December 2006

ANALYSES SUPPORTING BUFFER WIDTHS OF 50 FEET OR LESS

Surveys of buffer science relating to wetlands, streams and tidewater are increasingly pointing toward narrow buffers as having attributes adequate for protecting watered lands. Here is some of the relevant literature. There is little Puget Sound data available; most is from Northwest stream shores.

Drift logs and natural weirs

Large wood debris (LWD) is considered important to wildlife and invertebrate welfare, especially in creating riffles and pools along streams of certain sizes. Narrow buffers are more effective than wide vegetation belts in providing LWD. Windthrow from narrow buffers is credited with most of the dead-and-down material:

> [In a study of 39 West Side streams] "...with 11% of the total number of debris pieces originating within 1 m of the channel and over 70% originating within 20 m."[1]
>
> "In fact, the majority (well over 50%) of all LWD in streams arises from trees growing within 5 m (15 ft) of stream banks..."[2]

Shade aid for fish-bearing streams

In some streams shade has been considered important to keep water cool for fish breeding. Recent studies find that although warm water increases fish mortality, it speeds maturity of the fish while also increasing production of invertebrates on which juvenile fish feed. Thus, on the Northwest's West Side, waterway buffers are in many cases counterproductive. See the further discussion on page 7 ff. For now, Washington's Standard Forest Practice Rules call for an average of 50-foot "core zone" buffers on fish-bearing streams.[3] (Shade along tidal shores is discussed on page 10.)

> "Increased temperatures following logging, together with increased light levels and increased nutrient concentrations, often lead to general increases in productivity in the trophic [food] levels that form the

basis of fish production. Increased temperatures, light, and nutrients all play a role. Temperature directly affects development rates of fish; in some systems, the temperature increases lead to earlier emergence, longer growing seasons, and increased survivals at critical times in the life histories of fish."[4]

Stormwater and waterborne sediments and chemicals

Water quality protection is often assigned to wetlands and their buffers.[5] If sediment is the concern:

> "...a narrow buffer of 8 m might suffice..."[6]

Stopping or at least slowing stormwater is frequently mentioned as a key role for buffers. This would be a good thing, partly because water would have more time to soak into aquifers, partly because wetlands and streams would be spared dissolved chemicals as well as pollutants clinging to sediment particles. There is a tradeoff here: dissolved pollutants go either to the aquifer or to the watercourse.

There are also claims that buffer vegetation, especially trees, capture water, dissolved nutrients like nitrogen, and even some bad chemicals. It can't happen here: Puget Sound stormwater arrives when trees are dormant.

Finally, any advantage of buffers depends on what buffers would replace. For instance, lawn grass removes 78-83 percent of sediment,[7] and is twice as effective as woodland at retaining sediment.[8] Concerning buffer widths:

> "Desbonnet et al (1994) determined that a small buffer (7 feet [2 m]) could effectively remove up to 60% of suspended sediment..."[9]

Other selected studies collected by Desbonnet et al indicate these buffer widths and effectiveness levels in removing sediment (repeated author entries reflect different sites studied by the same group; a reference without a note is from the same pub as the one above it),

Neibling & Alberts[10]	1.6 feet	91 percent reduction
Neibling & Alberts	4	78
Neibling & Alberts	8	82

Neibling & Alberts	16	83
Neibling & Alberts	29	90
Dillaha et al[11]	15	63
Dillaha et al	30	78

And for nitrogen removal,

Doyle et al[12]	12 feet	95 percent reduction
Doyle et al	25	96
Doyle et al[13]	50	97
Dillaha et al	15	63
Dillaha et al[14]	15	61
Dillaha et al	15	67
Dillaha et al	30	71
Dillaha et al	30	77
Dillaha et al[15]	30	78

A Chris May report[16] adds these studies for sediment,

Magette et al[17]	16-30 ft	66-82 pct removal
Ghaffarzadeh et al[18]	30	85

And for nitrogen,

Madison et al[19]	15-30	90
Xu et al[20]	33	95
Osborne & Kovacic[21]	52	96

The Desbonnet group concludes:

