studies or other evidence to refute completely the buffer widths used by Island County under its existing CAO (widths of 25, 50, or 100 ft depending on zoning designation, size, and wetland type). Literature reviewed for this report indicates these widths effectively retain sediment and nutrients under most conditions of light to moderate pollutant loading, gentle semi-permeable slopes, and normal storm events. The BAS indicates wider buffers may be needed to ensure effectiveness of buffers over the long term and during unusual storm events (Dillaha et al. 1989), especially where high-intensity activities occur on erodible soils, steep slopes, and/or around wetlands with limited hydrologic connectivity or especially sensitive vegetation (e.g., bogs). The BAS does not indicate precisely by how much a buffer's width should be extended to address these factors, but some general guidelines are available.

3.3 Buffers for Protecting Water Quality *Functions* of Wetlands

On a different topic, it remains unclear what role buffers of various widths around a wetland can do to protect not just wetland water quality, but also the water quality *functions* within a wetland (i.e., wetland capacity to alter loads of contaminants, nutrients, sediments, harmful bacteria, and alter stream temperatures). This is an important distinction. The buffers themselves are intended to perform many

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[15] such as Island County will obtain from its new Surface Water Quality Monitoring Program

of the same water quality functions as wetlands, although usually to a much lesser degree depending on characteristics discussed in Section 3.2.2. Compared to impervious surfaces, vegetated buffers potentially enhance a wetland's capacity to improve or maintain water quality, partly by delaying slightly the arrival of most runoff from a storm event, thus allowing some "pre-treatment" to occur upslope.

Buffers located on permeable soils (e.g. glacial outwash soils) appear more capable of attenuating storm runoff before it reaches wetlands (Reinelt & Taylor 2001). However, evidence for this is limited. Wetlands are known to usually experience larger water level fluctuations in urban than in rural landscapes (Azous & Horner 2001). Large water level fluctuations (>1 inch fluctuation, Magee & Kentula 2005), when occurring regularly as a result of water withdrawals for irrigation use or because of altered conditions in the contributing area (ditching, extensive impervious surface), encourage invasion by non-native plants and thus are detrimental to some native plant species and to wetland-breeding amphibians. However, a study in the Portland area did not find an increase in water level fluctuation to be clearly associated with increased alteration of surrounding areas (Shaffer et al. 1999), and another study suggested the effect of buffers on hydrologic functions was negligible (Detenbeck et al. 2002), except when dedicating land to buffers prevented their conversion to impervious surface. In contrast, within rural landscapes, wetlands surrounded by natural grasslands may receive less runoff volume and experience less water level fluctuation than wetlands surrounded by tilled soils (Euliss & Mushet 1996).

3.4 Buffer Widths for Protecting Habitat and Wetland Species

3.4.1 Background

In County and local critical areas ordinances, "habitat function" – which generally includes habitat for all animal and plant species – is typically addressed both as a distinct kind of critical area ("Fish and Wildlife Habitat Conservation Areas," WaCTED 2003) and as one of several functions of wetlands when planning for wetlands as critical areas (Hruby 2004). Within Island County there regularly occur at least 700 plants, 8 amphibians, 6 reptiles, 158 birds, 45 mammals, and an unknown number of fish species. Most have a unique set of environmental requirements but those are poorly known for most species. Washington law (365-190-080(5) WAC) states that jurisdictions must work cooperatively to ensure that isolated subpopulations of a species are not created.

Table 9 shows wildlife species of Island County that are most closely associated with wetlands specifically. These may be categorized as wetland-obligate species or primarily-associated species. **Obligate** species are those that require wetlands for some part of their life cycle, and would disappear if wetlands 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 Island County. In this report, obligate and primarily-associated species together are termed **wetland-dependent** species, 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.

Table 9. Island County species that have an obligate or primary association with wetlands and may benefit from wooded surroundings

Wetland-associated species in this table are in 3 groups of descending priority: (1) Designated Species of Local Importance or WDFW Threatened, Endangered, or Sensitive Species; (2) Wetland obligate species requiring woody surroundings; (3) Species with a primary (not obligate) association with wetlands and needing woody surroundings for much of their life.

Species	Official Designations
Wetland-dependent Species with Special Designations	
Great Blue Heron	Species of Local Importance
Bald Eagle	Species of Local Importance; WDFW Threatened
Osprey	Species of Local Importance
Peregrine Falcon	Species of Local Importance; WDFW Endangered
rare wetland plants (5 species)	Species of Local Importance
Salmonids: Puget Sound Chinook Hood Canal Summer Run Chum Puget Sound Bull Trout	Threatened (Federal)
Wetland Obligates – May Need Forest Nearby	
Western Toad	Candidate WDFW
Long-toed Salamander	
Northwestern Salamander	
N. Red-legged Frog	
Rough-skinned Newt	
Wood Duck (cavity-nesting)	Priority Species* WDFW
Hooded Merganser (cavity-nesting)	Priority Species* WDFW
American Beaver	
some fish (e.g., coho, cutthroat)	
wetland plants (124 species)	
Species Associated Primarily with Wetlands – May Need Forest Nearby	
Western Screech-Owl	
Willow Flycatcher	Species of Concern (Federal)
Olive-sided Flycatcher	Species of Concern (Federal)
Pacific-slope Flycatcher	
Winter Wren	
Swainson’s Thrush	
Warbling Vireo	
Yellow Warbler	
Black-throated Gray Warbler	
Wilson’s Warbler	
wetland plants (105 species)	

* “Priority Species” include species of recreational, commercial, or tribal importance that the WDFW considers to be especially vulnerable. They need not be listed as threatened, endangered, or sensitive. Priority Species “require protective measures for their perpetuation” according to WDFW.

Table 10. Wetland types used by wetland-dependent species in Island County

Information in the table on the following pages is drawn from the author's experience as a wildlife biologist, and the general literature on wildlife ecology.

Species are the same as in the preceding table and are in 5 groups of descending priority: GROUP 1: Designated Species of Local Importance or WDFW Threatened, Endangered, or Sensitive Species; GROUP 2: Wetland obligate species requiring woody surroundings; GROUP 3: Species with a primary association with wetlands and needing woody surroundings; GROUP 4: Wetland obligate species with no data showing need for woody surroundings; GROUP 5: Species with a primary association with wetlands and no data showing need for woody surroundings. Numbers in table indicate relative degree of use of that wetland type: (3= primary use; 2= strong use; 1= some use; 0= mostly avoided) ("f" indicates use only when surface water is present).

<u>Wood Need</u> This describes the species' relative need for surroundings that include trees and/or shrubs: **No**= wetlands with surrounding woody vegetation are avoided by the species, or the species does not require that woody vegetation be located contiguous to the wetland except perhaps for narrow (<50 ft) band around part of wetland to screen out visual disturbances, slow the invasion of wetland by non-native species, or as a perch (for birds). Woody buffers are nonetheless needed around active nests of Great Blue Heron and Osprey. **Mod**= a wider woody buffer may be beneficial to the species. **High**= an even wider woody buffer may be needed by the species. Data are inadequate to support specific buffer thresholds for the Moderate and High species. Buffer vegetation need not be in a contiguous patch completely surrounding the wetland.

<u>Patch/Mosaic</u>: The seasonal home range of the species (or for Group 1 species, their nest site only) typically requires the following: **S**= small-sized patch or cluster of suitable habitat (<5 acres), **M**= moderate-sized patch or habitat cluster; **H**= large patch or habitat cluster (generally >100 acres). "Patches" include both the wetland, any internal streams, and contiguous upland surroundings that are suitable as habitat for the species. "Mosaics" are the same except the habitat is not necessarily contiguous to the wetland, but is within a distance regularly traveled by individuals of the species.

Wetland types relevant to wildlife and fish species are:

- <u>Estuarine</u>: Salt marshes coded EEM on NWI maps
- <u>Ponded/ Lagoon</u>: Non-estuarine herbaceous (emergent, EM) wetlands with (a) long-duration surface water as indicated with NWI codes PUB, POW, PAB, or L (lacustrine); or (b) PEM with a perennial low-gradient stream or with appended hydroperiod codes F, G, or H (long-duration flooding) in all or part of the wetland polygon. Includes coastal lagoon wetlands.
  - <u>Marsh</u>: Non-estuarine herbaceous (emergent, EM) wetlands with surface water present at some time each year, or with a perennial low-gradient stream.
  - <u>Shrub</u>: Scrub-shrub (SS) wetlands with or adjoining a perennial low-gradient stream or with appended hydroperiod codes F or G (long-duration flooding) in all or part of the wetland polygon.
- <u>Not Ponded</u>:
  - <u>Marsh</u>: Non-estuarine herbaceous (emergent, EM) wetlands without appended hydroperiod codes F or G (long-duration flooding) in all or part of the wetland polygon, and with no perennial low-gradient stream.
  - <u>Shrub</u>: Scrub-shrub (SS) wetlands with no perennial low-gradient stream and without appended hydroperiod codes F or G (long-duration flooding) in all or part of the wetland polygon.
  - <u>Forested</u>: Forested (FO) wetlands, without appended hydroperiod codes F or G (long-duration flooding) in all or part of the wetland polygon, and with no perennial low-gradient stream.

Wetland types used by wetland-dependent species in Island County (continued)

(3= primary use; 2= strong use; 1= some use; 0= mostly avoided) ("f" indicates use only when flooded, i.e., surface water is present). See legend, preceding page.

	Wood need	Patch/ mosaic	Estuarine wetland	Ponded /Lagoon		Not Ponded (saturated only)			Notes
				Marsh	Shrub	Marsh/ Bog	Shrub/ Bog	Forest	
Wetland-dependent Species with Special Designations									
Great Blue Heron (breeding only)	low	S	3	3	1	1	0	0	Needs trees for nesting, avoids closed-canopy wetlands when foraging.
Bald Eagle (breeding only)	low	S	3	2	1	0	0	0	Needs trees for nesting but avoids closed-canopy wetlands when foraging
Osprey (breeding only)	low	S	3f	2	1	0	0	0	Needs trees for nesting but avoids closed-canopy wetlands when foraging
Peregrine Falcon (non-breeding)	low	S	3	2	0	0	0	0	No nesting in Island County
rare wetland plants (5 listed spp.)	mod	S	0	1-3	1-3	1-3	1-3	1-3	Varies by species.
Salmonids: Puget Sound Chinook, Hood Canal Summer Run Chum Puget Sound Bull Trout	mod	L	3f	2	2	0	0	0	Of these 3 species, only Chinook are documented to use non-estuarine streams in Island County
Wetland Obligates That May Need Forest Nearby									
Western Toad	mod	M	0	3	3	1	1	2	Declining sharply in Western Washington
Long-toed Salamander	mod	M	0	2	2	1	1	0	
Northwestern Salamander	High	L	0	2	2	1	1	0	
N. Red-legged Frog	High	L	0	2	2	1	1	0	Needs large wooded patches
Rough-skinned Newt	High	L	0	2	2	1	1	0	
Wood Duck	mod	M	1f	2	2	0	0	1	Cavity-nesting species.
Hooded Merganser	mod	M	1f	2	2	0	0	1	Cavity-nesting species.
American Beaver	mod	M	0	2	3	1	1	1	
some fish species (e.g., coho, cutthroat)	mod	S	1-3	1-3	1-3	0	0	0	
wetland plants (124 species that are obligates)	mod	S	1-3	1-3	1-3	1-3	1-3	1-3	Some may not require woody surroundings

Wetland types used by wetland-dependent species in Island County (continued)

(3= primary use; 2= strong use; 1= some use; 0= mostly avoided) ("f" indicates use only when flooded, i.e., surface water is present).

