BEST AVAILABLE SCIENCE
Wetlands

1. Overview

The State of Washington, through its Growth Management Act, requires local jurisdictions to protect the functions and values of wetlands. As defined by the Act,

> '[w]etland' or 'wetlands' means areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. Wetlands do not include those artificial wetlands intentionally created from nonwetland 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.

RCW 36.70A.030(21). Wetlands can include areas that never have visible surface water so long as they meet the above criteria. In fact, wetlands that provide valuable functions such as water purification often are wetlands that do not contain visible surface water. Along with water purification, wetlands also sequester sediment, remove pollutants from surface water, reduce impacts from flooding, stabilize soil, recharge groundwater, and provide important habitat. These functions are easily destroyed or degraded by development and other human activities. However, this destruction and degradation of wetland functions can be prevented through the implementation of management protection tools such as wetland buffers and wetland mitigation. To that end, this chapter provides a review of the best available science as it pertains to wetland functions and values, wetland rating systems, recommended buffer widths as well as other wetland management and protection tools that can be used to regulate activities in or near wetlands in order to minimize or prevent destruction and degradation of wetland functions. This science was included throughout the county's planning process as it updated its regulations pertaining to wetland designation and protection.

1.1 Characteristics and Distribution of Wetlands in Thurston County

Wetlands in Thurston County are a key component of our surface and groundwater systems. They help to prevent flooding and erosion during times of heavy rainfall by absorbing floodwater and sending it slowly to rivers, streams and aquifers. This function acts to reduce the number and severity of flood events in the County's five major river systems – the Deschutes, Chehalis, Nisqually, Skookumchuck and the Black – as well as the seven percent of the county that experiences groundwater flooding (TRPC 2009). Through this process of absorbing and slowing releasing surface water, wetlands also provide filtration for the surface and groundwater systems that are the source of drinking water for Thurston County residents. Additionally, wetlands are habitat for the many native species of plants and wildlife that call Thurston County home, including those that are threatened and endangered. However, the water purification capacity of wetlands can become overtaxed if too much pollution accumulates in the wetland and in the end this pollution also adversely affects the wildlife wetlands support.

There are 4,708 mapped wetlands in Thurston County that encompass 42,588 acres. These maps were created in the late 1990's using detailed GIS data layers including topography, soil mapping, the vegetation signature that appears on digital aerial photos and a limited number of field inspections. Because of the challenges inherent in delineating wetlands without on-site inspections by a qualified wetland specialist, this mapping inaccurately portrays some wetlands and omits others altogether. Despite these inaccuracies, these maps of Thurston County wetlands are specific enough to have assisted in regional groundwater, stormwater and watershed planning efforts. They are also used by the County's Permit Assistance Center as a screening tool to identify properties which may contain wetlands and/or their buffers and thus require environmental review during the permitting process.

1.2 Principal Sources of Best Available Science

The Washington State Department of Ecology (Ecology) has identified and synthesized current best available science pertaining to wetland functions and values, the impacts of human disturbance and the effectiveness of wetland management tools in the following 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.

Like most jurisdictions in Washington, Thurston County has relied heavily on this synthesis document in updating its Critical Areas Ordinance (CAO) regulations pertaining to wetlands. When applying information from that document to decisions about wetland management and protection, the county also relied on the following four comprehensive 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 No. 05-06-008. Washington Dept. of Ecology, Olympia.
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> Hruby, T. 2004. Washington State Wetland Rating System for Western Washington, Revised. Washington Dept. of Ecology, Publication No. 04-06-025, Olympia WA.
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> Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance (Version 1). Washington State Department of Ecology Publication No. 06-06-011a. Olympia, WA.
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> Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1). Washington State Department of Ecology Publication No. 06-06-011b. Olympia, WA.

For a complete listing of literature Thurston County included in its update to the wetland regulations contained within the Thurston County CAO please refer to the Literature Cited and Other Sources of Best Available Science section at the end of this chapter and to the Best Available Science Summary contained in Appendix A.

2. Regulatory Requirements

Staff note: this section will include a discussion of the legal framework pertaining to wetland regulation and will be added at a later date.

3. Wetland Functions and Values

Wetlands are important because they improve water quality by removing sediment, nutrients and toxic organic compounds; reduce peak flows in a watershed, preventing or minimizing flooding; decrease erosion; recharge groundwater; and provide habitat for plants, fish and wildlife, including many which are threatened or endangered. Wetlands perform these functions to a greater degree than non-wetland areas of comparable size but not all wetlands perform these functions to an equal degree. Determining the exact degree of function of a specific wetland is not an easy matter (Adamus 2011). The type and degree of functions performed depend on various factors including size, physical configuration, location within a watershed, vegetation community structure and diversity, and degree of disturbance (Adamus et al 1987, 1991). Some of the factors determinative of the degree of function have been incorporated into Ecology's *Washington State Wetland Rating System for Western Washington* (Revised) (Hurby 2004). The functions selected for this rating system were determined to be valuable to local communities and thus the most important to consider when managing wetlands (Hurby et al 1999, 2000, 2004).

3.1 Water Quality Improvement

Wetlands help to improve water quality, including that of drinking water. They do so by intercepting surface runoff and removing or retaining sediment, inorganic nutrients and toxic organic compounds before they can reach surface or groundwater. This is especially true if wetlands are located downstream from sources of pollution, include diverse and persistent vegetative classes, contain organic or clay soils, have more than 80 percent vegetation cover, include seasonal pond areas, contain a restricted outlet, and experience low velocity stormwater flows (Sheldon et al 2005).