> "In general, greater than 50 percent removal standards can be met with vegetated buffers about 5 meters [16 feet] wide."[22]

> "From the values presented...a multiple-use vegetated buffer

of five meters could be considered a reasonable minimum-buffer-width standard. A five-meter-wide vegetated buffer will provide approximately 50 percent sediment and nutrient removal (except for nitrate). While a vegetated buffer of this width may not provide good overall wildlife habitat, it may be sufficient to provide resting and feeding areas for both resident and migratory species. A five-meter-wide multiple-use buffer can be practically implemented, except in areas of very dense development, and these exceptions could be reviewed as a variance to general buffer policy. A five-meter-wide vegetated buffer could be established as a minimum goal for the restoration of already developed areas. Establishing a minimum buffer width will also maintain or improve the scenic and aesthetic quality of the area, and will act as nondestructive, natural fencing between public waters and private uplands."[23]

"In summary, most studies reviewed by Desbonnet *et al.* indicate that a vegetated buffer of 10-20 m (30-60 ft) is sufficient to remove all or nearly all excess nutrients and other pollutants, except in areas where side-slopes exceed 30-50%."[24]

Biologic pollutants

Other studies have shown the efficacy of narrow grass buffers in removing pathogens, notably coliform bacteria. This, of course, is the premier role of drainfields, where perforated effluent pipes are quite closely spaced:

"Under proper site and operating conditions, [septic systems] can achieve significant removal rates (i.e., greater than 95 percent) for biodegradable organic compounds and suspended solids."[25]

The percent removal of subsurface wastewater infiltration system [drainfield] percolate at 3 to 5 ft depth was found to be over 99.99%.[26]

Insects for fish diets

Salmon are opportunistic diners, snapping up anything interesting.[27] Down-migrating salmon consume invertebrates including insects, and eggs and then the adults of amphibians and other fish. Most of the inverts are aquatic, leaving the water only briefly to mate.[28] There is disagreement on the import of inverts in tidewater; however stomach studies have regularly

found them in the guts of Puget Sound transients. Some are terrestrial (land-born), notably aphids and lice.[29] But among summaries of 66 studies of salmon diets, only one mentions terrestrial insects.[30] Stream studies in Oregon have shown insects more abundant along banks without overhanging canopies than with the cover.[31] Analysts in Alaska found no difference among canopy types in their delivery of large inverts. In fact:

> "Canopy removal has been reported to increase primary and secondary productivity in fish-bering streams in southeastern Alaska...and elsewhere in the Pacific Northwest."[32]

The conclusion was that although alder was better for producing fishes' prey than was conifer cover along streams, clearcutting was even better.

> There are other papers along this line, with the conclusion that the narrower the buffer and the less shade the better, at least for streams and wetlands.[33]

Buffers as vehicles for restoration

Proposals for wide buffers are generally, though silently, targeted at return of the site to some years-ago state of nature, typically pre-European, with towering trees if not ancient forests. But this is largely wrong:

> "We know very little about historic conditions anywhere."[34]

> "...first, it is impossible to replicate historical landscape dynamics exactly because significant changes have occurred already in these forests, and climate changes over time. Second, the historical variability included some large oscillations, such as large, severe fires that would be unacceptable to most people now. And finally, management techniques such as cutting, prescribed fire, and reforestation are very different from natural processes."[35]

There is also the matter of knowing what the general landscape was like. Old forests are remarkably diverse, having lived tumultuous lives.[36] We do not know what the County's districts were like 150 years ago, which was certainly different from the oak-grass savanna of 3000 years ago. It is estimated that at any time, the amount of old-growth ranged from 30 to 70 percent of the forest area, averaging 40 percent.[37] We know that in 1792 George Vancouver saw shorelines broken by openings caused by fires, wind, and massive slumps. We know that serious forest fires were common. Which parts of the Island shall we burn?