	Wood need	Patch/ mosaic	Estuarine wetland	Ponded /Lagoon		Not Ponded (saturated only)			Notes
Species Associated Primarily with Wetlands & May Need Forest Nearby									
Western Screech-Owl	High	L	0	1	2	1	2	3	
Willow Flycatcher	mod	S	0	0	3	0	3	0	Mainly deciduous shrubs
Olive-sided Flycatcher	mod	S	0	0	1	0	2	2	Declining in Pacific Northwest.
Pacific-slope Flycatcher	High	L	0	0	1	0	1	3	
Winter Wren	High	L	0	0	1	0	1	3	
Swainson's Thrush	mod	M	0	0	3	0	2	2	
Warbling Vireo	mod	M	0	0	1	0	1	3	Mainly deciduous trees.
Yellow Warbler	mod	M	0	0	3	0	2	1	Mainly deciduous shrubs
Black-throated Gray Warbler	High	L	0	0	1	0	1	3	
Wilson's Warbler	mod	M	0	0	3	0	2	2	Mainly deciduous shrubs
wetland plants (105 species with a primary association with wetlands)	mod	S	1-3	1-3	1-3	1-3	1-3	1-3	Some may not require woody surroundings
Wetland Obligates Possibly Not Needing Woody Surroundings									
Shorebird concentrations	No	L	3	1	0	0	0	0	Mostly migrants
Waterfowl concentrations	No	L	3f	2	1-2	0	0	0	Mostly migrants; few nest
many fish species			1-3	1-3	1-3				
Pacific Chorus Frog	No	M	0	3	2-3	1	1	1	
Muskrat	No	M	0	3	0	0	0	0	Mainly large deep ponds
River Otter	No	M	1	2	1-2	0	0	1	rare
Pied-billed Grebe	No	M	1f	3	0-2	0	0	0	
American Bittern	No	L	1	3	0-2	0	0	0	Mainly large cattail ponds
American Coot	No	L	1f	3	0-2	0	0	0	
Virginia Rail	No	M	0	3	1-2	0	0	0	
Marsh Wren	No	M	2	3	0	0	0	0	
Yellow-headed Blackbird	No	S	1	3	0	0	0	0	Only at Deer Lagoon

Wetland types used by wetland-dependent species in Island County (continued)

(3= primary use; 2= strong use; 1= some use; 0= mostly avoided) ("f" indicates use only when flooded, i.e., surface water is present).

	Wood need	Patch/ mosaic	Estuarine wetland	Ponded /Lagoon		Not Ponded (saturated only)			Notes
Species Associated Primarily with Wetlands & Possibly Not Needing Woody Surroundings									
Common Garter Snake	No	M	0	3	2-3	1	1	1	
Painted Turtle	No	M	0	3	1-3	1	1	1	Glendale watershed
American Mink	No	L	1	2	1-2	1	1	1	rare
Northern Harrier	No	L	3	3	1	2	0	0	Island County has most nest sites in W. Washington
Short-eared Owl	No	L	3	3	0	2	0	0	No nesting in County, declining.
N. Rough-winged Swallow	No	S	2	3	0	1	0	0	Forages over any water
Barn Swallow	No	S	2	3	0	1	0	0	Forages over any water
Tree Swallow	No	S	2	2	0	1	0	0	Forages over any water
Belted Kingfisher	No	S	3	3	1-3	0	0	0	
Common Yellowthroat	No	S	0	3	2	2	1	0	
Lincoln's Sparrow	No	S	1	3	1-2	2	1	0	No nesting in Island County
Red-winged Blackbird	No	S	1	3	2	2	0	0	
shellfish & other estuarine invertebrates	No	S	1-3	0	0	0	0	0	
other estuarine fish	No	S	1-3	0	0	0	0	0	

Vegetated buffers do several things that are relevant to supporting habitat. They (a) filter pollutants before they contaminate 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, (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.

It is not necessary that a buffer always be wooded (dominated by trees and shrubs) in order for it to do these things, 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). Dense rows of shrubs can limit 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 that maintenance of cool shaded conditions is essential to most aquatic species (aside from salmonids and other coldwater fish) that use non-estuarine wetlands in Island County. Thus, if a wetland lacks a surface connection to a salmonid 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 may be other reasons for having such buffers around some wetlands. In Island County, among all non-estuarine wetlands having water that lasts through all or most of the growing season (and thus potentially supports aquatic amphibians), woody vegetation covers an average of 48% of the land cover within 300 ft of the wetland. At least 19% of the County's wetlands are dominated by trees or shrubs, but few of these are accessible to salmonids.

Although wooded surroundings are important to a few wetland-dependent species, many more species (e.g., waterfowl, shorebirds) seem not to have this need, as suggested partly by their frequent use of flooded agricultural lands (Hirst & Easthope 1981, Baldwin & Lovvorn 1994a, b; Shepherd & Lank 2004, Slater 2004, Slater et al. 2005). For those species, trees next to wetlands sometimes discourage wetland use by attracting eagles and falcons that use the trees as perches while preying on birds (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, less late-summer water is available to wetlands surrounded by wooded buffers as a result of soil moisture uptake and transpiration by the buffer's shrubs and trees.

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 Island County. 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 the presence in wetlands of only one of five amphibian species to be correlated with surrounding forest cover, and another one of the amphibians (Pacific chorus frog) 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 central and northern Whidbey Island, there are large areas on "prairie" soils that have been without forest cover for centuries, partly as a result of fires set regularly by native Americans prior to the arrival of settlers. Native plant communities in these areas include some that may not tolerate woody buffers. In summary, requirements for wooded buffers around all wetlands potentially benefit some species (e.g., rough-skinned newt, winter wren) but will have detrimental effects on others (e.g., Pacific chorus frog, marsh wren, shorebirds, geese). Table 10 shows wetland-dependent species of Island County that do or do not appear to require wooded surroundings, based on the author's knowledge of their ecology and technical literature.

Other factors frequently control wildlife populations. In the case of amphibians, these limiting factors include roads (Trombulak & Frissell 2000, Gucinski et al. 2001), the extent of wooded corridors and reserves (Findlay & Houlahan 1997, Hannon et al. 2002, Willson & Dorcas 2003), introduced predators such as bass and sunfish (Pearl et al. 2005), herbicides and fertilizers used commonly in gardens, lawns, and along roads[16] (Bortleson & Ebbert 2000, Voss et al. 1999, Relyea 2005, Relyea et al. 2005), fungal infections, ultraviolet radiation (Hatch & Bluestein 2003), and land alterations or groundwater withdrawals that can induce lower and less persistent water levels in wetlands.

3.4.2 Buffer Purposes and Widths for Wetland Habitat Protection

As noted above, wetland buffers do many things relevant to habitat: (a) filter pollutants, (b) limit disturbance by humans, (c) limit the spread of non-native plants into wetlands, (d) help maintain wetland microclimate conditions, and (e) provide habitat and food for some wetland-dependent species that require both wetlands and upland or deepwater habitats in close proximity. Upland buffers also provide habitat and food for species that occur purely or preferentially in uplands. Although submerged wood is important to many fish and invertebrates, wetlands in Island County are probably not a major source of wood because few are connected to streams. Moreover, most are not accessible to fish.

There are two basic approaches for determining buffer widths appropriate for protecting wetland habitat. One is to identify the buffer widths needed to support a full array of ecological niches (i.e., "good structure and good connections," Granger et al. 2005) within a wetland. Under a risk minimization philosophy, doing so is *assumed* to maximize the chance of addressing the needs of all or most wetland-dependent species, thus maximizing the number of species occurring within a wetland (T. Hruby, WDOE pers. comm.). The other approach is to identify the buffer widths needed to support each of the buffer functions just listed. These two approaches are compatible, but differ in the amount of scientific information available to support them.

Considering the first approach, both the number of ecological niches in a wetland and the number of species filling these niches are difficult to measure directly. The number of niches might be estimated by scoring the structural features of the Habitat Functions component of the WDOE *Rating System*. 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. And there are no data to support recommendations regarding specific buffer widths needed to (1) maximize the *Rating System's* Habitat Functions score (assuming that score adequately represents the number of ecological niches), or (2) maximize the number of wetland-dependent species that regularly use a wetland.

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[16] Even herbicides such as glysophate (Roundup, Rodeo) which have a reputation for being relatively benign, have been shown to kill Pacific chorus frog 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)

Alternatively, the second approach can be used, in which buffer widths needed to support each of the buffer functions are identified. With regard to the buffer function mentioned first above (filtering pollutants), buffer widths for that purpose have been described in Section 3.2. With regard to the second item (b, **limiting disturbance by humans**) -- and for the purpose of minimizing physical alteration of vegetation within a wetland by trampling, vandalism, or non-permitted clearing – a study by Cooke (1992) found a buffer width of less than 50 feet might be insufficient. 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. Also, some studies have found some waterbirds to use developed more intensively than undeveloped lake shorelines (Traut & Hostetler 2003). Wide buffers might be especially appropriate in situations where a bald eagle nest or heron rookery (both Species of Local Importance) is present in a wetland, due to the reputed sensitivity of these species during the nesting season. In those few cases, the WDFW and County buffer widths specified for those species may represent BAS and are applicable.

Perhaps the only study of buffers around wetlands of western Washington was conducted by Milligan (1985), during the breeding season in 23 wetlands mainly in King County. She monitored all bird species, *not just wetland-dependent ones*. Thus, it is not known if her conclusions apply to wetland-dependent bird species or to the more species-rich assemblage of terrestrial birds that are not wetland-dependent. She measured the percent cover of woody vegetation at distances of 0-50 ft, 0-100 ft, and 0-200 ft from the wetland, rather than measuring different wetlands each with a different buffer width of contiguous vegetation (pages 44 and 66 of her thesis). She spent more time in densely-vegetated wetlands, thus likely causing the species count to be artificially higher for those. She found that presence of woody vegetation along a greater proportion of the wetland edge had a greater effect on number of species detected than did increased cover of woody vegetation at increasing distances from the wetland (p. 80 of thesis). Although she found bird species diversity to correlate with the percent cover of woody vegetation near a wetland, she found no statistically significant increase in bird diversity with increasing "buffer widths" (actually, the percent cover of woody vegetation in various zones around the wetlands)[17]. Specifically, she concluded that "the amount of buffer [percent woody vegetation] around a wetland was not correlated with measures of bird species richness, relative abundance, the number of breeders, or the number of wetland breeders." She also noted (p. 81 of thesis) that "a 50 foot buffer or a 100 foot buffer was as useful in encouraging bird species use as a 200 foot buffer." She opined that "some wetlands may require a 200 foot buffer because of a combination of site and post-development conditions" but her study never tested that. Several previous BAS reports have interpreted Milligan's study erroneously, saying, for example, that she "found a reduction in bird species diversity when adjacent buffers of intact forest were less than 50 feet" and "buffers of 50 to 100 to 200 ft were found to effectively maintain diversity." Milligan did not estimate woody cover in any zone narrower than 50 ft, so it is not possible to infer the narrowest buffer that would still correlate significantly with bird diversity.

