From:	Janet Way
To:	City Council
Cc:	Debbie Tarry; Jessica Simulcik Smith; Heidi Costello
Subject:	: Comment on 145th Subarea, FEIS, Comp Plan Amendment and Code Amendments
Date:	Monday, September 12, 2016 11:13:41 AM
Attachments:	Don Norman Report.doc file0001.pdf 1306011.pdf Comment and questions for Council on 145th Subarea 91216

Dear Jessica, Mayor and Council:

Please forward this letter to Council and appropriate staff.
Please read our attached Comment letter and other documents on 145th Subarea, FEIS, Comp Plan Amendment and Code Amendments.

Please call if you have any problems with attached documents.
Thank you.

Janet Way
Shoreline Preservation Society
206-734-5545

SHORELINE PRESERVATION SOCIETY
c/o Janet Way
940 NE 147th St
Shoreline, WA 98155

September 12, 2016

Shoreline City Council
c/o Mayor Chris Roberts
council@shorelinewa.gov
17500 Midvale Ave N
Shoreline, WA 98155-2148

RE: **Comment on 145th Subarea, EIS, Comp Plan Amendment and Code Amendments**

Dear Mayor Roberts, City Council:

We are writing to comment and ask questions on the current proposal for the 145th Subarea passed by the Planning Commission.

Please accept these comments as a part of the official public record and we request status as Party of Record with Legal Standing on the matter of the proposed **145th Subarea Plan, Planned Action, FEIS, and Rezone, including Ordinances 750, 751, and 752.** As you know, the Shoreline Preservation Society has longstanding interest and involvement in the community, protection of natural and cultural resources, the character of our neighborhoods and the Thornton Creek watershed. We assert GMA and SEPA standing in this matter on behalf of the Shoreline Preservation Society (SPS) and Janet Way, the President of SPS.

1. Relocation of 145th Street Transit Station

Question #1 Doesn't the issue of moving the 145th Station Location require a Supplemental EIS or Addendum in order for the changes to be properly noticed to the public and considered with regard to the proposed Subarea?

Most urgently, it came to our attention only Monday before the Planning Commission Hearing, that Sound Transit is now proposing to move the Station a block north from the location analyzed in the FEIS and shown in the proposed ordinances. Mayor Roberts confirmed on Monday evening that he found out about this change while on a City Council tour of the Station areas just recently. We requested the opportunity to study this new location, study related environmental analysis, and comment upon it prior to the close of the public record. But, unfortunately the Planning Commission disregarded the need for the public to weigh in on this matter.

Of particular concern to us is whether the new location has the potential to interfere directly with the proposed Subarea border at 148th, which has an currently proposed MUR 70 designation. Assuming that Mayor Roberts' comments are accurate, relocation of the proposed transit station will have potentially new and unmitigated significant adverse impacts on traffic patterns, land use, and the environment that have not yet been considered either during the planning or environmental review process. This major change in the proposal alters the fundamental assumptions that were made in planning for the 145th Street Subarea.

Adopting a changed project that was not provided a full and adequately noticed public hearing creates procedural issues for Shoreline citizens and problems the City Council will inherit (unless of course it holds its own public hearing, which we understand is not the City's preference).

Please postpone the public hearing currently scheduled before the Planning Commission on August 18, 2016, until the staff have provided further study to analyze the effects of this change on the planning proposals and environmental review. We understand that when a new public hearing is scheduled, it must be re-noticed and sent to all parties of record and all residents affected in the entire proposed Subarea. This is particularly true since a Planned Action Ordinance is being pursued that will eliminate project level environmental review. While this will cause some delay, presumably it will not be significant compared to the procedural problems created by a hearing scheduled without adequate notice.

2. <u>Scheduling of the Public Hearing on the Same Night as a Large Ridgecrest Ice Cream Social Event</u>

In addition to the last minute change to the location of the station, the need to postpone the public hearing is compounded by the fact that it was scheduled on the night of the Annual Ice Cream Social in the Ridgecrest neighborhood, the same area that will be directly affected by the subarea plan. While this was just an instance of unfortunate scheduling, we believe that public participation and transparency would be better served by rescheduling this hearing to sometime in the fall when citizens are back from vacation and not otherwise occupied with a busy social calendar, as is usually the case in late summer.

2. **Has true "Project Level Review" been done yet, in reality to adopt an Planned Action Ordinance as required by State Law?**

In RCW 43.21C.440. under the clear language of Section (1)(b) and(c), the Legislature requires that the use of this early planned-action designation contain sufficient environmental analysis of project-level impacts to take the place of any normal project environmental review. We believe it is easily proven that the proper review has NOT been done. Evidence: Incorrect environmental analysis of Critical Areas, buffers and borders affected by proposed zoning and lack of notice and analysis of the Station move changes. Real public participation and analysis is REQUIRED under state law (SEPA) and the GMA for a proposal of this magnitude. This test has not been met as yet in our opinion.

SPS established months ago within this process through our own research with noted Wetland expert Sarah Cooke that the OTAK report on Paramount Natural Area and wetlands, commissioned by the City was insufficient and inaccurate. The map sent out to the community last week is inaccurate and the Critical Area layer provided in City Map files is merely estimated, NOT DELINEATED. The creek shown on the Planning Commission is roughly drawn in and completely wrong. Key creek sections are missing and the steep slope Critical Areas are ignored as important. Also, the “FEMA Liquifaction Zone” established by the City itself on the lower WEST side of Paramount Open Space is not identified.

Here is a link to her reports that we submitted then:

https://cookescientific.box.com/s/mqjxjaklmvi5uos8bpfkkk0z1e56ntv9

We are also attaching a document from the WA State Department of Ecology supporting the need to protect wetlands in this urban environment with substantial buffers, including “upland forested ecosystems.”

The document states: “Key point # 4: Page 5-38. *The literature is consistent in finding that it takes a proportionally larger buffer to remove significantly more pollutants because coarse sediments and the pollutants associated with them drop out in the initial (outer) portions of a buffer. It takes a longer time for settling, filtering, and contact with biologically active root zones to remove fine particles and dissolved nutrients.”*

Considering the need to protect the critical areas in this sensitive natural area it is crucial to protect the surrounding buffers. As a side note, I have personally seen several Priority Species and other interesting wildlife in the neighborhood adjacent to Paramount Park in the last month. These include Band Tailed Pigeon, Pileated Woodpecker, Red-Shafted Flicker, Barred Owl, Rufous Hummingbird and a family of five Racoons. Our neighborhood has documented over 40 species of birds in this vicinity and noted local expert Don Norman has written a report documenting these here as well. (attached)

Sincerely,

Janet Way, President

Shoreline Preservation Society

cc: Ms. Debbie Terry, Shoreline City Manager
dtarry@shorelinewa.gov

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Wildlife Toxicology and Environmental Assessment

DRAFT FINAL

An Annotated Bird Species List of Paramount Park and Surrounding Areas, City of Shoreline, for Use in Park and Private Property Evaluation for Widlife Protection.

Compiled by Donald Norman, Norman Wildlife Consulting, September 2007.

As part of the appeal of development on 145th (The Plateau at Jackson), a document of the environmental importance of the Paramount Park area for wildlife is needed. NWC has developed a method for producing a validated list of the occurrence of birds for such areas. This approach allows a focus upon goals for enhancement, restoration and mitigation that can be designed for the site. Once such goals are established, it is much easier for property owners to understand their role in providing and maintaining appropriate buffers to parks, and for developments to address their impacts with mitigations that produce the best results. Such goals are based upon the local inventory and park plans. In Shoreline, the City has recently begun to address an inventory need for some of its parks with a study by Seattle Urban Nature. The local Paramount Park group is beginning to establish such goals.

The Plateau on Jackson has several important issues relating to such Park goals. There is habitat set aside for protection on a steep slope, which should be integrated into a maintenance plan. The property is adjoining to the Park and should have appropriate native plant buffers. The property has large trees on the property, especially madrone, and it has connectivity to Jackson Park across 145th in Seattle.

This list has two purposes, first to validate species occurrence and second to provide a professional comment on which species should benefit from mitigation actions and why. This is critical information for species that WDFW designated at PHS species in the GMA, and that are incorporated in local Critical Area Ordinances. Unfortunately, information about many other bird species were lacking when GMA was passed, and current information on their status has been validated in several reports and management plans (Altman 2000, Rich et al 2004). How these species occur and survive in urban areas in at the core of determining the practical goals for parks and open space areas. Recent studies at the University of Washington have validated that size and habitat type are extremely important in the retention of species typical of Puget Sound Lowland forests (Donnelly and Marzluff. 2004). Many breeding species using conifers have been eliminated due to the lower percentage of conifers in the canopy. Preserves less than 100 acres also have lost a majority of the species requiring large tracts of habitat.

Many areas in urban areas also provide migration habitat and also wintering area for some species. A recent study on Vashon Island has also provided some baseline information relating to non-breeding season species (Hudson and Norman 2007). This annotated list of bird species is based upon the species observed at Paramount Park, as well as explanations for species potentially expected but not observed due to the lack of adequate surveys at the appropriate times.

Because bird surveys of small areas are typically beyond the scope of local bird studies, a habitat-based approach is necessary to provide some basis for determining whether the site is important for a particular species. The origin of the expected list comes from the excellent Birds of King County by Gene Hunn (1982, Seattle Audubon Society), and the recently published Breeding Bird Atlas (BBA, Smith et al., 1997). No list of bird species of Jackson Park has been located, but there are ongoing Neighborhood Bird Surveys performed at many Seattle Parks by Seattle Audubon, and these data are being compiled (Seattle Audubon Science Committee, personal communication). NWC has been performing bird surveys for the past 14 years in the Puget Sound Lowlands, many in urban settings, so these lists are based upon their experience.

A Key to the Annotated Lists

The list below is provided to confirm occurrence, and also to provide the status and comments on particularly important species. Local information provided to NWC is a list of 42 species that have occurred in the Paramount Park area and those that have been evaluated by NWC are indicated in **BOLD**. A total of 55 species have been observed at Hamlin Park or adjoining property and these species are given an (H). At least 24 species are likely breeding in Paramount Park, which are noted with an **"?*"** , with additional species breeding in associated residential habitat (like swallows) indicated by (*? parentheses). An additional 16 species probably occur or will occur are designated in ***Bold Italics***, but have not been confirmed. There are other species listed that might be considered to occur, but specific habitat requirements and local populations probably prevent their occurrence, they are given in italics if more possible than plain text. Species that were reported but are very rare or could be errors were given an explanation and are listed in (parentheses).

In assessing the importance of habitat for birds in Shoreline Parks, there are several important considerations for success. These include: Nesting Habitat, Foraging Habitat, Disturbance, and Invasive Species (Plants and Animals). The majority of nesting birds fall into three categories: cavity, branch and ground nesting birds. The cavity nesters rely heavily on snags and older trees for breeding and are typically the most lacking in urban parks. Retention of the trunk as tall as possible during tree removal should be the goal of all neighbors. Ground nesters need areas free from disturbance in which to build their nests, brood their young, and safely forage on the ground for food. Cavity nesters can tolerate some ground disturbance as long as there are snags and suitable nesting holes; ground nesters cannot tolerate disturbance in their area—their nests will fail or be destroyed, and they will leave the area. Ground nesters are greatly impacted by the presence of invasive plants, as most birds have very specific nesting micro-habitat selection requirements, which are generally not in invasive plants.   Disturbance can be from human use, as well as from pets. Invasive species of importance include cats, eastern gray squirrels, Norway rat, English Ivy, “stinky”Bob (a geranium), holly (Ilex opaca and varations), laurel, evergreen and Himalayan blackberry, and numerous other ornamental shrubs and trees. Recent studies have shown that bird diversity and abundance is negatively associated with invasive plants and positively associated with native vegetation, each separately measured (Henning 2007). Work to increase native plant species diversity and to remove invasive ground covers are both especially important.

The Annotated List

MALLARD   (MALL) ?*   *Anas platyrhynchos*

This species breeds in most wetlands in the Seattle area (BBA Smith et al., 1997). It is difficult to tell if the birds are from wild or domesticated stock.

BUFFLEHEAD   (GBHE)   *Ardea herodias*

The fact that this species was observed on one of the ponds at Paramount Park indicates that the wetlands is visible and at least worth investigating by species that are likely using the Jackson Park ponds.

GREAT BLUE HERON   (GBHE)   *Ardea herodias*

This species breeds in several areas in Seattle (BBA Smith et al., 1997) and is observed feeding in any area with water, including such small areas as Paramount Park.

Bald Eagle   (BAEA)   *Haliaeetus leucocephalus*

This species is listed as breeding in several areas in King County   (BBA Smith et al., 1997) and is still increasing in Washington. Likely observed flying over Paramount Park.

SHARP-SHINNED HAWK (H)   (SSHA)   *Accipiter striatus*

This species occurs as a migrant and winter resident. Its presence in the summer is possible, as there have been breeding records in mixed deciduous conifer forest on nearby Bainbridge Island.   (BBA Smith et al., 1997). Since this species' diet is strictly passerine birds, the presence of many birds in the woodland edge and with probable bird feeders at nearby houses, makes Paramount Park particularly favored for occurrence. Has been seen at Grace Cole park in the summer

COOPER'S HAWK (H)   *?   (COHA)   *Accipiter cooperii*

Similar to the Sharp-shinned Hawk, but this species is more likely to be a breeding species, as it breeds in lowland sites in Puget Sound (BBA Smith et al., 1997). The isolation of the site also increases its appeal as a breeding site. Observed hunting in Paramount Park.

RED-TAILED HAWK   (RTHA)   *Buteo jamacaiensis*

The isolated woods make an idea location for nesting of this resident of open space but it requires more open space for breeding, which occurs in Jackson Park and along I-5. Red-tails have been seen during migration and may perch in some of the tall trees. Observed flying over Paramount Park.