It follows that we know not how to design a wide buffer, while we know that look-alike designer buffers replicate little but themselves.

Too, a basic issue: Does the Growth Management Act limit buffers and related treatments to protection, not restoration?[38]

Buffers as wildlife habitat

They certainly are. Narrow buffers -- 10 to 15 feet wide -- are judged adequate for nesting habitat for wetland birds. The same University of Washington ornithologist has found that the array of bird species is broader in urbanizing (suburban) areas than in forests. This in the Seattle-Snoqualmie Pass corridor.[39] The reason is the greater range of habitats in developing areas. By extension, birds are more varied in the present diverse landscapes along Bainbridge edges than would live in a uniform tree/thicket perimeter.

Narrow buffers are considered important to amphibians, for shading underwater egg masses; thereafter the buffer is typically a pass-through on the way to distant parts away from breeding ponds, and some don't need the ponds.[40] All amphibs need moisture. An informal survey of Kitsap County people, during a conference, indicated that many had found amphibians under boards and similar damp places in their yards and gardens.

Mammals, small and large, seem indifferent to buffers relative to other habitats. Deer and coyotes have demonstrated across North America their adaptability to exurban settings like those of the Island. No garbage can is safe from raccoons. Few yards escape the vigilance of crows, possums, squirrels. Feral cats, the worst enemy of Island birds, roam at large.[41] Critters go where they wish, regardless of designated corridors.[42]

> "...the legal intent of those buffers is to protect functions in adjacent shorelines or critical areas, not to provide upland habitat for terrestrial species."[43]
>
> "...the great majority of benefit is realized in the first few to tens of meters from the stream edge."[44]

Clearly, for most birds, animals, and fish, buffers have a limited role. Formal refuge and forage areas are assigned to 'Habitat Conservation Areas', and there is remarkably wide local latitude in defining these areas. 'Habitats and species of local importance' could include terrain for coyotes, squirrels, or crows if they are of 'local importance'.

It is interesting that discussions of habitat turn on amounts of land to set aside, the 'supply side'. Nobody talks much about the 'demand side'--how many of what species we want here and how much habitat that requires. It isn't even clear that habitat is a limiting or enabling factor for fish or wildlife on the Island; other things may be more important. Nor have we information on the useful habitat roles of developed lands.

SOME NEAR-ZERO BENEFITS OF BUFFERS

There is considerable research showing that buffers, regardless of width, have little utility. This is important considering the many miles of buffers in prospect; the social and private costs of buffers; the fact that buffers typically conscript premier, highly cherished places; and the many land uses foregone.

Here in the Puget Sound lowland, buffers of *any* width discourage wetland birds:

> "Most shorebirds...shun small wetlands surrounded by trees."[45]

Wildlife-oriented buffers of *any* width along Northwest West Side streams do not benefit fish nor nearby wildlife. This according to nine very large, peer-reviewed, published studies with controls, which overturn conventional wisdom:

> [Along 62 Olympic Peninsula headwater streams]
> "...characteristics of the riparian forest had no influence on fish abundance in these streams" and "fishes, birds and mammals...persisted in sites after logging whether or not buffers were present." "...most streams, regardless of previous forest management history, maintained temperatures within the critical thermal limits of even sensitive species." "These results indicate that fish, birds, and mammals...persisted in sites after logging whether or not buffers were present." [46]

> [Along 8 Oregon streams]
> Macroinvertebrates were identified and counted in 4 canopied and 4 uncanopied streams over 3 years. More macro- invertebrates were found in no-canopy streams (54.5 thousand to 47.9 thousand).[47]

[And along 3 other Oregon streams]
Three watersheds were either clearcut, patch cut, or left uncut. Coho and anadromous cutthroat were the fish studied. Relative to the uncut stream, patch cutting produced no significant changes in the fish population or its habitat. No mortality in the clearcut watershed despite higher temperatures.[48]

