

Geotechnical
Water Resources
Environmental and
Ecological Services

Efficacy and Economics of Riparian Buffers on Agricultural Lands

Phases I (2002) and II (2005)

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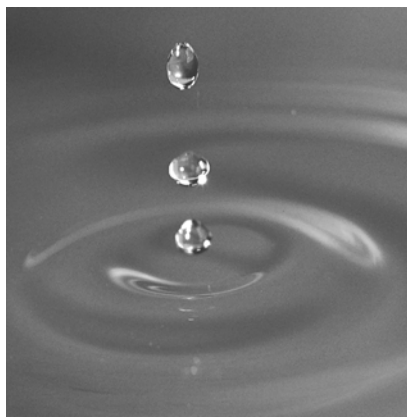
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Efficacy and Economics of Riparian Buffers on Agricultural Lands

State of Washington

Phase I

Work In Progress



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SUBMITTED TO

**Washington Hop Growers Association
Ag Caucus**

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Executive Summary

While recognizing the importance of protecting listed anadromous salmonids that migrate through streams on agricultural lands, the Washington State agricultural community is concerned about the potential mandating of fixed-width riparian buffer zones. Natural resource agencies, including the Washington Department of Fish and Wildlife and the National Marine Fisheries Service, have proposed mandatory, fixed-width riparian buffers on agricultural lands throughout the state. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises serious issues related to private property, economic impacts, and the most effective means of salmon habitat recovery and protection.

In response to these concerns, the Washington Hop Commission, Ag Caucus, of the Ag Fish Water Process, retained GEI Consultants, Inc. (GEI), Pacific Northwest Project (PNWP) and Mason Bruce & Girard (MBG) to review the functions and design dimensions for riparian buffers, their use and efficacy, their applicability to agricultural lands, and potential alternatives to fixed-width riparian buffers.

This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of agricultural buffers, and whether the data and analyses are being appropriately matched to buffer zone applications, and (2) to evaluate the economic costs associated with the proposed land set-asides. The general value of riparian vegetation for fish, wildlife, and water quality is well established in the literature and is not disputed by our findings. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to protect listed salmon. The report relies primarily on reviews of peer-reviewed scientific literature and is therefore consistent with use of Best Available Science regulations (Appendix B).

Large, fixed-width riparian buffers have five primary economic costs: (1) the cost to remove land from production, (2) the loss of economic benefits from agricultural production on those lands, (3) costs to monitor, administer, and maintain buffers, (4) loss of tax base, and (5) loss of economic infrastructure.

The prototypes for current buffer-width recommendations derive primarily from models of timberland set-asides in the Pacific Northwest forests. Thus the science relied on to formulate buffer widths is mostly forest-based. There are, however, important shortcomings to applying methodologies and science associated with timberland to agricultural lands. The landscape, stream gradients, harvest practices, and impacts all differ.

The six primary functions and values attributed to riparian buffers in forests are large wood recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes. The Forest Ecosystem Management Assessment Team (FEMAT) process developed models to determine how much timber to preserve in riparian zones adjacent to harvested areas. Those models led to buffers up to 300 feet or more, depending on floodplain limits, on each side of a stream.

The function that requires the widest set-aside is recruitment of large woody debris (LWD), which improves the quality and quantity of fish habitat in small forest streams. In reviewing literature provided by resource agencies to the Ag Caucus, it appears that data gathered in the timber assessment process and especially curves for LWD are the principal basis for wide buffer recommendations in agricultural areas. Also, the general value of wildlife habitat is emphasized in this literature.

The scientific literature of agricultural buffer widths on to streams in the Pacific Northwest is quite limited. In general, agricultural impact analysis suggests riparian functions other than LWD are far more important on agricultural lands. Vegetation traps sediment, filters pollutants, retains storm water, and stabilizes streambanks on agricultural lands. An important and related issue on agricultural lands is protecting streams from direct and indirect impacts of domestic animals. Peer reviewed studies found applicable in this report suggest that relatively narrow buffers of 10 meters (33 feet), or less, can be highly effective in protecting ecological functions against these types of agricultural impacts. Physical stability and filtration absorption is provided by roots adjacent to the channel and up to the stream's normal high-water mark. In addition, separation of livestock from the stream by only a small margin has proven effective in restoration of water quality and physical habitat. With proper livestock management, fencing may not be needed.

Thermal protection from shade is another desirable riparian function that is dependent on a number of site-specific factors. In larger lowland streams, thermal benefits from riparian shade are reduced. Data and thermodynamic considerations show that small streams can be protected from overheating on a diurnal cyclic basis; however, a relatively narrow buffer within a few meters of the stream can be effective in blocking direct sunlight from the water surface.

Cost effective approaches to protecting salmon streams on agricultural lands will benefit both small agricultural enterprises and the State of Washington. Agricultural production, including agricultural services and food processing, generates almost \$8 billion annually in state income. The agricultural industry is a leading economic sector in several rural counties, in some cases

producing more than \$100,000,000 annually in farm gate production values. This production, in turn, produces ongoing economic activity in other sectors.

Index values can be used to estimate economic impacts of fixed-width riparian buffers in a given county. On a per mile basis, the costs of buffer zones for select counties reviewed in this report could range from \$11,000 to \$81,000 for lost crops, \$67,000 to \$88,000 for lost dairy production, and \$45,000 to \$95,000 for reduced land values. The loss of total direct and indirect county income per 100 acres of riparian set-backs could range between \$190,000 and \$240,000 per year.

Cost analyses, marginal benefit assessments, and cost effective analyses can be useful means for assessing marginal benefits and trade-offs within economic sectors. These tools can be used accurately at the county or regional level to compare the costs of variable width buffers or other approaches. Additionally, local enterprise economic models are in development that will help individuals evaluate and understand the economic cost of decisions that affect their land.

One alternative to mandatory, fixed-width riparian buffers that may be preferable to farmers and ranchers would be a voluntary, incentive based program that may include variable width buffers. The agricultural community has already adopted many conservation practices based on local environmental needs and identifiable conditions in an ongoing betterment process that includes economic considerations. Variable width buffers that consider land use, gradient, and proximity to points of maximum return flows are preferable and will likely be more effective than fixed-width buffers. A more in-depth analysis of needs and alternatives is proposed for Phase II of this work in progress. A possible linkage could come from on-going watershed planning. Phase II of this research will elaborate on methods to encourage habitat improvement on agricultural lands and provide regulatory and economic certainty.

In summary, after reviewing numerous peer-reviewed studies related to agriculture, we conclude that riparian buffers, based on site potential tree heights of up to 300 feet wide, often greatly exceed what is required to protect water quality and the ecological function of aquatic habitat on agricultural lands. Fixed-width buffers do not offer targeted solutions to site-specific issues. Fixed widths are independent of site-specific gradient, overland and channel flow regimes, and locations of maximum return flow. When buffers zones are wider than a site requires, it can be difficult to justify the adverse economic impacts that a mandated width would produce. For alternative purposes, such as enhanced habitat connectivity to benefit terrestrial wildlife, greater widths may be desirable, but go beyond what is necessary to recover listed fish. Riparian buffer zones are ecologically beneficial; however, the width and composition of a buffer zone should be tied to specific management objectives.

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Section 1 - Introduction

1.1 Background and Purpose

The Washington Department of Fish and Wildlife (WDFW) and National Marine Fisheries Service (NMFS) are recommending mandatory, fixed-width buffers as the primary tool to reduce adverse agricultural impacts to salmon recovery under the Endangered Species Act. The regulatory agencies recommend mandatory buffers as a means to improve water quality and retain or enhance aquatic, terrestrial, and riparian habitat for fish and wildlife (Mankowski and Landino, 2001; Knutson and Naef, 1997). Some counties have adopted agency recommendations.

While recognizing the importance of protecting listed anadromous salmonids that migrate through streams on agricultural lands, the Washington State agricultural community is concerned that mandatory, fixed-width riparian buffers could have severe economic consequences, including putting many small enterprises out of business. In response to these concerns, the Washington Hop Commission, Ag Caucus, of the Ag Fish Water Process, retained GEI Consultants, Inc. (GEI) and its teaming partners, PNWP and MBG, to review the functions and design dimensions for riparian buffers, their use and efficacy, their applicability to agricultural lands, and potential alternatives to fixed-width riparian buffers (including variable width buffers).

This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of agricultural buffers, and whether the data and analyses are being appropriately matched to buffer zone applications, and (2) to evaluate the economic costs associated with the proposed land set-asides.

A literature review was undertaken to assess the scientific and technical bases for proposed agricultural riparian buffers, and whether the proposed buffer applications are consistent with goals and needs specific to endangered salmonid recovery. The literature review is focused on a relatively limited set of scientific investigations dealing with a specific set of agricultural management issues. The review is not intended to be a comprehensive review of riparian science although the basic ecological functions of riparian areas are addressed.

Specific questions to be answered relative to the science and technical function of agricultural buffers include:

1. What is the body of science, scientific analyses, and reviews pertinent to an evaluation of agricultural buffers?
2. What do the empirical data and analyses suggest about buffer requirements to manage adverse agricultural impacts to salmon habitat?
3. When adverse agricultural impacts are present, what management practices can reduce the need for riparian buffers or the required width of riparian buffers?
4. What are the potential economic costs of buffer zone management alternatives?
5. What are appropriate bases for evaluating and comparing economic impacts and trade-offs?

1.2 Authorization

GEI Consultants, Inc. (GEI) was authorized to complete the scope of work for this report by a contract, dated June 1, 2002 between Washington Hop Growers Association and GEI. GEI's subcontractors in this authorized work include Pacific Northwest Project of Kennewick, WA (Dr. Darryll Olsen) and Mason, Bruce & Girard Inc. of Portland, OR. (Mr. Michael Bonoff).

1.3 Scope of Work

In completion of this report, GEI and its teaming partners completed the following scope of work:

1. Reviewed and summarized literature and references provided as Best Available Science by Washington Department of Fish and Wildlife as justification for agricultural buffer recommendations (Appendix A).
2. Reviewed relevant scientific and technical literature related to riparian buffer zones. The review was not intended to be exhaustive, but focused on minimum buffer width that could significantly reduce known impacts to water quality and salmonid species on agricultural lands.
3. Summarized findings and conclusions in this report.

1.4 Project Personnel

The following personnel played key roles in the development of this report:

John Pizzimenti, Ph.D.	Project Manager, GEI
Ginger Gillin, M.S.	Fisheries Biologist, GEI
Duane McClelland, E.I.T.	Reviewer, Editor, GEI
Darryll Olsen, Ph.D.	Natural Resource Economist, PNWP
Michael Bonoff, M.S.	Limnologist / Ecologist, MBG

Jennifer Ennis M.S., J.D.
Hushmandi Ziari, Ph.D.

Biologist / Regulatory Specialist, MBG
Minnesota IMPLAN Model Specialist

In addition to the above staff, we received comments, literature and or general assistance from several outside persons and anonymous reviewers of various drafts from Oregon State University, Iowa State University, National Resource Conservation Service, National Marine Fisheries Service, Skagit County Washington, Ag Caucus, the Washington Agricultural Caucus, and the Washington Department of Agriculture. However, this document is the independent product of GEI and our subcontractors.

Section 2 - Overview

2.1 Rationale for Fixed-Width Riparian Buffers

The proposed width of agricultural riparian buffer zones and the activities that are allowed within these zones are based on a complex set of timber harvest regulations in the Washington Forest and Fish Report (Appendix A.10). Buffer widths in timber zones in excess of 300 feet on both sides of a stream were established primarily to ensure continued recruitment of large woody debris (LWD) to enhance salmonid pool habitat (FEMAT, *op.cit.*). Forest removal impairs the recruitment of LWD until a new forest matures. Temporary loss of mature forests can adversely impact aquatic habitats for hundreds of years. Riparian buffers provide other ecological benefits, including nutrients, shade, bank stability, and terrestrial habitat (FEMAT, *op.cit.*). Each of these benefits can be provided within the buffer width established for LWD.

2.2 State's Best Available Science for Riparian Buffers

The State of Washington and NMFS (Mankowski and Landino, 2001) provided a compendium of literature citations to the Ag Fish Water's Agricultural Caucus. The compendium is considered by WDFW and NMFS to represent the Best Available Science (BAS) in support of proposed fixed-width, agricultural riparian buffers. This document is a bound collection of hundreds of references from 15 different source documents. Two of the documents pertain directly to agricultural data and the remaining 13 documents pertain to forests or other subjects or focal points (Appendix A).

2.3 Limited Applicability of State's Science for Riparian Buffers

In our opinion, the compendium of literature citations provided by the State does not meet traditional BAS criteria and does not provide an adequate basis for establishing appropriate sized buffers on agricultural lands. The compendium describes itself as follows: "Please recognize the proposed approach represents a synthesis of a consolidation of a large amount of scientific information and best professional judgment by natural resource scientists" (Mankowski and Landino, *op cit.*). BAS has key components: peer review, scientific methodology, logical conclusions, reasonable inferences, statistical analysis, applicable context, and references (Alverson, 2000, *in* Natural Resources Consultants, 2000). By itself, a compendium of literature citations is not subject to peer review and does not reflect a scientific method. The document does not synthesize, make conclusions, or make inferences. The context for the collection of

references is primarily forested lands. The compendium does not synthesize or draw conclusions based on the literature compiled for agricultural lands.

To better understand how this body of literature was used to arrive at the recommended agricultural buffer widths, we have read and summarized each of the 15 primary sources (Appendix A). Of the 15 bibliographies, six focus on general riparian science, five focus on forestry science, two involve permitting, and two involve agriculture. We estimate that less than 1 percent of the literature cited deals with agricultural data, and none of it is synthesized to develop buffer width recommendations for agriculture.

In addition to our review of the above compendium (Mankowski and Landino, *op. cit.*), we have obtained peer reviewed literature (consistent with BAS criteria) pertinent to the issue of buffer width and effectiveness on agricultural lands. In general, studies have shown that the fixed-width approach *is easier to enforce and administer, but often fails to provide for many ecological functions* (Castelle *et al.*, 1994). We summarize this information in Section 3. Our search was not exhaustive and if we missed important work, we hope that others familiar with the literature will bring it to our attention, as this is a Work In Progress.

2.4 Different Buffer Widths for Forest and Agriculture

It is important to recognize that riparian buffer widths suitable for mitigating the effects of timber harvest are not directly applicable quantitatively, or in many cases qualitatively, to agrarian activities in physically and biologically dissimilar environments. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises serious issues related to private property, economic impacts, and the most effective means of salmon habitat recovery and protection.

In developing this report, we examined the scientific literature on riparian buffers and found that: (1) the use of buffer prescriptions for timber exaggerates the conditions that apply to agriculture for a variety of ecological needs, impact assessment, or salmon protection, (2) uniform prescriptions for wide buffers on every stream are generally based on the mistaken assumption that all or even most agricultural streams are currently unsuitable for salmonids, and that, if impaired, are primarily caused by agricultural activities, and (3) that impairment of agricultural streams is primarily from loss of large woody debris, an assumption not verified by data on agricultural lands. Recruitment of LWD requires the widest buffers according to forest science (*cf.* Knutson and Naef, 1997).

We have examined numerous peer-reviewed studies on stream buffers and found that buffer widths developed to mitigate impacts of timber harvest may be hundreds of feet wider than required for agriculture when the purpose is to reduce nutrients, chemicals, sediment, and

erosion, or to provide shade (see Section 3). The literature we reviewed demonstrates that buffers of 5 to 30 meters function adequately for water filtration, sediment reduction, animal exclusion, shade, nutrient removal and bank stabilization for conditions reported on agricultural lands.

Recommendations for buffers wider than 100 feet on each side of streams are primarily consistent with accommodation for LWD recruitment and for terrestrial wildlife, not for restoration of salmon streams on agricultural lands (*cf.* Appendix C in Knutson and Naef, 1997). Although wildlife corridors may be worthy conservation objectives, it is not the legal or management objective of agriculture. The literature also shows that LWD is primarily a product and function of large trees from coniferous forests, rather than valley bottoms. LWD from upland forests eventually reaches valley bottoms via hydraulic transport and may contribute as much as 50 percent of the woody debris there (*op.cit.*). For approximately 20 years, fishery management practices removed large woody debris from forested streams—a legacy that is best corrected by regeneration of upland forests and anthropogenic habitat improvement measures during the regeneration process.

2.5 Alternatives to Mandatory, Fixed-Width Riparian Buffers

The general value of riparian vegetation for fish, wildlife, and water quality is well established in the literature and is not disputed by our findings. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to restore habitat for listed fish. The proposals to develop buffer widths to fully establish riparian habitat preserves or wilderness corridors (Knutson and Naef, 1997) probably go beyond the needs of salmon habitat restoration. A scientific basis for salmon habitat restoration will match form to function: that is, buffers will be one tool to restore identified habitat deficiencies along specific stream reaches when preferred alternatives are ineffective. In some cases, riparian buffers will be the preferred alternative, but the width of each riparian buffer should be established to meet site-specific criteria based on BAS that is specific to agricultural lands.

The scientific literature and historical experience indicate that agricultural impacts can be effectively managed using a variety of tools known as Best Management Practices. Through assistance of the National Resource Conservation Service (NRCS), the vast majority of agricultural lands have BMPs in place that can either prevent or reduce major impacts, and BMPs can provide immediate benefits through direct intervention. For example, if bank erosion is occurring, a direct solution BMP will stabilize the bank. This may be through a variety of approaches including buffers, but may also include other techniques. As another example, if nutrient overloading is a concern, the first action should be to eliminate direct irrigation runoff or animal waste input to the stream. If that is only partially effective, then secondary actions,

including use of buffers or exclusion devices, may be needed. BMPs can include riparian buffers, vegetation strips, and other land set-asides based on site-specific requirements. The width, importance, and form of a riparian buffer can be established on a case-by-case basis where site-specific data demonstrate that it is the appropriate BMP. These types of actions typically occur through voluntary collaboration of farmers with NRCS scientists and gain cost shared support via federal, state, and local programs.

2.6 Report Contents

Under the Endangered Species Act and Washington's Growth Management Act, county and city planning must give "special consideration" to conservation or protection measures to preserve or enhance anadromous fisheries for listed species and to preserve or enhance "critical areas" based on the Best Available Science. BAS guidelines include:

- Entities should consult with qualified scientific experts.
- Entities may use information that resources agencies have determined represent BAS.
- Other peer-reviewed literature is an important source of BAS.

Reports and documents referenced in Section 3 have met the criteria for BAS as presented above. We expect the findings of this report and references herein will be useful to those local governments that are establishing the need for riparian buffers to protect salmonids and critical areas.

Our review of the literature confirms that riparian habitat is valuable to fish and wildlife. The report explores the appropriate role and width of riparian buffers on agricultural lands. Our findings suggest that: (1) performance and effectiveness of buffers on agricultural land is highly variable and both site-specific and function-specific, (2) the few studies that evaluate buffer widths experimentally have shown improved ecological function with buffers between 5 and 30 meters wide, and (3) a quantitative approach to buffer width is inadvisable without site-specific data (*e.g.*, O'Connell *et al.*, 1993; *In*, Knutsen and Naef, 1997; Metro, 2002).

In Section 3, we review the science associated with riparian buffers, with an emphasis on buffers as a management tool for controlling non-point source impacts to agricultural streams. We review applicability of the six ecological functions of riparian buffers as developed by the Forest Ecosystem Management Assessment Team (FEMAT; Appendix A.3). Section 4 discusses economics of buffers, in terms of both land value and revenue impacts. Section 5 lists the peer-reviewed references and other sources of information we used in this review. The appendices provide our review of the literature and regulatory requirements provided by State and Federal agencies to the Ag Caucus.

Section 3 – Science of Riparian Buffers on Agricultural Lands

3.1 Background

In response to a request by the Ag Caucus, the NMFS and WDFW provided an extensive bibliography of research papers related to riparian ecosystem functions (Mankowski and Landino, 2001). NMFS and WDFW indicated that this body of literature provides the basis for ongoing initiatives to protect riparian functions—initiatives that are the focus of Habitat Conservation Plans, the Forest and Fish Report, Tri-County Conservation Planning, and Endangered Species Act Section 7 Consultations. The 15 primary documents contained in the bibliographic compendium (Appendix A) range from studies that are directly applicable to riparian buffers in agricultural areas (USDA:National Resource Conservation Service, 1997), to those that are relevant but clearly focused on forest management and defining properly functioning conditions within riparian areas (FEMAT, 1993; NMFS, 1996). Together, these studies represent a comprehensive body of information on the ecology and major functions of riparian forests: provision of large wood, shade as it affects stream temperature and microclimate, streambank stability, litter-fall, sediment filtration, and floodplain processes (Naiman *et al.*, 1992; Spence, *et al.*, 1996; FEMAT, 1993; Chamberlin *et al.*, 1991; Sullivan *et al.*, 1987; CH2M HILL, 1999).

While the general function of riparian zones and needs of aquatic and terrestrial biota that depend on them are well established, there is considerable debate about the widths of riparian buffers needed to restore and/or ensure properly functioning conditions (PFCs) in salmon bearing streams. Given the regulatory climate that frames much of this discussion, the use of PFC as defined by NMFS is an appropriate gage of the health of agricultural streams. As described in the Citizen's Guide to the 4(d) Rules (NMFS, 2000), the NMFS defines PFC as the sustained presence of natural habitat-forming processes (*e.g.*, hydraulic runoff, bedload transport, channel migration, riparian vegetation succession) that are necessary for the long-term survival and recovery of the species (NMFS, 1999). Thus, PFCs constitute a species' habitat-based biological requirements—the essential physical features that support spawning, incubation, rearing, feeding, sheltering, migration, and other behaviors. Such features include adequate instream flow, appropriate water temperature, loose gravel for spawning, unimpeded fish passage, deep pools, and abundant large tree trunks and root wads.

Issues associated with buffer widths have recently come before the Western Washington Growth Management Hearings Board (WWGMHB) for several Washington counties, including Island

and Skagit Counties, where riparian buffers and the Best Available Science underlying their adoption have been challenged. Literature reviewed in this section focuses on the efficacy and need for buffers to achieve ecological function on agricultural lands. Specifically, we address transport of unwanted materials into the stream, transport of needed materials into the stream, shade and temperature, physical habitat, and its protection and enhancement. The section concludes with remarks on the values of fixed versus variable buffers and research needs for better data and experimental design on agricultural lands.

3.2 Origins of Recommendations: Forest-Based FEMAT Curves

The majority of the literature now relied on for determining buffer widths in Washington State can be traced to models developed by the Forest Ecosystem Management Assessment Team (FEMAT, 1993) in connection with development of the Northwest Forest Plan (Appendix A.3). Geographically, FEMAT criteria were developed to determine required widths of riparian reserves for streams on federal lands within the range of the northern spotted owl. These models, Riparian Process Effectiveness Curves, are a series of functions that relate buffer width to a specific ecological function considered critical to aquatic and riparian habitat preservation on lands being harvested for timber. The functions are plotted as a two-dimensional relationship of distance from the stream and effectiveness with respect to the various functions provided by the riparian zone. The curves were developed from a number of studies showing decreasing effects of riparian vegetation on streams with increasing distance from the streambank (VanSickle and Gregory, 1990; McDade *et al.*, 1990; Beschta *et al.*, 1987). As noted above, these functions include large woody debris recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes.

Riparian reserve widths recommended in the FEMAT Report are based on multiples of a site-potential tree height (SPTH), defined as “the average maximum height of the tallest dominant trees (200 years or older) for a given site class.” The distance is measured from the edge of the area within which a stream naturally migrates (the channel migration zone) or a prescribed slope distance, whichever is greater. A report prepared for the NMFS (Spence *et al.*, 1996), known as the ManTech Report, makes similar recommendations for the design of Habitat Conservation Plans on non-federal lands in the same areas. Reserve widths may be adjusted based on watershed analysis to meet Aquatic Conservation Strategy objectives (FEMAT, 1993). Since the FEMAT curves were developed as a product of the Northwest Forest Plan, and were a key element of the Timber Fish and Wildlife Process that led to the Forest and Fish Report, they are naturally oriented to managed forested lands. Under Option 1 (maximum protection), the FEMAT prescribed widths on both sides of streams for all watersheds are:

- Fish-bearing streams - the larger of two site potential trees or 300 feet.
- Perennial non-fish-bearing streams - the larger of one site-potential tree or 150 feet.
- Intermittent streams - the larger of one site-potential tree or 100 feet.

For western and eastern Washington, the State's Forests and Fish Rules governing private and State lands require a riparian buffer on either side of a stream that may contain fish habitat. The required buffer extends to one SPTH from bankfull width or the edge of the channel migration zone (CMZ). The SPTH varies from 90 feet to 200 feet (27 m to 61 m) depending on the site class (V-I) location and whether fish are present. The riparian buffer is divided into three zones—the core zone, the inner zone, and the outer zone—which are further defined for east and west sides of the Cascades.

1. The west side core zone extends 50 feet (15 m) from bankfull width or the edge of the CMZ. No harvesting is allowed in this zone. The east side core zone is 30 feet (10 m).
2. The west side inner zone extends from the outer edge of the core zone to 67 percent of the SPTH for streams less than 10 feet (3 m) wide or 75 percent of the SPTH for streams greater than 10 feet (3 m) wide. Limited harvest is allowed in this zone only if the remaining number of trees, basal area, and proportion of conifer are sufficient to meet Desired Future Conditions (DFC) when the stand is 140 years old (WAC 222-30-021). The east side inner core zone would be 75 to 100 feet (25 m to 30 m), depending on stream width.
3. The outer zone for both the east and west side extends from the outer edge of the inner zone out to the SPTH. Harvest is allowed in this zone as long as 20 conifers per acre (49 per ha) over 12 inches (30 cm) in diameter are retained as leave trees. If the inner zone is harvested under Option 2, a basal area credit may be available that decreases the outer zone leave tree requirements to as low as 10 per acre (25 per ha).

The FEMAT report has been thoroughly independently reviewed. For forests, it is not clear that these multiple SPTH recommendations do not overstate the widths needed to meet proper functioning conditions where tree harvest is the impact (CH2M HILL, 1999). However, it is clear that retention of large wood and shade have been the dominant factors in determining buffer widths and management zones specified in the FEMAT report, as well as in the Washington Forest and Fish Report.

Agricultural impacts differ significantly from those due to timber harvest, and can be broadly classified as follows (from Knutson and Naef, 1997):

- Soil erosion and sedimentation
- Pesticides and fertilizers
- Animal wastes
- Irrigation/water withdrawal
- Grazing

A basic conclusion of this review is that, if the management focus is tied directly to agricultural impacts, the required width of riparian buffers will be substantially less than those recommended in forested ecosystems.

3.3 Performance of Buffers in Agricultural Areas

3.3.1 Introduction

Castelle *et al.* (1994), Wenger (1999), Platts (1991), and Castelle and Johnson (2000), review the scientific literature on ecological functions of riparian buffers, and discuss widths of buffers needed for various ecological functions. In general, these reviews, which collectively summarize hundreds of different studies of buffer effectiveness, found that relationships are non-linear such that the marginal benefit of increasing buffer width is greatest at low-width values and becomes progressively smaller at higher width.

Castelle and Johnson (2000) considered buffer effectiveness relative to six functions: three “sink” functions (streambank stabilization, sediment reduction, and chemical removal) followed by three “source” functions (Large Organic Debris (LOD) production, Particulate Organic Matter (POM) Production, and Shade Production for stream water temperature maintenance). Studies reviewed by Castelle and Johnson (2000) indicate that for five of the six functions considered, the effectiveness of riparian buffers increases with buffer width; however, most of the potential contributions of riparian vegetation to these functions are realized within the first 5 to 25 m (16 to 82 feet) from the streambank. Buffer widths of 5 to 25 m typically provide at least 50 percent of the potential effectiveness, and often 75 percent effectiveness or greater. Disproportionately wider buffers are needed to achieve greater effectiveness (i.e., the marginal benefit of making buffers wider declines rapidly as buffer widths increase beyond 5 to 25 m (16 to 82 feet) (Castelle and Johnson, 2000).

Based on a large body of literature reviewed by Castelle and Johnson (2000), the authors developed curves of effectiveness versus buffer width, similar to those developed for the FEMAT report. A summary of the literature for each ecological function of buffers follows.

3.3.2 Streambank Stabilization and Sediment Reduction

Castelle and Johnson (2000) summarized factors affecting streambank stability as a balance of forces, including soil properties such as moisture content and texture, erosive forces such as overland flow, and external factors such as compaction by vehicular traffic, wildlife, and livestock trampling. High moisture content enhances sediment transport rates by accelerating

detachment of particles, thus increasing transport of adsorbed nutrients, bacteria, or other contaminants downslope (Henderson, 1986).

Interception of sediment and debris by vegetated buffers reduces velocity of overland flow, increasing infiltration of soil particles through leaf litter, and retention via metabolism by microbes and plant uptake (Lee *et al.*, 1999). These factors counter the transport of sediment-bound contaminants in surface flow. Roots maintain soil structure, physically restraining otherwise erodible soil, and helping to maintain sheet flow by resisting formation of channels (Castelle and Johnson, 2000). Zimmerman, Goodlett, and Comer (1967) observed that the width-to-depth ratio of a stream was three times greater in forested reaches (ratio of 6.1) than in meadow reaches (ratio of 2.0), and attributed this difference to the extensive root systems of herbaceous plants in meadows that have a stabilizing influence on the stream channel.

Roots of woody plants may also play an important role in streambank stabilization, particularly deep-rooted trees and shrubs. Deep roots can penetrate the soil profile and become anchored in more stable strata, such as weathered or fractured bedrock. It has also been suggested that streambank undercutting is possible because streambank collapse is prevented or at least delayed by roots (Richards, 1977). Note that other vegetative factors, such as the presence of large woody debris, may have the effect of armoring streambanks and increasing streambank stability.

Research conducted by Tufekcioglu *et al.* (2001) indicates that vegetative buffers had significantly higher soil respiration rates than did adjacent crop fields, suggesting higher levels of biological activity within the buffers. This factor has implications not only for streambank stabilization but also for the presence of added organic matter, providing better conditions for nutrient sequestration within the riparian buffers (Tufekcioglu *et al.*, 1999).

Waldron and Dakessian's (1982) examination of the influence of plant roots on soil stability included seven grass species, two legumes, and two trees. These investigators measured direct shear resistance in packed soil columns. Generally, their findings support the observations of Zimmerman, Goodlett, and Comer (1967) and others, in that herbaceous roots were found to provide significant soil stabilization. However, they noted that the roots of all species examined increased soil strength to varying degrees. Specifically, many of the grass species planted in early autumn produced nearly a three-fold increase in soil shear resistance by late spring, less than eight months after planting. Tree roots (*Pinus ponderosa* and *Quercus agrifolia*) were also found to provide soil shear resistance of this magnitude, but only after tree saplings were 3 to nearly 5 years old.

Kleinfelder *et al.* (1992) examined streambank collapse due to compressive forces, such as those imparted by livestock trampling. They also noted that the important relationship between root-length density and compressive strength of non-cohesive soils was non-linear, with substantial

increases in strength occurring from moderately dense root systems—about 2 mm/mm³. Beyond that point, increased root-length density increased soil strength by progressively smaller amounts, reaching an apparent asymptote at approximately 50 kPa. They also found that the roots of different plants provided varying amounts of compressive soil strength. In their study, *Carex nebrascensis* imparted the greatest compressive soil strength. In un-incised headwater streams in eastern Oregon, Toledo (2001) found significantly greater root biomass and structural integrity at the immediate margins of the streambank than in incised channels.

Balsky *et al.* (1999), Ehrhart and Hansen (1997), and Platts (1991) summarize much of the technical literature describing the impacts of livestock on riparian ecosystems. A review of technical sources that assess the impacts of grazing on riparian habitat and salmonid populations uncovered a range of observations surrounding the magnitude of impacts. What is apparent is that grazing impacts are highly dependent on site conditions and the types of grazing management practices that are employed.

Concern for grazing impacts has led researchers and managers to identify grazing strategies that can be compatible with healthy riparian ecosystems (Ehrhart and Hansen, 1997; Mosley *et al.*, 1999). Several published reviews discuss strategies for riparian grazing that have been found to be effective in maintaining riparian health. Some strategies include the use of riparian buffers and more intensified land and grazing management.

In his review of livestock grazing strategies, Platts (1991) rated corridor fencing as a nine on a scale of one to ten with one being poorly compatible with fishery needs and ten being highly compatible. Corridor fencing results in good to excellent streambank stability, excellent brushy species composition, good to excellent seasonal plant new growth, and excellent stream riparian rehabilitation. However, there is little literature that scientifically assesses the width of the fenced corridor needed to provide for healthy riparian habitat in rangeland (Mosley *et al.*, 1999).

Relative to fecal coliform impacts on water quality, minimal buffer zones may be adequate. In the literature review done by Mosley *et al.* (1999), they cite Doyle *et al.* (1975) and Oskendahl (1997) for their recommendation that a buffer strip of 12.5 feet on each side of a stream may be adequate to protect water quality from coliform bacteria and effectively filter nutrients. Jefferson County Conservation District (2001) actually demonstrated these improvements in western Washington.

A number of measures other than corridor fencing have been evaluated that can improve riparian conditions on rangelands. Ehrhart and Hansen (1997) investigated cattle grazing practices that were compatible with healthy riparian ecosystems in Montana. They did this by inventorying a number of pastures that had healthy riparian areas and then interviewing the landowner or manager to determine how cattle were managed in that pasture. They found that what operators

did to encourage livestock not to loiter in the riparian zone, while in a pasture, was more important than either season of use or length of time in the pasture per se. With proper management under specific conditions, many pastures containing a variety of riparian types may be grazed in various seasons and for various periods of time without adversely impacting the health of the riparian area (Ehrhart and Hansen, 1997).

One quantifiable factor noted by Ehrhart and Hansen (1997) was that many of the healthy riparian pastures also contained alternate water sources off the stream. The second theme noted by Ehrhart and Hansen (1997) was a high degree of operator involvement. All the operators were actively involved in managing their land and had a keen interest in the condition and trend of their riparian areas. Managers willing to modify management practices and conduct monitoring, whether formal or informal, was a component to the successful maintenance of riparian areas with livestock.

The conclusions of Ehrhart and Hansen (1997) were that riparian grazing might be incorporated into each of the traditional grazing systems, as long as the condition of the riparian zone itself remains of primary concern. They concluded that management, not the grazing system, is the key.

Mosley *et al* (1999) conducted a literature review of the management of cattle grazing in riparian areas. Like Ehrhart and Hansen (1997), they also concluded that there is not one particular grazing system that can be applied in all situations. They recommend that grazing plans be site-specific and based upon the best research available. They have provided several suggestions for a riparian grazing plan:

- Determine the tolerance of a riparian site to grazing and then limit the grazing periods to avoid exceeding the critical period length.
- To increase vegetative density, increase rotational scheduling of cattle grazing.
- To graze a site more than once per growing season, moisture and temperature conditions should be conducive to vegetative re-growth. Grazing more often and for shorter periods is preferable to fewer and longer grazing periods.
- Adjusting timing, frequency, and intensity of grazing in individual pasture units is more important than adopting a formalized grazing system.
- Prevent cattle from congregating near surface waters. Fencing, supplemental feeding, alternative water sources, and herding work best.
- Locate the edges of features where cattle congregate—such as salt grounds, water developments, and winter-feeding grounds—away from surface waters and buffer strips.
- Maintain at least 50 percent protective ground cover along streambanks. Vegetation buffer strips should usually not be necessary to protect banks and reduce impacts from

cattle urine and feces unless cattle congregate near surface waters to the point that protective ground cover is less than 50 percent.

Mosley *et al.* (1999) concluded that the impact of cattle grazing on riparian ecosystems depends entirely on how the grazing is managed. The important variables are timing, frequency, and intensity of grazing. Each situation is unique and requires its own creative, locally tailored solution. The best way to know whether a particular management strategy is suitable for a particular site at a specific point in time is to implement the strategy, and then monitor its effectiveness and adjust the practice as needed.

When buffer width is graphed against sediment removal from multiple peer-reviewed studies, it is apparent that little additional benefit is gained beyond 15 m (49 feet), and maximum benefits at much less than 15 meters (Figure 3.1). Effective sediment removal in an agricultural setting was illustrated by a study in which various treatments (buffer widths) were matched by controls (Ghaffarzadeh, Robinson, and Cruse, 1992). Using grass filter strips ranging from 0 to 18.3 m (0 to 60 feet) on 7 and 12 percent slopes, these authors found no difference in sediment removal on either slope beyond 9.1 meters (less than 30 feet), where 85 percent of the sediment was removed. Further, there was no difference in sediment removal between the two slope angles beyond 3.1 m (10.2 feet). The sedge *Carex nebrascensis* imparted the greatest compressive soil strength of various species used in this study. In un-incised headwater streams in eastern Oregon, Toledo (2001) found significantly greater root biomass and structural integrity at the immediate margins of the streambank than in incised channels.

According to a review by Desbonnet *et al.* (1994), the most efficient width of vegetated buffers for sediment removal is 25 m (82 feet). For total suspended solids (TSS), buffer widths need to increase by a factor of 3.0 for a 10 percent increase in removal efficiency, and greatest efficiency is provided by 60-m (197-foot) buffers. Note that this review was conducted for riparian buffers in the coastal zone and may not be directly applicable to inland areas of the Pacific Northwest.

Wenger (1999) points out that the Desbonnet (*op.cit.*) review was based on a composite of data from studies conducted with various methods at different locations. Studies that compare multiple buffer widths in the same location and the same study conditions are more illuminating. Figure 3-2 (from Wenger, 1999) graphically depicts the results of several studies of this type. Although percent removal of TSS increases with buffer width in all these studies, most of the results indicate that buffers between 10 and 20 m (33 and 66 feet) remove between 80 percent and 90 percent of the TSS.

Wenger (1999) noted that most of the studies described above were short term. There is evidence from long-term analysis that wider buffers are necessary to maintain sediment control. Long-term studies by Lowrance *et al.* (1988) and Cooper *et al.* (1987) indicate that, although

riparian zones are efficient sediment traps, the width required for long-term retention may be substantially more than is indicated by short-term experiments. Buffers of 30 m to 100 m (98 to 328 feet) or more might be necessary for long-term protection (Wenger, 1999). Overall, Wenger (1999) concluded that a 30-m (98-foot) buffer is sufficiently wide to trap sediments under most circumstances, and a 9-m (30-foot) wide buffer would be the absolute minimum width.

Curves fit to studies included in Figure 3-2 illustrate that buffer widths of 7 m to 60 m (23 to 197 feet) all produce a similar effect of arresting about 80 percent of sediment, and that little additional benefit is gained beyond approximately 7 m (23 feet). Another observation is that of the various types of landscapes, the agricultural studies showed that narrow buffers of 7 m and 15 m (23 to 49 feet) were as effective as buffers up to 8 times wider on other types of habitats. The inclusion of the agricultural studies completely changes the shape of buffer-width benefit curves in agricultural settings and conclusions about the effectiveness of narrow buffers. Again, where agricultural data are available, considerably different conclusions are reached than if only forest data are used.

3.3.3 Water Quality Protection

Protection/maintenance of water quality is arguably the most important function for buffers in agricultural areas. Riparian buffers, (or vegetated filter strips (VFS)), protect stream water quality by physical entrapment of chemicals bound to sediment particles and uptake by plants (nutrients, pesticides, herbicides, other cations and anions).

Wenger (1999) cites several studies that document removal of a large proportion of pollutants in the first few meters of a riparian buffer (Dillaha, 1988; Dillaha 1989; Castelle and Johnson, 2000) (Figure 3.3). These data include an obvious outlier, without which it could be concluded that no further increases in removal occurs beyond approximately 15 m (49 feet). The steepness of the effectiveness/width curve can be attributed to uptake of dissolved nutrients, coupled with rapid removal of sediment-bound pollutants within the first few meters, such that 10 meters (30 feet) of buffering is adequate to remove up to 90 percent of chemical runoff. Lowrance (*op. cit.*) noted that field studies of nitrate removal show that much of the nitrate is removed in the first few yards of a 90- to 100-foot buffer. These studies suggest that buffers much narrower than 10 meters may be quite functional. Some additional peer reviewed literature further elucidate buffer width and chemical removal (from Wenger 1999):

- Lowrance *et al.*, 1997, in Isenhardt examined changes in pesticide concentrations crossing a 50-m (164-ft) wide buffer in the Georgia coastal plain. Atrazine and Alachlor were reduced from 34 $\mu\text{g/L}$ and 9.1 $\mu\text{g/L}$, to less than 1 $\mu\text{g/L}$.

- Hatfield *et al.* (1995) found that grassed filter strips of 12.2 m and 24.4 m (40.0 and 80.1 feet) removed 10 to 40 percent of the atrazine, cyanazine, and metolachlor passing across them.
- Arora *et al.* (1996) found that a 20-m (66-ft) wide riparian buffers of 3 percent slope retained 80 – 100 percent of the herbicides (atrazine, metolachlor, and cyanazine) that entered during storm events. The variation was related to the amount of runoff.
- Neary *et al.* (1993) concluded that, generally, buffers of 15 m (49 feet) or larger are effective in minimizing pesticide residue concentration of stream flow.

In a review of BAS associated with riparian buffers to protect in-stream water quality and fish habitat, Castelle (2000) provided the Island County Board of Commissioners with a summary of literature focusing on buffer widths needed for proper functioning conditions in agricultural riparian buffers. The Island County Board of Commissioners had specifically requested a review of BAS supporting an 8-m (25-ft) riparian buffer. Pertinent findings of this review include:

- Ahola (1990) recommend 2- to 10-m (7 to 33 feet) buffers for stream habitat protection.
- Dillaha *et al.* (1989) found that 4.6-m (15-ft) vegetated filter strips removed 70 percent of suspended solids, 61 percent of phosphorus, and 54 percent of nitrogen.
- Doyle *et al.* (1975) reported 95 percent nitrogen removal and 99 percent phosphorus removal in 3.8-m (12-ft) buffers, and recommended 7.6-m (25-ft) forested buffers to protect water quality from animal wastes.
- Doyle *et al.* (1977) found substantial removal of nitrogen, phosphorus, potassium, and fecal bacteria in 3.8-m (12-ft) forested buffers and in 4-m (13-ft) grassy buffers.
- Ghaffarzadeh *et al.* (1992) reported no further improvement in vegetated filter strip efficiency in removing sediments beyond 9.1 m (30 feet).
- Hubbard and Lowrance (1992) stated that nitrate had "very little impact" on riparian systems after passing through a 7-m (23-ft) forested buffer.
- Madison *et al.* (1992) reported 90 percent removal of nitrogen and phosphorus by a 4.6-m (15-ft) grassy buffer.
- Neibling and Alberts (1979) found 82 percent sediment removal in 2.4-m (8-ft) buffers, and 90 percent sediment removal in 4.6-m (15-ft) buffers.
- Reneau and Pettry (1976) demonstrated 94 percent removal of phosphorus in shallow groundwater after a distance of 3 m (10 feet).
- Xu *et al.* (1992) found similarly high nutrient removal rates, nearly 100 percent removal of nitrate-nitrogen in a 10-m (33-ft) mixed herbaceous/forested buffer.
- Fisher (1999) and Fisher *et al.* (1999) point out that recommended widths for ecological concerns in buffer strips typically are much wider than those recommended for water quality concerns.

In addition to the above, Mendez and Mostaghimi (1999) found that 8.5-m (28-ft) riparian buffers reduced sediment, nitrate, dissolved ammonium, and total Kjeldahl nitrogen yields significantly with mean reductions of 90, 77, 85, and 82 percent, respectively. These authors also reviewed the effectiveness of 4.3-m (14-ft) filters and found no significant differences in pollutant trapping efficiencies of the 8.5- and 4.3-m (27.9- and 14.1-ft) buffer widths.

Addy *et al.* (1999) concluded that riparian zones composed of a mix of forested and mowed vegetation may remove substantial amounts of groundwater nitrate nitrogen. The authors qualify this conclusion with a note that uncertainty exists regarding the site characteristics that promote substantial groundwater nitrate nitrogen removal in riparian zones and the influence of different types of riparian vegetation cover on groundwater nitrate nitrogen removal.

Corley *et al.* (1999) found that a 10-m (30-ft) wide riparian buffer zone was an efficient filter of inorganic nitrogen and inorganic phosphorus in a montane riparian community as about 84 percent nitrate nitrogen and 79 percent phosphate phosphorus were removed from the applied treatment. No consistent differences were found among specific vegetation height treatments or communities in the removal of N and P nutrients.

For concentrated runoff, *e.g.*, feedlot effluent, buffer widths may need to be considerably wider than for general protection from non-point runoff. Dickey and Vanderholm (1981) reported that flow lengths of 305 m (1,001 feet) were required to achieve reductions of 60 percent of nitrate and chemical oxygen demand (COD), and only 16 percent for phosphorus. Runoff from a feedlot of 450 cattle was sent through a fescue- and alfalfa-lined, serpentine channel with a 2 percent slope. A similar test using overland, rather than channelized flow filters, required much shorter distances [90 m (295 feet)] to achieve 70 percent reduction in nitrate and total solids.

Chimacum Creek watershed in western Washington (Jefferson County Conservation District, 2001) improved fecal coliform counts and other water quality parameters via implementation of improved livestock management on pastures, and on riparian area fencing. The fencing, constructed since 1988 along 8 miles of stream, mostly protects the bankfull width of the stream creating a set-back zone of about 8 to 20 feet (personal communication, Al Lathum, JCCD, 2002). The reported fecal coliform bacteria counts dropped from over 400 FC/100 mL (GMV) to under 100 FC/100 mL. Fecal coliform concentrations in the Chimacum Creek watershed were lower in 2000 than at any other time since monitoring began in 1988 (Jefferson County Conservation District, 2001).

Subsurface removal of nutrients in groundwater within the riparian zone may be an important mechanism in addition to buffer widths. Removal rates in groundwater are dependent on soil properties and water table height, and increase with decreasing distance to the stream (Simmons *et al.*, 1992). Groffman *et al.* (1996) concluded that although measured groundwater

denitrification rates were lower than surface rates, they may be high enough to create a significant sink for nitrate due to much lower flow rates, and could remove large percentages of incoming nitrogen loading.

While studies of nutrient reduction by riparian buffers are common in the literature, effects on herbicide transport have received relatively little study. Lowrance *et al.* (1997) reported that rates of herbicide reduction were greater in a grass strip immediately adjacent to the application zone than in an intermediate area of planted pines or in a zone of hardwoods closest to the stream channel (all three zones totaled 38 meters) [125 feet] in width. Concentration reduction was greatest per meter of flow length in the grass buffer adjacent to the application zone.

3.3.4 Shade Protection

Riparian vegetation can directly affect stream temperature by blocking or reflecting solar radiation and reducing stream heating (IMST, 2000), thus helping to maintain ambient (incoming) water temperatures. The biological and physical values of shade to aquatic systems in forested ecosystems are well established (Beschta *et al.*, 1987; Patton, 1973; Brown and Krygier, 1970; Brown, 1969; Brett, 1973). The value to terrestrial (air) temperatures is less clear. Dong *et al.* (1998) found that forest buffers provided minimal protection for stream air temperatures during mid-summer and that buffer width was not a significant variable in predicting stream air temperatures.

Thermal models of natural streams demonstrate that the best predictor of instream temperatures at any given point on a stream is the input temperature immediately upstream of the location in question (see Knutson and Naef, 1997, for a discussion and references). Thus, the role of buffers with respect to shade provision on agricultural lands is to reduce warming of inflow temperatures originating at the transition zone of the forested/mountainous areas and lowland valleys. The distinction between reduced heating of streams and actual cooling is important given that shade can, at best, maintain inflow temperatures by reducing incident radiation falling onto the stream surface, thus reducing natural warming. Heat transfer in streams is governed a number of factors, but largely by radiation and evaporation (*cf.* Oregon Department of Environmental Quality, 2000a, 2000b, 2001; and Washington Department of Ecology, 2002). In general, more extensive riparian vegetation ameliorates solar heating and maintains ambient water temperatures, although the influence of riparian shade on water temperature declines as streams widen in downstream reaches (IMST 2002).

Cascade mountain streams are generally between 40 and 50°F because groundwater and surface waters are thermally shielded from solar radiation by trees, snow and/or rocky soils. When forested systems are removed, surface water and snowmelt are released in greater volumes over a shorter time. This leads to higher peak flows, and greater ratio of surface to groundwater, thus

increasing stream temperatures. Many thermal problems in agricultural basins can be partially traced to hydrological changes in upland basins due to logging (*cf.* Knutson and Naef, 1997).

Castelle and Johnson (2000) reviewed a study by Steinblums *et al.* (1984) in which the effectiveness of 40 streamside buffer strips were assessed in the Cascade Mountains of western Oregon. These authors define buffer strip effectiveness in terms of angular canopy density (ACD). ACD effectively integrates spatial factors such as stream width, tree height, and canopy density for a given site. The relationship of ACD to buffer strip width was curvilinear, yielding ACD values of 17 and 73 percent, respectively, for buffer widths of 6 and 31 m (20 and 102 feet). They also concluded that 90 percent of the maximum ACD could be obtained with a 17-m (56-ft) buffer strip.

A summary of findings of several studies (*in* Castelle, 2000) indicate that the asymptote of effectiveness of buffers with respect to shade provision is approximately 10 m (33 feet), beyond which little additional benefit is gained (Figure 3.4). Osborne and Kovacic (1993 *In* Wenger, 1999) report similar findings, and conclude that buffer widths of 10 to 30 m (33 to 99 feet) can effectively maintain stream temperatures. The Oregon Forest Industries Council (OFIC) commissioned a review study of the scientific evidence supporting the FEMAT riparian shade effectiveness curve. The resulting 1999 report found that neither the scientific source nor the technical basis of the FEMAT shade curves could be independently verified. In addition, the data and curves from the FEMAT-referenced studies did not fit the published FEMAT shade relationship. The same study also found empirical data that indicated that the FEMAT curve underestimates the shade contribution from riparian vegetation. The relative ability of shade to reduce stream warming depends on many factors, such as quality of shade, angle of sun, degree of cloud cover, leaf angle, aspect and orientation of watershed, time of year, stream volume, volume of subsurface flows, width and depth of water column, and height and density of vegetation (IMST, 2002).

In summary, thermal modeling has shown that stream temperature in a given location is primarily influenced by its boundary condition, or input temperature. Next, its future temperature is a function of the net energy that is exchanged at the surface; thus, the surface-to-volume ratio (width-to-depth ratio) is important. Aspect of the stream, stream width, surface-to-volume ratio of the stream, and the height of the natural vegetation are all factors that determine the thermal benefits of shade to a particular reach. However, review of the literature indicates that buffer effectiveness for shade protection is near 80 percent at approximately 10 m (33 feet), and that substantially wider buffers are needed to achieve relatively little additional benefit. This finding is supported by Wenger (1999) who reported that, to maintain stream temperatures, riparian buffers must be at least 10 meters (30 feet) wide, forested, and continuous along the stream channel.

3.3.5 Large Woody Debris

Large woody debris (LWD) is stems, branches, and roots greater than 10 cm in diameter, and are an important structural component affecting the behavior and morphology of small forested streams (Lisle, 1986). LWD improves both quality and quantity of fish habitat by varying stream velocity and depth, providing habitat with lower risk of predation (Harvey *et al.*, 1999; Lisle, 1986). In smaller channels, LWD can stabilize landslide debris, store sediment, and prevent gully formation. In larger channels, LWD can trigger accumulation of spawning gravels, and create backwaters and pools (Reid and Hilton, 1998). Many of the effects of LWD on channel processes can be locally counteractive, but globally beneficial—for example, flow around LWD can scour away local gravel, but slow velocities enough to promote gravel deposition over a wider area (Lisle, 1995).

From 1950 to 1970, large woody debris was considered harmful to salmon and was purposely removed from streams (Knutson and Naef, 1997). However, research conducted over the last 20 years has shown that LWD is a critical component of aquatic habitat, and to headwater streams in particular. Sedell and Beschta (1991) summarize six functions of LWD: (1) creating and maintaining pools, (2) causing local reductions in stream velocities that serve as foraging sites for fish feeding on drifting food items, (3) forming eddies where food organisms are concentrated, (4) supplying protection from predators, (5) providing shelter during winter high flows, and (6) trapping and storing organic inputs from streamside forests, enabling them to be processed biologically.

The needed buffer width to provide adequate LWD from forests is controversial, given economic implications and the scientific uncertainty regarding needs of listed fish (Reid and Hilton, 1998). FEMAT (1993, Appendix A.3) developed models predicting effectiveness of forest buffers in providing LWD. However, these models assumed random tree fall (i.e., fall direction was independent of slope), a factor that has led to criticism of the FEMAT models (CH2M HILL, 2000).

In their critique of the FEMAT model curves, CH2M HILL (*op. cit.*) discusses factors that cause modeled data to depart from empirical data with source distance relationships. Factors such as variability in tree height, degree of bank erosion, and propensity of trees to lean down-slope cause the distance to effectiveness curves to shift toward the streambank, i.e., a narrower buffer can produce the same effectiveness as a wider (modeled) buffer. However, the LWD curves shown in the FEMAT report are based on modeled data, and rise slower, resulting in wider predicted buffers (CH2M HILL *op. cit.*).

Empirical data reported by McDade (1990, *in* CH2M HILL, 1999) indicate that 70 percent of LWD originated within 20 m (66 feet), and 100 percent within 61 m (200 feet). Murphy and

Koski (1989), in studying input and depletion of woody debris in Alaskan streams, found that for streams that are 8 to 30 m (27 to 98 feet) in width, 99 percent of identified sources of woody debris were within 30 m (98 feet) of the streambank. Nearly half of the woody debris came from trees that stood on the lower bank [less than 1 m (3 feet) away], and 95 percent was from trees within 20 m (66 feet) of the stream. They also noted that distances to the source of woody debris differed between channel types (alluvial or non-alluvial). On alluvial soils, these authors found that more than half (55 percent) of LWD was delivered by bank erosion (Castelle and Johnson, 2000; CH2M HILL *op. cit.*). Reid and Hilton (1998) found that 96 percent of potential woody debris sources occur within a single-tree height in a 50- to 60-m (164- to 197-ft) tall, second growth redwood forest.

Van Sickle and Gregory (1990) report that the decrease in the amounts of *in situ* LWD in larger streams is also due to the relative importance of transport and input of these systems. A model they produced shows that the number of trees contributed is independent of stream width, i.e., identical riparian stands along a small stream and a large river may contribute the same number of LWD pieces per unit channel length. The decline in the number of pieces of resident LWD in large streams was due to the greater transport capacity of larger streams, rather than to changing LWD inputs.

The CH2M HILL study recommends that the LWD curves be re-constructed to reflect LWD volume, not piece count, and that they be based on actual data as opposed to theoretical distributions. In addition, stand characteristics and erodibility of the channel (alluvial and non-alluvial) must be considered. Castelle and Johnson (2000) provide a graphical summary of distance-effectiveness relationships based on several of the field studies noted above (Figure 3.5). Their summary shows that 80 to 100 percent of the LWD originates within 20 to 30 m (66 to 98 feet) of the stream.

Bisson *et al.* (1987) showed that (evergreen) coniferous forests produce more durable and long lasting LWD than deciduous forests. This is probably a function of the size, quality and abundance of contributing wood. LWD in agricultural areas may owe as much as 50 percent of its content to upland forests as opposed to locally produced material (*cf.* Knutson and Naef, 1997). The functions of LWD in pool formation, velocity refugia, and spawning gravel retention are arguably more important in high gradient streams where unimpeded velocities may be unsuitable for salmonid habitat and life history functions.

The role and needs of LWD in lowland streams are less studied and demonstrated. In a recent research proposal to link salmonid fish abundance with land use and land cover in the agricultural Willamette Basin, Feist (2002) showed that LWD in this large agricultural watershed had only a 0.2 (not significant) correlation coefficient with riparian tree abundance along the banks of the Willamette River. Thus, presence of riparian forests is not a good predictor of

LWD in the Willamette Basin, nor, by extension, of salmonid abundance. It is likely that predictive models of LWD effectiveness and corresponding buffer requirements do not apply well in agricultural settings, although literature on this particular topic is severely lacking.

In summary, peer-reviewed studies on LWD suggest that: (1) LWD originates primarily from forests where velocities and erosive forces would otherwise limit habitat quality and quantity, (2) buffer widths to meet this need, even in forests, may be exaggerated in the forest ecosystem literature, and (3) the ecological function of LWD is likely a dominant factor in establishing wide buffer requirements in forests but its need in agricultural areas is not well demonstrated in the literature.

3.3.6 *In-Stream Functions*

Properly functioning streams have a diverse mixture of primary and secondary producers and consumers (i.e., attached algae, benthic macroinvertebrates, and fish) that are dependent on the riparian zone for a variety of biological and abiotic functions. However, few studies have looked at the adequacy of buffers and buffer widths needed to protect in-stream functions. In a statistically designed, paired watershed analysis, Whitworth and Martin (1990) assessed effectiveness of stream buffers in protecting and improving in-stream biological resources. This study demonstrated improved diversity in both fish and aquatic insect communities in filter-stripped (buffered) streams in Indiana and North Carolina. Buffer widths at the Indiana sites were 15 to 66 feet, and in North Carolina from 20 to 30 feet. The research was sponsored by the USEPA, entitled “Instream Benefits of the Conservation Reserve Program,” and conducted in eight watersheds, two “treatment” sites with riparian buffers, and two control sites without buffers in each state. Streams were low gradient (< 1 percent), first or second order, and drained corn and soybean row-crop agriculture.

Density and species of insects were statistically greater at buffered sites in both states. Researchers considered the reduction of fine particulate organic material by stream buffers to be a key reason for healthier benthic communities at treatment sites. Diversity, but not density, of fish was also greater at all treatment sites; 21 fish species were collected at treatment sites, and 10 at control sites. Treatment sites had greater percentages of pollution-sensitive or intolerant fish species, in comparison to control sites. Average habitat quality, as measured using a modified Index of Biotic Integrity (IBI), was approximately 65 percent higher at treatment sites.

The USEPA study was specifically designed to assess the ability of buffers to improve the ecological integrity of streams draining agricultural lands. The results obtained for biological metrics, as opposed to those more temporally sensitive (water quality and sediment), clearly showed biological benefits obtained from buffers that are considerably narrower than those currently considered necessary for lowland streams in Washington (Knutsen and Naef, 1997).

3.4 Fixed Versus Variable Width Buffers

3.4.1 Science and Policies of Variable Buffers

In reviewing buffer zones for agricultural lands, USDA resource managers (USDA-NAC, 1997; USDA-NRCS, 2000) draw attention to two important tasks: (1) determine what site-specific benefits are needed and (2) determine the minimum acceptable buffer width. In evaluating need, the buffer zone should be designed to improve a specific function, such as improving stability or decreasing concentrations of coliform bacteria. The minimum acceptable width is one that provides acceptable levels of benefit at acceptable costs—the economics of the particular farmland involved cannot be ignored (a factor also stressed by USDA-NRDC, 2002). In effect, the recommendation for buffers is that they should be employed to target specific water quality problems, and their design should be based on marginal effectiveness and farm cost-effectiveness. To the extent that the objective is to stabilize banks or prevent sediment-attached contaminants from entering streams or water bodies, buffer zones of 25 to 30 feet can be used where slopes are less than 15 percent. This would be sufficient for many lowland areas where production agriculture occurs.

As noted by Castle and Johnson (2000), riparian buffers may be prescribed using a mandated fixed-width, or allowing for variable widths based on local parameters. Fixed-width riparian buffers are more easily implemented and less costly to administer by resource agencies (Metro, 2000). However, this one-size-fits-all approach results in arbitrary buffer distances that may not always be appropriate to a particular site or management objective. Corner and Bassman (1993) concluded that although riparian buffer zones can be instrumental in protecting against non-point source pollution, their effectiveness is directly related to physical properties and the nature of management on the upland area. They recommend that a buffer zone width be calculated as a function of physical parameters (*e.g.*, slope, soil permeability, soil erodibility) and intensity of management practices, rather than as a designated fixed distance. A pertinent statement in the FEMAT (1993) report is that “[S]tructural components of stream habitat must not be used as management goals in and of themselves. No target management or threshold level for these habitat variables can be uniformly applied to all streams.” The team further concludes, “while this approach [fixed-width buffers] is appealing in its simplicity, it does not follow for natural variation among streams.”

IMST (1999) stated the following about the Oregon Department of Forestry’s fixed-width riparian buffer system: “Given the distinctive differences between stream functions based on size, we conclude it is scientifically sound to vary riparian widths with stream size” (p. 94). Although both fixed-width buffers and variable-width buffers may be related to stream size, variable-width buffers can be refined based on other stream attributes: soil type and erosion

potential, vegetation (organic inputs, shading, large wood, wildlife habitat), landscape (topography, elevation, slope, stream structure and flow), and land-use characteristics (IMST, 1999). May and Horner (2000) stated simply that "...a one-size fits all buffer is not likely to work"

If a fixed-width riparian buffer must be used, an alternative approach bases buffer width on the *flood-prone area* of a stream or river, which can be described operationally as the area inundated when a stream floods to twice the bankfull depth (Rosgen 1996). However, this definition applies to small streams and does not work well in large or lowland rivers with wide floodplains that may or may not be feasibly protected (IMST, 2002).

No uniform prescription exists for riparian buffers, as evidenced the wide variety of widths and lengths now in use for various functions (Table 3.1 from Lowrance, *et al.*, 2001). Six types are currently eligible for federal (CRP) cost sharing however, many others can be funded through state and local programs. In 2001, NRCS added a new type of in-field conservation buffer, sometimes called grass hedges. These are narrow strips of coarse grass 3 feet to 6 feet wide. Coarse stems withstand greater runoff rates without becoming submerged (Dabney, 2002, In Lowrance *et al.*, 2001) and are thus effective in preventing gullies, and depositing soil in the field where it can further contribute to soil fertility and crop production. Thus buffers as narrow as 1 meter can be of value in agricultural landscapes. The list in Table 3.1 shows that most of the NRCS prescribed buffers on agricultural lands are as small as 6 meters to be effective.

3.4.2 Mandated versus Voluntary Programs

Bear Creek, Iowa, is a model agricultural restoration project being studied and managed by scientists at Iowa State University (Isenhardt *et al.*, 1998). The Bear Creek restoration project recognized early on that floodplains that are heavily used for agriculture and streams are part of a continuous ecosystem (National Resource Council (1992) *in* Isenhardt *et. al.*, 1998). Restoration to pre-agricultural conditions is not the goal of the project because of the destruction of the enormous economic wealth of the agricultural system. Their goal is an ecologically functioning system that uses *voluntary participation* [italics added] and incorporates economic considerations into recommended actions. To quote Isenhardt (*op.cit.*):

"The social acceptance of the riparian management model is assessed through the use of surveys, focus groups and one-on-one information exchange. A better understanding of landowner objectives and economic considerations has resulted in numerous variations of the model system. What initially began as just the buffer strip component of the system now includes the three other components: streambank stabilization, constructed wetlands and rotational grazing. This flexibility is designed

to encourage adoptions of the management practices by satisfying the landowner goals and concerns as well as a fitting specific biogeophysical conditions of the site. For example, the buffer strip component of the model can be modified by using different species combinations and by varying the width of each zone. Although such variation in design may not be optimal for water quality or wildlife benefits, the flexibility is important if it means that a landowner is accepting the concept. After the landowner has had experience with a smaller system, he or she may be willing to increase the size and effectiveness of the buffer or add additional system components.” (Isenhardt et al., 1998, p.332)

Elaborating further, the Iowa State University Team approach (IStART) shows:

“Technology transfer efforts are geared toward quickly getting the results and information into the hands of landowner and natural resource professionals. This is accomplished through on-site tours, field days, self-guided walking tours, videos and extension bulletins. Other methods of information dissemination include presentations at meetings of natural resource professionals, conservation groups, and local civic organizations, articles in local newspapers and trade publications and publications in refereed journals. Local ownership of the restoration effort is encouraged through the development of voluntary citizen action teams that assist in buffer strip establishment, water quality monitoring, and constructing of wildlife nesting boxes. Finally, training workshops are being organized for agricultural and natural resource professionals to help disseminate the information and validate results.” (Isenhardt et al., 1998, p.332). The Iowa State University experience and demonstration program stresses voluntary adoption versus regulatory approaches of buffer strip installation: “Regulation usually sets rigid parameters that do not apply well to the wide range of conditions encountered.” (Isenhardt et al., op cit.).