Merlin (MERL)   *Falco columbarius*

This species is a wintering species in King, as well as a migrant, and often associates with wetlands, where it hunts for small waterfowl and shorebirds. Merlins do breed in the mountains of King County (BBA Smith et al., 1997), but it is unlikely that this species uses such small isolated forest patches for breeding. Merlins are not as likely to be observed foraging in dense woods, as would the sharp-shinned or Cooper's Hawk. They are regularly observed each winter in Richmond Beach (DMN, personal obs.)

PEREGRINE FALCON (PEFA)   *Falco peregrinus*

Similar to Merlin but much rarer, and likely observed as a rare occurrence in Paramount Park. The presence of nearby ducks at Jackson Park ponds could be responsible for its occurrence. It has only been observed 3 times at Richmond Beach in over _ days of observation, compared to 35 times for the Merlin.

CALIFORNIA QUAIL (H) *(*nearby)* CAQU   *Callipepla califronica*

This resident species occurs in brushy open areas and uses the forest in the Paramount Park as cover from cats and dogs in surrounding open areas (AG). This species has certainly declined in areas with denser housing in Richmond Beach (DMN, personal obs). This species has dramatically declined in Discovery Park, mostly due to loose dogs disturbing their breeding/roosting areas. The open area in the proposed development is likely an important area for quail to cross 145th into Jackson Park.

ROCK PIGEON (Rock Dove) (ROPI) *herodias*

This species is common at feeders at the edge of Paramount Park, but it is not clear where it breeds. Typically this species breeds in building eaves or under bridges.

BAND-TAILED PIGEON * ? (BTPI) *Columba fasciata*

This species occurs in mixed forest sites in western Washington, especially associated with edges, and it is also fond of madrone and native dogwood in the fall when the fruit are present. This is a WA state PHS species, and impacts to this species require management plans in many critical area ordinances (CAOs). Breeds in trees at NE 163 and 28 Place NE.

Western Screech-Owl (SCOW) *Otus kennicottii*

Screech owls in western Washington are associated with wooded areas especially near streams or wetlands. the forest surrounding the 16 Acres Reserve would provide a particularly important place for the owls to hunt, and it's trees were large enough, to nest. This species will utilize nesting boxes.

GREAT HORNED OWL **?* (GHOW) *Bubo virginianus*

This species requires forest for nesting, but hunts in many urbanized areas, especially those with open areas. Large trees are acceptable for nesting as long as the site is not disturbed. Nesting begins late in winter. The dense forest in the retained area on the proposed development site would be good nesting habitat on the top of a snag in a dense area, as it is close to the open area at Jackson Park where there are likely lots of rats, and perhaps rabbits.

Northern Pygmy-Owl (NOPO) *Glaucidium californicum*

This is a species of coniferous forest, but also occurs on forest edges to hunt. Though there are no breeding records for this species in urban lowland Puget Sound, it has been observed breeding at Fort Lewis in the summer (Donald Norman, personal observations).

Northern Saw-Whet Owl (NSWO) *Aegolius acadius*

This species is common to uncommon in the mixed coniferous forests of the Puget Sound lowlands during winter and early spring, (Hunn, 1982). Though this species has not been observed in Paramount Park, the coniferous forest is appropriate for this species.

Barred Owl (H) (BAOW) *Strix varia*

This species has invaded the Pacific Northwest in the past 40 years, as a result of habitat openings in the forested areas. It has become a regular breeder in the Puget Sound Lowlands. It has been seen at Grace Cole Park, with newly fledged young.

Vaux's Swift (VASW) *Chaeture vauxi*

The status of breeding swifts in the Urban King County area has not been confirmed. This is a Washington State species of concern (PHS); it requires large snags as nesting trees that often occur in forested wetlands (BBA Smith et al., 1997). It is likely to be seen overhead in the early fall, or on some summer days when it is stormy in the mountains, requiring foraging in the Lowlands.

RUFOUS HUMMINGBIRD (H) *? (RUHU) *Selasphorus rufus*

This species is an abundant migrant and common summer breeder, using Indian Plum (*Oemleria cerasiformis*), honeysuckle (*Lonicera ciliosa*), thimbleberry (*Rubus parviflorus*) snowberry (*Symphiocarpos alba*) and twinberry (*L. involucrata*) flowers for nectar. This species has been declining in numbers on the Washington State BBS routes. The presence of various nectar sources in Paramount Park ensures that this species is present during the spring and summer, and if all of the plant species necessary are present, it may remain and breeding would be an indicator of success of the Park.

***Anna's Hummingbird* (H) *** ? (ANHU) *Calypte anna*

This species arrived from Oregon in the 1950's and has become a common breeder in the coastal areas of Puget Sound. Anna's are being banded in the area (DMN personal Obs.). Year-round population banded at NE 163 and 28 Pl NE.

BELTED KINGFISHER (BEKI) *Megaceryle alcyon*

Kingfishers are typically more common in winter than in summer in the Pacific Northwest, as this species requires a sandy bank for nesting by digging a tunnel. It is unknown but doubtful there is habitat at Jackson Park, making the occurrence of this species a migrant or wintering bird.

***Red-Breasted Sapsucker* (H)** (RBSA) *Sphyrapicus ruber*

This resident species has bred in Lowland King County (BBA Smith et al., 1997) and is associated with riparian and wetland areas, though it is not a common species. It is a quiet species, so it is often not detected and often only seen along the shoreline in winter. Observed flying over Paramount Park.

DOWNY WOODPECKER (H) *? (DOWO) *Picoides pubescens*

This resident breeding species (BBA Smith et al., 1997) is the most llikely species encountered in a forested urban area. It does not occur as frequently on the BBA as a confirmed breeder as the flicker from the 16 - 9 square mile BBA blocks from Edmonds to South Seattle, but is much more common than the Hairy Woodpecker (DMN Unpublished compilation of BBA). Newly fledged feeding at NE 163 and 28 Pl NE.

HAIRY WOODPECKER (H) **?* (HAWO) *Picoides villosus*

This resident breeding species (BBA Smith et al., 1997) is more associated with coniferous forest than the Downy Woodpecker, but it will also use wetlands, as they often have many snags which are important for sources of food and nesting sites. This species is also an indicator of good habitat. Newly fledged feeding at NE 163 and 28 Pl NE.

NORTHERN FLICKER (H) *? (NOFL) *Colaptes auratus*

This resident breeding species is more common in migration and winter than in summer with the addition of migrants and wintering individuals. The presence of many snags in the Park make this species likely to breed, as the dense forest deters Starlings, which can evict Flickers from a nest. Newly fledged feeding at NE 163 and 28 Pl NE.

PILEATED WOODPECKER (H) **?* (PIWO) *Dryocopus pileatus*

The status of this resident species is quite rare because of the large snags it requires. Paramount Park benefits this species as it provides an isolated location with snags large enough for nesting. This is another WDFW PHS species, and any projects destroying large trees should address whether this species occurs in the project areas, as outlined in many CAOs. A dead recently fledged juvenile was retrieved by DMN in Woodway. Observed at HAmlin Park. (Reports of nest tree in proposed dog park area.) Newly fledged young were observed feeding at NE 163 and 28 Pl NE.

Olive-Sided Flycatcher **(H)** (OSFL) *Contopus borealis*

This Neotropical migrant summer breeder in western Washington is associated with upper canopy openings in coniferous forests. Its call can be heard from a great distance but observations are few. There are no known nesting records for the Puget Sound Lowlands of King County (BBA Smith et al., 1997). Observed at NE 163 and 28 Pl NE.

Western Wood-Pewee (WWPE) *Contopus sordidulus*

This Neotropical migrant summer breeder in western Washington is associated with open coniferous and deciduous habitats. It is listed as core habitat in coastal King County (BBA Smith et al., 1997), but is has not been observed in the Park. Migrants have been observed in Richmond Beach as late as June (DMNorman, Pers Obs.)

***Pacific-Slope Flycatcher* (H)** (PSFL) *Empidonax difficilis*
This Neotropical migrant summer breeder in western Washington is associated with open coniferous forests with deciduous understory, and is an abundant breeder in many areas (BBA Smith et al., 1997). It has seen in Shoreview Park and also in Richmond Beach during migration. Observed at NE 163 and 28 Pl NE.

Willow Flycatcher **(H)** (WIFL) *Empidonax trailii*
This Neotropical migrant is a common summer breeder in western Washington and is associated with the edges of many riparian areas and also occurs in many clear cuts. This species has bred in King County (BBA Smith et al., 1997), and though it might not breed at Paramount Park, because of the lack of open brushy habitat, it is also an abundant species in migration and would occur then. Observed at NE 163 and 28 Pl NE.

Dusky/Hammond's Flycatcher (UNFL) *Empidonax* sp.
It is very difficult to distinguish these two species apart in migration, which is when they would be expected to be observed. The Dusky Flycatcher has been observed in May at McChord AFB (Donald Norman personal observations), but they do not remain to breed.

VIOLET-GREEN SWALLOW (H) *? ** (VGSW) *Tachycineta thalassina*
This species commonly breeds in urban areas in buildings, so although it is unlikely to be breeding at the site, it could be seen feeding over the forest and along the edges near houses. Observed flying over Paramount Park. This species readily accepts boxes.

Tree Swallow (TRES) *Tachycineta*
This species was recorded as occurring in Paramount Park, but it is more likely to be the Violet-green Swallow. This species could occur at Jackson Park if there were nesting boxes and also in migration, but prefers more open areas than the park.

BARN SWALLOW (BASW) *Hirundo rustica*

This species commonly nests in urban buildings especially where there is open area for insects, so although it is unlikely to be breeding at the site, it was observed feeding over the forest and along the edges near houses.

STELLER'S JAY (H) ?* (STJA) *Cyanocitta stelleri*
This is a common resident of coniferous forest that has adapted well to suburban areas, and is regularly observed in the Park but is quiet during the breeding season and seldom observed. It is very fond of hazelnuts.

AMERICAN CROW (H) ?* (AMCR) *Corvus brachyrhynchos*
There remains some nomenclature indicating there are two crows species, with the coastal Northwestern Crow, common in flocks along the coast, breeding colonially, and feeding along the tideline, being the "species" occurring along the Olympic Coast. Color banded crows may be part of UW studies.

Common Raven (H) (CORA) Corvus corax
Has been observed at Hamlin Park and nearby wetlands since 2003. Pair occasionally using trees behind NE 163and 28 Pl NE as recently as October 2006. Likely a nest predator of crows.

BLACK-CAPPED CHICKADEE (H) ?* (BCCH) *Parus atricapillus*
This is a common resident that uses wetlands extensively, but not exclusively. It is also a species that uses wetlands in small flocks in the winter, and especially in colder periods may be protected from freezing weather there. It is a cavity nester and readily accepts boxes.

CHESTNUT-BACKED CHICKADEE (H) *? (CBCH) *Parus rufescens*
This resident species prefers more coniferous habitat for foraging, but often nests in open habitats. This species needs used cavities for nesting, as it cannot excavate its own and readily accepts boxes. This species is also very associated with western hemlock. It is a common breeder in King County (BBA Smith et al., 1997).

COMMON BUSHTIT (H) ?* (old BUSH, new COBU) *Psaltriparus minimus*
This common resident species of the Puget Sound Lowlands is typically associated with human dominated landscapes..

RED-BREASTED NUTHATCH (H) ?* (RBNU) *Sitta canadensis*
This common resident species is encountered in almost all wooded habitats. This species needs snags for nesting, as it does not use boxes .

BROWN CREEPER (H) *?** (BRCR) *Certhia americana*

This common resident species of coniferous forest in western Washington (BBA Smith et al., 1997). Preservation of local trees is essential for its protection. Protection of large conifers is essential for its breeding.

[House Wren] (HOWR) *Troglodytes*

This species was reported as being seen at Paramount Park, but was likely a Bewick's Wren, as it occurs in the Puget Sound Lowland in only a few dry habitat areas like the oak-prairie and ponderosa pine at Fort Lewis or the dry San Juan Islands.

BEWICK'S WREN (H) * (BEWR) *Thryomanes bewickii*

This common resident species of western Washington is associated more with brushy areas than wetlands (BBA Smith et al., 1997) but will use wetlands for foraging, especially during colder weather. Newly fledged feeding juveniles observed at NE 163 and 28 Pl NE.

WINTER WREN (H) *? (WIWR) *Troglodytes troglodytes*

This is a common resident species of well vegetated coniferous forest floor in western Washington. In migration and winter it utilizes a variety of shrubby habitats, and is likely to be present in wetland vegetation, especially during freezing weather. Individuals are heard singing in Richmond Beach into April but do not breed there (DMN Pers Obs.). There are _ records for breeding in the Seattle area (BBA Smith et al., 1997).

VARIED THRUSH (H) (VATH) *Zoothera naevia*

This common resident species of coniferous forest breeds in King County (BBA Smith et al., 1997), but is rarely observed in the Puget Lowlands in summer. In the fall and winter it occurs in deciduous habitats, including forested wetlands, and the wetlands play an important role for winter cover and forage during rare winter storms, when hundreds of varied thrushes can be observed foraging on litter under wetland deciduous trees. This species is also associated with the fall madrone berry crop.

***Swainson's Thrush* (H)** (SWTH) *Catharus ustulatus*

This is an abundant summer breeding thrush in the Puget Lowlands in forested habitat (BBA Smith et al., 1997), along with the American Robin. This species disappears in the winter. Banded at NE 163 and 28 Pl NE.

Hermit Thrush (HETH) *Catharus guttatus*

This species is a common migrant and rare but regular wintering thrush in the Puget Sound Lowlands, where it uses the litter area under wetland deciduous trees for foraging and cover, and uses coastal wetland areas during cold periods. Over the winters of 1998-2002, thrushes have been banded at Shoreview Park between November and March (DMN Unpublished banding results).