In evaluating the literature on wildlife disturbance, the type and frequency of disturbance is also important. Perhaps not understanding the source of the data, some planners have recommended wetland buffer widths based on studies of birds disturbed by motorboats, but this is inappropriate

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[17] The County's survey of native plants in 100 wetlands yielded similar results: number of plant species within a wetland increased with increasing woody cover, but it did not matter significantly if the woody cover was measured within 50, 100, or 150 ft of the wetland (Adamus et al. 2006b).

because most wetlands do not support motorboating or have analogous types of disturbances. Although a few studies have found some bird species can be disturbed by humans approaching on foot from as far away as 175 ft (Josselyn et al. 1989), individuals of many species appear to habituate to human presence over time and become less prone to fleeing at the first sign of people. Shallow wetlands with open water tend to host more disturbance-sensitive waterbirds than wooded wetlands and wetlands that mostly lack surface water. In the latter type, vegetation within the wetland usually provides ample cover for most species, so narrower buffers may be appropriate. However, if open-water wetlands are large enough or adjoin marine waters, the greater expanse of water can provide refuge for waterfowl disturbed along the edge.

With regard to the third-listed buffer function (c., **limiting the spread of non-native plants into wetlands**), only limited data were found. Potentially, seeds of non-native plants can be carried for miles by wind and water, so no buffer is likely to eliminate this threat completely. Studies of some forest floor plant communities have suggested that most invasion by field- or clearcut-associated non-native plants is limited mostly to within 10 ft (Honey et al. 2002) of the edge, but invasions can occur commonly within 66 ft of the forest edge (Neunkirchen et al. 2001) or even 197 ft into the forest (Fever 1994). The width needed to develop a self-sustaining buffer of native vegetation with minimal need for regular weed control was estimated to be at least 32-64 ft (Parkyn et al. 2000). 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). Invasions by non-native species often occur disproportionately near roads (Pilchard & Layback 2006). Data collected from 103 Island County wetlands in 2005 revealed 89% had experienced invasion by at least one non-native species, but non-natives dominated the cover in only 21% (Adamus et al. 2005b).

With regard to the fourth-listed buffer function (d., **maintaining wetland microclimate conditions**), the objective of this function is to maintain natural patterns of temperature, humidity, wind, and soil moisture within wetlands, especially forested wetlands, because these are important to ensuring the persistence of wildlife (especially amphibians) and native plants. As summarized by Rise et al. (2004) and Moore et al. (2005), the influence of adjoining fields or clear-cuts on these parameters can extend up to 164 ft into a forest. Data from riparian areas in western Washington suggest a wooded buffer of about 150 ft is needed to approximate the natural microclimate gradients around streams (Brosofske et al. 1997). However, wooded buffers are likely to be less effective in maintaining or reducing water temperature in wetlands with large wide open areas -- such as waters of estuarine wetlands, lakes, and large ponds. Moreover, salmonid fish which require cool water temperatures are not known to use Island County non-estuarine wetlands extensively, due to lack of access and suitable spawning or rearing habitat. In the southeastern United States, buffers as wide as 538 ft were recommended by Semlitsch (1998) for protecting the microclimate important to salamanders *around* (not just within) wetlands.

For forested wetlands, another consideration related to microclimate is the potential for long-term reduction in wooded buffer effectiveness as a result of tree blowdown. Based on a review of several studies, a wooded buffer of at least 75 ft width was recommended by Pollock and Kennard (1998), to minimize windthrow losses of trees. In California, researchers found that 100-ft buffers were inadequate to protect trees from windthrow (Reid and Hilton 2001). Tree fall rates were abnormally high for a distance of at least 656 ft from clearcut edges. The blowdown and uprooting of trees in wetlands is a natural phenomena with probable benefits for several wetland functions and species (e.g., coho). Excessive rates may change some of a wetland's habitat functions.

With regard to the fifth-listed buffer function (e., **providing habitat for wetland-dependent species that seem to require both wetlands and uplands**), the following Island County species which have an *obligate* relationship to wetlands appear to fit this category: Northern Red-legged Frog, Northwestern Salamander, Rough-skinned Newt, and possibly Western Toad. Literature on this topic will be summarized in a future BAS document addressing parts of the Island County CAO dealing with Fish and Wildlife Conservation Areas.

In addition, the following Island County species which seem to have a *primary* relationship to wetlands appear to also require wooded uplands as complementary habitat, or for the ability of wooded uplands to help maintain normal wetland temperatures: three listed anadromous fish (Puget Sound Chinook, Hood Canal Summer Run Chum, Puget Sound Bull Trout), Great Blue Heron, Bald Eagle, Osprey, Western Screech-Owl, Pacific-slope Flycatcher, Winter Wren, and Black-throated Gray Warbler. Where the last four species occur in wetlands, it is almost entirely in forested wetlands. Except for the owl, all the bird species are common in Island County both within and outside of wetlands. Buffer width research was identified only for Pacific-slope Flycatcher, Winter Wren, and Black-throated Gray Warbler. One study (Shirley & Smith 2005) found Pacific-slope Flycatcher was absent from streamside buffers narrower than 145 ft. In the forested landscape of the Cedar River watershed east of Seattle, Black-throated Gray Warbler appeared to need riparian buffer widths of almost 150 ft to approach the numbers found in unlogged areas (Pearson & Manuwal 2001). Winter Wren in the Oregon Coast Range seldom occurred in stream buffers narrower than about 60 ft (Hagar 1999). In the Seattle metro area, that wren occurred mostly in areas with <20% surrounding urban cover and forest patch size of more than 3 acres (Donnelly 2002). No published data relevant to buffer requirements were found for the other species (but for Bald Eagle and Osprey, see previous paragraph on limiting disturbance). Although several studies have shown that wooded buffers of at least 200 ft may be needed to support forest bird communities *generally*, application of these studies to Island County's specifications for wetland buffers may be inappropriate because (a) all such studies included many species that are not wetland-dependent, and (b) nearly all such studies were conducted in the eastern United States, whereas at least one study of non-urban forests in the Pacific Northwest showed that most species of birds that occur here may be less susceptible to adverse effects of forest fragmentation (Schieck et al. 1995).

Another suite of wetland-dependent species have not been proven to require wooded surroundings, but may benefit from them in some cases. Among the *obligates*, this includes Western Toad (a WDFW Candidate Species of Concern), Long-toed Salamander, Wood Duck, Hooded Merganser, American Beaver, and an unknown number of obligate plants. 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). This species and the Long-toed Salamander occur widely in open rangelands so perhaps do not always require a contiguous forest canopy. 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) and this clearly does not mean these species *require* contiguous wooded buffers of that width. Both species regularly use artificial nest boxes, often placed in the open close to human habitation. In a literature review on American Beaver, Allen (1982) states that "Jenkins (1980) reported that most of the trees utilized by beaver in his Massachusetts study area were within 98.4 ft of the water's edge. However, some foraging did extend up to 328 ft. Foraging distances of up to 656 ft from water have been reported in Michigan (Brandt 1938)" This does not mean beaver *require* wooded buffers of that width. Foraging distances away from water vary greatly depending on the tree species and sizes available, as well as the length of shoreline containing suitable trees.

Island County species with a *primary* association with wetlands may include Willow Flycatcher, Olive-sided Flycatcher, Swainson's Thrush, Warbling Vireo, Yellow Warbler, Wilson's Warbler, and many plants. Although most of these bird species require trees or shrubs for nesting, those may be either in the wetland or in the wetland's buffer.

A final suite of wetland-dependent species quite clearly do not regularly inhabit wooded buffers. In Table 10, they are the ones in Group 4 (obligates) and Group 5 (primaries).

3.4.4 Summary: Buffer Widths for Protecting Habitat and Wetland Species

Buffer effectiveness in protecting wetlands is highly dependent on adjacent land use activities, the amount and configuration of development that is present, structure and type of vegetation within the buffer, and the particular species that use the wetland regularly.

Buffers of natural vegetation need not be *wooded* to benefit many wetland-dependent wildlife species, and wooded buffers may actually discourage wetland use by some. Thus, a requirement that all buffers be wooded implicitly trades off one suite of species for another. For wildlife, wide wooded buffers seem to be most beneficial around permanently or semipermanently-flooded forested and scrub-shrub wetlands, because those tend to support the types of species that benefit the most from wooded buffers. Taken as a whole, the buffer literature pertaining to wildlife has at least two major flaws:

1. Many studies recommend wetland buffer widths based on the number of species (animal diversity) found in buffers of increasing width, without differentiating between "wetland-dependent species only" and the "total of all species" including terrestrial species. Without such differentiation, the conclusion is foregone that wider buffers will have more species, because they encompass a larger area and the number of wildlife species is widely known to increase with increasing area. However, there are few or no studies that convincingly demonstrate that the number of ***wetland-dependent species*** is greater in wetlands that are surrounded by wider wooded buffers, and wetland-dependent species are the appropriate focus for CAO's that are 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 Island County wetlands. Many were conducted where buffers and surrounding lands were severely fragmented by urbanization and clearcutting, rather than by low-intensity agriculture as is mostly the case in Island County.

3.5 Land Use Intensity and Buffer Width

3.5.1 Zoning Designations and Land Uses

Not all land uses have the same impact on wetlands. 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, 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. Guidance from the WDOE (Granger et al. 2005, Appendix 8C-3) categorizes various land use changes according to their expected level of impact on wetlands, but does not provide documentation specifically supporting the assignment of the various land uses or zoning designations to the intensity categories. The WDOE suggests that local jurisdictions might consider using the impact intensity ratings to help define appropriate buffer widths, by associating the impact intensity ratings to local zoning designations, thus tailoring these to specific local circumstances. The 3-category rating system the County has used since 1984 to determine which wetlands deserve more protection includes zoning designations~~., but those designations are used mainly to simplify regulation, rather than as indicators of wetland function, value, or sensitivity.~~

3.5.2 Recent Technical Literature on Land Use Impacts to Wetlands

Emphasis has been placed on literature published subsequent to the WDOE BAS document, or not included in that document.