In summary, fixed-width buffers are relatively easy to enforce, provide for regulatory predictability, and cost less to administer because those applying the regulations do not need specialized skills (Johnson and Ryba, 1992). Fixed-width buffers, however, do not account for site-specific conditions; the riparian corridor may not be adequately protected in some areas and, in others, the buffer might unnecessarily restrict development (Fisher and Fischenich, 2000, Todd, 2000, in Metro, 2002). In contrast, variable-width buffers account for site-specific conditions, provide a greater level of protection to important resources while reducing the impact on private property when wider buffers are unnecessary (Johnson and Ryba, 1992; May, 2000). The approach of using voluntary systems (NRCS, Iowa State) includes economic considerations as well as scientifically justified techniques, and is much more likely to gain acceptance and implementation than regulatory requirements that put farmers out of business.

3.5 Proper Experimental Design

Only a few studies have approached the issue of buffer widths experimentally, in terms of analysis of multiple buffer widths under similar conditions of vegetation, slope, and adjacent land use. These have been cited herein. Much of the ecological literature observes existing buffers and describes its function or compares it to the absence of a buffer. For example, Whitworth and Martin (1990), in assessing ecological benefits of filter strips, utilized sites with 15- to 66-foot-wide established buffers. Buffer widths in this study, as in most, were not varied as part of the experimental design, and there is no indication of what results would have been obtained with larger or smaller buffers. Fennessy and Cronk (1997) *In* Wenger, 1999) note that “one problem in assessing minimum widths necessary to protect adjacent surface water is that many studies that make recommendations regarding the minimum width necessary have arrived at the figure as a byproduct of sampling design rather than deriving it experimentally.” (p. 14)

Three studies reviewed for this report did approach this issue experimentally, and on agricultural lands (Dillaha *et al.*, 1989; Mendez *et al.*, 1999; Ghaffarzadeh *et al.*, 1992). These experimental studies with variable and controlled widths provide experimental descriptions of the effectiveness of buffers by size. Dillaha (*op. cit.*) established vegetated grass filter strips (VFS) of 9.1 and 4.6 m and evaluated differences in the rate of sediment and nutrient reduction from adjacent cropland. Results for sediment reduction are shown on Figure 3.6. For a gradient of 11 percent, this study showed nearly 100 percent effectiveness for 9.1-m-wide buffers for sediment reduction (measured as total suspended solids), and between 82 and 90 percent for 4.6-m buffers. As expected, increasing gradient reduced effectiveness; a 9.1-m buffer on a 16 percent slope had an average effectiveness of 70 percent, versus 53 percent for a 4.6 m buffer. Buffer effectiveness at a gradient of 5 percent was similar to that at 11 percent: over 90 percent effectiveness was observed for 9.1 m and approximately 80 percent for 4.6 m.

Mendez (*op.cit.*) evaluated 4.3-and 8.5-m buffers as treatments for row crops, in comparison to a zero width control. Like Dillaha (*op. cit.*), Mendez evaluated buffer effectiveness in reducing sediment and nutrients from tilled cornfields. In addition, he monitored effectiveness of buffers in reducing runoff volume. Results for sediment (measured as total suspended solids) indicated that while the 8.5 and 4.3 m buffers significantly reduced sediment concentrations from the no buffer condition, there were no significant differences between the 8.5-m and 4.3-m buffer treatments (i.e., the narrow buffer is as effective as one twice as wide). Similarly, runoff volume was statistically lower with both narrow and wide buffers compared to no buffer, but there was no significant difference between the two treatments (8.5 and 4.3 m). Again, a narrow buffer was as effective as a wide buffer. Finally, Mendez showed the same results for nitrate: 8.5-m buffers significantly reduced nitrate concentrations relative to the zero meter control, but not significantly greater than the 4.3-meter buffer.

Ghaffarzadeh (*op. cit.*) found that the first 3 m of a vegetated filter strip filtered 70 percent of the runoff sediment, and approximately 90 percent in 9 meters. This study was conducted at distances of 0, 3, 6, 9, 12, and 18 meters downslope of bare, plowed surfaces.

The above experiments demonstrate the need for scientifically controlled experiments to reach valid conclusions about the effective width needed to achieve specific functioning conditions. They highlight the weakness of simply making comparisons among existing buffers that do not have experimental controls. Comparing buffers on generally steeper, forested uplands to generally lower gradient agricultural lands with different vegetation types is not appropriate in many cases and thus is not consistent with intent of legislation and regulation calling for Best Available Science.

3.6 Future Research Needs – Inadequacy of Data

The width of a specific buffer on agricultural land is highly site-specific. Lowrance (*op.cit.*) and his colleagues write: *“Buffer widths have for the most part been set and constrained by federal cost-share programs with minimal scientific evidence. We need field studies that test various widths of buffer of different plant community compositions for their efficacy in trapping surface runoff, reducing non-point source pollutants and subsurface waters and enhancing the aquatic ecosystem”* (p. 41).

In his review of Riparian Vegetation Effectiveness, Castelle (2000) concluded his review of the literature on buffer width effectiveness:

“Generally, there are two types of research needs. The first entails re-visiting some of the data generated by past studies that examined only one buffer size, but did not study the effects of increasing or decreasing the size of the buffer”. (p. 20). Unfortunately, information from such studies may be construed by resource agencies and land managers as minimum guidelines. For example, if a study stated that a 30 m buffer adequately protected streams, it might be inferred that smaller buffers were studied, and that 30 m buffers should be a minimum standard width. However, if that study were re-visited using buffers of 5, 10, 15, and 20 m, it might be determined that somewhat smaller buffers may be as or nearly as effective, particularly for specific riparian functions (e.g., Figure 3.1 Chemical Removal Graph). As an alternative to studying varying buffer widths, other buffer zone management practices should be investigated. For example, stand composition could be manipulated to favor tree species which provide exposed roots (for sediment trapping), high transpiration rates (for nutrient uptake), and broad canopies (for shade production).” (p. 20)

Castelle further remarks:

“The second type of needed research should focus on the interactions between vegetative and non-vegetative factors. Depending on site specifics and the nature and degree of potential impacts, it might be determined that abiotic factors are more important than vegetation in determining buffer effectiveness. These various factors can be isolated and studied in laboratory or other controlled settings, but in nature all biotic and abiotic factors work together, and isolating individual parameters provides insight into only artificial environments. In both types of research, the focus should be on the physical, chemical, and biological mechanisms, which are responsible for buffer effectiveness. Understanding why a particular buffer parameter has a certain effect will allow for more effective buffer management, which in turn will result in higher levels of stream protection and optimum timber yields.” (p. 20)

Reflecting on the larger scale of the watershed or ecosystem, what defines a conservation buffer is dependent on the intensity of adjacent land uses. Pastoral systems can serve as a buffer to row crops and agriculture itself can serve as a buffer to more intensive development of suburban and urban growth (Lowrance *et al.*, p. 42). Elaborating further, they state:

“The optimal arrangement of conservation buffers intended to meet multiple objectives is seldom a uniformly wide green strip along a stream. Actually, buffers placed along large rivers provide habitat, bank stability and flood control function, but may have relatively less impact on water quality” “ Even in headwaters, optimal arrangement calls for a variety of buffer sizes and types at different landscape locations. Very dense narrow buffers may be the most cost-effective way to reduce sediment delivery at critical points in a field or riparian area. Large blocky buffers may be needed elsewhere to provide optimal wildlife habitat and groundwater clean up” “The field--, farm-- and watershed-- scale research needed to define how to make these practices work in concert with one another has just begun.”

TABLE 3.1
COMPARISON OF SELECTED PURPOSES AND CRITERIA FROM
THE USDA-NRCS NATIONAL HANDBOOK OF CONSERVATION PRACTICES
FOR THE TEN CORE₄ BUFFER TYPES AND SOME RELATED PRACTICES

Practice	NRCS Code	Erosion Control Purposes				Other Purposes					Criteria (minimum or maximum)					
		Reduce Sheet and Rill Erosion	Reduce Concentrated Flow Erosion	Reduce Wind Erosion	Reduce Sediment Delivery	Increase Wildlife Habitat	Reduce Contaminant Transport	Increase Carbon Storage	Produce Harvest	Protect Crops	Field Slope	Along-strip Gradient	Strip Width (SW)	Strip Spacing	Field Length	Stem Density
CORE ₄ Buffer Types																
Riparian Forest Buffer	391 ¹		+		+	+	+	+	+			along stream	>30 m			
Field Boarder	386		+	+	+	+	+					field edge	>6 m			
Filter Strip	393 ¹				+	+	+				1 to 10%	<0.5%	>6 m		<50*SW	1500/m ²
Grassed Waterway	412 ¹		+		+		+					along gradient		concentrated flow areas		n-VR curve, permissible velocity
Alley Cropping	311	+			+	+	+	+	+	+		contour	>6 m	species light requirements		
Contour Buffer Strip	332 ¹	+			+		+				2 to 8%	<2%	>5 m (grass) >9 m (legume)	½ RUSLE Crit. Slope Length (CSL)	RUSLE CSL	540/m ² (grass) 320/m ² (legume)
Vegetative Barrier	601	+	+		+							<1%	>1 m	1.3 to 2.0 m vertical int.		depends on stem diameter
Shelter Belt	380 ¹			+	+	+		+		+		across prevailing wind direction		12 H, +		
Crosswind Trap Strip	589C			+	+	+	+			+			5 to 8 m	upwind of protected area		
Herbaceous Wind Barrier	422A ¹			+	+	+				+			1 m	<10 H, +		at least 2 rows, 0.5 m tall (H)
Related Practices With Buffering Attributes																
Constructed Wetland	656				+		+									
Channel Vegetation	322	+	+		+		+					Channel banks				
Terrace	600	+	+		+		+					Across slope		>27 m		
Water and Sediment Cont. Basin	638		+		+		+					Across flow areas				
Grade Stabilization Structure	410		+		+		+					Field edge, side inlet				

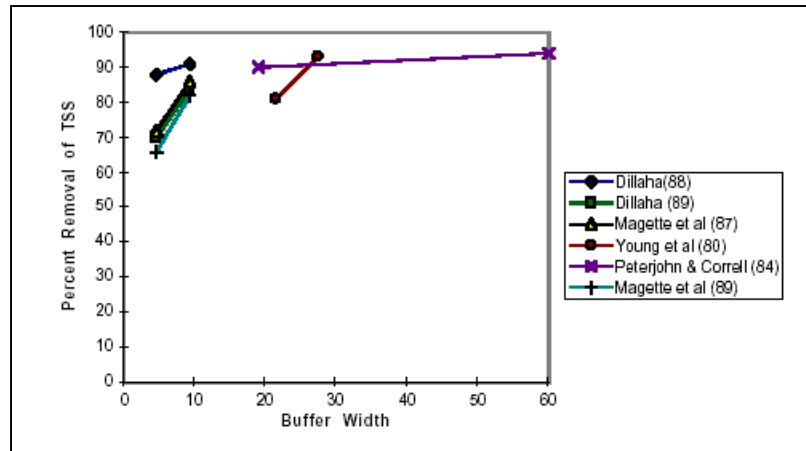


Figure 3.1
Removal of Total Suspended Solids by Buffers of Different Widths (from
Wenger, 1999)
X-axis in Meters

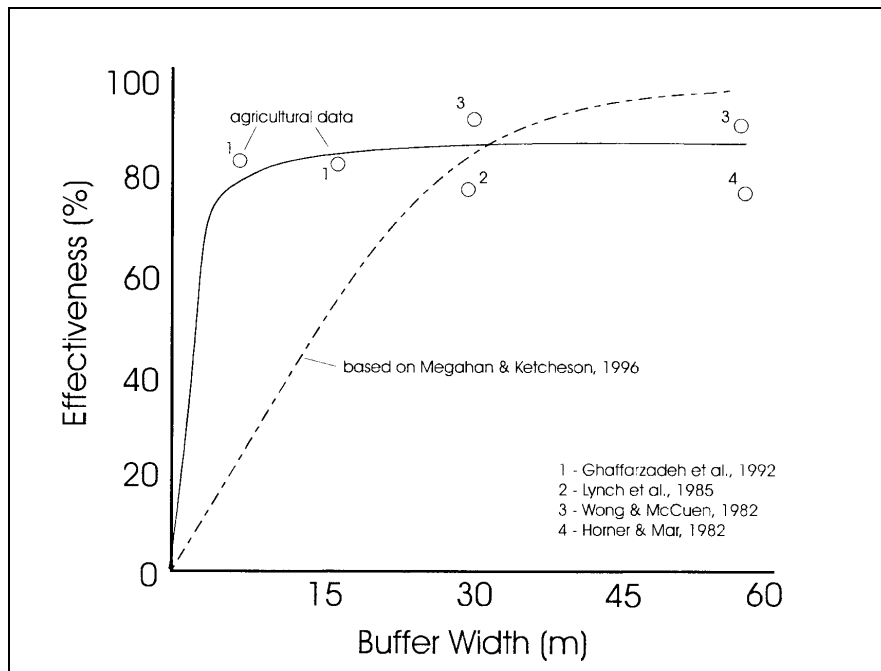


Figure 3.2
Effectiveness of Vegetation for Sediment Removal
(from Castelle and Johnson 1999).

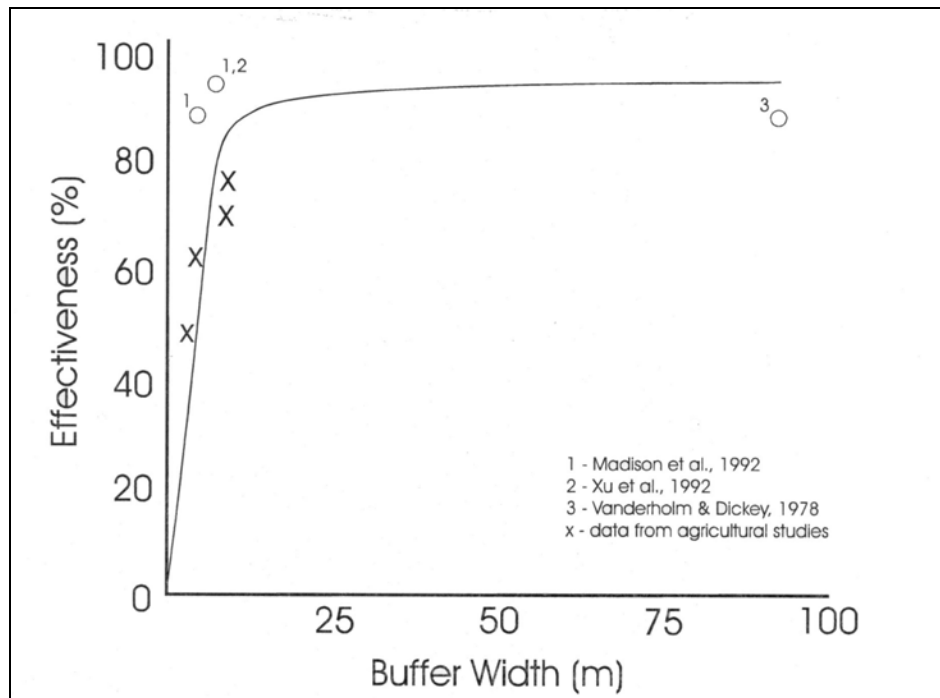


Figure 3.3
Effectiveness of Vegetation: Chemical Removal
(from Castelle and Johnson, 1992).

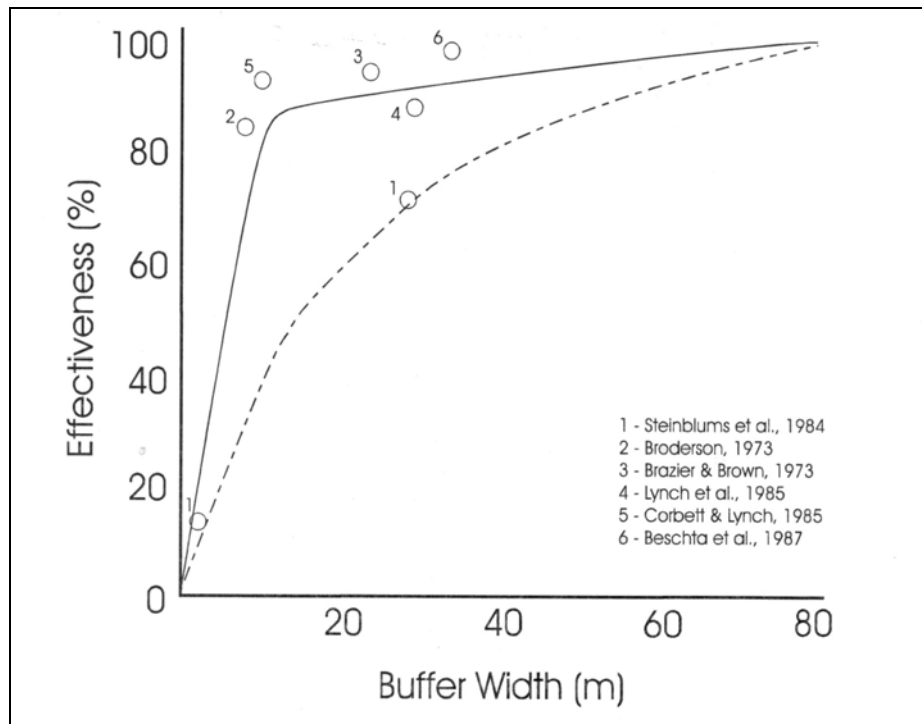


Figure 3.4
Effectiveness of Vegetation: Shade Production
 (from Castelle and Johnson, 1992).

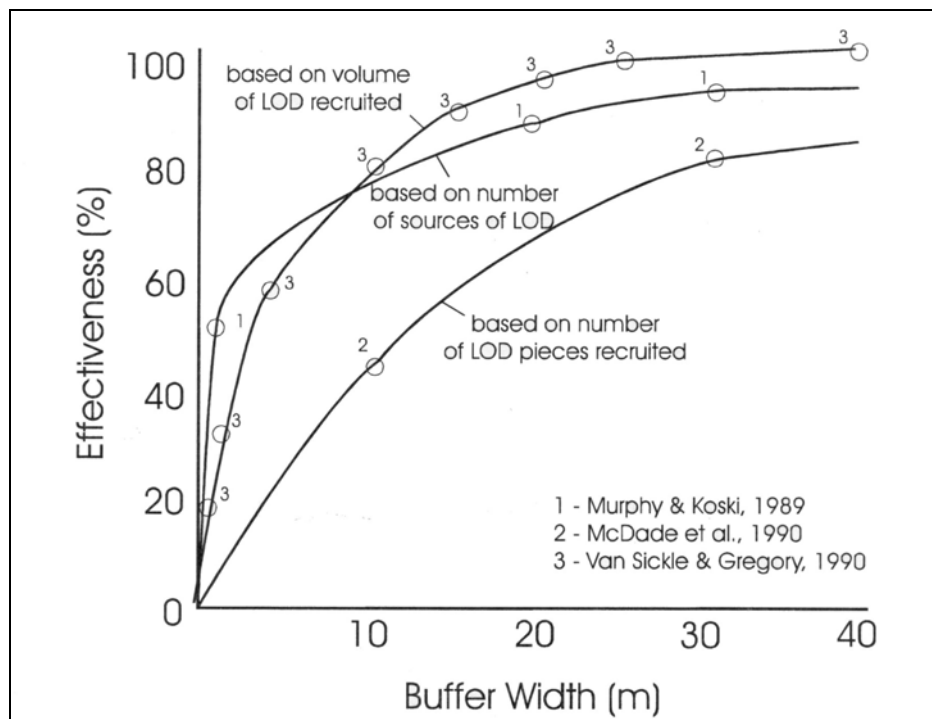


Figure 3.5
Effectiveness of Vegetation: LOD Production
(from Castelle and Johnson, 1992).

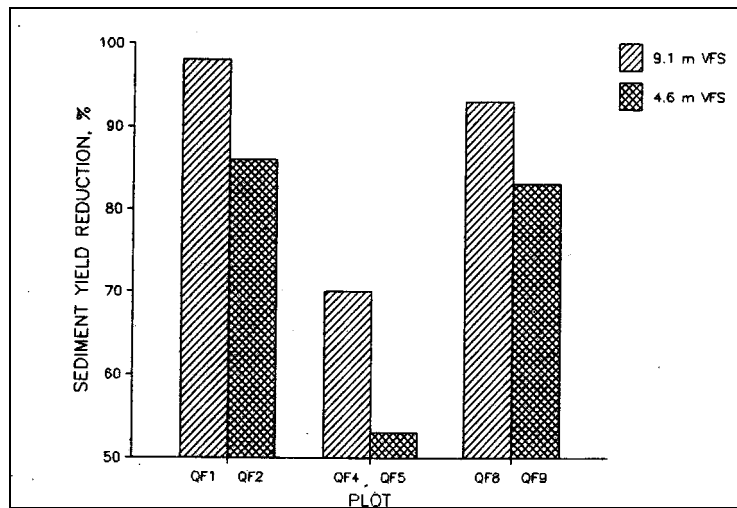


Figure 3.6
Percent Reduction in Sediment Yield from Vegetated Filter Strips
Gradients: QF1/QF2: 11%; QF4/QF5: 16%, QF8/QF9: 5%
(from Dillaha et al., 1989).

Section 4 – The Economic Significance of the Agricultural Industry and Estimated Economic Impacts from Buffer Zones

4.1 Introduction

Washington State’s agricultural industry plays a meaningful role in the economy, and is often a leading economic sector for many counties located away from major urban centers. The “agricultural industry” is defined here as being composed of three key economic sectors: direct farm production, agricultural services, and the food processing industry.

This report section focuses on the economic impact of the agricultural industry and how riparian buffer zones could affect industry values. Economic impact, or significance, is described in terms of direct production value, agricultural land and local taxation values, and the direct and secondary economic affects on local and state income. These types of values and economic measures can be applied to an assessment of economic impacts directly related to buffer zones, and examples of such are estimated. The industry values and economic impacts are presented at the state level, and they are developed for selected counties for illustration purposes. The selected counties reviewed here are representative of east- and west-side counties that host large agricultural economic bases and would likely be affected by buffer zone management regimes.

The following information provides an overview of the agricultural industry’s economic base for the State, the industry’s economic influence within selected counties, and general or “index” value impacts that would result from buffer zones. Related issues also are discussed, including factors for consideration in water use reallocation and more vigorous economic frameworks from which to judge the economic effectiveness and trade-offs inherent to developing buffer zones.

4.2 Farm Production Values

Agricultural production values can be expressed in several ways, but one of the more common measures is farm-gate value, the gross revenues received by farm operators for their products. These values represent the total dollars that are received by farm producers, most of which are then spent locally, regional, or nationally to cover production expenses. A small percentage of farm-gate value usually “stays in the hands” of owners and managers, but the bulk of the value is

transferred to other sectors of the economy to cover the variable and fixed costs of farm operations. As such, farm-gate value can be viewed as the total value of input costs to the primary farm production sector, plus the value of farm management, labor, and investment returns.

At the overall state level, the farm-gate value for agriculture amounts to about \$5.4 billion in year 2000 dollars (National Agricultural Statistic Service, 2002). About \$1.7 billion are derived from field crops, about \$1.2 billion from fruits and nuts, and about \$1.5 billion from livestock and direct products. During the past decade, the year 1995 represents the peak production value year, with about \$5.8 billion in gross farm-gate revenues. Since then, many commodity prices have fallen, particularly in the tree fruit industry.

For selected counties, Tables 4.1 and 4.2 summarize the farm-gate values received by farm operators for their leading crop and livestock products, based on a 1998 through 2000 annual average value range.

**TABLE 4.1
FARM-GATE VALUES**

Farm-Gate Value For Leading Value Crops, 1998 to 2000					
County	Crop	Production Values, by Year (Year 2000 Dollars)			Annual Average Production Value 1998-2000 (In Year 2000 Dollars) (\$/Acre for Key Crops in Parentheses)
		1998	1999	2000	
Benton	Apples	84,285,796	93,518,335	82,475,828	86,760,000 (4,500)
	Cherries	23,763,423	21,130,520	27,704,002	24,199,000 (8,600)
	Grapes	44,503,785	45,342,446	46,124,331	45,324,000 (2,900)
	Potatoes	89,312,812	96,935,700	91,825,500	92,691,000 (3,000)
	Hay	9,317,351	10,102,800	13,088,000	10,836,000
Kittitas	Apples	8,504,059	9,435,581	8,321,442	8,754,000
	Pear	1,514,171	1,679,069	1,435,818	1,543,000
	Hay, total for crop	29,666,317	31,901,928	33,502,000	31,690,000 (600)
	Potatoes	1,103,855	1,009,476	1,096,500	1,070,000 (1,800)
	Wheat	676,790	n/a	8,321,442	4,499,000
	Oats	118,093	137,088	132,000	129,000
Skagit	Apples	1,633,109	1,811,997	1,598,039	1,681,000
	Corn	11,025,509	9,424,188	8,464,500	9,638,000
	Hay, all	3,071,495	2,489,004	3,188,600	2,916,000 (280)
	Potatoes	13,151,786	12,750,000	14,088,750	13,330,000 (1,700)
	Green peas	n/a	3,836,009	2,193,740	3,015,000
	Wheat, all	826,358	882,259	1,131,300	900,000
Yakima	Apples	344,297,757	382,011,614	336,904,243	354,405,000 (4,400)
	Cherries	45,245,735	40,232,668	52,748,626	46,076,000 (7,100)
	Grapes	43,386,232	44,203,833	44,966,083	44,185,000 (2,700)
	Pears	46,614,506	51,690,966	44,202,386	47,503,000
	Hay, all	20,997,486	19,852,872	22,520,000	21,123,000

Note:

Sources: See Economics Appendix C.

The leading crop values for the selected counties are displayed in Table 4.1. To a large extent, the direct production values for Benton and Yakima Counties illustrate the large contribution agriculture can make to local and regional economies. The combined fruit and crop production amounts to about \$260 million in Benton County, and about \$513 million in Yakima County.

And within Kittitas and Skagit Counties, fruit and crop production values comprise about \$43 million and \$29 million, respectively.

TABLE 4.2
FARM-GATE VALUES

Farm-Gate Values for Animal Production and Products, 1998 to 2000					
County	Commodity	Total Farm Gate Values by Year (2000 Dollars)			Average Farm Gate Value (Dollars)
		1998	1999	2000	
Benton					
	Milk Production	8,097,563	7,921,844	6,607,440	7,542,000
	Cattle & Calves	8,079,766	6,882,698	8,913,090	1,956,000
	Hogs & Pigs	36,241	35,118	49,840	40,4000
	Sheep	91,214	77,306	83,545	84,022
Kittitas					
	Milk Production	1,913,841	1,873,179	1,562,022	1,783,000
	Cattle & Calves	20,776,092	17,697,880	22,919,233	20,464,000
	Hogs & Pigs	63,167	57,695	82,357	68,000
	Sheep	176,095	140,789	152,152	156,000
Skagit					
	Milk Production	72,520,769	69,535,810	59,409,000	67,156,000
	Cattle & Calves	21,930,232	18,681,854	24,192,250	21,601,000
	Hogs & Pigs	71,635	69,311	69,391	80,000
	Sheep	26,835	22,782	24,621	25,000
Yakima					
	Milk Production	181,832,563	174,352,096	148,357,314	168,381,000
	Cattle & Calves	130,949,365	90,212,420	133,207,488	118,123,000
	Hogs & Pigs	189,417	173,971	247,172	204,000
	Sheep	792,458	633,549	690,908	706,000

Note:

Source: See Economics Appendix C.

Milk production and livestock are significant local industries within counties like Skagit and Yakima, holding high production values (Table 4.2). The average annual milk and livestock production values amount to about \$89 million in Skagit County, and about \$287 million in Yakima County. For Benton and Kittitas Counties, the annual value of milk and livestock production is about \$16 million and \$22 million, respectively.

These farm-gate values transfer into expenditures for agricultural services and goods, equipment, supplies, labor, and other production inputs obtained from local, state, and out-of-state areas.

4.3 Agricultural Land Values and Taxation Rates

Table 4.3 displays estimated agricultural land value ranges (market values) for the selected state counties. The land values are important to local areas both as retained, long-term capital value for farm owners and as the base value for local taxation to support infrastructure projects and services (schools, roads, hospital districts, fire districts, other). Also, these land values represent values for the maintenance of agricultural production, not values associated with the transformation of agricultural lands to non-agricultural uses.

As presented in Table 4.3, the estimated land values for agriculture in Skagit County range from about \$2,800 to \$4,000 per acre. Higher values can be obtained for certain specialty crops, like blue berries, depending on the condition of the field. A similar range exists for Kittitas County, with values at about \$2,000 to \$3,000 per acre for most farm ground (including some value for site buildings as estimated by the Census of Agriculture).

Higher land-value ranges occur for Benton and Yakima Counties due to the higher percentage of specialty crops—wine grapes, cherries, and certain apple varieties—grown within the region. Land values here are about \$3,500 per acre for high quality row-crop ground, and as much as \$7,000 per acre (or more) for specialty crop ground. These land values include the value of water rights (or water delivery) and irrigation distribution systems (on-site irrigation systems).

Taxation rates for agricultural areas vary depending on what is included within the county tax base (exclusive of other consolidated land taxes), but a mid-range value would be about \$10 to \$14 per \$1,000 of assessed land value (Pacific Northwest Project, 1994, 2001). If assessed land values (exclusive of buildings and other improvements) are assumed to reflect the lower range of the land market values (assessed values are typically lower than average market values), then the local tax benefits for the lands identified in Table 4.3 would amount to about \$42 per acre, or \$6.4 million for Benton County; about \$24 per acre, or \$1.8 million for Kittitas County; about \$34/acre, or \$3.1 million for Skagit County; and about \$30 per acre, and \$8.3 million for Yakima County (at \$12 per \$1,000 value tax rate).

Actual tax revenues obtained from agricultural lands, for each county, will depend on specific land assessments including improved property, and tax rates, but the above estimates serve as a useful and realistic value for consideration across statewide agricultural lands.

Also, it is important to note that agricultural land (market) values are significantly different than land values for undeveloped, idle ground. The difference is usually at least a factor of 5 to 10 or more. Consequently, for many counties, the developed agricultural lands are a major source of county revenues to support local infrastructure and services.

TABLE 4.3
ESTIMATED LAND (MARKET) VALUES FOR SELECTED COUNTIES

County	Total Farmland (Acres)	Estimated Land Values (\$/Acre)	Estimated Total Values (\$ Millions)	Estimated Average Value (\$ Millions)
Benton	153,000*	\$3,500-\$7,000**	\$535-\$1,071	\$803
Kittitas	75,600*	\$2,000-3,000	\$151-227	\$189
Skagit	93,000	\$2,800-4,000+	\$260-372	\$316
Yakima	277,000*	\$2,000-\$7,000	\$554-\$1,939	\$1,247

Notes:

Sources: Census of Agriculture, Washington, 1997; Personal communications with Polygon Management (farming and land developers), Mount Vernon, Washington, and Northwest Farm Management/Clark Jennings and Associates, Pasco, Washington (commercial agricultural land managers and brokers), July 2002; and review of active REALTOR MLS listings for Skagit County and Kittitas County (internet sites), July 2002.

* Irrigated acreage only.

** Irrigated agriculture for production agriculture only.

To the extent that buffer zones would be adopted within these selected counties, individual landowners would incur reduced land and farm production values, and the local economic benefits of production agriculture would diminish. Adverse economic impacts would include both secondary economic impacts and reduction in local taxation benefits.

4.4 Measuring Economic Impacts within State and Local Economies

The regional economic impacts of the agriculture industry—including impacts from direct agricultural production, agricultural services, and food processing—can best be described in terms of direct income (or earnings) and the secondary or "indirect" income it creates in other sectors of the economy. This direct and indirect relationship is often referred to as the multiplier effect, the secondary economic impact generated by "basic" economic sector activity. This dependence and multiplier effect exists within state, regional, and local economies.

Economists and regional planners often refer to specific sectors of local or regional economies as either being basic (export-based) or non-basic (service). In particular, economists are interested in how changes to the basic economic sectors affect secondary and induced economic activity

within an area. Some economic activities exert multiplier effects to relatively confined local areas (labor services), while others create economic activity throughout a state or larger area (equipment purchases and durable manufactured goods).

While there are several different types of multipliers to gage the magnitude of economic activity within a defined area, the emphasis on income multipliers reflects a conservative perspective. Income does not depict the value of goods and services traded by a specific economic sector; it only constitutes the actual net income produced by a set of economic transactions that actually stays within the defined area. For example, the agricultural sector may purchase farm equipment within a local county, but most of the income value of the purchase flows to the county of origin where the equipment was manufactured. Economists refer to this transfer of value outside the county of purchase as “leakage.” Consequently, income multipliers only measure an economic sector’s real income generation within a fixed area (defined economy) and tend to be “lower values” when compared to other types of measures, such as the value of production for affected goods and services. But for many economists and decision makers, the “bottom line” question surrounding an economic activity is: how much real income did this activity bring into my county or state?

There are several tools or methodologies that can be employed to measure the multiplier effect of specific types of economic activity (see Schaffer, 1999, and Bendavid-Val, 1991, for an overview of impact models, methodology, and applications). These include economic base analyses (location quotient or minimum requirements methods), and input-output analyses that review the cumulative economic transactions among multiple economic sectors. These methods each have advantages and disadvantages. Economic base methods do not require extensive data, but are limited in accuracy; their application must take into account distortions in geographical scope and interaction with other types of basic economic activities within a specified economy. In contrast, input-output (I/O) analyses (models) can require an extensive amount of data and adjustment, but they yield far more descriptive and usually accurate information about specific economic sector impacts.

For review purposes here, estimates of direct and indirect economic impact within states and counties based on contributions to income are measured using the IMPLAN modeling system. IMPLAN is an I/O model that has been used in numerous economic impact studies and is maintained by a technical consulting group (Minnesota IMPLAN Group). The basic model consists of regional and national data and I/O algorithms for impact analysis. The IMPLAN model is based on national average economic relationships between economic sectors, buying and selling of goods and services with state and regional (county) level data adjusted or recalibrated to better match regional transactions (from regional data obtained from the Bureau of Economic Analysis). As such, IMPLAN is an I/O model that allows for an assessment of

regional economic conditions using non-survey data, providing for an acceptable range of accuracy for the purposes needed herein.

Based on consultations with IMPLAN technical support staff, IMPLAN is used for state and county-level analyses to estimate direct and indirect economic impacts for the agricultural industry, with modeling adjustments made to avoid double-counting errors among the agricultural production, agricultural services, and food processing sectors. The I/O model uses 1999 regional data for calculating sector relationships. The income values depict 2000 data and expressed in year 2000 dollars. A state-level analysis is used to illustrate the "linkages" among the major economic sectors, for example, the buying and selling of goods and services by the agricultural production and food processing sectors to several other sectors of the economy. By identifying these linkages, the flow of economic activity created by the agricultural industry can be revealed.

Estimates of direct and secondary income effects from agriculture and irrigated agriculture are displayed in Table 4.4. These estimates are based on 1999 I/O model data (recent version of IMPLAN model with 1999 data sets), with the resulting direct and indirect relationships carried over to the most recently available Bureau of Economic Analysis state income data sets (2000 data). The I/O model estimates for indirect income generated by the agricultural industry sectors are founded on conservative modeling techniques to avoid double-counting and other errors that could over-estimate the direct and indirect based on consultations with IMPLAN Group technical staff and a review of Rodolfo *et al.* (1996).

TABLE 4.4
AGRICULTURAL INDUSTRY DIRECT AND SECONDARY ECONOMIC IMPACTS*

Washington State and Selected Counties	Agricultural Industry Direct Income (\$ Millions)			Total Direct & Indirect Agricultural Industry	Ag. Industry % of Total Industry Income
	Agriculture Production (Direct)	Agricultural Services (Direct)	Food Processing (Direct)		
Benton	\$97	\$22	\$80	\$307	17%
Skagit	\$77	\$15	\$32	\$228	13%
Yakima	\$369	\$57	\$124	\$1,050	41%
Washington State	\$1,379	\$890	\$1,461	\$7,768	7%

Notes:

Sources: U.S. Dept of Commerce, Bureau of Economic Analysis Data Series, Regional Economic Information System (REIS) 2000 data series, Minnesota IMPLAN Group 1999 model data bases, and modeling analyses prepared by Pacific Northwest Project, June-July 2002.

*Income defined by Bureau of Economic Analysis as net earnings by each economic sector.

In Table 4.4, Washington State and selected county estimates are reviewed for direct income (in year 2000 dollars) derived from the agricultural industry. The industry generates about \$3.7

billion in direct income, representing about 2.8 percent of the state's \$136 billion industry-related income, not including government and government services. Compared to other state industry-group sectors, the agricultural industry ranks fifth in producing direct income. The four leading sectors are health services, the combined finances insurance and real estate business, manufacturing of transportation equipment, and engineering and management services (Bureau of Economic Analysis, 2000).

Also in Table 4.4, state and selected counties were directly modeled with IMPLAN, producing an overall agricultural industry multiplier for the state of about 2.3 (multiplier is for aggregated agricultural production, agricultural services, and food processing sectors). That is, for every dollar of income directly produced by the agricultural industry, an additional 1.3 dollars of income are indirectly generated within the state economy. This estimate is slightly higher than previous IMPLAN modeling estimates using 1994 data, which suggested a state multiplier of about 2.0 (Pacific Northwest Project, 1998). The larger 2000 multiplier would tend to indicate that the percentage of higher-value and value added crops (more food processing) in the state has increased slightly since the mid-1990s.

The model analyses for the selected counties suggest multipliers ranging from about 1.5 to 1.9, which is consistent with other analyses for county-level income multipliers dealing with county and regional level data (IRZ Consulting and Pacific Northwest Project, 1998; Pacific Northwest Project, 1996, 1998; Northwest Economic Associates, 1994). This produces a range of about 1.7 to 2.0. Based on these data estimates, a "general" county multiplier of about 1.8 would be acceptable for broad-based observations across the state, representing a conservative estimate of county impacts relative to the economic sector linkages involved. The extent of the economic sector links (total generation of income) is less within counties than at the state level; thus, the income multiplier for counties is less than at the state level.

The indirect income effect represents the flow of dollars through the economy that create secondary income in economic sectors indirectly supported by the agriculture industry. The total amount of annual (2000) state income generated by the agricultural industry—agricultural production, agricultural services, and food processing—is about \$7.8 billion; the indirect portion being about \$4 billion. At the overall state level, the agricultural industry generates about 7 percent of the total household income, not including the government and government services sectors (direct and indirect income).

At the county or regional level, the agricultural industry's impact can be far more pronounced. For example, in selected counties that could be directly affected by buffer zones, the income contribution ranges from about 13 percent to over 40 percent, not including the government and governmental services sectors.

Relative to the issue of buffer zone impacts at the county level, the above economic analyses indicate that buffers would be affecting economic sectors that are major contributors to income and economic activity within affected counties. The important questions become: (1) to what degree would buffer zones impact income generation, and (2) can such zones be managed to reduce economic impacts?

4.5 Sector Linkages within the Economy – The Flow of Economic Transactions

One further point should be made in considering the direct and indirect economic impacts exerted by the agricultural industry. The industry affects almost all economic sectors of the state economy. This is observable through the I/O modeling exercise, where the links between economic sectors are identified and the purchases (or sales) estimated (see Table 4.5).

The links represent the buying (input) and selling (output) conducted among the different economic sectors as they develop products and provide services within the overall economy. This activity is often referred to as the “flow” of economic transactions within an economy.

Table 4.5 displays the economic links associated with the agricultural industry for the State of Washington (1999 data). Estimates of inter-sector buying and selling are quantified based on the IMPLAN modeling assumptions (Minnesota IMPLAN Group, 1999). The economic links indicate that Washington’s irrigated agriculture industry annually (1999) buys about 60 to 70 percent of the value of purchases made by the direct agricultural production in Washington. Food processing sectors buy from other economic sectors within the state (about 30 to 40 percent out-of-state); and the agricultural services sector buys about 30 percent of its value of purchases from other in-state economic sectors.

At the county level, similar ratios exist for local versus non-local purchase values. For the selected counties, the direct agricultural production and food processing sectors buy about 60 percent of their value of purchases from other local economic sectors, with the agricultural services sector buying about 20 to 30 percent of its value of purchases from other local sectors (Minnesota IMPLAN Group, 1999 data sets).

TABLE 4.5
ECONOMIC SECTOR LINKAGES TO THE AGRICULTURE SECTOR
(IMPLAN MODEL AND 1999 DATA ESTIMATES)

Economic Sectors	Agricultural Production Buying From State Economic Sectors	Agricultural Services Buying From State Economic Sectors	Food Processors Buying From State Economic Sectors
	Total Purchase in 1999 (\$ Millions)	Total Purchase in 1999 (\$ Millions)	Total Purchase in 1999 (\$ Millions)
Agricultural Production	458.9	73.3	1,343.7
Ag Services	268.0	2.7	3.6
Construction	87.4	13.7	67.6
Food processing	131.6	0.8	451.5
Wood products	13.3	0.0	1.4
Chemicals and allied	84.2	20.8	44.7
Petroleum products	72.2	6.0	25.1
Industrial machinery	9.6	0.5	5.5
Electrical equipment	9.1	0.9	1.0
Transportation equipment	7.0	2.1	7.1
Railroads & Related Services	21.4	0.8	36.6
Motor Freight Transport & Warehousing	77.7	8.7	171.6
Water Transportation	8.4	0.4	25.4
Transportation Services	2.9	0.4	3.9
Communications	14.0	5.1	29.7
Utilities	52.3	0.5	76.1
Wholesale Trade	298.8	36.8	674.3
Retail Trade	0.5	1.7	43.8
Financial Institutions	49.1	13.0	115.7
Real estate	247.2	8.2	34.8
Hotels and Lodging Places	2.3	1.9	36.0
Business services	11.4	13.2	328.3
Automotive services	23.6	15.1	39.7
Repair services	17.3	1.5	20.5
Health services	12.6	0.0	0.0
State & Local Non- Educational Government	25.7	2.1	47.4
Other Sectors	21.9	41.1	163.4
TOTAL	2,028	271	3,799

4.6 Direct Economic Impacts from Buffer Zones – What is at Risk?

While the economic impacts of buffer zones are very site-specific in nature, depending on the type and extent of land and farm operations being affected, there are methods that can be used to estimate indicator or “index values” for such impacts. Because the index values represent generalized estimates of broad-based compiled data sets and assumptions, they should not be considered as “precise impact values.” In many circumstances they would underestimate or overestimate economic impacts because of their comprehensive basis for compilation.

Nevertheless, they can be used to assess an approximate magnitude of impact and would be appropriate for general resource planning and decision-making purposes, where broad-based economic impacts are being considered.

The methodology used to estimate the index values for the selected counties is developed in Table 4.6. In Table 4.6, crop, milk production, land, and local income values are estimated on a value per acre basis for each county, given the available production estimates and data sources. Using this methodology and data sources, crop production values per acre range from about \$600 to \$4,500, dairy production values per acre range from about \$4,050 to \$5,400, county income values per acre range from less than \$1,000 to about \$2,400; and land values per acre range from about \$2,500 to \$5,250. Values are weighted averages.

TABLE 4.6
ESTIMATED INDEX VALUES FOR AVERAGE AGRICULTURAL PRODUCTION AND
LAND VALUES

Counties	Affected Crop Production Value/Acre	Average Dairy Production Value/Acre*	Average County Income Value/Acre	Average Land Value/Acre
Benton	\$4,500	-----	\$1,900**	\$5,250
Kittitas	\$600	-----	< \$1,000***	\$2,500
Skagit	\$1,700	\$4,050	\$2,400***	\$3,400
Yakima	\$4,000	\$5,400	\$1,900**	\$4,500

Notes:

- * Based on average dairy farm size of 400 acres east-side and 200 acres west-side, 2000 average value milk production estimates above, and Census of Agriculture estimates for total dairy farms per county; information from Soil Search Consultants, Kennewick, Washington, July 2002; and Washington State Dairy Federation staff (estimated average dairy sizes for Washington state); and milk production values from above tables and sources cited therein. Value is highly sensitive to assumptions about number of farms and average size.
- ** Based on irrigated crop lands for Benton County and Eastern Oregon, USACE 2000, Pacific Northwest Project 2001, and IRZ Consulting and Pacific Northwest Project 1998.
- *** Based on above direct and secondary income estimates for Skagit and Kittitas Counties and total estimated farm acreage.

The values derived in Table 4.7 are converted to potential value losses related to buffer zones, where the zones are defined as value per mile of 75-foot buffers, for both sides of the affected stream. The general assumption for value loss is based on loss of economic activity tied directly to affected land acreage. For illustration purposes here, it is assumed that all acreages included within buffer zones would have a uniform or linear impact on the various measures of local economic value, such as crop production, milk production, and county income. On an empirical basis, this may or may not be the case, depending on the extent that economic activity is allowed within some portion of the buffer zone, the Table 4.7 index values would overstate the levels of impacts. Inversely, to the extent that a buffer zone caused a farm operation to be no longer

economically viable, forcing it to go out of business, the index value would underestimate the impact magnitude.

TABLE 4.7
ESTIMATED INDEX VALUES FOR BUFFER ZONE IMPACTS

Counties	Crop Value Loss/Mile 75 ft Buffers*	Dairy Prod. Value Loss/Mile 75 ft Buffers*	Ave. County Income Loss/Mile 75 ft Buffers*	Ave. Land Value Loss/Mile 75 ft Buffers*	Ave. County Income Loss/100 acres of Buffer
Benton	\$81,000	-----	\$34,200	\$94,500	\$190,000
Kittitas	\$10,800	-----	-----	\$45,000	-----
Skagit	\$30,600	\$66,960	\$43,200	\$61,200	\$240,000
Yakima	\$72,000	\$88,200	\$34,200	\$81,000	\$190,000

Notes:

Table values based on above tables and sources cited therein.

* Assumes riparian buffer impacts on both sides of stream, approximately 18 acres per mile.

4.7 The Farm Economics of Agricultural Buffer Zones – Some Examples

One of the best ways to understand the economic impacts of buffer zones on farm owners is to review available examples where farm managers have installed buffers. The Natural Resources Conservation Service has provided a multi-state case study of several farm types and buffer programs currently in operation (USDA-National Resources Conservation Service, 1997). By reviewing this information, it is possible to identify certain trends affecting farm economics and the types of buffers being implemented.

First, large riparian buffers, about 50 feet wide, have been adopted by some landowners (without compensation) where high-value crops are involved, such as oranges and grapes, and where acreages affected are relatively large (100 acre blocks or larger). Some farmers have accepted the buffers as “a cost of doing business,” relying solely on the buffer zones to protect water quality, as opposed to employing other management tools. The high-value crops allow farm operators greater flexibility to adjust to relatively large buffer zone sites, and other direct land management actions are relegated to resolution by buffer zones. Examples are cited from Florida and California.

Examples where relatively large riparian buffers about 35 to 50 feet wide have been adopted by landowners and farmers involve large acreages (greater than 500 acres), and it has been the landowner’s choice to use buffers as a preferred management alternative to control for water quality problems. Here the affected lands do not appear to contribute significantly to farm production revenues. Landowners with large acreages are receiving acceptable compensation

through the CRP program to offset costs. Examples are cited from South Carolina and New York.

In Utah, Oregon, and Idaho, some examples are offered where buffers are limited to agricultural management zones, where cover crops and animal grazing periods are controlled. Some range operations are providing minimal buffers but have fenced livestock away from critical stream habitat areas. In these examples, the application of buffer zones is limited or includes multi-purpose land management objectives that minimize the costs involved to farmers and ranchers.

What emerges from these buffer zone examples is that buffer applications have been tailored to meet the specific economic circumstances of individual farmers. Farm operators have elected to adopt buffer zones that do not measurably interfere with or negatively impact farm economic vitality. In these cases, cost and/or compensation is an important factor in buffer zone applications.

4.8 Agricultural Water Reallocation and Buffer Zones – Economic Issues

The economics of buffer zone impacts can be, and often are, related to water reallocation actions. This can occur indirectly in terms of water rights affected by irrigated land loss to the buffer zone, thus reducing the water quantity of the water right held by the land owner; and it can occur directly in an economic sense, where the question of water value trade-offs occur for fish or other non-market value resources.

The economic value of water can be expressed in terms of direct net value (National Economic Development standards used by federal water resources agencies) per acre-foot of water used for specific sectors, such as irrigation, municipal, hydroelectric power production, fisheries and wetlands restoration or enhancement, and recreational activities. Several estimates of the value of water related to these activities have been made in the west, depicting economic values derived from (1) use of market transactions (irrigation, hydroelectric power, and commercial fisheries sectors), (2) use activities that are non-market in nature (sport fisheries and recreation), and (3) option and existence values related to both non-use and non-market perceptions of value (various types of environmental resources) (for example, see summary in Pacific Northwest Project (1998).

Any review of economic value estimates for water resources brings forward several issues surrounding water use trade-offs, such as reallocating water away from irrigated agriculture to environmental resources. First, while the value of water for irrigated agriculture falls within a relatively narrow range, the water values for environmental resources can be either well below the value of irrigation, or they can appear to be much higher. This suggests that relying on

preconceived assumptions about the economic benefits or costs of water transfers will likely lead to poor water reallocation decisions. The economic benefits and trade-offs must be dealt with on a local or regional basis.

Second, it should be noted that while water values for irrigation are "user values," many water values (or much of the economic value) for environmental resources are non-use values. In fact, much of the value attributed to environmental resources is a non-use, non-market value that is quantified through survey methods into monetary terms. For example, survey respondents are asked to state their "willingness-to-pay" for environmental resources that would be protected or restored to some positive condition (some very specific examples of this methodology for the Northwest region are in Pacific Northwest Project, 1994; Olsen, D. *et al.*, 1991; and Olsen, D. 1993; and also refer to Loomis, 1997).

When we compare water values for irrigation to those for non-use, non-market entities, the economic nature (or actual impact) of the direct net values is quite different. For example, the direct net value for irrigation consists of material production that generates direct net economic activity and secondary/regional economic activity-both of which can be measured in terms of net production value, income, or employment. When non-use values are measured, no actual income is generated within the economy. What is being measured is an expression of willingness-to-pay, which may or may not be an accurate measurement of economic value (consumer surplus value if a market transaction could actually be provided), and may or may not be considered as contributing to measures of real income gain. There is a tangible difference between actual direct net value within a real market transaction or use circumstance, versus the pure perception of economic value. This is an issue that some resource economists believe should temper how existence values are used, and may limit their relevance when being contrasted directly to use values-particularly when the existence values exceed use value by several factors.

Third, non-use, non-market measures of existence value are seldom handled equivalently between resource comparisons. For example, while economic valuation estimates have been made to capture use and non-use values for many environmental resources, existence values are seldom, if ever, considered for activities such as the irrigation sector; there is, no doubt, some existence value that society attaches to irrigated agriculture and all of its environmental qualities, either real or imagined. This can be illustrated by the types of economic valuation studies that have been recently conducted for the Central Valley Project and the Columbia-Snake River Basin (major EIS studies conducted by the USBR and Army Corps of Engineers). Non-use existence values have been estimated for fish resources (which also retain use values), but no attempt is made to calculate non-use existence values for the irrigation sector benefits. In effect, the value estimates used to assess economic trade-offs, in these situations, are not equivalent in structure.

Consequently, the economic trade-offs involving water reallocation decisions must be weighed with great caution. While decision makers may harbor the best of intentions, the end result of incompletely reviewed decisions could lead to a real loss of economic benefits.

4.9 Assessing Economic Impacts from Buffer Zones – Three Methods

There are some standard economic “tools” that are employed to assess land and water use impacts when considering major project developments or when significant economic sector trade-offs are being contemplated: benefit-cost analysis, marginal benefit assessment, and cost-effectiveness analysis. Unlike local or regional impact analyses that concentrate on measures of income or employment (Regional Economic Development), these tools primarily focus on measures of direct net value and net social welfare trade-offs between major economic sectors (National Economic Development values).

Benefit-cost analysis could be employed to measure the direct net benefits versus costs for setting aside buffer zones for specific streams and counties. To do so, the direct net value of production per acre (cost) would be contrasted to the direct net value of fish resources, based on increased fish production leading to increased sport and commercial fishing (benefits). The cost would not be difficult to measure, and the benefits could be estimated based on assumptions affecting the increased survival rates for fish for specific stream reaches. Alternatively, the agricultural cost estimate could be used as an economic criterion to assess the required fish production increase per acre to balance the benefit-cost trade-off.

A marginal benefit assessment would scrutinize the value of incremental benefits—fish production or habitat units—based on specific actions taken. For example, a review of the litter-fall effectiveness for habitat enhancement by the Oregon Forest Industries Council (CH2M HILL, 1999) demonstrated that FEMAT effectiveness curves produced very little effectiveness per tree height distance (unit) from streams beyond a unit value (tree-height) of 0.5. In effect, the marginal value of the buffer zones’ effectiveness, based on tree-height distance, declined sharply after a 0.5 unit value. Other studies suggested even more limiting marginal values of effectiveness. Under marginal benefit assessment, the production gained per incremental input unit of increase is evaluated and, at some point, diminishing gains per unit of input are deemed to be unacceptable or providing inadequate production value.

Cost-effectiveness analysis could be employed where a specific objective is sought, and different alternatives to achieve that objective are possible. The emphasis is on finding a more cost-effective solution to the problem rather than comparing different sectors’ direct net value changes. For example, if the objective is to control water quality impacts from animal wastes,

then the annual costs of buffers per unit of control (reduced impacts to water) can be compared to the annual costs of animal waste management measures. Cost-effectiveness analyses could be employed in a more detailed economic review of buffer zones for specific areas, such as the Skagit Valley.

All of these analysis tools offer a means to consider economic sector trade-offs and marginal benefits and costs (USDA-Economic Research Service, 1999). Still, returning to a regional economic development (RED) perspective and framework, it should be understood that direct land impacts to specific agriculture production operations may be marginal, but can remove the profitability from the operation, thus forcing producers out-of-business. Consequently, a buffer could have a relatively small land impact, but result in forcing a farming operation out-of-business, affecting the direct and secondary income stream throughout the community. Then the economic question becomes, will the buffer zones generate economic activity from other sectors, and provide income to the local area to offset the direct impact to production agriculture?

4.10 Summarizing Key Points – Agricultural Economic Base and Impacts

Some highlights and key points of the preceding technical analyses and observations are summarized below:

- Farm-gate production values exceed \$100,000,000 annually in several Washington State counties. This production value is largely transferred to other sectors of the county, state, and national economies creating further economic activity.
- The agricultural industry increases land values in several rural counties, contributing millions of dollars to each county tax base—paying for infrastructure and services.
- The agricultural industry, including agricultural production, agricultural services, and food processing—is a significant economic sector within Washington State, generating almost \$8 billion annually of state income. In particular, the agricultural industry is a leading economic sector in several counties located away from the major urban centers.
- The agricultural industry possesses linkages to almost all other economic sectors of the state economy—buying and selling diverse goods and services throughout the state.
- Representative “index values” can be calculated at the county level to estimate the regional impacts of 75-foot buffer zones. On a per mile basis, the costs of buffer zones (for selected counties reviewed here) could range between \$11,000 to \$81,000 for affected crops; \$72,000 to \$97,000 for affected dairy production; and \$45,000 to \$95,000 for affected land values. On a 100-acre impact basis, the loss of total county income (direct and secondary) could range between \$190,000 to \$240,000 annually.

- Water reallocation issues can be tied to buffer zone impacts. Because of the varying economic value of water within economic sectors, relying on preconceived assumptions about the economic benefits or costs of water sector transfers will likely lead to poor reallocation decisions. The economic benefits and trade-offs must be dealt with on a local or regional basis.
- In water, land, and environmental resources valuation and trade-off decisions, the use of non-market values should be approached carefully. The value ranges can vary greatly depending on the quality of measurement, some non-market values do not reflect real measures of income gain or loss for an economy, and non-market values are seldom handled equivalently among resource comparisons.
- There are elaborate economic analysis “tools” that can be used to assess economic sector marginal benefits and trade-offs surrounding buffer zone management. These tools are: benefit-cost analysis, marginal benefit assessment, and cost-effectiveness analysis. They can be used appropriately, and accurately, at the county or regional level.

Section 5 – References

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Appendix A

Review of Riparian Ecosystems Literature Citations

Appendix A
Review of Riparian Ecosystems Literature Citations. Communicated to the
Ag Fish Water Agricultural Caucus from John Mankowski, WDFW and
Steve Landino, NMFS,
May 30, 2001.

This Appendix A. is a synopsis of the literature and evidence that the WDFW and NMFS use to support recommendations for maximum riparian buffer widths in Washington State's Agricultural Lands. We review the basis of the citations and comment on them from the perspective of Best Available Science.

These reports, other supporting citations and literature, form the basis of this Review of Science Recommendations for Agricultural Buffers for the Ag Fish Water Agricultural Caucus.

They are reviewed in the same sequence as collated by the originating agencies.

We were unable to review two sources directly, one was an REMM model in press (Appendix A.11) and the other was a paper by Murphy 1995 on effects of logging salmonid habitat in Alaska (Appendix A.8). We did review other research by this same author elsewhere and on this topic by other authors such as by S. Gregory Or.St.Univ.

Appendix A.1

Conservation Buffers to Reduce Pesticide Losses

Appendix A.1

United States Dept. of Agriculture-Natural Resources Conservation Service. 2000. Conservation Buffers to Reduce Pesticide Losses. Source available at: <http://www.nrcs.usda.gov>.

This NRCS report discusses several studies that have evaluated the effectiveness of buffer zones to trap pesticide field losses.

On key point that is made by the report is that pesticide field losses are largely occur at locations of heavy rainfall and pesticide use or where some types of irrigation practices are used. Water run-off is the measure that is being controlled by the buffer zones.

Another characteristic of the report is that it reviews technical studies almost exclusively conducted within the Southwest or Midwest.

The review of buffer sizes and conditions varies greatly, with some buffer in the 15-30 ft. width range and others much larger—as much as 164 ft. for multipurpose buffers. The authors note that buffer widths ranging from 16 to 59 ft. have been effective to filter out agri-chemicals depending on buffer types and land conditions.

For sediment trapping, the report acknowledges studies suggesting 15-30 ft. wide buffers as being adequate, while other studies recommended 50 ft. buffers, as a general rule.

In designing buffers, the report stresses that the buffer purpose must be defined and applied taking into account local conditions (land-use, soil composition, and climate conditions). For sedimentation problems, buffers of 20 ft. are deemed adequate, while if the focus is on nitrates and pesticides, wider buffers are recommended. But the key factor in designing buffers will be site-specific conditions.

The report also stresses that on-farm manages practices (best management practices) should be considered in designing buffer zones, as well as farm-specific economic conditions.

Appendix A.2

Ecological Issues in Floodplains and Riparian Corridors

Appendix A.2

Bolton, S. and J. Shellberg. 2001. Ecological Issues in Floodplains and Riparian Corridors. White Paper. Prepared by University of Washington, Center for Streamside Studies. Submitted to Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Transportation.

This report focuses on the ecological effects of channelization, channel confinement, and construction in riparian areas. As such, it really does not provide any information about the specific topic of riparian buffers in agricultural areas. The report makes no recommendations for riparian buffer zones. It does, however, discuss channel migration zones (CMZ). This is the area in which the stream is expected to move. The report reviews a number of definitions of the CMZ.

Appendix A.3

Forest Ecosystem Management: An Ecological, Economic, and Social Assessment

Appendix A.3

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Washington, D.C.: US Department of Agriculture, Forest Service; US Department of Commerce, National Oceanic and Atmospheric Administration, US Department of Interior, Bureau of Land Management, U.S. Fish and Wildlife Service, and National Park Service; and Environmental Protection Agency.

The Forest Ecosystem Management Assessment Team (FEMAT) was commissioned to formulate new management options to address the crisis caused by federal court bans timber harvest on federal lands with spotted owls and other listed species. Scientists from universities and agencies USFS, BLM, EPA, USFWS, NPS, NMFS, comprised the team.

FEMAT was instructed to identify management alternatives for establishing a network of late-successional/old-growth reserves and a prescription for the management of the intervening forestland. The Plan was to attain the greatest economic and social contributions from the forests but also meet the requirements of the Endangered Species Act, the National Forest Management Act, the Federal Land Policy Management Act, and the National Environmental Policy Act.

The management options incorporated conservation measures for the recovery of the identified listed species, with northern spotted owl as a guiding species. The area addressed by FEMAT is the range of the northern spotted owl within the United States, which includes western Washington, western Oregon, and northwestern California. The resulting stream buffer subscriptions were based on the life history needs of a multitude of species and their habitat structure but primarily driven by recovery needs of spotted owls. The Team was commissioned to formulate and assess the consequences of an array of management options that might solve timber cutting and other operation issues within the northern spotted owl range. The objectives were to produce management alternatives that would comply with existing laws and produce the highest contribution to economic and social wellbeing. Note: **This is considerably different need and goal for riparian buffer protection of salmonids in agricultural lands (emphasis AgFishWater Review).**

Each of the ten options contains reserve areas in which timber harvests are either not allowed at all or are limited, and areas outside of reserves (referred to as the Matrix) where most timber cutting occurs. The reserves are of two types: Late-Successional Reserves, encompassing older forests stands, and Riparian Reserves, consisting of protected strips along the banks of rivers, streams, lakes, and wetlands, which act as a buffer zone between the water and areas where cutting is allowed.

The forthcoming discussion will focus on salient Riparian Reserve issues.

All options contain some form of Riparian Reserves. Riparian Reserves are intended to address the habitat requirements for fish and other aquatic and riparian species. They also

protect water quality, maintain appropriate water temperatures, and reduce siltation and other degradation of aquatic habitat that results from timber cutting on adjacent land. This degradation has been an especially serious product of past road building and cutting practices and is a contributing reason why certain fish species are now at risk of extinction.

Under different options, Riparian Reserves vary in width depending on the size of the body of water and the ecological importance of the watershed. Options 1 through 4 provide the greatest amount of riparian protection. Options 7 and 8 provide the least. The rest are in the middle of the range of protection.

The options recognize three categories of waters: (1) permanently flowing fish-bearing rivers, streams, lakes, and reservoirs; (2) permanently flowing nonfish-bearing streams, ponds, and wetlands larger than 1 acre; and (3) intermittent streams and wetlands smaller than 1 acre.

All options except Options 7 and 8 incorporate buffer widths that are a minimum of 300 feet on each side of the water for the first category of streams, and a minimum of 150 feet for permanently flowing streams of the second category. Option 7 buffers were established by Forest Service and the BLM and are generally narrower. Option 8 uses 75 foot buffers for the second category.

In addition, all options except Option 7 prescribe minimum buffer widths for intermittent streams and for small wetlands:

Options 1 and 4 use a buffer width of at least 100 feet for these areas.

Options 2, 3, 5, 6, 9, and 10 use a 100-foot minimum width for intermittent streams and certain Key Watersheds and a 50 foot minimum elsewhere. In Option 9 an effort was made to delineate the Late-Successional Reserves in Key Watersheds.

Option 8 uses a 25-foot minimum for all intermittent streams and small wetlands.

Option 7 is based on the plans of the Forest Service and the BLM. Those plans do not generally prescribe a minimum buffer for intermittent streams; where they do the buffer width is usually 25 feet.

Initially, under all options but 7, no harvest would be allowed in Riparian Reserves, and agencies would be required to minimize the impact of roads, cattle grazing, and mining activities. Prescriptions under Option 7 are less restrictive. The options that prescribe buffers allow for the adjustment of buffer widths and may allow some timber cutting after completion of watershed assessments.

In planning for ecosystem management and establishing Riparian Reserves to protect and restore riparian and aquatic habitat, the overall watershed condition and the suite of processes operating need to be considered in a watershed analysis. Watershed analysis is required in Key Watersheds before moving forward with all options except Option 7.

The FEMAT team predicted that increased levels of protection of old growth forests provided by larger reserve systems should foster an increased likelihood of successful persistence of organisms associated with late-successional and old-growth forest. **Note: This orientation is for the preservation of old growth tree habitat and is not directly applicable to secondary growth riparian forests of agricultural lands (emphasis AgFishWater Review).** FEMAT found that if a species did not fare well under a particular option its response generally improved under a more conservative option. This conclusion can be linked to agricultural buffers in a general fashion. It is arguable that more conservative options will allow a species to fare better in agricultural systems as well. However, the Team did identify species and situations where particular organisms or groups did not respond to the level of habitat protection provided.

Critical issues in management of aquatic resources are; (1) at-risk fish stocks and species; (2) stream, riparian, and wetlands habitat; (3) water quality; and (4) nonfish species of aquatic and riparian-dependent organisms.