In general, the ability of a wetland to remove sediment depends on several factors. The longer water spends in a wetland the greater the amount of sediment removal. This is because it takes longer for smaller particles to settle out. Further, the presence or absence of vegetation also affects how much sediment is trapped. Whether wetlands function to remove sediments depends on the amount of sediment pollution in the watershed and what type of wetland (flat, depressional, lacustrine fringe, riverine, or slope) is receiving the surface water (Sheldon et al 2005). Because there is a moderate to high amount of topsoil removing activities such as logging, agriculture and residential development in Thurston County, watersheds in the county tend to have high sediment loads.

These and associated activities also contribute to excessive nutrient loads in Thurston County’s surface waters. The use of fertilizers and pesticides by county residents, failing septic systems, and stormwater runoff from impervious surfaces all contribute to high levels of nitrogen and phosphorus in the county’s waters. Because the South Sound is characterized by a high marine shoreline to water surface-area ratio, this leads to especially excessive nutrient levels in Thurston County’s marine waters, which in turn creates water quality problems such as eutrophication (algae blooms) and low levels of dissolved oxygen (hypoxia) (Grette Associates 2009). Wetlands remove phosphorus and nitrogen from the surface water that is filtered through them. Most phosphorus that enters wetlands is transported attached to particles. Thus, wetlands that are effective at trapping sediment are also effective at removing phosphorus (Sheldon et al 2005). However, phosphorus retention in wetlands is highly variable and depends on the type of sediment present in a wetland. Chemical processes bind phosphorus to clay and organic matter, especially those high in iron or aluminum and thus wetlands whose sediments are rich in these materials are most effective at retaining phosphorus (Adamus 2011). Nitrogen removal mainly occurs through denitrification – a process whereby nitrates are transformed into nitrogen gas and removed from the aquatic system. Additionally, plants uptake both phosphorus and nitrogen but because the nutrients become available again once the plants die and break down this uptake does not permanently remove nutrients (Sheldon et al 2005).

Wetlands also have the ability to remove toxic compounds so that they do not make it into surface or groundwater. These contaminants include metals such as copper, zinc, mercury and other chemicals such as flame retardants and PCBs. Studies have shown that toxic contaminants which make their way to Puget Sound degrade shellfish beds, water quality and marine habitat. Further, once toxins reach the Sound they are concentrated in the food chain and have detrimental effects on marine organisms, including threatened and endangered species (the Puget Sound orca have some of the highest concentration of fire retardants and PCBs found in marine mammals) (Grette Associates 2009). The same principles apply to all of the county’s water sources. If toxic compounds are not filtered out, these waters will have degraded water quality, which in turn will have detrimental effects on the species that rely on them. The potential for wetlands to remove toxic compounds is based on the composition of their soils. Clay soils and organic soils such as peat bogs have the necessary soil conditions to react with and remove toxic compounds (Sheldon et al 2005).

3.2 Erosion / Shoreline Protection

Wetlands slow down the velocity of water and thereby reduce downstream erosion. The amount of velocity reduction depends on the frictional resistance of vegetation and substrate in the wetland as well as the presence or absence of channel constriction. (Sheldon et al 2005). For this reason, erosion control is especially effective in depressional and riverine wetlands where velocity is slow, the vegetation dense and woody and there are channel constrictions (Sheldon et al 2005; Hruby et al 2004). In addition, wetlands located adjacent to shorelines containing dense vegetation and extending more than 200 feet from the ordinary high water mark provide the highest level of erosion control along shoreline areas (Hruby et al 1999).

3.3 Biological Support and Fish and Wildlife Habitat

Wetlands are among the most productive ecosystems in the world and as a result support numerous species including those that are threatened or endangered. These wetland-dependent species can be classified as obligate species, those that require wetlands for some part of their life cycle, or primarily-associated species, those that occur in wetlands disproportionately to their occurrence in other habitat types.

3.4 Reduce Downstream Flood Damages

Floods are the most prevalent and costly natural hazard that affect Thurston County. On average the county experiences a major flood event every 2.33 years causing millions of dollars in damage (TRPC 2009). These floods are caused by excessive standing or flowing water. The amount of flow in streams and rivers and water table levels is directly related to the total area of wetlands in a watershed. Wetlands control stormwater flow by storing water and slowing its release into groundwater and adjacent water bodies. At the landscape scale this process is called desynchronization and occurs when floodwaters are stored in many wetlands within a watershed. The water released from these wetlands is staggered and gradual, resulting in more persistent, but lower flows (Sheldon et al 2005). The effectiveness of a specific wetland in reducing downstream flooding depends on that wetland's volume of water storage, proximity to the flooded area and other wetlands, and the lack of other storage areas such as ponds, lakes and reservoirs in the area (Mitsch and Gosselink 2000).

3.5 Stream Baseflow Maintenance and Groundwater Recharging

As discussed above, wetlands store water and then slowly release it to streams or groundwater. This contributes to stream baseflow and groundwater recharge (Mitsch and Gosselink 2000). This is especially important for the region's stream flow-sensitive salmonids during the dry season. The movement of water into aquifers is dependent on the elevation of the wetland relative to the groundwater, the mass and pressure of water in the wetland, and the physical characteristics and frictional resistance of the sediments underlying the wetland (Hruby et al 1999). How well a wetland recharges is dependent on the groundwater flow rates under the wetland, the storage capacity of the wetland, water movement within the wetland, and evapotranspiration (Sheldon et al 2005).

3.6 Additional Functions and Values of Estuarine Wetlands

Estuaries are the areas where fresh and salt water mix. Wetlands located within these ecosystems are relatively rare. They are especially vulnerable to human activities and as a result up to 99 percent of estuarine wetlands have been lost in some areas of the state. Further, because of their unique physical processes, while estuarine wetlands provide many of the functions outlined in previous sections, they do so in a unique context (Hruby 2005). These are the most downstream wetlands located within a watershed, which means they are the most vulnerable to effects from upstream pollution and land uses. At the same time, water and sediment quality are especially important to the protection of estuarine resources including native shellfish, aquaculture, juvenile salmon feeding and rearing habitat, bottom-feeding fish, as well as birds, predatory fish, marine mammals and humans that feed on estuarine species. Estuarine wetlands also perform unique functions. For example, they provide protection to groundwater from saltwater intrusion by helping to maintain the location of the estuarine salinity gradient within the estuarine landscape. Given the rarity and importance of estuarine wetlands, preserving these areas is critical in Thurston County.