Impacts of Agriculture: Pastures, Grazing, and Haying

- In Alberta summer storm runoff rates were higher in lightly grazed (<1 animal unit per month per acre) than ungrazed pasture (Chanasyk et al. 2003).
- Data from wet meadows in the Sierras suggests that no more than 45% of the annual herbage production can be grazed without adversely affecting meadow productivity (Ratliff 1985).
- Generic estimates of pollutants from pastures are 4.5 lbs/ac/yr of nitrate and 0.76 lbs/ac/yr of phosphorus. On a per-animal basis, horses (the most common pastured animal in Island County) are estimated generically to contribute 99 lbs/yr of nitrate and 17 lbs/yr of phosphorus (Ruddy et al. 2006). One horse generates annually the same amount of nitrate and phosphorus as 13 people or 4 households (Burdett & Sullivan 2005).
- Several studies have found grazing to stimulate the denitrification function of wetlands (LeRoux et al. 2003). Numbers of denitrifying bacteria were found to be higher in heavily grazed than lightly grazed pasture. By stirring the soil with their hooves, cows temporarily (for 3 weeks) stimulated the denitrification function in pasture soils (Menneer et al. 2005)
- In one study, grazing at a density of 1 animal unit per 5 acres was associated with increased species richness of native plants and native perennial grasses (Hickman et al. 2004).
- Another study found plant species richness declined with grazing at sites that were already nutrient poor, whereas at sites that were nutrient rich, grazing appeared to have no effect or a positive effect on plant diversity (Proulx & Mazumder 1998).
- Phosphorus in runoff was not increased by summer grazing of pastures, but did increase where animals were grazed year-round due to winter damage to the soil surface (trampling from hooves that compacted soils and damaged vegetation, and thus increased runoff and nutrient export) (Chichester et al. 1979).
- Repeated haying of riparian and wetland areas can assist the nutrient removal functions of these areas (Bedard-Haughn et al. 2004), although disrupting nesting of some birds if done before mid-July.

Impacts of Agriculture: Cropland

- In Skagit County (Monohan 2004), streams adjoined by *row crops* were found to have significantly higher concentrations of total nitrogen, ammonium, organic nitrogen, and total phosphorus than *pasture* streams, even greater than the pasture streams that lacked buffers. High total nitrogen concentration in row-crop streams was driven by ammonium, which was over 5 times greater in row-crop streams, and organic nitrogen, which was twice as much in row-crop streams than pasture streams. There was no significant difference in nitrate concentrations between row-crop streams without buffers and pasture streams without buffers.
- Native amphibians in ponds surrounded by row crops may have reproductive success rates that are similar to those in ponds surrounded by natural wetlands, and to those surrounded by ungrazed pasture, provided that livestock are kept from actually entering the water (Knutson et al. 2004).
- Small mammal use in Wisconsin was found not to differ significantly between areas with managed intensive rotational grazing, as contrasted with continuous grazing. Buffers with natural vegetation were used more than both (Chapman & Ribic 2002).

- In Maryland, agricultural streams with extensive buffers and other BMP's had greater diversity of aquatic invertebrates (fish foods) than urban streams (Moore & Palmer 2005)

Impacts of Urban/ Residential Land Cover

(NOTE: None of these studies involved *low density* rural development**)**

- In Seattle area streams, degraded physical condition of streams was best explained statistically by quantity of intense urban and grassy urban land in the contributing area, and percent grassy urban land within 1650 ft of the stream. Proximity of a road crossing also negatively influenced stream physical condition. Conditions improved where a stream flowed through an intact riparian buffer with forest or wetland vegetation and without road crossings (McBride & Booth 2005).
- In the Seattle metro area, native forest bird species tended to disappear when forest patch size fell below 104 acres. Species commonly associated with development tended to disappear when urban land cover fell below 60% of the landscape. Buffers that are contiguous to upland and wetland forests such that a threshold of about 104 acres is achieved will be most effective in maintaining native forest birds. Patch size was found to be more important to birds in urban and suburban landscapes than in rural landscapes. Bird community composition was more frequently related to urban land cover and attributes of the canopy and ground vegetation than urban patch size and lack of forest isolation. Species that are area-sensitive generally disappeared above 52% urban land cover and below a tree density of 4 per acre. (Percentages are for landscapes of 4-40 square miles) (Donnelly 2004).
- In Rhode Island, plant zonation in tidal marshes was correlated negatively with surrounding residential land use. Nitrogen concentration in marsh plant leaves correlated positively with surrounding residential land use Some non-native plants are more able than native plants to exploit nutrient increases and this may be a factor in their spread (Wigand et al. 2003).
- In Portland, the winter wren and Pacific-slope flycatcher were correlated positively with patch width of riparian forest (Hennings & Edge 2003).
- Nests in "rural" shrublands may be less prone to cowbird parasitism than those in urban shrublands (Burhans & Thompson 2006).
- In Maryland, urban streams were found to have a high diversity of invertebrates when a riparian forest canopy had been preserved, even when impervious surfaces were extensive in their watersheds (Moore & Palmer 2005).
- In an urbanizing area of North Carolina, mammalian nest predators were significantly more abundant in greenways within narrower forested corridors. Mammalian nest predator abundance was lowest in greenways with forested corridors wider than 656 ft, and continued to decline as forest corridor width increased. There was no relationship between categorical measures of land-use context (low-density residential, high-density residential, office/institutional) and mammalian nest predator abundance (Novotny 2003).
- In coastal North Carolina, bacteria counts near new developments -- despite shoreline buffers and new septic systems -- were almost as much as near old developments. Bacteria counts increased with increasing water level (caused by wind tides) and during heavy rain, but not on weekends with greater recreational boating use (Kirby-Smith & White 2006).

Impacts of Forests and Timber Harvesting

- Timber harvesting has been shown to increase, decrease, or have no effect on the concentrations of nearly every chemical studied (Feller 2006). For example, 14 studies of nitrate in streams following clearcutting have found results ranging from a mean annual decline of 0.04 mg/L to an increase of 3.7 mg/L (Brown & Binkley 1994).
- Timber harvesting can cause undesirable sedimentation of adjoining surface waters, but the impact severity depends on type of harvest and implementation of BMPs. Construction on a forest road increased fine sediments more than 4000 times higher than pre-construction. The impacts of a diameter-limit cut that removed 85% of the canopy were mainly due to heavy ground disturbance and channeled flow paths from skidders. No measurable increases in sediment deposition in streams were noted in association with shelterwood cuts. Selective harvesting (up to 50% canopy removal) of hardwood forests did not increase sediment inputs to streams (Kreutzweiser & Capell 2001).
- A comparison of 80 watersheds with varying amounts of forested and agricultural land showed that nutrient concentrations in streams could be predicted by the percent of land cover in forest or agriculture. However, there was no statistically significant relationship with the proximity of the forest to the stream (Omernick et al. 1981). Their study suggested that as the amount of forest cover decreased from more than 75 percent to less than 25 percent of the watershed, there was a corresponding increase in nitrogen and phosphorus concentrations in streams, regardless of whether the forest was located adjacent to or away from the stream itself.
- Stream invertebrate communities in Florida appeared to be unaffected 1-2 years after timber harvesting using BMPs (Vowell & Frydenborg 2004).

- In most cases timber harvest initially makes more water available to downslope wetlands, prolonging their seasonal flooding or saturation. However, as new forest regenerates, water demand from shrubs can reduce water otherwise available to wetlands, until a forest reaches maturity (Feller 2006).
- In Oregon's mostly agricultural Willamette Valley, the presence of only 1 of 5 amphibians in 85 wetlands was found to correlate positively with surrounding forest cover measured within 3281 ft, that being rough-skinned newt. Species uncorrelated or correlated to a lesser degree with forest cover were northern red-legged frog, Pacific chorus frog, long-toed salamander, and northwestern salamander (Pearl et al. 2005).
- Following timber harvest in southwestern Washington, a wooded buffer of 200 ft appeared to protect small forest floor mammals within a wetland, but may have been inadequate to protect pond-breeding amphibians (northwestern salamander, rough-skinned newt, red-legged frog) (MacCracken 2005).
- Small mammal abundance in a 100-ft wooded buffer was compared with that in a clearcut and an unlogged forest. No dramatic differences were noted (Cockle & Richardson 2003).
- In timber harvest areas of western Oregon, wetland-associated species that increased with increasing riparian buffer width were winter wren and Pacific-slope flycatcher. Riparian buffers along headwater streams provided the most benefit to forest birds generally (not just wetland-associated ones found in Island County) when they were at least 131 ft wide. (Hagar 1999).
- In Portland, the winter wren and Pacific-slope flycatcher were correlated positively with patch width of riparian forest (Hennings & Edge 2003).
- In a logged landscape near Seattle, riparian 50-ft buffers did not maintain the pre-logging assemblage of bird species, whereas most species were maintained by 100-ft buffers on both sides of a stream. Black-throated gray warbler, which has a primary associations with forested wetlands and riparian areas, needed buffer widths of almost 150 ft to maintain numbers found in unlogged areas (Pearson & Manuwal 2001).
- In Norway, bird species richness increased in buffers (forest strips) up to 98 ft wide, but remained constant as buffer width increased up to 328 ft, suggesting buffers that wide were not critical. (Hågvar et al. 2004).
- In Alberta, forested buffer strips of 66, 328, 656, and 2625 ft were created around lakes. The narrowest of the studied buffers in which yellow warbler and song sparrow were found was 66 ft. The authors note, "Our results suggest that the creation of buffer strips is not an appropriate strategy for conserving habitat required to retain intact old-forest vertebrate communities." (Hannon et al. 2002).
- In southeastern British Columbia, a study compared buffers of 46, 121, and 230 ft. Increased buffer width was associated with greater density of riparian birds and total birds. Species most associated with riparian habitat were Hammond's flycatcher, golden-crowned kinglet, Townsend's warbler, varied thrush, and winter wren. All except the flycatcher were more common in wider buffers (Kinley & Newhouse 1997).
- In old growth riparian areas of coastal British Columbia, deciduous tree density was higher, and shrub richness was lower in wide buffers compared with narrow buffers. Birds were surveyed in replicate streamside wooded buffers of varying widths (33, 82, 145, and 472 ft) as well as in uncut forest. Abundances of three bird habitat guilds: riparian specialists, forest-interior, and open-edge species, and 6 of 10 species were explained better by specific vegetation features than by buffer width (Shirley 2004). Even narrow buffers provide foraging sites or travel corridors for many birds (Shirley 2006). Pacific-slope flycatcher was absent from buffers narrower than 83-145 ft (Shirley & Smith 2005).
- In southeastern Ontario, water quality in 71 wetlands was compared with percent of forest vs. agriculture measured at various distances around each wetland, ranging from 330 ft to 3.1 miles away. The positive effect of forest cover in reducing water-column nitrate and phosphorus was strongest when measured within 1.4 miles, whereas that critical distance for sediment phosphorus was 2.5 miles (Houlahan & Findlay 2003).
- In Ontario, the number of plant species found in a wetland increased mostly as wetland size increased, but also with increasing amount of surrounding forest cover. The effect of surrounding forest cover was most pronounced on plant diversity within forested wetlands (i.e., increased number of forest obligate species), although an increase also occurred in total plant species, native species, and perennial species. The statistical relationship between plant species richness and forest cover was strongest where forest cover was measured at a distance of about 820 ft from a wetland, less so at 394 ft.