The Team developed a set of options for management of aquatic and riparian ecosystems based on scientific understanding of the functional links between stream and wetland ecosystems and adjacent terrestrial vegetation. Streamside forests profoundly influence habitat structure and food resources of stream systems for lateral distances exceeding a tree height for many functions. Tree height distance away from the stream is a meaningful indicator that is crucial for providing aquatic habitat components, including wood recruitments and degree of shade. The Team defined site-potential tree height as the average maximum height of the tallest dominant trees (200 years or more) of a given site.

Riparian Reserves are portions of watersheds where riparian-dependent resources receive primary emphasis and where species standards and guidelines apply. Riparian Reserves include those portions of a watershed that are directly coupled to streams and rivers, that is, the portions of a watershed that directly affect streams, stream processes, and fish habitats. Every watershed in National Forests and BLM Districts within the range of the northern spotted owl will have Riparian Reserves. Land allocated to Riparian Reserves status varies between options from 0.62 to 2.88 million acres.

In summary Options 1 and 4 had the greatest likelihood, 80 percent or greater, of attaining sufficient quality, distribution and abundance of habitat to allow the species populations to stabilize across federal land. The positive outlook for these options resulted from the relatively larger amount of area in Late-Succession Reserves and the Riparian Reserves.

Options 2, 3, 5, 6, 9, and 10 generally had a 60-70 percent likelihood of attaining an outcome where habitat for the seven species/groups of anadromous fish was sufficient to support quality spawning and rearing habitat well-distributed across federal lands. These options had a smaller likelihood of attaining this outcome than Options 1 and 4 because of less area in Late-Successional Reserves and the Riparian Reserves.

Option 7 and 8 were ranked low and the reduced likelihood was due to the reduced size of Riparian Reserves, particularly along intermittent streams.

A very applicable statement to the current project can be found in the FEMAT report, “(I)n considering the effects of any federal land management option on aquatic resources, two points are key: overharvest, disease, artificial propagation practices, and habitat impacts such as urbanization and agricultural practices have degraded and may continue to degrade aquatic habitat; and a plan for managing federal lands alone will not solve these problems. Ecosystem management cannot be successful without participation of all federal and nonfederal landowners and agencies that affect a watershed. The federal agencies must foster a partnership for ecosystem management with these entities to ensure conservation and prevent further degradation of the region’s aquatic resources.”

Another pertinent statement in the FEMAT (1993) report is that “(S)tructural components of stream habitat must not be used as management goals in and of themselves. No target management or threshold level for these habitat variables can be uniformly applied to all streams.” The Team further concludes “while this approach (fixed-width buffers) is appealing in its simplicity, it does not follow for natural variation among streams.”

The Team states, “(T)ree heights and slope distance provide ecologically appropriate metrics with which to establish Riparian Reserve widths. For example, tree height distance away from the stream is a better indicator of potential wood recruitment or degree of shade than is an arbitrary distance. Likewise, slope distance is a more meaningful ecological distance than horizontal distance.”

The Oregon Forest Industries Council (OFIC) commissioned a review study of the scientific evidence supporting the FEMAT riparian shade effectiveness curve. The resulting 1999 report found that neither the scientific source nor the technical basis of the FEMAT shade curves could be independently verified. In addition, the data and curves from the FEMAT-referenced studies did not fit the published FEMAT shade relationship. The same study also found empirical data that indicated that the FEMAT curve underestimates the shade contribution from riparian vegetation. This 1999 OFIC-sponsored study focused on forest ecosystem buffer management. While this report would be helpful for the proposed project, it is by no means comprehensive for agricultural applications. There are three other riparian processes FEMAT cumulative effectiveness curves (Figure A.3.1): litter fall, root strength, and coarse woody debris. In addition, FEMAT produced six microclimate curves, which are relevant to the agricultural land management options.

Given this background information, it is not surprising the resulting FEMAT curves may not be applicable to lowland agricultural streams. FEMAT centered their research and management options on predominately coniferous late-successional, high gradient, forested areas. The form and function of coniferous forests are quite different from deciduous, low gradient riparian habitat of agricultural lands in Washington.

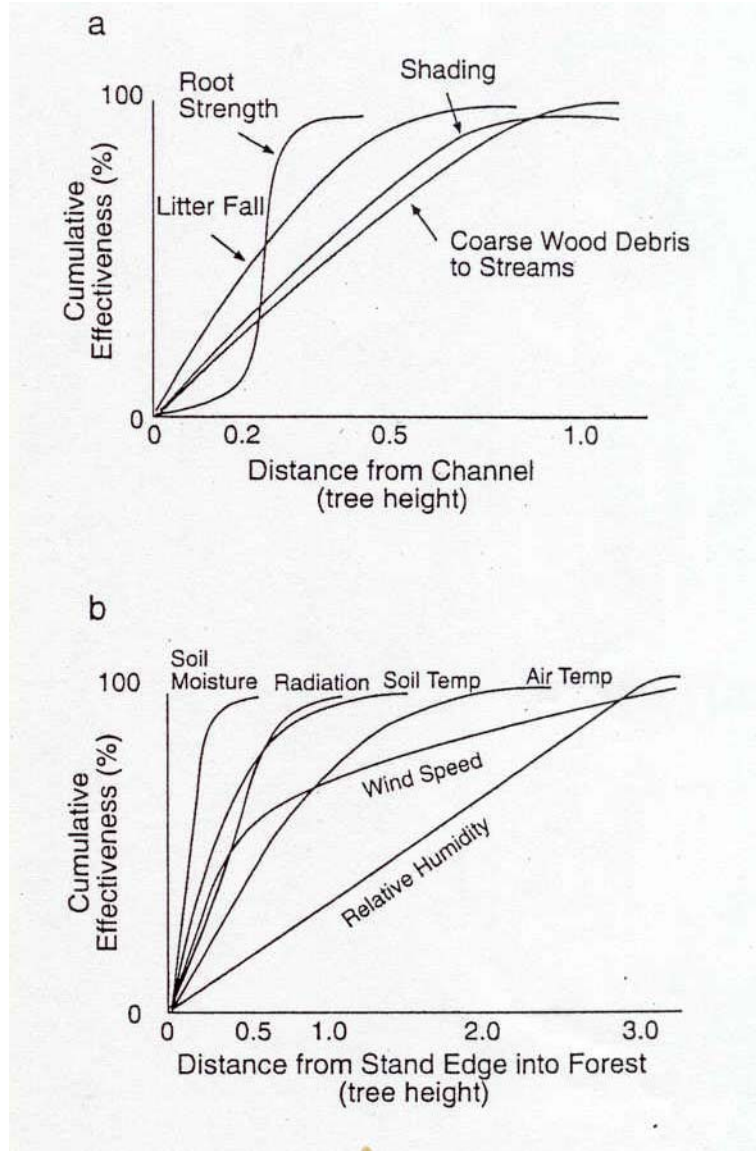


Figure A.3.1. See text for discussion.

At issue is the scientific basis for applying the FEMAT curve to lowland habitats and their relevancy to assessing agricultural impacts on aquatic systems. Much of the basis for concern is exactly how much impact agricultural uses are having on water quality and riparian/aquatic habitat. Although there is no denying that 100 years of agricultural improvements have changed local ecology, it is less clear that imposing maximum width stream buffers on every mile of agricultural stream channel stream buffers calibrated to coniferous forest removal is a cost-effective means of large woody debris recruitment. In fact, lowland riparian forests cannot supply the same quality of LWD of old-growth forests (see Bisson, 1987). Buffers may be needed in some places and may be the best means to restore some ecological functions; however, identifying the specific non-functioning parameter is important because each different function requires significantly different buffer accommodations. In some cases, alternatives to buffers may be better

solutions. Specifically, the magnitude and location of agricultural habitats not meeting proper ecological functions is key to identifying the right buffer width or alternative strategy to achieve proper function if it is impaired. This is key in determining appropriate management actions: it is knowing which agricultural practices are actually contributing to the problem and whether a more direct type of mitigation might restore proper ecological function. .

The Team concluded that the best approach would be through a continuing three phase process. The first phase involved development and assessment of management options for establishment of a network of late-successional/old-growth forest reserves and prescriptions for the management of the intervening forestland (i.e., the Matrix). The first phase also included selection of ten options and the completion of the procedures required by the National Environmental Policy Act (NEPA) (i.e., the Environmental Impact Statement). The second phase in the shift to ecosystem management is reinstituted forest planning – a process the Team feels must include federal, state, local government, and private interests if ecosystem management is to be achieved. The third phase involves implementation, monitoring, and adaptive management.

A key on-point biological objective involved aquatic and riparian habitats and wetlands on federal lands. These habitats are key to aquatic organisms including anadromous fish considered to be “at risk” of extinction. Because of this objective, riparian management options for habitat adjacent to streams were developed.

Appendix A.4

**Final Environmental Impact Statement on Alternatives for Forest Practices
Rules**

Appendix A.4

Washington Forest Practices Board. 2001. Final Environmental Impact. Statement on Alternatives for Forest Practices Rules.

The Washington Forest Practices Board (Board) proposed to modify the Forest Practices Rules. The objectives of this proposal were to more fully address the impacts of forest practices on water quality, salmon habitat, and other aquatic and riparian sources. The primary impetus for the adoption of the rule proposal was the recent decline in fish stocks throughout much of Washington State and the large number of streams identified as having water quality problems.

The Board determined that changes in the Forest Practices Rules have the potential for significant adverse environmental impacts and therefore an Environmental Impact Statement was required under the State Environmental Policy Act to analyze the significant environmental impacts of the alternatives under consideration. This document is the Final EIS (FEIS). Note that the document that we reviewed is an executive summary of the FEIS and therefore only contains a brief summary description of the various alternatives and their impacts. The full EIS may contain more background information and justification based on science for the changes in the riparian buffer zones that are proposed.

The FEIS is organized into three parts. Chapter 1 provides the background and objectives. Chapter 2 provides the alternatives including the proposal. Chapter 3 provides an overview of the affected environment and environmental effects.

The document reports that four major discoveries/events support the need for revised Forest Practices Rules. The first area of need is related to water typing. "The water typing system used in Washington's Forest Practices Rules is based on beneficial uses, one of which is fish. Type 1, 2, and 3 Waters contain anadromous and resident fish, while Type 4 and 5 Waters do not. The water typing system has been in place for more than 20 years. Maps developed to implement the system were based on aerial photo interpretation with limited field verification. Over the years, field verification has provided data on actual fish use of waters, which has led to updated water type maps. While water types are continually reviewed and updated, large numbers of waters have not been field verified. In August 1994, Point-No-Point Treaty Council published a report, Stream Typing Errors in Washington Water Type Maps for Watersheds of Hood Canal and the Southwest Olympic Peninsula. Simultaneously, the Quinault Indian Nation and the Department of Fish and Wildlife were also reviewing water types in the southwest part of the Olympic Peninsula. Data from both studies indicated that seventy-two percent of Type 4 streams were actually Type 2 or 3 streams. Because water typing triggers riparian protection throughout the Forest Practices Rules, the definitions used to determine water types must reflect current knowledge about fish use and habitat."

"The second indication that Forest Practices Rules were inadequate was the prescriptive outcomes from watershed analysis. Watershed analysis is a process that reviews all forest lands within a watershed, finds sensitive resources within that watershed, and prescribes methods for protecting those sensitive resources. The watershed analysis rules were adopted in 1992 (chapter 222-22 WAC). Through the years, watershed analysis prescriptions for riparian areas have consistently been more stringent than the current

Forest Practices Rules. This led to the realization that the current rules were not doing an adequate job of protecting riparian functions.”

“A third indicator of need for change in the Forest Practices Rules was the listing of many salmonid species on the federal and state threatened and endangered species lists. The lists include multiple races of chinook salmon, chum salmon, sockeye salmon, and steelhead, as well as the Columbia River bull trout. Other salmonids are being considered for listing. When a species is either federally or state-listed as threatened or endangered, the rules require DNR to consult with WDFW and make recommendations to the Forest Practices Board as to what, if any, modifications to the rules are necessary. The Forest Practices Board developed emergency salmonid rules, which were first put in place in May 1998. The maps which governed where the emergency salmonid rules applied were updated each time a new listing occurred.”

“The fourth reason for changes was EPA’s identification of over 660 Washington streams as water-quality-impaired under the Clean Water Act. Past forest practices in Washington are considered as one of a number of factors contributing to these listings.”

Three alternatives are considered in detail in Chapter 2 of the FEIS.

Alternative 1

Alternative 1 entails continuing with the existing permanent Forest Practices Rules and does not include the revisions to these rules produced by the water typing, salmonid, or Forests and Fish Emergency Rules.

Alternative 2

Alternative 2 represents the alternative defined by the Forests and Fish Report (April 1999), as supplemented by House Bill 2091 and as subsequently refined. The provisions of the Forests and Fish Report and the Forests and Fish Emergency Rules are collectively referred to as the Forests and Fish Plan and are discussed in the previous section of this summary memorandum. The groups contributing to this report include Washington state agencies (Department of Natural Resources, Department of Ecology, Department of Fish and Wildlife), federal agencies (National Marine Fisheries Service, U.S. Environmental Protection Agency), the Colville Confederated Tribes, the Northwest Indian Fisheries Commission, The Washington State Association of Counties, the Washington Forest Protection Association, and the Washington Farm Forestry Association.

Alternative 3

Alternative 3 is representative of the alternatives produced by groups that were not among the authors of the Forests and Fish Report. Separate proposals were made by an environmental caucus (led by the Washington Environmental Council and the Audubon Society) and by the Muckleshoot Indian Tribe, Yakama Indian Nation, and Puyallup Indian Tribe. Elements of these proposals are incorporated into Alternative 3.

The following table provides a summary of provisions for each alternative applicable to the riparian buffer issue.

TABLE 1
SUMMARY DESCRIPTION OF THE ALTERNATIVES CONSIDERED IN DETAIL

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Water Typing	<u>Five-type System</u> <u>Fish-bearing waters</u> 1=shorelines of the state 2=generally > 20 feet 3=generally < 20 feet <u>Non fish-bearing waters</u> 4=generally > 2 feet 5=generally < 2 feet	<u>Three-type System</u> <u>Fish habitat waters</u> S=shorelines of the state F=other fish habitat waters <u>Non fish-habitat waters</u> Np=perennial waters Ns=seasonal waters	<u>Three-type System</u> <u>Geomorphic-based</u> Gradient = 0 – 20 % Gradient = 20 – 30 % Gradient = > 30 %
Riparian Habitat	<u>Shorelines of the State (Type 1)</u> Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. <u>Westside Fish Habitat (Type 1-3)</u> 25 – 100 feet managed buffer <u>Westside Non Fish Habitat (Type 4-5)</u> Type 4: riparian leave tree areas sometimes required Type 5: no requirements	<u>Shorelines of the State (Type S)</u> Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. <u>Westside Fish Habitat (Type F)</u> No management allowed inside channel migration zone (CMZ). Three zones: core, inner, outer Core Zone: no management Inner Zone: 2/3 SPTH buffers on streams <= 10 feet wide, managed with stand requirements; ¼ SPTH buffers on streams >10 feet wide with stand requirements Outer Zone: SPTH buffer with 10-20 trees/acre <u>Westside Non Fish Habitat (Type N)</u> Perennial: 50-foot no-cut buffer, sensitive sites; discontinuous with at least 50% buffer on length Seasonal: 30-foot equipment limitation zone	<u>Shorelines of the State</u> Requirement of no more than 30% volume removal every 10 years within 200 feet of shoreline. <u>Westside Fish Habitat</u> No management allowed inside channel migration zone (CMZ) or beaver habitat zone (BHZ). 200 feet additional managed buffer; only thin to improve riparian function through SEPA <u>Westside Non Fish Habitat</u> No management allowed inside channel disturbance zone (CDZ). In addition, the following buffers are added: Perennial: 100-foot continuous no-cut buffer Seasonal: 70-foot no-cut buffer

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Riparian Habitat (continued)	<u>Eastside Fish Habitat</u> 30- to 300-foot managed buffer <u>Eastside Non Fish Habitat</u> Type 4: riparian leave tree areas sometimes required Type 5: no requirements <u>Small Landowners</u> None	<u>Eastside Fish Habitat</u> Three additional zones: core, inner, outer. Core: no management Inner: 70 or 100 feet; management with stand requirements Outer: SPTH buffer with 10, 15 or 20 trees/acre <u>Eastside Non Fish Habitat</u> Perennial: 50-foot managed buffer with uneven-aged management; discontinuous buffer with up to 300 ft. clearcut, but maximum of 30% length under even-aged management; plus 30-foot equipment limitation zone Seasonal: 30-foot equipment limitation zone <u>Small Landowners</u> Exemption from new rules for <20-acre parcels for landowners who own less than 80 acres of forested land; DNR can add 15% of stand volume to current riparian buffers	<u>Eastside Fish Habitat</u> 200 feet managed buffer; only can thin to improve riparian function through SEPA <u>Eastside Non Fish Habitat</u> Perennial: 100 feet continuous no-cut buffer Seasonal: 70-foot no-cut buffer <u>Small Landowners</u> Exemption from new rules for <20-acre parcels for landowners who own less than 80 acres of forested land; DNR can add 15% of stand volume to current riparian buffers
Unstable Slopes	Reviewed in forest practices application process SEPA trigger	Reviewed in forest practices application process; improved definitions, screens, training and field verification SEPA trigger Addresses public safety Identification of high hazard and moderate hazard landforms	Reviewed in forest practices application process; improved definitions, screens, training and field verification SEPA trigger Addresses public safety Identification of high hazard and moderate hazard landforms. Add all >80% planar slopes to definition of high hazard; no harvest on high hazard; additional 50-ft. buffer around high hazard slopes; all > 50% slopes classed as moderate hazard
Watershed Analysis	Mandatory for DNR as funding allows Voluntary for landowners Nine modules currently included Improved hydrology and water quality modules Prescriptions written for all modules	Mandatory for DNR as funding allows Voluntary for landowners Nine modules plus new ones Improved hydrology and water quality modules New cultural and restoration modules No prescriptions for riparian, mass wasting, and surface erosion.	Mandatory for DNR as funding allows Voluntary for landowners Nine modules plus new ones Improved hydrology and water quality modules Monitoring of forest practices in watersheds without watershed analysis. New cultural and restoration modules. No prescriptions for riparian, mass wasting, and surface erosion

Forestry Module Topic	Alternative 1 (No Action = Current Rules)	Alternative 2 (Proposed Action = Forests and Fish Report w/modification)	Alternative 3
Forest Pesticides	Current rules allow no chemicals in streams 50-foot buffer along streams 100-foot buffer adjacent to other properties 200-foot buffer adjacent to residences	No chemicals in streams or core or inner zones. Variable width buffer depending on equipment and wind conditions New BMPs	Protect plants of cultural value Require 50-foot buffer for hand application of chemicals Use of alternate plan for restoration of riparian functions
Hydrology	Rain-on-snow rule Eastside hydrology watershed analysis module	Rain-on-snow rule Eastside hydrology watershed analysis module	Rain-on-snow rule strengthened to limit harvest based on cumulative past harvest Eastside hydrology watershed analysis module

Chapter 3 summarizes the environmental impacts associated with each of the alternatives. The impacts reviewed are sediment delivery to streams, hydrology, riparian habitat, wetland habitat, water quality, fish, wildlife, risk of fire initiation, undiscovered cultural resources, and cumulative effects on the aquatic ecosystem.

Applicable conclusions to riparian buffers are discussed below.

Sediment

Under Alternative 1 the risk of fine and coarse sediment delivery to streams would be high. One reason given is the lack of riparian management zones (RMZs) on Type 4 and 5 streams. Alternative 2 is expected to produce a low to moderate risk of fine sediment delivery. The moderate rating is associated with the lack of RMZs along many steep headwater streams. The authors believe that Alternative 3 would produce a low risk of fine and coarse sediment delivery to streams because of the requirement for RMZs on all streams, including steep seasonal streams and channel disturbance zone buffers.

The applicability of this section to agricultural buffers is linked to the conclusion that increased riparian buffers decrease the delivery of coarse and fine sediment to streams.

Riparian Habitat

Alternative 1 would result in a high risk of diminished large woody debris (LWD) recruitment along fish-bearing streams and a very high risk along nonfish bearing streams.

The authors conclude that Alternative 2 appears to provide adequate protection for most riparian functions except those along many small streams that have no RMZs. In general, the risk of inadequate protection of riparian function appears to be higher for the eastside.

Alternative 3 would result in low risk of effects on LWD recruitment potential due to increased RMZ widths, addition of channel migration zones (CMZs), and a prohibition of harvest.

Again, the applicability of this document to agricultural buffers appears to be that RMZs and additional riparian protection measures are important to provide protection for riparian functions. The conclusion appears to be that as the RMZ increases more protection of riparian functions are provided.

Water Quality

Alternative 1 would result in a low to moderate risk of stream temperature increases along fish-bearing streams and a high risk along nonfish-bearing streams, a high risk of sediment-related effects on stream water quality, and a low to moderate risk of localized pesticide contamination of surface waters.

The authors believe that under Alternative 2 a possibility exists for a low risk of temperature increases in fish-bearing streams and a moderate to high risk in nonfish-bearing streams. Additionally, Alternative 2 is believed to result in a moderate risk of sediment water quality impacts in the short-term and a low to moderate risk in the long-term, however, the authors note that a moderate degree of uncertainty is associated with this conclusion.

Alternative 3 is thought to result in a low risk of temperature increase in all streams, a moderate risk of sediment water quality impacts in the short-term, and a low risk in the long term. Again, the authors note a moderate degree of uncertainty is associated with this conclusion.

Fish

Under Alternative 1, habitat degradation on private forest lands and eastside state forest lands would likely continue and contribute to further declines in listed fish species.

Alternative 2 would result in a low to moderate risk of continued habitat degradation over the short-term. Over the long-term, monitoring and adaptive management would result in reduction in this risk even further.

Alternative 3 would result in a low to very low risk of continued habitat degradation over the short-term. Over the long-term, monitoring and adaptive management would result in reductions in this risk even further.

Wildlife

Alternative 1 would result in high risk for amphibian microhabitat variables along larger streams and essentially no protection along smaller streams. This alternative would provide high risk associated with habitat for most other riparian species.

Alternative 2 would result in moderate risk for amphibian microhabitat variables along larger streams and high risk along smaller streams. This alternative would provide low to moderate risk associated with habitat for most other riparian species.

Alternative 3 would result in low risk for amphibian microhabitat variables along larger streams and moderate risk along high gradient streams. This alternative would provide low risk associated with habitat for most other riparian species.

Cumulative Effects

The rules under Alternative 1 are not protective enough to prevent cumulative effects in these watersheds.

Although the riparian, forest roads, and unstable slope rules under Alternative 2 would be substantially more protective than under Alternative 1, the authors conclude that they are unlikely to be protective enough to prevent cumulative effects in watersheds containing high levels of past harvest or other disturbances. In particular, a high degree of uncertainty exists regarding the potential for cumulative effects relative to the lack of RMZs on many perennial and all seasonal nonfish-bearing streams. This uncertainty is increased in watersheds with high levels of recent past harvest.

Under Alternative 3 the riparian rules would be substantially more protective than under Alternatives 1 or 2. Therefore, the authors conclude, the cumulative effects are unlikely, except in watersheds with the highest level of past harvest or other disturbances.

Overall, this document is useful because it provides an analysis and comparison of the Forests and Fish Plan's provisions (Alternative 2) for possible effects on riparian buffers and the associated waterways with a less protective plan (Alternative 1) and a more protective plan (Alternative 3). The general trend in this analysis of effects is that larger RMZs provide more protection for riparian ecological functions.

Appendix A.5

**Management Recommendations for Washington's Priority Habitats:
Riparian**

Appendix A.5
Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's Priority Habitats: Riparian. Wash. Dept. Fish and Wildl., Olympia. 181pp.

According to the executive summary for this report, "The Washington Department of Fish and Wildlife (WDFW) has developed statewide riparian management recommendations based on the best available science. Nearly 1,500 pieces of literature on the importance of riparian areas to fish and wildlife were evaluated, and land use recommendations designed to accommodate riparian-associated fish and wildlife were developed. These recommendations consolidate existing scientific literature and provide information on the relationship of riparian habitat to fish and wildlife and to adjacent aquatic and upland ecosystems. These recommendations have been subject to numerous review processes". Per our (AgFishWater) review of the controversy of Best Available Science elsewhere in this document, by definition therefore, this paper assumes that its recommendations are by fiat. There can be no other science. Unfortunately, the situation is far more equivocal.

"Recommendations on major land use activities commonly conducted within or adjacent to riparian areas are provided, including those relative to agriculture, chemical treatments, grazing, watershed management, roads, stream crossings and utilities, recreational use, forest practices, urbanization, comprehensive planning, restoration, and enhancement. Management recommendations for riparian areas are generalized for predictable application across the Washington landscape and include the following standard riparian habitat area (RHA) widths".

Standard recommended Riparian Habitat Area (RHA) widths for areas with typed and non-typed streams. If the 100-year floodplain exceeds these widths, the RHA width should extend to the outer edge of the 100-year floodplain.

<u>Stream Type</u>	<u>Recommended RHA widths in meters (feet)</u>
Type 1 and 2 streams; or Shorelines of the State, Shorelines of Statewide Significance	76 (250)
Type 3 streams; or other perennial or fish bearing streams 1.5-6.1 m (5-20 ft) wide	61 (200)
Type 3 streams; or other perennial or fish bearing streams <1.5 m (5 ft) wide	46 (150)
Type 4 and 5 streams; or intermittent streams and washes with low mass wasting* potential	46 (150)
Type 4 and 5 streams; or intermittent streams and washes with high mass wasting* potential	69 (225)

“Recommended RHA widths in this document only apply to riparian areas associated with streams and rivers. The widths should be applied to both sides of a stream or river, and width measurements should begin at the ordinary high water mark. The channels of some streams, particularly larger streams and rivers in broad, alluvial valleys, may migrate across the valley as a result of natural erosional and depositional processes; the area over which the channel is expected to migrate is called the channel migration zone. For these streams and rivers, RHA width measurements should begin at the edge of the channel migration zone”.

The following are important additions to the recommended RHA widths:

- Larger RHA widths may be required where priority species occur; consult Appendix D for these widths.
- Add 30 m (100 ft) to the RHA’s outer edge on the windward side of riparian areas with high blowdown potential.
- Extend RHA widths at least to the outer edge of unstable slopes along Type 4 and 5 waters in soils of high mass wasting potential.

The report states, “There is agreement in the literature that restricted use of riparian habitat is needed to retain the functions of aquatic and riparian ecosystems. Schaefer and Brown (1992) stated that width is one of the most important variables affecting riparian corridor functions. **However, there is less agreement on the specific width needed to protect riparian and stream habitat (O’Connell et al.1993) Nor is there agreement on which land use activities might be compatible with fish and wildlife in riparian habitat (our emphasis).** Recommendations to retain riparian areas are usually designed to retain specific functions (e.g., water quality and temperature) and rarely address the full range of ecological functions necessary to support fish and wildlife, as is the goal of these management recommendations”.

“Recommended RHA widths are intended to encompass the full extent of riparian habitat associated with streams and rivers. Where appropriate, the RHA widths also include an additional area necessary to protect the RHA from windthrow or unstable slopes. In developed areas or areas where natural resources have been extensively modified, there may be man-made features or vegetation that do not resemble natural conditions within the recommended RHA. In these areas, the RHA width still provides an indication of the area that is influencing the stream system and the area that could potentially serve as fish and wildlife habitat, if it were restored. Recommended RHA widths generally include a zone of riparian vegetation plus a transition zone dominated by upland vegetation. Even though it may not be obvious that upland vegetation is part of riparian habitat, scientific studies clearly describe the critical function of transitional areas in maintaining riparian and aquatic systems (e.g., Gregory and Ashkenas 1990, Gregory et al. 1991)”.

“Riparian habitat area widths are measured on the horizontal plane. They begin at the change in topography or vegetation that marks the ordinary high water line on each side of the active channel. Ordinary high water line is defined as the mark on the shores of all waters that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual and so long continued in ordinary years, as to mark upon the soil or vegetation a character distinct from that of the abutting upland, provided that in any area where the ordinary high water line cannot be found, the

ordinary high water line is the line of mean annual high water (approximated by a flood recurrence interval of 2.33 years) (WAC 220-110-020). The active channel is defined as all portions of the stream channel carrying water at bankfull flows (Thomas et al. 1993:279). The active channel will generally encompass meanderings, braids, and irregularities characteristic of larger streams and rivers (Gregory and Ashkenas 1990). For streams and rivers in channel migration zones, RHA width measurements should begin at the edge of the channel migration zone”.

“Recommended RHA widths are to be applied to both sides of a stream. Recommended RHA widths are designed to retain fully functional riparian habitat. The Washington Department of Fish and Wildlife has not identified minimum widths because minimal conditions do not offer adequate habitat to support healthy fish and wildlife in the long run. With the current state of knowledge, no one can definitively say at what point each riparian function is lost. At the same time, WDFW recommendations are not to be considered maximums. Maximum protection from a fish and wildlife perspective would likely involve no development anywhere”. In other words, maximum protection is recommended even though no knowledge of the point at which ecological function is 50%, 60% or even 95% restored. In a world of unlimited resources, such an approach is understandable. However, since the economic burden of such an approach belongs to others, and not WDFW, no consideration is apparently given to cost-effectiveness or cost-benefit or diminished returns. This is surprising since even the FEMAT curves, if taken on faith as accurate, show an asymptotic curve of diminished ecological benefits usually considerably closer to the stream bank than maximum benefits. When connected with the statement that these recommendations must be followed since they are defined by the authors as “Best Available Science”, we arrive at WDFW’s self-fulfilling syllogism that maximum buffer coverage is required because it is Best Available Science. Best Available Science is defined by WDFW as maximum ecological function.

“Beyond the standard recommended RHAs, it must be recognized that larger areas are needed by some wildlife species, including yellow-billed cuckoo, great blue heron, mule deer, elk, marten, osprey, and bald eagle (Gaines 1974, Thomas et al. 1979, Knight 1988, Freel 1991, Rodrick and Milner 1991). Larger RHA widths should be added to standard RHAs where these and other priority species require such increases”.

“For RHAs to be effective in maintaining quality riparian and aquatic habitat, **they should be applied in all areas throughout Washington to the greatest extent possible (AgFishWater review emphasis—see discussion above regarding syllogisms)**. The implementation of RHA protection should be combined with watershed analysis and planning to comprehensively address problems and solutions at the ecosystem level”.

“Site-specific modifications to recommended RHAs can be made using *Habitat Characteristics Important to Fish and Wildlife* (p. 79 in report) as a guide. Important characteristics should be retained or restored in all riparian areas in order to provide suitable habitat for fish and wildlife”.

The report includes examples of recommended riparian buffer widths from the literature. This summary is reproduced below.

Table 2. Examples of riparian habitat buffer recommendations found in the literature. Widths apply to each side of the stream.

Source	Recommended riparian buffer widths	Notes
Washington Department of Ecology (1985)	60 m (200 ft) buffer on all streams	Buffer to protect riparian ecosystem.
Gregory and Ashkenas (1990)	Class I Streams: 61 m (200 ft) ave., 46-122 m (150-400 ft) range Class II Streams: 30 m (100 ft) ave., 30-61 m (100-200 ft) range Class III Streams (stable): 23 m (75 ft) ave., 15-30 m (50-100 ft) range Class III Streams (unstable): 30 m (100 ft) ave., 23-38 m (75-125 ft) range	Recommendations for the Willamette National Forest, Oregon.
Johnson and Ryba (1992)	Recommends 15-30 m (50-100 ft) buffer to protect most stream functions. Reports buffer recommendations from the literature ranging from 3-200 m (10-656 ft).	Based on a literature review of buffer recommendations. Recommendations do not include wildlife habitat, only riparian functions to maintain instream habitat.
U.S. For. Serv. et al. (1993), Reeves and Sedell (1992)	Fish-bearing streams: outer edge of the 100-year floodplain, or the outer edge of riparian vegetation, or the distance equal to the height of 2 site-potential trees, or 92 m (300 ft), whichever is greatest. Permanently flowing non-fish-bearing streams: outer edge of the 100-year floodplain, or the outer edge of the riparian vegetation, or the distance equal to the height of 1 site-potential tree, or 46 m (150 ft), whichever is greatest. Intermittent streams: the extent of unstable or potentially unstable area, or the outer edge of riparian vegetation, or 30 m (100 ft), whichever is greatest.	Buffers are part of an Aquatic and Riparian Conservation Strategy. Buffers are recommended for areas within the range of the northern spotted owl, including western Washington and the east slope of the Cascades.

Source	Recommended riparian buffer widths	Notes
Washington State Forest Practices Board (1992)	Riparian Management Zones for western Washington: Type 1 and 2 water (≥ 23 m): 30 m (100 ft) Type 1 and 2 water (<23 m): 23 m (75 ft) Type 3 water (≥ 2 m): 15 m (50 ft) Type 3 water (<2 m): 8 m (25 ft) Riparian Management Zones for eastern Washington: Partial harvest units: 9-15 m (30-50 ft) Other harvest types: 9-91 m (30-300 ft)	These Riparian Management Zones are not 'no entry' zones as are most others reported in this table. Specific restrictions regarding the number of trees to leave during timber harvest are set forth in the Forest Practice Rules.
Cederholm (1994)	Based on Forest Practices Water Types: Types 1 and 2: 76 m (250 ft) Type 3 [2-6 m (5-20 ft) stream width]: 61 m (200 ft) Type 3 [<2 m (5 ft) stream width]: 46 m (150 ft) Types 4 and 5 (low mass wasting potential): 46 m (150 ft) Types 4 and 5 (high mass wasting potential): 69 m (225 ft)	Buffers designed for western Washington riparian ecosystems. Add 50 ft buffer on windward side in area of high blowdown potential. Provide additional buffers to include entire unstable slope on Type 4 and 5 streams.
Ecosystem Standards Advisory Committee (1994)	Riparian Management Zones, defined as: Type 1-4 waters - 30 m (100 ft) Type 5 waters - 15 m (50 ft)	Developed as ecosystem standards for state-owned agricultural and grazing land under HB1309. These recommendations were based on an earlier draft of this PHS Management Recommendation document.

Regarding variable riparian widths, the report states, “While variable riparian habitat widths may allow landowners greater flexibility, sufficient information does not currently exist to provide variable width recommendations that adequately accommodate the extreme variability of riparian widths, land uses, and fish and wildlife communities across the Washington landscape. Therefore, any application of variable riparian widths must first include additional site-specific and watershed-level studies”.

The report includes specific recommendations for agriculture. “Agricultural activities may contribute significantly to riparian and instream habitat degradation locally and across the landscape. A shift from conventional to sustainable agricultural practices would reduce or eliminate impacts to riparian and aquatic habitats and their fish and wildlife communities. Protection of RHAs, conservation tillage, use of cover crops, integrated pest management, use of non-chemical alternatives to pesticides, and alternative irrigation systems that reduce water use, erosion, and return flows are all techniques that should be explored and implemented across the landscape (Grue et al. 1989). Below are recommendations for protecting riparian and stream habitat in agricultural areas. Also, see the recommendations regarding grazing (p. 97) and chemical treatments (p. 104). The Washington Department of Fish and Wildlife recommends that farmers seek further assistance from local soil scientists, fish and wildlife biologists, and agricultural professionals in order to develop more specific agricultural activity plans using the guidelines presented here”.

“Provide a buffer of natural vegetation between perennial or intermittent stream courses and cropland of 61 m (200 ft) or the above recommended RHA width, whichever is greatest. If cropland currently exists within riparian areas, explore ways to cease farming in that area and pursue restoration and revegetation with native riparian plants. See the section on *Restoration and Enhancement* (p. 113) and seek assistance from the Natural Resources Conservation Service or the Washington Department of Fish and Wildlife”.

“In all agricultural areas, use techniques to eliminate or minimize soil erosion. Such techniques include: 1) conservation cropping systems (e.g., cover crops and conservation tillage); 2) selection of crops that hold soil and have high ground cover; 3) harvest techniques that minimize soil disturbance; 4) maintenance of continuous plant cover to the greatest extent possible; and 5) cultivation and harvest techniques that reduce the time that the soil is bare. Use drip irrigation or lateral piping rather than sheet or rill irrigation to reduce sedimentation and water consumption (P. Harvester, pers. comm.)”.

Other recommendations for agriculture include pursue alternatives to harmful fertilizers in uplands, increase efficiency of water use, treat agricultural waste water, and limit accumulations of animal wastes near riparian habitat.

The report includes an appendix that summarizes the riparian habitat buffer widths needed to retain various habitat functions. It is reproduced below.

Appendix C. Riparian habitat buffer widths needed to retain various riparian habitat functions as reported in the literature, organized by riparian habitat function.

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
WATER TEMPERATURE CONTROL		
60-80% shading	11-38 (35-125)	Brazier et al. 1973
	11-37 (35-120)	Johnson and Ryba 1992
	12 (39)	Corbett and Lynch 1985
	15-30 (49-100)	Hewlett and Fortson 1982
	18 (59)	Moring 1975
50-100% shading	18-38 (60-125)	U.S. Forest Service et al. 1993
	30 (100)	Lynch et al. 1985
	30 (100)	Beschta et al. 1987
	30 (100)	Johnson and Ryba 1992
	30-43 (100-141)	Jones et al. 1988
80% shading	46 (151)	Steinblums et al. 1984
LARGE WOODY DEBRIS		
	30 (100)	Murphy and Koski 1989
	31 (103)	Bottom et al. 1983
	45 (148)	Harmon et al. 1986
	46 (150)	McDade et al. 1990
	46 (150)	Robison and Beschta 1990
	50 (165)	Van Sickle and Gregory 1990
	55 (180)	Thomas et al. 1993
FILTER SEDIMENTS		
75% sediment removal	30-38 (100-125)	Karr and Schlosser 1977
90% of sediment removal at 2% grade	30 (100)	Johnson and Ryba 1992
Sediment removal	30 (100)	Erman et al. 1977, Moring et al. 1982, Lynch et al. 1985
	61 (200)	Terrell and Perfetti 1989
50% deposition	88 (289)	Gilliam and Skaggs 1988
Effective control of non-channelized sediment flow	60-91 (200-300)	Belt et al. 1992
FILTER POLLUTANTS		
Nutrient reduction	4 (13)	Doyle et al. 1977
Minimum	10 (33)	Petersen et al. 1992
	15 (49)	Castelle et al. 1992
	16 (52)	Jacobs and Gilliam 1985

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Nutrient removal using the multi-species riparian buffer strip system described by the authors	20 (66)	Schultz et al. 1995
Remove fecal coliforms	30-43 (100-141)	Jones et al. 1988
	30 (100)	Grismer 1981
	30 (100)	Lynch et al. 1985
Nitrates removed to meet drinking water standards	30 (100)	Johnson and Ryba 1992
Nutrient pollution in forested riparian areas	30 (100)	Terrell and Perfetti 1989
Nutrient removal	36 (118)	Young et al. 1980
Pesticides and animal waste	61 (200)	Terrell and Perfetti 1989
Nutrient pollution in herbaceous or cropland riparian areas	183 (600)	Terrell and Perfetti 1989
EROSION CONTROL		
Bank erosion control	30 (100)	Rakeigh et al. 1986
High mass wasting area	38 (125)	Cederholm 1994
MICROCLIMATE INFLUENCE		
In forested ecosystem	61-122 (200-399)	Chen et al. 1990
	160 (525)	Harris 1984, Franklin and Forman 1987
WILDLIFE HABITAT		
General wildlife habitat	23 (75)	Mudd 1975
	9-201 (30-660)	Johnson and Ryba 1992
	61 (200)	Zeigler 1992
Species sensitive to disturbance	25 (82)	Croonquist and Brooks 1993
Aquatic insects	30 (100)	Erman et al. 1977
Benthic invertebrates - food supply	30 (100)	Erman et al. 1977
Macroinvertebrate density	30 (100)	Newbold et al. 1980
Macroinvertebrate diversity	30 (100)	Gregory et al. 1987
Riparian invertebrates	30 (100)	Erman et al. 1977, Roby et al. 1977, Newbold et al. 1980
Brook trout	30 (100)	Rakeigh 1982
Chinook salmon	30 (100)	Rakeigh et al. 1986
Cutthroat trout	30 (100)	Hickman and Rakeigh 1982
Rainbow trout	30 (100)	Rakeigh et al. 1984
Reptiles and amphibians	30-95 (100-312)	Rudolph and Dickson 1990

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Reptiles and amphibians	30 (100)	Rudolph and Dickson 1990
Birds	75-200 (246-656)	Jones et al. 1988
Full complement of birds	127 (417)	Sedgewick and Knopf 1986
	125 (410)	Croonquist and Brooks 1993
Nest predation reduced	100 (328)	Temple 1986
Forest interior birds only occur in corridors wider than 50 m	50 (164)	Tassone 1981
Minimum riparian width to sustain forest dwelling birds	60 (200)	Darveau et al. 1995
Minimum distance needed to support area-sensitive neotropical migrant birds	100 (328)	Keller et al. 1993
Distance needed to maintain functional assemblages of common neotropical migratory birds	100 (328)	Hodges and Krementz 1996
Great blue heron feeding	100 (328)	Short and Cooper 1985
Great blue heron nesting	250 (820)	Short and Cooper 1985
	250-300 (820-984)	Parker 1980, Short and Cooper 1985, Vos et al. 1985
Wood duck nesting	80 (262)	Gilmer et al. 1978
	183 (600)	Grice and Rogers 1965, Sousa and Farmer 1983
	200 (656)	Lowney and Hill 1989
Harlequin nesting	50 (164)	Cassirer and Groves 1990
Bald eagle buffer from human disturbance	121 (396)	Grubb 1980
Bald eagle disturbance during feeding	200 (656)	Skagen 1980
Bald eagle feeding areas	75-100 (246-328)	Stalmaster 1980
Bald eagle nesting	100 (328)	Small 1982
Bald eagle perching	50 (164)	Stalmaster 1980
Osprey nesting - no cut zone	61 (200)	Zarn 1974, Westall 1986
Pheasant and quail, eastern Washington	23 (75)	Mudd 1975
Mourning dove	15 (50)	Mudd 1975
Belted kingfisher roosts	30-61 (100-200)	Prose 1985
Downy woodpecker	15 (50)	Cross 1985
Hairy woodpecker	40 (133)	Stauffer and Best 1980
Pileated woodpecker and some neotropical migrants	15-23 (50-75)	Triquet et al. 1990
Pileated woodpecker nesting	150-183 (492-600)	Conner et al. 1975, Schroeder 1983

Riparian habitat function	Perpendicular distance from stream in meters (feet)	Source
Pileated woodpecker nesting	100 (328)	Small 1982
Black-capped chickadee	15 (50)	Cross 1985
White-breasted nuthatch	17 (57)	Stauffer and Best 1980
Red-eyed vireo	40 (133)	Stauffer and Best 1980
Warbling vireo nesting	90 (295)	Gilmer et al. 1978
Spotted towhee breeding populations	200 (656)	Stauffer and Best 1980
Brown-headed cowbird penetration from edge	240 (787)	Gates and Giffin 1991
Large mammals	100 (328)	Jones et al. 1988
Small mammals	67-93 (220-305)	Jones et al. 1988
	12-70 (39-230)	Cross 1985
	67 (220)	Cross 1985
Dusky shrew food and cover	183 (600)	Clothier 1955
Beaver	30-100 (100-328)	Allen 1983
Beaver foraging	100 (328)	Allen 1983
Fisher travel corridor	183 (600)	Freel 1991
Marten food and cover	61 (200)	Spencer 1981
Marten travel corridor	92 (300)	Freel 1991
Mink	100 (328)	Melquist et al. 1981, Allen 1986
	200 (656)	Melquist et al. 1981
Red fox, fisher, marten	100 (328)	Small 1982
Deer, Eastern Washington	23 (75)	Mudd 1975
Deer and elk cover	61 (200)	Mudd 1975

INSTREAM HABITAT

Minimal maintenance of most functions	15-30 (50-100)	Johnson and Ryba 1992
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Mean buffers:*

(147 ft)	Temperature Control	27 m (90 ft)	Erosion Control	34 m (112 ft)
	Large Woody Debris	45 m	Windthrow Protection	15 m (50 ft)
			Microclimate Influence	126 m (412 ft)
	Filter Sediments	42 m (138 ft)	Wildlife Habitat	88 m (287 ft)
	Filter Pollutants	24 m (78 ft)	Instream Habitat	15.30 m (50-100 ft)

* If a range of values was reported in the literature, the median of that range was used to calculate the means.

Appendix A.6

An Ecosystem Approach to Salmonid Conservation

Appendix A.6

Spence, B.C., G.A. Lomnický, R.M. Hughes, and R.P. Novitzki. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

The document is organized generally into three parts. Chapters 1-10 (Part I) provide the technical foundation for understanding salmonid conservation principles from an ecosystem perspective. They discuss the physical, chemical, and biological processes operating across the landscape, within riparian areas, and in aquatic ecosystems; these processes ultimately influence the ability of streams, rivers, and estuaries to support salmonids. Specific habitat requirements of salmonids during each life stage are detailed. They then review the effects of land-use practices on watershed processes and salmonid habitats, focusing on the impacts of logging, grazing, farming, mining, and urbanization on hydrology, sediment delivery, channel morphology, stream temperatures, and riparian function. An overview is presented on the importance of ocean variability in determining production of anadromous salmonids and the implications of this variability on restoration of freshwater habitats of salmonids. Next, land-use practices that minimize impacts to salmonids and their habitats are discussed followed by a brief review of Federal laws that pertain to the conservation of salmonids on private lands. The Technical Foundation concludes with a review of strengths and weaknesses of existing programs for monitoring aquatic ecosystems; this chapter provides the basis for monitoring recommendations presented in Part II.

Chapters 11-16 (Part II) provide a general conceptual framework for achieving salmonid conservation on nonfederal lands in the Pacific Northwest, as well as specific guidelines for the development of Habitat Conservation Plans (HCPs) pursuant to the Endangered Species Act. Included in this discussion is an evaluation of the effectiveness of State rules for riparian management to protect specific processes that directly affect aquatic habitats. Compliance and assessment monitoring strategies for HCPs and other conservation efforts are proposed. The document concludes with a suggested strategy for implementing salmonid conservation efforts on nonfederal lands. An appendix (the third part) lists sources of data that landowners and agencies may find useful in developing and evaluating habitat conservation plans. Over 1100 sources are cited within this document and listed in the references section.

This is a long report that covers a great deal of material. Salient conclusions regarding riparian buffer zones in agricultural areas are summarized below.

The overall recommendation of the report with regards to buffers is, “We recommend that habitat conservation plans and other conservation agreements include a comprehensive plan for protecting riparian areas along all fish-bearing and nonfish-bearing streams, including ephemeral channels. Riparian buffers should be established for all land use types and should be designed to maintain the full array of ecological processes needed to create and maintain favorable conditions through time. Consideration should also be given to protecting microclimatic conditions to ensure the persistence of vegetation communities and, where applicable, other riparian-dependent terrestrial and semi-aquatic species.”

The report includes a literature review on riparian buffers for each of the ecological processes identified as being critical to riparian zones. The ecological functions of riparian zones are stream shading, LWD recruitment, fine organic litter recruitment, bank stabilization, sediment control, dissipation of nutrients and other dissolved materials, They specifically describe the literature for forested lands as well as other land types, when available.

For stream shading, the report concludes, “The apparent consensus that buffers exceeding 30 m are needed for stream shading has been based largely on studies in the Cascade and Coast ranges. There is little published information regarding buffer widths needed to provide natural levels of shade for streams in eastside forest, rangeland, and agricultural systems... More research on riparian influences on shading for all ecosystems east of the Cascades is needed before specific criteria can be recommended; however, in most instances, buffer widths designed to protect other riparian functions (e.g. large woody debris (LWD) recruitment) are likely to be adequate to protect stream shading”.

Because of the importance of LWD recruitment as a criterion for evaluating riparian buffers, we have included the entire section of the report of recommendations for buffers related to LWD.

LWD Recruitment. Large wood enters stream channels by a variety of mechanisms, including toppling of dead trees, windthrow, debris avalanches, deep-seated mass soil movements, undercutting of streambanks, and redistribution from upstream (Swanson and Lienkamper 1978). Most assessments of buffer widths required for maintaining natural levels of large wood have considered only wood delivered by toppling, windthrow, and bank undercutting. Yet in some systems, wood delivered from upslope areas (via mass wasting) or upstream reaches (via floods or debris torrents) may constitute a significant fraction of the total wood present in a stream reach. In attempting to identify sources of large wood pieces in 39 stream reaches, McDade et al. (1990) failed to account for more than 47% of the woody debris pieces, suggesting that upslope and upstream sources potentially may be quite important. These mechanisms of delivery are more difficult to model, thus the discussion below focuses on recruitment from the immediate riparian zone. Nevertheless, in evaluating habitat conservation plans, consideration should be given to potential recruitment of wood from upslope areas and nonfish-bearing channels.

The potential for a tree or portions of a tree to enter the stream channel by toppling, windthrow, or undercutting is primarily a function of slope distance from the stream channel in relation to tree height and slope angle. Consequently, the zone of influence for large wood recruitment is defined by the particular stand characteristics rather than an absolute distance from the stream channel or floodplain. Other factors, including slope and

prevailing wind direction, may influence the proportion of trees that fall in the direction of the stream channel (Steinblums et al. 1984; Robison and Beschta 1990b; McDade et al. 1990); however, if the goal is to maintain full recruitment of large wood to the channel, then protection of all trees within the zone of influence is desirable.

FEMAT (1993) concluded that the probability of wood entering the active stream channel from greater than one tree height is generally low (see Figure 3-2). Exceptions occur in alluvial valleys, where stream channels may shift in response to sediment deposition and high flow events. Two models of large wood recruitment also assume that large wood from outside of one tree height seldom reaches the stream channel (Van Sickle and Gregory 1990; Robison and Beschta 1990). Murphy and Koski (1989) found that 99% of all identified sources of LWD were within 30 m of the stream channel in hemlock and Sitka spruce forests of southeastern Alaska with site potential tree heights of approximately 40 m (131 ft) (M. Murphy, personal communication). Their study defined LWD as pieces greater than 3 m length and 10 cm diameter and thus excluded smaller fractions classified as large wood in other studies. In addition, because trees far from the stream channel generally contribute smaller individual pieces (i.e., the tops of trees) that are more easily transported downstream, the authors' abilities to identify sources likely decreased with increasing distance from the channel. Consequently, protecting all LWD recruitment may require slightly larger buffer zones. McDade et al. (1990) examined LWD recruitment to streams at 37 sites in the Cascade and Coast Ranges of Oregon and Washington and found that source distances were as far as 55 m in old-growth (> 200 years) coniferous forests and 50 m in unmanaged, mature (80-200 year old) conifer stands. Tree heights averaged 57.6 m in old-growth stands and 48 m in mature stands; thus, source distances were approximately equal to one site-potential tree height. In this study, woody debris was defined as pieces greater than 1 m length and 0.1 m diameter at the small end. Cederholm (1994) reviewed the literature regarding recommendations of buffer widths for maintaining recruitment of LWD to streams and found most authors recommended buffers of 30-60 m for maintaining this function. In summary, most recent studies suggest buffers approaching one site-potential tree height are needed to maintain natural levels of recruitment of LWD.

An additional consideration in determining appropriate activities in riparian zones relative to large wood recruitment is the potential size distribution of LWD. Murphy (1995) notes that larger pieces of wood form key structural elements in streams, serving to retain smaller debris that would otherwise be transported downstream during high flow events. Bisson et al. (1987) suggest that the size of these key pieces is approximately 30 cm or more in diameter and 5 m in length for streams

less than 5 m in width and 60 cm or more in diameter and 12 m in length for streams greater than 20 m in width.

For making Endangered Species Act determinations of effect, NMFS (1985c) uses large-size fractions of wood to define properly functioning habitats. These key pieces are defined as greater than 60 cm in diameter and 15 m in length for westside systems and greater than 30 cm in diameter and 11 m in length for eastside systems. Consequently, riparian protection plans need to ensure not only an appropriate amount or total volume of wood, but pieces of sufficient size to serve as "key pieces" (Murphy 1995).

For fine organic litter, the ManTech report states, "in most cases buffers designed to protect 100% of LWD recruitment will likely provide close to 100% of small organic litter as well." For bank stabilization, the report states that, "in most instances, vegetation immediately adjacent to the stream channel is most important in maintaining bank integrity, however, in wide valleys with shifting streams vegetation throughout the floodplain may be important over longer time periods." They cite FEMAT (1993) conclusions that, "most of the stabilizing influence of root structure is probably provided by trees within 0.5 potential tree height of the stream channel. Consequently, buffer widths for protecting other riparian functions are likely adequate to maintain bank stability".

For sediment control, they concluded that, because of the high degree of variability in the effectiveness of buffers, "we cannot draw any definitive conclusions regarding buffer widths required for sediment control. On gentle slopes, buffers of 30 m may be sufficient to filter sediments, whereas on steeper slopes, buffers of 90 m or more may be needed. In addition, riparian buffers are most effective in controlling sediments from sheet erosion and have less influence on sediments that reach the stream channels via channelized flow... We suggest that, except on steep slopes, buffers designed to protect other riparian functions will generally control sediment to the degree that they can be controlled by riparian vegetation. It is essential however, that riparian protection be complemented with practices for minimizing sediment contributions from outside areas"

Regarding nutrients and other dissolved materials, the review of the literature indicates that, "those studies that have been published indicate substantial variability in the effectiveness of buffer strips in controlling nutrient inputs... For rangelands, agricultural systems, and urban areas, we believe current understanding is insufficient to make specific buffer recommendations. The review of Johnson and Ryba (1992) suggest that buffers for nutrient control on forest and grasslands range from approximately 4 – 42 m, but that substantially wider buffers are needed to control nutrients and bacteria (fecal coliform) from feedlot runoff. We recommend that buffer widths for nutrient and pollution control on these lands be tailored to site-specific conditions, including slope, degree of soil compaction, vegetation characteristics, and intensity of land use. In many instances, buffer widths designed to protect LWD recruitment and shading may be adequate to prevent excessive nutrient pollution concentrations. However, where land

use activity is especially intense, buffers for protecting nutrient and pollutant inputs may need to be wider...”

The final recommendations for riparian buffers in agricultural areas are, “riparian buffers are recommended for all permanent streams on agricultural lands that support salmonids, as well as ephemeral streams that influence salmonid habitats downstream. The dimensions of riparian buffers should depend on the specific ecological functions for which protection is desired (see above discussion). Use of agricultural machinery within the riparian zone or disturbance to vegetation and soils within the riparian zone should be avoided. Where channels have been degraded by agricultural activities, planting of riparian vegetation native to the region is recommended. Conservation can be further enhanced by retiring converted wetlands from agriculture”.

Appendix A.7

Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale

Appendix A.7
National Marine Fisheries Service, Environmental and Technical Services
Division, Habitat Conservation Branch. 1996. Making Endangered Species
Act Determinations of Effect for Individual or Grouped Actions at the
Watershed Scale.

This document contains two primary parts, a matrix which is designed to summarize important environmental parameters and levels of condition and a checklist, which is used for determining the current condition of the environment and the potential effects of an action on the current environmental condition. The matrix is of interest to us for evaluating riparian buffers in agricultural lands.

This document does not include standards and guidelines for specific management actions. That is, it does not include specific requirements for riparian buffer zone widths. It also does not prohibit any particular activities in riparian buffer zones. What it does is define a “properly functioning” aquatic ecosystem in terms of “indicators”.

The matrix is reproduced below in Table 1. There are a number of “pathways” and “indicators” that can be influenced by human activities in riparian zones, such as water temperature, streambank condition, sediment/turbidity, large woody debris, and others. The matrix describes what a properly functioning aquatic ecosystem would have for each of these indicators. For example, the matrix shows a properly functioning ecosystem would have a temperature between 50 – 57 °F, less than 12% fines in gravel, and low turbidity. Riparian buffers are one tool that could be used to restore or maintain these qualities.

In addition, one of the “indicators” listed is riparian reserves. A properly functioning riparian reserve is described as, “[a] riparian reserve system that provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts; percent similarity of riparian vegetation to the potential natural community/composition >50%”. No definitions are provided as to what constitutes “adequate shade”. There is no quantification of the requirement for large woody debris recruitment. There is also no explanation of how to determine if the refuge for sensitive aquatic species is 80% intact. The reference that is cited for this indicator is:

Winward, A.H. 1989. Ecological Status of Vegetation as a base for Multiple Product Management. Abstracts 42nd Annual Meeting, Society for Range Management, Billings, MT. Denver, Colorado, Society for Range Management: p 277.

Unfortunately, this document has some weaknesses. The indicators of properly functioning ecosystems are defined very vaguely in many cases. Even where the indicators include a quantitative standard there is room for interpretation. For example, the temperature indicator is undefined. Is it a maximum daily temperature, a mean daily temperature, or some other metric? In addition, the matrix, particularly the indicators for

large woody debris and riparian reserves, may not be applicable to ecosystems that are not forested, particularly if the historic condition was grassland.

Overall, this document has very limited usefulness for evaluating the effectiveness of any particular standard for riparian buffers on agricultural lands. It provides no scientific background that could be used to develop a standard for riparian buffers.

TABLE 1. MATRIX of PATHWAYS AND INDICATORS

(Remember, the ranges of criteria presented here are not absolute, they may be adjusted for unique watersheds. See p. 3)

PATHWAY	INDICATORS	PROPERLY FUNCTIONING	AT RISK	NOT PROPERLY FUNCTIONING
Water Quality:	Temperature	50-57° F ¹	57-60° (spawning) 57-64° (migration & rearing) ²	> 60° (spawning) > 64° (migration & rearing) ²
	Sediment/Turbidity	< 12% fines (<0.85mm) in gravel ³ , turbidity low	12-17% (west-side), 12-20% (east-side) ² , turbidity moderate	> 17% (west-side) ² , > 20% (east-side) ² fines at surface or depth in spawning habitat ² , turbidity high
	Chemical Contamination/ Nutrients	low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches ²	moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach ²	high levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach ²
Habitat Access:	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows
Habitat Elements:	Substrate	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20% ²	gravel and cobble is subdominant, or if dominant, embeddedness 20-30% ²	bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness >30% ²
	Large Woody Debris	Coast: >80 pieces/mile >24" diameter >50 ft. length; East-side: >20 pieces/mile >12" diameter >35 ft. length; and adequate sources of woody debris recruitment in riparian areas	currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	does not meet standards for properly functioning and lacks potential large woody debris recruitment

	Pool Frequency	meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)	meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	does not meet pool frequency standards
	channel width: <u>feet/mile</u> ⁴ 5 feet 104 10 " 96 15 " 70 20 " 56 25 " 47 30 " 36 35 " 23 100 " 18			
	Pool Quality	pools >1 meter deep (holding pools) with good cover and cool water ² , minor reduction of pool volume by fine sediment	few deeper pools (>1 meter) present or inadequate cover/temperature ² , moderate reduction of pool volume by fine sediment	no deep pools (>1 meter) and inadequate cover/temperature ² , major reduction of pool volume by fine sediment
	Off-channel Habitat	backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.) ²	some backwaters and high energy side channels ²	few or no backwaters, no off-channel ponds ²
Channel Condition & Dynamics:	Refugia (important remnant habitat for sensitive aquatic species)	habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations ²	habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations ²	adequate habitat refugia do not exist ²
	Width/Depth Ratio	<10 ^{2,4}	10-12 (we are unaware of any criteria to reference)	>12 (we are unaware of any criteria to reference)
	Streambank Condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding ²	80-90% stable	<80% stable
	Floodplain Connectivity	off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

Flow/Hydrology:	Change in Peak/ Base Flows	watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	zero or minimum increases in drainage network density due to roads ¹³	moderate increases in drainage network density due to roads (e.g., 5%) ¹⁴	significant increases in drainage network density due to roads (e.g., 20-25%) ¹⁵
Watershed Conditions:	Road Density & Location	<2 mi/mi ² , no valley bottom roads	2-3 mi/mi ² , some valley bottom roads	>3 mi/mi ² , many valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or riparian area; and for NWFP area (except AMAs), 15% retention of LSOG in watershed ¹⁶	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or riparian area; and for NWFP area (except AMAs), 15% retention of LSOG in watershed ¹⁷	>15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or riparian area; does not meet NWFP standard for r LSOG retention
	Riparian Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact) and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community composition >50% ¹⁸	moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community composition 25-50% or better ¹⁹	riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community composition <25% ²⁰

- ¹ Bjornn, T.C. and D.W. Reiser, 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138. Meehan, W.R., ed.
- ² Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Walla-Walla National Forests. March 1, 1995.
- ³ Washington Timber/Fish/Wildlife Cooperative Monitoring Evaluation and Research Committee, 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.
- ⁴ Biological Opinion on Implementation of Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH). National Marine Fisheries Service, Northwest Region, January 23, 1995.
- ⁵ A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.
- ⁶ USDA Forest Service, 1994. Section 7 Fish Habitat Monitoring Protocol for the Upper Columbia River Basin.
- ⁷ Frittsell, C.A., Liss, W.J., and David Bayles, 1993. An Integrated Biophysical Strategy for Ecological Restoration of Large Watersheds. Proceedings from the Symposium on Changing Roles in Water Resources Management and Policy, June 27-30, 1993 (American Water Resources Association), p. 449-456.
- ⁸ Wemple, B.C., 1994. Hydrologic Integration of Forest Roads with Stream Networks in Two Basins, Western Cascades, Oregon. M.S. Thesis, Geosciences Department, Oregon State University.
- ⁹ e.g., see Elk River Watershed Analysis Report, 1995. Siskiyou National Forest, Oregon.
- ¹⁰ Northwest Forest Plan, 1994. Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl. USDA Forest Service and USDI Bureau of Land Management.
- ¹¹ USDA Forest Service, 1998. Determining the Risk of Cumulative Watershed Effects Resulting from Multiple Activities.
- ¹² Winward, A.H., 1989. Ecological Status of Vegetation as a Base for Multiple Product Management. Abstracts 42nd annual meeting, Society for Range Management, Billings MT, Denver CO: Society For Range Management: p277.

Appendix A.8

Forestry Impacts on Freshwater Habitat of Anadromous Salmonids in the Pacific Northwest and Alaska—Requirements for Protection and Restoration

Appendix A.8

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—Requirements for Protection and Restoration. U.S. Department of Commerce, NOAA Coastal Ocean Program, Decision Analysis Series No. 7. Silver Spring, Maryland.

This synthesis presents a science overview of the major forest management issues involved in the recovery of anadromous salmonids affected by timber harvest in the Pacific Northwest and Alaska. The key approaches to watershed management that are covered by this review are buffer zones, best management practices, cumulative impact prevention, and restoration.

The conclusion of the report with regard to buffer zones are that, to maintain or restore optimal habitat in fish-bearing streams, buffer zones should be at least as wide as the height of a mature tree, usually 30 – 40 m. Buffers should be managed to attain characteristics of mature native forest. Narrower buffers may not maintain adequate large woody debris (LWD) over the long term, and selected harvest within buffers further reduces LWD sources. No-harvest buffers are most appropriate along fish-bearing streams with mature forest, most common in Alaska and in National Forests. The report concludes that on private lands in other states, the number and size of leave trees should be increased where additional large conifers are available.

The author notes that many previously logged areas have degraded vegetation consisting mostly of hardwoods and brush and lacking large conifers. Restricting harvest would not necessarily improve habitat protection nor help restore riparian functions. The author states that active management of these riparian areas is needed to meet habitat requirements of fish. Selective harvest within these buffers could be used to improve riparian vegetation by thinning and conifer planting.

These above comments appear to be specific to areas where conifers are the native riparian vegetation. Areas where hardwoods are the native riparian vegetation do not necessarily need to be modified to a conifer forest.

The author notes that buffer zones are also needed along small non-fish streams that affect salmonid habitat. Except for federal lands under NFP and PACFISH, the usually minimal buffers on these streams on private lands means that their protection must rely on BMPs which do not always protect them from disturbance.

Appendix A.9

Rationale for a Managed Agricultural Buffer Zone in Skagit County

Appendix A.9
Natural Resource Consultants , Inc. 2000. Rational for a Managed
Agricultural Buffer Zone in Skagit County, Draft. Prepared for the Skagit
County Planning and Permit Center, Mount t Vernon, Washington,
October 2000

Agricultural Impacts Information:

In response to “critical areas” designations under the state Growth Management Act and Endangered Species Act considerations, agricultural buffer zones are under review in Skagit County. This document provides technical justifications for specific buffer requirements.

The report states that agricultural practices may be a source of non-point pollutants reaching the Lower Skagit River through tributary streams, drainage ditches, and overflow lands. The key concern appears to be fecal coliform bacteria (from livestock waste); low dissolved oxygen, ammonia nitrogen, and silt deposits are noted as secondary problems.