4. Wetland Management and Protection Tools

The proposed revisions to the wetland section of Thurston County's Critical Areas Ordinance contain buffer and mitigation requirements and also regulate certain activities in wetlands and their buffer areas. This section provides a review of wetland identification, rating and classification systems, buffer functions and recommended widths and other wetland management and protection tools that can be used to regulate activities in or near wetlands.

4.1 Identification, Rating and Classification

Whether an area legally qualifies as a "wetland" is determined by the presence or absence of wetland plant species ("hydrophytic plants"), wetland soils and whether it meets the definition of RCW 36.70A.030(21) (see Overview section of this document). Although it is possible for untrained individuals to recognize some wetlands, wetlands and their boundaries generally are not casually identifiable. Thus, identification of wetlands and delineation of their boundaries must be made by wetland professionals with advanced skills in identifying wetland plants and soils in accordance with state definitions and the federal wetland delineation manual and applicable regional supplements (*1987 US Army Corps of Engineers Wetlands Delineation Manual and the 2008 Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region*) (WAC 173-22-035).

Once a wetland has been identified, rating that wetland based on its functions allows for the tailoring of protection standards based on the specific needs of different types of wetlands. As discussed further in the following section, a rating system can be an inexpensive and efficient way to fashion buffer width requirements that are site specific. For these reasons, the State of Washington, in its *Critical Areas Assistance Handbook (*CTED 2003), encourages jurisdictions to use a rating system and requires that if a county or city chooses not to use the wetlands rating system developed by the state, the rationale for that decision be included in its legal record. The state's tiered ranking system was developed by Ecology and divides wetlands into four classifications (Category I, II, III, and IV) based on the following characteristics: rarity, irreplaceability, sensitivity, and functions performed. Category I wetlands are those with the highest functions and value while Category IV have the lowest functions and value. Ecology recommends using this rating system for developing standards for regulating activities in wetlands and wetland buffer areas. However, they do not recommend that it replace a full wetland functional assessment needed for compensatory mitigation projects. This rating system is described in more detail in the *Washington State Wetland Rating System for Western Washington* (Revised) (Hurby 2004).

4.2 Wetland Buffers

Wetland buffers are vegetated upland areas directly adjacent to wetlands whose purpose is to reduce or prevent impacts to wetland function that may occur from adjacent land uses. Buffers are generally considered to be off-limits to most activities and land uses. Ecology's review of the pertinent scientific literature indicates that the protection of buffers around wetlands is necessary in order to protect and enhance the many functions and values of wetlands (Granger et al 2005).

4.2.1 Approaches to Wetland Buffers

There are three basic types of buffer regulations: variable-width, fixed width, or some combination of variable- and fixed width. The variable-width approach is most consistent with what the scientific literature says about buffer effectiveness. This case-by-case approach involves considerations of site-specific factors such as wetland type, vegetation, soils, intensity of development and wildlife species. Through the consideration of site-specific factors, it is ensured that the required buffer will be adequate to protect wetland functions without being any larger than necessary. However, such an approach does not provide predictability to land use applicants, is costly and time-consuming to implement, and can result in attempts to manipulate site-specific data.

Conversely, while a fixed width approach is predictable and inexpensive it results in some buffers being too small to adequately protect wetland functions and others being larger than necessary. It is also difficult to determine an appropriate standard width because no single buffer has been demonstrated to protect all wetland types in all situations unless that buffer width is very large. The best of both worlds, predictability and appropriately sized buffers, can be achieved by combining the fixed width approach with site specific variables. The most common way Washington jurisdictions have tailored the fixed width approach to address site-specific factors is by using a wetland rating system. Such a system categorizes wetlands based on specific characteristics and assigning different buffer widths to each category (see Section 4.1 of this chapter for a discussion of the rating system developed by Ecology). Other ways to tailor a fixed width buffer scheme to meet site-specific conditions include establishing criteria and procedures for varying from standard buffer widths, and allowing for buffer reconfiguration to maximize protection of natural features in the upland areas adjacent to wetlands or to respond to site-specific limitations. (Granger et al 2005)

4.2.2 Buffer Widths and Protection of Water Quality

Buffers protect the water quality of wetlands by removing sediment and pollutants from surface water flowing across the buffer, removing nutrients from surface and shallow groundwater through plant intake or biological conversion, binding dissolved pollutants by adsorption onto soil particles, and maintaining water temperature (Sheldon et al 2005). These processes in relation to buffer width are discussed below.

4.2.2.1 Buffer Width and Sediment Removal

The ability of a buffer to remove sediment is dependent on the slope of the buffer, the density of the vegetation within the buffer area, the presence of large woody debris/surface roughness within the buffer area and the size and velocity of sediment. Large particles are dropped in the outer portion of the buffer with increasingly larger areas needed to filter out finer particles. Because the slow movement of water allows for particles to drop out of the water column, larger buffers are needed in sloped areas and smaller buffers are required where vegetation and surface roughness act to slow down water flow (Sheldon et al 2005).

Summary of studies on sediment control provided by buffers of various widths, reported in Sheldon et al 2005.