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Appendix A. Primary Information Sources Pertinent to Wetland Wildlife Buffers and Not Cited in the WDOE's BAS Report

Many of these were not cited in the WDOE's BAS report because their publication occurred subsequently. See References section for full citations of the papers below.

Bartelt, P. E., C.R. Peterson, and R.W. Klaver.	2004	Sexual differences in the post-breeding movements and habitats selected by western toads (*Bufo boreas*) in southeastern Idaho.

Location: southeastern Idaho (forested landscape)
Findings: Although requiring ponds for breeding, toads spent almost 60% of their time in terrestrial areas farther than 33 ft from the pond. On a daily basis individuals traveled 127 ft, and seasonally they typically moved at least 0.36 (females) to 0.69 miles (males) from their pond, generally favoring shrublands and open forest.
Implications & Limitations: Wetland buffers alone will not be adequate to preserve this species in Island County, but they will help. The authors state that the buffers must be at least 500 ft wide to sustain this species, but the data they provide are insufficient to support this.

Belisle, M. and A. Desrochers.	2002	Gap-crossing decisions by forest birds: an empirical basis for parameterizing spatially-explicit, individual-based models

Location: Quebec
Findings: The forest bird species that were studied rarely ventured more than 82 ft from forest edges despite having the opportunity to do so. birds preferred to travel under forest cover rather than cross open areas, even when the forested detour conveyed a substantially longer route than the short cut in the open.
Implications & Limitations: Species were mostly different from those in Island County.

Bentrup, G. and T. Kellerman.	2004	Where should buffers go? Modeling riparian habitat connectivity in northeast Kansas

Location: Kansas
Findings: GIS was used to identify areas that would benefit the most from increased habitat connectivity.

Burhans, D.E., Thompson, F.R. III.	2006	Songbird abundance and parasitism differ between urban and rural shrublands.

Location: Missouri
Findings: Nests in "rural" shrublands were less prone to cowbird parasitism than those in urban shrublands.
Implications & Limitations: Applicability to Island County is probably low due to different species and shrub assemblages.

Chapman E.W. and C.A. Ribic.	2002	The impact of buffer strips and stream-side grazing on small mammals in southwestern Wisconsin.

Location: Wisconsin
Findings: Small mammal use did not differ significantly between areas with managed intensive rotational grazing, as contrasted with continuous grazing. Buffers with natural vegetation were used more than both.
Implications & Limitations: Species and grazing intensities differ from those typical of Island County, so extrapolation is probably not appropriate.

Cockle, K.L. and J.S. Richardson.	2003	Do riparian buffer strips mitigate the impacts of clearcutting on small mammals?

Location: British Columbia. Forested landscape.
Findings: Small mammal abundance in a 100-ft wooded buffer was compared with that in a clearcut and an unlogged forest. No dramatic differences were noted. Only the shrew-mole and montane shrew were less numerous in the 100-ft buffer, and then only slightly so. At increasing distances from streams, creeping voles increased and deer mice (during 1 of 2 years) decreased. Riparian reserves helped reduce short-term effects of clearcutting on small mammal communities.
Implications & Limitations: All 6 studied species are ones that occur in Island County. None have a primary association with wetlands.

Creegan, H.P. and P.E Osborne.	2005	Gap-crossing decisions of woodland songbirds in Scotland: an experimental approach.

Location: Scotland

<u>Findings</u>: Some species would not cross gaps in the forest canopy that were wider than 150 ft.
<u>Implications & Limitations</u>: Care should be taken in the design of corridors and buffers to avoid breaks wider than about 150 ft. Conclusions are limited by the geographic differences in the bird species.

DeLuca, W. V., C. E. Studds, and P. P. Marra.	2004	The influence of land use on the integrity of marsh bird communities of the Chesapeake Bay.

<u>Location</u>: Virginia-Maryland (Chesapeake Bay)
<u>Findings</u>: Land cover alterations, occupying as little as 6% of the landscape at distances at least as far as 3000 ft from a tidal wetland, were found to influence the species composition of the wetland's bird community. Birds were impacted when urban development occupied 14% of the area within 1640 ft of a wetland and/or 25% of the area within 3281 ft.
<u>Implications & Limitations</u>: None of the studied species occur in Island County, and tidal marsh plant communities also differ, so extrapolation may not be appropriate. Nonetheless this is perhaps the only study that has examined (indirectly) the benefits of shoreline buffers on wildlife.

Donnelly, R.E.	2004	Design of habitat reserves and settlements for bird conservation in the Seattle metropolitan area

<u>Location</u>: Washington (Seattle metro area)
<u>Findings</u>: Native forest bird species tended to disappear when forest patch size fell below 104 acres. Species commonly associated with development tended to disappear when urban land cover fell below 60% of the landscape. Patch size was more important to birds in urban and suburban landscapes than in rural landscapes. Bird community composition was more frequently related to urban land cover and attributes of the canopy and ground vegetation than urban patch size and lack of forest isolation. Species that are area-sensitive generally disappeared above 52% urban land cover and below a tree density of 4 per acre. (Percentages are for landscapes of 4-40 square miles).
<u>Implications & Limitations</u>: Buffers that are contiguous to upland and wetland forests such that a threshold of about 104 acres is achieved will be most effective in maintaining native forest birds.

Hagar, J.C.	1999	Influence of riparian buffer width on bird assemblages in western Oregon.

<u>Location</u>: Oregon (forested landscapes of the central Coast Range).
<u>Findings</u>: In timber harvest areas, the Island County species that increased with increasing riparian buffer width were winter wren*, Pacific-slope flycatcher*, brown creeper, and chestnut-backed chickadee (* indicates wetland-associated species): Even the widest buffers (131-230 ft on one side) failed to support Hammond's flycatcher, varied thrush, and golden-crowned kinglet.
<u>Implications & Limitations</u>: The author concluded that riparian buffers along headwater streams provided the most benefit to forest birds if they are at least 131 ft wide. Bird counts were done during only a single year. Twelve sites containing buffers of 0 to 246 ft width were studied.

Hågvar, S., P. Nygaard, and B.T. Baekken.	2004	Retention of forest strips for bird-life adjacent to water and bogs in Norway: effect of different widths and habitat variables.

<u>Location</u>: southeastern Norway
<u>Findings</u>: Bird species richness increased in buffers (forest strips) up to 98 ft wide, but remained constant in buffers up to 328 ft width.
<u>Implications & Limitations</u>: The studied species do not occur in Island County.

Hannon, S.J. and F.K.A. Schmiegelow.	2002	Corridors may not improve the conservation value of small reserves for most boreal birds

<u>Location</u>: Alberta (forested landscape)
<u>Findings</u>: Wooded corridors 328 ft wide that were used to connect buffer strips and reserves did not appear to benefit any bird species, except perhaps western tanager (not a wetland-dependent species) and some resident species not associated with wetlands.
<u>Implications & Limitations</u>: Most of the studied species do not occur regularly in Island County.

Hannon, S.J., C.A. Paszkowski, S. Boutin, J. DeGroot, S.E. Macdonald,M. Wheatley, and B.R. Eaton.	2002	Abundance and species composition of amphibians, small mammals, and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta.

<u>Location</u>: Alberta. Forested landscape.

Findings: Buffer strips of 66, 328, 656, and 2625 ft were created around lakes. For species that also breed in Island County, the narrowest of the studied buffers in which species bred were as follows (* indicates wetland-associated species): 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. Data on western toad and small mammals were too variable to draw conclusions. The authors note, "Our results suggest that the creation of buffer strips is not an appropriate strategy for conserving habitat required to retain intact old-forest vertebrate communities."
Implications & Limitations: The results for Swainson's thrush seem inconsistent with those of Shirley & Smith (2005), who found that species more commonly in buffers than uncut forest. The results for common yellowthroat are counterintuitive because it breeds in herbaceous wetlands, not forested areas. Buffers in the range of 328-656 ft were not surveyed so precise width recommendations cannot be made from this paper.

Hennings, L.A. and W.D. Edge	2003	Riparian bird community structure in Portland, Oregon: Habitat, urbanization, and spatial scale patterns

Location: Oregon (Portland urban landscape).
Findings: Among species found in common with Island County, the winter wren, brown creeper, and Pacific-slope flycatcher were correlated positively with patch width of riparian forest.
Implications & Limitations: Retaining buffers for these species may be especially important.

Herrmann, H.L., K.J. Babbitt, M.J. Baber, and R.G. Congalton.	2005	Effects of landscape characteristics on amphibian distribution in a forest-dominated landscape

Location: New Hampshire
Findings: In the northeast US, wetlands with <40% forest cover within a 1000 m radius have fewer larval amphibians (e.g., tadpoles), and forest cover above 60% within a 1000 m radius is likely to ensure species-rich and abundant amphibians within the wetlands.
Implications & Limitations: Somewhat limited because none of the species occur in Island County.

Homan, R.N., B.S. Windmiller, and J.M. Reed.	2004	Critical thresholds associated with habitat loss for two vernal pool-breeding amphibians.

Location: Massachusetts
Findings: Presence of spotted salamanders in wetlands was influenced the most by forest cover within 100 m and 300 m of the wetlands. Within 100 m, a threshold of at least 30% forest canopy was noted.
Implications: Although this species does not occur in Island County, the results might be applicable to species that do (e.g., rough-skinned newt). If so, that suggests that buffers contain at least 30% canopy cover.

Houlahan, J.E. and C.S. Findlay.	2003	The effects of adjacent land use on wetland amphibian species richness and community composition.

Location: Ontario
Findings: Species richness of amphibians in wetlands was positively correlated with wetland area, surrounding forest cover, and the amount of wetlands on adjacent lands. It was negatively correlated with road density and nitrogen levels. The effects of adjacent land use were strongest at around 656 ft. Amphibian abundance was positively correlated with forest cover, distance to wetlands >50 acres, and amount of marsh habitat and negatively correlated with road density. Land-use and water quality effects varied widely across species.
Implications & Limitations: Somewhat limited because none of the species occur in Island County.

Houlahan, J.E., P.A. Keddy, K. Makkay, and C.S. Findlay.	2006	The effects of adjacent land use on wetland plant species richness and community composition.

Location: Ontario.
Findings: The number of plant species found in a wetland increased mostly as wetland size increased, but also with increasing amount of surrounding forest cover. The effect of surrounding forest cover was most pronounced on plant diversity within forested wetlands (i.e., increased number of forest obligate species), although an increase also occurred in total plant species, native species, and perennial species. The statistical relationship between species richness and forest cover was strongest at a distance of about 820 ft from a wetland, less so than at 394 ft. Increasing nutrients measured in the wetlands were correlated with reduced number of plant species.
Implications & Limitations: Somewhat limited because few of the species occur in Island County, and because the conclusions were based on statistical analysis of a relatively small number of sites with many confounding variables, with

no actual replication of different buffer widths. This is one of only a very few studies of the effects of surrounding landscapes on wetland plant communities.