AMERICAN ROBIN (H)* (AMRO) *Turdus migratorius*

An abundant adaptable open space and woodland breeding summer resident in Puget Sound, with differing subspecies appearing in migration and in winter (Hunn, 1982). This is one of the most abundant species in all forested habitats, and one of the most common species in Paramount Park.

***Ruby-Crowned Kinglet* (H)** (RCKI) *Regulus calendula*

This is an abundant migrant and wintering species in the Puget Lowlands, occurring in a wide variety of habitats, including forested wetlands, and undoubtedly one of the most likely encountered species at the Paramount Park in the winter. It arrives in October and is gone by mid-April.

GOLDEN-CROWNED KINGLET (H) *? (GCKI) *Regulus satrapa*

This abundant coniferous forest resident is an abundant breeder in King County (BBA Smith et al., 1997), and is commonly heard on all coniferous forests. During the winter, especially in cold weather, it is known to forage in non-coniferous habitats, including wetlands, and forage close to the ground. The close proximity of conifer forest to wetland provides an important benefit of this species. It is a breeder in large cedar dominated conifer forests. New fledglings feeding and banded at NE 163 and 28 Pl NE.

CEDAR WAXWING (H) *? (CEWA) *Bombycilla cedrorum*

This is a common breeding species in the Puget Sound lowlands, rare in winter (Hunn, 1982; BBA Smith et al., 1997). Birds are common in wetland habitats, but avoid more closed forested habitats. This species feeds heavily on fruit.

Bohemian Waxwing (BOWA) *Bombycilla garrulus*

This is a winter vagrant from north and has been seen on ly once in Richmond Beach (DMN Pers Obs.). It occurs in King County from November to March (Hunn 1982).

European Starling* (H) (Residential**)** **(**EUST] *Sturnus vulgaris*

This species was introduced into eastern North American in the late 1800's, and the first starlings occurred in Washington in 1945, and by 1956 winter roosts in the thousands were seen in Seattle (Hunn, 1982). It breeds generally in human associated habitats, though it will occupy appropriate sized nesting holes. It is actually not a species that uses wetlands much, but might visit habitats in the Park in late summer and fall foraging for fruit.

Hutton's Vireo (H)**?* (HUVI) *Vireo huttoni*

This is a resident species in western Washington, associated with mixed coniferous-deciduous forest and is an uncommon breeder in King County (BBA Smith et al., 1997). It is often not recorded during the June BBS surveys because it sings more in early spring and nests as early as March. It is quite retiring in habit when not singing and is therefore not observed, and is often mistaken for the abundant ruby-crowned kinglet. It has never been observed in DMN's Richmond Beach yard (DMN Pers Obs.).
It has been heard at NE 163 and 28 Pl NE.

Western Warbling-Vireo (WAVI) *Vireo swainsonii*

This Neotropcal migrant is an uncommon summer breeding vireo in western Washington, where it nests in deciduous woodlands (BBA Smith et al., 1997.

[Red-eyed Vireo] (REVI) *Vireo*

This species was reported on the Paramount Park list and is possible but is a very uncommon species associated with cottonwood areas, especially on the Snoqualmie River. This species is also easily mistaken for Warbling Vireo, which is a common spring migrant in the city.

C[assin's Vireo] (CAVI) Previously Solitary Vireo *Vireo cassinii*

This is also a Neotropical migrant that breeds in deciduous forest, but it is more abundant in the oak-pine forests in eastern Washington and is less common than the warblng vireo in western Washington. It has not been recorded at DMN's Richmond Beach yard (DMN Pers Obs.) and was only recorded once on the Vashon Island surveys.

Orange-crowned Warbler (OCWA) *Vermivora celata*

This Neotropical Migrant is a common breeding warbler in brushy habitat, breeds in King County (BBA Smith et al., 1997), and is an abundant migrant. It has a well established decline in western BBS counts, making it an important species to protect. Wetland habitat is important is important for this species.

Yellow Warbler **(H)** (YWAR) *Dendroica petechia*

This Neotropical Migrant is a very common bird in willows and wetland vegetation in western Washington, and has shown declines in the BBS. It is not a common breeding species in King County (BBA Smith et al., 1997), but it is expected to breed at the Park because of the open deciduous habitat, and is likely to be observed. Observed at NE 163 and 28 Pl NE.

Yellow-rumped Warbler (H) (YRWA) *Dendroica coronata*

This species is an abundant migrant in the Puget Sound Lowlands (BBA Smith et al., 1997), and uses wetlands as well as forested areas for foraging

Black-throated Gray Warbler (BGWA) *Dendroica nigrescens*

This Neotropical Migrant is listed as a breeding species in King County (BBA Smith et al., 1997), where it uses both riparian as well as coniferous forest. It has never been recorded in DMN's Richmond Beach yard (DMN Pers Obs.).

Townsend's Warbler **(H)** (TOWA) *Dendroica townsendii*

This species is a common migrant and uncommon wintering species in the Puget Sound Lowland, and a rare breeder. Observed at NE 163 and 28 Pl NE.

MacGillivray's Warbler **(H)** (MGWA) *Oporornis tolmiei*

This summer breeding Neotropical Migrant breeds in eastern King County, but the Puget Sound Lowlands are not listed as core habitat, and the Park is west of the edge (BBA Smith et al., 1997). It is typically seen in migration.

Common Yellowthroat (COYE) *Geothlypis trichas*

This common Neotropical Migrant is an unlikely breeder at the Paramount Park. Though it is surprisingly adaptable to a variety of habitats, forested wetlands are not among the preferred sites without some open areas. It may be present at Jackson Park along the many ponds (water hazards). This specie has only been recorded once in Donald Norman's Richmond Beach yard (DMN Pers Obs.).

Wilson's Warbler **(H)** (WIWA) *Wilsonia pusilla*

This is one of the most commonly encountered warbler in Paramount Park in migration, as it is a vocal singer. It is also listed as a declining species in the BBS in WA. It is a confirmed breeder in King County (BBA Smith et al., 1997), using forested sites similar to the Park, and breeding would be a goal of restoration actions in the Park.

Bullock's Oriole (BUOR) *Icterus bullockii*

This species has become rare in King County where it occurs in deciduous habitats, especially cottonwoods wetlands foraging high in the trees. There are breeding records in the 1980's from Richmond Beach, but none for the 1990's and recent years (DMN, personal Obs).

Red-winged Blackbird (RWBL) *Agelaius phoeniceus*

One would not expect this species to be a breeder at the site, but red-wings often appear in early spring visitor at the Paramount, singing in forested areas in migration.

***Brown-Headed Cowbird* (H)** (BHCO) *Molothrus ater*

This species is abundant in the Puget Lowlands in the summer especially in farmed and open areas, where it forages. It is an important species because it parasitizes many nests of Neotropical Migrants, but the rates of parasitism are not known for many Washington state species of concern. It has been observed at Paramount Park and is likely using Jackson's Park's open areas for foraging. It has adapted to suburban yards to parasitize White-crowned Sparrows and towhees.

WESTERN TANAGER (H) (WETA) *Piranga ludoviciana*

This Neotropical Migrant species is associated with coniferous forest in the Puget Sound Lowlands, and is a common breeder in such habitats in King County (BBA Smith et al., 1997. Pair observed at NE 163 and 28 Pl NE May 2006.

House Sparrow **(***Residential nearby**)** (HOSP) *Passer domesticus*

This abundant semi-domesticated species nests near all human activities, and would be expected to be seen on roads and yards adjacent to the site, but not in the forest interior.

***Pine Siskin* (H)** (PISI) *Carduelis pinus*

This abundant resident species, occurring more at higher elevations, is a breeder in King County but its status in the Puget Sound Lowlands is not well known (BBA Smith et al., 1997). In migration and winter, it occurs in flocks in all forested areas, especially in riparian deciduous forests, and is common, especially in migration. Birds have been confirmed breeding in Richmond Beach. Banded at NE 163 and 28 Pl NE.

AMERICAN GOLDFINCH (H) (*Residential**)** (AMGO) *Carduelis tristis*
This resident of the Puget Sound lowlands becomes abundant in May when additional migrants arrive. It breeds in open fields often later in the year and is a common breeder in King County (BBA Smith et al., 1997). In migration and the winter, it occurs in many forested areas, seeking seeds and catkins of deciduous species, often in the accompaniment with Pine Siskins. Observed flying over Paramount Park. Banded at NE 163 and 28 Pl NE.

Cassin's Finch *Carpodacus purpureus*
This is the resident finch of east-side coniferous forest, and is rare outside of the Cascades, so this species was removed from the annotated list as a regular species in Paramount Park.

PURPLE FINCH (H) (PUFI) *Carpodacus purpureus*
This is the resident finch of coniferous forest, and is rare outside of the forests where House Finches dominate the open suburban yards. Its status in the Paramount Park is unclear. No birds have been seen in Richmond Beach for over 10 years (DMN, Pers. Obs.). Seen at NE 163 and 28 Pl NE in 2005.

HOUSE FINCH (H) (*Residential nearby**)** (HOFI) *Carpodacus mexicanus*
This species has expanded its range into the Pacific Northwest, and now occurs in all areas associated with human activity. It is breeding in close proximity to houses. Observed at Paramount Park. Newly fledged feeding and banded at NE 163 and 28 Pl NE.

Red Crossbill (RECR) *Loxia curvirostra*
This common resident of the coniferous forest wanders widely in the Puget Sound lowlands and is generally recorded flying overhead. It is likely to be seen in Douglas Firs on the site. It has been documented as a breeder in nearby Shoreview Park.

EVENING GROSBEAK (H) (EVGR) *Hesperiphona vespertina*
Though this species breeds in King County (BBA, Smith et al 1997), it is mostly observed flying overhead, or seen feeding on seeds and catkins of deciduous trees, some of which occur in the Paramount.

SONG SPARROW * (H) (SOSP) *Melospiza melodia*
This is a common resident of brushy habitat and is a common breeder in King County (BBA, Smith et al 1997). In the Park it uses wetter areas for

breeding and additional birds may arrive as early as August from other areas (as confirmed by banding records in Richmond Beach in August 2002) and spread out into other habitats during the wintering season. Observed at Paramount Park. Newly fledged feeding and banded at NE 163 and 28 Pl NE.

Lincoln's Sparrow (LISP) *Melospiza lincolnii*

This species may breed in the mountains of King County (Hunn 1982, and is a common migrant and rare winter resident in the Puget Sound Lowlands, where it prefers open grassy wet areas so it is unlikley that it would occur in the forested areas or wetlands of Paramount Park. It does occur in more forested areas during migration, as evidenced by several banding records in Richmond Beach (DMN, personal obs).

***Fox Sparrow* (H)** (FOSP) *Passerella iliaca*

This species may breed in the mountains of King County (Hunn 1982). It is a common winter resident, most abundant in salal in the winter, but it also occurs in brushy areas and wetlands, and is especially common in cold events. It is also associated with madrone forests, especially where there is salal in the understory.

WHITE-CROWNED SPARROW *? (H) (WCSP) *Zonotrichia leucophys*

There are several White-crown subspecies in western Washington, one present only in the summer as an abundant breeder in variety of field and shrubby habitats, but several other subspecies are common migrants and uncommon winter residents, and just at the Golden-crowned Sparrow, may occur on more of the upland sites, except in cold periods, when it may use wetland areas for water and cover

GOLDEN-CROWNED SPARROW (H) (GCSP) *Zonotrichia atricapilla*

This is an abundant migrant and common winter resident in western Washington, and it is more of an upland brushy habitat species than a forested wetland species. This species may occur on more of the upland sites, except in cold periods, when it may use wetland areas for water and cover.

DARK-EYED (Oregon) JUNCO *? (H) (DEJU) *Junco hyemalis*

This is a resident common species of coniferous forest edge and an abundant winter resident in western Washington, using a variety of edge habitats, and foraging in wetlands especially in cold weather, and using wetlands for cover. In many areas in the Puget Sound Lowlands it disappears in the summer, but the presence of the bird in the summer indicates that good nesting habitat exist in the upland mixed forest. It breeds in the Highlands and Grace Cole Park, which has a much larger open coniferous forest, so it is not clear if it remains to breed at Paramount.

SPOTTED TOWHEE * (H) (SPTO) *Pipilo erythrophthalmus*

This is a resident common species of brushy habitat especially associated with wetlands (BBA Smith et al., 1997). It may also tend to flock in wetland areas in the winter, as banding studies have shown larger numbers of towhees in a small wetland at McChord AFB in the winter than occur in the area in summer. Towhees were heard singing on the April 2000 visit, and heard on the August 2000 visit (DMN), as well as on many other trips. Observed at Paramount Park. Newly fledged feeding and banded at NE 163 and 28 Pl NE.

***Black-Headed Grosbeak* (H)** (BHGR) *Pheucticus melanocepalus*

This Neotropical Migrant breeding species is confirmed as a breeder in King County (BBA Smith et al., 1997) though it is not nearly as common as in eastern Washington. It occurs in forested wetland and deciduous areas, but may not breed at Paramount Park.   It uses the site during migration and appears to be more common in the fall, when birds start passing thru the area in early August (DMN Pers Obs, Richmond Beach).   Observed flying over Paramount Park and feeding at NE 163 and 28 Pl NE.

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DEPARTMENT OF
ECOLOGY
State of Washington

Update on Wetland Buffers: The State of the Science

Final Report

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Update on Wetland Buffers:

The State of the Science

Final Report

October 2013

by;

Thomas Hruby, PhD

Shorelands and Environmental Assistance Program

Washington State Department of Ecology

Olympia, Washington

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Acknowledgements

This update would not have been possible without the help of all those who participated in the original 2005 synthesis. The 2005 synthesis provided an easy format to follow in updating the science and this helped focus our efforts in our search for more recent studies. I also wish to thank all the reviewers of this update within the Washington State Department of Ecology, Washington Department of Fish and Wildlife, and wetland scientists and regulators outside these agencies. Their efforts have made this a much better and coherent document.