[Along southwest Washington streams]
9 pairs of logged and unlogged old-growth sites on streams in SW Washington and the west slope of the Washington Cascades were studied. Total salmonid biomasses averaged 1.5 times greater after logging than in adjacent unlogged sections.[49]

[18 sites on Washington Cascade streams]
6 3-unit groups that include a control site, a site harvested according to current DNR guidelines, and a site cut according to wildlife parameters set by the study team. "O'Connell et al (2000), in their study of riparian sites in managed forests of the Cascade Range of Washington, found that total abundance and species richness of birds and small mammals using areas close to streams before any timber harvest were comparable to the number and kinds after harvest. [They] found that diversity of breeding birds increased on sites with narrow buffers relative to non-harvested control sites after logging. In their study, total bird abundance did not differ between treatments and controls."[50]

[Vancouver Island paired rivers]
Two river watersheds south of Pt. Hardy were logged. One was left alone afterward. Rehab of the other included stone and log in-stream structures, nutrient briquettes, and off-channel ponds and side-channels. "The Keogh River was heavily rehabilitated and fully protected using all the latest techniques of environmental river management. The Waukwaas River on the other hand was left entirely unprotected. Almost immediately, the project determined that artificial feeding of fry was required in the Keogh. Even with artificial feeding the Keogh was still solidly outperformed by the "poor habitat" in the Waukwaas River."[51]

[18 streams in southeast Alaska]
6 replications: each rep was a cluster of 3 nearby streams, each with three sample reaches. Each of the 3 streams was either clearcut, cut with buffers, or uncut oldgrowth. In summer, buffered and clearcut reaches had twice as much algae, benthos, and salmonid fry as oldgrowth reaches. Removing cover clearly increased primary biomass production.[52]

[More Cascade streams]
Fish populations in headwater streams respond positively to increased solar radiation, resulting in elevated primary and secondary production.[53]

[Snohomish County lowland lakes]
"The county study found no correlation between a lake's health and size, depth, amount of development in its watershed or percentage of shoreline planted in native vegetation versus unnatural armored banks. "There is a high positive correlation between settlement and water quality. And there is no correlation between absence of onshore vegetation and low water quality/contamination. [A corollary is that settlement has not brought contamination to clear lakes.][54]

Forested buffers of *any* width are perilous:

"In the Pacific Northwest, forested buffers are often "created" as leave-strips around wetlands or along streams when the surrounding forest is cleared for land development. These forested strips are then exposed to winter windstorms, which are common, often resulting in substantial loss of large trees due to blowdown."[55]

"For [glacial till] bluffs to become and remain stable they should be planted with shrubs and trees not more than 15 feet high, and no tall trees should be allowed to grow landward of and close to the top of the slope....Large trees, especially firs, are at greatest risk of failure from high wind velocities. The wind velocities cause the trees to fail by rocking back and forth, and are especially susceptible to failure near the brows of the slope where wind velocities are highest."[56]

"Large trees should be used on the face of slopes sparingly and with caution. Should these trees collapse because of undermining of the root system by erosion or by windthrow, large volumes of earth can be disturbed by the tree roots when they pull from the slope. The resulting large, bare areas are opened to further erosion, which may endanger adjacent land and vegetation. New major trees should not generally be established on the face of coastal slopes."[57]

"Any process that adds weight to the top of a potentially unstable slope can increase the risk of sliding." "Vegetation growth increases weathering of soils and root action can,

particularly in compact units like glacial till, loosen natural fractures and joints in the material, leading to failure. Movement of trees by wind stress may loosen soils, enhancing infiltration, and in some cases, may impart significant loads to the slope itself that may trigger failure."[58]

Forested buffers of *any* width do little to stop debris flows coming down from above:

> "Debris flows can remove all the sediment and large wood from the steep swales and first-order stream channels, leaving a bedrock channel."[59]