Kinley, T.A. and N.J. Newhouse	1997	Relationship of riparian reserve zone width to bird density and diversity in southeastern British Columbia.

<u>Location</u>: southeastern British Columbia
<u>Findings</u>: Compared buffers of 46, 121, and 230 ft. Increased buffer width was associated with greater density of riparian birds and total birds. Species most associated with riparian habitat were Hammond's flycatcher, golden-crowned kinglet, Townsend's warbler, varied thrush, and winter wren. All except the flycatcher were more common in wider buffers.
<u>Implications & Limitations</u>: Did not consider the reproductive success of these species.

Knutson, M.G., W.B. Richardson, D.M. Reineke, B.R Gray, J.R. Parmelee, S.E. Weick.	2004	Agricultural ponds support amphibian populations.

<u>Location</u>: Minnesota
<u>Findings</u>: The variety of amphibians (and the reproductive success of 2 amphibians similar to those occurring in Island County) was the same in ponds surrounded by row crops as in natural ponds and ponds surrounded by ungrazed pasture. Amphibian reproductive success was lower in ponds used to water livestock (this study may be the first documented case of this). Diversity was highest in small ponds with low nitrogen concentrations. American toad (assumed analogous to our western toad) was less likely to be found in shallow turbid ponds, and was actually more likely to succeed reproductively when there were fewer wetlands within 1640 ft of the pond. Chorus frog (related to our Pacific chorus frog) was more likely to be found in shallow ponds with low conductivity, especially with extensive tree and shrub cover along the shoreline and grassland in the farther surrounding area. Nitrogen concentrations as low as 0.1 to 14 mg/L (well below standards for drinking water) had negative effects.
<u>Implications & Limitations</u>: The findings about negative effects of nitrogen and livestock use of ponds (and by inference, wetlands) are especially pertinent to Island County, although the species differ.

MacCracken, J.G.	2005	Effects of uneven-aged timber harvest on forest floor vertebrates in the Cascade Mountains of southern Washington.

<u>Location</u>: southern Washington Cascades (forested landscape).
<u>Findings</u>: Following timber harvest, a wooded buffer of 200 ft appeared to protect small forest floor mammals within a wetland, but was inadequate for pond-breeding amphibians (northwestern salamander, rough-skinned newt, red-legged frog).
<u>Implications & Limitations</u>: This study did not compare alternative buffer sizes.

Machtans, C.S., M.A. Villard, and S.J. Hannon	1996	Use of riparian buffer strips as movement corridors by forest birds

<u>Location</u>: Alberta
<u>Findings</u>: Forest birds use 328-ft wide buffers along lakes as corridors for movement, as much or more as they use uncut forest. Especially important for dispersal of juvenile birds.
<u>Implications & Limitations</u>: Buffers should be connected by corridors whenever possible.

Moore, A.A. and M.A. Palmer.	2005	Invertebrate biodiversity in agricultural and urban headwater streams: Implications for conservation and management

<u>Location</u>: Maryland
<u>Findings</u>: Agricultural streams with extensive buffers and other BMP's had greater diversity of aquatic invertebrates (fish foods) than urban streams. Even when impervious surfaces were extensive in their watersheds, urban streams also had high diversity of invertebrates when a riparian forest canopy had been preserved.
<u>Implications & Limitations</u>: Results probably depend on buffer widths, which were not specified.

Muths, E.	2003	Home range and movements of boreal toads in undisturbed habitat

<u>Location</u>: Colorado
<u>Findings</u>: Toads were found in uplands at mean distances of 715 ft (males) and 2366 ft (females) from breeding ponds.
<u>Implications & Limitations</u>: Boreal toad is closely related to western toad, a wetland-associated priority species in Island County, so results are moderately applicable. They imply the need for very wide buffers and/or provision of sufficient natural vegetation in other contiguous surrounding areas.

Novotny, K.E.	2003	Mammalian nest predators respond to greenway width, habitat structure, and landscape context.

Location: North Carolina suburban landscape
Findings: “Mammalian nest predators were significantly more abundant in greenways within narrower forested corridors. Mammalian nest predator abundance was lowest in greenways with forested corridors wider than 200 m, and continued to decline as forest corridor width increased. There was no relationship between categorical measures of land-use context (low-density residential, high-density residential, office/institutional) and mammalian nest predator abundance. Specific landscape features adjacent to the greenway, however, did affect mammalian nest predator abundance. Greenways adjacent to landscapes with fewer buildings had a higher abundance of total mammalian nest predators. Segments with wider trails had a higher abundance of mammalian nest predators.”

Parker, T.H., B.M. Stansberry, C.D. Becker, and P.S. Gipson.	2005	Edge and area effects on the occurrence of migrant forest songbirds.

Location: mostly eastern U.S. (analysis of existing studies only).
Findings: The analysis of 33 published studies determined that in many instances, poor study design did not allow drawing of valid conclusions about the relationship of migrant bird species presence to forest patch size. The limitation is due to confounding edge effects.
Implications & Limitations: None of the species analyzed occur regularly in Island County, so minimally relevant.

Pearl, C.A., M.J. Adams, N. Leuthold, and R.B. Bury.	2005	Amphibian occurrence and aquatic invaders in a changing landscape: implications for wetland mitigation in the Willamette Valley, Oregon

Location: Oregon (Willamette Valley)
Findings: Presence of only 1 of 5 amphibians in 85 wetlands was found to correlate positively with surrounding forest cover measured within 3281 ft, that being rough-skinned newt. Species uncorrelated or correlated to a lesser degree with forest cover were northern red-legged frog, Pacific chorus frog, long-toed salamander, and northwestern salamander. Thus, structural characteristics of individual wetlands were more important than landscape characteristics in predicting presence of most breeding amphibian species.
Implications & Limitations: All species occur in Island County so results should be applicable.

Pearson, S.F., and D.A. Manuwal.	2001	Breeding bird response to riparian buffer width in managed Pacific Northwest Douglas fir forests.

Location: Western Washington (Cedar River watershed east of Seattle, forested landscape)
Findings: In a logged landscape, riparian 50-ft buffers did not maintain the pre-logging assemblage of bird species, whereas most species were maintained by 100-ft buffers on both sides of a stream. Black-throated gray warbler, which we have categorized as having a primary associations with wetlands, needed buffer widths of almost 150 ft to maintain numbers found in unlogged areas. Other species that were less numerous in buffers than in uncut forest were brown creeper and golden-crowned kinglet (neither is associated primarily with wetlands), and possibly Wilson’s warbler (strongly associated with wooded wetlands).
Implications & Limitations: A highly relevant study, but results are applicable mainly to forested wetlands and riparian areas. See also related report by O’Connell et al. (2000).

Rail, J-F., M. Darveau, A. Desrochers, and J. Huot.	1997	Territorial responses of boreal forest birds to habitat gaps.

Location: Quebec
Findings: Several forest bird species appeared to avoid flying across canopy gaps wider than about 82 ft. (habitat specialist species) or 213 ft (habitat generalist species).
Implications & Limitations: Care should be taken in the design of corridors and buffers to avoid breaks wider than about 82 ft.

Richter, K.O., D.W. Kerr, and B.J. Blessing	in press	Buffer-only wetland protection for amphibians

Location: Washington (King County)
Findings: For 2 sensitive amphibians (red-legged frog and northwestern salamander), the authors determined the acreage of total accessible habitat, defined as undeveloped land or water within a radius of 3281 ft of a wetland and not separated from the wetland by major roads. Within this radius a subtotal was calculated just for patches at least 63 contiguous acres with a minimum width of 1864 ft throughout most of the patch. This was assumed adequate to include a typical dispersal distance from wetlands of 538 ft for most salamanders. Separately, the authors calculated the area of accessible undeveloped

patches of any size within a radius of 656 ft of each wetland. Among 15 wetlands, an average of 68% of the 656 ft circle, and 38% of the 3281 circle, was accessible to frogs. When the additional criteria for minimum patch size and width were applied, slightly less than half of the wetlands met them. Wetlands whose surface water in mid-August occupied less than 215 sq. ft were considered too small to allow complete larval development of these species. The authors identified "manicured lawns" as presenting a likely barrier to amphibian movements due to increased risk of desiccation or predation.
Implications & Limitations: The authors stated that a buffer width of 100 ft is insufficient to meet the needs of these species, which also occur in Island County wetlands, and suggested that case-by-case exceptions might be made where buffer width would be increased if sufficient accessible habitat remained around a particular wetland. The spatial analysis techniques described in this paper could be applied Countywide, in conjunction with evaluations of wetland flooding duration and other stressors, to evaluate wetland health.

Rittenhouse, T.A.G. and R.D. Semlitsch	2006	Grasslands as movement barriers for a forest-associated salamander: migration behavior of adult and juvenile salamanders at a distinct habitat edge.

Location: Missouri
Findings: Individuals of a wetland salamander species avoided moving through a lightly-grazed grassland, instead using an adjoining woodland.
Implications & Limitations: The species (spotted salamander) does not occur in Island County, so applicability of findings to Island County is uncertain, but deserves consideration.

Rodewald, P.G. and S.N. Matthews	2005	Landbird use of riparian and upland forest stopover habitats in an urban landscape

Location: Ohio
Findings: "During spring migration, of 27 transient species, 22 species differed in their use of riparian and upland forests, and 20 of those were most abundant in upland forest. Species richness was 58% and 75% higher in upland forests relative to riparian forests for Neotropical transient and temperate transient groups, respectively. Percent urbanization within 1 km was unrelated to abundance of Neotropical transients and temperate transients. Abundance of Neotropical transients and temperate transients was unrelated to percent forest cover within 1 km."
Implications & Limitations: Applicability of findings to Island County is uncertain due to species differences, but deserves consideration.

Rogers, C.M., M.J. Taitt, J.N.M. Smith, and G. Jongejan	1997	Nest predation and cowbird parasitism create a demographic sink in wetland-breeding song sparrows

Location: coastal British Columbia
Findings: Song sparrows (an Island County species with a primary association with wetlands) are declining in the region and a major reason may be cowbirds. Cowbirds are an "edge" species that is closely associated with agricultural areas, lawns, and fragmented forests. They parasitize nests of song sparrows and a few other species. In a wetland with cowbirds, song sparrows experienced a net loss over multiple years.
Implications: Wider buffers should help reduce pressures on song sparrow populations.

Rothermel, B.B.	2004	Movement behavior, migratory success, and demography of juvenile amphibians in a fragmented landscape.

Location: Missouri
Findings: Two amphibians (spotted salamander, American toad) require both wetlands and forest. When the forest was more than 150 ft from the wetland, only 15% of the individuals of these species moved successfully between the wetland and forest.
Implications: The findings suggest that for these or similar species the presence of wooded areas farther than about 150 ft from a wetland may not compensate for loss of a wooded buffer that adjoins a wetland. Although these 2 species do not occur in Island County, the results might be applicable to some species that do (e.g., rough-skinned newt, western toad).