Author(s)	**Date**	**Buffer width**	**Comments**
Broderson	1973	200 feet (61 m)	Effective sediment control "even on steep slopes"
Desbonnet et al.	1994	6.6- 82 feet (2-25 m)	60% removal in 6.6 feet (2 m); 80% removal required 80 feet (25 m)
Desbonnet et al.	1994	16-49 feet (5-15 m)	On grassy buffers on slopes with less than 5% slope, removed all but the finest particles
Ghaffarzadeh et al.	1992	16-49 feet (5-15 m)	Found 85% removal in 30-foot (9.1 m) buffers
Horner and Mar	1982	200 feet (61 m)	80% of sediments. As cited by Castelle and Johnson (2000)
Lynch et al.	1985	98 feet (30 m)	75-80% removal of sediment from logging activities into wetlands
Norman	1996	9.8 feet (3 m): sands 49.9 feet (15.2 m): silts 400 feet (122 m): clays	Distances required for effective removal of progressively smaller particle sizes
Wong and McCuen	1982	100-200 feet (30.5-61 m)	90% at 100 feet (30 m), need 200 feet (61 m) to obtain 95% removal effectiveness
Young et al.	1980	80 feet (24.4 m)	92% sediment removal rate from feedlot through vegetated buffer strip

4.2.2.2 Buffer Width and Nutrient Removal

Nitrogen and phosphorus are the primary nutrients that are of concern to wetland water quality. As much as 85% of phosphorous in surface water is bound to sediments and is removed when sediment is dropped into buffer areas. However, nitrogen is only removed effectively from water flowing toward a wetland when it comes into subsurface contract with fine roots and thus requires longer residence time and prolonged contact with vegetation for effective removal from the water column to occur. Thus, while the largest portion of phosphorus removal occurs within the outer portions of the buffer, larger buffers are required to remove nitrogen and other dissolved nutrients (Sheldon et al 2005).

Summary of studies on nutrient removal provided by buffers of various widths, reported in Sheldon et al 2005.

Author(s)	Date	Buffer width	Comments
Daniels and Gilliam	1996	20-66 feet (6-20 m)	47-99% removal of nitrogen
Desbonnet et al.	1994	30 feet (9 m): 60% removal 197 feet (60 m): 80% removal	Small buffers could have effective removal rates for nitrogen; much larger buffers are necessary for a significant increase in effectiveness
Desbonnet et al.	1994	Averages: 39 feet (12 m): 60% 279 feet (85 m): 80%	When all the findings from the literature synthesis were averaged, the average removal efficiencies were non-linear: larger buffers were needed for increases in effectiveness
Dillaha	1993	15 feet (4.6 m): 70% 30 feet (9.1 m): 84%	Percent removal of suspended solids and their associated nutrients with vegetated filter strips. As cited in Todd (2000)
Dillaha	1993	15 feet (4.6 m): 61% 30 feet (9.1 m): 79%	Removal of phosphorus with vegetated filter strips. As cited by Todd (2000)
Dillaha	1993	15 feet (4.6 m): 54% 30 feet (9.1 m): 73%	Removal of nitrogen with vegetated filter strips. As cited by Todd (2000)
Doyle et al.	1977	12.5 feet (3.8 m) forested 13.1 feet (4 m) grass	Reduced nitrogen, phosphorus, and potassium levels
Edwards et al.	1983	98 feet (30 m)	50% removal rate of phosphorus
Lowrance	1992	23 feet (7 m)	Forested buffer zones were effective at removing nitrate through plant uptake and microbial denitrification
Lynch et al.	1985	98 feet (30 m)	Forested buffers reduced soluble nutrient levels from logging activities to “appropriate” levels
Patty et al.	1997	20-66 feet (6-20 m)	47 - 99% removal of nitrogen
Shisler et al.	1987	62 feet (19 m)	Forested riparian buffers effectively removed up to 80% and 89% of phosphorus and nitrogen, respectively
Thompson et al.	1978	39-118 feet (12-36 m)	Found a range of removal effectiveness of 44 to 70%
Vanderholm and Dickey	1978	>853 feet (260 m)	Removal of 80% of nutrients, solids, and BOD from feedlot runoff with shallow (<0.5%) buffer slopes. Cited in Castelle et al. (1992b)
Young et al.	1980	69 feet (21 m): 67% removal 89 feet (27 m): 88% removal	Removal of phosphorus
Xu, Gillam, and Daniels	1992	33 feet (10 m)	Significant reductions in nitrate through a mixed herbaceous and forested buffer strip (as cited by Castelle and Johnson 2000)

4.2.2.3 Buffer Width and Toxin and Pathogen Removal

The effectiveness of buffer width on toxin and pathogen removal has not been thoroughly studied. It has been determined that toxins and pathogens attached to soil particles will be filtered out when the sediment is deposited in the buffer. However, while wind born toxins such as agricultural pesticides and herbicides are influenced by wind conditions, timing of precipitation relative to the application of chemicals and height and density of vegetation within the buffer, the amount of filtration of these toxins provided by various buffer widths has not been adequately studied and represents a data gap. Appropriate buffer widths for toxin and pathogen removal range from 12.5 feet to 115 feet (Sheldon et al 2005).

Summary of studies on pathogen control provided by buffers of various widths, reported in Sheldon et al 2005.

Author(s)	Date	Buffer width	Comments
Doyle et al.	1977	12.5 foot (3.8 m) forested buffers 13.1 foot (4 m) grass buffers	Reduction in fecal coliform bacteria levels.
Grismer	1981	98 foot (30 m) grass filter strip	Removal of 60% of fecal coliform bacteria.
Young et al.	1980	115 foot (35 m) grass buffer	Reduced microorganisms to acceptable levels.

4.2.2.4 Adjusting Buffer Widths for Slope

Buffers are most effective in protecting the water quality of wetlands when the buffers are relatively flat. Flat terrain results in slower water velocity, allowing more time for water to move slowly on the surface and through the roots of the buffer vegetation for more effective removal of pollutants and sediments. Therefore, sloped buffer areas require larger buffers in order to protect wetland functions.