Thirteen benefits ('functions') are claimed for buffers. Regardless of the buffer's width, five 'benefits' aren't needed, three scarcely occur, and for four there are better alternatives.[60]

One claimed function is provision of nutrients. Yet nutrients are commonly cited as a problem, and in places where salmon spawn they contribute nutrients to the water and even to the riparian area.[61]

Shade along tidewater shores, to shelter migrant fish and resident spawning, is another specious matter. Surf smelt eggs may be most vulnerable to sun because they are laid high on the beach, in summer. However a warm beach has offsetting advantages to other beach biota, consumed by smelt and other fish.

As for migrating fish, their claimed need for shade is puzzling. They cross wide stretches of open water, close to the surface, and their passage along the Island is not timed to high tide nor mid-day. Nor is it apparent that they choose routes most covered by leaning shoreline trees.

Berg, McKee and Maki have shown that a dense tree line 40 feet tall might produce shade reaching 20 feet maximum at the summer solstice.[62] Allowing 10 feet for setback from the bank, another 10 for the bank's slope, and 10 feet for the backshore doesn't yield much horizontal shade for cooling the beach.

Tripp Truisms

Gary Tripp's analyses include a number of Kitsap-related statements:

> We do not have a problem with surface erosion nor sediment; we don't have feedlots nor the scale of agriculture that prompted most buffer studies.
>
> Kitsap's streams and uplands do not have a problem with temperature regulation nor recruitment of large woody debris.
>
> Microclimate is not known to be a problem on our upland nor shores.
>
> There is no evidence that our current buffers are not working.
>
> There is no supporting literature that indicates our current buffers will likely fail in future.
>
> Our low-intensity residential use produces less contaminants than the uses cited in the literature, which are primarily agriculture and logging.
>
> There is no local evidence of yard chemical pollution after years with the current buffers and 100 years of no buffer requirements.
>
> The largest sources of single point discharge here are roads and drainage ditches. Wherever their sources, chemistry problems will not be solved by buffers, whatever their width.
>
> The Pacific Northwest's weather patterns are less likely to flush contaminants into streams and wetlands during the period when residential chemicals are used.
>
> None of the literature on offer factors in the supportive functions of our low-intensity and vegetated upland development.

An addendum on 'big-buffer mythology'

Excerpts from a paper by attorney Alexander W. Mackie[63]:

> "Big buffers are, at heart, a 'restoration program' going far

beyond the mandate to 'protect' existing functions and values. Restoration programs are designed to return the land to some prior state or condition." "Such programs are designed to result in the ultimate removal of 'nonconforming' uses and structures and to replace them with more 'natural', 'native', or 'habitat friendly' vegetation."

"The 'mythology of buffers' is grounded in the belief that buffers must be the foundation and universal underpinning of all critical area ordinances. This is not the case. Local governments need not make entire regions of the community into nonconforming uses, restricting use of developed properties within the buffers to the limits of constitutional authority. Other tools are much better designed to deal with the protection of critical areas in the built environment."

"The mythology of buffers seeks to find a simple answer to the protection of critical areas. The truth is much more complex, and the 'science' promoted to support the universal buffer approach cannot withstand tight scrutiny ...As local governments face a draft ordinance based on 'big buffers' as a first line of defense, with buffers designed to render large portions of the developed community nonconforming, proponents must be put to the test that effective alternatives are not available and that the recommended programs are required for protection of existing conditions, not restoration."

D. F. Flora

NOTES

1. McDade, M. H., F. J. Swanson, et al. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington. Canadian Journal of Forest Research 20(3):326.

2. Buell, J. W. 2000. Review of Kitsap County draft "Land Use & Development Policies", "Critical Areas Ordinance" and supporting documentation. Portland, OR: Buell & Associates, Inc., Consulting Biologists.

3. Washington Forest Practices Board. 2000. Forest Practices Board manual. Olympia: Forest Practices Division, Department of Natural Resources.