NOTE: We are using an alternate format for scientific citations in this report. Instead of citing the authors and the date, each reference is assigned a number based on its position in the alphabetic list of references at the end of this document. This is the format used by scientific journals such as *Science, Nature,* and the *Proceedings of the National Academy of Science.* This format is easier to read when a statement is supported by multiple citations, and it reduces the length of the text.

1.0 Introduction

In 2005 the Washington State Department of Ecology (Ecology) published a synthesis of scientific information available on freshwater wetlands, their functions, and their management (81). The purpose of the synthesis was to provide local governments in the state with the best available science (BAS) when managing their wetland resources. Using BAS in making decisions was mandated by the 1995 amendment to the Growth Management Act (Revised Code of Washington (RCW) 36.70A.172[1]).

Our scientific knowledge is continually increasing and changing and we recognized that the synthesis would need periodic updates. Much of the information presented is still valid, but research in the last decade has provided new data to expand and clarify many of the conclusions made in the original synthesis. This is especially true for the information on the role of buffers in protecting wetland functions.

Buffers are vegetated areas adjacent to aquatic resources that can, through various physical, chemical, and/or biological processes, reduce impacts to these resources from adjacent land uses. Buffers also provide some of the terrestrial habitats necessary for wetland-dependent species that require both aquatic and terrestrial habitats.

Several jurisdictions, including Island County and San Juan County, have developed their own syntheses of scientific research based on some of the more recent information on buffers. These syntheses focused on the wetlands found within their jurisdiction and the information may be limited relative to other areas in the state. Ecology is expanding on these efforts. The goal is to provide updated information on wetland buffers that can be applied statewide. The objective is to synthesize the information on buffers that was published between 2003 and the winter of 2012. We focus on wetland buffers, since buffers are one of the most common elements of wetland regulations in Critical Area Ordinances (CAO's), and they are consistently the part of a CAO of most interest and concern to the public. Limited resources prevent us from expanding our review and update to other issues at this time.

This update revisits the conclusions and key points concerning wetland buffers made in the 2005 synthesis. Each conclusion is reviewed with respect to any new information that was published between 2003 and 2012, or information in earlier studies that we may have missed and that has come to our attention. If the conclusion is still valid, new references supporting it are noted. If the conclusion needs to be expanded or modified, then revised conclusions are presented based on the new information. In reviewing the recent information we also found that some of the studies address issues that were not commonly discussed in the past. New conclusions that can be made from this information are presented as updates of old conclusions in the appropriate sections.

This synthesis DOES NOT contain agency recommendations or suggestions for implementing programs to protect or manage wetlands using buffers. Its purpose is to identify the sources of information reviewed and relied upon by Ecology in the process of updating our guidance on wetland buffers as required in state law (HB1113). Any recommendations documented here are those that have been described in the literature. They are included here only as part of the synthesis of existing scientific information. Agency recommendations that stem from this synthesis will be provided as supplements to the Appendices in Ecology publication #05-06-008, Wetlands in Washington State, Volume 2: Guidance for Protecting and Managing Wetlands.

2.0 Approach Used to Synthesize the Literature for the Update

As the amount of scientific information grows exponentially, scientists are developing tools to help synthesize this information. This update was conducted using the guidelines for scientific syntheses described by Pullin and Stewart (61). The guidelines involve a six-step process that includes:

- Formulating questions that need to be answered by the synthesis
- Defining and implementing a strategy for searching the literature
- Cataloguing and prioritizing the importance of articles based on the questions in #1
- Reading and extracting key information relevant to the questions
- Synthesizing the information by identifying connections among topics
- Peer review of synthesis

2.1 Questions that need to be answered by the synthesis:

The questions posed for this synthesis are:

- Are the conclusions and key points regarding wetland buffers made in the 2005 synthesis still valid?
- If not, what new conclusions can be made from the recent research about how buffers protect wetland functions?

> The scope of the literature review on buffers is the same as described in Sections 1.2 and 1.3 of our original synthesis in 2005 (81). We focus our review on information relevant to the effectiveness of buffers at protecting the functions of freshwater wetlands in Washington State.

2.2 Strategy for searching literature

We began by starting a project file to hold paper copies of all the studies found in the search. If we printed an article from a digital file, we also saved the digital version.

Initially, we reviewed and compiled articles referenced in more recent syntheses done for Island County (http://www.islandcounty.net/planning/criticalareas/BestAvailableSciencePhaseII.pdf.pdf) and San Juan County (http://www.co.san-juan.wa.us/cao/BAS_Synthesis.aspx). We flagged all articles whose title or summaries met our search criteria (see bulleted list below) and that were published after 2002. We obtained copies of these articles from web searches, and if the entire article was not available, we printed and filed copies of the abstract.

In addition, Ecology maintains a library of more than 5000 scientific articles related to wetlands that has been updated weekly since 1992. The original database used to store bibliographic information was RefBase® but all entries were moved to Endnote® when we switched to a Windows 7® platform. Ecology subscribed to ISI's Current Contents ® which provided a weekly list of the table of contents of over 150 journals in the ecological and biological sciences. Articles of interest to the program were requested from the authors and added to the library and database when received. For this synthesis we searched our database for articles published after 2002 using the same keywords listed below. The abstracts of these selected articles were read, and if the data presented were relevant to the questions being asked in this synthesis, a copy of the article was placed in the project file.

Next, we searched Google Scholar ® using "buffers" as a keyword, followed by each of the following terms separately:

- Wetland
- Amphibians
- Mammals + wetland
- Birds + wetland
- Fish + wetland
- Names for each species of amphibians found in Washington as listed in Leonard and others (46).
- Wetland + water quality
- Wetland + flood reduction
- Wetland + hydrologic functions
- Wetland + functions

Titles that appeared potentially useful were accessed on the web, and if the abstract indicated the data were relevant to the questions, a copy of the article or abstract was placed in the project file.

Finally, we searched for articles of interest that were cited in those found during the basic search.

We reviewed over 300 abstracts and obtained 144 published articles for the project file.

2.3 Cataloguing and prioritizing the importance of articles

All of the articles and reports in the project file were read and the important information each contained was highlighted in the document. Articles were sorted based on the following topics:

- Amphibians
- Birds
- Mammals
- Reptiles
- Fish
- Water Quality
- Policy and Regulation

In the 2005 synthesis we concluded that buffers do little to protect the hydrologic functions of wetlands (storing water and reducing the velocity of flows within the wetland itself). No articles were found in this search to suggest this conclusion needs to be changed so we did not include this topic in the sorting.

Within each topic, articles were further sorted based on the location of the research (Northwest, U.S. outside of the Pacific Northwest, elsewhere) and whether the research discussed landscape issues or site scale issues.

During the initial screening, each article was categorized by its importance and relevance to the synthesis as A (highest priority for inclusion in the synthesis), B (moderate priority), and C (lowest priority). Highest priority was assigned to publications that described original research in the Pacific Northwest and that met the highest standards for "Best Available Science" as outlined in WAC 365-195-900 through 925. We assigned a lower priority (B) to publications that dealt with buffers in general or research done outside the Pacific Northwest, and (C) to those that did not undergo peer review. By peer review we mean articles that have been published in peer reviewed journals or documents that were reviewed by outside experts and that describe the review process in the document. We made a special effort to obtain copies of articles in Category A.

2.4 Reading and extracting key information

We read all articles in Categories A and B, and some in Category C. As each article was read, the keywords originally assigned to the article were checked and modified as needed. Notes and keywords were written directly on a copy of each article and it was then filed by topic and sub-topic. If an article addressed more than one topic we made an additional copy for each topic. We incorporated relevant information from each article directly in the text of this synthesis as it was being written, using the notes made on the paper copy.

2.5 Synthesis of information

The 2005 synthesis contained numerous conclusions and key points made from the literature review. Conclusions were in the beginning of each section and key points at the end. For this synthesis we treated each of conclusion and key point made as a separate item to update. Our objective was to determine if the new information in the recent scientific studies was consistent with the older studies. If conclusions and key points were not consistent, they were modified based on the more recent information compiled.

2.6 . Peer Review

A preliminary draft was reviewed by habitat biologists from the Washington Department of Fish and Wildlife and by wetland scientists at the Department of Ecology. Their comments were incorporated into a draft that went out for a more general review. This latter draft was sent to over 900 subscribers of Ecology's wetlands list serve for comment and review. Subscribers to the list serve include wetland scientists, consultants and regulators. The final draft incorporates the comments received through October 2013 from these outside reviewers. All the comments and our responses to them will be published in a separate document, and will be available on our web site after January 2014: http://www.ecy.wa.gov/programs/sea/wetlands/bas/index.html.

3.0 Update on the Conclusions and Key Points from the 2005 Synthesis

We include all the conclusions and key points regarding buffers from the 2005 synthesis in italics. These are copied, unedited, from the original text.

3.1 General conclusions in the introduction to section 5.5 (section on buffers)

Conclusion - *Page 5-23: The majority of research on buffers tends to focus on the processes that buffers provide to filter sediment or take up nutrients (i.e., their influence on water quality). Far fewer studies look at the influence of a buffer's physical characteristics on attenuating surface water flow rates, except as it relates to water quality. The long-term effectiveness of buffers in providing such mechanical and biological processes is not well documented in the literature and may represent a critical need for future research.*

Update: This conclusion is still valid. We were unable to find any new research documenting how buffers can attenuate surface water flow rates in the context of reducing the intensity of stormwater flows and potential flooding in a wetland. Some reports discuss the increased infiltration that occurs in vegetated buffers (35, 90), but these studies are focused on the higher rates of nutrient removal that occur when polluted waters enter vegetated buffers.

There is, however, one logical inference that can be made on how buffers protect the hydrologic functions of certain types of wetlands. Depressional wetlands, especially those with no outlet, reduce storm flows by storing water and releasing it more slowly than the surrounding uplands (9, 40). The amount of stormwater a wetland can store will be reduced if the surface flows coming into the wetland contain sediment and fill the depression. A vegetated buffer can trap sediments before they reach the wetland (35, 55, 95), and thus protect its storage capacity. This inference, however, has not been validated with any studies.

Conclusion - *Page 5-23: The literature on buffers related to wildlife is, in general, less focused. Most studies document the needs of a particular species or guild relative to distances for breeding or other life-history needs within a radius from aquatic habitats.*

Update: Studies that document the needs of particular species or guilds continue to be published. However, there have also been recent attempts to document and model the abundance and extinction rates of amphibian populations relative to specific buffer widths (e.g. 5, 29).

Conclusion - *Page 5-23: There is substantial literature on the implications of habitat fragmentation and connectivity, some of it related specifically to agricultural practices, forestry practices, or the impacts of urbanization. This literature does not specifically address the role of buffers in providing connectivity between wetlands and other parts of the* *landscape. It does, however, unequivocally support maintaining connectivity between wetlands in order to maintain viable populations of species that are closely associated with wetlands.*

Update: The relationships between buffer width, habitat fragmentation, and connectivity are increasingly being studied, especially as it relates to birds and amphibians. Buffer widths are one of the variables that are analyzed in studies that look at several landscape factors together to explain population dynamics and abundances of wetland-dependent species (e.g., 54, 68, 69, 74, 83, 94). The new information takes a closer look at the relationships between buffers, corridors and fragmentation. These studies are reviewed in the sections discussing wildlife, specifically birds and amphibians.

Conclusion - *Page 5-23: Older research studied the tolerance limits of wetland wildlife for disturbance—how closely a disturbance can approach animals before they are flushed from wetlands—with particular emphasis on waterfowl. These studies tend to be older than 1990 and focus on the prairie pothole region of North America. Where the findings are germane and where they have not been superseded by more recent work, they are included.*

Update: A number of new articles have been published on the flushing distances for wetland birds in different parts of the world (6, 22, 41, 93) to supplement past research. In addition, one study (15) documents the impact of disturbance from a major highway on populations of frogs in wetlands at different distances from the road.

3.2 The role of buffers in protecting water quality

Conclusions: Page – 5-27. *Buffers protect the water quality of wetlands through four basic mechanisms:*

- *They remove sediment (and attached pollutants) from surface water flowing across the buffer.*
- *They biologically treat surface and shallow groundwater through plant uptake or by biological conversion of nutrients and bacteria into less harmful forms*
- *They bind dissolved pollutants by adsorption onto clay and humus particles in the soil*
- *They help maintain the water temperatures in the wetland through shading and blocking wind.*

Update: Recent research indicates that buffers protect water quality through several additional mechanisms:

- They remove pollutants from groundwater flows through interaction of the soils and deep-rooted plants (36, 49, 60, 63, 90).
- They infiltrate polluted surface waters and slow the flow so pollutants can be removed more effectively (8, 60).

- They may lose their effectiveness if they are subject to very high levels of pollutants. If they become saturated with sediment and phosphorus they can no longer trap these pollutants (56).

Some of the studies on the effectiveness of buffers at protecting water quality cited in the original synthesis (81) and in this update were done in the buffers of streams and rivers (commonly called the riparian zone). The ecological attributes by which buffers protect water quality do not depend on whether the buffer is adjacent to a stream or a wetland. The original synthesis (81) describes these ecological attributes that are common to buffers of riparian areas and wetlands in more detail (Section 5.5).

<u>Key point #1</u>: Page 5-38. *The use of buffers to protect and maintain water quality in wetlands (removing sediments, nutrients, and toxicants) is best accomplished by ensuring sheet flow across a well-vegetated buffer with a flat slope (less than 5%).*

Update: Recent research suggests that the effectiveness of a buffer is also based on factors other than sheet flow, vegetation, and slope.