Summary of studies on adjusting buffer width for slope, reported in Adamus et al 2011.

	Increase buffer width by:	Source
For every 1 degree increase in slope…	1 ft	State of Maryland timber harvest regulations
	2 ft	Georgia Department of Natural Resources
	3 ft	Connecticut Assn. of Wetland Scientists
	3 ft, if 10-30 degrees	Nova Scotia
	10 ft	Minnesota Dept. of Natural Resources
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
	4 ft (only if >15% slope, and\no more than 10 ft beyond the top of the slope)	Cities of Salisbury & Easton, MD
	5 ft	Palone & Todd 1997
For all slopes >30%.	50% more than the width otherwise recommended	Washington Dept. of Ecology (Granger et al. 2005)

4.2.2.5 Buffer Width and Maintaining Microclimate

Forests create shade and block wind, helping to moderate temperatures in adjacent aquatic systems. Cooler water temperature helps in maintaining water quality for a number of reasons. Warmer water causes a looser bond between sediment particles and nutrients resulting in an increase in nutrient loading. Additionally, cooler water carries higher loads of dissolved oxygen – essential for aquatic biota (Sheldon et al 2005).

Summary of a study on the influence of microclimate provided by buffers of various widths, reported in Sheldon et al 2005.

Author(s)	Date	Buffer width	Comments
Harper and MacDonald	2001	Approx. 131 feet (40 m)	Influence of large aquatic systems on adjacent upland forest composition and structural complexity

4.2.2.6 Buffer Width and Wetland Species and Habitat Protection

Wetland buffers provide habitat for wetland-dependent species that require both wetland and upland habitat, including birds, amphibians and mammals. These species depend on terrestrial habitats for food, cover, nesting and/or travel corridors. Appropriate buffer widths to maintain habitat range from 100-300 feet for most species provided that they contain a diversity of native vegetation. Some species require larger distances (Sheldon et al 2005).

Summary of studies on wildlife habitat provided by buffers, reported in Sheldon et al 2005.

Author(s)	Date	Buffer width	Comments
Allen	1982	328 – 590 feet (100 – 180 m)	Mink use: generally concentrated within 330 feet (100 m) of water but will use upland habitats up to 590 feet (180 m) distant
Burke and Gibbons	1995	240 feet (73 m): 90% 902 feet (275 m): 100%	Buffer to encompass % nesting and hibernation of turtles in North Carolina
Castelle et al.	1992b	197 – 295 feet (60 – 90 m): Western Washington 98 – 197 feet (30 – 60 m): Eastern Washington	Range for all species they noted Range for all species they noted
Castelle et al.	1992b	263 feet (80 m) avg. - 590 feet (180 m)	Wood duck nesting locations from wetland edge (non-Washington data)
Castelle et al.	1992b	98 feet (30 m): Eastern Washington 328 feet (100 m): Western Washington	Distance of beaver use of upland habitats from water edge
Chase et al.	1995	98 feet (30 m) or more	100 feet (30 m) would be “adequate”;buffers larger than 100 feet needed to meet habitat needs, including breeding for birds and some mammals
Cross	1985	220 feet (67 m)	Forested “leave-strips” for small mammal richness adjacent to streams in SW Oregon
Desbonnet et al.	1994	49 – 98 feet (15 – 30 m): low intensity 98 – 328 feet (30 – 100 m): high intensity	Variable buffer widths using adjacent land uses as decision-making criteria

Fischer et al.	2000	98 feet (30 m) minimum	Literature review; majority of literature cited recommends buffer widths of 330 feet (100 m) for reptiles, amphibians, birds, and mammals
Foster et al.	1984	98 feet (30 m): 68% of nests) 312 feet (95 m): 95% of nests	Waterfowl breeding use of wetlands in the Columbia Basin greatest in smaller (<1 acre [0.4 ha]) wetlands; 68% of waterfowl nests within 100 feet (30 m) of wetland edge; to encompass 95% of waterfowl nests would require 310 feet (95 m) of buffer
Groffman et al.	1991a	197 - 328 feet (60 - 100 m)	For most wildlife needs
Groffman et al.	1991a	328 feet (100 m)	Neotropical migratory bird species
Howard and Allen	1989	197 feet (60 m)	For most wildlife needs
McMillan	2000	98 – 328 feet (30 – 100 m)	Based on a synthesis of literature
Milligan	1985	49 feet (15 m)	Bird species diversity strongly correlated with the percentage of the wetland boundary buffered by at least 50 feet (15 m) of tree and shrub vegetation
Norman	1996	164 feet (50 m)	To protect wetland functions; more buffer may be required for “sensitive wildlife species”
Ostergaard	2001	3,280 feet (1,000 m)	Forested habitat surrounding stormwater ponds, related to native amphibian richness
Richter	1996	3,280 feet (1,000 m)	Literature review and synthesis
Richter	1996	3,280 feet (1,000 m)	Native amphibian use
Richter and Azous	2001b	1,680 feet (512 m)	Distance from wetland edge necessary to include all bird richness in Puget Sound lowland wetlands
Richter and Azous	2001c	1,640 feet (500 m): 60%	Highest small-mammal richness when 60% of first 1,640 feet (500 m) of buffer was forest habitat
Semlitsch	1998	1,969 feet (600 m)	Salamanders
Semlitsch	1998	228 – 411 feet (69.6 - 125.3 m) 539 feet (164.3 m) for 95% of all species	Six species of adult salamanders and two species of juveniles; mean distance from wetland edge was 228 feet (juveniles) – 411 feet (adults). To incorporate 95% of all species, buffer mean would have to be 539 feet
Short and Cooper	1985	164 – 328 feet (50 – 100 m)	164 feet (50 m) for foraging
Temple and Cary	1988	> 656 feet (200 m): 70% success 328 – 656 feet (100 – 200 m): 58% success < 328 feet (100 m): 18% success	Nesting success rates for interior-dwelling forest birds related to distance into the interior of a forest from the forest edge

Wetland buffers screen wildlife from disturbances caused by human activities. This disturbance can come in the form of light, noise, or from human presence. Noise and light especially can disrupt feeding, breeding and sleeping habits of wildlife. Screening wildlife habitat reduces the effects of noise, light, dust, motion and other activities associated with human habitation. Appropriate buffer widths to screen wildlife from human disturbance range from 46 to 328 feet.