4. Beschta, R. L. et al. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo, E. O. and T. W. Cundy, eds. 1987. Streamside management: forestry and fisheries interactions. Contribution No. 57. Seattle: University of Washington, College of Forest Resources, Institute of Forestry Research.

Quoted in Buell, J. W. 2000. Review of Kitsap County draft "Land use & development policies", Critical Areas Ordinance" and supporting documentation. Memorandum 21 January 2000. Portland, OR: Buell & Associates, Inc., Consulting Biologists.

5. Sheldon, D., T. Hruby, et al. 2003. Freshwater wetlands in Washington State, Volume 1, A synthesis of the science. Draft. Publication 03-06-016. Olympia: Department of Ecology. p. 2-5.

6. O'Connell, Margaret A. et al. 2000. Effectiveness of riparian management zones in providing habitat for wildlife. Final report, Timber Fish and Wildlife Program. University of Washington and Washington DNR Timber Fish Wildlife Report TFW-LWAG-00-001.

7. Sheldon et al, 2003. p. 5-27.

8. Desbonnet, Alan, et al. 1994. Vegetated buffers in the coastal zone, a summary review and bibliography. Narragansett, RI: Rhode Island Sea Grant.

9. Sheldon et al, 2003, p. 5-28.

10. Neibling, W. H. and E. E. Alberts. 1979. Composition and yield of soil particles through sod strips. Paper No. 79-2065. St. Joseph, MI: American

Society of Agricultural Engineers. Not available at UW.

11. Dillaha, T. A., J. H. Sherrard, et al. 1986. Use of vegetative filter strips to minimize sediment and phosphorus loss from feedlots. Research Bulletin 151. Blacksburg, VA: Virginia Water Resources Center. Not available at UW.

12. Doyle, R. C., D. C. Wolf, et al. 1975. Effectiveness of forest buffer strips in improving the water quality of manure polluted runoff. In: Managing livestock wastes, Proceedings of the third international symposium on livestock wastes. Champaign, IL: University of Illinois. Not available at UW.

13. Doyle, R. C., G. C. Stanton, et al. 1977. Effectiveness of forest and grass buffer filters in improving the water quality of manure polluted runoff. Paper No. 77-2501. St. Joseph, MI: American Society of Agricultural Engineers. Not available at UW.

14. Dillaha, T. A., J. H. Sherrard, et al. 1988. Evaluation of vegetative filter strips as a best management practice for feed lots. Journal of the Water Pollution Control Federation 60(7):1231. Not available at UW.

15. Dillaha et al, 1986.

16. May, Christopher W. 2003. Stream-riparian ecosystems in the Puget Sound Lowland eco-region, a review of best available science. [Place of publication unk.] Watershed Ecology LLC.

17. Magette, W. L., et al. 1989. Nutrient and sediment removal by vegetated filter strips. Transactions of the American Society of Agricultural Engineers 32(2):663.

18. Ghaffarzadeh, M., et al. 1992. Vegetative filter strip effects on sediment deposition from overland flow. Agronomy abstracts p. 324. Not available at UW.

19. Madison, [?], et al. 1992. Tillage and grass filter strip effects upon sediment and chemical losses. Agronomy Abstracts p. 331. Not available at UW.

20. Xu, L., J. W. Gilliam, et al. 1992. Nitrate movement and loss in riparian buffer areas. Agronomy Abstracts p. 342. Not available at UW.

21. Osborne, L. L. and D. A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology 29:243.

22. Desbonnet et al, 1994, above. p. 28.

23. Desbonnet et al 1994, p. 31.

24. Buell, J. W., 2000, above, p. 14.

25. U.S. Environmental Protection Agency. 2002. Onsite wastewater treatment systems manual. EPA/625/R-00/008. Cincinnati: National Risk Management Research Laboratory. p. 3-28.