Rubbo, M.J. and J.M. Kiesecker	2005	Amphibian breeding distribution in an urbanized landscape

Location: central Pennsylvania
Findings: The number of wetland amphibian species was found to decline with increasing urban land and decreasing forest cover.
Implications & Limitations: Substantiates what's been found previously here in the Pacific Northwest.

Shirley S.M.	2004	The influence of habitat diversity and structure on bird use of riparian buffer strips in coastal forests of British Columbia, Canada

Location: British Columbia (coastal old growth forest)
Findings: Deciduous tree density was higher, and shrub richness was lower in wide buffers compared with narrow buffers. Abundances of three bird habitat guilds: riparian specialists, forest-interior, and open-edge species, and 6 of 10 species were explained better by specific vegetation features than by buffer width.
Implications & Limitations: Some of the habitat benefits attributed to wider buffers might be due instead to differences in the structure and component vegetation types associated systematically with wider buffers, rather than to the buffer width. Species using those habitats might be served best by well-targeted enhancements of buffer quality rather than width.

Shirley, S.M.	2006	Movement of forest birds across river and clearcut edges of varying riparian buffer strip widths.

Location: coastal British Columbia. Forested landscape.
Findings: Even narrow buffers provide foraging sites or travel corridors for many birds. Riparian associates were Hammond's flycatcher, warbling vireo, Wilson's warbler, and yellow warbler.

Shirley, S.M. and J.N.M. Smith	2005	Bird community structure across riparian buffer strips of varying width in a coastal temperate forest

Location: coastal British Columbia. Forested landscape.
Findings: Birds were surveyed in replicate streamside wooded buffers of varying widths (33, 82, 145, and 472 ft) as well as in uncut forest Of the species that also occur regularly in Island County, the following were more abundant in the uncut forest than in the buffers generally: Pacific-slope flycatcher, brown creeper, pileated woodpecker, golden-crowned kinglet, varied thrush, and red-breasted sapsucker. (Note: only the first of these species has a primary association with wetlands). Several other species were more common in buffers than in uncut forest. This included two wetland-associated species: warbling vireo and Swainson's thrush.
Implications: Absence of the Pacific-slope flycatcher from buffers narrower than 83-145 ft suggests the advisability of maintaining wooded buffers at least as wide as those in this range, especially around the forested wetlands which this species typically inhabits.

Steen, D.A. and J.P. Gibbs	2004	Effects of Roads on the Structure of Freshwater Turtle Populations

Location: central New York
Findings: Road density of >1.5 km/km^2 was associated with detectable impacts to painted turtle populations.
Implications & Limitations: Applicable to Island County because that species also occurs here. Important when measuring effective buffer widths.

Trenham, P.C., H.B. Shaffer	2005	Amphibian upland habitat use and its consequences for population viability.

Location: California
Findings: A study of pond-breeding tiger salamanders found 85% of the subadults concentrated in an upland area located 656 to 1968 ft from the pond (uplands at distances of 33 to 2624 ft away were surveyed).
Implications & Limitations: This species does not occur in Island County, and the validity of extrapolation of results to other salamanders that do is arguable.

Willson, J.D. and M.E. Dorcas	2003	Effects of habitat disturbance on stream salamanders: implications for buffer zones and watershed management

Location: North Carolina
Findings: Stream-dwelling salamander abundance was related more to lack of disturbance in the watershed than to naturalness of conditions in the riparian buffers (35, 100, and 200 ft buffers).
Implications & Limitations: Species are different than ones in Island County.

Appendix B. Secondary Sources (Review Articles) Pertinent to Wetland Wildlife or Water Quality Buffer Requirements and Not Cited in the WDOE's BAS Report

Agouridis, C.T., S.R. Workman, R.C. Warner, and G.D. Jennings.	2005	Livestock grazing management impacts on stream water quality: a review.

Findings: "While numerous studies have documented the negative impacts of grazing on stream health, few actually examined the success of BMPs for mitigating these effects."

Cushman, S.A.	2006	Effects of habitat loss and fragmentation on amphibians: a review and prospectus.

Findings: No specific thresholds given, but cites many studies supporting the importance to amphibians of having complementary undisturbed upland habitats next to wetlands, as well as the requirement for good habitat connectivity.

Hayes, M.P., T. Quinn, K.O. Richter, J.P. Schuett-Hames, and J.T. Serra-Shean.	in press	Maintaining lentic-breeding amphibians in urbanizing landscapes: the case study of the northern red-legged frog (*Rana aurora*)

Findings: Recent studies show that adult frogs typically require at least 262 ft and often more than 984 ft of wooded habitat contiguous to wetlands for essential seasonal movements. They do not venture more than about 40 ft from vegetation or other cover. On an annual basis many frogs travel as much as 3 miles from their birth ponds through wooded areas. Red-legged frogs (an Island County species) travel farther, cross more roads, and are thus at greater risk than most species of wetland breeding amphibians in the Pacific Northwest.

Hickey, M.B.C. and B. Doran	2004	A review of the efficiency of buffer strips for the maintenance and enhancement of riparian ecosystems.

Findings: After reviewing all research on buffers and water quality, the authors concluded that data may be insufficient for specifying buffer widths because too few studies have been done of buffers narrower than 32 ft, resulting in a bias for larger buffers.

Hubbard, R.K., G.L. Newton, and G.M. Hill	2004	Water quality and the grazing animal

Findings: On a daily basis each horse contributes about 0.30 kg of nitrogen and 0.07 kg of phosphorus. Forage crops (especially perennial grasses) are associated with less field erosion than row crops. Manure helps build soil organic matter, resulting in increased soil water-holding capacity, soil invertebrate abundance, and soil structural stability, which in turn promote rapid nitrate removal (via denitrification) and increased soil stability. Fertilization of forage crops can compound the risk of groundwater pollution by nitrate.

Lee, P; C. Smyth, and S. Boutin.	2004	Quantitative review of riparian buffer width guidelines from Canada and the United States

Findings: Cites 13 studies, none from the Pacific Northwest, that together imply riparian and buffer widths of 164 to 574 ft might be needed to maintain forest dwelling wildlife following timber harvest operations.

Melcher, C.P. and S.K. Skagen	2005	Grass buffers for playas in agricultural landscapes: A literature synthesis

Findings: "Buffers 10-60 m wide are generally considered adequate for trapping most sediments." "Where focused runoff occurs (channels, abrupt changes in landscape contour), buffers may need to be as wide as 50-70m [164-230 ft]."

Polyakov, V., Fares, A., and M.H. Ryder	2005	Precision riparian buffers for the control of nonpoint source pollutant loading into surface water: A review

Findings: Buffers should be designed site-specifically rather than using a fixed width. Cites many studies that describe buffer percent removal rates for pollutants, but little information is given on widths.

Rittenhouse, T.A.G. and R. D. Semlitsch	2007	Distribution of amphibians in terrestrial habitat surrounding wetlands

Findings: Based on statistical analysis of 13 published radio telemetry studies, some frogs and salamanders use the areas directly adjoining a wetland to a lesser degree than areas farther away. Salamanders wandered less than frogs. Up to half the frog individuals occurred within 305 ft of wetlands, and 95% occurred within 2179 ft. Typical widths for water quality buffers do not address needs of all amphibians.

Implications & Limitations: Only 3 of the analyzed studies are for Island County species. The authors note the results depend to an unknown degree on the amount and degree of habitat modification (impact intensity) that has occurred within the wetland buffer, and the distribution of resources critical to the species within the buffer.

Semlitsch, R.D. and J.R. Bodie	2003	Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles

Findings: The authors recommend a minimum buffer width of 532 ft around wetlands for reptiles and amphibians generally. Some low-intensity uses in the outer 164 ft of the buffer might be compatible with wildlife protection.
Implications & Limitations: Mostly cites eastern U.S. studies. Only 2 of the 32 amphibians and 1 of the 33 reptile species used to support the findings are species that occur in Island County. Those species are Pacific chorus frog (buffer of >300 ft based on 1 study), rough-skinned newt (buffer of >600 ft based on 1 study), and painted turtle (buffer of >380 ft based on 3 studies). An assumption is the distances these species have been found from wetlands are a sound basis for predicting appropriate buffer widths. The type of land cover that must be present in the buffer is not stated.

Wenger, S.	1999	A review of the scientific literature on riparian buffer width, extent, and vegetation. University of Georgia, Athens, GA.

Findings: Concluded “a 100 ft buffer is sufficiently wide to trap sediments under most circumstances, although buffers should be extended for steeper slopes” and “100 ft buffer should provide good control [of excessive nutrients], and 50 ft buffers should be sufficient under many conditions.”

Appendix C. Primary Sources (Field Studies) Pertinent to Water Quality Buffers and Not Cited in the WDOE's BAS Report

Many of these were not cited in the WDOE's BAS report because their publication occurred subsequently. See References section for full citations of the papers below.

Bedard-Haughn, A., K.W. Tate, and C. van Kessel.	2004	Using nitrogen-15 to quantify vegetative buffer effectiveness for sequestering nitrogen in runoff

Location: California (grazed irrigated pasture)
Findings: A 26-ft non-woody (herbaceous) buffer decreased nitrate load by 28% whereas a 52-ft buffer decreased nitrate load by 42%. However, the wider buffer was actually a source of dissolved organic nitrogen (DON) because most N loss was from uptake by plants, which released N after they died at the end of each growing season. Most N loss was in the pasture, before the N even reached the buffer. When the N reached the buffer, loss rates were greatest in the first 13 ft of the buffer. Stimulating plant uptake of N (perhaps through mowing or grazing at critical times) might improve buffer effectiveness.

Bedard-Haughn, A., K.W. Tate, and C. van Kessel.	2005	Quantifying the impact of regular cutting on vegetative buffer efficacy for nitrogen-15 sequestration.

Location: California (grazed irrigated pasture)
Findings: Mowing caused the remaining plants to take up nitrogen from subsurface and surface water more rapidly, 3-6 weeks after mowing occurred. However, the nitrogen was released again when the plants senesced. Reducing runoff volume did more to reduce nitrogen loading.

Blanco-Canqui, H., C.J. Gantzer, S.H.Anderson and E.E. Alberts.	2004	Grass barriers for reduced concentrated flow induced soil and nutrient loss.

Location: Missouri
Findings: Effectiveness of vegetated filter strips was improved by first intercepting runoff with a barrier of stiff-stemmed grasses. The difference as compared to traditional filter strips was greatest during high runoff events. The modified filter strip decreased runoff by at least 10% and sediment runoff by over 90%. In a strip that was 26 ft long, greatest reductions (>60%) in sediment and nutrients occurred in the first 3 ft.

Brown, R.B., M.H. Carter and G.R. Stephenson.	2004	Buffer zone and windbreak effects on spray drift deposition in a simulated wetland.

Location: Ontario
Findings: A hedgerow 32 ft wide prevented an herbicide applied by a boom sprayer from drifting into a wetland under wind conditions allowable for spraying. At higher winds, either a 66-ft wide hedgerow or the same 32-ft hedgerow plus a dense tree stand was effective.