Summary of studies on screening provided by buffers, reported in Sheldon et al 2005.

Author(s)	**Date**	**Width**	**Comments**
Castelle et al.	1992b	200 feet (61 m)	General wildlife considerations
Cooke	1992	50 feet (15 m)	Analyzed 21 sites in King County. Buffers less than 50 feet were often disturbed by human activities and were not effective at screening “human effects.” Found in Castelle et al. (1992b)
Groffman et al.	1991a	105 feet (32 m)	Dense forest to filter sound from commercial land uses to natural background levels
Josselyn et al.	1989	49-164 feet (15-50 m)	Unscreened human activity within 50 – 164 feet was disruptive to waterbirds in San Francisco Bay area
Rodgers and Smith	1997	46 to 112 feet (14-34 m) 61 to 78 feet (18.5-24 m)	Waterbirds in Florida: flushing distance from walkers 46 – 112 feet; flushing distance from autos 61 – 78 feet. Nature observation had greatest impact if involving walking activities. Nesting birds tolerated closer human approach than birds that were perching/foraging
Shisler et al.	1987	50-100 feet (15-30 m) 100-164 feet (30-50 m)	Low-intensity land uses (agriculture, recreation, and low density residential): 50 - 100 feet High-density residential housing and commercial/industrial: 100 - 164 feet Most effective buffers had steep slopes, dense shrubs
Short and Cooper	1985	328 feet (100 m)	328 feet to buffer nesting great blue herons from human disturbance

4.2.2.7 Buffer Management

In order to ensure that established buffers continue to protect wetland functions, certain management tools must be employed. Clearly delineating a buffer area ensures that it is not encroached upon or degraded during or after construction. During construction this can be achieved by constructing a temporary fence. This ensures that the various people involved with construction will be aware of the protected areas. Erosion control measures such as a sediment catching fence should also be employed. Following construction, depending on the potential for intrusion by humans and domestic and farm animals, a permanent fence may be needed. In addition to fencing, placement of signs along a buffer boundary will help to identify the wetland boundary. The draft revisions to Thurston County’s Critical Areas Ordinance include standards for signage and fencing (Draft Chapter 24.60 TCC). Finally, regular monitoring of buffer areas is essential to ensure that buffers are actually functioning to protect wetlands. Where buffer vegetation and soils have been illegally disturbed, enforcement actions to restore buffers should be taken (Granger et al 2005).

4.2.2.8 Special Conditions for a Possible Reduction in Buffer Widths

In certain circumstances, if the impacts from high-intensity uses are mitigated, the buffer widths recommended for those uses can be reduced to those recommended for moderate-intensity impacts. Mitigation of high-intensity uses includes directing lights away from wetland areas, locating noise-generating activity away from wetland areas, establishing covenants limiting use of pesticides within 150 feet of a wetland, applying integrated pest management, routing untreated runoff away from wetland areas, preventing channelized flows from entering buffer areas, infiltrate, treat, or detain and disperse runoff before it reaches buffer areas, installing privacy fencing, planting dense vegetation to delineate buffer edge, and using best management practices to control dust (Granger et al 2005).

4.2.2.9 Enhancement and Restoration of Buffer Areas

Upland areas adjacent to wetlands have often been altered by land use practices such as logging, agriculture or residential development. Generally, these practices have resulted in vegetation removal, soil disturbance and colonization by non-native plants. In other cases, an upland buffer area can remain undisturbed but be sparsely vegetated. In both situations the designated protective buffer width will fail to provide the characteristics required to protect wetland function. Consequently, restoration of the buffer area will result in a more functional wetland. For this reason, buffer requirements should be designed to ensure that buffers provide adequate protection of wetland functions. The standard required buffer widths should be designed based on the assumption that the buffer area is well vegetated. If a site's buffer area is not well vegetated, in order to obtain protection of adjacent wetland, the size of the buffer must be increased or the standard buffer area must be revegetated (Granger et al 2005).

5. Wetland Mitigation

State (SEPA) and federal (Clean Water Act) regulations pertaining to wetland mitigation require that a sequence of steps/actions be taken for proposals involving alterations to wetlands. This process is known as "mitigation sequencing" (WDOE et al 2006). The first two steps of the sequence are avoidance and minimization of adverse impacts. Compensatory mitigation is only appropriate when this cannot be achieved and loss of wetlands and/or their functions is unavoidable (i.e., not due to convenience or cost). Compensatory mitigation itself is made up of several steps which include: restoring (rehabilitating, re-establishing, or repairing) the affected environment, reducing the impact over time through preservation and maintenance, and compensating for the impact through enhancing or creating wetlands. The last step in the sequence is to monitor and take any required protective measures (WAC 197-11-768). This section provides a review of the various compensatory mitigation methods and replacement ratios as well as a discussion of the need for monitoring and maintenance of a wetland mitigation project.