The report states that a certain amount of the application of buffer zones has been based of best professional judgment and is most effective for specific ecological conditions. Also, much of the science and application of buffer zones has been applied to upland (forest) land conditions. In particular, the role of buffer zones in agricultural areas of the Pacific Northwest is very limited, thus yielding little empirical data from which to base decisions.

The report also details an adaptively managed agricultural riparian buffer for Skagit County. This includes buffer components related to large woody debris, temperature, and water quality, noting the relative effectiveness of various buffer options. The effectiveness levels are well qualified in some cases, noting that buffers can have limited impact depending on stream location and other conditions.

Buffer zones are prescribed as: Managed Riparian Buffer Zone (RBZ) first 25-ft from the ordinary high water mark; and Agricultural Management Zone next 50-ft. landward.

The RBZ would be a full buffer area, with self-sustaining vegetation and protection corridor; the AMZ would be limited agricultural uses and high-intensity management practices (limited crop types and pasture use periods).

Overall, the report does not “directly tie” the buffer zone recommendations to specific scientific observations; the emphasis is on general applicability. And the report does include considerable discussion about the variable level of effectiveness of specific buffer components, depending on several factors.

Appendix A.10

Review of the Scientific Foundations for the Forests and Fish Plan

Appendix A.10
CH2MHILL, Review of the Scientific Foundations of the Forests and Fish Plan.
2000. Prepared for the Washington Forest Protection Association.

This document is a review (Review) of the science upon which the Forests and Fish Plan (Plan) is based. The Plan is the collective term for the Forests and Fish Report (Report) and the Forests and Fish Emergency Rules. This Review contains two parts. The first section contains an overview providing the purpose of the review, the background and history of the Plan, a summary of the Plan, the legal context, a summary of the current habitat conditions and the science, and an overview of the adaptive management program. The second section provides seven in-depth discussions that review the habitat variables as they relate to each of the prescriptions outlined in the Report. Each functional discussion describes the ecological importance of each habitat variable, identifies the primary source areas and mechanisms for delivery to streams, describes the potential effects of forest practices on each input variable, and evaluates the possible effectiveness of the Plan's prescriptions in contributing to complex in- and near-stream habitats and/or desirable water quality.

The stated purpose of the Review is to identify the scientific foundations for the recommendations contained in the Report and to assess the effectiveness of the recommendations in meeting the goals set forth by the Washington Forest Practices Board and the authors of the Report.

The Plan was created to meet the following goals:

1. To provide compliance with the Endangered Species Act for aquatic and riparian-dependent species on non-federal forestlands.
2. To restore and maintain riparian habitat on non-federal forestlands to support a harvestable supply of fish.
3. To meet the requirements of the Clean Water Act for water quality on non-federal forestlands.
4. To keep the timber industry economically viable in the State of Washington.

In summary the Plan is a consensus recommendation for changes in forest practices statutes, regulations, and management systems to attain the stated goals. The Plan recommends increased resource protection through programmatic and prescriptive standards and guidelines. A primary focus of these new standards and guidelines is to manage riparian vegetation and sediment input to maintain or enhance stream habitats and water quality. The recommendations are intended to improve management in several key resource areas: large woody debris (LWD), heat energy, coarse sediment, fine sediment, hydrology, pesticides, and litterfall.

The Plan would broaden the list of fish covered by the rules and change the classification of streams to expand the area where protection is applied. Under the Plan, all fish would receive the same protection. The Plan proposes different riparian strategies for streams

west of the Cascade crest (Westside) and streams east of the Cascade crest (Eastside) and for fish-habitat streams and non-fish-habitat streams.

Westside fish-habitat streams would be protected with buffers that extend up to site-potential tree height from the outer edge of the stream or channel migration zone. This distance is 90 to 200 feet, depending on the productivity of the land near the stream. Timber management within the buffers is progressively more restrictive in the zones closer to the stream. The riparian strategy consists of three zones. The “core zone” is the 50-foot no-harvest area closest to the stream. The “inner zone” is the area between 50 feet and 80 to 150 feet from the stream. Management in the inner zone would be prescribed to ensure that desired future riparian conditions grow and develop. The “outer zone” is the area beyond the inner zone. It would be managed to leave up to 20 trees per acre to protect special sites such as seeps, springs, or forested wetlands, or to provide permanent leave trees to support riparian protection. The Plan claims that management in the inner and outer zones would be controlled by rules to ensure that goals for riparian functions will be met, and that most protection is provided closest to the stream.

Westside non-fish-habitat streams are divided into two categories, perennial and seasonal streams. Perennial non-fish-habitat streams would receive a 50-foot-wide no-harvest buffer on each side for at least 50 percent of their length. The buffer would be placed at sensitive sites, such as perennial seeps, springs, unstable inner gorge slopes, alluvial fans and perennial stream intersections; and could border up to 100 percent of a reach’s length. A 30-foot-wide equipment limitation zone on each side would border portions of perennial and all seasonal non-fish-habitat streams that do not receive 50-foot-wide no-harvest buffers.

Eastside fish-habitat streams would receive buffers that would extend to at least one site-potential tree height from the edge of the stream or channel migration zone, up to 130 feet. The no-harvest core zone would be 30 feet wide. The restricted inner zone would extend 75 or 100 feet from the core zone, depending on stream width. Where site-potential tree height is greater than the fixed inner zone width, up to 20 of the largest trees per acre would be left in the outer zone. Timber management in the inner zone would be controlled by maximum and minimum tree densities over a range of growing sites to address current and future riparian function and forest health.

Eastside non-fish-habitat streams would receive either a continuous managed 50-foot buffer where partial-cut management techniques are used, or a no-harvest, discontinuous buffer where clear-cut management techniques are used. The 30-foot equipment limitation zone would apply to portions of perennial streams without a leave-tree buffer and all-seasonal non-fish-habitat streams.

In addition to the riparian strategies, the Plan provides many other recommendations to improve forest practices permitting processes. These recommendations address: unstable slopes, forest roads, pesticide application, and wetland protection.

The Plan provides an overview of current habitat conditions on private forestlands. The Plan states that the most common factors influencing fish habitat are riparian harvest, stream cleaning, and road development. Grazing, water diversions, dams, and surface erosion are listed as more frequent factors in eastern Washington than in western Washington. Debris flows are listed as more common factors in western Washington.

The Review notes that the Plan was designed to adapt and change as new scientific learning becomes available. A cornerstone of the Plan is adaptive management which is the process of gathering and using scientific information to evaluate and improve management decisions. Monitoring is considered an important element of this adaptive management process and necessary to determine whether the aquatic resource goals, objectives, and targets are being achieved.

The following section summarizes the relevant watershed functions at the heart of the Plan that are contained within the Functional Discussions in Chapter 2. Chapter 2 contains seven Functional Discussions that review the habitat variables as they relate to each of the prescriptions of the Plan.

Functional Discussion 1: Large Woody Debris

This section discusses the ecological importance of LWD in streams, identifies the primary source areas and mechanisms for delivery to streams, describes the potential effects of riparian management on LWD, and evaluates the possible effectiveness of the Plan's prescriptions in contributing to complex in-and near-stream habitats and desirable water quality.

The Plan defines criteria and proposes forest practices standards to deliver LWD in riparian and aquatic areas. The Plan provides rationale for using LWD as a standard due to LWD's importance to the formation of fish habitat in streams and the influences on water quality and habitat quality in riparian areas. Further rationale given is the fact that forest practices may have an effect on the amount and timing of LWD in recruitment to streams from riparian areas and unstable hillslopes. The Plan states that forest practices need to ensure adequate supplies on LWD over the short and long terms.

Large woody debris is important because it influences channel morphology and fish habitat by:

- Forming pools where fish rear, feed, and seek refuge.
- Storing sediment to improve water quality and provide spawning areas.
- Scouring the streambed and banks to diversify water depths and gradients, and to deliver nourishment and shade.
- Producing a diverse channel morphology that contributes to habitat and hydraulic complexity.

The Plan concludes that natural wood recruitment to Westside streams is governed by a relatively small set of landscape disturbance factors, which includes: bank erosion, windthrow, tree mortality, and mass wasting. LWD recruitment mechanisms for trees to

the Eastside stream channels are unique. Stream capture and deadfall are the most common recruitment mechanisms; and mass wasting, windthrow, and transport from upstream are the least common mechanisms cited by watershed analyses.

The Plan identifies three LWD source areas:

1. Near-stream riparian stands: areas directly adjacent to the stream where coarse wood is delivered directly to a given reach through mortality, windthrow, and streambank erosion processes;
2. Upstream riparian stands: near-stream riparian sources that are upstream of a given reach (flotation during flood water or debris torrents transports the wood to its current location after initially falling into an upstream reach from an adjacent stand); and
3. Upslope stands: zero-order channels, hollows, or hillslopes (landslides and landslide-debris torrent combinations that transport large wood to a given reach).

The Review states that in a riparian zone, the width of the source area for delivery of wood of any size approaches a distance that is approximately equal to the average height of trees in the riparian stand. The source area for functional LWD is narrower than the average tree height because the top 10 to 15 feet (3 to 5 m) of trees are branches and leaders less than 4 inches (10 cm) in diameter (minimum functional wood size). The width of the source area varies by site, and is a function of site productivity and stand age. Research studies have reported that most of the potential LWD supply comes from widths of 31 to 131 feet (9 to 40 m), depending on location and stand type.

The contribution of LWD from riparian trees is greatest for trees near the channel and decreases with distance from the stream because the probability of a tree intersecting a stream decreases with distance away from channel (Van Sickle and Gregory 1990). Hence, the potential for recruitable trees decreases with increasing distance from the channel. In addition, bank erosion causes trees to preferentially fall toward the stream so that the trees closest to stream bank have the highest probability of recruitment. This is evident in the LWD source-distance curves. The source-distance curves of McDade et al. (1990) represent LWD delivery to steep, small channels, which are almost always constrained by boulders and bedrock. They probably over-represent the source-distance relationship for LWD delivery along alluvial channels, which are more likely to be fish-habitat streams. Therefore, using the McDade source-distance curves probably results in overestimates of the relative contribution from trees standing farther from lower gradient, alluvial, fish-habitat channels.

The following table appears in the Review:

Width of the Source Area Providing 95 Percent of the LWD Supply from Old-Growth and Mature Stands		
Location (Stand Type)	Width of the Source Area Providing 95% of the Potential LWD Supply feet (meters)	Reference
Southeastern Alaska (old growth)	31 ft (9 m)	Martin et al. 1998
Southeastern Alaska (old growth)	66 (20)	Murphy and Koski 1989
Eastern Washington (mature)	91 (28)	Light and Cupp 1999
Western Cascades, Washington (mature)	49 (15)	McKinley 1997
Western Cascades, Washington and Oregon (mature)	108 (33)	McDade et al. 1990
Western Cascades, Washington and Oregon (old-growth)	131 (40)	McDade et al. 1990

Regarding the influence of LWD on fish habitat the review states that few studies have provided empirical data that can be used to determine desirable and acceptable amounts of LWD. Studies have shown that the effectiveness of LWD for forming pools declines with an increase in LWD load, and the relationship varies by geomorphic channel type. Additional studies have concluded that pool frequency increases as the number of pieces of LWD increase.

The Plan addresses LWD by using the desired future condition (DFC) of forests and riparian areas as a planning concept for forest management. The DFC sets a vision for a development trajectory and a range of future conditions. For Westside riparian zones the Plan identifies mature conifer stands as a target for a DFC. The Westside DFC was developed by recognizing that large trees are needed close to streams to supply functional wood and that the size of trees in the current managed forests is limited by age. On the Eastside, the DFC concept is implicit in the management goals for riparian forest stands. Eastside riparian vegetation reflects the growing conditions and habitats created by climate and associated disturbance regimes. The goal of the Eastside riparian strategy is to create healthier riparian forest conditions that are more sustainable and resistant to catastrophic fires, and disease and insect infestations.

The Plan contains prescriptions that aim to maintain a long-term supply of LWD by addressing the major source areas and input processes. The LWD management measures include:

- Riparian Management Zones (RMZs) and Sensitive RMZs
- Management of Potentially Unstable Slopes and Landforms
- Forest Road Management
- Wetland Protection

The Review concludes that riparian forests that maintain growth trajectories toward DFCs that are similar to mature forests are presumed to provide adequate and functional levels of LWD to streams. The Review further concludes that the Plan's proposals for silvicultural options for management of LWD protects LWD sources where they are most needed and at locations where LWD can be most effective, particularly near aquatic resources and along fish-habitat streams.

The Review states that to consider the adequacy of the *Forests and Fish* plan, the following critical question needs to be addressed:

Are the proposed forest practices rules in the Forests and Fish plan adequate for providing sufficient amounts of LWD to streams to attain water quality standards, and support fish and other aquatic and riparian life?

The authors of the review attempt to assess the effectiveness of the prescriptions for supplying LWD by comparing the proposed RMZ widths to the widths of the potential LWD source areas. It is important to note that proposed buffer widths along fish-habitat streams are based on SPTH, depending on forest Site Class. Therefore, on the Westside, RMZ widths range from 90 to 200 feet (27 to 61 m) for Site Classes V through I, respectively. Similarly, on the Eastside, RMZ widths range from 60 to 130 feet (18 to 40 m) for Site Classes V through I, respectively. Because the width of the source area varies with site productivity, the actual source-distance data that were gathered in terms of horizontal distance from channels were normalized, for purposes of this analysis, to a representative site-potential tree height (SPTH) for the Westside and Eastside. SPTHs of 200 and 130 were used to normalize the Westside and Eastside data, respectively. For western Washington, the old growth data from McDade and others (1990) were adjusted to SPTHs for Site Classes I to IV. The old-growth data from McDade and others were used instead of their mature-stand data to be a more conservative estimate of the potential LWD supply. [Note: the data from McDade and others were derived from steep, confined channels, and that they likely over-estimated the contribution of trees farther from the channel.] For eastern Washington, the data from Light and Cupp (1999) were adjusted to SPTHs for Site Classes I to IV. Site Class V was not included because it represents a very small percentage of forest stands in Washington.

In this evaluation, the width of each prescribed riparian management zone (i.e., core, inner, outer) was converted to its equivalent SPTH by Site Class, and the corresponding potential LWD supply (i.e., cumulative percent of LWD pieces) was determined from either McDade and others' or Light and Cupp's source-distance curves, depending on region.

This defines the proportion of the potential LWD supply that would be affected by the prescription for each zone in the RMZs. A conservative assumption for source distance is made because trees at increasing distances from channels have a decreasing probability of contributing functional LWD to streams—their tops are too small to contribute functional wood due to stem taper.

The amount of in-stream LWD produced by the *Forests and Fish* plan's prescriptions is a function of the riparian source area width and riparian stand characteristics. These characteristics include tree species, size, and density; tree growth and mortality rates; tree recruitment processes; tree fall direction; and wood loss over time. Riparian protection prescriptions that allow some management in riparian zones can have an effect on all of these processes perhaps with the exception of wood loss. The minimum effectiveness of the prescriptions is the product of source area width and the percent of

the timber stand retained within source areas, based on the silvicultural prescriptions in the *Forests and Fish* plan. The results of the prescription effectiveness evaluation are presented in Tables 2.1-8 and 2.1-9.

The relative proportion of the SPTH that would be in the core zone (i.e., unharvested) is a progressively larger portion of the SPTH distance for each lower Site Class. For example, in Site Class I for the Westside, the 50-foot-wide (15-meter-wide) core zone represents 25 percent of SPTH, but 62 percent of the potential LWD supply. However, in Site Class III, the 50-foot-wide core zone represents 36 percent of SPTH, but 73 percent of the potential LWD supply (Table 2.1-8). It should be noted that the average site productivity on western Washington forestlands is Site Class III. For purposes of this analysis, prescriptions that maintain all existing timber (no harvest option), or improve stand conditions to achieve a prescribed DFC, are considered 100 percent effective.

The Review's analysis found that the general effects of the prescriptions for fish-habitat streams are similar for both the Westside and Eastside. In both regions, the intensity of harvest and RMZ management increases with distance from the stream, and the proportion of the LWD source area affected decreases with distance from the stream. On the Westside, for example, zero harvest in the core zone would maintain an unmanaged stand supplying 62 to 79 percent of the potential LWD. Limited-harvest options within the inner zone would supply 14 to 34 percent of the potential LWD. The relatively greater tree harvest in the outer zone would affect only 5 percent or less of the potential LWD supply.

The Review concluded that indications are that the proposed prescriptions would contribute less than the maximum LWD recruitment potential, but an amount similar to natural circumstances, and likely to be effective for forming fish and riparian habitat. In addition, the proposed new water-typing system would extend buffer zone protection over a larger portion of the stream network than the old rules because it would protect all fish habitat, not just fish habitat that is currently occupied by fish.

A few more details of the Review's analysis are described below:

Variations of harvest options within the Westside inner zone would affect the percentage of trees retained and the long-term potential of this zone to supply LWD. The *Forests and Fish* plan would make both the thinning and clearcut options for the inner zone dependent on meeting the DFC. Harvest would not occur in the inner zone unless it could be demonstrated that sufficient trees would be retained in the combined core and inner zones to meet the functional targets of DFC. The only trees that could be removed are ones that would be surplus to what is needed to grow to DFC. Thinning would be further constrained by the stipulation that only the smallest trees be removed, that the proportion of conifer not be reduced from the pre-harvest level and that a minimum of 57 trees per acre remain in the zone.

Under the inner-zone Westside thinning option and Eastside partial-cut, growth rates of residual trees would be greater over time and the future stand would be more likely to contribute large pieces of wood. By leaving the largest conifer trees and reducing

competition, thinning accelerates diameter growth of the leave trees, making large wood available for recruitment to streams sooner than would otherwise be the case. Where trees are thinned (Option 1) or where a partial cutting is applied (Eastside only), the stand would maintain or improve LWD supply because thinning and partial cutting are designed to increase the growth rate of leave trees, which would become large enough to contribute LWD from the inner zone. Therefore, thinned and partially cut inner zone stands, combined with unmanaged stands in the core zone, could supply at least 91 to 100 percent (Eastside) and 95 percent (Westside) of the potential LWD, depending on stream size and region.

If, on the Westside, the clearcut harvest (Option 2) is applied to the inner zone, the source area in the inner zone would be reduced. The minimum no-harvest width of the core and inner zones (combined) under Option 2 would be no less than “floors” of 80 feet for small streams and 100 feet for large streams; this unmanaged stand would supply 78 to 96 percent of the potential LWD. Reduction in source area from the full core/inner zone widths toward the floors would be limited by the need to retain sufficient trees to achieve the DFC targets.

In other words, the inner zone can be made more narrow only if sufficient trees to meet functional targets are retained in the riparian zone. Under the clearcut option, individual tree growth rates would be unchanged, but more trees would hit the stream due to proximity, and the sizes of wood would be greater because a lower proportion of trees would consist of tops. Timber harvest in the outer zone of fish-habitat streams would have a limited effect on LWD supply because only a very small portion of the LWD is derived from this area and a higher proportion of trees would consist of tops. Tree clumping around sensitive areas and minimum tree retention requirements (i.e., 10 to 20 trees per acre) in this zone would maintain some of the LWD supply.

Unlike the Eastside prescriptions in the Forests and Fish plan, riparian management strategies that promote unmanaged riparian forests, combined with fire suppression, may result in unintended consequences related to the local natural disturbance regime. For example, riparian reserve areas where management is excluded can become corridors for severe wildfire (Segura and Snook 1992; Agee 1998). This is particularly true on the Eastside where fire suppression can increase the rate and magnitude of disease and insect outbreak. The inability to manage within portions of the RMZ along fish-habitat streams may increase the risk of fire and its associated impacts to fish habitat. Active management prescriptions of the Forests and Fish plan provide assurances that catastrophic and unnatural stand replacement fires would be minimized.

Results of the review are summarized for the east and west sides in the Tables below:

Proportion of Potential LWD Supply to Streams in Western Washington under the *Forests and Fish Plan* ^a

Zone	Proportion of Potential LWD Supply (%)				Percent of Timber Stand Retained Within Potential LWD Source Area ^d
	Site Class ^{b, c}				
	I	II	III	IV	
Fish-Habitat Streams (Type S and F Waters)					
Core Zone (50-ft)	62	68	73	79	100% (No harvest)
Inner Zone					
Small Streams					
Option 1 (Thinning)	33	27	22	16	100% (Over the long term as stand reaches DFC target)
Option 2 (Clearcut)	14-33	13-27	8-22	n/a	100% (No harvest in unmanaged area)
Large Streams					
Option 1 (Thinning)	34	28	23	17	100% (Over the long term as stand reaches DFC target)
Option 2 (Clearcut)	21-34	25-28	n/a	n/a	100% (No harvest in unmanaged area)
Total RMZ (Small and Large Streams Combined)					
Option 1 (Thinning)	95	95	95	95	
Option 2 (Clearcut)	78-96	81-96	81-96	n/a	
Perennial Non-Fish-Habitat Streams (Type N Waters)					
First 300-500' Above Fish-Habitat Streams	62	68	73	79	100% (No harvest)
Full Length	31-62	34-68	36-73	40-79	6-100% (No harvest over at least 50% of length)

^a Based on old-growth data from McDade et al. (1990) (See Figure 2.1-6).^b Site Class V was left out because it represents a very small percent of forest stands in Washington.^c Because the Westside outer zone represents 5 percent or less of the recruitment area and prescriptions have a limited potential to supply LWD, it is not included in the total.^d Excludes timber retention along sensitive sites and potentially unstable slopes and landforms.

Proportion of Potential LWD Supply to Streams in Eastern Washington under the *Forests and Fish Plan* ^a

Zone	Proportion of Potential LWD Supply (%)				Percent of Timber Stand Retained Within Potential LWD Source Area ^d
	Site Class ^{b, c}				
	I	II	III	IV	
Fish-Habitat Streams (Type S and F Waters)					
Core Zone (30-ft)	66	70	76	82	100% (No harvest)
Inner Zone					
Small Streams					
Ponderosa Pine & Mixed Conifer	25	24	21	18	100% (Over the long term as stand reaches DFC target)
High Elevation Option 1 (Thinning) ^d	28	24	18	12	100% (Over the long term as stand reaches DFC target)
Large Streams					
Ponderosa Pine & Mixed Conifer	30	26	24	18	100% (Over the long term as stand reaches DFC target)
High Elevation Option 1 (Thinning) ^a	30	28	24	18	100% (Over the long term as stand reaches DFC target)
Bull Trout Habitat	25	24	21	18	100% (No harvest)
Total RMZ					
All Streams & Habitat Types Combined	91-96	94-98	94-100	94-100	
Non-Fish-Habitat Streams (Type N Waters)					
Partial-Cut Units	81	85	91	95	100% (Over the long term as stand reaches DFC target)
Clearcut Units	81	85	91	95	0-100% (No harvest over at least 70% of length; minimum BA and density are designed to meet DFC)

^a Based on source-distance data from Light and Cupp (1999) (See Figure 2.1-6).^b Site Class V was left out because it represents a very small percent of forest stands in Washington.^c Because the Eastside outer zone represents 5 percent or less of the recruitment area and prescriptions have a limited recruitment potential, it is not included in the total.^d The clearcut option does not apply to Eastside, high-elevation forests.^e Excludes timber retention along sensitive sites and potentially unstable slopes and landforms.

Functional Discussion 2: Heat Energy

CH2M HILL reviewed the scientific foundations effectiveness of temperature amelioration by shading from forest buffers. After summarizing various physical processes that impact stream heating, the review notes the physical conditions of upper watershed tributaries in forest have greater ground water influx that provides a substantial proportion of total stream inflow. Groundwater of course is generally uniformly between 40-50 C in cascade mountain environments. The review also describes the diminishing impact of groundwater influx has on cooling as the stream flow grows larger and collects more and more surface water at the lower altitude reaches and in the lower order streams. The review suggests that as the total volumetric flow rate of a stream increases, the total surface flow tends to grow larger faster in proportion to the rate of ground water influx.

This effect tends to afford larger streams less cooling effect from ground water influx than that expected for smaller streams toward the head of the watershed.

The review describes other factors that come into play as the stream widths increase with decreases in altitude. In the upper reaches of the watershed, riparian shading tends to more effectively cover the entire stream. As the streams coalesce to the lower altitude reaches, the streams become wider, so riparian canopies contiguous to the wider streams automatically provide less shade for a given canopy height due to the greater mean distance from the stream banks to the stream centerlines. This tends to effectively shift the mean distance to the start of the buffer zone away from the stream centerline. Thus, shade function becomes a decreasingly effective treatment in larger order (wider and deeper) streams. Since most agricultural streams are in valley bottoms, not mountain tops, there are probably more higher order (larger) streams than in the upland forests. Shade has less of a total impact on reducing temperature in larger order streams because the mass of larger order streams is larger and thus more resistant to heating and cooling. Thus the general importance of shading is probably a less important factor in influencing temperature in agricultural ecosystems than in forest ecosystems.

Many local factors influence the actual stream temperature response, so it is difficult to quantify average impacts or effects. A wide range of variability appeared in the results obtained for canopy cover effects as presented in the review. In this same section, (Effects of Proposed Rules on Shade) a discussion of potential shade effectiveness was addressed. One group of cited studies came to agreement that most of the potential shade effectiveness comes from the buffer region within 75 feet of the stream bank, they differed considerably on the exact value for an appropriate optimal buffer zone width. Effective buffer zone widths ranged from 39 to 98 feet from the stream bank. No information describing the total stream width or total canopy height was supplied in the review to supplement the reported findings.

The review then describes additional studies done to verify the abilities of the various geographically developed shade rules to adhere to target temperature criteria. For that investigation, the effective shade was expressed in terms of the buffer zone width as a percentage function of the theoretical site potential tree height. In this case, a site potential tree height of 200 feet was used, and a quantity referred to as the Angular Canopy Density (ACD) was used to define the effective shade potential of a buffer zone. The results of two different studies were compared in which it was found that considerable discrepancies existed for buffer zone widths inside about 50% of the (200 ft) theoretical site potential tree height, but that the results tended to converge to close agreement above about 65% of the site potential tree height.

A comparison of target vs. actual canopy closure was then compared to target vs. actual temperature standards. The results of this study tended to show a strong inverse relationship between canopy density and temperature standard attainment. However, it did not describe whether the observation sites were compared under otherwise uniform conditions of stream width, depth, and altitude to describe whether the stream reaches compared here were otherwise relatively equivalent. The concern is that the results

could easily be skewed by the fact that narrower streams at higher altitudes will be more likely to attain their targets and would be covered more effectively by increased canopy density than would the wider streams at lower altitudes.

In terms of the transferability and applicability of this type of an approach for use in agricultural systems, the same theory and the same potential benefits are certainly legitimate. There is obvious applicability to irrigation canals, and to smaller rivers and waterways to varying extent would be worthy of consideration. One issue would be the existing local conditions that would play a larger role in the approach than for higher altitude narrower streams where a reasonably dimensioned buffer zone would impart significant reductions in radiation loading. On very wide rivers, buffer zones could delay the onset of direct incident solar radiation, but inevitably the sun would reach a high enough solar angle to overtop the buffer zone. The relative orientation of the river comes into play as well. Rivers running directly north or south would tend to be subjected to direct midday sunlight even with a dense, tall riparian buffer zone in place. Rivers running east to west would benefit more from a buffer zone situated on the south bank than from one on the north bank since the sun is always south of the zenith in the northern hemisphere for any latitude north of 21° north of the equator. Thus the idea that a uniform buffer width on either side of a stream imparts the same benefits is completely false when it comes to shade benefits.

It should be pointed out that some apparent rules of thumb described in the CH2M HILL review are not necessarily always true. For example, the report tends to suggest that shallow streams always tend to heat more rapidly than deeper streams. This is only true in cases where the surface area to volume ratio of the shallow stream is greater than that of the deeper stream. The important characteristic to judge the tendency of a stream to respond aggressively to energy inputs is the surface area to volume ratio; not the depth.

Functional Discussion 3: Coarse Sediment

This section discusses the ecological importance of coarse sediment delivery to streams, the primary sources and mechanisms for delivery, and the potential effects of forest practices on potentially unstable slopes and landforms, and evaluates the possible effectiveness of the Plan's proposed programmatic and prescriptive rule changes and implementation commitments.

The Review concludes that the Plan contains a clear and defensible list of the diagnostic landforms of Washington that are potentially unstable, and an administrative process for identifying, reviewing, and regulating forest practices on potentially unstable slopes. It targets the highest-risk areas (e.g., road-related mass wasting) first, and would accelerate problem-reduction activities. The Review further concludes that the Plan contains appropriate ingredients for significantly reducing the effects of forest practices on landsliding and the introduction of excessive coarse sediments to public resources.

The Review summarizes the coarse sediment issue by concluding that coarse sediment delivery to streams may have positive and negative effects on aquatic habitats. Mass

wasting (landsliding) in forested drainage basins is given as the principal, natural mechanism by which coarse sediment enters stream channels from hillslopes. Forest practices are also mentioned as having a possible effect on mass wasting by reducing root strength, increasing soil moisture, and altering slope stability characteristics during road construction and maintenance.

The stated resource objective of the Plan is “to prevent the delivery of excessive sediment to streams by protecting unstable slopes, and preventing the routing of sediment to streams.” The Plan addresses this objective by containing programmatic and prescriptive rule changes to address forest practices on potentially unstable slopes and landforms.

The Review begins this section by discussing the immediate short-term effects of mass wasting on channel habitat. These effects are:

- The capacity of the stream to transport material downstream is overwhelmed by the large influx of sediment, wood and other organic material.
- The increased sediment deposition aggrades channels.
- The average grain size of the channel bed decreases.
- Riparian vegetation is damaged or removed.

The potential negative impacts from mass wasting on aquatic habitats include direct fish kills and habitat loss by burial, increase in the potential for dam-break floods, and influx of excess fine sediment.

The Plan identifies erosion processes and input sources that cause coarse sediment to enter stream channels including mass wasting, bank erosion, sheet wash, and gullyng.

The potential effects of forest practices can contribute to slope instability and fall into the following categories:

- Failure of road fills or sidecast material.
- Reduction in rooting strength.
- Increase in soil moisture due to increased snow accumulation and subsequent melt and/or loss of evapotranspiration potential.
- Alteration of drainage patterns due to road construction or road maintenance.
- Alteration of near-stream channel riparian vegetation.

The most on-point discussion to riparian buffers regarding coarse sediment in the Review involves vegetation removal. The Review states that vegetation removal increases the amount of precipitation reaching the ground and decreases the amount of water that is removed from the ground by vegetative transpiration.

Numerous studies of landslide incidence have pointed to poorly planned, designed and maintained legacy roads that were constructed prior to modern forest practice rules as the greatest forestry-related contributor increasing the rate of landslides in managed forests (NCASI 1985; Robison et al. 1999; Pyles et al. 1998). Such roads can increase soil

saturation enough to trigger shallow landslides. It is well demonstrated that the concentration of road drainage onto steep, unstable slopes can lead to increased landslide activity (Megahan 1972). While this discussion is presented in the context of forest practices, it can also be relevant to agriculture in situations where roads have been constructed for agricultural purposes, particularly in situations where slopes are moderate to steep.

The authors describe the effect of forestry harvest on slope stability. This discussion is specific to forestry and it may be less relevant to agriculture because crops are not usually grown in areas with steep slopes and shallow soils. In addition, agriculture replaces trees with other types of vegetation, which may or may not have similar root strength as the native vegetation. Root strength is important in shallow soils on steep slopes where studies that have documented an increase in shallow landslides following timber harvest (Burroughs and Thomas 1977; Ziemer 1981). The effect is similar to the effect of stand replacement fires on landsliding and continues until new vegetation attains approximately 10 to 30 years of age (Robison et al. 1999; Benda et al. 1998).

To address the general concern about removing riparian trees that could stop debris flows the Plan would mitigate potential negative effects through two mechanisms. First, it would protect the bedrock hollow initiation points and a substantial portion of the downstream first- and second-order channel network that contains trees to stop debris flows before they could build too much momentum. Second, it would provide substantial protection for riparian areas and some unstable slope areas along higher-order confined channels that may experience dam-break floods.

The Review notes that a theoretical basis exists for leaving trees to reduce landslide potential. The Review then notes that there has been very limited field application of leave areas and only one study has evaluated their effectiveness. This study was conducted in the Suislaw National Forest in Oregon and concluded that leave areas had either no effect or led to an increased rate of failures due to tree blowdown (Martin 1997).

Functional Discussion 4: Fine Sediment

This section discusses the ecological importance of fine sediment delivery to streams, the primary sources and mechanisms for delivery, the potential effects of forest practices on roads and drainage systems, and evaluates the possible effectiveness of the Plan's proposed programmatic and prescriptive rule changes and implementation commitments.

The Review concludes that the Plan contains a clear and defensible administrative process for identifying, reviewing, and regulating forest practices that may contribute to fine sediment delivery. The Plan's prescriptions address the management practices and landscape areas with the highest potential to deliver fine sediments to streams. The Review further concludes that the recommended management prescriptions are stricter than the old rules, and their potential effectiveness is supported by scientific research.

The stated resource objective in the Plan is to “prevent the delivery of excessive sediment to streams by protecting stream bank integrity, providing vegetative filtering, and preventing the routing of sediment to streams.” The Plan provides management prescriptions to prevent or minimize the impact of forest practices on surface erosion processes. The major commitments to reducing sediment delivery to streams are:

- Disconnecting road drainage systems from streams.
- Reducing water and sediment delivery from existing stream-adjacent roads.
- Higher construction standards for new roads.
- 30- or 50-foot-wide no-entry core zones with additional tree retention out to a distance equal to one site-potential tree height for fish-habitat streams.
- 30-foot-wide equipment limitation zones with leave-tree requirements for non-fish-habitat perennial streams.
- Riparian management zones on non-fish-habitat perennial streams avoid ground disturbance at seeps, springs, and other sensitive areas.

The Plan provides an overview of studies that have shown that increases in stream sedimentation can lead to impacts on aquatic habitat and water quality. Specifically, high fine sediment levels can reduce salmonid survival-to-emergence ratios by entrapping eggs within the streambed and limiting inter-gravel flow of oxygenated water. Also, fine sediment can fill the interstitial spaces between gravels that juvenile salmonids, benthic invertebrates, and amphibians use for cover and reduce growth and survival. Additionally, increases in fine sediment levels can impact biota such as benthic invertebrates that are a significant food source for adult salmonids, and the filling of pools by fine sediment can reduce rearing habitat for salmonids.

Fine sediment can be generated from on-site processes, such as physical and chemical weathering of geological features, loss of vegetation or organic duff, and streambank erosion. Fine sediment can be transported off-site by wind or surface water run-off.

The Review concludes that forest practices that remove or disturb the protective duff layer on the forest floor, compact the soil, or increase the slope angle have the greatest potential to increase soil erosion rates. Additionally, activities that increase or concentrate the flow of water over soil can increase the amount of erosion and the likelihood of delivering sediment to streams. Specific activities that can increase soil disturbance and surface erosion include road construction, road maintenance, ground and cable yarding, and site preparation.

The Review states that roads represent the greatest potential source of fine sediment production from forest practices. Importantly, the Review concludes that soil compaction and displacement in riparian areas can change soil physical properties and increase delivery of sediment to streams. Soil compaction from ground-based logging or roads can reduce infiltration rates and impede the ability of soils to store water.

Rashin et al. (1999) found that streamside buffers are generally effective at preventing sediment delivery, but that yarding timber within 30 feet of streams without buffers often causes soil disturbance, bank erosion, and sediment delivery to streams.

The Plan includes numerous prescriptions to address the potential for delivery of fine sediment from roads and timberlands. It addresses surface erosion within riparian harvest units by providing 30- or 50-foot-wide no-harvest core zones along fish-habitat streams, and 30-foot-wide equipment limitation zones along all non-fish-habitat streams. The new rules would make it more difficult to build roads in riparian areas or adjacent riparian forest. The Review states that research suggests that, on average, leave-tree widths of 30 feet or more should be effective at filtering out sediment from adjacent timber harvest activities (Brake et al. 1997; Rashin et al. 1999). The Review concludes that the 30- or 50-foot-wide no-harvest zones along fish-habitat streams, and equipment limitation zones on non-fish-habitat streams should prevent soil compaction and bank disturbance in the area with the greatest potential for sediment delivery. The Review further concludes that in most cases, the leave-tree requirements for fish-habitat streams would provide buffers that are wider than the maximum sediment delivery distance reported for older roads (Brake et al. 1997).

The Review further concludes that forest practices rules are proven to be effective when properly implemented. Therefore, the fine sediment problems that have been identified in Washington can be solved through proper application of well-understood forestry best management practices (BMPs).

Functional Discussion 5: Hydrology

This section discusses the ecological roles of forest hydrology, identifies the primary hydrologic processes and water input sources, describes the potential effects of forest and road management on hydrologic regimes, and evaluates the possible effectiveness of the Plan's prescriptions in reducing the effect of forest practices on hydrologic processes.

The Plan proposes forest practices standards to help maintain the hydrological regimes of private forestlands. The resource objective for hydrology stated in the Plan is to "maintain surface and groundwater hydrologic regimes (magnitude, frequency, timing, and routing of stream flows) by disconnecting road drainage from the stream network, preventing increases in peak flows causing scour, and maintaining the hydrologic continuity of wetlands." This objective is important because the hydrologic regimes influence water and habitat quality in watercourses and riparian areas and are important to the formation of fish habitat in streams.

The Review discusses the scientific principles of hydrology. In this discussion the Review concludes that by virtue of their location in watersheds and proximity to watercourses, riparian forests may influence the local hydrologic condition and bank stability. Vegetation primarily influences flow through interception (collection of rain and snow by the canopy) and evapotranspiration. Additionally, historical fire suppression and the build up of abnormal quantities of biomass in riparian areas have

altered forest hydrology and its associated ecological processes to create conditions outside the natural ranges of variability, particularly in many Eastside forest locations.

The Review discusses how forest practices have affected hydrologic processes and concludes that forest practices can affect hydrologic processes primarily through the alteration of vegetation and soil properties. Additionally, tree removal can temporarily reduce interception and evapotranspiration, increase soil water storage, and affect the quality and timing of streamflows.

The Plan addresses hydrology by providing for changes in the application of rules to reduce the influence of forest practices on hydrologic regimes. The pertinent change is that riparian protection is to be extended to include entire channel migration zones associated with fish-habitat streams. This change is to ensure that trees are retained within the area of active channel movement within valleys. The extended protection is expected to protect the zones of shallow subsurface flow beneath and adjacent to migrating streams.

The Plan also includes additional prescriptive changes to further reduce the effects of forest practices on hydrologic processes. The pertinent changes are to establish Riparian Management Zones (RMZs) and Sensitive Site RMZs which have tree retention provisions for priority areas and aquatic features on perennial, non-fish-habitat waters and equipment limitation zones.

The Review concludes that the Plan provides additional provisions that will further reduce the effect of forest practices on hydrologic processes in three general areas: roads, wetlands, and riparian zones. The changes are expected to reduce soil disturbance and compaction at areas with significant shallow subsurface flow and reduce the amount of concentrated road drainage flowing directly to streams.

The Review further concludes that the riparian prescriptions that address hydrologic processes are expected to provide a higher level of hydrologic protections. Sensitive Site RMZs emphasize tree retention around seeps, springs, and forested wetlands, which may be hydrologically sensitive. Channel migration zones are recognized as part of the channel, and therefore are included within the no-harvest portion of the RMZ. These measures are expected to protect shallow subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms.

Functional Discussion 6: Pesticides

This section discusses the role of herbicides in managing forests, describes the potential effects of herbicide application on fish habitat and water quality, and evaluates the effectiveness of the Plan's BMPs. The Plan proposes BMPs designed to eliminate the direct entry of herbicides to waters and wetlands, to protect riparian vegetation, and to minimize off-target drift to water and vegetation in riparian zones.

The Review claims that herbicide research confirms that the RMZs in the Plan would eliminate the direct entry of herbicides to water and wetlands, and protect riparian vegetation and that the Plan's prescriptions substantially increase the confidence that herbicides can be used without adverse environmental effects.

Concern about herbicide use generally focuses on its potential toxicity to unintended targets. For example, sublethal effects of some herbicides on salmonids include reduced growth, decreased reproductive success, altered behavior, and reduced resistance to stress.

Payne and others (1989) found that a buffer width of 82 feet (25 m) around water bodies is adequate to protect salmon, rainbow trout, and aquatic invertebrates from significant direct effects resulting from application of certain technologies.

The discussion and conclusions in this section may not be applicable to agricultural buffers due to the fact that herbicides are commonly undetectable in managed forest environments. For example, the USGS (1996) reported, "Of the 25 most frequently detected pesticides, 3 were found primarily at urban sites, 6 were found primarily at agricultural sites, and 7 were found at all types of sites except forested sites." The Review discusses that one reason herbicides are undetectable on forestland may be that the frequency of herbicide application on forestland, compared with agricultural and urban land, is relatively low.

The Plan recommends a very low risk approach under favorable wind conditions of 50-foot-wide (15 m) off-sets on non-fish-habitat streams with open water, and 60- to 150-foot-wide (18 to 46) off-sets, depending on inner riparian zone width. Under unfavorable wind conditions when potential drift is a concern, the Plan's low risk approach to stream protection would invoke 145- to 325-foot-wide (44 to 99 m) buffers, depending on application height and nozzle type.

The Review concludes that the Plan's goals of eliminating direct entry of herbicides to waters and wetlands, minimizing off-target drift, and protecting riparian vegetation in RMZs should be accomplished under these off-set widths with a large margin of safety.

Functional Discussion 7: Litterfall

This section discusses the importance of organic inputs from forestlands, describes the effects of forest practices on organic litter, and evaluates the effectiveness of the Plan's prescriptions to restore and maintain adequate levels of organic inputs to streams.

The Plan defines ecological criteria and proposes forest practices standards to deliver organic litter to riparian and aquatic areas. Organic litter inputs to streams are important food and energy sources for a variety of organisms that, in turn, provide food and energy for fish and other aquatic organisms. Forest practices have the potential to affect organic litter generation and transport from riparian forests to aquatic areas.

The Review discusses the effectiveness of organic litter sources in stream ecology. This effectiveness is based on the interaction of vegetation with the stream. Stream size influences the role of litterfall and, generally, a relatively higher proportion of litter function is provided by near-stream vegetation as stream size decreases.

In an overview of the science the Review discusses deciduous riparian forests versus coniferous riparian forests. In deciduous riparian forests, approximately 80 percent of the organic material input to streams is derived from leaf litter. In coniferous riparian forests, needles contribute a major portion of the terrestrial input to streams, and fallen cones or wood may account for 40 to 50 percent of the total terrestrial litter input.

The Review assumes that most litterfall to streams is generated close to the channel. This assumption is based upon the Forest Ecosystem Management Assessment Team (FEMAT) litterfall effectiveness curve that suggests that approximately 90 percent of the litterfall to streams originates within half a site-potential tree height from the stream (FEMAT 1993). Indirect evidence of litterfall effectiveness is suggested by benthic invertebrate communities. Studies in streams with managed riparian buffer zones at least 100 feet (30 m) wide had benthic communities that were indistinguishable from streams flowing through logged watersheds (Erman et al. 1997; Belt et al. 1992). However, maintenance of overhanging trees and shrubs within just 10 feet (3 m) of the bank has been found to maintain the sources of most litterfall (Newton et al. 1996). The Review concludes that forest practices that affect litterfall processes have the potential to modify the vegetation-stream relationship, including nutrient and energy sources to streams.

The Plan's forest practices measures are essentially the same as the ones intended to maintain and enhance the heat energy and large woody debris of streams. The Review concludes that with the proposed forest practices in place the range of vegetative cover desired for thermal protection and LWD recruitment to streams and adequate sources of litter from trees and understory vegetation should be present to support the aquatic food chain. The Review then states that not enough is known about nutrient cycling in forest streams to determine "adequacy" of the Plans prescriptions, or any other prescriptions. No studies exist that measure the total amount and timing of litter inputs required to maintain aquatic functions. Additionally, no studies exist that indicate the desirable loadings of nutrients and organic matter downstream.

The Review concludes that applying the RMZ prescriptions in the Plan will protect the fish-habitat streams sufficiently to maintain near-maximum effectiveness of litter input sources. For non-fish-habitat waters the probable amount of litter input will be less than maximum. The Review concludes that this reduction in litter delivery may not be important for maintaining aquatic systems, or may be compensated by adjustments in in-stream photosynthesis, terrestrial vegetation, and aquatic communities that change in equilibrium with the physical stream conditions.

Summary

Chapter 2 of this document contains detailed reviews of the scientific foundations of the *Forests and Fish* plan. The chapter is organized into discussions of the functions that the *Forests and Fish* Plan are designed to enhance.

Here's what the review says about the effectiveness of the buffer zones that are recommended in the Forest and Fish Plan for each function.

Large woody debris (LWD):

The *Forests and Fish* Plan proposes to maintain and enhance large woody debris recruitment through several prescriptions related to: riparian management zones (RMZS) and sensitive site RMZS, management of potentially unstable slopes and landforms, forest road management, and wetland protection. In other words, riparian management zones are one tool that is used for management of LWD.

The Review concludes that "Riparian forests that maintain growth trajectories toward desired future conditions that are similar to mature forests are presumed to provide adequate and functional levels of LWD to streams. The *Forests and Fish* plan proposes silvicultural options for management of LWD that protects LWD sources where they are most needed and at locations where LWD can be most effective, particularly near aquatic resources and along fish-habitat streams. Proposed prescriptions would provide varying amounts of LWD to all streams and in relation to channel type and presence of fish habitat".

"The prescriptions in the *Forests and Fish* plan propose buffers and leave-tree areas for riparian management zones and potentially unstable slopes to maintain LWD supply. They would be more restrictive than the old forest practices rules. Indications are that the proposed prescriptions would contribute less than the maximum LWD recruitment potential, but an amount similar to natural circumstances, and likely to be effective for forming fish and riparian habitat. In addition, the proposed new water-typing system would extend buffer zone protection over a larger portion of the stream network than the old rules because it would protect all fish habitat, not just fish habitat that is currently occupied by fish."

Heat energy:

Riparian management zones are the primary tool that is used in the *Forests and Fish* Plan to maintain shade in streams. The Review concludes that:

“Where the riparian stands at the time of harvest meet or exceed the shade target, the Shade Rule provides assurances that, barring catastrophic loss following harvest, adequate shade would be maintained along fish-habitat streams. Where stands present at the time of harvest are not providing adequate shade, the *Forests and Fish* plan would maintain more than adequate buffer widths to allow development of the shade potential of riparian forests. The prescriptions would provide varying amounts of shade, not unlike many unmanaged forests. These may be less than the maximum potential shading, but would maintain water temperatures at or below state water quality standards in most situations.”

“In cases where the existing riparian stands at the time of harvest would not meet shade targets, they also would be unlikely to meet the DFC trajectory. Therefore, harvest would not be allowed within the area that could influence shading of the stream. Water temperature in perennial non-fish-habitat stream reaches may increase over limited distances as a result of staggered shade retention zones, but these changes are not expected to affect beneficial uses of downstream fish-habitat waters because strategic watershed locations would be shaded and stream temperature relaxes toward equilibrium with the surrounding environment.”

Coarse sediment:

The prescriptions in the *Forests and Fish* plan that relate to coarse sediment have to do with identifying source areas and road management, not specifically riparian buffers. The Review concludes that the *Forests and Fish* plan contains a clear and defensible list of the diagnostic landforms of Washington that are potentially unstable, and an administrative process for identifying, reviewing, and regulating forest practices on potentially unstable slopes.

Fine Sediment:

The *Forests and Fish* plan includes numerous prescriptions to address the potential for delivery of fine sediment from roads and timberlands. The plan addresses fine sediment inputs from roads through proposed programmatic and prescriptive rule changes. Surface erosion within riparian harvest units is addressed through the use of riparian management zones. That is, RMZS are one tool that is utilized to reduce forestry impacts to fine sediment in streams.

The Review concludes that “Overall, the plan appears to contain appropriate ingredients for significantly reducing the effects of forest practices that otherwise could deliver excessive fine sediment to public resources.

Hydrology:

RMZS are one tool in the *Forests and Fish* Plan to protect hydrology. Other tools are forest road management and wetland protection. The Review concludes that, “The riparian prescriptions that address hydrologic processes (and CMZs) are expected to provide a higher level of hydrologic protection [than the old forest practices rules]. Sensitive Site RMZs emphasize tree retention around seeps, springs, and forested wetlands, which may be hydrologically sensitive. Channel migration zones are recognized as part of the channel, and therefore are included within the no-harvest portion of the RMZ. These measures protect shallow subsurface flows beneath and adjacent to these streams, which are important for supporting a variety of aquatic organisms.”

Pesticides:

The *Forests and Fish* Plan includes prescriptions for the application of herbicides within the RMZ. These prescriptions are expected to reduce the direct entry of herbicides into aquatic habitats. The Review concludes that, “Water quality standards have not been shown to be exceeded when herbicide is applied according to EPA labels and forest practices rules. The *Forest and Fish* plan would further reduce the potential for undesirable impacts to surface waters and streamside vegetation by restricting aerial herbicide applications in the core and inner riparian zones along fish-habitat-streams and wetlands, and applying off-sets that vary with wind conditions, application height, and nozzle type.”

Litterfall:

A number of prescriptions in the *Forests and Fish* plan simultaneously address a number of riparian functions including input of organic litter to streams. All the proposed prescriptions in the *Forests and Fish* plan which address riparian vegetation management, including establishment of RMZS, have the potential to directly or indirectly influence the input of litter to streams and wetlands. The Review concludes, “The proposed prescriptions would contribute less than the maximum potential organic litter delivery, but an amount and quality likely to be functionally effective for fish and other aquatic resources.”

The overall conclusion of the review is that “The *Forests and Fish* plan contains biologically sound and economically practical solutions that will improve and protect riparian habitat on non-federal forestlands in Washington.”

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Appendix A.11

REMM Model (in process, not available)

Appendix A.12

**Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients,
Sediments, and Toxic Substances**

Appendix A.12

Correll, D. 2001. Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances An Annotated and Indexed Bibliography of the world literature including buffer strips, and interactions with hyporheic zones and floodplains. Sustainable Florida Ecosystems, Inc., 3970 N. Timucua Point, Crystal River, FL 34428 USA Tenth Edition, September 2001

The goal of this document is to comprehensively cite and subject index the world literature on vegetated stream riparian zone water quality effects. The scope of the bibliography has been expanded to include literature on hyporheic zone and floodplain/stream channel interactions. Buffer strip research is also included, since these studies seem easily transferable. This document is a bibliography. It does not contain any research information in and of itself but simply refers to other literature. It does not contain data or facilitate evaluation of the science of buffer widths on any landscapes including agricultural.

Appendix A.13

Water Quality and Agriculture: Status, Conditions, and Trends

Appendix A.13
USDA-NRCS. 1997. Water Quality and Agriculture: Status, Conditions, and Trends. Natural Resources Conservation Service Working Paper #19.

Agricultural Impacts Information:

This paper provides a substantial overview of identified and potential agricultural impacts that can affect water quality, including: sedimentation, nitrates, animal wastes, and pesticide loss in field run-off.

The paper does identify several measures that can be applied to reduce water impacts from agricultural production. These include the following:

Soil erosion and sedimentation:

- Water efficient application systems and management for irrigation.
- Crop rotations and cover crops.
- No-till or conservation tillage practices were viable.

Nitrogen use problems:

- Water efficient application systems and management for irrigation.
- Crop monitoring for nitrogen pick-up rate and optimal applications; efficient application rates.
- Crop rotations and cover crops.
- Vegetative filter strips.

Animal wastes:

- Efficient pasture management and field rotations for livestock.
- Adequate containment and control measures for waste management.
- Water efficient application systems and management for irrigation.

Pesticide loss and residues:

- Compliance with recommended application rates.
- Careful monitoring of crop conditions and optimal use of pesticides; improve pesticide application timing to reduce application rates.
- Use integrated pest management methods where possible.
- Water efficient application systems and management for irrigation.

The use of buffers, as a water quality management tool for agriculture, is not given as much attention as other management actions. The focus is on targeted management actions to reduce impacts or the potential for impacts rather than buffers to mitigate for impacts. In summary, the authors, using Best Available Science, provide alternatives to

maximum buffer widths as a means to address proper ecological function in agricultural streams (AgFishWater Review emphasis)

Appendix A.14

Final Environmental Impact Statement for the Wild Salmonid Policy

Appendix A.14
Washington Department of Fish and Wildlife. 1997. Final Environmental Impact Statement for the Wild Salmonid Policy. Olympia, Washington.

This document is a programmatic EIS for the wild salmonid policy that Washington State has adopted. The purpose of the proposed Wild Salmonid Policy (WSP) is to, “protect, restore, and enhance the productivity, production, and diversity of wild salmonids and their ecosystems to sustain ceremonial, subsistence, commercial, and recreational fisheries; non-consumptive fish benefits; and other related cultural and ecological values”. The critical issues actions described in a Wild Salmonid Policy include fishery management issues, hatchery operations, spawning numbers, and habitat matters. Riparian buffers are included in the discussion of habitat matters.

Under the agency’s preferred alternative, “habitat protection and restoration would occur primarily through locally-based watershed planning that would have the flexibility to adapt performance measures and action strategies to local conditions. State and local or federal regulatory authorities would not be relinquished during locally-based watershed planning, but these authorities should be used in a manner that supports locally-based planning. Regulatory action could be taken wherever standards and requirements are not being met, and voluntary actions are either not being taken or are insufficient to achieve compliance. Statewide planning or rule-making would occur on a collaborative basis.”

The report states that, “There are no single, agreed-upon, statewide numeric standards for riparian areas or wetlands. Because the Department of Natural Resources maintains and updates a fairly extensive, and fairly accurate, water typing system (defined and mapped per WAC 222-16-030), and since many local governments use this system, we would use that system as a point of reference. It should be noted that the performance measures below provide general guidance for riparian buffers that protect aquatic functions and salmonid fish habitat. These buffers should be applied regardless of land use (e.g., forest lands, agricultural, rural, or urban lands).”

“Regional or watershed specific standards may need to be applied, based upon watershed analysis, the development of specific and detailed standards in individual watershed plans, or other assessments of site conditions and intensity of land use. It is anticipated that statewide standards for state and private forest lands would be developed through the TFW process, and provided to the Forest Practices Board for formal rule making. It is also anticipated that, in many instances, existing encroachments in riparian areas or parcel size and configuration, may preclude attainment of riparian buffers”.

“Nonetheless, in the absence of any other quantified alternative that provides riparian area functions described above the performance measures below are recommended to maintain functions and conditions which protect salmonid habitat:

1. Riparian Areas

- a. For Water Types 1-3, a buffer of 100 - 150 feet (measured horizontally), or the height of a site potential tree in a mature conifer stand (100 years), whichever is greater, on each side of the stream.
- b. For Type 4 streams, a buffer of at least 100 feet (each side)
- c. For Type 5 streams, a buffer of at least 50 feet (each side).
- d. For streams not administered directly or indirectly per WAC 222-26-030, apply a buffer of 100-150 feet each side on salmonid streams larger than 5 feet wide, a buffer of 100 feet (each side) on smaller perennial streams, and a buffer of 50 feet (each side) on all other streams.
- e. The buffers may need to be expanded to accommodate anticipated channel migration, as an additional buffer against windthrow, or to address upslope instability.
- f. Type 4 and 5 streams, with low stream gradient and relatively flat slope topography, may not need the full buffer width and the buffer width may be reduced to that necessary to protect the stream from upslope sedimentation and significant changes in stream temperature. The actual buffer width and composition should be based on site-specific conditions.
- g. To the extent possible, buffers should be continuous along the stream channel. Selective tree removal may occur where site review and prescription clearly demonstrates removal can occur without significantly affecting the function of the riparian area, or that removal and subsequent rehabilitation will improve the functional characteristics of the riparian area. Complete removal should be limited to road alignments, stream crossings, or other corridors where no feasible alternative exists.
- h. Riparian area restoration is strongly recommended. Plant community structural complexity (understory herbaceous and woody overstory canopy) and density should be similar to what would occur at the site under natural conditions (also known as site potential).
- i. Grazing, if allowed, should be managed to maintain or allow reestablishment of functional riparian vegetation. Other management activities occur within the riparian area, provided the functional characteristics of the riparian area necessary to protect the stream are not significantly impaired.
- j. The performance measures for Basin Hydrology and In-stream Flow, and Water and Sediment Quality and Sediment Transport and Stream Channel Complexity, should also be met to ensure riparian functions will be meaningful and attainable”.

Appendix A.15

Riparian Buffer Literature Review

Appendix A.15

List of 20 Citations

Appendix B

Review of Best Available Science, WAC 365-195-900

Appendix B

Review of Best Available Science, WAC 365-195-900

Background Purpose

- Counties and cities planning under RCW development regulations must include “best available science” when developing policies and development regulations to protect the functions and values of critical areas and must give “special consideration” to conservation or protection measures necessary to preserve or enhance anadromous fisheries. (RCW 36.70A.1.72(1).)
- The rules in WAC 365-195-900 are intended to assist counties and cities in identifying and including the best available science in newly adopted policies and regulations in the periodic review of plans and regulations under the Growth Management Act. (RCW 36.70A.130.)

WAC 365-195-905

Criteria for determining which information is the “best available science

- The ordinance provides assessment criteria to assist counties and cities in determining whether information obtained during development of critical areas policies and regulations constitutes the “best available science.”
- Entities should consult (when feasible) with qualified scientific experts. The scientific experts may rely on professional judgment but should use criteria in the ordinance and technical guidance provided by the department.
- Entities may use information that local, state or federal natural resources agencies have determined represents the best available science if it is consistent with criteria set out in this ordinance.
- The use of criteria should guide entities but the criteria is not intended to be a substitute for assessment and recommendation by a qualified expert.
- To assess whether an expert is qualified or not is determined by the person’s professional credentials and/or certification, any advanced degrees earned in the pertinent scientific discipline from a recognized university, the number of years of experience, recognized leadership in the discipline, formal training in the specific area of expertise, and field and/or laboratory experience with peer-reviewed publications or other professional literature.

To ensure that the best available science is being included, meaning scientific information produced through a valid scientific process, the entity should consider the following:

A. Characteristics of a valid scientific process.

The characteristics generally to be expected in a valid scientific process are as follows:

1. Peer reviewed

The information has been critically reviewed by other qualified scientific experts, and the proponents of the information have addressed the criticism. Publication

in a refereed scientific journal usually indicates that the information has been appropriately peer-reviewed.

2. Methods

The methods used were clearly stated, replicatable, and standardized in the discipline. If not standardized then the methods have been peer-reviewed.

3. Logical conclusions and reasonable inferences.

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

4. Quantitative analysis

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

5. Context

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

6. References

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

Common Sources of Scientific Information

- Some sources of information routinely exhibit all or some of the characteristics listed above, and a city or county may consider information to be scientifically valid if the source possesses the characteristics listed above.
- Information derived from the following sources may be considered scientific if the source possesses certain combinations of the above characteristics.

Sources of scientific information

Research

- Meaning: Data collected and analyzed as part of a controlled experiment to test a scientific hypothesis.
- To be considered scientific information the research must possess the following characteristics:
 - Peer review, methods, logical conclusions and reasonable references, quantitative analysis, context, references.

Monitoring

- Meaning: Data collected periodically over time to determine a resource trend or evaluate a management program.
- To be considered scientific information the monitoring must possess the following characteristics:
 - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Inventory

- Meaning: Data collected from an entire population or population segment.
- To be considered scientific information the inventory must possess the following characteristics:
 - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Survey

- Meaning: Data collected from a statistical sample from a population or ecosystem.
- To be considered scientific information the survey must possess the following characteristics:
 - Methods, logical conclusions and reasonable references, context, references. Additionally, the presence of quantitative analysis strengthens the scientific validity and reliability of information, but is not necessary.

Modeling

- Meaning: Mathematical or symbolic simulation or representation of a natural system. Models generally are used to understand and explain occurrences that cannot be directly observed.
- To be considered scientific information the modeling must possess the following characteristics:
 - Peer review, methods, logical conclusions and reasonable references, quantitative analysis, context, references.

Assessment

- Meaning: Inspection and evaluation of site-specific information by a qualified scientific expert. An assessment may or may not involve collection of new data.
- To be considered scientific information the assessment must possess the following characteristics:
 - Methods, logical conclusions and reasonable inferences, context, and references

Synthesis

- Meaning: A comprehensive review and explanation of pertinent literature and other relevant existing knowledge by a qualified scientific expert.

- To be considered scientific information the synthesis must possess the following characteristics:
 - Peer review, methods, logical conclusions and reasonable references, context, references.

Expert Opinion

- Meaning: Statement of a qualified scientific expert based on his/her best professional judgment and experience in the pertinent scientific discipline. The opinion may or may not be based on site-specific information.
- To be considered scientific information the synthesis must possess the following characteristics:
 - Logical conclusions and reasonable references, context, and references.

Nonscientific Information

- Information from nonscientific sources (i.e., information that does not exhibit the necessary characteristics for scientific validity and reliability) is not an adequate substitute for scientific information although it may be used to supplement scientific information.

Common sources of nonscientific information include:

- i. Anecdotal information.
Observations that are not part of an organized scientific effort.
- ii. Nonexpert opinion
- iii. Hearsay
Information repeated from communication with others.

WAC 365-195-910

Criteria for Obtaining the Best Available Science

- Suggests consulting with state and federal natural resources agencies and tribes to develop scientific information and recommendations.
- If an entity compiles scientific information it should assess whether the scientific information constitutes the best available science using the criteria in this ordinance and any technical guidance provided by the department.

WAC 365-195-915

Criteria for Including the Best Available Science in Developing Policies and Development Regulations

- To demonstrate that the best available science has been included in the development of critical areas policies and regulations, entities should address each of the following on the record:
 - (a) The specific policies and development regulations adopted to protect the functions and values of critical areas at issue.
 - (b) The relevant sources of best available scientific information included in the decision-making.

- (c) Any nonscientific information used as a basis for critical areas policies and regulations that depart from the recommendations derived from best available science.
 - If an entity departs from science-based recommendations it should
 - (i) Identify the information in the record that supports its decision to depart from science-based recommendations.
 - (ii) Explain its rationale.
 - (iii) Identify potential risks to the functions and values and any additional measures chosen to limit the risks.
- Entities should include best available science in determining whether to grant variances and exemptions from provisions in policies and development regulations protecting critical areas.

WAC 365-195-920

Criteria for Addressing Inadequate Scientific Information

- Entities should take the following approach when uncertainty exists regarding which development and land uses could harm critical areas due to a lack of valid or incomplete scientific information.
 1. Precautionary approach
 - Activities are strictly limited until uncertainty is resolved
 2. Use an effective adaptive management program that relies on scientific methods to evaluate how well regulatory and nonregulatory actions achieve their purposes. Management, policy and regulatory actions are monitored and evaluated to determine if they are effective and if not determine how to increase effectiveness.

WAC 365-195-925

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

- In addition to the requirement that cities and counties include the best available science when developing policies and management decisions, entities must give “special consideration” to conservation or protection measures necessary to preserve or enhance anadromous fisheries.
- The entity must include in the record evidence that it has given “special consideration” to conservation or protection measures using the criteria in the ordinance to ensure these measures are grounded in the best available science.
- These measures include measures that protect habitat important for all life stages of anadromous fish.
- Special consideration should be given to habitat protection measures based on best available science relevant to stream flows, water quality and temperature, spawning substrates, instream, structural diversity, migratory access, estuary and nearshore marine habitat quality, and the maintenance of salmon prey species.

Appendix C

Notes and Additional References on Agricultural Production Values

Appendix C

Notes and Additional References on Agricultural Production Values

Livestock and Direct Products

The following outlines how the calculations in the above summery tables (and other more detailed spreadsheets) were made. The discussion is by each livestock animal or commodity (milk production). The methodology is much the same between each. As a result, once the process is explained, only differences between the basic approaches will be noted.

Sheep

Value of sheep and lambs sold and slaughtered is determined by taking the state level year end inventory (obtained from Washington State Department of Agriculture statistical publication, see references below) and dividing that into the number of sheep and lambs sold or slaughtered (including farm slaughter) times the estimated inventory of animals at the county level. County level inventory is based on U.S. Department of Agriculture's 97 Census of Agriculture estimated inventory of sheep and lambs at the individual county and state level. The percentage change in inventory at the state level from year to year is then taken times the base 1997 county inventory to arrive at the estimated number of sheep and lambs sold or slaughtered at the county level for a particular year.