26. US EPA, 2002. Table 3-19 at p. 3-29.

27. For example, Groot, C. and L. Margolis, eds. 1991. Pacific salmon, life histories. Vancouver, BC: UBC Press.

28. McCafferty, W. Patrick. 1998. Aquatic entomology. Boston: Jones & Bartlett.

29. Homoptera and Psocoptera, per Sobocinski, K. L. 2003. The impact of shoreline armoring on supratidal beach fauna of central Puget Sound. MS thesis, School of Aquatic and Fishery Sciences, University of Washington. She cites a personal communication with C. Staude at UW's Friday Harbor Laboratory.

30. Weitkamp, Don E. 2000. Estuarine habitat used by young salmon, an annotated bibliography. Kirkland, WA: Parametrix, Inc.

31. Meehan, William R. 1996. Influence of riparian canopy on macroinvertebrate composition and food habits of juvenile salmonids in several Oregon streams. Research paper RP-496. Portland: US Forest Service, Pacific Northwest Research Station.

32. Piccolo, Jack J. and Mark S. Wipfli. 2002. Does red alder (*Alnus rubra*) in upland riparian forests elevate macroinvertebrate and detritus export from headwater streams to downstream habitat in southeastern Alaska? Canadian Journal of Fisheries and Aquatic Science 59:503-513.

33. For instance Bilby, R. E. and P. A. Bisson. 1992. Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old-growth forested streams. Canadian Journal of Fisheries and Aquatic Science 49:540-551.

Young, K. A., S. G. Hinch, and T. G. Northcote. 1999. Status of resident coastal cutthroat trout and their habitat twenty five years after riparian logging. North American Journal of Fisheries Management 19:901-911.

34. Hibbs, David E. and Sam Chan. 2004. Developing management strategies for riparian areas. 22nd Forest Vegetation Management Conference. Corvallis: Department of Forest Science, Oregon State University.

35. Cissel, John. 2002. Quoted in Science Update. Issue 3, December 2002. Portland, OR: US Forest Service, Pacific Northwest Research Station.

36. Same source.

37. Pacific Northwest Research Station. 2003. Science Update, Issue 4. Portland: USDA Forest Service.

38. Mackie, Alexander W. 2004. Critical areas and big buffers--six questions your local officials must answer before adopting a buffer-based critical area program. Olympia: Perkins Coie. Presented at "Growth Management in Washington" seminar, Seattle, November 15-16, 2004.

39. Marzluff, John [Professor of Wildlife Science]. 2003. Data presented at a seminar on urban ecology, November 7, University of Washington, College of Forest Resources, Seattle.

40. Gomez, D. M. and R. G. Anthony. 1996. Amphibian and reptile abundance in riparian and upslope areas of five forest types in western Oregon. Northwest Science 70(2):109-119.

Arlen, Rob. 2004. Amphibians of Bainbridge Island. Scotch Broom. Summer/fall. Bainbridge Island: Association of Bainbridge Communities.

41. An estimated 90 prey per year killed by each feral cat, on average. Per Sheldon et al, p. 4-68.

42. D. Flora presentation at Kitsap County public panel, 'Issues relating to

Critical Areas planning', October 27, 2004.

43. Houghton, Jonathan. 2003. Review of incorporation of best available science in proposed City of Bainbridge Island shoreline rules. Edmonds, WA: PENTEC Environmental. p. 19. The reference is to shoreline buffers.

44. Buell, J. W. 2000. Review of Kitsap County draft "Land Use & Development Policies", "Critical Areas Ordinance" and supporting documentation. Portland, OR: Buell & Associates, Inc., Consulting Biologists.

45. Adamus, P. R. [date unk] Personal communication cited in King County Best Available Science [draft], October 2003. p. 9-6.

46. US Forest Service, Pacific Northwest Research Station, Science Findings 53 (May 2003). [REMS (Riparian Ecosystem Management Study.)]