5.1 Enhancement and Preservation Methods

As outlined above, compensatory mitigation is achieved through restoration, preservation, enhancement and creation. Restoration includes actions that return the natural or historic functions of a former or degraded wetland. Restoration is divided into two categories: re-establishment (rebuilding a former wetland to result in a gain in wetland acreage and functions) and rehabilitation (the repair of a degraded wetland that does not result in a gain in wetland area). Re-establishment is generally available for wetland areas that have been drained, filled or diked at a time when these activities were legal. It involves manipulation such as removal of fill, dikes and plugging ditches. In comparison, rehabilitation could involve removal of a dike to reconnect wetlands with a floodplain or tidal influence (WDOE et al 2006). Restoration is generally more feasible and successful than wetland creation. These sites may already contain the appropriate substrate, hydrological conditions and the seeds of wetland species. Historically, restoration of wetlands has occurred on a lesser scale than creation. This is because many impacts and associated mitigation projects are small. Restoration is typically only feasible or cost-effective when done on a larger scale. However, because of the greater likelihood of success and reduction of impacts to potentially valuable upland areas restoration should be the first option to be considered. Other options further along the mitigation sequence should only be considered if restoration is not practical (WDOE et al 2006).

Preservation involves “[t]he removal of a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland” (WDOE et al 2006). Examples of preservation actions include retiring development rights to a wetland and its buffer area through fee acquisition or conservation easements, or by repairing water control structures. This method is applicable only when the wetland to be preserved is not legally protected (e.g., unjurisdictional and exempted wetlands) and does not result in a gain in wetland acreage (WDOE et al 2006). The appropriateness of preservation is limited because it always results in a net loss of wetland resources and because many legally exempt wetlands are unprotected because they do not provide high value in terms of their functions. Thus, preservation should be reserved for protection of wetlands that are critical for the health of a watershed, provide habitat connectivity or have some other significant value (e.g. important habitat) (WDOE et al 2006).

Enhancement is “[t]he manipulation of the physical, chemical or biological characteristics of a wetland to heighten, intensify or improve specific function(s) or to change the growth stage or composition of the vegetation present” (WDOE et al 2006). These types of actions occur in areas that currently qualify as wetlands or their buffers. Enhancement actions aim to improve specific functions such as water quality improvement, flood water retention or enhancing wildlife habitat. Examples of enhancement include: maintaining long-term control of non-native and invasive species; planting and maintain native vegetation, modifying site elevation to alter hydroperiods, increasing habitat complexity (e.g. adding large woody debris), and installing wetland fencing. This method does not result in an increase in wetland resources (WDOE et al 2006). Concerns have been raised about the value of enhancement as the modest gains in function it provides tend to come at the expense of other functions of a wetland. Further, the use of enhancement as a compensatory mitigation method contributes to an overall net loss of wetland acreage (WDOE et al 2006). Enhancement is very similar to rehabilitation as both involve enhancing the functions of existing wetlands. In fact, Ecology’s wetland mitigation guidance document states that while rehabilitation involves actions that reinstate large scale environmental processes and enhancement involves gains in only one or a few functions, “[a]ctions that rehabilitate or enhance wetland span a continuum and cannot be strictly defined as one or the other" (WDOE et al 2006).

Creation or establishment is the manipulation of the physical, chemical or biological characteristics of an upland or deepwater site in order to create a wetland where one did not previously exist. Typically, this includes excavating down into the water table in order to create a pond or by legally impounding drainages. This type of compensatory mitigation creates wetland acreage. This method of mitigation is the least desirable due the difficulty of creating a full suite of wetland functions and to their failure rates and should be considered only when restoration, preservation and enhancement are not viable options. Although many created wetlands in Washington State have resulted in contributing to water quality and quantity functions, most creation projects have not been fully successful in replacing lost functions (WDOE et al 2006). This could be due to inadequate design, failure to implement the design, lack of proper maintenance, invasion of the site by non-native species, and failure to protect project from animals, vehicles or other impacts (Castelle et al 1992). Conversely, the most successful creation projects had long-term monitoring and applied adaptive management strategies (Ecology 2001).

5.2 Replacement Ratios for Restoration Re-Establishment and Creation

Whenever a wetland is altered and mitigation required, Ecology's guidance recommends the use of mitigation ratios. "The mitigation replacement ratio reflects the area of a particular type of compensatory mitigation (e.g., creation, restoration, enhancement, or preservation) needed to make up for the loss of one unit of area of wetland" (WDOE et al 2006). These ratios require a greater amount of acreage be restored, enhanced, preserved or established than was impacted. This is due to the amount of time it takes to successfully restore, re-establish and create wetlands as well as the poor track record of compensatory mitigation. Studies show that it takes up to 100 years to achieve a fully-functioning restored or created wetland (WDOE et al 2006). Mitigation ratios depend on two factors: The method of mitigation employed and the importance of the wetland being impacted (determined by its category and type, functions, sensitivity and other factors). The lowest ratio Ecology's guidance document recommends is 1.5:1 and the highest is 24:1. Both increases and decreases in the replacement ratio may be appropriate under certain circumstances (WDOE et al 2006).

5.3 Monitoring and Contingency Plans

Monitoring is essential to ensuring that a compensatory mitigation project achieves its stated objectives. A plan for monitoring is therefore a crucial part of a mitigation plan and includes the methods, duration and frequency of data collection and reporting. Most mitigation projects are monitored on an annual basis for at least 5 years. This monitoring is documented in a report that should address the established goals, objectives and performance standards of the mitigation project. The information in the report will be used to determine whether the project is achieving ecological success within the required timeframe. The monitoring report also provides an opportunity to identify problems and employ contingency plans or adaptive management (WDOE et al 2006). Because mitigation projects can run into unpredictable difficulties, every mitigation plan should also include within them a contingency plan. This plan will be needed if events such as floods, droughts, or changes in environmental processes occur (WDOE et al 2006). When unforeseen circumstances arise that a contingency plan has failed to address, adaptive management may be needed. This is the process by which modification to a mitigation plan is made based on what has or has not been effective in achieving ecological success. It requires the applicant and the governmental agency to get together and discuss both the problem and potential solutions. In some extreme circumstances this may involve an overhaul of the project goals and objectives (WDOE et al 2006).