- Buffer width and slope are only two of the six factors found to be important (8). The other four are soil infiltration, surface roughness (partially caused by vegetation), slope length, and adjacent land use practices.
- Mayer and others (49) analyzed 45 published studies on nitrogen removal in buffers and concluded that there was a broad range of results in effectiveness when only buffer width and vegetation were considered. Their analysis suggests that soil type, subsurface water regime (e.g. soil saturation, groundwater flow paths) and subsurface biogeochemistry (the supply of organic carbon and inputs of nitrate) are also important factors.
- A review of the literature on the removal of phosphorus in buffers (36) found that the interactions between groundwater and surface water are important for the biogeochemical processes governing phosphorus dynamics in buffers. The different paths by which water moves through the buffer determine where and how phosphorus compounds meet and interact with the minerals and how phosphorus attached to sediments is trapped.

<u>Key point #2</u>: Page 5-38. *Significant reductions in some pollutants, especially coarse sediments and the pollutants adhered to them, can be accomplished in a relatively narrow buffer of 16 to 66 feet (5 to 20 m), but removal of fine sediments requires substantially wider buffers of 66 to 328 feet (20 to 100 m).*

Update: Owen and others (55) confirmed the original conclusion that fine sediments are not effectively removed in narrow buffers. Most of the recent research however, has focused on refining the factors that have caused the large variations in the earlier measurement of the efficiency of a buffer at trapping sediments.

- Yuan and others (95), in a review of literature on vegetated buffers in agricultural areas, concluded that the efficiency in trapping sediments depended on vegetation type, the density and spacing of plants, the size of sediment particles, the slope gradient and length, and flow convergence, as well as the buffer width.
- Site-specific factors (vegetation density and spacing, initial soil water content, saturated hydraulic conductivity, and sediment characteristics) are so important in determining the effectiveness of a buffer that simple designs that do not account for these factors can fail to perform their protective functions (60).
- Only a small fraction of the total buffer area (9%-18%) in four sites measured actually was in contact with surface runoff which may result in reducing the trapping efficiency from 41%-99% to an actual 15%-43% (13).

Key point #3 – Page 5-38. *Removal of dissolved nutrients requires long retention times (dense vegetation and/or very low slope) and, more importantly, contact with fine roots in the upper soil profile (i.e., soils that are permeable and not compacted). Distances for dissolved nutrient removal are quite variable, ranging in the literature from approximately 16 to 131 feet (5 to 40 m).*

Update: More recent research has focused on identifying the specific environmental processes that remove nutrients in buffers and in modeling the removal of nutrients by buffers at a watershed scale. Again, the research shows that the processes are more complicated than initially reported, and they are very site specific (14). Also there are differences in the processes that remove nitrogen from those that remove phosphorus (25, 36, 49). During certain times of the year a buffer might release phosphorus rather than trapping it, especially if it has been receiving excessive amounts (87, and a review in 36).

Most of the studies that have been done in the last three decades focus on the efficiency with which a buffer removes pollutants. These studies do not address the potential impacts of the pollutants that escape the buffer into the wetland. We only found one study (38) that monitored water quality in wetlands relative to the amount of forest present in the surrounding landscape. The levels of sediment, nitrogen, and phosphorus in 73 wetlands in Ontario, Canada were analyzed statistically relative to the amount of forest to a distance of 5000m from the wetland. When these data were analyzed, Houlahan and Findlay (38) found that the level of nitrogen and phosphorus in wetlands was negatively correlated (i.e., concentrations of the pollutants in the wetlands increased as the amount of forest decreased) with forest cover up to a distance of 2250 m. The levels of phosphorus attached to the sediments coming into wetlands was negatively correlated (using multiple linear regression models) with forest cover up to a distance of 4000m from the wetland.

Update on the information on nitrogen (N) removal:

- Removal of nitrogen in the groundwater flowing through a buffer does not appear to be related to buffer width, while removal of nitrogen from surface water was only partly related to the width of the buffer (49). The reduction of nitrate in groundwater flowing through a buffer has been attributed to denitrification, uptake by vegetation as function of its density, and immobilization by micro-organisms (review in 63).

- Plant uptake and microbial immobilization represent only a temporary storage since the nitrate will be released on death of the organisms (63).
- Measurable rates of denitrification occur only if there is organic matter in the soil and anoxic conditions (49, 63). Denitrification generally does not occur in surface waters because they are oxygenated. In addition to anoxic conditions and organic matter, the rates of denitrification are controlled by variability in nitrate concentrations in the groundwater (13 references cited in the review by 63) and the flow path of groundwater (49).
- The relative removal of nitrate in a buffer is reduced as the concentration of nitrate in the incoming water is increased. Data collected in 14 sites across Europe found that the rate of nitrate removal dropped to 0% when the concentration of nitrate was above 20 mg/l (75).
- Modeling nitrate removal at a watershed scale supports the view that in some cases a buffer width of less than 20m (66ft) is sufficient for nitrate removal. This conclusion, however, does not hold if the soils in the buffer are coarse grained or nitrate transport occurs mainly through groundwater seeps that are fed by infiltration within the watershed (90). Baker and others (2) have also found that buffer width does not adequately quantify the effects of buffers on nutrient dynamics at a watershed scale. They analyzed 503 watersheds in the Chesapeake Bay drainage and found that variables based on the flow path through the buffer and how the buffer functions provided greater detail and flexibility in understanding nitrogen dynamics than just the width.

Update on the information on Phosphorus (P) removal:

- Phosphorus in runoff coming into a buffer can be removed by sorption onto soil particles, sedimentation of phosphorus bound to other particles, and through uptake by plants. These processes however, may not be linked so it is difficult to predict how well a buffer will remove phosphorus (35, 36). A review of the research done regarding phosphorus (36) found that the effectiveness of a buffer depends on many different factors including:
    - Soil type (sorbents, redox state, pH)
    - The degree of saturation of phosphorus on soil particles.
    - The slope and width of the buffer.
    - The types of plants present and how they are managed.
    - The amount of land in the surrounding landscape that is the source of the phosphorus.

- The ratio of the buffer area to the area of the source of the phosphorus.
- The flow path of surface and groundwater and its interaction with iron, aluminum oxides, or other minerals that bind dissolved phosphorus.

- Most of the phosphorus coming into a buffer is bound to sediments. Removal of phosphorus is closely linked to the effectiveness of a buffer at trapping sediments (8, 35, 36, 55).
- The capacity for phosphorus removal is finite and a buffer may become saturated so that it no longer removes phosphorus. This is especially true for dissolved phosphorus that relies on binding to minerals in the soil. Once all binding sites are full, the dissolved phosphorus will flow through the buffer. (35, 90).
- Buffers may release stored phosphorus under certain conditions. This can result in pulses of much higher phosphorus concentrations (8, 36 , 87) to the wetland. If the soils in a buffer are saturated with phosphorus, changes in temperature, pH, and volume of the flows coming through the buffer can cause a release of phosphorus (87, 90).

Key point # 4: Page 5-38. *The literature is consistent in finding that it takes a proportionally larger buffer to remove significantly more pollutants because coarse sediments and the pollutants associated with them drop out in the initial (outer) portions of a buffer. It takes a longer time for settling, filtering, and contact with biologically active root zones to remove fine particles and dissolved nutrients.*

Update: The recent research and reviews confirm this conclusion (13, 49, 76, 95). In general, the removal of pollutants relative to the width of the buffer follows a mathematical curve that is exponential with fractional exponents (Figure 1). The figure also shows that the relationship between the effectiveness of a buffer and its width is not statistically very strong. Many data points lie far away from the actual curve. This provides a graphical representation of the conclusion that buffer width is only one of several variables that determine the efficiency of the buffer at removing nitrogen.

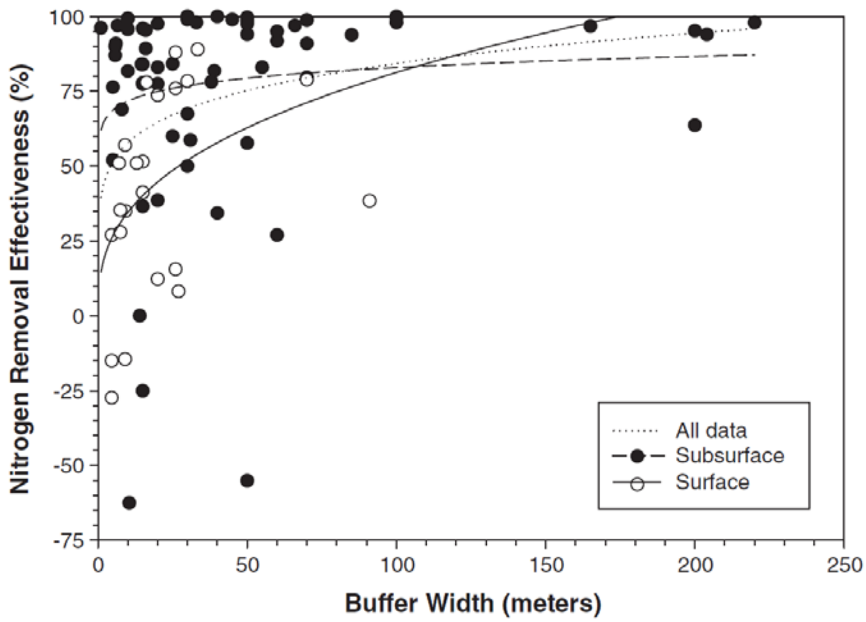


Figure 1: An example of the removal of nitrogen as a function of the width of the buffer based on data published for 89 individual measurements (figure is from 49).

Another meta-analysis by Zhang and others (96) analyzed the data from 73 published papers on the effectiveness of buffers at removing pollutants. Their conclusions were that width alone explains only part of the effectiveness of a buffer at removing pollutants. Width alone as a variable explains only:

- 37% of the effectiveness at removing sediments,
- 60% of the effectiveness at removing pesticides,
- 44% of the effectiveness at removing nitrogen compounds,
- 35% of the effectiveness at removing phosphorus compounds.

The other environmental variables that were analyzed were slope, drainage category of soil, and type of vegetation (trees, grasses, trees + grasses). Of these four additional variables, only three were significantly correlated with removing pollutants. The soil drainage type did not show a significant effect on the efficacy of removal.

Both the Mayer (49) and Zhang (96) studies have fit mathematical curves (called models) to the data showing how effectiveness at removal increases with increasing buffer width (the lines in Figure 1 above). These models however, do not provide much useful information for establishing standards for removing pollutants based on width alone. The variability in the data makes it difficult to assume that a specific width will provide adequate protection. For example six of the 89 measurements (7%) show a release of nitrogen (rather than removal) for buffers widths up to 50 m (~160ft). A buffer of 20 m (66ft) can remove 30% of the nitrogen in one case and 75% in another.

Statisticians calculate a number called R^2 that provides an estimate of how much the data vary relative to the mathematical line they calculate. It is an estimate of the fraction of the variability in the data can be explained by the model. An R^2 of 1 means all points lie on the line and there is a perfect fit between the line and the data. An R^2 of 0 means the data do not fit the proposed mathematical line. In Figure 1 shown above (from 49) the R^2 for all data was 0.09 and 0.21 if only the nitrogen removal along the surface was considered. This indicates that a buffer width chosen using the line will match the removal effectiveness (numbers on vertical axis) only 21% of the time. For example, the model shows that a buffer width of 50 meters (164 ft) will remove about 60% of the nitrogen coming through in surface water. However, the low value for the R^2 indicates that this will be true only 21% of the time.

Similar graphs in Zhang and others (96) had R^2 values of 0.37 for the removal of sediment vs. width; R^2 = 0.44 for the removal of nitrogen; R^2 = 0.60 for the removal of pesticides and 0.35 for the removal of phosphorus. Scientists, however, usually consider a line is a good fit to the data if the R^2 value is at least 0.7 or higher. From a management perspective, an R^2 of 0.7 indicates that a proposed buffer width that falls on the line will provide the level of protection modeled 70% of the time.

Key point #5: Page 5-38. *The role of buffers in protecting the microclimate of streams is well documented and may be applicable to wetlands, but no specific data on buffers and wetland microclimate maintenance were found.*

Update: We were unable to find any new information on how vegetated buffers may protect the microclimate of wetlands. This function is acknowledged as probable (50), but we have not found any field data to support this assumption.

The focus of current research is still on the role buffers play in protecting the microclimate of streams. However, we judge that this information has a limited applicability to wetlands. The shading and attenuation of wind by trees in the buffer will only extend a short distance from the edge. Thus, the microclimate in the center of larger depressional wetlands will be dependent on other factors. Forested buffers on streams can have a larger impact on microclimate because streams are narrow and linear, and the ratio of edge to total area is much larger. In addition, the research on buffers, streams, and microclimates has focused on forested buffers. Many wetlands in eastern Washington do not have forested buffers, and this work would not be applicable in any case.

3. 3 The role of buffers in protecting wildlife habitat

Conclusions on how buffers function: bulleted list on Page 5-38. *Wetland buffers are essential to maintaining viable wildlife habitat because they perform three overlapping functions:*

- *Buffers can provide an ecologically rich and diverse transition zone between aquatic and terrestrial habitats. This includes necessary terrestrial habitats for many wildlife species that use and/or need wetlands but also need terrestrial habitats to meet critical life requirements.*

Update: Some ecologists are now calling buffers that provide critical life requirements for wetland dependent species "core habitats" rather than buffers (10, 79, 80, 82). The distinction is related to the idea that the buffer is not reducing (buffering) impacts to the functions provided by a wetland. Rather, wetlands in proximity to adjacent upland habitat provide a critical function. The combination of the two habitat types is essential to a suite of species that would be absent from either habitat alone. These core habitats are essential to a number of wetland-dependent species, including amphibians (80). Inadequate quantity or quality of core habitat will increase the probability of local amphibian population extinction (77). In addition, some scientists suggest that the core habitat itself requires a buffer to protect its habitat functions from outside disturbances (80).