2 papers in PNW Station GTR 563, 2002: Congruent Management of Multiple Resources, Proceedings from the Wood Compatibility Initiative Workshop. Authors are Martin G. Raphael, Peter A. Bisson, Lawrence L. C. Jones, Alex D. Foster.

47. Meehan, William R. 1996. Cited earlier.

48. Hall, James D. and Richard L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. [The Alsea Study in SW Oregon.] In: Northcote, T. G., ed. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, a symposium held the University of British Columbia February 1968. Vancouver: Institute of Fisheries, University of British Columbia.

49. Bisson, Peter A. and James R. Sedell. 1984. Salmonid populations in streams in clearcut vs old-growth forests of western Washington. In: Meehan, William R., et al, eds. Fish and wildlife relationships in old-growth forests, proceedings of a symposium, April 1982. American Institute of Fishery Research Biologists.

50. O'Connell, M. A., et al. 2000, cited earlier.

51. Dodds, Don. 2004. Saving Salmon [Pamphlet]. Portland, OR: North Pacific Research.

Ward, Bruce R., Donald J. F. McCubbing, and Patrick A Slaney. 2003. Evaluation

of the addition of inorganic nutrients and stream habitat structures in the Keogh River watershed for steelhead trout and coho salmon. In: Stocker, John G., ed. Nutrients in salmonid ecosystems: sustaining production and biodiversity. Proceedings of the 2001 Nutrient Conference, Eugene. Bethesda: American Fisheries Society.

52. Koski, K. V. et al. 1984. Evaluation of buffer strips for protection of salmonid rearing habitat and implications for enhancement. In: Proceedings: Pacific Northwest Stream Habitat Management Workshop, October 10-12, 1984, Humboldt State University, Arcata. Arcata: Humboldt State University, California Sea Grant; and American Fisheries Society, Western Division. 138-155.

53. Gregory, S. V., G. A. Lamberti, D. C. Erman, et al. 1987. Influence of forest practices on aquatic production. In: Salo, E. O. and T. W. Cundy, eds. 1987. Streamside management: forestry and fishery interactions. Contrib No 57. UW Inst of Forest Resources 233-255.

54. Williams, Gene and Heidi Reynolds. 2003. State of the lakes report. Everett: Snohomish County Public Works Department.

55. Sheldon, Dyanne, et al. 2003. Freshwater wetlands in Washington State, Volume 1: A synthesis of the science. Publication 03-06-016. Olympia: Washington Department of Ecology. p. 5-46.

56. Jones, Leland B. 2003. Puget Sound shoreline erosion and erosion control. Bainbridge Island. p. 6.

57. Myers Biodynamics, Inc. 1993. Slope stabilization and erosion control using vegetation, a manual of practice for coastal property owners. Publication 93-20. Olympia: Washington Department of Ecology. p. 25-26.

58. Shipman, Hugh. 2001. Coastal landsliding on Puget Sound: A review of landslides occurring between 1996 and 1999. Report 01-06-019. Olympia: Washington Department of Ecology. p. 19, 20.

59. Skaugset, Arne E., et al. 2002. Landslides, surface erosion, and forest operations in the Oregon Coast Range. In: Hobbs, S. E., et al, eds. Forest and stream management in the Oregon Coast Range. Corvallis: Oregon State University Press. p. 216, 223.

60. Flora, Donald. 2004. On buffers around Kitsap County's watered places.

Bainbridge Island.

61. Bilby, Robert E., et al. 2003. Transfer of nutrients from spawning salmon to riparian vegetation in western Washington. Transactions of the American Fisheries Society 132:733.

62. Berg, Dean Rae, Arthur McKee, and Michael J. Maki. 2003. Restoring floodplain forests. In: Montgomery, David R., et al, ed. Restoration of Puget Sound rivers. Seattle: University of Washington Press. p. 256.

63. Mackie, Alexander W. 2004. Protection of critical areas and the mythology of buffers. Olympia: Perkins Coie. Presented at "Growth Management in Washington" seminar, Seattle, November 15-16, 2004.