5.5 Maintenance

Every mitigation plan should include within it a maintenance plan in order to ensure that the performance objectives of the mitigation project are achieved. This plan should outline the activities necessary to ensure that performance standards within the mitigation plan are achieved. This could include removal of invasives and other unwanted species, upkeep of irrigation systems, replacing dead or dying plants, weeding, and mulching. Ecology's guidance states that maintenance ideally should occur monthly for up to five years (WDOE et al 2006).

6. Literature Cited and Other Sources of Best Available Wetland Science

Adamus, P.R., E.J. Clairain, Jr., D.R. Smith, and R.E. Young. 1991. Wetland Evaluation Technique (WET). Vol. I. Literature Review and Evaluation Rationale. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Adamus, P.R., T.J. Danielson, and A. Gonyaw. 2001. Indicators for monitoring biological integrity of inland, freshwater wetlands: A survey of North American technical literature (1990-2000). EPA843-R-01. Fall 2001. Available: http://www.epa.gov/owow/wetlands/bawwg/monindicators.pdf U.S. Environmental Protection Agency, Office of Water.

Adamus, P.R., A. Azous, J. Biletnikoff, C.Brummer, J.Carrasquero, M.Fontaine, S.Hale, D.Nickel, J.Parsons, E.Schwartz, R. Strathmann, and S. Tomassi. 2011. San Juan County Best Available Science Synthesis. Report to San Juan County Community Development & Planning, Friday Harbor, WA. Available: http://www.sanjuanco.com/cao/BAS_Synthesis.aspx

Alberti, D.B., et al. 2006. The impact of urban patterns on aquatic ecosystems: An empirical analysis in Puget lowland sub-basins. *Landscape and Urban Planning*. 80(2007): 345-361.

Bolton, S., and J. Shellberg. 2001. White Paper: Ecological Issues in Floodplains and Riparian Corridors. Prepared for Washington State Transportation Commission, Department of Transportation, and in cooperation with U.S. Department of Transportation and Federal Highway Administration.

CH2M HILL. 2001. Washington Stormwater Management Study – Report and Recommendations from the Stormwater Policy Advisory Committee. Final Report to the Washington State Legislature.

Cooke Scientific Services, Inc. 2000. Wetland and buffer functions semi-quantitative assessment methodology (SAM), Final working draft user's manual. Available: http://cookescientific.com/SAM%20Stuff/SAM2000.pdf

Granger, T., T. Hruby, A. McMillan, D. Peters, J. Rubey, D. Sheldon, S. Stanley, E. Stockdale. April 2005. Wetlands in Washington State - Volume 2: Guidance for Protecting and Managing Wetlands. Washington State Department of Ecology. Publication #05-06-008. Olympia, WA.

Grette Associates, 2009. Thurston County Shoreline Master Program Update: Shoreline Analysis and Characterization. Prepared for Thurston County Strategic Planning.

Hruby, T. 2004. Washington State Wetland Rating System for Western Washington, Revised. Washington Dept. of Ecology, Publication No. 04-06-025, Olympia WA.

Hruby, T., T. Granger, K. Brunner, S. Cooke, K. Dublanica, R. Gersib, L. Reinelt, K.Richter, D. Sheldon, E. Teachout, A. Wald, and F. Weinmann. 1999. Methods for Assessing Wetland Functions, Vol. I: Riverine and Depressional Wetlands in the Lowlands of Western Washington. 2 Parts, Publication #99-115 and #99-116.Washington State Department of Ecology, Olympia, WA.

Hruby, T., K. Harper, and S. Stanley. 2009. Selecting Wetland Mitigation Sites Using a Watershed Approach (Western Washington). Publication 09-06-032. Washington Department of Ecology, Olympia, WA.

King County Departments of Natural Resources and Parks; Department of Development and Environmental Services; and Transportation. 2004. King County Executive Report. Best Available Science Volume I: A Review of Science Literature. Critical Areas, Stormwater, and Clearing and Grading Proposed Ordinances.

Knutson, K.L. and V.L. Naef. 1997. Management Recommendations for Washington’s Riparian Habitats Riparian. Washington Department of Fish and Wildlife, Olympia. 181 pp.

Larsen, E., J. M. Azerrad, N. Nordstrom, editors. 2004. Management recommendations for Washington’s priority species, Volume IV: Birds. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Mitsch, W. J. and J.G. Gosselink. 2000. Wetlands. 3rd ed. Van Nostrand Reinhold, New York.

Parametrix Engineering, Planning & Environmental Services. 2002. Biological Review: Tri- County Model 4(d) Rule Response Proposal. Prepared for Tri-County Salmon Conservation Coalition.

Sheldon, D., T. Hruby, P. Johnson, K. Harper, A. McMillan, T. Granger, S. Stanley, and E. Stockdale. March 2005. Wetlands in Washington State - Volume 1: A Synthesis of the

Science. Washington State Department of Ecology. Publication #05-06-006. Olympia, WA.

Simenstad, C.A. 1983. The ecology of estuarine channels of the Pacific Northwest coast: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-83/05. 181 pp.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. (Available from the National Marine Fisheries Service, Portland, Oregon.)

TRPC, 2009. Natural Hazards Mitigation Plan for the Thurston Region. The Emergency Management Council of Thurston County.

Tubbs, D.W. 1975. Causes, Mechanisms and Prediction of Landsliding in Seattle. Ph.D. Dissertation, University of Washington.

Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance (Version 1). Washington State Department of Ecology Publication #06-06-011a. Olympia, WA.

Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State – Part 2: Developing Mitigation Plans (Version 1). Washington State Department of Ecology Publication #06-06-011b. Olympia, WA.