- *Buffers can screen wetland habitat from the disturbances of adjacent human development.*

  Update: This conclusion is often made (42, 50), but there is little new research to provide additional documentation. Noise from an adjacent highway has been hypothesized as one factor that reduces the species richness and abundance of frog populations in wetlands with smaller buffers (15).

- *Buffers may provide connectivity between otherwise isolated habitat areas.*

  Update: Recent research is emphasizing that relatively undisturbed uplands between wetlands are important for maintaining the populations of many wetland-dependent species (3, 5, 66, 69, 77). A narrow undisturbed buffer can provide the first stage of a connection between wetlands, or it alone can provide that connection if wetlands are close together. A buffer, however, that is not part of a system of connected upland and wetland habitats may not provide adequate protection for populations of amphibians (5).

<u>Conclusion</u>: Page 5-38. *In regard to wildlife, most of the scientific research is not directly focused on the effectiveness of buffers for maintaining individuals or populations of species that use wetlands. Some of the research simply documents use of upland habitats adjacent to wetlands by wildlife to meet their life-history needs. For example, a substantial body of research identifies the distances that amphibians may be found away from a wetland edge. However, the implications to amphibian populations of providing buffers that are smaller than those identified ranges are not well documented.*

Update: The effects of buffers, their width and structure, on wildlife populations are being increasingly studied. In the last decade there have been numerous studies assessing the impact of buffer widths on populations of amphibians (5, 15, 29, 86) and wetland-associated birds (12, 27, 28, 33, 48, 52, 58, 83, 84). These will be discussed in more detail in the sections on amphibians and birds.

<u>Conclusion:</u> Page 5-41. *One consideration not found for this synthesis was the implication of the condition of the upland buffer relative to its provision of wildlife habitat. In several studies on the use of upland buffers by native species, the study identified that the buffer was upland forest. However, no studies were reviewed for this synthesis that compared wildlife*

use of mature forested buffers with buffers composed of meadow, shrubland, harvest forest, or younger forests. Some research has identified the importance of intact forest habitat to wetland-related species (Azous and Horner 2001, Richter 1997), but a comparison study was not found for this synthesis.

Generally, wildlife species have varying needs for different types of adjacent habitat for different life needs, such as breeding, foraging, and resting (Brown 1985). This makes it difficult to prescribe one particular type of habitat as best for wildlife. Habitat is very species specific. However, as a general rule, most researchers have recommended that buffers be maintained or restored to a forested condition if only for the screening function they provide. (Obviously, this has little relevance to the shrub-steppe ecoregion in Eastern Washington, where trees are rarely found.)

> Update: More recent research confirms that preferences for the type of vegetation in a buffer are very species specific.
>
> For example, among species of amphibians found in Washington State, the western toad (*Bufo boreas*) prefers uplands that are forested (51) and specifically open forest over forests with closed canopies (4). On the other hand, the Woodhouse toad (*Bufo woodhousii*) and the northern leopard frog (*Rana pipiens*) prefer open landscapes dominated by natural grasses (51). The Columbia spotted frog (*Rana luteiventris*) found in Oregon prefers agricultural areas and shrub/clearcut (24).
>
> Another study (69) using radio tags found that spotted salamanders (*Ambystoma maculatum*) will actively seek a forested buffer for migration when part of the buffer is grassland. Salamanders moved from water to upland habitat only along the side of the wetland that was forested. If salamanders came across grasslands as they moved from a wetland, they often returned to the wetland. Another study of this species found that the strength of the grassland as a barrier can depend on weather conditions. Spotted salamanders did move into grasslands when it rained and the grasses were wet (89).
>
> The presence of a forested buffer was also found to be an insignificant factor in the distribution of many bird species. Smith and Chow-Fraser (83) found that the presence of a forested buffer surrounding a wetland in Ontario Canada was not an important factor in predicting the distribution of generalist, wetland-dependent, or synanthropic species in wetlands. (Synanthropic bird species are those that have adapted to living in developed and residential areas).

<u>Key point #1</u>: Page 5-49. *There is no simple, general answer for what constitutes an effective buffer width for wildlife considerations. The width of the buffer is dependent upon the species in question and its life-history needs, whether the goal is to maintain connectivity of habitats across a landscape, or whether one is simply trying to screen wildlife from human interactions.*

> Update: The recent research is showing that the answer for what constitutes an effective buffer is even more complex than summarized in Key point #1. Studies and models are beginning to address the impact of different buffer widths on populations.

These studies address the question: what is the probability of extinction for a population of a wetland-dependent species at different buffer widths?

For example, Figure 2 graphs the probability of extinction over time for the wood frog (*Rana sylvatica*) and the spotted salamander (*Ambystoma maculatum*) for different buffer widths (29, 51). The spotted salamander has a low probability of extinction as long as the buffer is wider than 20m. The wood frog on the other hand, has a 10% chance of extinction even with a buffer that is 1000m wide.

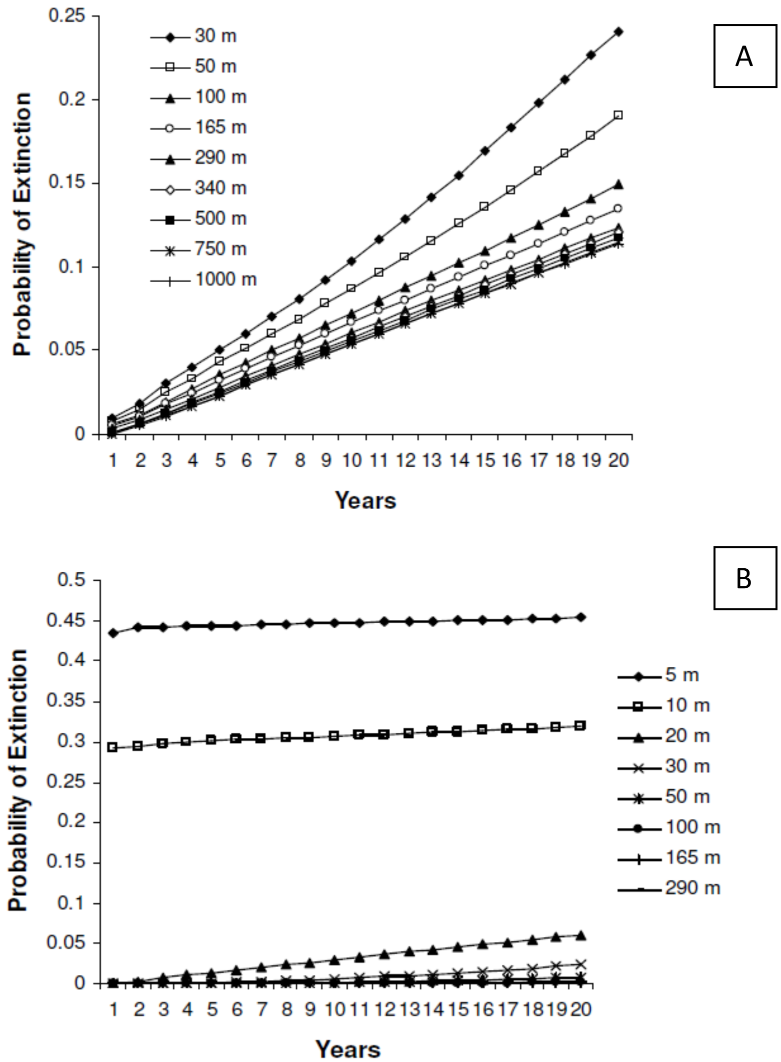


Figure 2: Results of model simulation predicting the probability of extinction of (A) wood frog populations and (B) populations of spotted salamanders as a function of the width of the terrestrial core habitat (buffer) [from 51].

<u>Key point #2</u>: page 5-49. *The majority of wildlife species in Washington use wetland habitats for some portion of their life-history needs. Many species that are closely associated with wetlands (those that depend upon wetlands for breeding, brood-raising, or feeding) depend upon surrounding upland habitats as well for some life-history stages.*

Update: The need for appropriate upland habitat has been well documented for amphibians and continues to be a focus of recent research (10, 11, 17, 21, 29, 37, 51, 70, 77, 86). Wetland-dependent birds are another wildlife group that continues to be a focus (22,28, 33, 48, 72, 83, 93). In addition the research has also expanded to include invertebrates such as dragonflies (7) and biting midges (Chironomids) (43).

Key point #3: Page 5-49. *Many terrestrial species that are dependent upon wetlands have broad-ranging habitats, some over 3,280 feet (1,000m) from the source wetland. Although this might be expected for large mammals such as deer or black bears, it is also true for smaller species, such as salamanders and other amphibians.*

Update: Numerous studies document the habitat zones and needs for individual wetland-dependent amphibians and birds. This research documents the movement of wetland-dependent species into the surrounding uplands. Increasingly, studies are also documenting the impact of types of buffer, their width, and other characteristics of the surrounding landscape on populations. These studies have collected data on species richness and abundance as well as presence/absence. Below is a summary of recent results sorted by the major taxa.

Amphibians and Reptiles:

Semlitsch (79) summarized the results from studies of core habitat for 32 species of amphibians and 33 species of reptiles in over 100 articles. The type and structure of the appropriate core habitat will differ among species, but in general, all core habitats are relatively undisturbed. Semlitsch's results (Table 1) show that the minimum distance required for buffer/core habitat ranges between 117m and 205m for amphibians and reptiles.

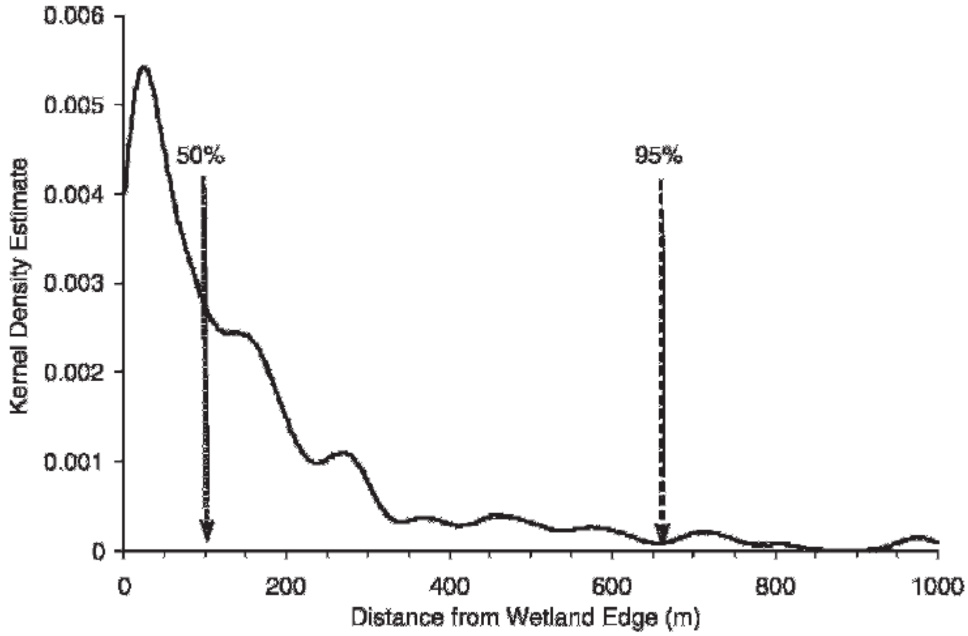
Table 1: Mean minimum and maximum core habitat (uplands) for amphibians and reptiles.* (copied from 79; We assume the last line represents the overall average, but this is not clear in the original review)

Group	*Mean minimum (m)*	*Mean maximum (m)*
Frogs	205	368
Salamanders	117	218
Amphibians	159	290
Snakes	168	304
Turtles	123	287
Reptiles	127	289
Herpetofauna	142	289

**Values represent mean linear radii extending outward from the edge of aquatic habitats compiled from summary data in Appendices 1 and 2.*

Rittenhouse and Semlitsch (70) analyzed the data from 13 studies that tracked 404 individual amphibians. They used these data to develop a mathematical model that plots the distribution of all these animals as a distance from the wetland edge. The model shows that one-half of the animals were found beyond 93 m (about 300 ft) (Figure 3) even though the peak of the distribution occurred at 30m (100 ft).

Figure 3: The density of amphibians as a function of distance from the wetland edge. Arrows represent the distance at which 50% and 95% of the populations were modeled (copied from 70).



One study (15) monitored the distribution and abundance of seven species of frogs as a function of the distance from a major highway in 34 wetlands in a rural section of Ontario, Canada. The distance of the wetlands from the highway ranged between 68m-3262m (223ft – 10,700ft). The wetlands were at least 500 m apart with mixed buffers of forest and fields. Lower abundances were measured in wetlands closest to the highway for all seven species. In addition, lower abundances were found for four of the seven species if the buffers were less than 250m (820 ft). The other three species had a relatively linear response in abundance out to the maximum distance of over 3000m (~10,000ft). This means that impacts on amphibian abundances were still being observed in the wetlands that were farthest from the highway.

The reviews cited above incorporate data on species found in Washington as well those that are not. Thus, the summaries they provide may not be exactly representative of what the amphibians in Washington's wetlands actually need as upland habitat. We were unable to find much information for the first synthesis on the upland habitat needs of amphibians specific to Washington. Research during the last decade however, has improved our knowledge. Table 2 summarizes the information on upland habitat use by amphibians found in Washington State. The research on a species may not have been done in Washington State, but we assume that the habitat needs for an individual species will not change significantly within its natural geographic range. Furthermore, the data summarized in Table 2 indicate that the habitat requirements of species found in Washington fall within the range found for species that have been studies more intensely.

Table 2: List of amphibian species found in Washington State. The second column summarizes the information on upland habitat use that was found in the literature search. The list of species found in Washington State is from the on-line field guide provided by the Burke Museum at the University of Washington. http://www.burkemuseum.org/herpetology/amphibians (accessed February 4, 2013).