Example – Benton – 1998

Lambs/sheep sold or slaughtered at the state level: 61,300
Final inventory of sheep and lambs at the state level: 50,000
 $61,300/50,000 = 1.23$ number of animals sold or slaughtered to base year inventory
 $50,000 \text{ year end } 1998 \text{ inventory} / 53,000 \text{ } 1997 \text{ year end inventory} = 0.9437$
decrease in inventory 1997 to 1998
 $1208 \text{ } 97 \text{ year end inventory for Yakima County} \times 0.9437 = 9857 \times 1.23 = 1,397$
sold/slaughtered in 1998

The next step is to determine average price per animal. This was accomplished by taking the gross income for the year in question and dividing it by the total number of sheep and lambs sold or slaughtered. All dollar values are adjusted to 2000\$ using the Gross Domestic Product implicit price deflator.

For Yakima and Kittas counties updated inventory data were used (Livestock Rankings, Washington 1999). In this case, the 1999 inventory data was as of January 1, 1999, or in effect December 31, 1998. So these numbers were used as the basis of inventory for 1998. And then the same process employed, as previously described, to modify the year-end inventory figures and to estimate the number of animals sold or slaughtered.

Sources:

Washington State Department of Agriculture. Sheep and Lambs.
<http://www.nass.usda.gov/wa/annual01/sheep01.pdf>. (Accessed June 30, 2002).

United State Department of Agriculture. Livestock Rankings, Washington. 1999. National Agriculture Statistical Service (NASS).
<http://www.nass.usda.gov/wa/counties/lvstrank.htm> (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Skagit County, Washington. National Agriculture Statistical Service (NASS).
<http://www.nass.usda.gov/census/census97/highlights/wa/wac029.txt> (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington. National Agriculture Statistical Service (NASS).
<http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt> (Accessed June 30, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP.
http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27, 2002).

Cattle and Calves

A similar process was employed for cattle and calves as for sheep and lambs. In this case, we had an inventory of all cattle for each of the four counties effective January 1, 1999. These numbers in effect became our year-end numbers for 1998 and then adjusted by the process previously described. Total income was derived in the same manner and expressed in 2000\$.

Sources:

Washington State Department of Agriculture. Cattle and Calves.
<http://www.nass.usda.gov/wa/annual01/cattle01.pdf>. (Accessed June 27 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP.
http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002).

Hogs and Pigs

Again, a similar process was employed for hogs and pigs as for sheep and lambs. The 1997 Census of Agriculture was used for Benton and Skagit counties and adjusted across 1998 to 2000 based on changes in state level data for those years. For Yakima and Kittas counties we had farm inventory data for December 31, 1998 and used this data to scale for these two counties. In this case, we had inventory of all cattle for each of the four counties effective January 1, 1999. Total income was derived in the same manner and expressed in 2000\$.

Sources:

Washington State Department of Agriculture. Hogs and Pigs.
<http://www.nass.usda.gov/wa/annual01/hogs01.pdf>. (Accessed June 27 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP.
http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Skagit County, Washington.
<http://www.nass.usda.gov/census/census97/highlights/wa/wac029.txt> (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington.
<http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt> (Accessed June 30, 2002).

Milk Production

For milk production (total market value all products), the 1997 Census of Agriculture was used to determine the total number of milking cows for Benton and Kittas counties. These values were then scaled, as previously described, employing state data. For Skagit and Yakima counties data that are more recent existed for the inventory of milk cows in these counties. The inventory date was as of January 1, 1999, or effectively December 31, 1998. These values were employed for 1998 and then scaled as previously described using state data.

The value of milk production per cow is determined by dividing the value of milk produced (inclusive of all mile products) by the average annual number of milk cows in Washington State. These values (per cow) were then multiplied by the estimated inventory of milk cows in each county.

Sources:

Washington State Department of Agriculture. Manufactured Dairy Products.
<http://www.nass.usda.gov/wa/annual01/milkpr01.pdf>. (Accessed June 27, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP.
http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27 2002)

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Benton County, Washington.

<http://www.nass.usda.gov/census/census97/highlights/wa/wac003.txt> (Accessed June 30, 2002).

United State Department of Agriculture. 1997 Census of Agriculture. Highlights of Agriculture: 1997 and 1992. Kittas County, Washington.

<http://www.nass.usda.gov/census/census97/highlights/wa/wac019.txt> (Accessed June 30, 2002).

**Methodology Employed in Deriving
Farm Gate Value for Orchard and Crops for
Benton, Kittas, Skagit and Yakima Counties
1998 – 2000**

Field Crops and Orchards

Field crops information for the four counties was obtained from the U.S. Department of Agriculture (USDA), National Agricultural Statistical Service's (NASS) on-line database. Values for the following crops were available for 1998 to 2000: barley, all; beans, all dry edible; beans, pink; beans, pinto; beans, small red; bean, small white; beans-dry edible, white, small flat; corn for grain and silage; green peas for processing; hay – alfalfa (dry), all (dry) and other (dry); oats; potatoes, all; sugar beets; wheat, all, other spring, and winter all. These data were used directly in the table.

Data for orchard crops for acres planted was available only for 1997. The assumption was made that these acreages would not materially change as far as productive acreage between 1998 and 2000. Thus, 1997 acreage values were used for orchard crops (1998 to 2000) unadjusted. However, it is acknowledged that there have been major changes in the apple industry over these years. Unfortunately, updated information by county reflecting these changes was not available.

Prices and values per acre (when yields per acre were not available for some crops) were determined using Washington State Department of Agriculture statistics for each year in the analysis. All dollar values are adjusted to 2000\$ using the Gross Domestic Product implicit price deflator.

Sources:

U.S. Department of Agriculture. National Agriculture Statistical Service (NASS). Published Estimates Data Base – County Washington Crops Grouping – Benton, Kittas, Skagit and Yakima Counties. <http://www.nass.usda.gov:81/ipedb/>. (Accessed June 30, 2002).

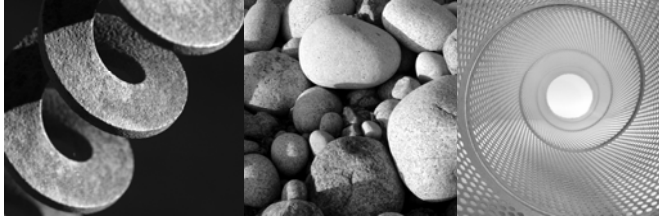
U.S. Department of Agriculture. National Agriculture Statistical Service (NASS). 1997. Orchard Rankings, Washington. <http://www.nass.usda.gov/wa/counties/orchrank.htm#appl>. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2001. "Top Forty Agricultural Commodities, Washington." Washington 2001 Annual Bulletin.
http://www.nass.usda.gov/wa/annual01/top40_01.pdf. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2002. Fast Facts. Latest Crop, Livestock and Economic Estimates for Washington. <http://www.nass.usda.gov/wa/>. (Accessed June 30, 2002).

Washington State Department of Agriculture. 2002. Washington Agri-Facts. <http://www.nass.usda.gov/wa/agri2feb.pdf>. (Accessed June 30, 2002).

United States Department of Commerce. Bureau of Economic Analysis. Gross Domestic Product (GDP) and Implicit Price Deflator of GDP.
http://www.info.gov.hk/censtatd/eng/hkstat/fas/nat_account/gdp/gdp1.htm (Accessed June 27, 2002).



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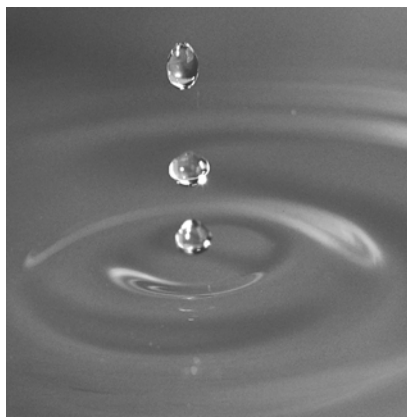
Efficacy and Economics of Riparian Buffers on Agricultural Lands - State of Washington Phase II

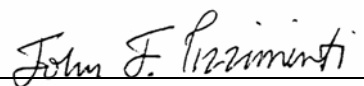
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Executive Summary

This Phase II Report is an extension of the work done in Phase I. In Phase I, we examined the scientific literature of riparian buffers on agricultural lands. Best available science validates the importance of riparian habitat for fish and wildlife, but it does not validate the State Caucus proposal that wide fixed-width riparian buffers should be mandatory on all agricultural streams in the State of Washington to protect listed salmon. The GEI Phase I Report is available by request from the Washington Hop Growers Association. We reprint the Executive Summary of the Phase I Report herein (Appendix I) for the convenience of readers without copies at hand. We also reprint a review publication of the Phase I work delivered by GEI at a National Riparian Conference in 2004 (Appendix IV).

Since Phase I was complete we received comments on the report and found new scientific literature relevant to protecting Washington's critical areas. Buffers are one means of protecting the states watersheds and fish from agricultural impact. But many other scientifically tested methods recommended by the USDA Natural Resource Conservation Service are also important and may be more effective and cost-effective than mandatory fixed width buffers. These are commonly known as "Best Management Practices" on the farm. Phase II addresses "Best Management Practices" (BMPs) including the use of riparian buffers, which is one BMP.

In summary, Phase II has three components: (1) a review of agriculture BMPs (2) a review of additional scientific literature on effectiveness of buffers and other BMPs and (3) suggested approaches for applying BMPs including riparian buffers in Washington agriculture. Two additional appendices support these as follows: Appendix II includes detailed reviews of additional Scientific Literature supplied by NOAA Fisheries and other scientists and agencies; Appendix III is a suggested model county ordinance that can be adopted for meeting Washington Growth Management Act to protect Critical Areas. That ordinance, based on the Phase I and II reports, suggests a specific range of riparian buffers between 25 and 60- feet contingent upon employment of other BMPs, slope (gradient) and local precipitation. The ordinance is intended to be broadly "protective" of all ecological and water quality functions of buffers. Because significant economic aspects of buffer prescriptions must also be considered as well as special natural resource conditions, the ordinance provides an exemption process for the local county government for exceptional circumstances.

SECTION 1

Introduction

Authorization and Purpose of Phase II

In 2002, GEI Consultants, Inc. (GEI), Pacific Northwest Project (PNW) and Mason Bruce and Girard (MBG) prepared a report entitled Efficacy and Economics of Riparian Buffers on Agricultural Lands, State of Washington, Phase I. This report responded to a request to review the scientific and economic merits of riparian buffers various dimensions in discussion by the Washington Agriculture and State Caucuses. The study was funded by a grant from Washington Department of Agriculture to the Washington Agricultural Caucus. The Caucus was formed in response to the Washington Department of Fish and Wildlife and the National Marine Fisheries Service recommendations for relatively wide mandatory buffers on all agricultural land in Washington in their Options 2 and 3 proposals. Their recommendation called for buffers 75-200 feet wide similar to criteria that had been adopted for harvest of timber. This raised serious economic questions for the agricultural community.

In addition to reviewing the scientific basis for the buffer recommendation provided by the agencies, GEI collected economic data from the State and from several counties for input into a peer-reviewed widely accepted economic model (*Implan*). The economic analyses suggested that to implement the agency proposals, assuming only 75-foot wide buffers, would cost between 190,000 and 240,000 dollars per one hundred acres. Agency suggestions during the Ag Fish Water Caucus included even wider setbacks than seventy-five feet if their Option 3 were to be mandated. Cost does not speak to the efficacy of buffer width function or protection of fish. But it does speak importantly to the reality that over-prescription of buffer requirements could be very costly to Washington's farm economy. This gave impetus to find specific scientific data and experiments that would speak to the relationship between buffer width, agricultural impact and fish habitat protection under the Growth Management Act.

We circulated the Phase I Report to interested parties. In a series of meetings, we presented the findings and the report to (1) state and federal agencies including the State Caucus and Ag Fish Water caucus (2) interested elected officials including key Committee Chairs in the Washington Legislature, (3) county planners and Commissioners that are preparing critical area ordinances to meet Growth Management Act provisions to protect sensitive or listed species of plants, animals and their habitats (4) national and regional scientific and legal conferences on riparian buffers and (5) to the agricultural constituents who may be affected by new regulations or ordinances.

Best Management Practices

In this Phase II Report, we review agricultural methods recommended by USDA Natural Resource Conservation Service that provide measurable protection from agricultural impacts. These are published in technical papers called FOTGs (Field Office Technical Guides, <http://www.nrcs.usda.gov/technical/efotg/index.html>). FOTGs include a variety of agricultural land and water use practices that reduce impact of agriculture on natural resources commonly known as Best Management Practices or BMPs. We also address how BMPs can lead to (1) increased protection of salmonid and riparian habitat, (2) willing participation by the agricultural community, (3) economically viable incentives for improvements, (4) scientifically valid applications, and (5) a means to monitor and evaluate results.

Review of Additional Scientific Literature in Phase II

The Phase I report examined all of the publications that were then provided by the State Caucus as supporting their Options 2 and 3 for 75-foot and 200-foot wide buffers on all agricultural lands in Washington. We summarized the scientific findings of those publications in Appendix A of the Phase I Report. The complete Phase I Report was available for a time on the Washington Department of Agriculture's website. The literature provided by the State Caucus was not synthesized, meaning the State Caucus did not show how the literature demonstrated scientific support for specific buffer widths for any specific agricultural condition. Washington supports a diverse agricultural mix of production that is as varied as the natural landscape. This presents an enormous analytical challenge to assess buffer-width functions and needs on all agricultural lands. Nonetheless, we reviewed the literature provided. The majority of the science was based on timber harvest (i.e. silviculture not agriculture). An important observation in Phase I was the differences in environments and impacts between agricultural and timber practices.

In addition to the literature provided by the State, an additional 126 research reports were reviewed and summarized in Phase I. We focused on agricultural experimental data with controls and various buffer-widths to understand the relationship between width and the measured impact or function. We gathered this information by presenting our Phase I findings at major riparian conferences and soliciting information from researchers therein. These included The 8th North American Agroforestry Conference: Agroforestry and Riparian Buffers for Land Productivity and Environmental Stability in Corvallis, Oregon June 23 –June 25, 2003; the American Water Resources Assn (AWRA), Riparian Ecosystems and Buffers Conference: Multi-Scale Structure, Function, and Management, June 28-30, 2004, Olympic Valley, CA. A copy of the AWRA publication is included (Appendix IV). We sought and received comments; some were in writing, some official

and some personal communications. We have learned much from those comments and dialogues.

Agriculture research focuses primarily on prevention of transport of sediment, chemicals and nutrients into streams. Ecological considerations of stream habitat: shade, organic input and bank stabilization, are generally not addressed by agricultural science. Thus in all there are six ecological functions of buffers: sedimentation, chemical (e.g. pesticide), and nutrient transport; bank stabilization, shade and organic input. Riparian science also focuses on benefits of terrestrial habitat conservation; however that is not the goal of the GMA or this research. Thus in Phase II, we emphasized review of the science of aquatic ecological function (Appendix II).

Regulatory Issues

Washington's Growth Management Act (RCW 90.58.020) includes provisions for local "critical area" ordinances to protect sensitive habitats and species in their jurisdictions. An issue that has arisen is whether fixed-width buffers should be mandatory in these areas and if so, what widths should be prescribed. Skagit County for example has developed an ordinance with 35-foot wide buffers. In order to assist counties that have not yet complied with GMA, we have developed a model for such critical area ordinances that may be helpful to planners in this process (Appendix III).

SECTION 2

Best Management Practices

Why BMPs

There are two important but unanswered questions from Phase I about protecting salmon habitat on agricultural lands: the first is whether buffers are the only treatment available to address agricultural impacts where they do occur; and secondly, given substantial costs of mandatory fixed-width buffers, are there more cost-effective approaches or prescriptive remedies available to agriculture. Scientific logic and the literature both confirm that a variety of solutions may be needed given the highly diverse set of conditions depending on location and type of agriculture.

The agricultural industry has a long history of developing and employing BMPs. As a general definition, BMPs are specific measures taken within an agricultural sector that (1) are developed through scientific review and on farm field trials, (2) are economically reasonable either through subsidies or via improved agricultural production or efficiencies and (3) contemporaneously reduce impacts to other natural resources. Many BMPs have their own economic incentive, i.e. farm management improvements that can benefit an operator's "bottom line," while reducing other types of resource impacts. Examples would include animal waste management plans, improvements to irrigation efficiency technologies, and monitoring practices for selective pesticide applications such as integrated pest management programs. Reducing use of water, pesticides, nutrients and their runoff makes good economic sense as well as ecological sense. Other "ecological issues" involve the protection of instream physical habitat – allochthonous (external) inputs like wood, leaves, and animal matter; bank and channel integrity and diversity; and energy exchange, primarily solar radiation. Before reviewing BMPs, we review the potential for impacts to salmon from agriculture. We then follow this up with a description of proven BMPs including the use of buffers

We describe two potential categories of agricultural impacts: water quality impacts, mostly from runoff, and ecological impacts, mostly from loss of riparian vegetation.

Water Quality Impacts

Within Washington State, identification of agricultural impacts to streams is largely based on water quality assessment conducted as part of the 303d list review, administered under the federal Clean Water Act (Washington Dept. of Ecology, 2002). Several water bodies that are included on the [303d] list of limited water quality streams pass through or adjacent to major agricultural production lands and operations. While several different

types of water quality impacts are noted—some related to agricultural production and some not—the more commonly recorded impairment problems are related to sedimentation, high concentrations of fecal coliform and nitrates, and higher water temperature levels.

The Natural Resources Conservation Service (NRCS, 1997) and the U. S. Environmental Protection Agency (2002) have prepared comprehensive reviews of potential impacts to water quality caused by agricultural practices. The primary impacts where they occur can include sedimentation, nitrates and phosphorus, animal wastes, and pesticides as follows:

Sedimentation, or excess fine sediment in rivers comes from excessive rates of soil erosion. This comes from removing rooted vegetation and soil manipulation, especially on steep slopes. Combined with runoff from rainfall or excess irrigation, sedimentation can increase water turbidity, smother important food chain organisms and fish eggs on the stream bottom. Soils also provide an adhesive medium for some types of farm chemicals carrying them into the stream network.

Animal waste impacts to water quality include the introduction of bacteria, viruses, and other microorganisms, and ammonia and oxygen-demanding substances. Anoxic or anaerobic conditions can occur causing harm to aquatic life, and high concentrations of fecal coliform and other bacteria pathogens can contaminate aquatic food sources or water supplies.

Nitrate and phosphorus can degrade water quality through eutrophication, excessive production. This increases levels of algal or plant production followed by high levels of decaying organic matter that then depletes oxygen levels.

Pesticides can enter water bodies through agricultural water run-off or return flows. Pesticides can affect salmon reproduction and if concentrated, kill important stream microorganisms.

Ecological Impacts

In addition to removing the filtration and absorption characteristics from riparian vegetation, other impacts to stream habitat can come from removal of streamside vegetation itself. There are three categories of potential ecological damage: (1) the loss of the vegetation reduces shading (increases thermal loading); (2) decreases organic input into the stream including nutrients and insects and other animals that serve the aquatic food web plus the loss of large wood for physical habitat; and (3) and reduces bank stability which degrades the channel and destroys habitat.

Shade from vegetation is considered an important ecological aspect of protecting streams from large diurnal swings in temperature and from excessive temperature loading.

However, detailed thermal models with data may be needed to assess basin specific benefits. Excess sunlight can also favor excess growth of algae to the detriment of other aquatic producers. This can increase or decrease the total productivity of the stream and change biotic diversity.

Organic Input from riparian forests falls into several categories including large wood, fine organic material, and prey species such as aquatic and terrestrial animals (primarily insects) that use riparian vegetation.

- Large Woody Debris (LWD) falls into streams and provides physical structure for aquatic organisms to live in, on or around. It also provides physical habitat, respite from current and can protect the stream channel. In our Phase I Report, the research on LWD related to upland forests not agricultural streams. In this report we have reviewed work by McDade et al that suggests 10m buffers in mature hardwood provides the majority of LWD found instream. The primary correlate of instream presence was not slope but height of the trees.
- Fine Organic Input such as leaves and small branches from outside the stream, (allochthonous material) powers the aquatic food chain. It provides food for bacteria and other microorganisms that themselves become food for larger organisms. When riparian vegetation is removed, more light reaches the stream stimulating increased algal growth which also energizes the food web but in different ways. We explore the ecological literature that shows that things change with some riparian removal, but not always for the worse.
- Prey Species such as insects, fall into the stream from the leaves of riparian vegetation. Removal of the vegetation reduces the load of insects falling into the stream. The loss of this food source may be compensated by other changes in the stream.

Best Management Practices to Prevent These Impacts

The question of what is needed to protect salmon and salmon habitat on agricultural lands in Washington is a complex one because of the diversity of that landscape and the issues. For example, are the potential impacts from grazing the same as farming row crops or wheat? And is one grazing operation the same as all grazing operations? What do dairy farms on the very wet Pacific coast have in common with irrigated fruit orchards east of the Cascades? The scientific literature and common sense suggest it is important to consider the types of impacts relevant to the different types and locations of agriculture.

The Washington agricultural BMP list includes various Natural Resource Conservation Service (see Bibliography) methods including tillage, use of cover crops, integrated pest management, precision applications for fertilizers and pesticides, and improved irrigation systems that reduce water use, erosion, and return flows. The most direct way to prevent

degradation of water quality is to prevent it rather than filter it. The most direct way to prevent physical degradation is to keep animals out of streams or severely limit their access. The use of fencing and creating buffers can help address both water quality and ecological impacts. Additional discussion of ecological issues is found in Section 4, Review of Best Available Science.

Strict and enforceable regulations exist for concentrated animal industries including dairies, feedlots and the measurable criteria for manure application. These are practical, solution-oriented approaches that have measurable benefits to aquatic resources and listed fish. Livestock industries can, and are, improving salmon habitat primarily through fencing watercourses or otherwise controlling animal waste, access and damage. State and federal monies help NRCS administer and provide incentives for voluntary enrollment in these programs.

Riparian Vegetation to Filter Runoff and Stabilize Banks

As described in the Phase I Report, riparian buffers can be used to protect water quality and enhance aquatic habitat. The buffer design should vary depending upon site-specific conditions and farm production practices. Best Available Science is not “one size fits all.” This over simplified concept has been criticized directly in the scientific literature (see Phase I Report) as not consistent with the data or the problems encountered because of the same reason all clothes do not come in one size or style. The agricultural research literature identified in Phase I and augmented in Phase II is replete with controlled experiments that show relatively narrow buffers often remove the majority of chemicals, nutrients and sediment in the first 30-60 feet. Most of the benefits occur in the very initial widths of the buffer. Additional literature reviewed in Phase II reinforces these conclusions.

Appendix II contains the following papers that support relatively narrow buffers of 10 m or less to contain the majority of runoff or direct input of contaminants from sediment, nitrogen, phosphorus, pesticides and manure, and provide large woody debris. (Arora et al, 1996, 1998; Lim et al, 1998; Robinson, 1996; de Snoo et al, 1998; McDade et al, 1990.) Other papers investigated other “phenomena” but either could not derive buffer width recommendations or had flaws in their designs that could not adjudge “effective-width”. Lowrance et al., 1997 showed a 50-60 m buffer effectively removed the majority of herbicide however the outer “grassy 8 m” portion removed the greatest amount per unit area – a total of 58%. It was five times more effective than the remaining 50 meters. Osborne and Kovacic (1993) emphasized the importance of economics and cost-effectiveness for acceptance of BMPs by agriculture. Wenger (1999) made global recommendations for buffers of 15-30 m wide plus a factor for slope but without consideration of cost vs. benefit. He acknowledged the highly variable response of varying practices and landscapes.

Filter strips, site-specific fencing, sediment control structures, stream-bank stabilization, and wetlands, are valuable measures to filter runoff and/or stabilize banks. If other BMPs are employed such as slope management, contouring, avoiding use of steep slopes, and proper irrigation techniques, it may reduce the design width for buffers needed for water quality protection. FOTGs (Field Technical Office Guides of NRCS) for each of these types of problems have been developed by NRCS and are detailed in FOTG Section IV (<http://www.nrcs.usda.gov/technical/efotg/index.html>). Washington Department of Ecology lists many similar measures that include buffers but go much further (www.ecy.wa.gov/programs/wq/wqguide/corridor.html).

Improved Livestock Management

With livestock, simply limiting the amount of time or access to the stream and streambank delivers huge benefits. And rooted vegetation along the margin high water mark stabilizes the banks from excessive degradation. Research shows that if the soil is at least 50% covered with vegetation, streams are largely protected (Mosley et al, 1999). Additionally, herbaceous vegetation is often more protective than woody vegetation as the tiller density and root mass is far more protective of topsoil than tree roots (see Nanson and Hickin, 1986 reviewed herein). It is good science as well as good economics when we match the extent of vegetation needed to local geographic and agricultural use conditions especially on-site slope and soil conditions. Careful consideration of the erosion potential of various farming practices, and adoption of BMP techniques that reduce erosion, can help limit stream sedimentation and preserve fish resources.

A review of technical sources that assess the impacts of grazing on riparian habitat and salmonid populations uncovered a range of observations surrounding the magnitude of impacts. This range results from varying study attributes and methods, physical settings, and empirical factors. What is apparent is that grazing impacts are highly dependent on site conditions and the types of grazing management practices that are employed.

Balsky et al. (1999), Ehrhart and Hansen (1997), and Platts (1991) summarize much of the technical literature describing the impacts of livestock on riparian ecosystems. It is observed that livestock grazing can affect the riparian environment by changing, reducing, or eliminating vegetation, and by impairing riparian areas or water quality through channel widening, channel aggradation, or increased sedimentation. Sediment fills pools, smothers gravels and destroys food production important to spawning and early life history stage habitat (Platts 1991).

Concern for grazing impacts has led researchers and managers to identify grazing strategies that can be compatible with healthy riparian ecosystems (Ehrhart and Hansen 1997, Mosley et al., 1999). Several published reviews discuss strategies for riparian

grazing that have been found to be effective in maintaining riparian health. Some strategies include the use of riparian buffers and more intensified land and grazing management.

In his review of livestock grazing strategies, Platts (1991) rated corridor fencing as a nine on a scale of one to ten with one being poorly compatible with fishery needs and ten being highly compatible. Corridor fencing results in good to excellent streambank stability, excellent brushy species composition, good to excellent seasonal plant new growth, and excellent stream riparian rehabilitation. However, there is little literature that scientifically assesses the width of the fenced corridor needed to provide for healthy riparian habitat in rangeland (Mosley et al. 1999). In fact, narrowly fencing small creeks may resolve many problems that begin in headwaters. We reviewed one experimental paper herein (Lim et al, 1998) that showed a 20 ft buffer would arrest all nutrients and pathogens from grazing cattle.

Relative to fecal coliform impacts on water quality, minimal buffer zones may be adequate. In the literature review done by Mosley et al. (1999), they cite Doyle et al. (1975) and Oskendahl (1997) for their recommendation that a buffer strip of 12.5 feet on each side of a stream may be adequate to protect water quality from coliform bacteria and effectively filter nutrients. The Chemicum Creek example (see Jefferson County Section 3) is an example of a narrow buffer improving fecal coliform contamination in a western Washington dairy area.

A number of measures other than corridor fencing have been evaluated that can improve riparian conditions on rangelands. Ehrhart and Hansen (1997) investigated cattle grazing practices that were compatible with healthy riparian ecosystems in Montana. They did this by inventorying a number of pastures that had healthy riparian areas and then interviewing the landowner or manager to determine how cattle were managed in that pasture. They found that what operators did to encourage livestock not to loiter in the riparian zone, while in a pasture, was more important than either season of use or length of time in the pasture per se. With proper management under specific conditions, many pastures containing a variety of riparian types may be grazed in various seasons and for various periods of time without adversely impacting the health of the riparian area (Ehrhart and Hansen 1997).

One quantifiable factor noted by Ehrhart and Hansen (1997) was that many of the healthy riparian pastures also contained alternate water sources off of the stream. The second theme noted by Ehrhart and Hansen (1997) was a high degree of operator involvement. All the operators were actively involved in managing their land and had a keen interest in the condition and trend of their riparian areas. Managers who modified grazing practices and conduct monitoring were successful in maintenance of riparian areas with livestock.

The conclusions of Ehrhart and Hansen (1997) were that riparian grazing might be incorporated into each of the traditional grazing systems, as long as the condition of the riparian zone itself remains of primary concern. They concluded that management, not the grazing system, is the key.

Mosley et al (1999) conducted a literature review of the management of cattle grazing in riparian areas. Like Ehrhart and Hansen (1997), they also concluded that there is not one particular grazing system that can be applied in all situations. They recommend that grazing plans be site specific and based upon the best research available. They have provided several suggestions for a riparian grazing plan:

- Determine the tolerance of a riparian site to grazing and then limit the grazing periods to avoid exceeding the critical period length.
- To increase vegetative density, increase rotational scheduling of cattle grazing.
- To graze a site more than once per growing season, moisture and temperature conditions should be conducive to vegetative re-growth. Grazing more often and for shorter periods is preferable to fewer and longer grazing periods.
- Adjusting timing, frequency, and intensity of grazing in individual pasture units is more important than adopting a formalized grazing system.
- Prevent cattle from congregating near surface waters. Fencing, supplemental feeding, alternative water sources, and herding work best.
- Locate the edges of features where cattle congregate—such as salt grounds, water developments, and winter-feeding grounds—away from surface waters and buffer strips.
- Maintain at least 50 percent protective ground cover along stream banks. Vegetation buffer strips should usually not be necessary to protect banks and reduce impacts from cattle urine and feces unless cattle congregate near surface waters to the point that protective ground cover is less than 50 percent.

Mosley et al. (1999) concluded that the impact of cattle grazing on riparian ecosystems depends entirely on how the grazing is managed. The important variables are timing, frequency, and intensity of grazing. Each situation is unique and requires its own creative, locally tailored solution. The best way to know whether a particular management strategy is suitable for a particular site at a specific point in time is to implement the strategy, and then monitor its effectiveness and adjust the practice as needed.

In summary, careful management and an understanding of the unique conditions that occur in riparian habitat can minimize or eliminate damage to riparian areas from grazing. Because each riparian area is unique, no one grazing strategy fits all conditions. A successful riparian grazing strategy will (1) incorporate sufficient vegetative re-growth, (2) retain sufficient vegetation during high flow periods to protect stream banks (3) control grazing time and intensity, and 4) develop attraction areas for food, water and rest

that reduces access to streams, stream banks and riparian vegetation, with or without the use of fencing. Vegetative cover of at least 50% appears to be correlated with good stream corridor conditions where livestock have access (Mosey, et al 1999). There is little scientific evidence however for recommending specific buffer width recommendations. To the contrary, where even very narrow animal exclusion fences keep them out of the stream, dramatic improvements are obtained (cf. Jefferson County, Section 3).

Animal Waste Management

There exist substantial bodies of technical literature—scientific, academic, and commercial—devoted to animal waste management technologies. Representative sources include Oregon State University, 1993; University of Kentucky, 1997; NRCS, 1996; and Canadian Agri-Food Council, 1996 many of which have been adopted by Washington farm operators. Existing animal waste management practices and technologies can substantially reduce potential water quality impacts. These involve waste containment facilities, pasture management, animal containment and movement strategies, selective fencing and proper utilization or disposal of manure including the time of year manure is applied to fields. Most agriculture is limited to timing of the application of manure (and pesticides) to avoid the rainy or runoff season. The right concentrations and application methods are also important and usually regulated by enforceable regulations. After these BMPs are implemented and where it becomes otherwise impossible to control runoff into streams, it makes sense to consider use of filter strips or vegetative buffers to protect stream water quality and habitat.

The NRCS (1996) has developed an animal-waste field handbook on which local conservation districts and farm operators have relied to upgrade existing waste management systems or design new facilities. The handbook advocates the use of a total system approach, where waste production, collection, storage, transfer, utilization and land application methods are all included within the waste management program. The handbook provides explicit design criteria and applications for all phases of the waste management system, and takes into account different system options for varying local conditions and needs. Technical design and recording forms for the preparation of waste management system plans are included, for use in developing systems, and for documenting system performance for monitoring and regulatory review.

Information tools and expertise in developing new engineering methods for waste management systems are readily available from local NRCS districts. Farm operators rely on the districts to improve waste management systems as well as to monitor for water quality impacts.

In 1996, USDA (1996) researchers interviewed milk producers throughout the West, and determined that commercial dairy operations rely on two primary methods to contain raw

wastes: slurry pits/basins and waste lagoons. The processed wastes from these sources are then transferred for pasture spreading, during periods of the year when low water precipitation is present to avoid run-off and return flow problems. This practice is coupled with manure nutrient analysis, monitored manure application rates based on pasture/crop nutrient uptake capacity, manure incorporation, and maintaining a buffer strip along waterways where no manure is spread. Animal grazing on pastures is monitored and controlled.

Water Management and Efficiency

Water that flows over and through agricultural areas can carry sediments, excessive nutrients, and pesticides to stream courses, thereby potentially degrading water quality in natural systems. Additionally such runoff often carries thermal loading to the stream as heat is transferred by convection from the land to the stream. Irrigation methods that reduce runoff and wastewater management from animal or other farm operations are the first line of defense to reduce water quality problems that adversely affect fish and wildlife. Additionally, if the basin is hydrologically limited by non-agricultural water use practices, these issues should be examined as potential palliative remedies as well. Wherever there are known return flows from agricultural operations, the first step should be avoidance or abatement from the source.

Non-point source runoff from fields and pastures can impact streams and will depend on the specific agricultural practices of pesticide and nutrient application, together with the criteria on slope, soil, precipitation and native vegetation. An important example comes from the Salinas Valley, California (Hunt et al, reviewed herein). One way to deal with these non-point threats is to prioritize both by understanding what problems there are in the watershed and whether the specific conditions on the farm are exacerbating or mitigating for those problems. Thus the first step is an examination of specific local watershed limitations. Existing data from Washington's 23 Water Quality Management Areas (<http://www.ecy.wa.gov/programs/wq/watershed/overview.html>) can provide data on the limiting factors in each basin. Other watershed studies include the NPCC Subbasin Planning Process (<http://www.nwppc.org/fw/subbasinplanning/Default.htm>). The 303(d) list (<http://www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html>) of water quality limited stream segments can also help. The watershed plans then provide areas for local agricultural and community interests to collaborate on voluntary programs and specific BMPs. Focusing efforts and dollars on the right problems and BMPs will be more cost effective than prescribing mandatory remedies everywhere (Personal communication, J.W. Gilliam, North Carolina State University, June 29, 2004).

Problems related to sedimentation, nutrient leaching, and agricultural chemical field losses can result from inefficient irrigation systems or poor water management. The problems are a side effect from field run-off or relative high volume levels of return

flows resulting from over-watering. Consequently, such problems can be directly controlled or substantially eliminated by adopting efficient, on-farm irrigation system technologies and relying on improved water management regimes.

Shade

The thermal condition of a stream or stream segment is influenced mostly by the temperature of water that is entering from upstream (boundary condition). Heating is a gradual process that involves energy exchange mostly at the water surface with direct sunlight providing the largest portion of the heat energy entering the stream. Overheating and the benefit of shade are most important in smaller headwater streams. This is because the rate of heating is affected by the surface to volume ratio. In headwater streams surface is much larger than volume maximizing heating. Evaporation provides the primary means of heat loss. In general, but not always, agriculture occurs in higher order larger streams at lower elevations in Washington. The lower surface to volume ratio and the incoming boundary conditions from the upper watershed limit the benefits shade can provide. Additionally, these higher order streams are much wider and shoreline vegetation cannot effectively shade the surface for as many hours. In Washington, it is more likely riparian vegetation removal from timber harvest in the upper watersheds controls the boundary condition of water entering agricultural parts of the watersheds.

Whether the upstream vegetation removal is from timber harvest, construction of new housing, or agriculture, the effects are the same. Vegetation removal in the upper watershed means spring runoff including snowmelt occurs more quickly exacerbating thermal conditions downstream due to heat accumulation coupled with reduced flows in summer.

For 303 (d) temperature limited streams, it will be important to assess the watershed specific problems as to if and where revegetation can be effective at temperature reduction. As in other impacts to water quality, it is important to understand what are the actual impacts (i.e. data) that must be addressed. If the boundary temperatures and inflows are already out of control as they enter agricultural stream reaches, shading in the agricultural areas may do little remedy the problem. Only a thermal model assessment of the entire watershed can provide an estimate of the thermal benefits of shade. This should be assessed for the upland as well as the lowland areas.

Large Woody Debris

Large woody debris has correlation with salmonid fish habitat and fish abundance as shown in studies conducted mostly in forested environments (cf. Phase I Report). Most woody debris comes from trees near the stream and hence the width of the buffer needed to supply large wood may be smaller than recommended by the State Caucus (see Bilby and Bisson, 1992 in this report). There is a limited amount of research on the benefits of

large woody debris in lowland streams. McDade et al (1990), reviewed herein, showed that the natural hardwoods contribute the majority of LWD to stream within 10 m compared to old growth conifers (forests). The explanatory mechanism appears to be a function of tree height and not slope. Old growth conifers contribute 53% of their LWD vs. 83% from natural hardwoods within 10 m of the stream. Some species of salmon, such as pink and chum salmon may be negatively correlated with LWD (Beamer and Henderson, 1998).

Sedell and Forggatt, (1984, reviewed herein) document the historic loss of riparian forests along the middle reaches of the Willamette River in Oregon. The trees were harvested for fuels; drowned logs were removed for improved navigation; berms and dams were built for flood control to benefit agriculture and urban growth. As a result, the natural riparian condition disappeared over a 150-year period of development. No data however are presented to assess its functional relationship to salmon numbers or their habitat or how to mitigate for such “channelization”.

Large wood was removed historically for navigation and is still capable of creating problems for navigation. It also exacerbates flooding in lowlands for both agriculture and developed areas because of logjams that occur in river bends, at bridges, culverts, dams and wherever the stream or its banks have been modified for development. Thus the public acceptability of the historic condition of larger amounts of woody debris in lowland and navigable streams must also be addressed even if LWD is beneficial to fish.

Currently there is a need for better documentation that more LWD in agricultural areas would actually measurably benefit salmon. Some species and life history stages of salmon need structure and LWD can provide it. Research is needed on how much is needed and where. Also, other forms of structure exist in streams and may be functionally good surrogates. Research may answer where and how to artificially augment large wood or surrogates for large wood in specific areas and taking potential hazards into consideration. For now, Best Available Science does not support the concept that LWD recruited from riparian buffers in agricultural lands is either necessary or sufficient to restore salmon. The literature shows that some species of salmonids are more likely to congregate near structure (Beamer and Henderson, 1998) and LWD can be one form. Not only is more research is needed but importantly, the potential for conflicts regarding navigation, culverts, flooding and other hazards of LWD that conflict or add O&M costs to other uses in those environments will need resolution in public forums.

SECTION 3

BMPs Practiced in Washington

History of farming practice has demonstrated that BMPs, and government programs that support them, have been modified and improved over time in response to field experience, monitoring results, and technological advances. This is consistent with adaptive management approaches, where resource management actions are developed, tested, and modified through results. The end objective is to improve farm production, limit external impacts, and stabilize or even enhance farm production economics.

For example, the efficiency gains obtained from new water application systems—such as low pressure, direct application machines and methods—reduce return flows to less than 5 percent of the consumptive use, making return flows empirically not measurable (Benton County Water Conservancy Board, 2004 efficiencies application table). With these water application rate efficiencies, field run-off becomes nonexistent or is reduced to insignificant levels.

Farm operators in Washington routinely adopt irrigation efficiency improvements as economics allows. The past few decades have witnessed significant improvements in production per acre and water application efficiencies have improved as well. For most crops and areas in Washington, water efficiency improvements have ranged between 10 to 25 percent per acre of production. As a west-side average, over 50 percent of the irrigated farms have made some type of changes to water application efficiency during the 1990-1995 period (ERS-USDA 1997; Pacific Northwest Project 1998). Improvements to irrigation technology include adoption of pressurized sprinkler irrigation systems; low-impact, energy-precision application systems; pumping plant and distribution line improvements; and drip irrigation system technologies where cost-effective.

On-farm changes to new systems and innovations occur during regular technology change cycles—i.e., when existing systems have completed their useful working and financial life and new capital investments are made for replacement systems. Upgrades of application equipment are also regularly made including the introduction of irrigation scheduling systems that respond to changing temperature, weather, and soil moisture conditions. Additional efficiency gains are anticipated in the future as farms continue to cycle through technology changes, and improvements to water application engineering, research, and technology continue.

Other BMPs have less economic incentive to the individual farmers but are of broad benefit to the community. These include protection of air and water quality and preservation of fish and wildlife habitat. Local statutes often protect air and water quality

and hence already afford some ecological protection; for example, there are enforceable regulations for management and use of animal waste and dairy operations discharging to local streams. Fish and wildlife BMP enhancements are supported by tax dollars back to the farmers through federal and state cost share programs managed by Natural Resource Conservation Service (<http://www.fsa.usda.gov/dafp/cepd/crep.htm>) and state agencies. The technical and economic benefits of specific BMPs are tested, proven and communicated in series of technical bulletins by NRCS known as Field Office Technical Guides of FOTGs that are used to meet funding or compliance guidelines. (<http://www.nrcs.usda.gov/technical/efotg/index.html>). These guidelines are voluntary but are generally required to obtain funding for USDA subsidy programs such as Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Wildlife Habitat Improvement Program (WHIP) etc.

Current on-farm management practices, either already adopted or being implemented in Washington place great emphasis on dealing with animal wastes and improving water delivery and application system efficiencies/management. These management measures seek to protect water quality, improve crop production and quality, and reduce farm operation costs. Some of these measures are reviewed below. In addition to cataloging a broad range of potential agricultural production impacts to water quality in their technical reports, the NRCS (1997) review devotes considerable attention to several key methods and management options available to reduce water quality impacts. These management options are relevant to Washington agriculture and are summarized below.

Soil Erosion and Sedimentation Control

- Water efficient application systems and management for irrigation—using new irrigation system technologies and direct irrigation management.
- Crop rotations and cover crops—improving soil conditioning and texture.
- No-till or conservation tillage practices where viable—reducing tillage activity that can cause erosion.

Keeping Nitrogen and Chemicals out of Streams

- Water efficient application systems and management for irrigation—reducing over-watering practices that can force nitrates into groundwater sources, and reducing irrigation to limit unwanted surface runoff return flows. Efficient water management also pays a double bonus is that less water is used leaving more ground or surface water intact; and less runoff will reduce thermal loading.
- Crop monitoring for nitrogen pick-up rates and optimal applications—efficient application rates should be tailored to actual crop needs. There is economic incentive to this practice as well.
- Crop rotations and cover crops—using crops with high nitrate uptake.
- Contouring slopes away from streams to increase percolation and reduce runoff.
- Avoiding tillage of steep slopes.

- Application of soil amendments after the natural runoff season (rain or snowmelt).
- Vegetative filter strips—applying on-ground, grass “filter” strips adjacent to streams to catch limited run-off from storm events. Such filter strips can serve as tractor “turn-arounds” for certain types of agriculture and be a double benefit.

Animal Waste Management

- Efficient pasture management and field rotations for livestock—reducing animal waste concentrations in fields and near stream areas.
- Adequate containment and control measures for waste management—using animal waste storage basins to control seasonal run-off problems. Washington dairy farms are strictly regulated and enforced for manure containment and use.
- Water efficient application systems and management of irrigation—reducing runoff.

Pesticide Field Losses and Residues

- Compliance with recommended application rates—ensuring that approved label mixing and dose levels are followed, along with application under appropriate conditions. Pesticide use is strongly regulated by US EPA guidelines. It is unclear whether violations are common or enforced in Washington.
- Careful monitoring of crop conditions and optimal use of pesticides—improving pesticide application timing to reduce application rates.
- Integrated pest management methods where possible including use of natural substances and pest resistant strains
- Water efficient application systems and management for irrigation.

Water Diversion and Distribution Systems

- Water diversion facilities are screened and approved by the WDFW. Many facilities have been inspected, and diversions not approved by WDFW are being brought into compliance.
- Pumping plants are being retrofitted with multi-speed drives and computer monitoring to enhance energy and water-use efficiency.
- Many distribution systems are closed, pressurized systems, with virtually no water transmission losses. The open systems are currently being evaluated for upgrades to reduce water loss.
- All distribution systems provide for metered water use estimates, or engineering estimates of water use based on power-use record data, known system flow rating curves, time recorders, and university approved crop duties.

Water Application Systems and Efficiencies

- Within production agriculture, conventional standards for crop water-use are being met or exceeded. Standards are established by the Washington State University crop water use requirements 1991 edition and technical appendices

(also known as the WSU Irrigation Guide.). Water use is measured in annual inches of consumptive use and evapo-transpiration by crop and microclimate area.

- On-farm water efficiency application rates for production agriculture averages about 75 to 80 percent across varying technologies. Within the next technology change-cycle period—about 10 to 12 years—90 percent of all irrigation efficiency rates will be at 85 percent or higher.
- Drip irrigation and precision irrigation systems are being introduced where crop types and technology allow (60 to 70 percent of available areas). Within 10 to 12 years, full application capacity will be achieved.
- Approximately 70 to 80 percent of the application systems rely on pressurized application technologies.
- For approximately 50 to 60 percent of the irrigated acres, soil moisture sensors and probes are employed for monitoring water needs. The data are reviewed jointly with real-time weather forecast data to establish daily, and near-term, irrigation schedules.
- For 90 percent of tree fruit crops, cover crops are used in the center rows to reduce water evaporation and eliminate any kind of soil erosion.

Active Water Application Research and Development

- Variable rate irrigation practices and new forms of precision application and emitter controls are being developed and tested. They are currently in experimental phases.
- Computer monitoring of irrigation systems for both efficiency and performance measures is being phased in to general production practices. Full monitoring capability will be employed within the next technology change-cycle period, about 10 to 12 years.
- Underground drip application systems are being evaluated for broad commercial applications for some crops. Full commercial employment, where viable and where crop practices allow, will be accomplished within 10 to 12 years.
- New soil conditioning products (“soil soap” or “wet soil” products) are being tested at several farms. Commercial applicability will be determined based on performance and cost-effectiveness.

Water Management and Cultivation-Horticulture Practices

- Cultivation practices such as residue management are used to enhance water infiltration and eliminate soil erosion. The practices are used on about 80 percent of applicable irrigated acreage.
- Water applications (nozzle types) and timing are used to enhance soil texture and structure for specific crops. The Practices are used on about 80 percent of applicable irrigated acreage.
- Water management is used to reduce chemical and fertilizer application rates per acre. It is a component of integrated pest management regimes to improve the effectiveness of biological controls and reduce pest habitats.

Water Management – Fish and Wildlife Programs

- Synergistic projects related to irrigation water management and improvements to fish habitat and rearing grounds are being identified, such as the Yakima River Basin water storage project and the Kennewick Irrigation District. Funding to develop key projects is being reviewed under programs such as the New Water Management Alternative.
- This review of existing applications and the ongoing adoption of efficient irrigation technologies illustrate how important water management has become to Eastern Washington farm operators. The benefits to crop production, on-farm costs, and water quality are not being ignored.

Examples of Washington BMPs and Buffer Recommendations

Yakima Valley

One indirect, empirical measure of how irrigation water delivery and on-farm application systems have increased efficiencies within the Yakima River Basin is demonstrated by river flow improvements under low water-year conditions. In analyses conducted by the Sunnyside Valley Irrigation District (2002), low water-year conditions were compared between the 1970s versus the mid-1990s and 2001. For the August period, Yakima River flows measured at Parker proved to be significantly lower for the 1970s' critical water years than when measured against the mid-1990s and 2001 low flow conditions. Based on these data, flow conditions improved by about 350 cfs (or about 125,000 acre-feet) relative to the prior decades, even with small increases in irrigated acreage within the Valley. Much of this change to low-flow conditions is credited to better on-farm irrigation practices and main delivery system improvements.

During the 1970s, much of the irrigation in the Valley depended on rill, row, or flood irrigation techniques, and some pressurized irrigation systems were in their first stage of development. Little upgrading had taken place to main distribution systems to convert open canals to pressurized mainline systems or by lining canals to reduce water conveyance losses. In the years that followed, pressured irrigation system technologies became the on-farm standard, and several irrigation districts retrofitted canals and pipelines. The Yakima-Tieton Irrigation District completed a major system renovation when an open canal delivery system was converted to a fully pressurized system, reducing conveyance and evaporation losses by an estimated 30 percent. Cumulatively, the on-farm and district-wide upgrades to new water-use efficiency levels appears to making a measurable difference.

Eastern Washington

During the 2001 drought season, key water management and operation practices that had been adopted, or were being adopted, by Eastern Washington farm operators were identified as part of the Washington State Department of Ecology's supplemental water right program (CSRIA, 2005.) These practices cover diversion and distribution systems; application systems and technology; new research, design and development projects; and benefits for fish and wildlife resources.

The Jefferson County, Chemicum Creek Experience

An excellent example of successful narrow buffer zone application in Western Washington is described in the water quality report prepared on the Chemicum Creek watershed (Jefferson County Conservation District (JCCD) 2001). Since the late 1980s, significant improvements to water quality, particularly with respect to fecal coliform counts, are attributed to the implementation of Best Management Practices (BMPs) by local landowners. The BMPs have primarily included improved day-to-day livestock management on pastures and riparian area fencing. The fencing, constructed since 1988 along eight miles of stream, mostly protects the bankfull width of the stream creating a setback zone of about 8 to 20 feet (Personal Communication with JCCD staff, 2002, and JCCD, 2001, Technical Report). The scientific research of Lim et al., 1998 reviewed herein (Appendix II) corroborates these results.

From ongoing analyses, the empirical data indicate a pronounced improvement to water quality conditions. As presented within the JCCD (2001) report, the fecal coliform bacteria counts dropped from over 400 FC/100 ml (GMV) to under 100 FC/100 ml. Fecal coliform concentrations in the Chemicum Creek watershed were lower in 2000 than at any other time since monitoring began in 1988 (Jefferson County Conservation District 2001).

Skagit County, Washington

In response to "critical areas" designations under the state Growth Management Act and Endangered Species Act considerations, agricultural buffer zones are under review in Skagit County. A detailed review of an application of agricultural buffer zones in Skagit County has been prepared by the Skagit County Planning and Permit Center (NRC 2000 Draft), evaluating technical justifications for specific buffer requirements.

The Natural Resource Consultants draft report (NRC 2000 Draft) states that agricultural practices and increased land development, associated with overflow from urban drains and failing septic tanks and drain fields, are likely origins of non-point pollutants that reach the Lower Skagit River system through tributary streams, drainage ditches, and overflow lands. The primary concern appears to be fecal coliform bacteria (from

livestock waste, urban drains, septic tanks, and drain fields). Low dissolved oxygen, ammonia nitrogen levels, and silt deposits are noted as secondary problems. While negative impacts to water quality like sedimentation can affect salmon spawning and rearing habitat, the report states that "...fecal coliform are not relevant to evaluation of salmonid habitat" (Natural Resource Consultants, 2000, p. 12), although concentration of fecal coliforms can be related to oxygen depletion, which can impact to salmon.

The report appears to suggest that the principal limiting factors for salmon production in the Skagit River drainage area are dredging and gravel mining activities, land drainage projects, diking, low summer flows, and stream bank vegetation removal. Considerable emphasis is placed on issues surrounding stream bank stability, sedimentation, sediment transport, and nutrient and chemical loading in streams. Here the report recommends that buffer zones can be used to adequately protect water quality through direct stream bank protection.

The report acknowledges that in many cases the past application of buffer zones has been based on best "professional judgment," and the zones have been most effective for application to well defined, site-specific ecological conditions. Also, much of the science and application of buffer zones has been applied to upland (forest) conditions, not to agricultural lands. In particular, the use of buffer zones for agricultural areas in the Pacific Northwest is very limited, thus yielding little empirical data from which to base management decisions: "...in the agricultural areas west of the Cascades, little has been done to study the interactions, positive or negative, between agriculture and salmonids" (Natural Resource Consultants 2000, p. 37).

In general, the report's "default" recommendation suggests a riparian buffer zone of 25 feet, with an additional agricultural management buffer zone of 25 feet. This secondary zone allows for some types of agricultural activity. But the report does not "directly tie" the buffer zone recommendations to scientific observations or site-specific conditions; the emphasis is on general applicability and past buffer zone use within forest conditions. The report does include considerable discussion about the variable level of effectiveness of specific buffer components, depending on multiple site and ecological factors. Also, based ongoing preliminary study results, the report infers that managed buffers of less than 50 feet wide are adequate to protect water bodies from most adverse agricultural activities.

SECTION 4

Review of Best Available Science

Since completing the Phase I Report, we have collected new literature about the ecological effects of removing riparian vegetation and the benefits of BMPs including biological effects that buffers have on fish, benthic organisms, water quality, and microclimate.

For each scientific publication, we include the citation and then summarize (1) the scientific content and (2) relevance to assessing buffer width. Relevance may include the applicability to Washington agriculture, need for additional research or specific criteria for buffer widths or other BMPs. In many cases, the research cannot speak to any BMP because the data or information is not directly applicable. The value or limitations of the data are discussed in each review.

We include a total of 28 academic research reports that cover all aspects of ecological function of buffers. Each review is 1-4 pages long and is found in Appendix II. The list of the 28 publications is summarized in Table 1 below and includes the focus of the research which fell into four general categories: Reviews, Ecological Papers, Watershed Studies we call “Basin” studies, and “Experiments” with treatment and control elements.

“Reviews” summarize large amounts of subject literature by experts and include digests and recommendations for buffer design and further research needs or issues to address.

“Ecology” papers focus on the observations of responses in the aquatic environment with the removal of riparian vegetation. Since many of these are not under the control of the scientist, there are usually severe limitations on understanding a specific efficiency of buffer width. The most common ecological condition reported is usually complete removal of riparian habitat compared to uncut forest. Complete removal invariably causes measurable change in the energy loading (sunlight) and organic inputs (reduced). Temperature changes seem to only occur when virtually all riparian vegetation is removed.

Riparian forest removal (usually in timber operations, not agricultural settings) is followed by “changes” in the physical habitat and diversity and abundance of fish, insects and aquatic plants, especially algae. Often there are macrobenthic (mostly aquatic insect) changes, especially in diversity when sediment is a factor; but the total biomass of productivity sometimes remains unchanged or even increases.

There are a few ecology papers that examine a series of different width buffers to refine

understanding of the importance of a narrow buffer versus wide buffer versus no buffer. Some of these are flawed in design by, for example, combining zero to 10 m buffers as a single classification. Most evidence suggests that a zero buffer condition elicits a much stronger or certain response instream than a 10 m buffer. Where effects of width are studied, it appears that zero to 10 meters is a common break point where ecologically measurable variables change suggesting that “protection” begins somewhere more than zero but less than 10 m. The ecological changes are observed are not necessarily deleterious. For example, productivity of coho juveniles increased when an old growth was cut. And alders and deciduous trees add significantly more nutrients and insects to streams than the climax evergreen conifers. These observations suggest that some old-growth and riparian removal can stimulate stream productivity. See the papers by Bilby on old growth and Volk on alders.

Large wood contribution to streams is more correlated with tree height than slope of the land adjacent to the stream. Thus in mature hardwood forests, most of the LWD came from within 10 m of the stream; in old growth forests, the majority came from within 20 m of the stream. This suggests that for agriculture, 10 m. buffers may be “protective” for large wood recruitment. See the work of McDade et al. on tree heights

“Basin” papers often examined broad scale phenomena such as effects of the extent of agriculture and soil erosion versus percent riparian cover, models that predict erosion or nutrient removal, and observations of un-compared phenomena such as performance of a single BMP design or natural observations without controls. For example, the work of Stauffer et al. showed riparian buffer extent was more predictive of fish and benthic diversity than was erodible soil in a Minnesota basin; but both are contributing factors. Erosion can be predicted based on power of a river (size) combined with grain size of soil (geomorphology). Grass and herbaceous vegetation are more resistant to river forces than trees. The physical model of Nanson helps explain why riparian vegetation may or may not be naturally present on river systems where channel migration is common and why grasses may be more stabilizing than trees.

The most compelling research on buffer width criteria are the controlled “experiments” where the researchers designed and controlled the experiment including variable width buffers to manage known agricultural impacts. In this regard, the focus was almost exclusively related to chemical or sediment filtration and maintenance of water quality. For the most part, grass buffers were generally more effective than trees for intercepting nutrients, sediment and chemicals; but trees and wet forests have some unique abilities to process nitrite and phosphorus. Most elegant was the experiment of Arora et al. that showed that grass buffers on 3% slopes under heavy rainfall, effectively as narrow as 17 feet, could capture the majority of sediment and herbicide and that doubling the width (area) provided very small but statistically non-significant improvements to effectiveness.

Table 1. List of 28 Scientific Research Reports as part of the Best Available Science for Riparian Buffers. The table summarizes key ecological functions including application to Best Management Practices.

Author	Brief Title	Category	Subject (s)	Ecological Function	BMP Recommendations
Sedell ¹	Riparian Forests on Large Rivers	Ecology	Historic Riparian Changes	Organic Input, Large Wood, Channel Maintenance	No analysis of buffer width or BMPs. Recommended preserving the few unaltered riparian sections of the Willamette for research.
Pinay ¹	Riparian Regulation of Nitrogen	Experiment	Nutrient Model	Nutrient Removal	30 m buffer absorbed 100% of nitrate with up to seven times (700%) unused capacity. Fertilizer management should be first employed to reduce nitrate concentrations.
Newbold ¹	Logging Effects on Macroinvertebrates in Streams	Experiment	Tree Removal	Benthic/Fish Diversity	Narrow stream buffer and bank protection enhance diversity in forest systems.
Brosofske ¹	Microclimatic Gradients After Logging	Experiment	Affect of Tree Removal	Shade and Stream Temperature	Complete riparian removal (zero buffer) showed stream temperature increase
Davies ¹	Buffer width vs. temperature, invertebrates and fish abundance	Experiment	Affects of Tree Removal	Shade Removal	Various 10 m buffers may be adequate but design flaws in experiment
Moore ¹	Pesticides and Salmon Effects	Lab Experiment	Physiological Response	Chemical Affects	No BMPs recommended. Tested lethal – sublethal limits of pesticide.
Zweig ¹	Sediment in Missouri Streams	Basin	Affects to Food Web	Sediment	No BMPs recommended. Shows sediment change affects distribution and abundance of insect taxa.
Wenger	Review of Buffer Science	Review	Overview of Science	Various	Recommended minimum buffer width of 15 m to cover all types of situations globally. Acknowledged wide variety of buffer function response. Did not consider cost.

¹ Recommended by NOAA Fisheries

Author	Brief Title	Category	Subject (s)	Ecological Function	BMP Recommendations
Osborne ¹	Buffers and Water Quality	Review	Overview of Function	Various	Recommended a variety of BMPs including 10 m buffers but indicated local conditions and economics should dictate the type of BMP selected.
Bilby	Organic Input Old Growth	Ecology	Affect on Fish Production	Organic Input, Fish	No BMPs recommended. Showed increased fish production in 7-year old clearcut vs. old growth forests; higher energy and less organic input into clearcut.
Allan	Salmonid Food Webs	Ecology	Affects of Tree Removal	Organic Input, Prey, Fish	No BMPs recommended. Showed greater abundance of terrestrial insects available from deciduous trees compared to evergreen species.
Delong	Organic Input Agriculture Affects	Ecology	Affects of Tree Removal	Organic Input, Fish	No BMPs recommended. Showed organic input (leaves) to streams is reduced commensurate with the amount of vegetation removed.
Delong	Ag Impacts to Stream Biota	Ecology	Affects to Prey Base	Organic Input, Prey	No BMPs recommended. Showed that with riparian removed, aquatic community becomes more homogeneous and autotrophic compared to uncut riparian.
Volk	Red Alder Nutrient Dynamics	Ecology	Alders Differ in Affects	Nutrient Balance, Fish	No BMPs recommended. Showed increased nutrients and macroinvertebrates in aquatic communities of Alder riparian compared to evergreen riparian areas. Alder colonizes clearcuts and disturbed areas prior to evergreen climax species.
Bishaw	Establishing Buffers in Oregon	Ecology	Case Study – Observed	Temperature, Cattle	No BMPs recommended. Cattle and beaver destroyed many reintroduced alder plantings. Fencing did not seem to improve results but other tree protection did. Bank shade increased only slightly from 20% to 34% after 5 years.

Author	Brief Title	Category	Subject (s)	Ecological Function	BMP Recommendations
Stauffer	Riparian vs. Basin Affects	Basin	Affect on Fish Community	LWD, Sediment, Fish Habitat	BMPs that preserved riparian vegetation and watershed soils from erosion produced more diverse fish communities than areas without riparian or with high soil erosion. No BMP criteria were provided but riparian presence was more important than basin soil conservation.
Peterjohn	Nutrient Dynamics Ag Basin	Basin	Models Riparian Effects	Nutrients in Runoff	No BMPs recommended. Modeled how watersheds and vegetation affect the nutrient cycle.
Lynch	BMPs to Control Non-Point	Basin	Timber BMPs in Non-point Runoff	Nutrients, Sediment	No BMPs for riparian width recommended. Did show limited water quality impacts for two years when logging BMPs were followed compared to uncut area.
Nanson	Bank Erosion in W. Canada	Basin	Models Forces vs. Vegetation	Bank Stability	Models bank stability and channel migration as functions of river size (power) and grain size (geology). Suggests grass and herbaceous vegetation more stabilizing than woody vegetation. Planting trees could destabilize some banks as shade kills grass.
Hunt	Pesticide Toxicity Coastal Stream	Basin	Observations Suggest BMPs	Chemical Filtration	No riparian BMPs studied or recommended however other BMPs that eliminated surface field runoff were probably responsible for differences in pesticide contamination.
Lowrance	Herbicide Transport in Buffers	Basin	Buffer Width Design / Results	Chemical Filtration	Showed an 8 m grass buffer removed 58% of herbicide while the remaining 50-60 m of pine and hardwood parts of the buffer retained 39% of the chemical. The use of other possible BMPs might reduce the buffer design width significantly.

Author	Brief Title	Category	Subject (s)	Ecological Function	BMP Recommendations
Arora ¹	Herbicide Retention in Buffers	Experiment	Buffer Width Performance	Chemical Filtration	Showed a 17-foot buffer arrested 55-84% of herbicide from a field with no other BMPs. Doubling the buffer increased absorption slightly to 60-88%. Other BMPs to reduce herbicide load are suggested. Field gradient was 3%.
Lim	Nutrient Retention in Buffers	Experiment	Buffer Width Performance	Nutrient Filtration, Livestock	Showed a 20-foot grass buffer optimized the control of runoff from cow manure constituents.
Robinson	Sediment Retention in Buffers	Experiment	Buffer Width Performance Crops	Sediment Filtration,	Showed a 30-foot buffer removed 85% of sediment with the first 10 feet retaining the majority of sediment under intense rainfall events on 7-12% gradient. Steeper slope had slightly more sediment escape. Details on functional design provided.
De Snoo	Pesticide Drift into Streams Exclusion	Experiment	Buffer Width Performance	Chemical Spray	Showed 10 to 20-foot buffers reduce pesticide drift into watercourses. Additional BMPs include maximum wind speed; nozzle design; weather related timing.
Richardson	BC Headwater Riparian Study	Experiment	Buffer Width Performance	Temperature, Organics, Light	Showed measurable changes in aquatic ecosystem including temperature increases with complete riparian deforestation compared to retention of 35 and 100-foot buffers. Suggests significant attenuation of benefits with increasing width.
Mc Dade	Large Wood Input Distances	Experiment	Old Growth vs. Mature Forest	Organic Input, Fish Habitat	Showed LWD recruitment primarily a function of tree height not slope. In mature hardwoods (shorter hardwoods), 83% of LWD in channel came from within 10 m of stream; in old-growth forests (taller conifers) only 53% came from within 10 m. but to 80% came from within 20 m in the old growth conifer areas.
Groffman	Denitrification in Grass / Forest	Experiment	Tress vs. Grass Effectiveness	Nutrient Filtration	No buffer width BMPs but showed wet soils more effective at denitrification than dry soils; grasses more effective at removing nitrogen than trees.

SECTION 5

Impediments to Progress and Future Needs

Barriers to BMP Implementation

There are two primary barriers to the successful implementation of BMPs: (1) cost-effectiveness and (2) regulatory constraints.

Cost Effectiveness

BMPs must be cost-effective and affordable. Specific tools that identify cost-effectiveness for individual farm operations are available to modify farm enterprise budgets to incorporate the adoption of new BMPs. Such tools allow for a documented and detailed approach to determining cost-effectiveness for individual farms.