Chichester, F.W., R.W. Van Keuren, and J.L. McGuinness	1979	Hydrology and chemical quality of flow from small pastured watersheds: II. Chemical quality.

Phosphorus in runoff was not increased by summer grazing of pastures, but did increase where animals were grazed year-round due to winter damage to the soil surface (trampling from hooves that compacted soils and damaged vegetation, and thus increased runoff and nutrient export).

Helmers, M.J., D.E. Eisenhauer, M.G. Dosskey, T.G. Franti, J.M. Brothers, and M.C. McCullough.	2005	Flow pathways and sediment trapping in a field-scale vegetative filter.

Location: Nebraska
Findings: Despite converging and diverging flow, the field-scale vegetative buffer trapped approximately 80% of the incoming sediment. Thus, sheet flow is not necessarily required, at least not in low-gradient landscapes, for buffers to be effective.

Houlahan, J.E. and C.S. Findlay.	2004	Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality

Location: southeastern Ontario (73 wetlands)

Findings: The study did not compare buffer widths, but correlated wetland water quality with percent of forest vs. agriculture measured at various distances around each wetland, ranging from 330 ft to 3.1 miles away. The positive effect of forest cover in reducing water-column nitrate and phosphorus was strongest when measured within 1.4 miles, whereas that critical distance for sediment phosphorus was 2.5 miles.

Hurd, T.M. and D.J. Raynal	2006	Comparison of nitrogen solute concentrations within alder and non-alder dominated wetlands

Location: New York (Adirondacks)
Findings: Alders contributed nitrate to groundwater and the stream channel, especially during peak runoff.

Kirby-Smith, W.W. and N.M. White	2006	Bacterial contamination associated with estuarine shoreline development.

Location: North Carolina
Findings: Despite shoreline buffers and new septic systems, bacteria counts near new developments were almost as much as near old developments. Bacteria counts increased with increasing water level (caused by wind tides) and during heavy rain, but not on weekends with greater recreational boating use.

Lee, K.H., T.M. Isenhart, and R.C. Schultz.	2003	Sediment and nutrient removal in an established multi-species riparian buffer.

Location: unknown
Findings: Trapping effectiveness of 23- and 54-ft buffers declined dramatically during intense and/or large storms. Mixed-species buffers were more effective than single-species, and removed 97% of the suspended sediment, 94% of the total nitrogen, and 91% of the total phosphorus.

Lowrance, R. and J.M. Sheridan.	2005	Surface runoff water quality in a managed three zone riparian buffer.

Location: Georgia
Findings: A buffer at least 75 ft wide and consisting of forest (lower zone) and grass (upper zone) reduced the loadings 27% for nitrogen and 63% for sediment phosphorus, despite some timber harvest occurring in the middle zone.

Mancilla, G.A., S. Chen, and D.K. McCool.	2005	Rill density prediction and flow velocity distributions on agricultural areas in the Pacific Northwest.

Location: eastern Washington
Findings: Formation of rills from soil erosion was greater on slopes and where soil moisture was greater, and less where crop residue was left.

Mapfumo, E., W.D. Williams and D.S. Chanasyk.	2002	Water quality of surface runoff from grazed fescue grassland watersheds in Alberta

Location: Alberta
Findings: Runoff volume and specific conductance (conductivity) increased with increased grazing intensity in a watershed. In two of three years a very heavy grazed watershed had greater nitrate concentrations than two other watersheds.

McBride, M. and D.B. Booth	2005	Urban impacts on physical stream condition: Effects of spatial scale, connectivity, and longitudinal trends

Location: Washington (Puget Sound area)
Findings: Degraded physical condition of streams was best explained statistically by quantity of intense and grassy urban land in the contributing area, and percent grassy urban land within 500 m of the stream. Proximity of a road crossing also negatively influenced stream physical condition. Conditions improved where a stream flowed through an intact riparian buffer with forest or wetland vegetation and without road crossings.

NRCS	2003	Filter Strip

For retaining sediment under the usual conditions of precipitation found in Island County, the NRCS recommends vegetated filter strips of 20-40 ft, and even wider in soils that are shallower than 5 ft. For retaining nutrients and other dissolved contaminants under the usual conditions of precipitation found in Island County, the NRCS recommends vegetated filter strips of 30-50 ft, and even wider in soils that are shallower than 5 ft. A range of widths is given depending on soil permeability, with narrower widths allowed where soils are more permeable.

Rutherford, J.C. and M.L. Nguyen	2004	Nitrate removal in riparian wetlands: interactions between surface flow and soils.

Location: New Zealand
Findings: Slope wetlands (riparian springs) were found to be capable of removing nitrate via denitrification.

Schultz, R.C., T.M. Isenhart, W.W. Simpkins and J.P. Colletti.	2004	Riparian forest buffers in agroecosystems - - lessons learned from the Bear Creek Watershed, central Iowa, USA.

Location: Iowa
Findings: A variable-width, site-specific approach to buffer width decisions is better for water quality than a fixed-width approach

Sridhar, V., A.L. Sansone, J. LaMarche, T.Dubin, and D.P. Lettenmaier	2004	Prediction of stream temperature in forested watersheds

Location: Cascades (Oregon, Washington)
Findings: A model showed that increasing the buffer width beyond 30 meters did not significantly decrease stream temperatures

Syversen, N.	2005	Effect and design of buffer zones in the Nordic climate: the influence of width, amount of surface runoff, seasonal variation and vegetation type on retention efficiency for nutrient and particle runoff.

Location: Norway
Findings: Comparing buffers of 16 ft and 32 ft, the latter were more effective for retention of sediment (81-91% retention), phosphorus (60-89%), and nitrate (37-81%). Retention did not decline even during several days of loading. Forested buffers were better for retaining sediment, whereas grass buffers were better for retaining nitrate and phosphorus.

Thompson, D. G., B.F. Wojtaszek, B. Staznik, D.T., and G.R. Stephenson.	2004	Chemical and biomonitoring to assess potential acute effects of Vision herbicide on native amphibian larvae in forest wetlands.

Location: Ontario
Findings: Buffers successfully protected 51 wetlands and their amphibians from adverse impacts of aerial spaying of herbicides.

Vellidis, G, R., P. Lowrance and R.D.Wauchope	2002	Herbicide transport in a restored riparian forest buffer system

Location: Georgia
Findings: A 125-ft forested and grass buffer effectively reduced the amount of herbicide reaching a stream. Other widths were not tested.

Vidon, P.G.F. and A.R. Hill	2004	Landscape controls on nitrate removal in stream riparian zones

Location: southern Ontario
Findings: Nitrate removal occurred within the first 50 ft of a riparian buffer at three sites with loamy sand and sandy loam soils overlying a shallow confining layer. However, at sites with more conductive sand and cobble sediments and with a confining layer at 20 ft, the buffer width required for 90% nitrate removal ranged from 82 to 577 ft.

Wigand, C., R. McKinney, M. Charpentier, M. Chintala, and G. Thursby	2003	Relationships of nitrogen loadings, residential development, and physical characteristics with plant structure in New England salt marshes.

Location: Rhode Island
Findings: Plant zonation in tidal marshes was correlated negatively with surrounding residential land use. Nitrogen concentration in marsh plant leaves correlated positively with surrounding residential land use Some non-native plants are more able than native plants to exploit nutrient increases and this may be a factor in their spread

Wigington, P.J. Jr, S.M. Griffith, J.A. Field, J.E. Baham, W.R. Horwath, J.H. Owen, S.C. Davis, Rain and J.J. Steiner	2003	Nitrate Removal Effectiveness of a Riparian Buffer along a Small, Agricultural Stream in Western Oregon

<u>Location:</u> Oregon (Willamette Valley)
<u>Findings:</u> A riparian buffer of uncultivated grasses and herbaceous vegetation was effective (perhaps more so than woody) in removing nitrate from agricultural fields. Removal efficiency was strongly influenced by how much of the runoff actually interacted with the soil. If channeling occurs (rills and gullies) and/or water tables are high due to flooding of hydric soils, there is less interaction. Use of buffers to alleviate nitrate runoff is a poorer strategy than limiting fertilizer application rates and implementing other BMP's. The primary benefit of buffers is to exclude producers from accidentally applying fertilizers directly to unrecognized seasonal wetlands that feed into streams and aquifers.

Young, E.O. and R.D. Briggs	2005	Shallow ground water nitrate-N and ammonium-N in cropland and riparian buffers

<u>Location</u>: Northeastern U.S.
<u>Findings:</u> Nitrate reductions occurred between cropland and buffers mostly where groundwater flowed from moderately well and well drained cropland to poorly drained riparian buffer soils.

Appendix D. Methods Used in Island County's Approach to BAS

For jurisdictions preparing CAO updates for wetlands, the most widely-used literature synthesis has been one published by the Washington Department of Ecology (the WDOE) (Sheldon et al. 2005). We augmented the WDOE document and a similar one that was reviewed by King County (2004) with our own review. Implementing the review consisted primarily of conducting keyword searches of computerized databases and the internet, obtaining potentially relevant articles and reports, and reviewing and extracting relevant information from those. Over 180 additional publications, most of them from peer-reviewed scientific journals, were reviewed and incorporated into this document. This represents a 15% expansion of the literature base of the BAS document published by the WDOE.

Obtaining and reading the current technical information was only part of the BAS process. Another key part was making reasonable inferences and reaching logical conclusions from the information, and placing those in the proper context[18]. Because of his prior experience conducting comprehensive national syntheses of wetland literature for the Corps of Engineers (Adamus et al. 1992) and the USEPA (Adamus and Brandt 1990, Adamus et al. 2001), Dr. Adamus did all the reading and made all the inferences contained in this document. To a limited degree, he also checked the inferences and logic paths behind key recommendations of the WDOE documents (Sheldon et al. 2005, Granger et al. 2005) to ensure they reflected both BAS at the time of those document's release and current BAS. Dr. Adamus also has received the WDOE training in the WDOE's *Washington State Wetland Rating System for Western Washington, Revised* (Hruby 2004) and has applied it extensively, along with ICPCD technical staff (Kirsten Harma and Chris Luerkens), to Island County wetlands.

The review focused on aspects of wetland literature most relevant to informing the revision of Island County's wetlands ordinance. Those aspects included but were not limited to interactions between wetlands and other landscape components, indicators of wetland functions, desirable characteristics of undeveloped buffers around wetlands, agricultural and urban impacts on wetlands, factors that determine wetland sensitivity, and threshold patch sizes needed to support wetland functions. Despite limiting the review to these topics and to literature not covered by the WDOE BAS, not all such literature could be reviewed. Priority was given to reviewing recent studies from the Pacific Northwest, especially those published in peer-reviewed journals in the last few years, and those from wetlands in agricultural rather than mainly urban or forested settings. Although several synthesis reports were reviewed, emphasis was placed on review of primary literature (i.e., the original sources).