Amphibian species Found in Washington	Information on buffer widths, population dynamics and landscape factors outside of wetland	Reference
Taricha granulosa, Rough-skinned newt	Occurrence best predicted by amount of forest cover within 1km of wetland	57
Ambystoma gracile, Northwestern salamander	200m of a forested upland buffer is home range for most	68
Ambystoma macrodactylum, Long-toed salamander	Presence is highest in wetlands surrounded by 500m of forest Preferred dispersing through forested areas rather than agricultural or shrub areas	51 24
Ambystoma tigrinum, Tiger salamander	Presence was best predicted by other landscape factors rather than forest cover within 1000m	51
Dicamptodon copei, Cope's giant salamander	*No information*	
Dicamptodon tenebrosus, Coastal giant salamander	*No information*	
Ensatina eschscholtzii, Ensatina	Populations did not decline over 10 years with forested buffers as small as 14m 20% of trapped animals within 0-20m; 40% in a buffer zone of 20-30m, and 40% in buffer zone of 30-40m (40m was maximum distance of sampling)	30 88
Plethodon dunni, Dunn's salamander	80% of trapped animals found within a buffer of 10m, remaining found within 40m (40m was maximum distance of sampling)	88
Plethodon larselli, Larch Mountain salamander	*No information*	
Plethodon vandykei, Van Dyke salamander	*No information*	
Plethodon vehiculum, Western red-backed salamander	Populations did not decline over 10 years with buffers as small as 14m 30% of captures in buffer zone 0-10m; 70% captures equally distributed to 40m (maximum distance of sampling)	30 88
Rhyacotriton cascadae, Cascade torrent salamander	*No information*	
Rhyacotriton kezeri, Columbia torrent salamander	70% of trapped animals within 0-10m buffer; the remaining 30% equally distributed out to 40m (maximum distance of sampling)	88
Rhyacotriton olympicus, Olympic torrent salamander	*No information*	
Rana pipiens, Leopard frog	Presence was best predicted by both grasslands within	51

	500m and other open areas Highway has a measurable impact on abundance in wetlands that are buffered by over 1000m of mixed forest and open land. Impacts are relatively linear with distance from highway.	15
Ascaphus truei, Coastal tailed frog	Populations declined over 10 years with buffers of either 14m or 30m	30
Ascaphus montanus, Rocky Mountain tailed frog	*No information*	
Bufo boreas, Western toad	Presence was best predicted by landscape factors rather than forest cover within 1000m Males traveled 581m from wetland, while females traveled 1105-m from wetland; females preferred shrub areas over forested buffers and open forest over closed canopies A buffer of 30.5m (100 ft) did not adequately protect critical upland habitat	51 87 23
Bufo woodhousei, Woodhouse toad	Presence in wetlands was best predicted by both grasslands within 500m and other open areas	51
Rana pretiosa, Oregon spotted frog	*No information*	
Hyla (Pseudacris) regilla, Pacific treefrog	*No information*	
Rana cascadae, Cascades frog	*No information*	
Rana aurora, Northern red-legged frog	Strongly associated or even limited to forest habitat and may commonly move >1000m in uplands 1000m of upland buffer is home range	31 68
Scaphiopus intermontanus, Great Basin spadefoot toad	*No information*	
Rana luteiventris, Columbia spotted frog	Presence was best predicted by landscape factors rather than forest cover within 1000m Preferred moving through agricultural and shrub/clearcut areas rather than forested	51 24
Rana clamitans, Green frog (introduced)	Highway has a measurable impact on abundance in wetlands that are buffered by over 1000m of mixed forest and open land. Impacts are relatively linear with distance from highway.	15
Rana catesbeiana, Bullfrog (introduced)	*No information*	

Information about the requirements of wetland-dependent reptiles in Washington State for buffers or core habitat is relatively sparse. The western pond turtle (*Clemmys marmorata*) is listed in Washington as an endangered species, but its habitat needs are not well documented and it has a very limited distribution in this state. The recovery plan for the pond turtle (65) states that females generally move 20–100m (65–328 ft) into the uplands, but nests have been found as far as 187m (614 ft) from the wetland edge. In California, the turtles moved as far as 500m from their aquatic habitat (64). The information on the painted turtle (*Chrysemis picta*) indicates that the distribution of this species was not influenced by proximity to roads or the amount of forested buffer surrounding the wetland at 30m, 125m, 250m, 500m or 1000m (1). Painted turtles are abundant in wetlands surrounded by a diversity of land uses in the immediate vicinity of the wetland, although their overall distribution is affected by the range of land uses at a landscape scale (71).

Birds

Much of the current research on birds involves riparian buffers along streams and lakes. While we read some of these studies we did not consider them applicable to this synthesis unless they also discussed wetlands. There is enough new research being done on wetland-dependent birds that we judged there was no need to try to extrapolate the information from streams to wetlands.

Recent studies indicate that the protection provided for wetland-dependent birds depends to a large degree on the species involved and on factors other than width, such as the type of vegetation in the buffer, land uses within 500m or 1 km of the wetland, and whether the setting is urban or rural.

Most of the wetland-dependent birds investigated have broad geographic ranges that include Washington State even though the studies were done outside our region. It was not, however, possible to sort out the data in these studies for those species found in Washington, and to summarize the information only for those species found in the state. Much of the recent research has focused on groups of similar birds (guilds and function groups) and it was not possible to separate out species based on their local distribution. Furthermore, the number of bird species involved is much larger than the number of amphibians. For example, McKinney and others (52) found 55 species associated with the wetlands in their study in Rhode Island. Of these, 41 species are also found in Washington (list in reference compared to list in BirdWeb: Seattle Audubon's Guide to the Birds of Washington State, http://birdweb.org/birdweb/ accessed February 6, 2013).

New information relating to the distribution of birds in wetlands and their buffers include:

- Obligate marsh-nesting species preferred rural over urban wetlands; generalist marsh-nesting birds showed no preference; while synanthropic generalist species had higher richness and abundance in urban marshes. The presence of a forested buffer surrounding the marsh in both rural and urban areas, however, was not an important factor in predicting the distribution of any of these bird groups (83).

- Ward and others (92) monitored the abundance and distribution of 12 species of wetland-dependent birds in 196 wetlands over a period of 26 years in the Chicago area. Seven species experienced significant declines, three showed no change, and two had significant increases. These changes were attributed to changes in the structure of the wetlands resulting from increased flows and nutrients caused by development. The percent forest cover or grasslands in a

2km buffer around the wetlands were not significant factors in explaining these changes because the extent of these land uses did not change as a result of development. The development occurred at the expense of agricultural lands.

- Large buffers of woods, grasslands, and other wetlands were a good predictor of abundance for 36 species of wetland-dependent birds [mean width of buffer in wetlands studied = 256m (840 ft) (range 20- 619m)] (53). Mathematical modeling of the data showed a potential benefit for the population as the width of a buffer increased up to 1000m (~3300 ft) for diving and dabbling ducks and up to 2000m (> 1 mile) for birds whose main habitat was the emergent plants in the wetland (53).

- The ecological integrity of a marsh bird community in the Chesapeake Bay area shows a threshold response to development within 500m and 1000m (1640 ft – 3281 ft). The integrity of the bird community was significantly reduced when the amount of urban/suburban development exceeded 14% or the total area within 500m of the wetland, or 25% within 1000m (12). Rooney and others (73) reported similar results where a bird-based index of integrity was best predicted by land used within 500m of wetlands rather than 100m, 300m, 1000m, or greater.

<u>Fish</u>

We did not find any references on the relationship between buffers and fish in wetlands for the initial synthesis in 2005. The studies reviewed addressed the effect of riparian buffers on fish populations in stream and river systems. It is difficult to extrapolate the results of studies in streams to those in wetlands because the habitat provided by streams is quite different from that in wetlands. This lack of information on fish in wetlands continues to this day. We were unable to find any articles on the subject that were written between 2003 and 2012. We did, however, find one study that analyzed the impact of vegetated buffers on fish species in lakes from the Pacific Northwest. This study might provide some useful insights into what might happen in larger, permanently ponded, wetlands.

Francis and Schindler (18) analyzed the food in the guts of fish from 28 lakes in the Pacific Northwest. They found a significant threshold when more than 10% of the lakeshores were developed; where "developed" was defined as shorelines where the vegetated buffers were less than 10m (33ft). The diet of trout and bass in lakes where more than 10% of the shoreline was developed was almost completely aquatic in origin. On the other hand, the diet of these species was over 50% terrestrial in origin in the lakes where less than 10% of the lakeshore was developed. Furthermore, a detailed analysis of the energy balance done in four lakes indicated that trout averaged a 50% greater energy intake in lakes that were not developed (i.e. had vegetated buffers of more than 10m for at least 90% of the lake's circumference).

Mammals

We found little new research on the buffer requirements of wetland-dependent mammals. One article (19) found that mammal diversity and abundance had some positive correlation with 500m and 1000m buffers, but not with 250m buffers. This complements the results from Puget Sound that were cited in the 2005 synthesis, where the highest number of small mammal species was found in wetlands that had a 500m buffer that was at least 60% forested.

Key point #4: page 5-49. *Human access and land uses adjacent to wetlands influence the use and habits of wildlife through noise and light intrusions, as well as elimination or degradation of appropriate upland habitats. Even passive activities, such as bird/nature-watching, have been shown to have effects on roosting and foraging birds.*

Update: The impacts of noise on amphibians and birds have received some attention in the last decade, and a wide variety of responses has been found, again based on differences among species. The overall impact of human land uses adjacent to wetlands has also been studied at a landscape scale. These results indicate that the impacts of such land uses on the richness and abundance of wetland-dependent species may take over two decades to become measurable. Specifically:

- Lengagne (45) found that playing traffic noises to male tree frogs triggered a decrease in calling activity. However, the impacts were decreased when tree frogs were calling in a chorus, probably because the frogs themselves were drowning out the traffic noise. Sun and Narins (85) found a similar response to airplane noise and low-frequency motorcycle noise in three species of frogs, but the noise increased the calling rate in one species.

- Herrera-Montes and Aide (34) found that the species richness of frogs in a wetland with a 100m forested buffer from a highway (noise>60db) was not different from a wetland with a 300m forested buffer (noise<60db). However, they also found that birds with low-frequency songs were absent from sites nearer the highway (at 100m).

- The severity of impacts from increasing development on amphibian populations may take several decades to manifest themselves. Lofvenhaft and others (47) measured a time lag of several decades between changes in urban land use and traffic density and the occurrence of amphibians. Gagne and Fahrig (20) found that the relative abundance of four out of five frog species continued to decrease for at least 54 years after residential development occurred.

- In Melbourne, Australia, Hamer and Parris (26) found that the breeding assemblage of frogs was greatly increased if the breeding ponds were surrounded by a high proportion of green open space within 1km. Conversely, there was a strong negative correlation between the number of people living within the 1km circle and the frog populations. They hypothesized that the human preference for tidy ornamental ponds where aquatic plants are often removed as well as shading from tall buildings could be factors for this negative correlation.

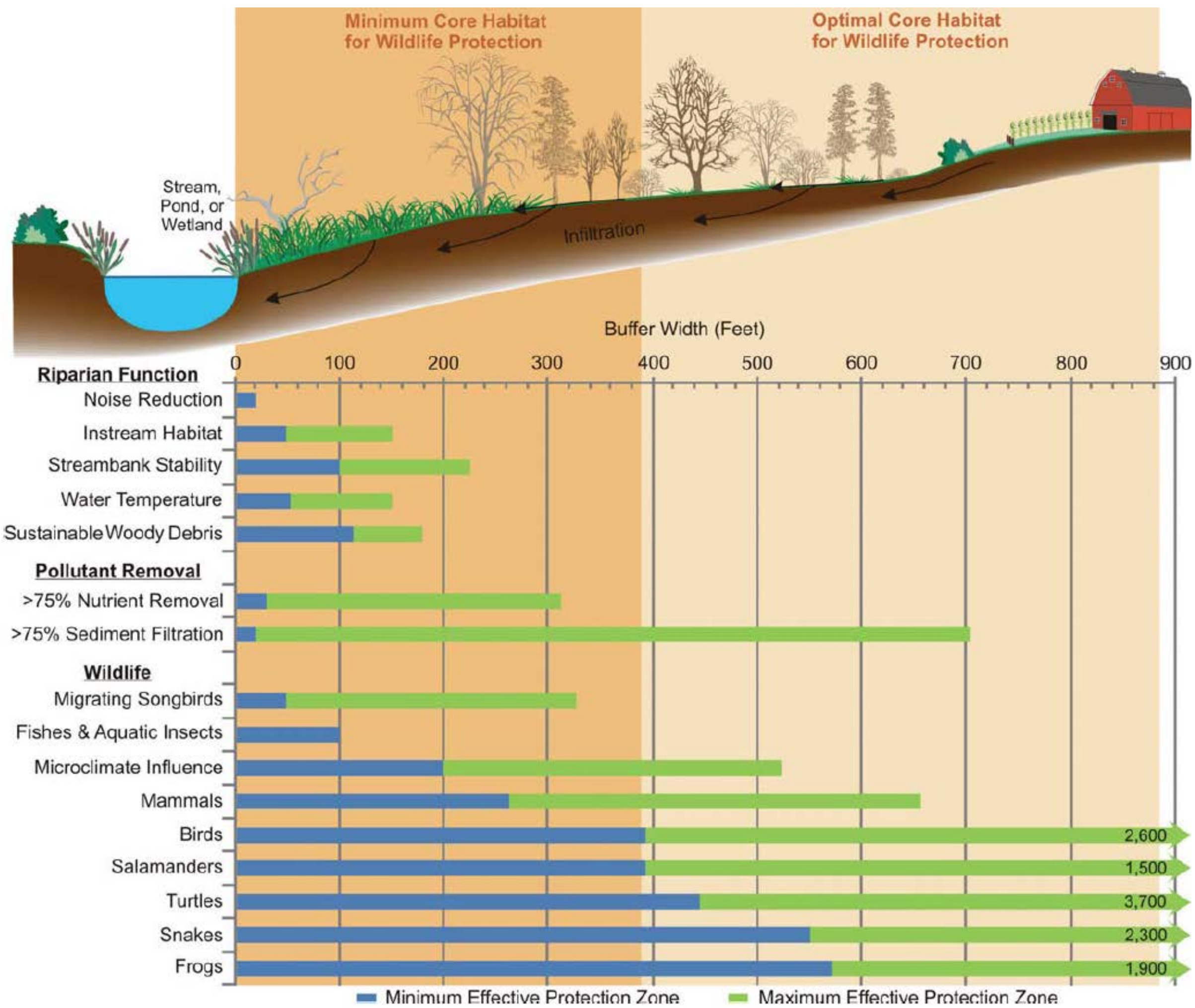
Key point #5: page 5-49. *Synthesis documents that evaluated many studies discussing the protection of habitat provided by wetland buffers generally recommend buffer widths between 50 and 300 feet (15 to 100 m), depending on specific factors. These factors include the quality of the wetland habitat, the species needing protection, the quality of the buffer, and the surrounding land uses*.