BMPs that improve the individual farm and help the farmer are their own incentive. BMPs aimed at broad community benefits but do not directly aid the farmer must be affordable. In some cases to be affordable means government subsidy or reimbursement. For example, some buffer applications that remove valuable agriculture may require significant Conservation Reserve Enhancement Program (CREP) payments in order to compensate farm operations for adoption. The 2002 Farm Bill has earmarked \$200 million for farm improvements including Conservation Reserve Program, Wildlife Habitat Improvement Program and Conservation Reserve Enhancement Program. Unfortunately, the rules for eligibility, incentives and effectiveness often do not match the science that dictates the most cost-effective places to spend the money. CREP funds frequently go to paying for lands that would not have been used for agriculture anyway or have little impact to agriculture production or would have limited benefits to mitigating watershed problems. One senior agricultural scientist opined that more good could be done by focusing most the available funds to just a few specific critical areas than by spreading it in small pieces randomly over the landscape, most of which is largely ineffective (Personal communication, J.W. Gilliam, North Carolina State University). This is the democracy of legislation that shares the funding broadly rather than targeting the funds effectively based on scientific analysis.

Regulations versus Voluntarism

Another important question is whether programs should be voluntary whether existing government subsidy programs have been appropriately targeted and sufficient to be effective.

Because of economic considerations, farm improvement programs must be voluntary to be successful. The Iowa State University Bear Creek Watershed program is one successful model (Personal Communication Richard Schultz, Iowa State University; see also GEI, 2003). It is based on scientific research in action combined with voluntarism and self-directed programs by local agricultural communities and scientists including federal and state agencies. This type of program does not instantly solve the state's problems. But it creates a model demonstrating both scientific and social progress. This model is one paradigm that may be considered for applicability in Washington State as a means of conducting meaningful research and demonstrating voluntary watershed improvements that once proven could be more widely applied. Once a program is started, the continuing process is one of identifying critical reaches or areas that need work, continuing to identify willing landowners and facilitating cost sharing programs.

The synoptic review of buffers and other BMPs by University of Illinois researchers (Osborne and Kovacic, 1993, reviewed herein) also stress the importance of economics, social acceptability and proven results to gain adoption by the agricultural community. They conclude significant questions remain unanswered regarding the detailed design and benefits of buffers on agricultural lands. In our discussion with other agricultural researchers in at the AWRA Riparian Conference (pers. comm. R. Schultz, Iowa State University; J.W. Gilliam, North Carolina State University), we have learned that without voluntarism, and without incentive programs that make economic sense to farmers, little or no progress has been made despite best of intentions or science.

On the other hand mandatory regulations including difficult permitting or complex cost-sharing processes in Washington will likely reduce the effectiveness of such programs due to apathy or active resistance. If BMP implementation involves new or modified Washington permits, then BMP implementation will not likely prosper and grow rapidly as documented by Iowa State University experiences such as the Bear Creek Watershed R&D program. Greater involvement in Washington State from NRCS, NPPC, NOAA Fisheries and positive cooperative involvement from Washington Departments of Ecology and Agriculture could change the current paradigm from confrontation to cooperation.

Most landowners do not want to install, design or build systems themselves so there is a need for consultants skilled in restoration, bioengineering, monitoring and maintenance of these newly established systems. Central to this program is involvement from organizations including the NRCS, the Washington State Departments of Agriculture and Ecology, and non-profits like Trees Forever.

Further Options for Collaboration

Relatively large sums of Farm Bill money for Conservation Reserve Program (CRP) buffers have gone unused partly due to some of the aforementioned reasons. There are also some “Catch 22” reasons for this. If funding requires a “Farm Plan” many who might otherwise participate in habitat set-aside programs may consider farm plans a burden or worse a threat due to an admission of problems. For this situation to change, it will be important for agencies to support flexible but useful agricultural initiatives for the benefit of salmon. Perceptions by the agricultural community are not imaginary when they hear calls for large, fixed-width buffers that are economically onerous and in some cases catastrophic to economic viability.

To encourage actions that are implemented to protect fish from harm, the agricultural community needs protection from legal liabilities of the Clean Water Act and the Endangered Species Act. One way to possibly deal with federal regulations to recover endangered salmon is to better integrate agricultural actions into more extensive basin wide plans such as those being developed by the Northwest Power and Conservation Council and State Salmon Recovery Boards and Watershed Councils. These plans are in the initial production stages and address fish and wildlife recovery. The idea is to use these plans somewhat analogous to a Habitat Conservation Plan (HCP). HCPs are one of NOAA Fisheries’ regulatory tools to meet its goals and provide regulatory protection. Once a subbasin has identified the problems and solutions it wants to address, each farm can look at the Watershed or Sub-Basin Plan (possibly with the assistance of the NRCS) and use it as a template for examining what methods can be employed on the individual farm to address the issues identified in the Sub-Basin Plan. Each farm would then identify a specific proposal to meet the goals of the Sub-Basin Plan. Once the approach is approved, funded, and implemented, it would provide Endangered Species Act protection via NOAA Fisheries (4d) rule but would be voluntary. If a landowner did not want to participate, because for example he determines that his land is in compliance or already consistent with the Sub-Basin Plan, he need do nothing. Non-compliant landowners however that do have problems would be subject to regulatory enforcement if they did not take mitigating action.

The process would be voluntary, but once a farmer goes through the checklist, he can then submit his proposal for funding, if needed. Given Bonneville Power Administration (BPA) and CRP funding, and the flexibility to select customized “tools,” small enterprises might find economically feasible solutions. Tools could include both buffers and BMPs that are consistent with the Sub-Basin Plan and relevant to improvements that make sense on the specific farm. For example, one of NOAA Fisheries Reasonable and Prudent Alternatives (RPAs) in the Federal Columbia River Power System BiOp (RPA No. 153) requires 100 miles of riparian habitat restoration per year. This possibly could be integrated with voluntary agricultural initiatives. Actions could integrate CRP, CREP

or WHIP set asides, conservation easements, addition of stock watering away from streams, fencing, irrigation improvements and water conservation measures to RPA 153 thus pooling interests and efforts toward common goals.

Linking Ag Fish Water process and product to the Sub-Basin Plans and BPA funding has the potential to be good for agriculture in that it is voluntary but could provide ESA coverage. It has potential for funding from two motivated agencies (BPA and Department of Agriculture) that must implement funding and meet ESA mandates themselves. This approach can resolve questions of Best Available Science because it will be linked to science-based watershed management plans and it can assist the resource agencies to obtain the desired goals to protect salmon.

Integration of BMPs with Basin and Watershed Planning

Agricultural impacts to water quality, and BMP measures employed to protect salmon, should be implemented the context of overall watershed planning. Actions undertaken by agriculture must work in conjunction with actions taken by other economic sectors. For example, industrial and municipal water run-off or waste management problems must be better defined and controlled in order for agricultural BMPs to be effective. These sectors cannot “pass-off” water quality problems to agriculture; nor can agricultural BMPs be expected to solve diverse water quality impacts throughout a watershed. The prioritization of the most important issues in the watershed will also help farmers better understand whether they are helping or hindering progress to improve watershed quality and which BMPs are most important and effective.

Monitoring and Evaluation

The agricultural community understands that results must be demonstrable and this should be an important component of future efforts. Agriculture has demonstrated some effective measures to improve water quality by employing some of these BMPs discussed herein. It is unclear that some of the ecological benefits perceived as beneficial to salmon are similarly documented. More data and research are clearly needed.

Research and Development

Clearly there is a need for more learning to occur as to what is needed where and what will work best in Washington (see Osborne and Kovacic. 1993). Most of the research cited herein was conducted in other states or countries, not in Washington. The basic principles apply, but must be adapted to Washington’s unique ecology and agricultural landscape. As in Iowa’s Bear Creek Watershed, the research must be combined with voluntarism in an atmosphere of positive not confrontational interactions among stakeholders. Funding must be available. Methods must be shown to work then extended.

SECTION 6

Summary and Recommendations

Although we understand many of the benefits of riparian buffers and their capacity to minimize impacts to streams and fish in Washington, there is much yet to learn. Nonetheless there are legal requirement and economic realities facing the agricultural community and agencies that must protect endangered species. The Growth Management Act compels counties to protect “Critical Areas” which include streams harboring endangered species. Counties are now drafting or will draft soon, new ordinances that limit the impacts that development, including agriculture, will have on these critical areas.

Based on developing a recommendation that is sensitive to both economic impacts to agriculture and the need to come up with a standard that, based on best available science, is protective of the water quality and ecology of most Washington streams, we drafted a model ordinance for counties to consider (Appendix III).

The model provides for three conditions: Farms that demonstrate they have implemented and actively employ Best Management Practices on modest slopes (less than 7 percent) in the drier sections of the state, should maintain no less than 25 feet of native riparian vegetation adjacent to either side of natural streams. Dry is defined as 18 inches of average annual precipitation. Farms that practice and employ BMPs and that are on steeper slopes of 7% gradient or more or in wetter parts of the State (greater than 18 inches of annual precipitation), should maintain no less than 35 feet of native riparian vegetation adjacent to either side of natural streams. Farms that do not utilize BMPs should maintain no less than 60 feet of native riparian vegetation adjacent to either side of natural streams. There should be an appeal process that considers exemptions from the county to these recommendations to handle special or rare situations. For example, it appears that in some grazing situations, appropriate animal management is more critical than maintaining or constructing a specific riparian barrier or buffer. NRCS or the local agricultural district office or extension agent should be consulted for local expertise on design and management of these riparian areas. Of course all other environmental laws and county ordinances should remain in place including the management of animals, animal waste and other regulations governing development.

SECTION 7

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APPENDIX I

Executive Summary from Phase I Report

While recognizing the importance of protecting listed anadromous salmonids that migrate through streams on agricultural lands, the Washington state agricultural community is concerned about the potential mandating of fixed-width riparian buffer zones. Natural resource agencies, including the Washington Department of Fish and Wildlife and the National Marine Fisheries Service, have proposed mandatory, fixed-width riparian buffers on agricultural lands throughout the state. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises serious issues related to private property, economic impacts, and the most effective means of salmon habitat recovery and protection.

In response to these concerns, the Washington Hop Commission, Ag Caucus, of the Ag Fish Water Process, retained GEI Consultants, Inc. (GEI), Pacific Northwest Project (PNWP) and Mason Bruce & Girard (MBG) to review the functions and design dimensions for riparian buffers, their use and efficacy, their applicability to agricultural lands, and potential alternatives to fixed-width riparian buffers.

This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of agricultural buffers, and whether the data and analyses are being appropriately matched to buffer zone applications, and (2) to evaluate the economic costs associated with the proposed land set-asides. The general value of riparian vegetation for fish, wildlife, and water quality is well established in the literature and is not disputed by our findings. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to protect listed salmon. The report relies primarily on reviews of peer-reviewed scientific literature and is therefore consistent with use of Best Available Science regulations (Appendix B).

Large, fixed-width riparian buffers have five primary economic costs: (1) the cost to remove land from production, (2) the loss of economic benefits from agricultural production on those lands, (3) costs to monitor, administer, and maintain buffers, (4) loss of tax base, and (5) loss of economic infrastructure.

The prototypes for current buffer-width recommendations derive primarily from models of timberland set-asides in the Pacific Northwest forests. Thus the science relied on to formulate buffer widths is mostly forest-based. There are, however, important shortcomings to applying methodologies and science associated with timberland to

agricultural lands. The landscape, stream gradients, harvest practices, and impacts all differ.

The six primary functions and values attributed to riparian buffers in forests are large wood recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes. The Forest Ecosystem Management Assessment Team (FEMAT) process developed models to determine how much timber to preserve in riparian zones adjacent to harvested areas. Those models led to buffers up to 300 feet or more, depending on floodplain limits, on each side of a stream.

The function that requires the widest set-aside is recruitment of large woody debris (LWD), which improves the quality and quantity of fish habitat in small forest streams. In reviewing literature provided by resource agencies to the Ag Caucus, it appears that data gathered in the timber assessment process and especially curves for LWD are the principal basis for wide buffer recommendations in agricultural areas. Also, the general value of wildlife habitat is emphasized in this literature.

The scientific literature of agricultural buffer widths on to streams in the Pacific Northwest is quite limited. In general, agricultural impact analysis suggests riparian functions other than LWD are far more important on agricultural lands. Vegetation traps sediment, filters pollutants, retains storm water, and stabilizes stream banks on agricultural lands. An important and related issue on agricultural lands is protecting streams from direct and indirect impacts of domestic animals. Peer reviewed studies found applicable in this report suggest that relatively narrow buffers of 10 meters (33 feet), or less, can be highly effective in protecting ecological functions against these types of agricultural impacts. Roots adjacent to the channel and up to the stream's normal high-water mark provide physical stability and both filter and absorb nutrients. In addition, separation of livestock from the stream by only a small margin has proven effective in restoration of water quality and physical habitat. With proper livestock and pasture management, fencing may not be needed.

Thermal protection from shade is another desirable riparian function that is dependent on a number of site-specific factors. In larger lowland streams, thermal benefits from riparian shade are reduced. Data and thermodynamic considerations show that small streams can be protected from overheating on a diurnal cyclic basis; however, a relatively narrow buffer within a few meters of the stream can be effective in blocking direct sunlight from the water surface.

Cost effective approaches to protecting salmon streams on agricultural lands will benefit both small agricultural enterprises and the State of Washington. Agricultural production, including agricultural services and food processing, generates almost \$8 billion annually in state income. The agricultural industry is a leading economic sector in several rural

counties, in some cases producing more than \$100,000,000 annually in farm gate production values. This production, in turn, produces ongoing economic activity in other sectors.

Index values can be used to estimate economic impacts of fixed-width riparian buffers in a given county. On a per mile basis, the costs of buffer zones for select counties reviewed in this report could range from \$11,000 to \$81,000 for lost crops, \$67,000 to \$88,000 for lost dairy production, and \$45,000 to \$95,000 for reduced land values. The loss of total direct and indirect county income per 100 acres of riparian setbacks could range between \$190,000 and \$240,000 per year.

Cost analyses, marginal benefit assessments, and cost effective analyses can be useful means for assessing marginal benefits and trade-offs within economic sectors. These tools can be used accurately at the county or regional level to compare the costs of variable width buffers or other approaches. Additionally, local enterprise economic models are in development that will help individuals evaluate and understand the economic cost of decisions that affect their land.

One alternative to mandatory, fixed-width riparian buffers that may be preferable to farmers and ranchers would be a voluntary, incentive based program that may include variable width buffers. The agricultural community has already adopted many conservation practices based on local environmental needs and identifiable conditions in an ongoing betterment process that includes economic considerations. Variable width buffers that consider land use, gradient, and proximity to points of maximum return flows are preferable and will likely be more effective than fixed-width buffers. A more in-depth analysis of needs and alternatives is proposed for Phase II of this work in progress. A possible linkage could come from on-going watershed planning. Phase II of this research will elaborate on methods to encourage habitat improvement on agricultural lands and provide regulatory and economic certainty.

In summary, after reviewing numerous peer-reviewed studies related to agriculture, we conclude that riparian buffers, based on site potential tree heights of up to 300 feet wide, often greatly exceed what is required to protect water quality and the ecological function of aquatic habitat on agricultural lands. Fixed-width buffers do not offer targeted solutions to site-specific issues. Fixed widths are independent of site-specific gradient, overland and channel flow regimes, and locations of maximum return flow. When buffers zones are wider than a site requires, it can be difficult to justify the adverse economic impacts that a mandated width would produce. For alternative purposes, such as enhanced habitat connectivity to benefit terrestrial wildlife, greater widths may be desirable, but go beyond what is necessary to recover listed fish. Riparian buffer zones are ecologically beneficial; however, the width and composition of a buffer zone should be tied to specific management objectives.

APPENDIX II

Review of New Literature

Since completing the Phase I Report, we have collected new literature about the ecological effects of removing riparian vegetation and the benefits of BMPs including their width, extent, specific biological effects such as before and after effects on fish, benthic organisms, water quality, micro-climate. We divide this literature into two groups: one supplied by NOAA Fisheries directly to us (App. B.1), and other literature we have acquired from other sources (App. B.2).

For each scientific publication, we include the citation details and then summarize the following key elements of the research: (1) summary of the scientific content and (2) relevance to assessing buffer width. The value or limitations of the data are discussed in each review. The latter category may include the applicability to Washington agriculture, need for additional research or how such information might be applied in a practical way to reducing impacts. For each paper we include (3) recommendations for specific BMPs including buffer design or width that would be supported by the data or logic inferred by the research. In some cases, the research cannot speak to any BMP or buffer width because the data or information is not directly applicable. The complete reviews follow the two lists in the numeric sequence provided.

Appendix B.1. Literature Recommended by NOAA Fisheries

List of Titles:

1. Importance of streamside forests to large rivers: The isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal
2. The role of riparian woods in regulating nitrogen fluxes between the alluvial aquifer and surface water: a conceptual model
3. Effects of logging on macroinvertebrates in streams with and without buffer strips
4. Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance
5. Herbicide retention by vegetative buffer strips from runoff under natural rainfall

6. (Tree) Harvesting effects on microclimatic gradients from small streams to uplands in western Washington
7. Herbicide transport in a managed riparian forest buffer system
8. Riparian vegetated buffer strips [vbs = buffers] in water-quality restoration and stream management
9. Sublethal effects of triazine pesticide on reproductive endocrine function in mature male Atlantic salmon (*Salmo salar* L.) parr
10. Biomonitoring for deposited sediment using benthic invertebrates: a test on four Missouri streams
11. Ambient toxicity due to chlorpyrifos and diazinon in a Central California coastal watershed

Appendix B-2. Additional Literature Reviewed by GEI

12. A statistical analysis of bank erosion and channel migration in western Canada
13. A Review of the scientific literature on riparian buffer width, extent and vegetation
14. Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old growth forested streams
15. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs
16. Allochthonous input of organic matter from different riparian habitats of an agriculturally impacted stream
17. Macroinvertebrate community structure along the longitudinal gradient of an agriculturally impacted stream
18. Role of riparian red alder in the nutrient dynamics of coastal streams of the Olympic Peninsula, Washington, USA
19. Riparian forest buffers on agricultural lands in the Oregon Coast Range: Beaver Creek riparian project as a case study

20. Relationship of wooded riparian zones and runoff potential to fish community composition in agricultural streams
21. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest
22. Evaluation of Best Management Practices for controlling nonpoint pollution from silvicultural operations
23. Vegetated filter strip removal of cattle manure constituents in runoff
24. Vegetative filter strip effects on sediment concentration in cropland runoff
25. Buffer zones for reducing pesticide drift to ditches and risks to aquatic organisms
26. An experimental study of the effects of riparian management on communities of headwater streams and riparian areas in coastal BC: how much protection is sufficient?
27. Source distances for coarse woody debris entering small streams in western Oregon and Washington
28. Denitrification in grass and forest vegetated filter strips

No. 1 - Title: Importance of streamside forests to large rivers: The isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal.

Authors: James R. Sedell and Judith L. Forggatt.

Citation: Verh. Internat. Verein Limnol., 23, 1828-1834, Stuttgart, Dec. 1984.

Summary of Scientific Content: This paper chronicles the systematic conversion of a 25 km section of a complex unregulated natural river system (Willamette) and adjacent lands into regulated (flood controlled) and navigable stream from 1854 to 1967. These changes and similar ones in other U.S. rivers took place during the past 150 years and were essentially financed by the U.S. Government and local efforts to promote agriculture, navigation and commerce in the undeveloped river basins. By 1946 the Willamette channel and flood plain between Eugene and Harrisburg had been cleared of most trees and snags to promote agriculture, urbanization and navigation. Riparian wood provided sources of fuel and paper production to a growing economy.

The research presents three types of data: (1) mapped change in channel configuration; (2) the number of snags/trees removed; and (3) anecdotal historic descriptions. The data document the use, disturbance or destruction of the riparian community. The result is less complex and less interconnected riparian and aquatic communities physically and biologically. The authors recommend preserving natural remnants for heuristic purposes.

Relevance to Assessing Riparian Buffer Width: Unfortunately this paper cannot help with the question of where and how much riparian buffer should be preserved on existing agricultural lands today. No data is provided on assessing the six ecological functions of buffers or specific relationships to fish habitat or populations. The paper cites Vonnote et al. (1980) contention that “the influence of the terrestrial system on a stream ecosystems diminishes as the stream gets larger.” This suggests more importance between the aquatic and terrestrial community lies upstream in headwater areas. But again, no data are provided to evaluate buffer width or extent needed for protection or ecological function. It does however document that our culture long ago traded riparian habitat along our navigable rivers for economically valuable water and agricultural resources.

No. 2 - Title: The role of riparian woods in regulating nitrogen fluxes between the alluvial aquifer and surface water: a conceptual model.

Authors: G. Pinay and H. Decamps

Citation: 14 December 1987 0886-9372//88/040507-10 © 1988 by John Wiley & Sons, Ltd.

Summary of Scientific Content: An important function of wet riparian buffers is the removal of nitrogen in shallow groundwater from the organic input. Nitrogen might come in excess runoff from agricultural fields or from inputs of natural vegetation decaying on the ground. The authors examine and model the denitrification process. This paper used data from waterlogged soils within a 30 m wide riparian buffer near Toulouse, France. The authors present evidence that 30 m of wet riparian forest removed 100% of the nitrate via soil bacteria. They also present evidence that there is excess capacity for denitrification up to seven times the observed rate (50 mg/m²/day vs. 350 mg/m²/day). The amount of nitrogen input is the limiting factor to denitrification up to the 350 mg limit. The data are consistent with those reported by Jacobs and Gilliam 1985 a, b) and Peterjohn and Correl (1984) where 90% was removed in 19 m.

Relevance to Assessing Riparian Buffer Width: This paper provides one data point that suggests that nitrogen can be completely removed by soil bacteria within a 30 m buffer. The data suggest that the 30 m has the potential to remove up to seven times as much nitrogen as observed. Does this mean that a 4.5 m buffer would be adequate; in theory yes. Other data suggest that narrower buffers remove as much as 90% nitrogen.

Recommendation: Per our Phase I report, we recommend the first problem is to identify the problem. If nitrogen is excessively leaching from farms, a variety of BMPs should be first implemented. These might include fertilizer management (timing and amounts), irrigation management (avoid return flows), amending soils to increase infiltration, contouring fields, not farming on steep slopes, and where there is runoff directly into streams and excess nitrogen entering the watershed, use narrow buffers with good soil infiltration. If the problem remains chronic, buffers of varying width may be depending on local conditions and economics and should be explored. Examples of this approach are contained in other papers reviewed in this section of the report.

No. 3 - Title: Effects of logging on macroinvertebrates in streams with and without buffer strips.

Authors: J.D. Newbold, D.C. Erman, and K.B. Roby

Citation: Can. J. Fish. Aquat. Sci. (1980) 37: 1076-1085

Summary of Scientific Content: This paper compared stream benthic invertebrates affected by logging of forests. The data were collected *a posteriori* of uncontrolled logging. Sites were grouped into unlogged vs. logged and arbitrary groups of sites were compared for differences: wide buffers (>30m) vs. narrow buffers (<30m). Comparison measured changed in taxonomic diversity from each other, density of animals or combinations of both. Results were highly mixed. Key conclusions included: (1) width of buffer may be less important than logging method; physical protection of the streams and banks seems to be an important differentiator; (2) geographic differences among sites could account for variation unrelated to logging or buffer width because geographic variation was not controlled (i.e. it is possible some differences were the result of random geographic variation rather than the assumed logging treatment; (3) the Shannon index (taxonomic diversity only) showed no differences between unlogged, narrow and wide buffers but all three were slightly higher in diversity compared to total removal. Some narrow buffers were as diverse as unlogged but averaged less diversity than unlogged or wide buffered reaches.

Relevance to Assessing Riparian Buffer Width: Results suggest stream reaches with buffer vs. those with no buffer retain greater stream invertebrate abundance and diversity. The benefits of narrow vs. wide buffers are more ambiguous; diversity is higher among sites with 30 m but taxonomic richness and productivity is similar. Thus logging reduces diversity of stream invertebrates. Forestry practices cannot be directly applied to agriculture. However, these findings are consistent with USEPA research cited in the GEI Phase I Report where agricultural streams with grassy buffers were more diverse for invertebrates and fish species than streams without buffers. A limitation of this experimental design was that variable widths were not investigated.

Recommendation: For lands adjacent to fish bearing streams or headwaters that have never been cleared for agricultural or other developed uses, a narrow vegetative buffer should be left in place sufficient to provide bank stability, some shade, a source of allochthonous material and sufficient cover to reduce land use interference with the stream. Other BMPs should be also considered depending on proposed land use (type of agriculture) and physical condition (soil, slope, native vegetation etc.). Where important conditions of economic or biologic importance apply, wider or narrower buffers should be considered.

No. 4 - Title: Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance.

Authors: P.E. Davies and M. Nelson

Citation: Aust. J. Marine and Freshwater Res., 1994, 45, 1289-305

Summary of Scientific Content: This paper compares a variety of benthic invertebrate and physical (e.g. temperature) comparisons among stream reaches where logging has occurred with varying buffer widths. The paper has limited value in that it does not relate to agricultural lands or practices. Other limitations of the application of this paper to the assessing buffer width prescriptions include geographic differences between Tasmania and the Pacific Northwest: (1) the latitude differences and hence the angular repose of sunlight (and energy differences) striking the earth may be very different and (2) potential differences in the canopy density of the species as these data are from Tasmanian forests. Most importantly, the paper suffers a fatal flaw – sites with zero buffer width up to 10 m buffers are clustered together as a single treatment and then compared to wider buffer groupings of 10-30 m. and 30-50m. Such grouping hides important functional relationships that occur within the initial 0-10 meters (see GEI Phase I Report for many examples).

Relevance to Assessing Riparian Buffer Width: Much research (See GEI Phase I Report) has shown significant functional benefits of buffers occur within the first 10 meters of width and that there is often a great difference between a zero-width (no) buffer and a narrow buffer of 10 m. or less. Further, this paper observed buffers as narrow as 10-30 m showed no effect on stream temperature compared to wider buffers or un-logged streams. This means that a buffer 10 m. or less may be adequate to prevent increases in stream temperature.

Recommendation: Do not use data from this paper to assessing buffer width or other BMPs in the Pacific Northwest agriculture as too many geographic, ecologic, interspecific and sampling differences confound comparisons.

No. 5 - Title: *Herbicide retention by vegetative buffer strips from runoff under natural rainfall.*

Authors: K. Arora, S.K. Mickelson, J.L. Baker, D.P. Tierney, and C.J. Peters

Citation: Transactions of the Am.Soc. Agri. Engineers (1996) 39 (6) 2155-2162

Summary of Scientific Content: This Iowa State University research experiment evaluated the effectiveness of grass buffer areas to retain sediment and three different herbicides during rainfall events under closely measured experimental and control conditions. The experimental design concluded there were no significant differences between two different treatments of 30:1 or 15:1 ratios of field area to buffer area for retaining either sediment (87.6% vs. 83.6%) or herbicide (58, 73, and 69% for *Atrazine*, *Metolachlor*, and *Cyanazine* respectively). Both buffer treatments however significantly reduced the amount of sediment and herbicide flowing into the buffer verses flowing out of the buffer. For example, Experiment No. 6 (15:1 ratio; 41 days after applications) released from the buffer less than 0.01% of the herbicides applied to the field. Experiment No. 1 (15:1 ratio; 2 days after application) released from the buffer about 2% of the herbicides applied to the field. The three herbicides “moderately” adsorb (bind) to soil particles however most of the retention in the buffers was due to “infiltration” into the soil. Key elements of buffer “effectiveness” relates to several factors:

- (1) Time (days) elapsed since herbicide application prior to a precipitation event;
- (2) Severity of the precipitation event (rate and amount); and
- (3) Soil infiltration rate with greater infiltration reducing runoff

Rainfall has the “added benefit” of diluting the herbicides in the buffer itself. Despite “absorption onto soil particles,” soil retention only explained about 5% of the buffer retention. Chemicals other than those used herein that adhere to soil would be expected to have significantly higher rates of retention within the buffer.

If the buffers used in the experiment had been located at the edge of the field as a normal farm layout the width of 15:1 buffer would have been 10 m. (33 ft) and the width of the 30:1 buffer would have been 5 m. (17 feet). Their dimensions would have approximately 27 m long. The slope was approximately 3%. Additionally, the experimental design exacerbated runoff because corn rows were oriented perpendicular to the approximately 154 m long (deep) slope (non-contoured). Contouring enhances infiltration by reducing runoff. Thus, the experiment probably exemplified a worst cast situation for BMPs and buffer effectiveness.

Relevance to Assessing Riparian Buffer Width: This is one of the best examples of controlled agricultural conditions to assess the effectiveness of buffers on reducing

sediment and herbicide into streams. Key conclusions from this experiment show that even a 17-foot (5 m) buffer can arrest the majority of sediment and herbicides from a low gradient (3%) crop field, one that is improperly contoured. Best Management Practices (BMPs) could potentially improve these results by the following practices: (1) contours would run across, not with slope to create further infiltration into the field; (2) developing buffer strips with good infiltration characteristics which could mean amending the soil adjacent to streams and choosing grass/plant species that create dense tiller coverage; (3) taking into account the absorption characteristics of the applied materials – those with strong absorption will be more likely intercepted with narrower buffers due to soil/sediment adhesion and (4) for those chemicals/nutrients such as nitrate nitrogen (fertilizer) which have no adsorption characteristics, these would primarily be intercepted by infiltration. Other research has shown that nitrogen is primarily “processed” in groundwater by denitrifying bacteria (op. cit. Pinay and Decamps).

Recommendations: Conclusions from this research suggest that where runoff flows directly into a stream carrying herbicide or nutrients, the following practices (BMPs) should be observed: (1) contour to reduce runoff and know that low gradient enhances infiltration and steep slopes exacerbate surface runoff (2) reduce or eliminate chemical or nutrient applications to fields during the precipitation and runoff season (3) select chemicals with good soil adhesion properties where possible (4) amend soils or contour slopes away from streams to improve drainage (5) when direct runoff into streams cannot be prevented, buffers as narrow as 5 m to 10 m with good soil drainage and dense tiller vegetation may be adequate to reduce or eliminate input of chemicals and nutrients from fields directly into the stream and (6) the use of wetlands to retain and take up chemicals and nutrients may be a better alternative than buffers, especially adjacent to steep slopes or where soils are impermeable.

No. 6 - Title: (Tree) Harvesting effects on microclimatic gradients from small streams to uplands in western Washington.

Authors: Brososke, K.J. Chen, R.J. Naiman and J.F. Franklin

Citation: Ecological Applications (1997) 7(4) : 1188-1200

Summary of Scientific Content: This paper measured one aquatic (temperature) and six microclimatic (terrestrial) variables in forest habitats along Washington streams 2-4 m wide that had been logged with various treatments: clearcut, uncut, and buffered habitats. Buffers widths varied from 17-72 m wide. Variables measured were the temperature of air, ground and soil, humidity, wind speed and solar radiation in addition to the stream temperature.

The removal of shade affects patterns of spatial variation of microclimatic variables but the data are strongly confounded by distance and daily weather variation. Stream temperature was not affected except in one site where no (a zero-width) buffer was left. The authors note the correlation of stream and soil temperatures. They naively conclude (p. 1198) “Stream temperature was strongly affected by soil temperatures in the surrounding area at our sites.” Exposing both soil and water to greater solar radiation mutually cause both to heat during the day and cool at night but at different rates. Thus they are correlated but not causally related. Water will cool mostly by evaporation with limited convective forces, where as soil (assuming it was not saturated with water) is mostly cooled by convection – a much weaker thermodynamic process.

Relevance to Assessing Riparian Buffer Width: This paper has almost no relevance to establishing buffer widths to protect agricultural streams with riparian vegetation. First, the data are from forestlands. Second, only when all vegetation is removed to the stream edge is any stream temperature affect observed. Streamside vegetation provides shade and thus may modify the ground surface microclimate in that the total energy striking the terrestrial environment will increase with the amount of vegetation removed. The authors naively suggest that the warmed ground is causing the stream to heat. In actuality, greater energy input is affecting both the terrestrial microclimates as well as loading additional energy into the stream directly when all vegetation is removed. The most important observation was that the only case where stream temperature was associated with vegetation removal was when all vegetation was removed (i.e. a zero width buffer).

Recommendation: Our recommendation continues to be that with regard to stream temperature impacts, the critical element in controlling temperature is the boundary (incoming) condition. Every stream will differ as to the temperature consequences of removing vegetation. If thermal conditions are a limiting factor in the basin, temperature

should be modeled to determine the source of inputs and potential mitigation alternatives. These may include enhancing shade, but also better management of water resources (runoff). Causes may relate to a variety of factors including storage, water withdrawals, altered basin runoff, upper basin vegetation (timber) harvest; topography and climatic trends and variations. In the case where existing streamside vegetation exists in headwater (first and second order) streams that are proposed for clearing, we recommend that some vegetation remain uncleared on both sides of the stream. The amount needed will depend on local conditions of stream size, slope, soils and native vegetation. This will provide shade, fish habitat cover, bank stabilization, sources of allochthonous input, sediment and chemical filtration and reduce the likelihood of physical disturbance from animals and humans. Headwaters comprise the greatest length of streams in a dendritic basin. Clearing a specific headwater reach of all vegetation may not create a measurable or significant impact. However, the cumulative impacts of total vegetation removal from all headwater stream banks is likely to change the thermal regime of the downstream stream reaches aggregately due to two factors: (1) cumulative energy loading from increased sunlight striking water directly more hours of the day and (2) more rapid loss of surface and groundwater running into the streams during precipitation and snowmelt causing lower dry season discharges. Lower discharge will also lead to higher thermal conditions. In Washington, most of the headwaters are in mountainous areas and have been affected by logging practices. In the rare cases where agriculture might be in development around headwater streams, protection of those streams with some vegetation would be an important BMP but tailored to the local situation.

No. 7 - Title: *Herbicide transport in a managed riparian forest buffer system.*

Authors: R. Lowrance, G. Vellidis, R.D. Wauchope, P. Gray, and D.D. Bosch

Citation: Trans. Amer. Soc. Agri. Engineers 40 (4):1047-1057

Summary of Scientific Content: This study tracked *Atrazine* and *Alachlor* applications to a cornfield through a 58 m – 68 m buffer (8 m grass; 40-50 m pine forest; 10 m hardwood forest).

Relevance to Assessing Riparian Buffer Width: The study has limitations in that the goal was not to evaluate the width of effectiveness but simply tested one “wide buffer” design for effectiveness. A review of the data showed that the 8 m grassy buffer segment removed the largest amount of chemical compared to the remaining 50-60 m of buffer: 58% of chemical was removed by the 8 m grassy buffer; up to 39% was removed by the remaining 50-60 m of harvestable and non-harvestable forest buffer sections. The rate of removal per meter in the grass (8 m) area was up to 4.84 times larger than the remaining buffer areas (6.44%/ 4.33%). Infiltration was the largest factor in explaining removal, yet little or no herbicide was found in ground water. Movement of ground water to the stream can take years further reducing the potential for impact to the stream.

Recommendation: If there is evidence of surface runoff from fields directly into streams and that upon testing, the runoff and / or stream is shown to contain unacceptable levels of sediments and contaminants, a number of BMPs can be implemented to abate or remove the impact: (1) contouring to reduce surface runoff (2) restricted or reduced applications to prevent high concentrations of chemical prior to runoff (3) appropriate pressurized irrigation to reduce surface runoff (note: improved irrigation also conserves surface and ground water and adding further benefit (4) improved soil infiltration by amending soils especially adjacent to streams (5) in the case of livestock or other human physical disturbance to the stream, providing fencing or other vegetation to prevent direct access to the streambank and streambed and (6) the use of grassy buffers of 5-10 m. in width along with the above BMPs should they not prove adequate to abate the direct input of chemical into the stream. Such buffers can also be enlarged up to the dimensions shown in this report if all these efforts still do not abate the presence of the chemicals or sediments in the stream.

No. 8 - Title: *Riparian vegetated buffer strips [vbs = buffers] in water-quality restoration and stream management.*

Authors: Lewis L. Osborne and David A. Kovacic

Citation: Freshwater Biology (1993) 29:243-258

Summary of Scientific Content: This paper is a synoptic literature review on the effectiveness of buffers to improve water quality as well as an original contribution of data. The authors cite extensive work that mostly is in the peer-reviewed literature. The review paper itself appears in a professional journal that likely had peer review.

Relevance to Assessing Riparian Buffer Width: Key conclusions of the review:

1. The effectiveness of buffers to remove nitrogen is highly variable. See Figure Plot of data from various sources in Table 3.
2. Effectiveness varies by type of plants used w/ trees more effective than grass at removing shallow groundwater nitrogen – but it was not clear whether the variation in groundwater was affecting streams.
3. Long-term benefits are unknown unless trees (plants) are harvested because new equilibrium between terrestrial and aquatic interface will be established
4. Economics must be considered. Farmers will not accept economically untenable solutions to improving water quality.
5. Removal of vegetation can increase stream temperature and is more important in headwater streams
6. Buffer width needed to protect temperatures is highly related to local conditions. Data suggests buffers as narrow as 10 m could be effective, but no experiments or data were presented on narrower buffers.
7. Alternatives to buffers should be considered including use of wetlands and other BMPs to prevent chemicals from entering lotic waters.
8. Buffers can help reduce sediment/nutrients but much more research is needed.

Here is a sample of direct quotes from the paper relating to the authors' conclusions:

“The amount of influence that riparian vegetation will have on stream temperature is dependent upon geographical location, groundwater input, and [buffer] width, composition and density.” p.245

“In North America [buffer] widths between 10-30 m have been shown to maintain effectively stream temperatures [supported by four citations in Table 1 p. 245].” Note: This does not prove that streams without buffers have thermal problems or that buffers of narrower dimension might not ameliorate a thermal impact [GEI comment].

“These data (see Table 3 plotted) demonstrate that fairly narrow forested [buffers] effectively remove nitrate from both surface runoff and groundwater.” p. 246

“Despite the extensive work completed on this topic, several questions and controversies regarding the utility and efficiency of [buffers] for stream restoration programs still remain unanswered or unresolved. For instance, what types of riparian [buffers] are most efficient at reducing land-use impacts to streams? Do [buffers] become saturated with sediment and nutrients, thereby becoming ineffective? Are they only temporary sinks? Does species composition make a difference? What is the necessary width of a [buffers] for specific regions and conditions?” p. 247

“Any proposed restoration strategy, regardless of its ecological merits, needs to be economically feasible and socially acceptable if it is to be adopted and implemented on a landscape level. Large-scale acceptance and implementation may involve changing age-old practices and approaches that is only possible through comprehensive education and extension programs, well-conceived government policies and support programs. Because the economic costs of such programs can be high, it is imperative that decisions be based on sound scientific information. Below we present data from our study site in central Illinois to add to this growing body of literature.” p. 247-248

“Omernik et al (1981) have suggested that forested [buffers] can become saturated with nutrients and become ineffective filters on an annual basis. While the results of others are inconsistent with this idea (e.g. Lowrance, Todd & Asmussen, 1983), this question still remains inadequately addressed. Our results suggest that forested [buffers] leak phosphorus to the adjacent stream channel to a greater degree than the grass [buffers].” p. 250

“The available evidence suggests that [buffers] can reduce N inputs to streams. Osborne & Wiley (1988) concluded that the mitigating benefits of [buffers] will be maximized if they are instituted in smaller headwater streams whose lengths dominate any drainage network.” p. 253

“Although limited, the evidence from this study suggests that both the grass and forest [buffers] leak phosphorous, possibly due to saturation. While additional research is needed in this area, it should be possible to further minimize the loss of nutrients by selective cropping of [buffers] and maintaining the vegetation at an intermediate successional state.” p. 253

“The results of our study indicate that [buffers] can reduce nitrate-N concentrations in shallow groundwater. These data also suggest that forested [buffers] are more efficient than grass [buffers] for reducing $\text{NO}_3\text{-N}$ but forested [buffers] are less efficient at

reducing P in shallow groundwater. Thus, selection of the appropriate cover type should be dependent upon the specific water-quality problem at hand.” p. 254

“Gough (1988) has suggested that herbaceous vegetation may be more desirable for use in [buffers] than larger woody vegetation because the greater stem density increases the hydraulic roughness, thereby decreasing the velocity of the water flow, and hence, its sediment carrying capacity (Meyer and Wischmeier, 1969).” p. 254.

“...but research on the most effective size, shape, and composition of vegetated buffers for specific situations is still needed. Although we have concentrated on water-quality benefits derivable from [buffers], similar information is needed on the beneficial aspects of [buffers] for increasing biodiversity, modifying hydrographs and groundwater recharge, reducing bank erosion, and as an energy source for stream organisms.

Recommendation: These comments are consistent with the conclusions that GEI drew in the Phase I report: (1) first determine if there is a problem before fixing it (2) economics are important and buffers will not be accepted if there is no scientific evidence that a problem exists or that there is a more cost-effective way, such as BMPs, in dealing with the problem (3) narrow buffers where needed can be highly effective in filtering chemicals and nutrients from streams, providing shade and controlling temperature but as a first line of defense, other BMPs should be first examined including land contouring, irrigation, soil condition, and proper use of chemicals and nutrients (4) buffers probably have greater effectiveness in headwater (high order) streams than in mainstem (lower order) rivers because there are many more miles of headwaters and whatever happens upstream will be carried and multiplied downstream (5) grassy buffers may be more effective for certain types of agricultural impacts compared to trees or shrubs although combinations may be most effective in some situations (6) wetlands may be an alternative to stream side buffers and (7) there is much to be learned about the dimension of buffers and their effects hence the widespread prescription of wide-buffers everywhere on agricultural lands is not supported by the literature nor does it make good economic sense.

Although agriculture is generally not associated with headwater streams in Washington state, in the rare cases where it may be in development, for uncleared lands, especially in headwater streams, it seems prudent to maintain some vegetative buffer in place rather than to remove all vegetation to the stream bank because the literature is clear that complete removal of stream bank vegetation will eventually lead to magnified problems downstream. As a prudent measure, we would recommend that 3 meters (10 feet) of riparian vegetation on both sides of the bank be left in place for uncleared headwaters. If there are strong reasons (economic or scientific) either not to leave a buffer or for the need for a wider buffer, these should be handled as special cases. For streams that have been already cleared of vegetation, the existing condition of the stream should be

examined for measurable impacts (sediment, chemicals, excess thermal condition, lack of physical fish habitat for fish bearing streams). Based on the existence of known impacts especially to critical areas, a plan to abate the specific problem using a variety of BMPs including vegetative buffers, should be made in consultation with local experts including university agriculture extension specialists, scientists/engineers from the Natural Resource Conservation Service (NRCS) or other similar agency.

No. 9 - Title: Sublethal effects of triazine herbicide on reproductive endocrine function in mature male Atlantic salmon (*Salmo salar* L.) parr.

Authors: A. Moore and C.P. Waring

Citation: Unpublished manuscript

Summary of Scientific Content: This paper demonstrates that the herbicide *Atrazine* can negatively affect the reproductive function of Atlantic salmon in laboratory experiments. This is demonstrated in the lab by exposing fish to specific concentrations of the toxin including perfusion of the olfactory epithelium for 30 minutes to five hours with varying concentrations of *Atrazine*, then observing reduction in milt production in males and precursors such as plasma sex steroids after exposure to urine from gravid females. Also examined were testicular responses to pituitary stimulation in an *in vitro* study. Details of the laboratory experiments: Concentrations tests ranged from 0.1 – 20 $\mu\text{g/l}^{-1}$ (e.g. 0:1 – 20 ppb). Post-test measurements of *Atrazine* showed actual fish concentrations varied because of the rapid degradation of *Atrazine*.

The authors cite a variety of negative (but sublethal) physiological effects that *Atrazine* can have on a variety of fish such as Atlantic salmon (*Salmo*), bluegill (*Lepomis*); and zebrafish (*Bradydanio*). Standard toxicity tests for rainbow trout show LD-50 concentrations as high as 18 mg/l^{-1} . Clearly, the evidence suggests that *Atrazine* can affect reproduction in fish.

Relevance to Assessing Riparian Buffer Width: What the study does not show is any herbicides that fish are actually exposed to in the natural environment either in England where the study was completed or any other environment including the Pacific Northwest. *Atrazine* and many other permitted herbicides have rapid deterioration and government approved application procedures. With proper (following labeled instructions) application, and the use of BMPs to prevent direct runoff into streams, the levels of *Atrazine* in Washington streams should be well below the exposure concentrations to fish in these experiments. This calls into the question what evidence is there that *Atrazine* or other chemical are in fact a problem.

In this report, we review a specific condition in the Salinas River watershed (see below) where herbicides are known to impact water quality in some drainage ditches in a highly modified hydrologic basin. The agricultural condition to avoid is the application of *Atrazine*, or any) herbicide, on lands where it can directly enter the stream in high concentrations. Potential causes for such violations might include (1) misapplication of rates or timing where application in a field is followed by a sufficient rain or irrigation event to cause direct runoff from field into stream and (2) modified hydrologic conditions dewatering streams and their dilution capacity. Agricultural research cited in other

sections of this report shows that with proper applications of herbicides combined with BMPs of contouring, vegetative cover, slope protection, soil infiltration rates and if needed, the use of vegetative buffers, all can reduce or eliminate herbicides, including *Atrazine*, from fish bearing streams. Further, the potential exposure rate (and reproductive consequences) in nature would also be related to the timing of fish species reproduction, the hydrology and runoff volumes (dilution factor) and rainfall/irrigation conditions. Thus, this paper does not support a mandatory prescription of buffers of any width on all agricultural lands to “protect” against herbicides in watersheds.

Recommendation: If *Atrazine* is shown to be present in a specific watershed at concentrations known to affect fish, BMPs as discussed above, would be the first line of action. Specifically determining why the herbicide is flowing directly into the watershed, then taking the proper preventative actions of to prevent recurrence. If these BMPs are not completely successful, Lowrance et al. (1997) have shown (reviewed in this report) that *Atrazine* concentrations can be reduced significantly by use of buffers as narrow as 8 m up to 60 m depending on the concentration in the runoff. The two question that need to be addressed first are, (1) where do the pesticide problems exist and (2) what BMPs have been employed first to avoid or prevent the problem. Once these have been shown to be ineffective, then buffer applications should be considered as a final line of defense.

No. 10 - Title: *Biomonitoring for deposited sediment using benthic invertebrates: a test on four Missouri streams.*

Authors: Leanna D. Zweig and Charles F. Rabeni

Citation: J. N. Am. Benthol. Soc., 2001, 20(4):643-657

Summary of Scientific Content: This paper is a rigorous examination of the effect of sediment on the types of stream benthic organisms that occur in four watersheds. Sedimentation may come from a variety of causes, agriculture being one. But land, building, urbanization, mining and deforestation, represent other major causes. The paper does not address the causes or sources of sediment nor does it examine the potential of any Best Management Practices (BMPs) to reduce sedimentation. What this paper does, is illustrate that under varying amounts of sediment in specific environments there is an observed change in the relative and absolute numbers of insect taxa that occupy them. In order to “correct” for confounding variables unrelated to sediment, the authors selectively chose sites with varying sediment coverage but other similar water quality conditions. To do this they operated within four watersheds and examined measures of taxonomic diversity and abundance against percent sediment cover in 10% (decile) categories, i.e. 0-10%, 11-20%...91-100%. The authors looked for correlations between eleven different metrics of diversity and abundance. Many of the metrics were not well correlated however five metrics were moderately correlated in some streams showing significant correlations (non-zero slopes) ranging between .534 to .868. Of the forty-four comparisons, only 16 paired relationships (36%) were significant ($P < 0.01$, Spearman Rank Test).

The primary value in this paper is that it shows that various insect taxa have different ecological preferences and tolerance to the amounts of sediment in their environment. Since these taxa evolved over thousands of years, adaptation reflects exploitation of habitats of varying substrate types. Thus in order to preserve insect diversity in a stream or watershed, excess sediment loading should be avoided because it eliminates the coarser sediments such as gravel and cobble that may be valuable, not only for insect diversity and abundance but also for coarse substrate spawning fish.

Relevance to Assessing Riparian Buffer Width: Unfortunately, this paper does little to answer the question how much riparian buffer would be needed to be protective of a stream’s coarse sediment environment. It does not even assess how much sediment is too much, regardless of source. Because correlation coefficients are low and the data are bivariately very scattered (see Figures 2 and 3), there are no obvious inflection points to suggest where things really deteriorate biologically. Most of the regression slopes are very gradual. About half of the taxa are categorized as “sensitive” where 5% sediment deposition is correlated with an implied reduction of 50% of that taxon’s. That does not

mean that if a basin has an excess of 5% sediment all the sensitive taxa disappear. It means that these taxa thrive abundantly only on habitats where sediment is limited. The amount of sediment-free habitat in any watershed is a complex function of slope, soils, geology, hydrology and disturbance.

Recommendations: USEPA and state water quality programs (303d listed streams) have identified basins with excess sediment that are ecologically limiting. We would suggest that a variety of BMPs (including the use of buffers) be considered in these basins where sedimentation is a known problem. This paper cannot be helpful in answering the details of that question nor in how wide or how extensive buffers need to be. Instead refer first to research on BMPs that reduce sediment runoff in the first place. After BMPs have been implemented, if sedimentation is still occurring, refer to the papers that measure sediment, chemical and nutrient trapping effectiveness of buffers as shown in other papers in this report.

No. 11 - Title: Ambient toxicity due to chlorpyrifos and diazinon in a Central California coastal watershed.

Authors: John W. Hunt, Brian S. Anderson, Bryn M. Phillips, P.N. Nicely, R.S. Tjeerdema, H. M. Puckett, M. Stephenson, K. Worcester and V. De Vlaming

Citation: Environmental Monitoring and Assessment (2003) **82 (1):** 83-112

Summary of Scientific Content: This paper evaluated the existing water quality in multiple reaches of the Salinas River using 96-hour *Ceriodaphnia* mortality tests. Concentrations as low as 0.3 ug / l⁻¹ can affect salmonid olfactory organs; a concentration comparable to LD 50 for *Ceriodaphnia*. The Salinas basin is one of the most highly developed agricultural regions in the world with a significant surrounding urban population and year round production. Two pesticides, *Diazinon* and *Chloropyrifos* were implicated as probable causes of high *Ceriodaphnia* mortality however the results were highly variable over time and space. Sample sites 1 to 4 were near tile drains. Water is drawn subsurface through fields. Site 5 receives urban storm water runoff. Site 6 receives direct runoff from agricultural fields. Site 7 was in the upper watershed. Site 8 was in an artificial channel draining agricultural and urban lands.

At tile drainage sites in the lower watershed, (sites 1, 2, and 3), only 1 of 15 samples showed high mortality; from Site 4 another tile drainage site, 3 of 15 samples were “toxic”. The upper watershed (Site 7) had no toxic samples. The urban drainage (Site 8) had 13 toxic samples out of 15; and at Site 6 where runoff came directly off the fields, every sample was toxic. Rainfall occurred producing runoff in the watershed prior to sampling. These chemicals are relatively short-lived; however continuous application creates a continuous source of potential contamination. Site 6 also had runoff from year-round irrigation and little instream dilution because headwaters go underground upstream of this site.

Despite similar agricultural practices at sites 1-4, instream toxicity was rare there and attributed to percolation of irrigation water through the soil (no runoff), even during low river discharge conditions. Thus porous soil is probably the source of prevention along with appropriate irrigation/runoff control.

Site 8 drained the majority of the City of Salinas plus adjacent agricultural areas. The sources of the pollutants at this site were probably a combination of both urban and agricultural sources as these pesticides are commonly used on urban/residential vegetation.

Relevance to Assessing Riparian Buffer Width: No data was presented on the existence of riparian buffers. It is expected that buffers protected none of the areas

sampled. The two areas that consistently have severe problems could be identified as “point source” type runoff where either direct flow from the field or stormwater drains together with limited dilution from upstream discharge caused toxic conditions. On the flip side, similar agricultural practices at four sites had very few problems as there was no direct runoff.

Recommendations: The solution in these cases should first be directed at asking whether a problem existed or not. Where problems do exist which seems to be at a minority of sites, removal of the source of the instream (point source) pollution flows such as from excess runoff in urban environments (possibly via better education, control or enforcement of urban chemical usage) and on agricultural lands by abating regular runoff the fields via removal of conditions where direct field runoff occurs into a stream. Whether a buffer, or installation of better drainage, contoured slopes or other methods would be the best management practice is not known with the data presented. Additionally pollution at some sites is exacerbated due to the lack of dilution from upstream discharge. This may be a result of overexploitation of the ground or surface waters in the basin further aggravating the condition. The fact that irrigation and rainfall often combine to cause runoff events suggest better control of irrigation that would be reduced in synchrony with rainfall events.

No. 12 - Title: *A statistical analysis of bank erosion and channel migration in western Canada*

Authors: G.C. Nanson and E.J. Hickin

Citation: Geological Society of America Bulletin (1986) 97: 497-504

Summary of Scientific Content: This paper addresses and models the causal elements of channel migration. In summary, channel movement is a function of river size (power and energy) and grain size (sediment or bedload characteristics in the flood plain). The paper elicits several key maxims (1) the idea that riparian vegetation can always function as a bank stabilizing force is not true; (2) planting trees can actually accelerate erosion because it shades out grass and smaller, finer rooted plants; (3) it is these finer rooted plants that physically resist forces of water erosion better than coarser rooted trees and shrubs.

Relevance to Assessing Riparian Buffer Width: This paper does not support the concept that wide riparian buffers are needed everywhere to protect streams from agricultural impacts. On the contrary, concepts presented herein run counter current to the hypothesis that all stream reaches must be lined with trees or shrubs to protect stream integrity and watershed health. Where bank protection would be a natural phenomena in the middle and upper watersheds, a variety of native woody and non-woody vegetation might be of benefit, depending on local conditions. This paper and other research cited in this review extol the benefits of grassy buffers to trap sediment, slow runoff from fields, adsorb and uptake nutrients and chemicals. This paper adds a quality to grassy buffers that shows it may have greater strength in resisting flood water erosion and protecting banks than shrubs or trees. The location of the stream, the characteristics of the watershed and the condition of the stream (i.e. the types of “problems” that actually exist) should be considered before prescribing a “one-size-fits-all” riparian buffer of any design including those described in the review (*cf.* Lowrance et al., 1997). The main lesson learned in this paper is that in lower watersheds, stream channels may migrate and the use of buffers will not be effective in retaining the channel configuration. The debate of whether the use of engineered structures such as rip-rap and training walls to retard channel migration is a very different question unrelated to the question of whether all agricultural lands should maintain wide riparian buffers.

No. 13 - Title: A review of the scientific literature on riparian buffer width, extent and vegetation.

Authors: Seth Wenger

Citation: Office of Public Service and Outreach, Institute of Ecology, University of Georgia, March 5, 1999.

Summary of Scientific Content: This University of Georgia, U.S.A review paper was developed to establish a legally defensible basis for determining riparian buffer width, extent and vegetation in Georgia. To achieve this goal, the author reviewed more than 140 articles and books with an emphasis toward determining the optimal width, extent (i.e. which streams are protected) and vegetation (e.g. forest or grass) of riparian buffers. To ensure that the review covered the most relevant research and had made reasonable conclusions, other members of the scientific community reviewed its findings.

Given the volume of literature available, the author gave priority to:

- Articles which specifically deal with the issues of riparian buffer width, extent and vegetation
- Previous literature reviews
- Articles focused on Georgia and the Piedmont
- Seminal articles in the field
- Recent articles (1990-1998) especially those not included in prior literature reviews
- Articles from refereed journals (although several good government documents and other works are included)

The review paper is organized by six topics, background and introduction, sediment, nutrient and other contaminants, other factors influencing aquatic habitat, terrestrial wildlife habitat, and development of riparian buffer guidelines. For the purpose of this document, we will not discuss either the background and introduction or the terrestrial wildlife habitat sections.

Sediment: The author notes numerous studies that have documented the effectiveness of buffers in trapping sediment transported by surface runoff, but the challenge lies in determining the necessary width of the buffer. Fennesy and Cronk (1997) noted this specific problem associated with studies that recommend buffer widths:

“One problem in assessing the minimum widths necessary to protect adjacent surface water is that many studies that make recommendations regarding the minimum width necessary have arrived at the figure as a byproduct of sampling design rather than deriving it experimentally.”

Although there is a large amount of evidence from the literature that there is a positive correlation between a buffer's width and its ability to trap sediments, the relationship varies. Six studies (Young et al 1980; Peterjohn and Correll 1984; Magette et al 1987, 1989; Dillaha et al 1988, 1989) have examined the effectiveness of buffers of two widths in trapping total suspended solids (TSS). In every case, buffer effectiveness increased with buffer width, but again the relationships varied. The smallest buffer width of all the studies was used by Dillaha et al. 1988. They found that a buffer of 4.6 m removed 87% of the TSS in an area with a slope of 11% and 76% of TSS in an area with a slope of 16%. The widest buffer used was by Peterjohn and Corell (1984) who compared a 19 and 60 m buffer. They found that a 60 m buffer (94% removal of TSS) only reduced TSS by an additional 4% over a 19 m buffer (90% removal of TSS). Young et al. (1980), found that a buffer of 27.4 m had varied results in an area with a slope of 4%. The removal of TSS ranged from 66 to 93% with a 27.4 m buffer, while a 21.3 m buffer ranged from 75 to 81% TSS removal.

There is evidence from long-term analyses that wider buffers may be necessary to maintain sediment control. Lowrance et al. (1988) found that sediments from an agricultural field were deposited throughout the riparian forest with the greatest depth occurring at 30 m inside the forest. Similarly, Cooper et al. (1988) found that a riparian buffer trapped 84-90% of the sediment eroded from agricultural fields, although nearly 50% was transported more than 100 m. Therefore the author concludes that these two studies suggest that riparian zones are efficient sediment traps, but the width required for long-term retention may be substantially more than what is indicated by short-term experiments. The author feels that buffers of 30-100m or more might be necessary for sediment retention of the long-term.

The sediment trapping efficiency of buffers can be expected to vary based on slope, soil, infiltration rate, and other factors. Slope may be the best studies of these relationships. Dillaha et al (1988, 1989) found that as buffer slope increased from 11% to 16%, sediment removal efficiency declined by 7-38%. This suggests that BMPs that reduce or eliminate agriculture on steep slopes may be effective alternative to buffers. Contouring may also be useful.

The studies that were reviewed by Werner suggest that for the purpose of trapping sediment, both grass and forested buffers are effective. Grass buffers, although more likely to be inundated by exceptionally high levels of sediment, are useful for maintaining sheet flow and preventing rill and gully erosion. A combination of grass and forested buffers has been advocated by many researchers (e.g. Welsch 1991, Lowrance et al. 1997).

Buffers are most effective when uniform, sheet flow through the buffer is maintained; they are less effective in stopping sediment transported by concentrated or channelized flow (Karr and Schlosser 1977, Dillaha et al. 1989, Osborne and Kovacic 1993, Daniels and Gilliam 1996). Sheet flow can be encouraged by the use of level spreaders and other structural techniques. Welsch (1991) recommended planting a strip of grass 6.1 m wide at the outer edge of a riparian buffer to help convert concentrated flow to dispersed sheet flow.

It is possible for buffer vegetation to be inundated with sediments and decline in effectiveness, although under normal conditions vegetation should be able to grow through the sediment (Dillaha et al. 1989). Therefore, buffers on agricultural land with very high erosion may require regular maintenance to remain effective and should always be used in conjunction with other erosion control methods (Barling 1994).

In summary, the author notes that riparian buffers are generally very effective at trapping sediment in surface runoff and at reducing channel erosion. Studies have yielded a range of recommendations for buffer widths; buffers as narrow as 4.6 m have proven fairly effective in the short term, although wider buffers provide greater sediment control, especially on steeper slopes. Long-term studies suggest the need for wider buffers. The author recommends an absolute minimum of 9 m and for maximum effectiveness buffers must extend along all streams, including intermittent and ephemeral segments.

Nutrients: Phosphorus and nitrogen are two of the main nutrients implicated in the eutrophication of lakes and streams. While both can have lasting impacts on aquatic ecosystems, each has very different properties that require distinct discussions.

Phosphorus usually arrives in a buffer attached to sediment or organic matter; therefore buffer widths sufficient to remove sediment from runoff should also trap phosphorus. In the short term researchers have found riparian buffers retain the majority of total phosphorus that enters, and retention increases with buffer width. Vought et al. (1994) found that in Sweden that a grassed buffer of 8 m retained 66% of phosphate in surface runoff while after 16 m 95% was retained. Other studies have found similar results (Mander et al. 1997; Dillaha et al 1989; Magette 1987 and 1989), although one study (Dillaha et al.1988) found that a larger buffer (9.1 m) actually decreased the amount of phosphorus retained when compared to a smaller buffer (4.6 m). The author's of many of these studies noted that effectiveness of the buffers on retaining phosphorus declined over time. They also noted that soluble phosphate reductions were lower than total phosphorus reductions.

It is possible for a buffer to become “saturated” with phosphorus when all soil binding sites are filled; any additional phosphorus inputs will then be offset by export of soluble

phosphate. Harvesting vegetation may be the only reasonable management technique that permanently removes phosphorous from the system.

While very high rates of phosphorus inputs over a long time period can saturate a buffer, riparian buffers are typically effective at short-term control of sediment bound phosphorus. Both grass and forested buffers have been proven effective at reducing total phosphorus, and both vegetative types have also been shown to lose phosphate to the stream. Riparian zones wide enough to provide sediment control should provide short-term control of sediment-bound phosphorus.

On the other hand there are two major ways in which a riparian buffer strip can remove nitrogen passing through it, both of which can be significant: 1) Uptake by vegetation, 2) Denitrification. Fennessy and Cronk (1997) reviewed riparian buffer literature with focus on nitrogen and concluded that riparian buffers of 20-30 m can remove nearly 100% of nitrate. Reduction of various forms of nitrogen in surface runoff is reasonably well correlated with buffer width.

The buffer width necessary for nitrate reduction depends greatly on the hydrologic flow paths. The distribution of denitrification sites vary spatially, therefore wider buffers on average will include more denitrification sites than narrower buffers.

Riparian buffers can also reduce the amount of organic matter and biological contaminants that enter a waterway. Coyne et al. (1995) applied poultry manure to two test plots and measured fecal coliform concentrations across 9 m wide grass filter strips. After artificial rain was applied, researchers found that fecal coliform concentrations were reduced by 74% and 34% in the two strips. In addition, Young et al. (1973) found that a 60 m long grass filter strip reduced fecal coliform by 87%. While these studies do show that riparian buffers can reduce the amount of biological contaminants, the results will likely vary depending on site characteristics.

Factors Influencing Aquatic Habitat: Many studies have focused on the removal of riparian vegetation and its effects on the inputs of large woody debris into a stream. According to May et al. (1996) large woody debris is the most important factor in determining habitat for salmonids. Stream temperature can also be influenced by the removal of streamside vegetation. Shading from riparian vegetation is usually most important on smaller streams. In a review of several articles on the subject, Osborne and Kovacic (1993) concluded that buffer widths of 10-30 m can effectively maintain stream temperatures.

Development of Riparian Buffer Guidelines: Wenger (1999) examined a variety of models to determine buffer width and their effectiveness. He concludes that none of the models are appropriate for delineating riparian buffers at the county scale. Some are too

data-intensive to be easily applied on large scale, some have not been properly field-tested or calibrated, some do not account for factors influencing significant processes, and some yield inconsistent results with one another. No economic considerations were made of the cost of the recommendations.

Wenger goes on to recommend three options for riparian buffers:

Option One:

- Base width: 30.5 m plus 0.61 m per 1% of slope
- Extend to edge of floodplain
- Include adjacent wetlands. The buffer width is extended by the width of the wetlands, which guarantees that the entire wetland and an additional buffer protected.
- Existing impervious surfaces in the riparian zone do not count toward buffer width.
- Slopes over 25% do not count toward the width.
- The buffer applies to all perennial, intermittent and ephemeral streams.

Option Two: *The same as Option One, except:*

- Base width is 15.2 m plus 0.61 m per 1% slope.
- Entire floodplain is not necessarily included in buffer, although potential sources of severe contamination should be excluded from the floodplain.
- Ephemeral streams are not included; affected streams are those that appear on US Geological Survey 1:24,000 topographic quadrangles. Alternatively, buffer can be applied to all perennial streams plus all intermittent streams of second order or larger.

Option Three:

- Fixed buffer width of 30.5 m.
- The buffer applies to all streams that appear on US Geological Survey 1:24,000 topographic quadrangles or, alternatively, all perennial streams plus all intermittent streams of second order or larger.

Quality of Research: This was a review paper so the scientific content was not readily available to scrutinize. The author leaves out many details about the studies that are discussed making inferences difficult. Although a large quantity of literature is cited, the results from the various studies vary greatly. The author makes recommendations on buffer widths without specifically describing what data he is using to reach these conclusions. The recommendations are often based on a few studies rather than the majority, and usually tends to lean towards larger buffers even if the majority of studies showed examples where smaller buffers were adequate. The premise of the paper was to recommend blanket guidelines for riparian buffers for a large area geographic area, an extremely challenging task.

Relationship of Riparian Condition to Fish and Fish Habitat: While most topics discussed within this review indirectly affect fish and fish habitat, few studies made a direct link. An example of one that did is Murphy et al. (1986). They found that streams in Alaska that had buffers of 15 to 130 m had similar fish habitat to old-growth reaches. Another was Barton et al. (1985) who found that temperature was the only important factor determining the presence of fish in small streams. They concluded that for fish to be present, 80% of banks within 2.5 km upstream had to have forests of at least 10 m wide, or sufficient to shade the stream. The author does not identify study location of Barton et al. (1985) nor what species of fish were present.

Few studies have actually evaluated how fish populations are effected by changes in buffer zone width. Therefore, the best we can do is hypothesize how factors like sediment, nutrients, and contaminants may affect fish populations with differing buffer sizes. It has been shown in the literature with some certainty that the larger the buffer the greater the ability the buffer has on reducing many constituents that may be detrimental to fish populations from entering lotic waters at a given site. However, it is still unclear what sized buffers are required to maintain fish or fish habitat for a variety of aquatic ecosystems in different environmental settings.

Relevance of Research to Washington: Most of the research discussed within this review is from southeast U.S.A. Nevertheless, many trends in the data may be relevant for other portions of the continent. Few examples were given in areas where salmonids are native. Overall, the review does not specifically report where the individual studies took place

Wenger's guidelines for buffer widths are a subjective albeit educated opinion and based on conditions primarily in the southeast United States (Georgia). The focus is primarily filtering sediment, chemicals and nutrients from agriculture before it runs off into streams and to a limited extent providing shade. His recommendations provide three options: (1) a variable wide (30 m) buffer for all drainages and up to flood plain in width; (2) a variable narrow (15 m) buffer for mapped perennial and some intermittent streams; and (3) a fixed wide (30.5 m) buffer on all mapped perennial streams and some intermittent streams. The variable buffers add width proportional to land slope.

Relevance to Assessing Riparian Buffer Width: While this paper has a plethora of information on the ability of riparian buffers to reduce unwanted constituents into water bodies, only the trends can be applied to other geographical areas. The recommendations for buffer widths of the author are somewhat arbitrary and may not be relevant for Washington. It is well documented within this review that on a site-specific basis, the larger the buffer the better it is at reducing loading of a variety of possible pollutants. However, the ability of a buffer to reduce pollutants varies greatly on a site-by-site basis.

Therefore developing buffer widths as BMPs in specific locals will require site-specific data and understanding of what pollutants need to be reduced and to what level is sufficient to maintain the desired ecological processes.

Mandatory buffers especially wide buffers on already cleared farm land creates a significant economic agricultural tax that may not be cost effective at protecting streams and salmonids. If the farm does not have runoff or detectible water quality problems, buffers may not be needed. The Natural Resource Conservation Service (USA) has many alternative BMPs to prevent erosion, runoff and contamination. Buffers should be considered after other BMPs have been implemented and found inadequate to meet the specific problem. For lands yet to be cleared adjacent to salmon bearing waters (for any purpose including agriculture), they should retain some vegetation to protect stream banks, provide shade, source of nutrients for the stream, and act as a “shield” from the developed activities that may include agriculture, animal husbandry or other types of land use. We recommend specific widths in Appendix III, Draft Model Ordinance.

No. 14 - Title: *Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old growth forested streams.*

Authors: R. E. Bilby and P. A. Bisson

Citation: Canadian Journal of Fisheries and Aquatic Sciences Vol. 49:540-551. 1992.

Summary of Scientific Content: This study monitored annual organic matter inputs and production of shorthead sculpin, coastal cutthroat trout, and stocked coho salmon from spring through early autumn for in two headwater tributaries of the Deschutes River, near Olympia, Washington. One site was bordered by old-growth coniferous forest; the other was an area clear-cut without buffer strips 7 years prior to the study. The data were collected from June 1982 to May 1984.

While both study sites were underlain with similar geologic formations, they varied in drainage area, stream size, discharge, and riparian vegetation composition. Douglas fir, western red cedar, and western hemlock dominated the old-growth site. Conversely, the riparian zone of the previously clear-cut site was composed primarily of willow, red alder, conifers, and dense growths of shrub and herbaceous vegetation. All estimates of fish production and organic inputs were calibrated to adjust for differences in stream surface area and discharge.

Allochthonous inputs of organic matter were sampled in six litter-traps suspended over the streams at randomly selected locations. In addition, six litter-traps were placed adjacent to the stream with trap openings facing upslope to sample organic matter entering the channel from the forest floor. Traps were emptied monthly. Inputs from herbaceous vegetation growing within the channel margins or overhanging the streams less than 1.5 m above the water surface were estimated from plots. Rooted vascular plants within the high-flow channel margins were collected to a height of 1.5 m at randomly selected 1-m² plots. It was assumed that all plant material growing within high-flow margins would become part of the organic matter inputs at some time each year. All collected organic inputs were dried, separated, combusted at 500°C and organic matter was determined by weight loss at ignition.

Autochthonous production was measured *in situ* with light and dark photosynthesis-respiration chambers. Measurements in each stream were taken at about 10-d intervals during the spring and summer months. The total amount of fixed organic carbon was estimated for each sampling period. For further details please see methods section of paper.

Solar input to the streams was extrapolated from light measurements taken near Olympia, Washington, at the mouth of the Deschutes River. Measurements from Olympia, 50 km from the study area, were applied directly to the clear-cut site. Decreased light inputs to the old-growth stream were estimated by comparing light intensity measurements taken simultaneously with a dome solarimeter at the old-growth site and clear-cut site under different cloud cover conditions.

Primary production was estimated from regressions of gross photosynthesis against light intensity, a procedure used for other small forested-streams by Murphy (1984).

Regressions were developed for each site during each of three intervals: July-October, November-February, and March-June.

Fluvial inputs were measured using a variety of methods including grab samples, automatic pump samplers, and drift nets. Organic matter contributed to the study reached by fluvial transport was separated into three categories based on particle size. Dissolved organic matter (DOM) was material < 0.001 mm diameter, fine particulate organic matter (FPOM) ranged from 0.001 to 1.0 mm, and course particulate organic matter (CPOM) was material > 1.0 mm. Fine and course particulate organic matter was dried, and organic matter content was determined by weight loss on ignition.

Two species of fishes resided naturally in the study streams, coastal cutthroat trout and shorthead sculpin. Once in the spring of 1982 and 1983 hatchery raised coho salmon fry were planted into both streams at the same densities (fish per m^2). However, the total number, time of stocking, and size of coho fry changed from 1982 to 1983. Stocking densities of coho in 1982 were approximately 16 fry/ m^2 , while stocking densities in 1983 were approximately 9 fry/ m^2 in 1983. Average weight of stocked coho fry at release was 1.88 g in 1982 and 0.75 in 1983.

The purpose of stocking coho fry was to evaluate the response of juvenile coho to differences in organic matter sources independent of differences in recruitment rates between the two streams. Changes in stocking density from 1982 to 1983 permitted examination of compensatory effects of population pressure on survival and growth. Fish populations were estimated in early summer and early autumn using a removal technique via electrofishing in randomly selected pools and riffles. Fish densities per habitat unit were used to extrapolate the population of the entire reach. Biomass estimates were based on length-weight regressions established from 30 fish selected randomly from each site on each sample date.

Downstream movements of fish were monitored with fish traps at the lower end of each study site. Actual mortality was calculated as the difference between the estimated population size and the number of downstream migrants. Production estimates assumed

that instantaneous daily rates of growth and “mortality” (actual mortality plus emigration) were exponential.

Stomach contents were sampled by flushing during June and July 1982 to evaluate possible differences in food organisms selected by coho between the two sites. In addition, they evaluated invertebrate drift for differences between sample sites. Both fish stomach content and invertebrate drift were only sampled once in each site and were not sampled on the same days.

Results revealed that the amount of terrestrial litter and inputs of organic matter blowing into the stream from the forest floor were significantly higher in the old growth site versus the clear-cut site. While leaves were the most common material collected in litter traps at the clear-cut sites, old growth sites showed greater variety. While leaves and needles were an important component of the autumn litter fall in the old-growth sites, small pieces of wood entered the stream throughout the winter.

Vegetation growing within or overhanging the channel less than 1.5 m above the water surface was an important source of the terrestrial organic matter at the clear-cut site where the proportion (60%) of allochthonous inputs contributed by “in-channel” and overhanging vegetation was nearly twice the amount from other sources. While the amount of this type of organic matter was actually greater at the old-growth site, input from in-channel and overhanging vegetation comprised only 20% with greater amounts of litter coming from other sources.

Diatoms always dominated the algal community of the old-growth stream. Conversely, the clear-cut stream was dominated by a dense growth of green algae in the spring, then by diatoms throughout the summer and winter. Gross primary production was approximately twofold greater in the clear-cut than in the old-growth stream from April to October.

Fluvial inputs of DOC, FPOM, and CPOM were all similar between streams, although the composition of CPOM differed between streams. Deciduous leaves comprised slightly more than half of the CPOM in the clear-cut site, but only 5% of the CPOM in the old-growth site. Concentrations of dissolved nutrients were low at both study sites. Average nitrate-N concentrations were significantly greater in the old-growth site than in the clear-cut site over the period of the study. On the other hand, average Kjeldahl-N, ammonia-N, and total dissolved P concentrations were not significantly different. However, increases in nutrient availability may not have been reflected in the samples if uptake by algae had kept concentrations at low levels. Similarly, reduced nitrate levels in the clear-cut area may have been related to increased uptake by algae.

In summary, autochthonous production in the clear-cut stream was about 70% greater than at the old-growth forested stream during 1982-83 and approximately 50% greater during 1983-84. In contrast, allochthonous input to the old-growth site was approximately five-fold greater than to the clear-cut site. At the clear-cut site, autochthonous production contributed about three times the amount of organic matter that was delivered from the terrestrial system.

Production of all fish species over the early summer measurement period was significantly greater in the clear-cut site than the old-growth site in both years. In 1982, the average daily rate of fish production during early summer in the clear-cut site was $87.8 \text{ mg/m}^2/\text{day}$, which was approximately 4.0 times greater than $19.7 \text{ mg/m}^2/\text{day}$ in the old-growth site. In 1983 fish production in the clear-cut site exceeded the old-growth site by a factor of 1.7. No significant differences in total fish production were observed between the sites from late summer to early autumn.

Production of coho salmon accounted for 30-97% of the total production in the old-growth site and for 59-92% of the total production in the clear-cut site. Initial stocking levels of fry influenced coho production rate. At high stocking densities in 1982, coho production was enhanced by the relatively large standing crop of biomass throughout summer and early autumn. In 1983, the year of lower initial stocking densities, coho production was supported by high growth rates. In 1982, production of coho was greater in the clear-cut site than in the old-growth site throughout the summer, but in 1983 there was no significant difference in coho production between the streams. Therefore, at lower stocking rates fish growth and production was approximately equal in the two streams, while at higher stocking densities fish growth was higher in the clear-cut stream, which in turn lead to higher fish production.

The differences in coho salmon growth rates between the two years suggested that food availability played a major role in controlling the production of juvenile coho in the two streams. Coho growth rates were much lower when fish were very abundant than when densities were low. Compensatory growth responses indicated that food availability may have limited coho production more in the old-growth site than in the clear-cut site, an observation similar to finding in other Pacific Northwest streams (Gregory et al. 1987; Hicks et al. 1991). Total fish production in early summer was consistently greater in the clear-cut than in the old-growth site despite approximately five times more terrestrial organic matter entering the stream in the old-growth forest.

While increased primary and secondary production may explain increased fish production at the clear-cut site, other factors are speculated to have played a role. The clear-cut stream exhibited higher maximum and average daily temperatures than did the old-growth stream increasing growth rates. Differences in coho salmon emigration after stocking and resulting density changes may also have influenced production, especially at higher stocking densities. Immediately after stocking, fewer coho emigrated out of the

old growth, which contained better physical habitat quality (more pools) than the clear-cut site. The higher densities of fish in the old-growth stream may have resulted in more intense intraspecific competition. Consequently, growth rates of coho in the old-growth site were low in the spring and early summer. At the clear-cut site, lower initial population densities coupled with apparently elevated food availability led to increased early summer growth rates and higher levels of production than at the old-growth site.

Quality of the Research: This study was conducted by experienced scientists and published in a peer-reviewed journal. While the study clearly demonstrated the difference in allochthonous inputs to the two study streams, estimates of autochthonous inputs were less reliable. Primary production was estimated using regressions of gross photosynthesis against light intensity, a procedure used for other small forested-streams by Murphy (1984). However, light intensity was not directly measured at study streams, instead it was extrapolated from an area 50 km from the study sites. Therefore, the combination of extrapolated light intensity data and estimates of primary production based on regressions, leave doubt as to the validity of the overall gross primary production estimates reported within the study.

The author's clearly note limitations of the study that may have changed the overall results. While the study clearly showed higher coho production ($\text{mg}/\text{m}^2/\text{d}$) in the clear-cut stream over the old-growth stream during spring through early autumn, the study did not evaluate winter production. Differences in over-winter production/survival between the two study streams, which have very different physical habitat conditions, may have offset the large differences in production observed during the period sampled. Since the study used stocking during both years of the study, over-winter survival and production was not evaluated.

The author's come to a valid conclusion: The challenge is twofold: 1) to determine if autotrophic production can be increased to desired levels in a sustained, cost-effective, and practical manner and 2) to determine if such increases can be achieved without concurrent deterioration in the quality of other environmental components such as stream temperature or large woody debris, both on-site and downstream.

Relationship of Riparian Condition to Fish and Fish Habitat: This study is an excellent example of how differences in riparian habitat can lead to differences in fish production and the quality of fish habitat. The study found that a previously clear-cut stream had much higher potential for fish production during the spring and summer due to increased autotrophic inputs. Although the old-growth forest had considerably higher allochthonous inputs, which are often regarded as being especially important for secondary production in streams, the higher autochthonous inputs observed in the clear-cut stream correlated to higher fish production during the study period. However, the

study did not clearly demonstrate how changes in habitat, especially over-winter habitat might effect fish production across an entire year.

Relevance of Research to Washington Agriculture: The study evaluated coho salmon production in two streams, in western Washington. The study area does not relate to agriculture, but to logging practices and thus may have limited applicability to agricultural activities.

Relevance to Assessing Riparian Buffer Width: The study did not evaluate differences in riparian buffer widths, only whether a partially recovering riparian removal condition could be evaluated against an unaltered riparian condition related to logging old growth forests. It evaluated two streams, one that had been previously clear-cut (7 years prior) and one that had not been altered (old-growth). The study attempted to assess whether there were differences in organic input and organic production in the two streams and how that might affect fish. Not surprisingly, there was more allochthonous organic input from the old growth forest. Possibly surprisingly, the clear-cut stream suggested more fish production was occurring in some seasons and some years in spite of lower allochthonous input. A possible causal explanation was due to a larger energy input from sunlight, which caused greater growth (production) of algae plus increased temperature. Other speculative explanations included differing densities of stocked coho salmon fry and habitat. The clear-cut site was recovering in pre-climax vegetation succession, so the potential impacts to fish production from initial years after clear-cutting were unknown. The results from this study may best be applied to BMPs by understanding that riparian vegetation removal sets up a complex set of interactions within the stream. While removal of the riparian zones may have many detrimental effects on the aquatic community, in certain places or life stages (e.g. juvenile salmon), it may actually have perceived benefits if increased fish production is a goal. It is possible to imagine too much of a “good thing” in that extrapolated to larger areas, increased algal production could lead to eutrophication and collapse of the fishery. The key is to understand how these possible benefits can be utilized while at the same time maintain a mosaic of complex habitats that benefit other organisms and various life stages for salmonids. Even in an undisturbed watershed, there will be reaches of stream with more or less open canopies. Changing canopy density will change energy input including both external organic material but also increase energy input via more solar radiation. The larger the geographic extent of change, the more likely will be changes in these factors globally. Thus incremental riparian loss should be evaluated, not just on a site-by-site basis, but also on a watershed scale basis as well.

No. 15 - Title: Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs.

Authors: J. D. Allan, M. S. Wipfli, J. P. Caouette, A. Prussian, and J. Rodgers

Citation: 2003. Canadian Journal of Fisheries and Aquatic Sciences 60: 309-320.

Summary of Scientific Content: This southeastern Alaska study examined the importance of terrestrially derived invertebrates as prey for juvenile coho salmon. In addition, they examined the influence of forest and plant type (old growth (OG) versus young growth (YG), deciduous versus coniferous, alder versus spruce-hemlock, and overstory versus understory) on the abundance of terrestrial derived invertebrates and their inputs into streams.

Twelve streams were studied, six in OG catchments and six in YG area that had been clear cut 35-50 years previously. Various vegetation and stream characterization metrics were sampled in each reach. Juvenile coho salmon were trapped in pools within reaches using minnow traps each month from June to September. Three coho per vegetation type, date, and stream site were treated as subsamples. Their stomachs were flushed to identify and quantify diet.

Invertebrate composition and abundance falling to the stream surface were assessed using floating pan traps. In 1996 six streams were sampled in YG streams to contrast surface inputs associated with locations of predominantly red alder or conifers. In 1997 eight streams were sampled to contrast inputs from OG and YG forest types. Pans were set at monthly intervals for approximately one week. Aerial stages of aquatic insects were excluded from the terrestrial category.

To quantify the invertebrate biomass and composition associated with specific vegetation types three overstory species (alder, spruce, and hemlock) and three understory taxa (salmonberry, blueberry, and currant) were sampled by clipping three haphazardly selected stems within 1 m of the stream bank at each site at approximately monthly intervals. All invertebrates residing on the stems and leaves were identified to order. All leaves were removed from each stem, dried, and weighed to express invertebrate biomass per leaf biomass sampled.

Juvenile coho salmon ingested a diverse mix of invertebrates that included both aquatic and terrestrial source organisms. Across all sites of the invertebrates that were identifiable, approximately 33% by mass of ingested prey were of terrestrial origin, while approximately 32% were of aquatic origin. Roughly one-third of ingested prey, largely Diptera, could not be reliably attributed to either aquatic or terrestrial origin at the level of taxonomic resolution that was employed.

No significant differences were observed for mean invertebrate biomass as prey between forest types, species, and forest type by species interaction. The biomass of terrestrial prey showed significant differences over time being higher in July and August and lower in June and September. There was no significant interaction between time and forest type or time and plant species. Terrestrial prey were more numerous than aquatic prey in 3 of 4 months, whereas both were similar by biomass. This indicates that terrestrial food items were smaller in size than aquatic types.

Much higher invertebrate biomass was found on deciduous plant stems when compared to coniferous plants. Taxonomic composition of terrestrially derived invertebrates also varied markedly among plant species, suggesting a role for plant heterogeneity in providing aerial inputs. Conversely, no significant difference was observed in aerial invertebrate biomass between conifer and deciduous plant types. The authors feel that this was likely due to sample design limitations. Mixing by wind dispersal may have affected the results. In addition, the data suggest much greater terrestrial derived invertebrates biomass per gram mass of deciduous leaves compared with conifers; however, the total tree volume was considerably greater at old growth compared with young growth streams, and these may have offsetting effects.

Quality of the Research: This study was conducted by university and government scientists and was published in a peer-reviewed scientific journal. It might be best used as a reference for the importance of terrestrial inputs as food as food source for juvenile salmonids rearing in small coastal watersheds. The authors point out any down falls in their experimental design and unveil any areas where it may have precluded their ability to make statistical inferences.

Relevance to Assessing Riparian Buffer Width: Although this study was very complete in fulfilling the stated objectives, it did not evaluate differences in buffer dimensions. Although the data presented indicate that terrestrial inputs from riparian areas are of importance to juvenile coho salmon, it found no statistical differences in coho diets between differing types of vegetation. Riparian vegetation may provide some critical prey supply element for salmonid growth and development by either seasonally, spatially, temporally or by species-specific factors. The authors cite Kawaguchi and Nakano (2001) that found that terrestrial invertebrates consumption by salmonids during summer was 77% in grassland dominated riparian zone. Although these findings reinforce the importance of terrestrial inputs to salmonid food webs, it is still unclear how varying types or dimensions of riparian communities effect terrestrial inputs except that it appears that some streamside vegetation may facilitate allochthonous input of both terrestrial and adult aquatic invertebrates into the food web of coho salmon.

Relationship of Riparian Condition to Fish and Fish Habitat: The findings in this study indicate that terrestrial invertebrate inputs into small coastal streams can be an important part of juvenile salmon diets. The authors note that the importance of terrestrial invertebrates to fish and very likely other consumers within stream food webs may be reinforced by the tendency for aquatic prey to become less numerous during summer because of emergence. Nakano et al. (1999) cited in this paper found that experimental reduction of terrestrial input led to greater predation on aquatic invertebrates by fish, which in turn enhanced algal growth.

The authors suggest that differences in riparian vegetation likely result in variation in quality, composition, and timing of terrestrial invertebrate subsidies for fish. In this study, deciduous trees supported much higher invertebrate mass per stem than did conifers, and alder substantially exceeded either spruce or hemlock. The fact that no difference between YG versus OG streams and alder versus conifer was found in pan trap inputs may be due to total tree volume, which was considerably greater in OG compared to YG streams.

This study emphasizes that changes in riparian condition in small coastal watersheds has the potential to impact prey available for juvenile salmonids. Terrestrial prey originating from the riparian zone was found to be a major portion of juvenile coho diets.

Relevance of Research to Washington: Although this study was conducted in southeast Alaska, it is a coastal climate and geographically adjacent to Washington and therefore is relevant. The study focused on overstory OG communities of western hemlock, Sitka spruce, and the occasional red cedar, while overstory YG sites consisted mainly of red alder. Identical species of riparian vegetation present within the study are also present in Washington. Whatever inferences can be drawn from this Alaskan study to Washington should be valid based on the vegetation types and the evaluation of coho salmon diets.

Appropriateness to Develop BMPs: This research suggests that streamside vegetation may play a role in salmonid food web. Abundance of terrestrial insects was greater on deciduous trees compared to evergreen trees and thus variable patchiness of riparian vegetation types may provide increased variation in the diversity of food types available to the stream. However no inferences can be drawn from study with regards to widths or extent of riparian buffers because no controls or variation in widths were tested.

No. 16 - Title: Allochthonous input of organic matter from different riparian habitats of an agriculturally impacted stream.

Authors: M. D. Delong and M. A. Brusven

Citation: Environmental Management 1994 Vol. 18, No 1, pp 59-71.

Summary of Scientific Content: This northern Idaho, U.S.A. study examined allochthonous inputs from riparian vegetation along the longitudinal gradient of Lapwai Creek, a fifth-order stream in a drainage extensively altered by agricultural practices. To assess potential effects of riparian habitat alteration on allochthonous inputs, Lapwai Creek was divided into eight distinct sections. Stream sections were determined based on some combination of stream order, stream linkage, catchment morphology, land use, and riparian vegetation type. Four types of riparian vegetation were identified: herbaceous species only; herbaceous species-shrub mix; shrubs only; and deciduous trees. Leaf traps (30 x 30 x 30 cm) were randomly placed along transects parallel to the shoreline in each stream section. Traps were suspended 1 m above water level. Traps were situated along each transect so that representative litterfall would be collected from each vegetation type found in a section. Monthly and annual allochthonous income for each stream section were determined for 1989 and 1990. Allochthonous income is a measure of the total amount of leaf litter (kg) entering a stream or stream section over some unit of time. In addition, optimal annual allochthonous income was calculated to quantify potential loss of detrital input due to alteration of riparian habitat. Optimal annual allochthonous input was calculated by multiplying the stream surface area for each stream section by the mean annual litterfall observed during the study for the optimum vegetation type of each section. Optimum vegetation type for each reach was assumed based on present riparian vegetation and geomorphology.

Litterfall occurred from August through November, with most entering the stream in October. Annual input from deciduous tree habitat was highest of all vegetation types. Monthly litterfall was usually least for riparian habitats consisting of herbaceous species and highest in deciduous tree habitats. Riparian habitats dominated by shrubs typically had greater mean monthly litterfall than habitats consisting of herbaceous-shrub mix. Of material entering the stream, non-woody material constituted a much higher proportion of litterfall for all habitat types than did woody material.

The removal of both streamside climax vegetation and climax vegetation in proximity to the stream reduced allochthonous input more than reductions seen in areas where only streamside climax vegetation was replaced by successful species. In addition, cottonwood leaves that most likely came from trees in adjacent riparian habitat often dominated litterfall associated with herbaceous-shrub and shrub habitat. This was especially true at

the one site that had the best-developed riparian habitat and intact climax vegetation away from the stream.

Several instances occurred where riparian vegetation type with the highest mean monthly litterfall (g Ash Free Dry Weight/m²) in a stream section did not have the highest monthly allochthonous income. Lower monthly allochthonous income for vegetation types with high monthly litterfall was due to the small amount of stream surface area associated with that vegetation type. The removal of vegetation producing large quantities of litter and its subsequent replacement by species producing smaller quantities reduced monthly and, therefore annual allochthonous income to the stream. As a result, the availability of allochthonous organic matter may be limited in stream sections where riparian vegetation has been severely altered. In fact, 54% of the total annual allochthonous income for the entire stream came from one section, which only accounted from 12% of the total stream length. Again, this was the section with the most intact riparian community along the stream and in the adjacent areas.

The effect of riparian habitat alteration was evident throughout the stream after total annual allochthonous income was compared to potential annual income. Actual annual income was 19% to 80% of the income expected if optimal riparian vegetation were present. Actual annual input was closet to potential income in the previously mentioned reach where a large proportion of climax vegetation exists both along the stream and in adjacent areas.

Quality of the Research: The research was conducted by university scientists and published in a peer-reviewed journal. The study's limitations in regards to evaluating buffers are derived from not having a control. All sites were situated on a longitudinal gradient of the same river in different geomorphologic settings and each having varying levels of agricultural influence. Although the study did a reasonable job at showing that intact deciduous forests input more allochthonous materials than other vegetation types, it did not clearly quantify how land use has affected the overall inputs. Potential annual income was calculated by assuming the major vegetation type would have historically encompassed the entire reach, which may or may not be valid, depending on the site-specific properties of each individual site.

Relationship of Riparian Condition to Fish and Fish Habitat: No data from this study is presented to show the relationship or benefits to fish directly, but the authors cite another study describing the macroinvertebrate community of Lapwai Creek. Delong (1991) found that shredding organisms never make up over 5% of the community within a stream section of the study site, while in other streams within the Lapwai Creek drainage where the riparian vegetation is less disturbed, shredders are often abundant, thus indicating that they are present in the area and if conditions were suitable they could more readily colonize Lapwai Creek. They suggest that removal and subsequent

replacement of riparian vegetation could result in localized patchiness of benthic organic matter. Often when benthic communities are disturbed or variable, the total biomass may be similar even though species composition or diversity may be similar to undisturbed areas. Thus shredders may be less abundant but replaced by other ecotypes such as grazers and predators. In fact, this is demonstrated in the accompanying paper by the same authors. Thus no data about the direct effects of riparian vegetation on fish, fish foods (benthos) or the width of buffers can be discerned from this research. Since allochthonous material is subject to movement in the stream with water currents, the analysis also provides no accommodation or understanding of a patchy environment where input budgets are evaluated from a watershed basis.

Relevance of Research to Washington: The study was conducted in northern Idaho. The data and conclusions are broadly applicable in principle to conditions throughout North America where climax riparian vegetation types have been either removed or changed to earlier successional stages. They cite others who observed similar results in other locals.

Relevance to Assessing Riparian Buffer Width: The primary observation the authors made was that the removal of both streamside climax vegetation and climax vegetation in proximity to the stream reduced allochthonous input more than reductions seen in areas where only streamside climax vegetation was removed. . Although this may be of importance when developing BMPs, no data was given as the distance that allochthonous inputs originated from or any quantitative effects on the instream community. The general observation that riparian and adjacent vegetation provides nutrients for a stream is demonstrated. What is unclear is how much nutrient is needed to support fish. Clearing of some vegetation in a watershed may also have potential benefits of increased sunlight (energy) that also can increase biomass in a stream. Thus, this study cannot provide any guidance as to the width of riparian forests that should be left. In evaluating a watershed, it is important to understand what the nutrient levels input into the stream are and their relationships with the stream ecosystem. Agriculture may end up trading nutrient input of one type (native vegetation) from another (agricultural runoff containing nutrients from fields).

No. 17 - Title: Macroinvertebrate community structure along the longitudinal gradient of an agriculturally impacted stream.

Authors: M. D. Delong and M. A. Brusven

Citation: Environmental Management 1998 Vol. 22, No. 3, pp. 445-457

Summary of Scientific Content: Delong and Brusven conducted this northern Idaho, U.S.A. study at the same sites on Lapwai Creek as the previously discussed study. Again Lapwai Creek is an agriculturally impacted stream that's riparian habitat once contained 5 to 15 m of woody deciduous vegetation of cottonwoods or alder. Anthropogenic activities have resulted in the removal or thinning of the original riparian vegetation in the plain, producing a riparian community dominated now by small shrubs and herbaceous species. The objectives of this study were to: (1) determine if macroinvertebrate community composition changed along the longitudinal gradient and if longitudinal changes followed predictions of the river continuum concept; and (2) determine if changes in community composition reflected changes in the availability of food resources. If Lapwai Creek followed the concepts of the river continuum (Vonnote et al. 1980) the authors expected to find a shift from heterotrophically communities in the headwaters to autotrophically structured communities downstream as the role of primary production increases with increasing stream size.

The study design consisted of taking two samples in each of three riffles using a Hess sampler in each of the eight sample sites over 48 km of stream. Random skewer analysis (Pielou 1984) was used to determine if the macroinvertebrate community composition changed along an abiotic gradient (e.g., longitudinal or elevational). Random skewers is a nonparametric procedure; therefore, it was not necessary to transform data to satisfy assumptions of normality. Random skewers were used on both total cumulative number of individuals per species and cumulative number of individuals per functional feeding group. Average linkage cluster analysis was employed to examine site associations based on number of individuals per species and per functional feeding group. Pearson product-moment correlation analysis was used to determine if any relationships existed between available food resources and macroinvertebrate community composition.

Random skewers results for the full data set indicated that there was no gradient in total number of individuals. In addition, random skewers for functional feeding groups again showed no gradient. The results of random skewers indicated that the community structure did not correspond to the abiotic gradients, specifically the longitudinal and elevational gradients of Lapwai Creek. The authors note that the broad-scale agricultural alterations of the catchment appears to have produced a relatively homogeneous macroinvertebrate community throughout the length of the study stream. Cluster analysis

indicated that the number of individuals in each functional feeding group over the entire study was similar among all locations, except for a site directly below a reservoir.

The functional feeding group grazers were relatively high at all sites during all seasons, while shredders exhibited low relative abundance throughout the stream. The authors note that shredding macroinvertebrates represent an important component of the biological processing of coarse particulate organic matter and are typically most abundant where there is a strong interaction between the riparian zone and the stream.

Quality of Research: The research was conducted by university scientists and published in a peer-reviewed journal. The research was thorough for answering the questions the authors posed. Although changing the age structure and composition of riparian habitats may in turn affect the aquatic macroinvertebrate community structure in a stream, this study was not set up to quantify how changing the riparian habitat affected the macroinvertebrate community (shredders were replaced by grazers). In regards to riparian buffers, the authors cite other studies done on relatively undisturbed streams with intact riparian zones that unlike this study did find longitudinal gradients in macroinvertebrate community structure that show a more classic community gradient from heterotrophic communities upstream to autotrophic communities downstream.

Relationship of Riparian Condition to Fish and Wildlife Habitat: No fish or fish habitat data are presented. The study does evaluate how macroinvertebrate community structure changes along the longitudinal gradient of an agriculturally impacted stream, which does have relevance for fish in regards to food supply. The study found a relatively homogenous macroinvertebrate community structure throughout a 48 km stretch of stream that is set in three geomorphologically distinct regions. Although this study did not present data or discuss the relationship with fish, the change in the macroinvertebrate community may have impacted fish diversity and abundance compared to reaches where riparian vegetation was left intact.

Relevance of Research to Washington: The study was conducted in northern Idaho. The data and conclusions may be applicable in principle to conditions throughout North America where anthropogenic and in particular agricultural practices have led to a stream where macroinvertebrate community structure is shaped primarily by autotrophic processes.

Relevance to Assessing Riparian Buffer Width: This paper can be useful to developing BMPs with respect to understanding that riparian zones do more than just stabilize banks and retain nutrients. Delong and Brusven observed in two studies on Lapwai Creek that thinned and cleared streamside and adjacent riparian habitats affect the amount of allochthonous inputs into a stream. They also hypothesize that increased solar radiation due to decreased shading and increased nutrient inputs due to agricultural practices within

the basin have lead to a relatively homogeneous autotrophic stream system. Other studies on streams with relatively unchanged riparian habitats have shown higher diversity in macroinvertebrate communities and have displayed a longitudinal gradient from heterotrophic to autotrophic processes. The importance of this longitudinal gradient in a stream with various fish species and life stages is an important but unanswered question. Even more importantly, this research is unable to evaluate in any way, the width or lengths of riparian buffers that should be protected along agricultural streams, especially if an important question is how does that affect diversity, abundance and standing crop of native fish, especially salmonids.

No. 18 - Title: Role of riparian red alder in the nutrient dynamics of coastal streams of the Olympic Peninsula, Washington, USA

Authors: C. J. Volk, P. M. Kiffney, and R. L. Edmonds.

Citation: American Fisheries Society Symposium 34: 213-225, 2003.

Summary of Scientific Content: This study compared the nutrient contributions of riparian areas composed mainly of red alder to those composed of coniferous species. The study was conducted on the Olympic Peninsula of Washington, U.S.A. Six second-order headwater streams were used as study sites, three with riparian corridors dominated by western red cedar, western hemlock, and Douglas fir, and three dominated by 30-40 year old stands of red alder. Red alder sites had been logged about 30-40 years prior to the study, while coniferous sites were old-growth forests located in Olympic National Park.

The study was designed to compare the following: litterfall, water chemistry, seston, and periphyton of two sets of replicated streams. Analysis consisted of single factor analysis of variance (ANOVA). Statistical differences were noted a $p < 0.05$. One hundred meter reaches at similar elevations (~ 100 m) and gradients ($\sim 15\%$) were selected for sample collections on each stream. Discharge averaged $0.02\text{-}0.15 \text{ m}^3/\text{s}$ on all streams, but was seasonably variable.

Leaf litter, water, seston, and periphyton were collected every 28 days from May 1999 to December 2000. Some addition samples were also collected from September to December 2000. Litterfall was collected using eight mesh-covered baskets (0.22 m^2) placed within 5 m of the active channel at each site each month during the sampling season. Litterfall was sorted by tree (alder or conifer) and tissue type (leaf, woody material, or reproductive), dried to constant mass, and ground. Periphyton was scrubbed from eight preconditioned ceramic tiles (144 cm^2) at each of the six sites. Five wood blocks (red alder, western red cedar, and maple) were placed in two of the streams to compare algae growth on three types of wood prevalent in the watershed.

Leaf litter, seston, and periphyton samples were macro and micronutrients. Carbon and nitrogen were analyzed and water samples were analyzed for dissolved NH_4^+ , NO_3^- , NO_2^- , dissolved organic carbon (DOC), and PO_4^{2-} and total Kjeldahl N and P.

Litterfall and periphyton biomass were significantly higher in alder than conifer sites. Two streams were used to represent all alder and conifer sites, since annual litterfall data were not available at all six study sites. Litterfall from all alder and conifer sites was not significantly different within the fall sampling period. The total annual biomass litterfall

biomass on alder-dominated streams (348 g/m^2) was significantly higher than coniferous (104 g/m^2) riparian areas and averaged more than three times as much input per year.

Monthly chlorophyll *a* measurements used to determine standing stock algal biomass from benthic periphyton samples indicated that alder sites averaged $0.32 \text{ } \mu\text{g/cm}^2$ of chlorophyll *a* and $0.13 \text{ } \mu\text{g/cm}^2$ for conifer sites from September 1999 to December 2000.

Concentrations of stream NO_3^- and total Kjeldahl nitrogen were almost twice as high in alder sites when compared to conifer sites. Concentrations of N, P, K, Ca, and Mg were significantly higher in alder leaf detritus than coniferous needles. Concentrations of P and K in periphyton from wood blocks were significantly higher in the alder site than the conifer site, regardless of block type.

Quality of Research: This study was conducted by university and governmental scientists and published in peer-reviewed symposium of the American Fisheries Society. The study design was sufficient for addressing their objective of describing the contributions of red alder to stream ecosystems in headwater streams in the Pacific Northwest. While the study was conducted well, it answers little for the purpose of prescribing buffer widths. The study did not quantify the width that riparian habitats covered along study sites. It can be used as a tool in prescribing heterogeneous buffers within a watershed to maintain both the habitat forming contributions of conifer stands and the added nutrient input from red alder stands.

Relationship of Riparian Condition to Fish and Fish Habitat: No fish or fish habitat data are presented in this study. However, data presented in this study clearly suggests that red alder stands can contribute a significant amount of nutrients to a headwater stream. In areas that are nutrient limited, this input may be especially important in maintaining the productivity of a stream for salmonid rearing. The author's suggest that riparian zones composed of red alder have less seasonal variability in the amount of nutrient input to streams than do other sources such as marine derived nutrients from anadromous salmon carcasses. The author's make note of other data from salmon and non-salmon bearing streams in Alaska where nitrate concentrations remained driven by the watershed coverage of alder, even when salmon bearing and non-salmon bearing streams were compared before and during spawning events. They go on to suggest that alder coverage may be a more important source of nitrate in surface water than salmon carcasses in streams where alder coverage is significant.

While this study presents data on nutrients in surface waters and compared algal growth between conifer and alder dominated riparian zones, it does not present data on how those differences may affect macroinvertebrates, which is where the productivity needs to go to benefit fish. Nevertheless, many other studies have shown how productivity in a stream at all levels of the food web can increase with an increase in nutrients such as

nitrogen and phosphorus. Alder trees often occur prior to the establishment of coniferous forests. They are common in disturbed areas. We would assume that a natural system would have a mix of conifer and deciduous (alder) species and contribute diversity spatially and temporally to the aquatic landscape. It seems reasonable to suggest that the presence of some alder forests will be a benefit to salmon productivity based on the increased productivity of the lower portion of the aquatic food chain. Conversely, although red alder stands may benefit salmon bearing streams by increasing productivity, red alder stands may be less likely to have as much of a habitat forming benefits of old-growth or mature stands of coniferous forests. Therefore, maintaining a natural mix of the two community types may be important in balancing nutrient inputs and habitat forming capabilities.

Relevance of Research to Washington: The study was conducted on the Olympic Peninsula in western Washington, U.S.A. Study sites were headwater streams where old-growth watersheds were dominated by western red cedar, western hemlock, Douglas fir, while previously logged sites were dominated by red alder.

Relevance to Assessing Riparian Buffer Width: No data was presented on riparian buffer width and how differing widths may affect nutrient input to streams. While much of the nutrient input literature associated with riparian buffers shows that riparian buffers can actually diminish the amount of nutrients and energy input into a stream by filtration and shading, this study showed that red alder stands have the potential to enhance stream loading. Because red alder is a precursor to conifer forests, excess clearing of conifers adjacent to streams and in a watershed in general might lead to dominance of pre-climax vegetation such as alders for several decades. It is difficult to predict whether this would actually enhance salmon productivity or reduce it. Most logging operations involve replanting of conifer trees so this is an unlikely outcome in forestry practice. However, if mature conifer stands are removed in agricultural lands and invaded by alder, the potential for eutrophication should be considered depending on the site-specific water quality and watershed conditions.

No. 19 - Title: Riparian forest buffers on agricultural lands in the Oregon Coast Range: Beaver Creek Riparian Project as a case study.

Authors: B. Bishaw, W. Emmingham, and W. Rogers.

Citation: Research Contribution 38, July 2002. Forest Research Laboratory Oregon State University College of Forestry, Corvallis, OR.

Summary of Scientific Content: The primary goal of this Oregon State University project was to develop information on how to establish riparian filter belts that lead to improved stream protection and fish habitat in the agricultural portions of coastal watersheds, while removing as little pasture as possible from production. The study site on Beaver Creek is used for pasture for cattle, which graze to the edge of the stream in many places. Prior to the project there were very few streamside trees. The study area is classified as summer rearing habitat for coho salmon. The data presented in the paper are for five years, including the first year of riparian filter strip planting.

Some of the specific objectives of the project were as follows: 1) establish tree filter belts to determine the effectiveness of various widths of tree planting in providing stream shading over time 2) to test a variety of approaches to establishing red alder, including planting individual trees, groups of trees, and rows of trees with and without predator protection, and using various vegetation management activities 3) to compare the costs and benefits of different strategies

During the winter and spring of 1995 riparian tree filter belts were planted along the banks of Beaver Creek. Various trials were installed along Beaver Creek, including fencing of the south side excluding cattle and leaving the north side unfenced. The fenced area encompassed a 335.3 m stream reach. To minimize soil erosion, a 3.1 m wide grass strip along the entire bank was left untreated. Treatment areas were 30.5 m in length and consisted of planting red alder seedlings in one row, three rows, or six rows, and a control where no seedlings were planted. Spacing between rows and individual trees was 1.8 m. Therefore complete buffer widths including the grassed area adjacent to the stream bed were 3.1 m for 1-row, 8.5 m for 3-row, and 13.9 m for the 6-row treatment. Each treatment was replicated three times. All treatments except for the control were prepared with herbicide treatment to eliminate existing pasture grasses to reduce competition.

In addition, a few unreplicated tests were used, which included and additional 30.5 m herbicide sprayed strip planted with 60 hybrid cottonwood (*Populus trichocarpa x deltoids*) cuttings. A small area on the streambank where alder seedlings or cottonwood cuttings were inserted through a weed control fabric, this was done to see if weed control could be obtained without spraying herbicides. Additional later plantings of western red

cedar, western hemlock, and grand fir were planted to test survival in a coastal riparian area.

Various trials were placed on the unfenced north bank of the stream. They included unprotected red alder planted through weed control fabric on unfenced pasture and caged red alder planted on unfenced pasture to see if trees could be established without cattle exclusion.

Numerous types of protective devices were used in the project to retard predation by beavers and other small rodents. Such devices included Vexar tubes, Magic Circle repellent, Protex tree shelters, and chicken wire fences.

To determine the amount of shade produced by tree filter belts, light measurements were recorded between 10:00 AM and 2:00 PM. Two instruments were used simultaneously: one was set in an open field to measure total direct and diffused light, while the other measured the amount of light at various locations, depending on the filter belt treatment. Measurements were taken at the stream bank for all treatments. Light readings were taken at five sample points for each treatment. The mean amount of shade produced was then estimated as the difference between the amount of light received in the open and the amount beneath the trees. Light was recorded in August of each year when trees were in full foliage.

Within two months of planting, cattle had eaten all trees planted in the unfenced area on the north side of Beaver Creek. Only about half of the trees planted in the Beaver Creek filter belt survived after 6 months. Early browsing and clipping by beaver and cattle caused most deaths. There was no trend in tree survival among treatments. Throughout the study different methods to reduce beaver predation and girdling by small rodents. After better protection was applied to trees (Protex tubes) only occasional beaver damage was observed after the initial year.

Throughout the measurement period, height growth was greater in the 6-row treatments. Trees grew about 1 m during the first year. By the end of the third growing season (1997), trees averaged 3 m in height and formed a closed canopy in the 3- and 6-row treatments. Trees achieved an average height of 5.6 m, 6.1 m, and 7.4 m for the 1-, 3-, and 6-row treatments respectively in 5 years. The mean 5-year tree height was statistically significantly higher for the 6-row treatment than the 1- or 3-row treatments.

The amount of shade produced at the bank of the stream ranged from 22% to 34% at the end of the fifth growing season, up only slightly from the 20% shade early in the experiment before the trees were established. As expected, the lowest percent shading was recorded for the 1-row treatment (22%), while the highest reading was recorded for the 6-row treatment (34%). Thus, the wider tree filter belts provided more shade than did

single rows after 5 years. This can likely be attributed to the fact that there were more trees in the 6-row treatment and that those trees were a little taller than the other treatments. Shade between trees was also highest for the 6-row treatment. The author's anticipated that the trees would incrementally but asymptotically cast more shade on the stream with each subsequent growing season.

Many different types of weed- and animal-damage control techniques were tried, although not all proved necessary. The author's note that the essential steps were fencing, herbicide application, planting good seedlings, tree protection with Protex growth tubes and chicken wire cages, and continued maintenance.

Quality of Research: The project/study was conducted by Oregon State University scientists, but was not published in a peer-reviewed journal. This is a good example of a case study on what considerations to take into account when planting a riparian buffer in agriculture watersheds of the Pacific coast. The lack of data and statistical validation of results leaves many questions unanswered.

The differing treatments to repel beaver and other small rodents throughout the course of the study were valuable for prescribing treatments for future riparian filter strips, but may have convoluted the results. It is not specifically mentioned if all treatments had equal predation by beavers, therefore we do not know how predation affected growth in the various treatments.

No measure of variability was given throughout the paper. The data presented on shading is only presented in a graph with only the mean displayed. This gives the reader no comprehension of how variable the readings were within treatments and how different each treatment actually was. In addition, the study was set up with control treatments, but they are never mentioned again outside of the methods section. Shade measurements were not compared to the control sites after the five-year growing period, which may have been valuable. Differences in rainfall or sunshine could have had an influence on riparian grass growth in all treatments during the fifth year, which would make treatment versus control differences more comparable.

A cost estimate was made for vegetation cattle fencing, vegetation management, beaver protection, and maintenance for the entire study site. Also, the costs associated with three different treatments were calculated for total cost and cost per tree. Although not explained, these two cost estimates used different labor costs per hour. In addition, although the author's note that much more land needs to be taken away from pasture in at least the first few initial years in the 6-row treatment versus the 1-row treatment, there is no mention of the possible costs associated with the loss of range lands from the varying treatments.

Relationship of Riparian Condition to Fish and Fish Habitat: There is no data presented to directly show the relationship or benefits to fish or fish habitat in this paper. However, one of the objectives of the study was to establish tree filter belts to determine the effectiveness of various widths of tree planting in providing stream shading over time. Planting 1-, 3-, and 6-row tree filter belts of red alder adjacent to the stream channel increased the amount of shade present at the edge of the stream bank after a five-year growing season. Increases in shade near the stream bank may decrease summer stream temperatures, which may benefit salmonid rearing habitat. No stream temperature data was sampled during the study; therefore it is unknown how the small increases in shading at the stream bank may have influenced stream temperature. The author's believed that stream bank shading would continue to increase with each additional growing season as the trees grew in height and their foliage became more dense. It was assumed that there was either a benefit or an optimization. Other publications suggest that a very narrow buffer, especially with small headwater streams may be adequate to reduce thermal loading from excess sunlight striking the water surface.

Prior to the project/study very few trees lined Beaver Creek, therefore coarse woody debris inputs would have been limited. After the five-year growing period, all treatments had red alders lining the stream bank of at least 5.6 m in height and 65 cm in mean diameter at breast height. Consequently the tree filter strips have the potential to act as a source of coarse woody debris for Beaver Creek. No data was presented on coarse woody debris inputs to Beaver Creek prior to planting or at the end of the five-year growing period.

Relevance of Research to Washington: The study took place in the agriculturally impacted Beaver Creek located in the coast range of Oregon. Red alder were used as primary tree in filter belts. Beaver Creek provides summer rearing habitat for juvenile coho salmon. The results from this study would apply to Washington coastal streams with similar climate, land use, and vegetation types. Results from this study indicate that when planting filter belts in areas where cattle and beaver are present, many animal damage prevention techniques are needed. Furthermore, site preparation with herbicides need to be used to create an essentially weed free environment to reduce competition for planted seedlings. The techniques recommended from this study for planting tree filter belts may be useful for similar operations in agricultural impacted drainages of WASHINGTON

Relevance to Assessing Riparian Buffer Width: Results from this study were not clear enough to prescribe specific buffer widths for stream temperature problems. Although the study did generate data that indicated stream bank shading had increased with all three treatments, no stream temperature data was presented. However, the lessons learned from this study may be applicable for developing BMPs for planting tree filter belts in areas where cattle, beaver, and other small rodents have the capability to disrupt or even destroy newly planted filter belts. Taking into consideration the problems encountered

with this study would likely increase the probability for success in the creation of any new filter belts in areas with similar pressures.

No. 20 - Title: Relationship of wooded riparian zones and runoff potential to fish community composition in agricultural streams.

Authors: J. C. Stauffer, R. M. Goldstein, and R. M. Newman

Citation: 2000. Canadian Journal of Fisheries and Aquatic Sciences 57: 307-316.

Summary of Scientific Content: The purpose of the study was to compare the influence of local versus basin wide variables, on the fish community composition in an agricultural landscape. The objectives were to determine: (1) if fish communities respond to differences in wooded riparian zones and soil runoff potential through changes in community composition and (2) which factor, riparian zone cover or watershed soil runoff potential, has more influence on fish community composition.

This study was conducted in the heavily agricultural Minnesota River Basin in Minnesota, U.S.A. The experimental design was a 2 x 2 factorial analysis of variance. The first factor was riparian zone cover (wooded, open). The second was soil characteristics (high runoff potential, low runoff potential). Twenty wadeable streams in the agricultural Minnesota River Basin were selected to have the four combinations of the two classification factors of the experimental design. The streams were perennial, had watershed drainage areas between 246 and 813 km², and had tilled acreage of greater than 50%. Row crops dominated the agricultural practices of the study area.

Fish communities were sampled by two-pass electrofishing. The fish community was primarily warm and coolwater species typical of Mississippi River fish fauna. Thus, it was quite different that the coldwater salmonid fish communities of Washington. A modified index of biological integrity (IBI) (Karr 1981) was used as a measure of fish community response and community health. Several other fish community descriptors were also used as response variables to the classification factors, including species richness. In addition, trophic guild distribution was also calculated and used to determine whether trophic composition was influenced by the classification factors. Descriptors were tested for normality and if they were not they were transformed. Those samples that did not respond to transformation were analyzed using a nonparametric statistics where normality does not affect analyses of variance.

There were significant differences in IBI scores due to both riparian zone cover and runoff potential. Mean IBI scores were highest at sites with wooded riparian zones and low runoff potential. In addition, significant differences in species richness were also explained by both habitat factors. There was not much difference in IBI scores between high and low runoff potential sites with wooded riparian zones. However, there was a large decrease in IBI scores between high and low runoff potential sites with open

riparian zones. Most of the differences in the physical habitat of the sites were between wooded and open sites, not between high and low runoff potential.

The authors conclude that fish community composition was significantly influenced by riparian cover and runoff potential. They believe that the local riparian zone condition seems to have more influence on fish community composition than the broad-scale watershed runoff potential. Runoff potential seems to become more important at sites where riparian zones become more open. In the majority of the streams sampled for this study, woody debris was the main physical habitat feature providing cover and hard surfaces. Although open areas probably had higher rates of primary production due to a lack of shading, streams without woody debris had significantly less surface area for periphyton growth. They believe that this study suggest that wooded riparian cover could be effective in maintaining and improving fish community composition in streams in heavily agricultural basins.

Quality of the Research: All three authors are employed by either state or governmental natural resource agencies. This study was published in a peer reviewed aquatic science journal. The statistics used were rigorous in looking for how confounding factors may have been influencing the significance of their experimental factors. Although this study lends evidence to the importance of streamside riparian zone habitat, it did not evaluate how changes in riparian buffer sizes affect fish communities. The sites were classified as wooded if the amount of wooded riparian zone was greater than 28% or open if the amount was less than 10%. More information on how the sizes of riparian buffers affect fish communities may have been gained if the experimental design had broken the riparian cover component into more than two groups.

Relationship of Riparian Condition to Fish and Fish Habitat: This study is an excellent example of how riparian condition can affect fish community structure. The study found that in a heavily agricultural basin (all sites had watersheds with over 50% of the land in row crop agriculture) both the local scale riparian zone condition and landscape scale runoff potential significantly influence fish community structure and instream habitat. The study found that sites with forested riparian zones had more complex habitat, which is the likely cause for higher IBI scores in those forested sites. The mean percentages of benthic insectivores and herbivores were higher in wooded than in open riparian zones. The authors postulated that the increase in macroinvertebrate community diversity likely increased the diversity in the fish community, however no data on causality was presented. It is possible that both fish and invertebrates were responding to a common variable such as physical heterogeneity or other factors causally related to terrestrial conditions. The fact that runoff potential did not significantly change IBI scores in forested sites lends evidence of the ability of riparian zones to buffer out at least some negative effects of larger scale land use practices in a watershed. Although this study did show how differences in riparian condition influenced the fish community,

the species of fishes sampled were very different than those of Washington and the Pacific Northwest.

Relevance of the Research to Washington: Although not directly related to Washington, or salmonid bearing streams, the importance of this paper suggests that both landscape and local scale watershed factors influence the diversity and health of fish communities in streams. While this study clearly showed that streams sites with wooded riparian vegetation had higher IBI scores than open sites, it did not study the effects that riparian zone size had on the biotic potential of the stream. The main points to take from this paper is that in an historically forested watershed, wooded riparian zones are important in maintaining the instream habitat and a diverse and healthy assemblage of fishes. Unfortunately, it does not allow a specific application to how this might be applied to specific riparian buffer widths on individual farms or to Washington. Clearly, the removal of all riparian vegetation and the thoughtless approach of not using BMPs to protect soil erosion into streams would be the exact opposite of what makes sense. However, the key question of how much riparian vegetation should be left in Washington cannot be answered with this data or research design.

Appropriateness to Develop BMPs: The paper has strong implications for the importance of wooded riparian zones in agriculturally dominated watersheds in Minnesota to protect fish assemblage health and diversity. However, the data presented does not detail or recommend what the minimum size riparian buffer is needed to propagate healthy and diverse fish assemblages. The fact that sites were lumped into only two riparian zone groups (forested or open) leads to further questions of where the law of diminishing returns comes into effect. BMPs that provide some riparian vegetation and reduce soil erosion on agricultural lands are clearly a take-home message from this paper.

No. 21 - Title: *Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest.*

Authors: W. T. Peterjohn and D. L. Correll

Citation: Ecology 65(5): 1466-1475. 1984.

Summary of Scientific Content: This Maryland study measured nutrient (C, N, and P) changes in surface runoff and shallow groundwater as they moved through a small agricultural (cropland) watershed. The study site was a small subwatershed of the Rhode River drainage basin, situated along the western shores of Chesapeake Bay. The subwatershed studied is a 16.3 ha basin of which 10.4 ha was planted with corn. Riparian forest and hedgerows were composed of broadleaved, deciduous trees and accounted for the remaining 5.9 ha. The soils are a fine sandy loam and are extremely deep (> 600 m). An underlying clay layer is thought to create an effective aquiclude near sea level for the entire basin.

Bulk precipitation for chemical analysis was continuously sampled during the study. Stream discharge and water samples were taken on a consistent basis with a higher frequency during higher discharge. Two transects of groundwater wells were established within the watershed. Each transect consisted of several clusters of samplers at different elevations along the expected direction of flow. Surface-water collectors located to collect only overland flow were associated with each groundwater well along the first transect. Nutrient analysis occurred at all sampling locations.

Standing biomass and leaf production of riparian vegetation were estimated. Estimates of fertilizer applications and crop yields were made for the cropland.

Of the 10,040 m³/ha of precipitation that fell on the watershed during the study year, 23% was discharged in stream flow. Surface flow comprised 7.1% of the annual discharge and was greatest during the summer. During the study year 14.2 kg/ha of total nitrogen was delivered to the watershed by bulk precipitation. Input of total phosphorus by bulk precipitation was 0.435 kg/ha. Management inputs occurred in three pulses of fertilizer application during the spring and summer of the study year.

The watershed as a whole discharged 17, 2, 4, and 10% of the total inputs of nitrate-N, ammonium-N, organic-N, and total-P, respectively. Output of organic-C was over four times the input in bulk precipitation. Peak output occurred in the winter for nitrate-N, orthophosphate-P, and organic-C; and the summer for organic-N and total-P.

In surface runoff between the first and last clusters of samplers, reductions of 94, 78, 86, 84, 74 and 64% were observed in the mean annual total particulate, exchangeable

ammonium-N, particulate organic-N, total particulate-P, exchangeable orthophosphate-P, and particulate organic carbon concentrations, respectively. Most of the total changes in concentration occurred within the first 19 m of riparian habitat. Dissolved nitrogen compounds in surface runoff also declined in concentration after traversing the riparian forest. Total reductions of 79% for nitrate, 73% for ammonium-N, and 62% for organic-N were observed. The mean annual concentration of dissolved total phosphorus changed little in the surface runoff. Dissolved organic carbon concentration increased 2.8-fold, but only 41% of this change occurred within the initial portion of riparian forest. The particulates leaving the forest were more organic in composition and had a greater exchange capacity.

The amount of nutrients or total particulates trapped or released per hectare of riparian forest was also estimated. For surface runoff the result was that during the study year an estimated 4.13 Megagrams of particulates were trapped along with 0.219, 11.2, 2.98, 0.172 and 32.2 kg/ha of exchangeable ammonium-N, particulate organic-N, total particulate-P, exchangeable orthophosphate-P, and particulate organic-C, respectively.

In general concentrations of nitrate in groundwater declined dramatically while traversing the riparian zone, while ammonium-N increased in concentration. A 90% and 98% total decrease in the mean annual nitrate concentration was observed for the two transects. Essentially all nitrate loss occurred within the first portion of riparian forest.

Nitrogen uptake by forest trees was calculated as ~ 77 kg/ha/yr. Nitrogen return in leaf litter was estimated as 62 kg/ha/yr. Throughfall was not measured at the site, but estimates were made using previous a ratio from the literature and therefore was estimated at 3.7 kg/ha/yr. Total phosphorus uptake by forest trees was calculated to be ~ 9.9 kg/ha/yr. Phosphorus return in leaf litter was estimated at 7.8 kg/ha/yr. The flux of phosphorus from leaves as throughfall was estimated as 0.53 kg/ha/yr.

Uptake by corn plants for N was estimated at ~250 kg/ha/yr and 45.0 kg/ha/yr for phosphorus. Nitrogen loss in harvested crop was estimated as 71.3 kg/ha/yr. Phosphorus loss in harvested crop was estimated at 10.3 kg/ha/yr.

Of the estimated total nitrogen exports from the cropland, 64% was in harvested crop, 9.2% in surface runoff, and 26% in groundwater flow. For the riparian forest, 17% of the estimated total-N inputs came in bulk precipitation, 61% in groundwater, and 22% in surface runoff. Of the estimated total-N losses from the riparian forest, 75% was lost in groundwater flow. Thus, it appears that the major pathway of nitrogen loss from the riparian forest was in subsurface flow. The calculated nitrogen retention by the riparian forest was 89%, much higher than the 8% calculated for the cropland.

Of the estimated total phosphorus exports from the cropland, 84% was apparently lost in harvested crop, 16% in surface runoff, and <1% in groundwater flow. Thus, the harvest seems to be the dominant pathway of phosphorus loss from the cropland, and surface runoff the dominant pathway of phosphorus flux between cropland and riparian forest. For the riparian forest, 3.8% of the estimated total phosphorus inputs came in bulk precipitation, 94% in surface runoff, and 2.5% in groundwater flow. Phosphorus export from the riparian forest was nearly evenly distributed between the estimated losses in surface runoff (59%) and groundwater flow (41%).

The author's note that while data from this study are insufficient to determine conclusively the reasons for nitrate loss from groundwater in the riparian forest; only two theoretically acceptable reasons are plausible, uptake by vegetation and denitrification. The conclude that the estimated removal in surface runoff of 4.1 Megagrams of particulates, 11 kg of particulate organic-N and 3.0 kg of total particulate-P per hectare of riparian forest is potentially an extremely important ecological function. In addition, the removal of nitrate-N at an estimated rate of 45 kg/ha in subsurface flow is especially important. Release of this amount would have doubled the amount of nitrate-N discharged during the study year. GEI notes that in other studies (Pinay and Decamps 1987), subsurface shallow groundwater in wet riparian forests has large denitrification potential that is limited by the inputs and the amount of anaerobic soil condition rather than the denitrifying bacteria.

Quality of the Research: This is a detailed paper on a quantitative study of nutrient budgets and the function of riparian buffers. The study was published by a peer-reviewed journal and was conducted by two highly experienced riparian buffer scientists. This paper clearly demonstrates through extensive measurement and modeling, the potential for riparian buffers to remove excess nitrogen and phosphorus from agricultural applications from both surface and groundwater pathways. Its relevance is that it convincingly shows how crops and riparian buffers utilize, process and disperse complex nutrient chemicals and physiochemical pathways. This basic research give functional rationale as to the value of riparian vegetation for controlling excess nutrients that come from agricultural land use.

Relationship of Riparian Condition to Fish and Fish Habitat: There is no data, nor intent in the paper to show the relationship or benefits to fish or fish habitat. Its purpose is to provide a nutrient model of how riparian vegetation affects nutrient dynamics in a watershed. Other research on nutrient inputs into streams and lakes have observed that excess nitrogen or phosphorus can change the trophic dynamics of the aquatic community. In addition, excess nutrients have been shown to suffocate waters by diminishing dissolved oxygen levels. On the other hand, research has also shown that in naturally nutrient poor waters, increased in nitrogen and phosphorous can benefit salmonid production if that is the goal of manipulation.

Relevance of Research to Washington: The study was conducted on the shores of Chesapeake Bay, Maryland. The data are quite specific to the location studied. However, we suspect that the model and processes would be broadly applicable to other watersheds; nutrient quantities and other model coefficients might vary dependent on the species composition of the riparian habitat, soil and slope conditions and local agricultural practices. For example, riparian buffers composed of red alder may actually increase the nitrogen inputs into adjacent water bodies, due to the ability of red alder communities to fix nitrogen (Volk et al. 2003).

Relevance to Assessing Riparian Buffer Width: While this study is an important publication for understanding nutrient dynamics of riparian buffers, it has limited use in developing specific BMPs. The general concepts of the paper can be applied when creating buffers, however there is not enough detailed information about buffer widths, species composition, or buffer slope to readily use for management applications. This study does little for understanding the sizes of buffers required to remove excess nutrients. Only qualitative comments are made about the distance that most of the nutrients were being taken up by the riparian forest in relation to the cropland. Therefore, this paper helps us understand on a watershed level the nutrient budgets from agriculture and how effective riparian buffers can remove excess nutrients, but does not lend itself to comparing buffers of various compositions or size.

No. 22 - Title: Evaluation of best management practices for controlling nonpoint pollution from silvicultural operations.

Authors: J. A. Lynch and E. S. Corbett

Citation: Water Resources Bulletin Vol. 26 No. 1 pp. 41-51. 1990.

Summary of Scientific Content: This central Pennsylvania study evaluated fifteen years of streamflow and water quality data to determine the effectiveness of BMPs in controlling nonpoint source pollution from a 110-acre commercial clear-cut. The paired watershed method was used where an undisturbed watershed was used as a control. The control watershed is 303 acres, while the treated watershed is 257 acres. Water quantity changes were based on linear regression analyses using 17 years of pre-harvest stream discharge measurements from both the treated and control watersheds. Changes in stream chemistry were based on weekly measurements collected during a three-year calibration period and an 11-year post-harvest period. Stream temperature and turbidity/sediment impacts were based on two years of pre-treatment data. Changes in water quality parameters were based, for the most part, on analysis of variance of seasonal and annual data before and following harvesting.

BMPs on the clear-cut applied during and post-logging included:

- The timber sale divided into 4 blocks; with sequential harvest approval only after specifications attained.
- A 100 ft buffer on each side of perennial streams.
- No skidding in perennial streams except over approved culverts and bridges.
- No slash permitted within 25 ft of all perennial and intermittent streams.
- Log landing sites no closer than 300 ft of all perennial and intermittent streams.
- Logging prohibited during excessive wet periods.
- Skid trails and logging roads laid out by professional foresters.
- All logging roads and skid trails were properly retired.
- The logging site inspected weekly by a professional forester.
- A performance bond required prior to logging.

For the logged sites, there were statistically significant increases in nitrate and potassium concentrations and temperature and turbidity levels the first two years following harvest. The increases were small, and with the exception of turbidity, criteria remained within state drinking water standards. Nitrate and potassium concentrations and turbidity levels remained above pre-harvesting levels for as long as nine years following harvesting, but remained within state drinking water standards.