Update: Recent synthesis documents provide a more focused approach to buffer widths that is based on the many functions provided by a buffer. In addition, the more recent recommendations specify buffer widths that go beyond 300 ft for many wildlife species. The *Planner's Guide to Wetland Buffers for Local Governments* prepared by the Environmental Law Institute (42) recommends a range of 100–1000ft for wildlife, 30–100ft for sediment removal, 100-180ft for nitrogen removal, and 30-100ft for phosphorus removal.[1] The Southeast Wisconsin Regional Planning Commission (82) recommends a minimum range of 400–580 ft for birds, salamanders, turtles, snakes and frogs (Figure 4) for buffers along streams and wetlands based on the research and synthesis done by Semlitsch and Bodie (79). The synthesis done for Wisconsin states:

> Determining what buffer widths are needed should be based on what functions are desired as well as site conditions. For example, as shown above *(figure 4)*, water temperature protection generally does not require as wide a buffer as provision of habitat for wildlife. Based on the needs of wildlife species found in Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. Hence, the value of large undisturbed parcels along waterways which are part of, and linked to, an environmental corridor system. The minimum effective buffer width distances are based on data reported in the scientific literature and the quality of available habitats within the context of those studies.

[1] This document was peer reviewed by five independent wetland scientists and and by staff from the Environmental Protection Agency. Normallly, scientific journals only require peer review by three scientists.

Figure 4: Recommended widths of buffers to protect aquatic resources (from 81).



The minimum recommended buffers for wetland-dependent species in Wisconsin (82) are shown in Table 3. The table also indicates the number of scientific studies on which the recommendations are based. Three of the 12 frog species, and one species of salamander, found in Wisconsin are also found in Washington State. The recommendations therefore are somewhat applicable to Washington.

Table 3: Minimum and optimum buffers (core habitat) recommended for wetland and riparian wildlife in Wisconsin (from 81). The last column shows the number of studies on which the recommendations are based. [2]

Wisconsin Species	Mimimum Core Habitat (feet)	Optimum Core Habitat (feet)	Number of Studies
Frogs	571	1,043	9
Salamanders	394	705	14
Snakes	551	997	5
Turtles	446	889	27
Birds	394	787	45
Mammals	263	No data	11
Fishes and Aquatic Insects	100	No data	11
Mean	388	885	

3.4. Buffers and Plants

We did not find any references on the relationship between buffers and the plant community in wetlands for the 2005 synthesis. The studies reviewed in that synthesis addressed the impact of increased nutrients on the plant community. Since buffers can reduce the nutrient input into wetlands, they can be considered important for protecting the plant communities sensitive to increased nutrient inputs. Several more-recent studies directly link the width of a buffer to the plant communities found in wetlands. The results show that buffers of at least 70-100m are needed to protect the diversity of the wetland plant community.

- Houlahan and others (39) monitored plant diversity in 58 wetlands in Ontario, Canada and found that forest cover in the buffer was an important predictor of species richness in the wetlands. Statistically significant changes in overall richness were observed when the forest cover was changed to other land uses as far as 250-300m (820ft – 985ft) from the wetland. The richness of the different functional groups of plants in the wetlands (e.g. native, exotic, annual, perennial, forest, open, aquatic), however, did not respond in the same way even though the overall trend was that larger buffers increased richness.

- Rooney and others (73) found that the integrity of the plant community in 45 wetlands in Alberta was best predicted using data on land cover within 100m

[2] This table was adapted from reference 78 by the author of reference 81.

(330ft) rather than other distances ranging up to 3000m (1.9 miles). They used a plant-based index of biological integrity (IBI).

- Ervin (16) found that the presence of a forested buffer of at least 70-100m (230 – 330 ft) was associated with an increase in the quality of wetland vegetation (using a modified plant-based IBI).

3.5. Buffer Maintenance and Effectiveness over Time

Key point #1: page 5-51. *Human actions can reduce the effectiveness of buffers in the long term through removal of buffer vegetation, soil compaction, sediment loading, and dumping of garbage.*

Update: We found no new research to support or refute this conclusion. General synthesis documents continue to make similar conclusions (42, 91).

Key point #2: page 5-51. *Buffers may lose their effectiveness to disperse surface flows over time as flows create rills and channels, causing erosion within the buffer.*

Update: Ongoing research supports this conclusion (60, 95). A study in an agricultural environment found that only a small fraction of the total buffer area (9% -18% of the buffer zone) in four sites was actually in contact with surface runoff (13).

Key point #3: page 5-51. *Leaving narrow strips of trees can result in tree loss due to blowdown.*

Update: We found no recent studies on this subject, but we did find one additional study done in 1998 in California. The results indicate that a 30m wide selective cut in a buffer increases the rate of fall in the innermost 15m of uncut buffer by an order of magnitude (65).

Key point #4: page 5-51. *Buffers may become saturated with sediment over time and become less effective at removing pollutants. The literature indicates that this should be considered when determining buffer widths.*

Update: In addition to becoming saturated with sediment, buffers can become saturated with phosphorus. Two reviews (56, 36) conclude that the effectiveness of a buffer at trapping phosphorus can be reduced because the soils become saturated with this pollutant.

4.0 Update on Buffer Ranges and Other Characteristics

Key point #1: page 5-51. *Many researchers have recommended using four basic criteria to determine the width of a buffer:*

- *the functions and values of the aquatic resource to be protected by the buffer*
- *the characteristics of the buffer itself and of the watershed contributing to the aquatic resource*
- *the intensity of the adjacent land use (or proposed land use) and the expected impacts that result from that land use*
- *the specific functions that the buffer is supposed to provide, including the targeted species to be managed and an understanding of their habitat needs.*

Update: Recent recommendations on buffers confirm that these basic criteria are still valid (42, 82). In addition, the recent research has focused on identifying the characteristics of the buffer itself that provide the protection of wetland functions (see sections 3 and 4). For water quality these include the soils, the source of water, the infiltration rate, the slope, and the surrounding land uses. For habitat, the research has reinforced the fact that buffer requirements need to be targeted at the species of interest. For example, a forested buffer is optimal for some species but not for others. Fish may need only a 100ft buffer, but some species of amphibians need a 1000ft buffer.

Key point #2: page 5-51. *Protecting wildlife habitat functions of wetlands generally requires larger buffers than protecting water quality functions of wetlands.*

Update: This conclusion is still valid and supported by the more-recent research (see sections 3.2 and 3.3).

Key point #3: page 5-51. *Effective buffer widths should be based on the above factors. They generally should range from:*

- *25 to 75 feet (8 to 23 m) for wetlands with minimal habitat functions and low-intensity land uses adjacent to the wetland*
- *75 to 150 feet (15 to 46 m) for wetlands with moderate habitat functions and moderate or high-intensity land uses adjacent to the wetland*
- *150 to 300+ feet (46 to 92+ m) for wetlands with high habitat functions, regardless of the intensity of the land uses adjacent to the wetland.*

Update: Recent synthesis documents recommend a focused approach to buffer widths that is based on the many functions provided by a buffer. In addition, the more recent recommendations specify buffer widths that are larger than those recommended in the 2005 synthesis. The *Planner's Guide to Wetland Buffers for Local Governments,* prepared by the Environmental Law Institute (42), recommends a range of 100ft–1000ft for wildlife, 30–100ft for sediment removal, 100-180ft for nitrogen removal, and 30-100ft for phosphorus removal.

If prescribed buffers are to be used to adequately protect wetland wildlife, they will probably have to be larger than what is currently used. Based on the needs of wildlife species found in Wisconsin (some of which are also found in Washington State), the minimum buffer width is about 400 ft, and the optimal width for sustaining the majority of wildlife species is about 900 ft (81).

Key point #4: page 5-51. *Fixed-width buffers may not adequately address the issues of habitat fragmentation and population dynamics. Several researchers have recommended a more flexible approach that allows buffer widths to be varied depending on site-specific conditions.*

Update: A request for a more flexible approach is a common theme among recent articles (42, 62, 67, 95). The research reinforces the fact that buffers and fragmentation are only two of many variables that affect the dynamics of wildlife populations. Other factors that have been found to affect the survival of wetland-dependent species are surrounding land use, the structure of the plant community, and the intensity of human disturbance. If buffers are to be used to protect the water quality in wetlands, the factors that need to be considered are slope, soil chemistry, soil structure and the plant community.

5.0 Synthesis of New Information on Buffers

The initial questions posed at the beginning of this literature review were:

1. Are the conclusions and key points regarding wetland buffers made in the 2005 synthesis still valid?
2. If not, what new conclusions can be made from the recent research about how buffers protect wetland functions?

In addition, a synthesis should "involve the integration of disparate data with existing concepts and theories to yield new knowledge, insights, and explanations." (59). Below we provide our synthesis of the information we presented in the previous chapters. Some conclusions that come out of a synthesis may not have been made previously by others and thus cannot be cited because they provide new knowledge and explanations.

5.1 Conclusions on protecting water quality by using buffers (Section 3.2)

The research in the last decade supports the basic conclusion that buffers trap pollutants before they reach a wetland, thus protecting its functions. The recent research has also increased our understanding of the many different factors that control the effectiveness of a buffer at trapping pollutants. These factors include:

- Width
- Slope
- Type of vegetation (herbaceous, shrub, trees)
- Type of pollutant (e.g. nitrogen, phosphorus, sediment, coliform bacteria)
- Geochemical and physical properties of the soil
- Infiltration rates of soils
- Source of pollutants (surface water or groundwater)
- Concentration of pollutants
- Path of surface water through the buffer
- For phosphorus, the amount of phosphorus already trapped by the soil.

All else being equal, wider buffers should be more effective than narrower ones. However, the other site-specific factors listed above can change the effectiveness of wider buffers. For example, a wide buffer where surface runoff has formed a small channel will probably not be as effective as a narrower buffer with no channels. In the latter case, the surface flows carrying pollutants have a chance to diffuse through the vegetation and percolate into the ground. In the former case the pollutants have less opportunity to interact with the processes that trap and transform them.

The approach of using the width of buffers as the only means for protecting water quality in a wetland can be complicated. Different buffers widths may be needed to achieve the same level of protection because other environmental factors are also important.

5.2 Conclusions on protecting wetlands as wildlife habitat by using buffers (Section 3.3)

The research in the last decade indicates the habitat needs of wetland-dependent species are highly variable. Protecting wetland-dependent wildlife will probably require a broader, landscape-based approach.

Current research indicates that:

- Some species of amphibians require large areas of relatively undisturbed uplands if their populations are to survive. Models that estimate the extinction rate show that some amphibian populations have a high probability of becoming extinct in a wetland within few decades as buffers are sized using current guidance (100 – 300 ft).

- We found information on the upland habitat needs for 15 of the 27 species of amphibians found in Washington State. These articles do not specify a minimum distance that is required to protect a population, but they show that the species can range 40m (~130ft) to over 1km (0.6 miles) from the edge of a wetland. The type of upland habitat used by species found in Washington are similar to what these species use in other parts of their range. Thus, many of the general conclusions reported in the literature will probably also be valid, even though the research was done on these species in other locations.

- The uplands surrounding a wetland can serve as critical habitat for certain wetland-dependent species. Because this expands the concept of wetland buffer from simply protecting the wetland to protecting species in the uplands, some have suggested using the term core habitat rather than buffer. Many wetland-dependent species will probably not survive unless an adequate amount of core habitat is present.

- Studies on birds as well as amphibians report that core habitat for many species needs to extend between 300m (1000ft) and 1000 m (0.6mi) from the wetland edge. However, we were unable to find information on how much of the wetland edge has to be connected to the core habitat to maintain populations.

- The composition of plants in buffers and core habitats is also an important factor. Some species prefer grasslands while others prefer shrubs and forests.

- Policies and regulations will probably need to protect the upland habitats that are an integral part of their habitat needs.

The current research indicates that a broader approach to protecting wildlife is needed. Buffers alone may not prevent the populations of many species from declining. Wetland policies that rely on only on buffer widths may be ineffective at protecting amphibians or other wetland species that disperse across the landscape. Bauer and others (5) combined an economic cost model with models of amphibian populations and found that in the majority of human-dominated landscapes, some amount of protection for the upland core habitat is necessary for long-term survival of these amphibians. However, in landscapes with less intense land uses, such as low-intensity residential, and a high pond density, wetland buffers may be all that is required (5).

5.3 Conclusions on protecting plant biodiversity in wetlands using buffers (Section3.4)

Very little research has been done correlating plant biodiversity in wetland with buffer width. The research that has been done suggest that wetlands may require buffers that are at least 200 ft (60m) to protect sensitive plants.

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