In most cases, the increased levels of turbidity were attributed to erosion from logging roads, skid trails, and log landing sites. Many of the BMPs were specifically employed to

reduce, restrict, or eliminate many of the sources of sediment. The author's speculated that for the most part the BMPs were effective in minimizing increased in turbidity. For the most part, increases in turbidity were observed during or immediately after logging activities.

Increased turbidity levels were measured the second and third year following harvesting. These increases were attributed to soil disturbances as a result of wind thrown trees that had either uprooted near the channel or fallen across the channel creating debris dams. Debris dams may have forced the stream out of its channel thereby increasing turbidity and sediment levels in the lower stream reaches. In addition, the buffer strip did not extend the full length of the channel. About 1500 ft (457.2 m) of a secondary, intermittent channel was exposed in the middle of the stream reach. Blowdown occurred in this area because the remaining trees could not withstand the increased wind velocities created by the opening. As result, the state of Pennsylvania modified its BMPs regarding the use of buffer zones to include all perennial and intermittent streams.

Clear cutting also significantly increased water yield, which in turn initially lowered the concentrations of most solutes because of dilution. Increased water yields returned to pre-harvest conditions within four years due to rapid re-growth of the forest. The author's did not state whether the forest was replanted after clear cutting.

Slight increases in the average daily maximum stream temperature were observed following harvesting. However, statistically significant increases in mean stream temperatures were only recorded during the spring months. The increases were generally less than 3° F, and were also attributed to the cutting of trees in the previously mentioned intermittent stream channel. Stream temperatures returned to normal within two years as regrowth occurred adjacent to the channel exposed by harvesting.

The author's make a recommendation of increasing buffer zone widths from 100 ft (30.5 m) on each side of the channel to one-and one-half times the average height of the trees adjacent to all perennial and intermittent channels. They believe that this would reduce potential sediment problems caused by wind thrown trees.

Quality of the Research: The study was conducted by university and governmental scientists and published in a refereed scientific journal. The research monitors the long-term effects of on water quality from clear cutting in a watershed with implemented BMPs. The use of a paired watershed approach using an uncut control, with sufficient data prior to harvesting allowed for a relatively good understanding of the impacts to water quality and quantity parameters that emerged from the BMPs employed. However, the author's speculation that the BMPs were effective in reducing water quality and quantity differences was based on metrics that compared violations in drinking water standards. The comparison was not between a clear-cut in a watershed without BMPs

versus one with BMPs. Consequently, we have no idea of the magnitude that the BMPs may have had on reducing nonpoint source pollution in the clear-cut watershed. A study comparing a clear-cut watershed with no BMPs or a different combination of BMPs may have made for a better comparison. In addition, the author's do not relate the data obtained in this study to other clear cut watersheds that did not employ the same BMPs, which would have at least given the reader some idea of what the water quality differences may be when no BMPs are used.

The recommendations of the authors to increase to change BMPs in regards to buffer widths were not fully explained. They do not specify any data that would suggest that changing the buffer widths from 100 ft (30.5 m) to one-and one-half times the average height of the trees would have made a difference in water quality in this study. Specifically, the average heights of the trees within the existing riparian buffers were not given. Convincing data for this recommendation might come from comparing two treatments and a controlled experiment with no buffer, a 100-foot buffer and a buffer 1.5 times the average tree height.

Nevertheless, the study did show that the two watersheds did not exhibit statistically significant changes in water quality and quantity over the course of the monitoring period. While we are left uncertain of the role of the specific buffer width because there is no way to separate other BMPs that were implanted to minimize impacts to streams. However water quality and quantity data suggest that the BMPs were collectively effective for the limited differences in water quality between the two watersheds.

Relationship of Riparian Condition to Fish and Fish Habitat: There is no data presented to show the relationship or benefits to fish or fish habitat in this paper. However, data was presented on differences in stream temperature, turbidity, and other water quality parameters. Depending on the specific environmental conditions of a site and the specific fish community at the site, changes in these parameters may impact fish and fish habitat different ways. Therefore, we can not necessarily assume that the changes in water quality and quantity that were shown in this study would have either negative or positive effects on fish and fish habitat.

Relevance of Research to British Columbia: The study was conducted in central Pennsylvania. No vegetation species composition or fish community composition data were given. The overall conclusion that implementing BMPs during timber harvesting may reduce the changes observed in stream water chemistry, quantity, and other parameters is likely applicable to other portions of the continent, although results would most likely vary.

Appropriateness to Develop BMPs: No data is presented on how the BMPs applied in the treated watershed were responsible for the differences in water quality parameters

observed between the two watersheds. Nevertheless, the author's conclude that the BMPs applied to the treated watershed were responsible for the minimal differences observed over the length of the monitoring period. Further data would be needed to determine what BMPs were most responsible for reducing the observed changes. In addition, only one buffer width was used throughout the study, thus eliminating the ability to compare the effects of varying buffer widths. Observations by the author's that the intermittent streams that were not buffered by riparian vegetation lead to the observed increases in sediment may be of most value. Thus, the recommendation of the author's to include all perennial and intermittent streams in developing BMPs for buffers may be valid in this geographical area. Still, no data was specifically shown to back up this recommendation, so further studies need to be evaluated to substantiate this recommendation.

No. 23 - Title: *Vegetated filter strip removal of cattle manure constituents in runoff.*

Authors: T. T. Lim, D. R. Edwards, S. R. Workman, B. T. Larson, and L. Dunn.

Citation: Transactions of the American Society of Agricultural Engineers Vol. 41(5) pp. 1375-1381. 1998.

Summary of Scientific Content: This University of Kentucky study evaluated the effects of vegetated filter strips (VFS) on concentrations and mass transport of Nitrogen (N), Phosphorous (P), solids, fecal coliform (FC), and other parameters in runoff from cattle mature-treated plots. Tall fescue was used in all plots (100% cover with a mean height of approximately 10 cm). Three plots were used for the experiment. Each plot had dimensions of 30.5 x 2.4 m, oriented with major axes running up and down-slope. The plots have a constant slope of 3% along the major axes. Gutters with removable covers were installed along the length of each plot, distributed at 6.1, 12.2, 18.3, 24.4, and 30.5 m from top, which separated the plots into five sections of equal area. The gutters, when uncovered, enabled periodic sampling at various down gradient locations. With covers in place, runoff drained down gradient over the gutters. Soils were sampled and analyzed prior to the treatment and experiment.

The upper 12.2 m of each plot was used to represent pasture and was treated with beef cattle manure, while the remainder of each plot acted as a VFS. The manure application rate was 60 kg N/ha. This rate of manure application is equivalent to a heavily grazed condition (stocking density of nine 450 kg animal units/ha for a seven days). The manure was applied along the lower edge of the simulated pasture, so that high concentrations of manure constituents in runoff could be produced as input to the VFS. The objective was to assess the effectiveness of VFS with regard to cattle manure constituents, so the manure application was structured to ensure sufficiently high incoming concentrations of manure to evaluate VFS performance.

Five rainfall simulators per plot were used to generate 100+ year precipitation event to cause some runoff. The soils were known to have good infiltration. The rainfall intensity used for the experiment was 100 mm/h. Runoff samples were collected manually at intervals seven times per hour creating three replicate experiments at VFS lengths of 0, 6.1, 12.2, and 18.3 m during runoff. Concentrations of total Kjeldahl N (TKN), ammonia N (NH₃-N), nitrate N (NO₃-N), ortho-P (Po₄-P), total P (TP), total suspended solids (TSS), total solids (TS), electrical conductivity (EC), and fecal coliform (FC) were analyzed.

Parameters that were significantly reduced by the VFS included TKN, Po₄-P, TP, FC, TSS, TS, and EC. No significant reductions in concentrations occurred beyond a VFS

length of 6.1 m. Approximately 75% of incoming TKN, TP, $\text{Po}_4\text{-P}$, and TSS were removed within the first 6.1 m of the filter strips. The removal of FC was found to be 100% after a VFS length of 6.1 m, which was likely due to high plot infiltration and was consistent with previous results that showed a 3 buffer, was adequate to arrest fecal coliform. In general, the buffer arrested chemical and biotic runoff exponentially with distance from the source described by a first order equation.

Analysis of variance showed that the concentrations of nitrate and ammonium were affected by the VFS. However, this was due to the fact that concentrations of nitrate and ammonium measured in the VFS were comparable to “background” concentrations measured in plots that had no manure added. Therefore, the manure applications added no significant amounts of nitrate or ammonium to the soil.

Quality of the Research: The study was conducted by experienced and previously published research scientists and published in a peer-reviewed scientific journal. The study design was excellent for meeting the objectives of the study, which was to determine the effectiveness of grassy buffers to remove contaminants from the equivalent of a heavily grazed pasture during an extreme rain event in over a 3% gradient. The distances are characteristic of the local soils and vegetation but suggest that relatively narrow grassy buffers under 10 m will be highly effective under low slope conditions to protect water quality. This of course presumes the cows are kept out of the buffer and the buffer is maintained in a quality vegetative state.

Relationship of Riparian Condition to Fish and Fish Habitat: There is no data presented to show the specific relationship or benefits to fish or fish habitat directly. The authors correctly note that the quality of the receiving body and the aquatic life therein are important aspects of understanding the potential benefits. However, other research has shown that excessive inputs of nitrogen and phosphorus may accelerate eutrophication of water bodies and promote growth of aquatic weeds and algae. In addition, the decomposition of excess organic matter in water bodies can lead to drops in dissolved oxygen concentrations below the respiration requirements of fish. Accordingly, reducing the amount of nutrients and pathogenic microorganisms that enter a water body may have benefits to fish and fish habitat. For example, fecal coliform from dairy cattle was dramatically reduced in Jefferson County, Washington with a similar narrow buffer.

Relevance of Research to Washington: The study was conducted on an experimental pasture in Kentucky. The general principles learned from this experiment should be applicable to other areas where tall fescue or similar grass can be maintained on well drained soils of modest slope; and with equivalent or lower cattle densities and rainfall parameters. Since good results have been obtained for fecal coliform in western Washington, we suspect this type of BMP would be highly effective. Obviously conditions and results should be verified locally

Relevance to Assessing Riparian Buffer Width: This research suggests that vegetated filter strips of grass can greatly reduce nutrients and pathogenic microorganisms from cattle grazing. This study found that maximum benefits were obtained within 6.1 m (20 feet) buffer. Broad application in other regions might vary with different species, tiller density, slope, and soil type but should be similar. The research confirms other research that relatively narrow grass buffers effectively eliminate many harmful nutrients contained in cow manure. Increasing buffer widths do not significantly increase the buffers effectiveness is also confirmed in other experiments. Nonetheless, because of the variation in vegetation expected in Washington, determining the most effective buffer width for cattle should be done on an experimental basis starting with the premises then corroborating with local data to confirm effectiveness.

No. 24 - Title: *Vegetative filter strip effects on sediment concentration in cropland runoff.*

Authors: C.A. Robinson, M. Ghaffarzadeh, and R.M. Cruse

Citation: Journal of Soil and Water Conservation 50(3) 227-230. 1996.

Summary of Scientific Content: This Iowa State University study was designed to evaluate sediment concentrations in runoff water flowing through a vegetated filter strip (VFS) as a function of: 1) distance from the edge of a fallow strip, 2) slope gradient, and 3) rainfall and runoff amount.

The study areas consisted of designing and constructing a collection system that would enable the estimation of runoff quantity and sediment concentration in a VFS downslope of a fallow plot. Two study areas were established, one on a uniform 7% grade and the other on a uniform 12% grade, both on Fayette silt loams in northeast Iowa. One study area 31 m perpendicular to the slope by 36.6 m parallel to the slope was established on each grade. The upper 18.3 m of each were managed as continuous fallow, tilled every three weeks from April through August as weather permitted. The lower 18.3 m were maintained as filter strip consisting mainly of brome grass. Total biomass (9.9 vs. 5.9 Mg/ha) and number of tillers (112 vs. 73 m²) were greater on the 12% than on the 7% grade, and tiller density on both slopes was greater in April than in July.

The collection apparatus was somewhat complex and therefore will not be discussed in detail. It consisted of a collection unit and a series of splitters to reduce sample size. For each rainfall event, the date, amount, intensity, runoff volume, at the edge of the fallow strip, soil loss, and the storm sequence relative to the most recent tillage event was recorded. Rainfall intensity was subjectively classified as low, medium, high, and very high. Observer's classification of very high-intensity storms coincides with storms having soil loss > 1.5 megagrams/ha and runoff volumes > 500 liters on both slopes.

The very high-intensity events accounted for 67% of the rainfall for the study period. Soil loss was greater when the first storm after tillage was a very high-intensity event. The author's chose to emphasize the results from the 12% slope because of the many similarities in trends. The 12% slope generally had greater soil loss from the fallow strip than the 7% slope. The 12% slope had greater runoff volumes and sediment concentrations at the edge of the fallow strip, showing that soil losses were greater from the 12% than the 7% grade for most events.

In all storms, the sediment concentration in the runoff decreased greatly in the initial 3.0 m of the VFS, and little change in sediment concentration was observed beyond a VFS width of 9.1 m. The initial 3.0 m of the VFS removed more than 70% of the sediment on

the 7% grade and 80% on the 12% grade, while 9.1 m filtered more than 85% on both grades. Little change in sediment concentrations were observed beyond a VFS width of 9.1 m. The lack of sediment removal beyond 9.1 m was likely related to soil texture and aggregate sizes. The particles remaining in suspension beyond 9.1 m were probably clays and organic colloids.

The sediment removal efficiency was higher in the low, medium, and high rainfall events than in the very high-intensity events. The VFS decreased the carrying capacity of runoff, encouraging sediment deposition, and also promoted infiltration, thus decreasing runoff volume. Although the VFS removed 4% more sediment on the 12% slope than on the 7% slope, more total sediment remained in the runoff from the 12% slope.

There was no evidence of decreased effectiveness of the VFS with time; the final series of storms in September of 1991 were filtered as effectively as the others beginning in August of 1990. Although vegetative growth and depth of sediment accumulation were not monitored during the growing season, these two factors could be important in determining if levees were stabilizing at the edge of the fallow strip.

Quality of the Research: The experiment was conducted by university scientists and was published in a peer-reviewed journal. While the experiment did a good job at quantifying the sediment removal efficiencies of a bromegrass VFS on both a 7% and 12% grade, it did not allow for a direct comparison of how slope effected the relationship. Due to the differences in bromegrass biomass and density on the two grades, the 12% grade VFS was more efficient than the 7% grade VFS. Although the 12% filter strip was more efficient, more sediment was still delivered past the VFS in the 12% grade VFS than in the 7% grade VFS, indicating the higher grade produced more overall sediment. The data presented do lend evidence to the importance of vegetation tiller density in reducing the velocity of overland flow, thus increasing the effectiveness of the VFS in settling out sediments.

Relationship of Riparian Condition to Fish and Fish Habitat: No fish or fish habitat data was presented in this paper. However, it is well understood that excess sediment inputs into streams via overland flow can lead to decreased fish habitat, especially for salmonids, which need unconfined sediments for spawning. Therefore, the data presented is relevant in regards to incorporating vegetated buffers to reduce sediment inputs from non-point source sediment sources.

Relevance to Washington: While the study took place in northeast Iowa, it may have relevance to other portions of North America. The results from this study highlight three important points; 1) vegetative tiller density plays an important role in the effectiveness of a grass buffer at reducing sediment concentrations in runoff, 2) slope exacerbates the total amount of sediment inputs when comparing two identically managed areas with the

same soil characteristics, and 3) increasing the width of a buffer beyond a certain point does not necessarily equate to increased sediment control because of the asymptotic relationship between sediment capture and distance.

Relevance to Assessing Riparian Buffer Width: This research suggests that several factors should be taken into account when recommending vegetative buffer strips as a BMP: 1) The tiller density in vegetated filter strips can greatly affect the ability of a buffer to reduce overland flow velocities and therefore increase the effectiveness of trapping sediments, 2) as slope increases the amount of suspended sediments being input into a buffer will likely increase, 3) wider buffers do not always correlate with more sediment control, once all sediment of a certain size are settled out, the remaining sediment that are in suspension may be carried through the buffer. This study showed that on both a 7% and a 12% grade, vegetated buffer strips of 9.1 m filtered more than 85% of suspended sediments out of cropland runoff. Other research shows the value of grassy vegetation to protect stream banks against erosion from flooding, runoff and livestock. Trees have the advantage of uptake of nutrients and then can be harvested; but they have the disadvantage of not being as effective as a filter medium compared to grass. If buffers to filter and remove nutrients are needed in cases where field runoff cannot be controlled, some have recommended a combination grassy outer buffer at the field edge, a harvestable shrub/tree middle buffer and a permanent tree buffer on the stream bank.

No. 25 - Title: Buffer zones for reducing pesticide drift to ditches and risks to aquatic organisms.

Authors: Geert R. de Snoo and P. J. de Wit.

Citation: Ecotoxicology and Environmental Safety 41, 112-118 (1998)

Summary of Scientific Content: This Leiden University study was conducted in The Netherlands. It investigated to what extent the creation of buffer zones can decrease pesticide emissions to adjacent ditch banks and ditches when being applied with typical farming equipment. A comparison was made between the drift deposition adjacent to sprayed field margins and that adjacent to unsprayed buffer zones of 3 and 6 m wide.

Three variables were used, spray nozzle type, wind speed, and width of the buffer zone. To investigate the influence of the buffer zones on drift deposition, spray booms were switched off in the outer 2 and 6 m of the field, to compare the sprayed situation with that with 3- and 6-m –wide buffer zones. Sprayers were driven parallel to the ditch, spraying a swath at least 50 m in length. For each spraying variant, measurements were made in duplicate, with 15 m between the measuring points. Water was used in all spraying as a representative of pesticide. Water sensitive paper (WSP) measuring 12.5 cm x 2.5cm were placed on pieces of triplex 5 cm above the vegetation at various locations. The paper turns blue when water is deposited on it, therefore the amount showing blue after a spray event was calculated using a video area meter (de Snoo and de Wit 1993). Wind direction was always perpendicular to the ditches.

A risk assessment for aquatic organisms was performed by comparing the predicted environmental concentration (PEC) in the ditch and the toxicity to aquatic organisms of the pesticides most frequently used in the research area. The PEC of the pesticides in the ditch was calculated using the SLOOTBOX model (Linders et al, 1990). Contamination of the surface water was calculated on the basis of the drift deposition measured in the present study, for both the normal sprayed situation and a 3- or 6- m buffer zone. Risk assessment for aquatic organisms was carried out by dividing the PEC by the LC₅₀ (crustaceans and fishes) and the EC₅₀/NOEC (algae). Calculations were based on the highest recommended pesticide dose and frequency for arable fields and current agricultural practice in the research area.

The results indicated that the drift deposition adjacent to the sprayed fields was dependent on wind speed and nozzle type. Wind speed had a major influence on drift deposition. For all nozzle types, drift deposition increased with wind speed.

Drift deposition was much lower on the ditch bank adjacent to the 3-m buffer zone than in the normal sprayed situation. On average only 0.03% (0.0 to 0.08%) of the ditch bank

was covered with sprayed water using the 3 m buffer, compared to 4.10% to 25.12% for un-buffered trials using various nozzles. Adjacent to the 6 m buffer zone there was even less drift deposition, only one nozzle caused a measurable deposition at 0.02%.

At a wind speed of 3 m/s the 3 m buffer zone reduced drift deposition on the ditch bank by a minimum of 99.5%, and the 6 m buffer reduced drift deposition by virtually 100%. Although the relative reduction decreases with wind speed, at a wind speed of 11 m/s the 3 m buffer zones still reduced the drift deposition on the ditch bank by 92.7%, and the 6 m zone by 95.0%.

Similarly, at all wind speeds the buffer zones reduced the amount of drift deposition directly into the ditch. At the highest measured wind speed of 11 m/s 29.00% of the ditch was deposited with spray under normal spray conditions. At the same wind speed the 3 m buffer zone reduced drift deposition by 88.7% and the 6 m buffer zone reduced drift deposition by 97.8%.

The SLOOTBOX model the PEC in the ditch was calculated for a wind speed of 5 m/s, was considered to be a realistic worst-case situation by the authors. Comparing no buffer and the 3 m buffer revealed that the buffer zone reduces the short-term toxic risks to aquatic organisms substantially. In this modeled situation, the risks are in most cases negligible. Only the use of parathion, oxydemeton, and fentil acetate cause a small risk for crustaceans or algae.

Quality of the Research: The experiment was conducted by university scientists and published in a peer-reviewed scientific journal. It was an excellent documentation of how vegetated buffers can directly decrease the amount of drift deposition into ditches, and thus reduce the potential impacts to aquatic resources. The study did not however evaluate if riparian buffers can reduce the amount of pesticides input into waterways via overland flow. This would assume a rain event after spraying. The results on the effects of pesticides on aquatic organisms are modeled and therefore should be interpreted with some caution. However, the model seems to provide a clear advantage to keeping pesticide out of the waterway. In addition, the model only includes the amount of pesticides directly sprayed into the ditch, and does not incorporate what size buffer would be needed to mitigate the effects of pesticides in overland flow due to precipitation events. Some pesticides rapidly disintegrate, thus the toxicity decreases rapidly with time. The importance of not spraying in windy conditions, remaining at least 3 m away from the stream with nozzles and is a direct BMP that will reduce impacts to streams.

Relationship of Riparian Condition to Fish and Fish Habitat: While there were no data presented directly on fish or fish habitat, the modeling effort that was used showed a decrease in toxicity to aquatic organisms. Results from the model trial indicated that a riparian buffer of 3 m adjacent to the ditches would reduce the short-term toxicity to

aquatic organisms substantially. It is well known that excess pesticides and herbicides that enter the aquatic food chain can be harmful to a variety of organisms. Therefore, by effectively eliminating the direct application of pesticides into the ditch should benefit a host of aquatic organisms including fish. The type and season of pesticide use should therefore become an important criterion when establishing the need for a buffer at a particular type of agricultural operation.

Relevance of Research to Washington: Although this study took place in The Netherlands, it may be applicable to many agricultural situations including Washington wherever pesticides and herbicides are applied to fields adjacent to water bodies. The results indicate that a riparian buffer as small as 3 m can greatly reduce the amount of drift deposition in ditches. Attention to meteorological conditions of wind and storms is also important in reducing or eliminating toxic insults to streams. There is no reason to believe that these results are not transferable to other locals that might use similar application equipment in similar weather conditions and buffer widths.

Relevance to Assessing Riparian Buffer Width: This research indicates that the use of riparian buffers as small as 3 m wide may greatly reduce the amount of drift deposition of sprayed herbicides or pesticides to an adjacent water body. The research also infers that three other BMPs could help reduce the amount of drift deposition of chemicals that occurs during the spraying of fields. 1) Wind speed has a positive relationship with the amount and distance that chemicals drift is deposited 2) Different spraying nozzles result in significantly different amounts of drift deposition 3) spraying in the dry season so that rainfall and runoff are unlikely events in the short run after application (Hunt et al. 2003).

No. 26 - Title: An experimental study of the effects of riparian management on communities of headwater streams and riparian areas in coastal BC: how much protection is sufficient?

Authors: J. S. Richardson, P. M. Kiffney, K. A. Maxcy, and K. Cockle

Citation: “Advances in Forest Management: From Knowledge to Practice”, Sustainable Forest Management Network Conference, 13-15 November 2002. Shaw Conference Center, Edmonton, Alberta.

Summary of Scientific Content: This University of British Columbia unpublished study was designed to evaluate how small streams (size not specified) and their riparian systems respond to streamside harvesting, and the effectiveness of fixed width buffers at mitigating changes. Because the study was not published, many details of the data are lost in summarization. The study site location was not specifically described, but we can assume it was in coastal B.C. from the title of the study. The watersheds ranged in size from 11.5 to 46.8 ha. The study encompassed both aquatic and terrestrial responses including stream food webs, small mammals, amphibians, and terrestrial invertebrates, but for the purpose of this report, GEI will focus on the aquatic portions of the study.

Three experimental riparian forest preserve treatments were used to evaluate riparian zone benefits on stream reaches as follows, controls, 30 m reserves, 10 m reserves, and clear cuts. Approximately 25% of the trees were removed in each study watershed for all treatments except the control where no trees were harvested. Prior to any logging activities, initial conditions of all streams and riparian areas were studied for at least 1.5 years. “Before-and-after” conditions were measured for the aquatic food web including aquatic invertebrate numbers, biomass, richness, and algal productivity. In addition, organic carbon dynamics and water quality were also monitored. All treatments were randomly assigned to sites, except for the control. The length of each stream affected by the treatment ranged from 250 to 600 m. The experimental forest is Coastal Western Hemlock. The time period between treatments and post sampling was not specified.

Not surprisingly, light fluxes reaching the stream surface were higher at the logged sites than controls, and increased as buffer width narrowed. Water temperatures were also elevated above controls at the logged sites. There was up to a four-fold increase in algal biomass relative to controls at the 30 m reserve streams, while even higher amounts of algae were observed in the 10 m buffers and clear cuts. A floral shift to filamentous algae occurred in the 10 m and clear-cut reserves. In general, the benthic invertebrate community changed to more generalist-type taxa in these same treatments.

Organic inputs to the streams for 10 and 30 m riparian reserves were similar to the controls. The organic inputs in clear-cut streams declined to about 10% of the inputs with

at least some forest cover (10 and 30 m). Interestingly, the amount of large particles exported to downstream reaches from streams with clear cuts and 10 m buffers declined to about 25% of the export from control and 30 m buffer streams. No detectable difference in dissolved organic matter (defined as $< 0.45 \mu\text{m}$) was observed between any sites.

Quality of the Research: Although university scientists conducted this study, it was not published in a peer-reviewed publication. As a conference presentation, the paper lacked the detail and data needed to statistically evaluate the study design and results. The authors summarized changes in measured attributes between control and the other treatments by average percentage figures and directional shifts. Although the size of streams was not documented, the small size of the watersheds (11.5 to 46.8 ha) suggest these were very small headwater tributaries.

Relationship of Riparian Condition to Fish and Fish Habitat: The absence of data caveats the veracity of the following conclusions in the paper about relationships to fish habitat. Nonetheless, the authors observed stream temperatures increased in logged sites versus control sites. The shift from a more benthic invertebrate community to a more generalist taxa may affect fish that have specific habitat requirements during portions of their life cycle. These observations are consistent with other research, however the significance of differences both statistically and to stream organisms cannot be discerned. The 10 m buffer streams had a 25% reduction in large particle organic matter exported downstream when compared to the 30 m buffered streams. This reduction may influence the food web, therefore resulting in changes to food availability or food quantity for fish. However, the reduction in allochthonous input combined with increase in energy (light) is correlated (although not necessarily causal to) shifts in algal and benthic faunistic shifts.

Relevance of Research to Washington: Although this study did not give detailed analysis of the data, it is very relevant to riparian zone buffers in Washington. The study took place in small headwater streams within coastal B.C. and evaluated how differing sizes of buffers affect the stream ecosystem. More data is needed to make specific recommendations or concrete conclusions about how differing buffer sizes affect the aquatic food web.

Relevance to Assessing Riparian Buffer Width: This paper supports the premise that complete riparian vegetation removal has the greatest affect on stream organisms and temperature consistent with other research. Thus, if the data can be corroborated, it should be useful for supporting retention of riparian vegetation during land clearing BMPs in Washington. The information presented suggests that there are measurable differences in how streams change between zero, 10 m, and 30 m buffer zones in logged watersheds. The overall study corroborates that leaving some riparian buffer zones will

preserve more of the status quo of the aquatic ecosystem, but the adjacent terrestrial ecosystem components as well.

No. 27 - Title: Source distances for coarse woody debris entering small streams in western Oregon and Washington

Authors: M. H. McDade, F. J. Swanson, W. A. McKee, J. F. Franklin, and J. V. Sickle

Citation: Canadian Journal of Forest Research 1990. 20: 326-330.

Summary of Scientific Research: The objective of the study was to determine the source distance patterns of coarse woody debris in selected small streams flowing through natural conifer forests in the Cascade and coastal mountains of western Oregon and Washington. Several stand and landform conditions were sampled to estimate their effects on source-distance patterns. Old growth (> 200-year-old) stands and mature (80- to 200-year-old) stands forests containing conifers and hardwoods were sampled to provide a data on a range of tree heights. Hillslope steepness was considered in the sampling because it was expected that if debris slid down steep slopes, source distances would be greater at sites with steeper side slopes and narrower floodplains. Sample sites included a range of stream orders from first to third because floodplain width in this region generally increases with increasing stream order.

Thirty-nine study sites located within 8 study areas were used. Approximately half of the sites were in old-growth stands and half were in mature stands. Hillslopes adjacent to sampled streams ranged in steepness from 3 to 40°, with first- order and second-order streams having significantly steeper side slopes than third-order streams. The majority of streams sampled are in the Cascade Range and are dominated by Douglas fir, western hemlock, and western red cedar. Streams sample in the Coast Range are dominated by Sitka spruce and western hemlock. Red alder is common at sites located in the Coast Range.

The length of stream sampled at each site ranged from 0.4 to 2 km and was determined by the distance required to locate 30 trees that had provided pieces of coarse woody debris to the stream; minimum diameters were greater than 10 cm at the small end and lengths were greater than 1 m. The origin of each piece of debris within or straddling the stream was determined. Pieces not identifiable as to source (47.7% of pieces encountered at the study sites) were not included in the study; they were usually short fragments that were quite mobile at high flows.

Source distance was measured from the origin to the stream bank along a line perpendicular to the channel. The origin to piece distance (how far the piece sits downhill from it origin) was measured to evaluate the distance debris moved downslope. Each study site was classified in terms of stream order, stand age, and average steepness of side slopes. These characteristics were pre-established so that selected sites would fit a 3 x 2 x 2 factorial design with a minimum of three sample sites (replicates) in each cell of

the matrix. A total of 1258 debris pieces were sampled: 619 conifer and 2 hardwood pieces in old-growth stands and 551 conifer and 86 hardwood pieces in mature stands. Nonparametric statistical methods were used due to the highly skewed distributions of the dependent variables.

Debris piece length and diameter were significantly less in mature stands than in old-growth stand, and in hardwoods than in conifers. The authors believe this is due to differences in tree heights of the two stands. Diameters of pieces from gentle slopes were significantly smaller than those of pieces from steep slopes. The author's note that this may be due to the fact that broad, flat valley floors contained a greater abundance of mature hardwoods and conifers than the old-growth. Piece length and diameter were significantly greater in third- than in first-order channels.

A significantly greater percentage of pieces moved toward the stream on steep slopes than gentle slopes, and the distance moved was also greater on steep slopes. Old-growth pieces moved significantly farther than did pieces from mature stands, possibly because of the downhill leaning tendency more commonly observed in old-growth trees than in those of mature stands.

Source distance was significantly less in mature than in old-growth conifers and least in mature hardwoods. As with piece size, the authors attribute the differences to different heights in the three types of trees. More than 83% of the hardwood pieces originated within 10 m of the stream channel, as compared with 53% of the conifer pieces. All hardwood pieces were delivered from within 25 m of the channel, but 13% of the conifer pieces had a source distance greater than 25 m.

No significant difference was observed between source distances on steep and gentle side slopes, even though the percentage of moving pieces and the distance moved were greater on steep slopes. No significant difference was observed between source distance of debris and stream order.

Pooling all sites in the study found that more than 70% of the woody debris originated within 20 m of the channel. Composite data from sampled old-growth conifer forests indicate that a 30 m wide strip of streamside forest would produce 85% of the observed debris and that a strip of forest 10 m wide would supply less than 50% of this debris. Although the authors do not give specific comments on composite data for mature conifer forests, from the data they present, approximately 70% of debris originated within 15 m of the stream channel, while approximately 80% of debris originated within 20 m. In addition, approximately 95% of all debris from mature conifer stands had a source distance less than 30m. In conclusion, stands with taller trees (old-growth conifers) contributed coarse woody debris to streams from greater distances than did stands with shorter (mature) trees.

Quality of the Research: This study was conducted by university and government scientists and published in a peer-reviewed journal. The study design was suitable for fulfilling the objectives of the study. The fact that 47.7% of the debris pieces in the streams or straddling the streams could not be identified to their source leaves some room for interpretation of the results. Although the author's state that the pieces of debris found but not used in the analysis were usually short fragments that were quite mobile at high flows, they give no data on these pieces that made up close to 50% of the woody debris found. Since the unidentified pieces were not necessarily smaller than others they used as data, identifying the source distance of these pieces may have altered the results in a significant, although unknown manner.

Although the study takes place in two separate mountain ranges, the Coast and the Cascade ranges of western Washington and Oregon, the author's do not present any data on the differences or lack of differences between the two ranges. Since these two mountain ranges are dominated by different conifer species and are presumably exposed to differing climatic factors, the comparison of the two may be a valuable tool for managers trying to apply the results to their own forest types.

Relationship of Riparian Condition to Fish and Fish Habitat: There is no data presented to show the relationship to fish populations. Although the paper describes how the source distance of woody debris and the characteristics of the woody debris that enter a stream differ with forest types and side-slopes, it did not present data on the overall amount of woody debris within the streams in these different forests. Therefore, we do not get a full understanding of how much woody debris enters an old growth versus a mature forest or a hardwood versus a conifer stand, or a first-order versus a third-order stream in the various forest types. More importantly, it is not clear how much LWD is needed to provide enhanced fish habitat in these environments. Other research will be needed to ascertain whether there are "critical limits or tipping points or possibly correlations" between the amount of LWD in a stream channel and the standing crop of salmon or some other measure of stream productivity.

It is well known that woody debris plays an important part in forming fish habitat, retaining allochthonous nutrients, and plays many important roles in shaping the physical structure of a stream. In that regard, this paper does have relevance for fish habitat. If it is known how much woody debris is inputted into a stream in its current condition and what percentage of that woody debris input would be adequate for forming acceptable fish habitat, then we might be able to surmise what buffer width is necessary to make sure those inputs are retained by leaving a buffer of a certain width.

Relevance of Research to Washington: The study was conducted in the Coast and Cascade ranges of western Washington and Oregon, U.S.A. These areas are

geographically proximal to B.C. and ecologically similar to some environments in B.C. The results may be applicable to portions of B.C. with similar forest types and environmental conditions.

Relevance to Assessing Riparian Buffer Width: The paper has strong implications for the width of riparian buffers in forested lands containing coniferous old growth and mature hardwood forest stands that may be more common at lower elevations and possibly more likely in agricultural areas. The data presented indicate that tree height is an important correlate of the distance at which trees contribute LWD into a stream. Old growth conifers are much taller and hence are more likely to contribute source material further from the stream. Steepness of slope is not a good predictor. Old growth conifer trees as far as 30 meters from the stream contribute coarse woody debris inputs into a stream channel. Conversely, 83% of LWD in mature hardwoods originated within 10 m. of the stream channel.

Hardwood forests are more common at lower elevations similar to agriculture. These findings suggest that to maintain LWD for streams in conifer forests, especially old growth, may require wider buffers than are needed in lowland forests. It is not known how much coarse woody debris is needed to maintain adequate salmonid habitat. Site-specific evaluation of the adequacy of instream cover, allochthonous input loads and the specific types of salmonids present should be considered when prescribing buffer widths. As a generalization, this research suggests that a 10 m. hardwood forest buffer may be adequate to supply LWD to agricultural (valley) streams as such a width provided 83% of the source material. Since LWD is carried downstream, additional LWD will be recruited from upstream into agricultural lands assuming they are downstream of source material forests in the mountains. In Washington most of the rivers emerge from the Coastal and Cascade mountain ranges and feed the coastal and inland valley watersheds. Wider buffers may be needed in coniferous forests due to the fact that as much as 13% of the LWD comes from more than 25 m from the channel. No data in this paper is developed as to whether mature hardwood or conifer forests provide an excess or a deficit amount of LWD to optimize or meet salmonid production needs.

No. 28 - Title: Denitrification in grass and forest vegetated filter strips.

Authors: P. M. Groffman, E. A. Axelrod, J. L. Lemunyon, and W. M. Sullivan.

Citation: Journal of Environmental Quality 20:671-674 (1991)

Summary of Scientific Content: This University of Rhode Island study evaluated the ability of different vegetated filter strips (VFS) to support denitrification and determined the factors limiting denitrification in VFS so that management strategies could be developed to increase this process.

Denitrification was measured in two grass and two forested VFS in Rhode Island. The grass plots (3 m x 5 m) were established on well-drained soil and were planted to either tall fescue or reed canarygrass. One forest site was on an excessively well-drained soil and was dominated by oak, while the other was on a poorly drained soil and was dominated by red maple. The reed canarygrass was chosen because it is well adapted to a moist environment (such as riparian areas) and has the ability to uptake large quantities of nutrients. The tall fescue was chosen because it is a common plant in areas of disturbed soil and vegetation and is used in many other studies.

On three occasions between April and September of 1988 the grass plots were treated with between 33 and 96 kg N/ha in the form of urea. There is no mention of the forested buffer strips being treated with N. A total of three experiments were run. All experiments consisted of taking core samples from the sites. The first experiment was run to establish the baseline rates of denitrification and to determine the factors limiting activity in the different sites. It consisted of amending the soil samples with NO_3^- or NO_3^- -plus glucose to test for NO_3^- or C limitations. The second experiment was to characterize the denitrification response of VFS to NO_3^- additions, as would occur during a runoff event. The amended soil samples were treated with NO_3^- -N solution and C_2H_2 , and incubated aerobically. The third experiment was run to further assess the factors controlling denitrification in natural forested VFS. Denitrification enzyme activity was measured in 14 forest soils of different natural drainage classes using anaerobic assay described by Smith and Tiedje (1979).

Results from the first experiment suggested that *in situ* rates of denitrification in all the VFS were very low and were limited by the presence of O_2 and an absence of NO_3^- and/or C. Oxygen and NO_3^- control of denitrification have been reported in many studies (Tiedje 1988).

The author's expected the forest plots to have a much higher potential for denitrification than the grass plots, since forest soils (especially poorly drained) generally have higher moisture and organic matter levels than upland agricultural soils. In contrast to their

expectations, soils from the grass plots exhibited consistently higher denitrification activity in response to added NO_3^- than soils from the forest plots. The grass plots had higher microbial activity than the forest plots in response to NO_3^- and NO_3^- -plus-glucose additions in aerobic incubations. These results suggest that the population of denitrifiers was bigger and/or more active in the grass plots than in the forest plots. It is possible that the repeated inputs of N fertilizer and lime created a more favorable chemical environment, with more suitable organic matter for supporting denitrification (and microbial activity in general) in the grass plots.

The tall fescue plots had higher denitrification than the reed canarygrass plots in aerobic incubations of NO_3^- and NO_3^- -plus-glucose amended cores. Tall fescue may provide a more favorable soil environment for denitrification than reed canarygrass. Denitrifier population size can be affected by differences in the nature and amount of C inputs from roots to soil (Myrold and Tiedje 1985), and these inputs may vary among the different grasses.

The lower pH of the forest plots (<4.5) compared to the grass plots (5.9) may have contributed to the low denitrification rates that were observed in the forest plots. However, the author's note that it was difficult to separate direct pH effects from other factors. Soil pH is influenced by the nature of the organic matter and parent material at a site, and may not have directly influence denitrification in their study. Preliminary short-term experiments with lime additions at the forest sites showed that an immediate increase in pH did not increase denitrification, likely because available C and NO_3^- levels were not immediately affected by the pH increase.

Results from the third experiment suggested that forested wetland VFS are likely to be more effective sinks for NO_3^- than upland forest VFS, and confirmed the apparent importance of pH in controlling denitrification capacity in forested sites. Wetland sites, and sites with highest pH, had highest denitrification capacity as measured by denitrification enzyme activity.

Denitrification N-removal efficiencies calculated from the addition of NO_3^- were quite high in the grass plots, suggesting that up to 50% of a very large N addition (> 30 kg N/ha) could be denitrified per day. The author's note that these results must be interpreted with great caution, since they were obtained with soil cores and are not field-measured fluxes. Adding amendments to confined soil cores does not allow for free drainage and thus stimulated the development of anaerobiosis in the cores, and maximizes the accessibility of NO_3^- to denitrifier.

From all experiments it was clear that the role of C in increasing denitrification occurred in all plots. These results suggest that runoff containing high levels of available C (feedlot or manured field runoff for example) may be more amendable to treatment in

VFS than runoff that is low in available C. Second, the results suggest that if free drainage can be prevented during certain periods, significant denitrification can occur in VFS.

Quality of the Research: The research was conducted by university scientists and was published in a peer-reviewed journal. This study tries to evaluate the different denitrification abilities of forested and grassland VFS, but there are many confounding factors that make results difficult to interpret. Different soils and treatments (urea additions prior to experiment only in grass areas) were used in the grass and forested VFS. This may inherently be needed to grow the different vegetation types, but does limit our ability to distinguish whether differences in denitrification rates are due to soil chemistry or vegetation type. In addition, all denitrification rates were measured with soil cores with additions of NO_3^- and NO_3^- -plus-glucose, which the author's note does not allow for natural drainage, which may reduce the development of anaerobiosis and the accessibility of NO_3^- to denitrify. In addition, all measurements were taken in core samples, the study was not set up to monitor the amount of N going into a VFS and the amount coming out into either streamflow or ground water.

The experiments do have certain conclusions that can be drawn even though the experiments are not completely representative of conditions in field soils. Especially the fact that increases in C increased the denitrification process and that if free drainage can be prevented during certain periods, significant denitrification can occur in VFS.

Relationship of Riparian Condition to Fish and Fish Habitat: Although no fish data or fish habitat data are presented, the study does have implications to fisheries. It is well known that excess N inputs into surface flows can cause eutrophication of waters. Eutrophication can create waters that are unsuitable to sustain native aquatic fauna. Therefore, the presented research may have uses in the design of buffer strips to reduce excess amounts of anthropogenic N entering surface waters.

Relevance of Research to Washington: The experiments were conducted in Rhode Island. Grass plots were planted on soils that had row crop agriculture for the previous five years. The climate and geology are probably different from that of Washington, yet the conditions may share some traits of coastal wet forests similar to those in the Fraser River Valley. Additionally, there are some similarities in this paper with research conducted on the Toulouse River, France. There, denitrification was limited by nutrient and carbon input and had seven times the capacity to denitrify the incoming nitrogen. It appears that wet forested lands with anaerobic soils are important to achieving effective nitrogen removal in the shallow soil layers.

Relevance to Assessing Riparian Buffer Width: This study did not investigate how differing buffer widths effected the denitrification of applied sources of NO_3^- .

Consequently no conclusions on buffer width can be made. However, the research indicated that wetland areas have greater potential than upland areas to denitrify excessive loads of NO_3^- and that grass buffer, especially fescue, may be more effective than forested buffers in denitrifying NO_3^- . In addition, it concludes that the denitrification process may be increased with additions of C rich sources such as field lot or manure field runoff.

APPENDIX III

Draft Model Ordinance Affecting Farm Lands

Proposed Model County Ordinance for the Application of Farm Land Buffer Corridors

For counties under Growth Management Act (GMA) jurisdiction, critical areas protection ordinances are adopted to be consistent with local, state, and federal environmental and land use laws, including the Endangered Species Act (ESA). For farm lands adjacent to public surface waters providing habitat for ESA-listed fish stocks, or where water sources directly drain into public surface waters, the review and applicability of agricultural buffer corridors will be established by a county's critical areas protection ordinance. The critical areas protection ordinance directs existing and future agricultural operations to review their potential impacts on water sources, and determine whether, and to what extent, agricultural buffer corridors should be adopted.

Counties should be reticent to adopt ordinances with a “one-size-fits-all” approach to agricultural buffer corridors. The objective should be to assess carefully where agricultural operations do have a direct affect on surface waters, to recognize whether agricultural operations employ best management practices or other operational measures that fully or partially mitigate potential impacts, and to determine what physical configurations for buffer corridors will be both ecologically effective and economically practical.

Concerning the physical design of buffers, this should be guided by: 1) the type of farm activity, local climate conditions (wet or dry climate areas), and topographical conditions; 2) the extent operations conform to recognized best management practices; and 3) the scientific and technical efficacy of buffers for production agriculture.

Even where buffer corridors are the primary form of potential impact mitigation, county and state regulators should acknowledge the analyses provided by the Phase I and II reports that forest land buffers are inappropriate for agricultural production lands; and that the efficacy—or marginal utility—of buffers diminishes rapidly as buffer size expands. Consequently, buffers should be used conditionally and implemented with optimal effectiveness in mind. The objective is potential impact mitigation, not the use of “one-size” buffers as a general default measure.

Buffer corridors are one form of mitigation “tool” for critical areas, but they are not always the best tool to accomplish the protective management objective. The complete

farm management program must be taken into consideration before determining the need and extent for buffer corridors.

The draft ordinance provided below focuses on the application of agricultural buffers to protect Washington Critical Areas as required in the Growth Management Act. County commissioners and planners may adopt it as a subsection for critical areas protection ordinances knowing that its foundation is in the Best Available Science cited in this Report (Phase I and II).

Draft Model County Ordinance

XX.XXX.XXX Buffer Corridors for Agricultural Lands and Operations.

For the protection of critical areas, the establishment of agricultural buffer corridors shall be conditioned on the types of farm management operations in place and the site-specific environmental conditions. The county shall take into full consideration: 1) the type of farm activity and management operations, along with local climate conditions and pertinent topographical conditions; 2) the extent farm operations conform to recognized best management practices or other recognized industry standards; and 3) the scientific and technically based effectiveness of buffer corridors for production agriculture, including cost-effectiveness.

For agricultural buffer corridors, the following evaluation criteria shall apply:

(A) Farm and Grazing Lands Affecting Critical Areas. Farm and grazing lands directly adjacent to public surface waters providing habitat for fish stocks listed under the Endangered Species Act (ESA), or surface waters draining into public surface water sources with ESA listed species, shall be subject to ordinance provision XX.XXX.XXX and the subsections thereof. The provisions and conditions authorized by this ordinance do not apply to other land use development types adjacent to or affecting critical area designations.

(B) Minimum Width Buffer Corridor (25 ft.). Where recognized agricultural best management practices, or other high efficiency management operations, are being implemented for irrigation water application, pesticide and fertilizer application, or animal management, a minimum 25 ft. buffer shall be established between the agricultural management zone and the stream (water body) high-water mark. Vegetation shall ideally consist of species native to the local area and not dependent on landowner management.

- (1) The use of best management practices (BMPs) includes operational practices recommended by the NRCS/USDA, university researcher or the Cooperative Extension Service

publications, or standards generally recognized within the industry as highly efficient.

- (2) Best management practices for pesticide application are based on compliance with application requirements under existing state and federal law, as noted on all pesticide package labels.
- (3) Best management practices are defined as being both efficient and cost-effective for production agriculture.
- (4) Buffer species selection and design should consider the agricultural uses and benefits to the stream in consultation with NRCS/USDA, university researcher, the Cooperative Extension Service.

(C) Medium Width Buffer Corridor (35 ft.). Where farm lands are adjacent to critical areas (as specified in section (A)), receive over 18 inches of precipitation annually, and have shorelines with steep banks or sloping gradients over 7 percent leading to the farm management zone, a minimum 35 ft. buffer shall be established between the agricultural management zone and the stream (water body) high-water mark. Vegetation shall ideally consist of species native to the local area and not dependent on landowner management.

- (1) For the conditions provided in section (C) above, a 35 ft or wider. buffer corridor shall be established in conjunction with the use of best management practices or operational practices recommended by the NRCS/USDA, university researcher or the Cooperative Extension Service publications, or standards generally recognized within the industry as highly efficient.
- (2) Best management practices for pesticide application are based on compliance with application requirements under existing state and federal law, as noted on all pesticide package labels.
- (3) Best management practices are defined as being both efficient and cost-effective for production agriculture.
- (4) Buffer species selection and design should consider the agricultural uses and benefits to the stream. The use of wetlands that act as a detention from runoff from agricultural lands may be considered an appropriate substitution for traditional riparian buffers. Design considerations should be made in consultation with NRCS/USDA, or a Washington Cooperative Extension Service.

(D) Maximum Width Buffer Corridor (60 ft.). Where farm lands do not adopt recognized agricultural best management practices, or other high efficiency management operations, for irrigation water application, pesticide and fertilizer application, or animal management, or where slopes exceed 7% gradient, a minimum 60 ft. buffer shall be established between the agricultural management zone and the stream (water body) high-water mark. Vegetation shall ideally consist of species native to the local area and not dependent on landowner management.

- (1) The use of best management practices includes operational practices recommended by the NRCS/USDA, university researcher or the Cooperative Extension Service publications, or standards generally recognized within the industry as highly efficient.
- (2) Best management practices for pesticide application are based on compliance with application requirements under existing state and federal law, as noted on all pesticide package labels.
- (3) Best management practices are defined as being both efficient and cost-effective for production agriculture.
- (4) Buffer species selection and design should consider the agricultural uses and benefits to the stream in consultation with NRCS/USDA, university researcher, the Cooperative Extension Service.

(E) Buffer Corridor Exemption. Farm owners and operators with farm or grazing lands subject to section (A) above may petition the county to be exempt from the provisions of ordinance XX.XXX.XXX based on unique farm organizing operations or site circumstances not impairing critical areas or affecting the ordinance objective; or based on other circumstances and conditions taking into account on a case-by-case basis. The county reserves the right to exempt a farm operation from this ordinance or parts therein based on a showing of good cause.

APPENDIX IV

AWRA Riparian Conference Paper

Riparian Ecosystems and Buffers: Multi-Scale Structure, Function, and Management, American Water Resources Association, Summer Specialty Conference, June 28-30, 2004; The Resort at Squaw Creek, Olympic Valley.

EFFICACY AND ECONOMICS OF RIPARIAN BUFFERS ON AGRICULTURAL LANDS

John J. Pizzimenti, Darryll Olsen, and Michael Bonoff*

ABSTRACT: The Washington Department of Fish and Wildlife and the National Marine Fisheries Service have proposed mandatory, fixed-width riparian buffers on agricultural lands throughout the state of Washington to protect endangered species of salmonid fishes. Arbitrary or uniform imposition of fixed-width riparian buffers on agricultural lands raises questions about economic impacts to agriculture and cost effectiveness for salmon recovery via habitat protection. This report has two primary objectives: (1) to determine what scientific and technical data and analyses have been applied to the issue of widths of agricultural buffers and (2) to evaluate the economic costs associated with the proposed land set-asides.

KEY WORDS: Mandatory Riparian Buffers; Fixed-width Buffers; Agricultural Economic Impacts; Endangered Salmon.

INTRODUCTION

The Washington Agricultural Caucus obtained a Department of Agriculture grant to review the functions and appropriateness of widths for riparian buffers proposed by the State Caucus in during salmon recovery planning what is known Ag Fish Water Process. At issue to the Ag community is the efficacy and costs of mandatory riparian buffers across all agricultural lands, and whether other alternatives that may be effective. Fixed-width riparian buffers have five primary economic costs: (1) the cost to remove land from production, (2) the loss of economic benefits from agricultural production on those lands, (3) costs to monitor, administer, and maintain buffers, (4) loss of tax base, and (5) loss of economic infrastructure.

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The general value of riparian vegetation for fish, wildlife, and water quality is well established in the scientific literature and is not disputed by this review. The goal of this study is not to determine if buffers are good for these purposes. It is to determine whether it is necessary to broadly prescribe buffers of a specific width on agricultural lands to protect listed salmon; or whether other alternatives to prescriptive buffers are worthy of consideration. The report relies primarily on reviews of peer-reviewed scientific literature and is therefore consistent with Washington's Best Available Science regulations. The report includes information about similar processes in other states, especially Iowa, where voluntary processes have evolved and are effective.

SOURCES FOR BUFFER RECOMMENDATIONS

The prototypes for prescribed buffer-width recommendations were derived primarily from models of timber-fish-wildlife negotiations with the Pacific Northwest timber industry in the 1990's. Thus the scientific basis to formulate Ag land buffer widths is mostly forest-based. It is focused on factors of site-potential tree height and the importance of large woody debris in forested streams. There are important shortcomings to applying methodologies and science associated with timberland buffers to agricultural lands. The landscape, vegetation, gradients, harvest practices and impacts are quite different.

The six primary functions and values attributed to riparian buffers in forests are large wood recruitment, shade, streambank stability, litter-fall, sediment filtration, and floodplain processes. The Forest Ecosystem Management Assessment Team (FEMAT) developed models to determine how much timber to preserve in riparian zones adjacent to harvested areas. Those models led to buffers up to 300 feet or more, depending on floodplain limits, on each side of a stream.

The ecological function that requires the widest buffer is recruitment of large woody debris (LWD). LWD improves the quality and quantity of fish habitat in forest streams. In reviewing literature provided by the State Caucus to the Ag Caucus, it appears that data gathered in the timber assessment process and especially curves for LWD are the principal basis for wide buffer recommendations in agricultural areas. Also, the general value of wildlife habitat is emphasized in this literature.

LIMITING FACTORS OF THE DATA

The scientific literature of agricultural buffer widths on to streams in the Pacific Northwest is quite limited. In general, agricultural impact analysis suggests riparian functions other than LWD are far more important on agricultural lands. Vegetation traps sediment, filters pollutants, retains storm water, and stabilizes streambanks on agricultural lands. An important and related issue on agricultural lands is protecting

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streams from direct and indirect impacts of domestic animals. Peer reviewed studies found applicable in this report suggest that relatively narrow buffers of 10 m (33 feet), or less, can be highly effective in protecting ecological functions against these types of agricultural impacts. Roots adjacent to the channel and up to the stream's normal high-water mark provide physical stability and filtration absorption. In addition, separation of livestock from the stream by only a small margin has proven quite effective to improve water quality and physical habitat. With proper livestock management, fencing may not even be needed.

Thermal protection from shade is another desirable riparian function that is dependent on a number of site-specific factors. In larger lowland streams, thermal benefits from riparian shade are reduced. Data and thermodynamic considerations show that small streams can be protected from overheating on a diurnal cyclic basis; however, a relatively narrow buffer within a few meters of the stream can be effective in blocking direct sunlight from the water surface. Riparian buffers on larger rivers are less effective in thermal protection since the majority of the stream is unshaded for most of the day.

ECONOMIC ISSUES

Agricultural production, including agricultural services and food processing, generates almost \$8 billion annually in Washington income. The agricultural industry is a leading economic sector in several rural counties, in some cases producing more than \$100,000,000 annually in farm gate production values. This production, in turn, produces ongoing economic activity in other sectors.

Index values can be used to estimate economic impacts of fixed-width riparian buffers in a given county. Assuming a 75-foot width buffer, on a per mile basis, the costs of buffer zones for select counties reviewed in this report could range from \$11,000 to \$81,000 for lost crops, \$67,000 to \$88,000 for lost dairy production, and \$45,000 to \$95,000 for reduced land values. Land taken from production has less market place value. The loss of total direct and indirect county income per 100 acres of riparian setbacks could range between \$190,000 and \$240,000 per year.

Cost analyses, marginal benefit assessments, and cost effective analyses can be useful means for assessing marginal benefits and trade-offs within economic sectors. These tools can be used accurately at the county or regional level to compare the costs of variable width buffers or other approaches. Additionally, local enterprise economic models are in development that will help individuals evaluate and understand the economic cost of decisions that affect their land.

NEED FOR BETTER SCIENCE AND DATA

Only a few studies have approached the issue of buffer widths experimentally, in terms of analysis of multiple buffer widths under similar conditions of vegetation, slope, and adjacent land use. Much of the ecological literature observes existing buffers and

describes its function or compares it to the absence of a buffer. For example, Whitworth and Martin (1990), in assessing ecological benefits of filter strips, utilized sites with 15- to 66-foot-wide established buffers. Buffer widths in this study, as in most, were not varied as part of the experimental design, and there is no indication of what results would have been obtained with larger or smaller buffers. Fennessy and Cronk (1997, *In* Wenger, 1999) note that “one problem in assessing minimum widths necessary to protect adjacent surface water is that many studies that make recommendations regarding the minimum width necessary have arrived at the figure as a byproduct of sampling design rather than deriving it experimentally.” (p. 14)

Three studies reviewed for this report did approach this issue experimentally, and on agricultural lands (Dillaha *et al.*, 1989). These experimental studies with variable and controlled widths provide experimental descriptions of the effectiveness of buffers by size. Dillaha (*et al.*, 1989) showed buffer widths of 9.1 were nearly 100 percent effective for sediment reduction and between 82 and 90 percent effective for 4.6-m buffers. As expected, increasing gradient reduced effectiveness; but were still 70 percent and 53 percent for a 9.1 and 4.6 m widths respectively.

Mendez (*et al.*, 1999) evaluated 4.3-and 8.5-m buffers as treatments for row crops, in comparison to a zero width control. Like Dillaha (*et al.*, 1989), Mendez evaluated buffer effectiveness in reducing sediment and nutrients from tilled cornfields. In addition, he monitored effectiveness of buffers in reducing runoff volume. Results for sediment (measured as total suspended solids) indicated that while the 8.5 and 4.3 m buffers significantly reduced sediment concentrations from the no buffer condition, there were no significant differences between the 8.5-m and 4.3-m buffer treatments (i.e., the narrow buffer is as effective as one twice as wide). Finally, Mendez showed the same results for nitrate: 8.5-m buffers significantly reduced nitrate concentrations relative to the zero meter control, but not significantly greater than the 4.3-meter buffer.

Ghaffarzadeh (*et al.*, 1992) found that the first 3 m of a vegetated filter strip filtered 70 percent of the runoff sediment, and approximately 90 percent in 9 m. This study was conducted at distances of 0, 3, 6, 9, 12, and 18 m downslope of bare, plowed surfaces.

The above experiments demonstrate the need for scientifically controlled experiments to reach valid conclusions about the effective width needed to achieve specific functioning conditions. They highlight the weakness of simply making comparisons among existing buffers that do not have experimental controls.

FUTURE RESEARCH NEEDS

The width of a specific buffer on agricultural land is highly site-specific. Lowrance (1992; 1988) and his colleagues write: “Buffer widths have for the most part been set and constrained by federal cost-share programs with minimal scientific evidence. We need field studies that test various widths of buffer of different plant community compositions for their efficacy in trapping surface runoff, reducing non-point source pollutants and subsurface waters and enhancing the aquatic ecosystem” (p. 41).

In his review of Riparian Vegetation Effectiveness, Castelle (2000) concluded his review of the literature on buffer width effectiveness:

Generally, there are two types of research needs. The first entails re-visiting some of the data generated by past studies that examined only one buffer size, but did not study the effects of increasing or decreasing the size of the buffer". Unfortunately, information from such studies may be construed by resource agencies and land managers as minimum guidelines. For example, if a study stated that a 30 m buffer adequately protected streams, it might be inferred that smaller buffers were studied, and that 30 m buffers should be a minimum standard width. However, if that study were re-visited using buffers of 5, 10, 15, and 20 m, it might be determined that somewhat smaller buffers may be as or nearly as effective, particularly for specific riparian functions. As an alternative to studying varying buffer widths, other buffer zone management practices should be investigated. For example, stand composition could be manipulated to favor tree species that provide exposed roots (for sediment trapping), high transpiration rates (for nutrient uptake), and broad canopies (for shade production).

The second type of needed research should focus on the interactions between vegetative and non-vegetative factors. Depending on site specifics and the nature and degree of potential impacts, it might be determined that abiotic factors are more important than vegetation in determining buffer effectiveness. These various factors can be isolated and studied in laboratory or other controlled settings, but in nature all biotic and abiotic factors work together, and isolating individual parameters provides insight into only artificial environments. In both types of research, the focus should be on the physical, chemical, and biological mechanisms, which are responsible for buffer effectiveness. Understanding why a particular buffer parameter has a certain effect will allow for more effective buffer management, which in turn will result in higher levels of stream protection and optimum timber yields.

Reflecting on the larger scale of the watershed or ecosystem, what defines a conservation buffer is dependent on the intensity of adjacent land uses. Pastoral systems can serve as a buffer to row crops and agriculture itself can serve as a buffer to more intensive development of suburban and urban growth (Lowrance 1992; 1988) Elaborating further, they state:

The optimal arrangement of conservation buffers intended to meet multiple objectives is seldom a uniformly wide green strip along a stream. Actually, buffers placed along large rivers provide habitat, bank stability and flood control function, but may have relatively less impact on water quality” “ Even in headwaters, optimal arrangement calls for a variety of buffer sizes and types at different landscape locations. Very dense narrow buffers may be the most cost-effective way to reduce sediment delivery at critical points in a field or riparian area. Large blocky buffers may be needed elsewhere to provide optimal wildlife habitat and groundwater clean up” “The field--, farm-- and watershed-- scale research needed to define how to make these practices work in concert with one another has just begun.

ALTERNATIVES TO MANDATORY FIXED-WIDTH BUFFERS

One alternative to mandatory, fixed-width riparian buffers that may be preferable to farmers and ranchers would be a voluntary, incentive based program that may include variable width buffers. The agricultural community has already adopted many conservation practices based on local environmental needs and identifiable conditions in an ongoing betterment process that includes economic considerations. Variable width buffers that consider land use, gradient, and proximity to points of maximum return flows are preferable and will likely be more effective than fixed-width buffers. A more in-depth analysis of needs and alternatives is proposed for Phase II of this work in progress. A possible linkage could come from on-going watershed planning. Phase II of this research will elaborate on methods to encourage habitat improvement on agricultural lands and provide regulatory and economic certainty.

EXAMPLES OF SUCCESSFUL PROGRAMS

Bear Creek, Iowa, is a model agricultural restoration project being studied and managed by scientists at Iowa State University (Isenhart *et al.*, 1998). The Bear Creek restoration project recognized early on that floodplains that are heavily used for agriculture and streams are part of a continuous ecosystem (National Resource Council (1992, *in* Isenhart *et. al.*, 1998). Restoration to pre-agricultural conditions is not the goal of the project because of the destruction of the enormous economic wealth of the agricultural system. Their goal is an ecologically functioning system that uses voluntary participation and incorporates economic considerations into recommended actions. To quote Isenhart:

The social acceptance of the riparian management model is assessed through the use of surveys, focus groups and one-on-one information exchange. A better understanding of landowner objectives and economic

considerations has resulted in numerous variations of the model system. What initially began as just the buffer strip component of the system now includes the three other components: streambank stabilization, constructed wetlands and rotational grazing. This flexibility is designed to encourage adoptions of the management practices by satisfying the landowner goals and concerns as well as fitting specific biogeophysical conditions of the site. For example, the buffer strip component of the model can be modified by using different species combinations and by varying the width of each zone. Although such variation in design may not be optimal for water quality or wildlife benefits, the flexibility is important if it means that a landowner is accepting the concept. After the landowner has had experience with a smaller system, he or she may be willing to increase the size and effectiveness of the buffer or add additional system components. (Isenhardt et al., 1998, p.332)

Elaborating further, the Iowa State University Agricultural Research Team (IStART) approach shows:

Technology transfer efforts are geared toward quickly getting the results and information into the hands of landowner and natural resource professionals. This is accomplished through on-site tours, field days, self-guided walking tours, videos and extension bulletins. Other methods of information dissemination include presentations at meetings of natural resource professionals, conservation groups, and local civic organizations, articles in local newspapers and trade publications and publications in refereed journals. Local ownership of the restoration effort is encouraged through the development of voluntary citizen action teams that assist in buffer strip establishment, water quality monitoring, and constructing of wildlife nesting boxes. Finally, training workshops are being organized for agricultural and natural resource professionals to help disseminate the information and validate results.” (Isenhardt *et al.*, 1998: p.332). The Iowa State University experience and demonstration program stresses voluntary adoption versus regulatory approaches of buffer strip installation: ‘Regulation usually sets rigid parameters that do not apply well to the wide range of conditions encountered’.

CONCLUSIONS

Peer-reviewed studies related to agricultural buffer width prescriptions suggest prescriptions based on site potential tree heights from forest models likely exceed what is required to protect water quality and the ecological function of aquatic habitat on

agricultural lands. Because agriculture is an important industry with extensive land use, the economic consequences could be considerably larger than is necessary to improve aquatic habitat for salmon. Fixed-width buffers do not offer targeted solutions to site-specific issues. Fixed widths are independent of site-specific gradient, overland and channel flow regimes, and locations of maximum return flow. Undoubtedly larger and more extensive buffers would enhance wildlife and also fish. But they are unproven to be necessary to recover salmon and would be costly and unnecessary for other wildlife purposes. Programs that involve voluntarism and that fit within the economic as well as site specific ecological framework such as being managed by the IStART team in Iowa are likely to be both effective at improving fisheries and retain the economic vitality and participation of local agricultural communities.

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