Guidelines for:
Riparian Restoration in British Columbia

Recommended Riparian Zone Silviculture Treatments

1st Approximation

October 2002

BRITISH COLUMBIA

Ministry of Forests
Located on the WEB at http://www.for.gov.bc.ca/hfp/pubsriparianSilv.htm

Preface

This guideline document is considered a ”1st approximation” and represents a compilation of accepted management practices for riparian restoration derived from Forest Renewal BC's Watershed Restoration Program and concurrent operational practices. Emphasis is on a risk-based approach to riparian restoration practices that achieves effective and cost-efficient results. The intention of this document is to provide the best available technical information on riparian restoration, while remaining independent of any present, or future, government program or funding mechanism.

As well, inclusion of any technical procedure in this document does not imply that the procedure is endorsed by, or eligible under, any government program or funding mechanism. Practitioners are responsible for ensuring that all work is carried out in compliance with all pertinent legislation and regulations. Material contained in this guideline document does not constitute a standard. Rather, the techniques discussed are proven examples of practices that have been used for riparian restoration. Practitioners are responsible for evaluating the suitability of the techniques for a given site or area.

In all cases activities need to be within the current regulations and legislated requirements.

The Ministry of Forests wishes to solicit any comments, feedback or suggestions with respect to the content of this document. Please direct your correspondence by e-mail to Ralph Winter *Ralph.Winter@gems9.gov.bc.ca* at the B.C. Ministry of Forests.

The document is formatted to allow periodic material updating. The readers should consult with local forest, fisheries and environment agencies to ensure that they have up-to-date information, or if more detail is required than is provided in this handbook. Your input is greatly appreciated, if you have any specific suggestions or concerns please pass them on as they can be incorporated into future versions.

Acknowledgements

This document is a compilation of concepts and techniques that have been used successfully for silvicultural riparian restoration in British Columbia. It was written and organized by Bryce Bancroft and Ken Zielke (Symmetree Consulting Group Ltd.) under contract to the Ministry of Forests.

It is based on field experience and input from a range of practitioners, specifically Vince Poulin (V.A. Poulin and Associates), Reinhard Muller (Fen Forest Consulting) Dean McGeough (Integra Forest Consulting), Tom Johnson (T. Johnson and Associates), and Donald McLennan (Oikos Ecological Services Limited) and those at LGL Company Limited who have pioneered much of the work in BC.

We would like to thank all those who participated in a Riparian Restoration: Best Management Practices Workshop held in Richmond BC on March 7-8th 2002 who provided background and details from riparian restoration from their geographic locations. Special thanks goes to Pat Slaney for his insightful comments and to Heather Deal (both of the Watershed Restoration Program) for organizing the workshop. Workshop participants are listed below:

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Vincent Poulin (Vince Poulin & Associates)
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Tanis Douglas (WLAP- terrestrial ecosystems)
Pat Slaney, Heather Deal (WLAP/MSRM)
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Photo credits – B. Bancroft or as acknowledged in the report.

How to use this document and the intended audience

This document provides numerous links to information sources for additional background and detail.

This document is meant to be used by practitioners to aid in prescribing or carrying out silviculture treatments in riparian areas. It can also be used by those from other disciplines and resource management students as an introduction to the literature on riparian silviculture in British Columbia. It provides suggested approaches to achieve a range of objectives in the riparian zone. To get to there, the document provides a brief overview of the linkage between stream types, desired riparian functional elements, expected vegetation types and treatment options that link objectives with the various vegetation types.

It is not meant to be used in isolation. This document has incorporated numerous references and web-based links to provide additional detail and background on the subject.

WEB friendly – check out the links within – download an electronic copy from

http://www.for.gov.bc.ca/hfp/pubsripariansilv.htm

For example, Poulin et al. (2000) provides an up-to-date annotated bibliography on the subject of Riparian Silviculture. The papers reviewed range from those covering the ecological rationale for undertaking forest restoration, silviculture strategies for brushing, thinning and planting in riparian areas along with results of operational trials. This reference is available on the web at http://www.for.gov.bc.ca/ftp/Branches/Resource_Tenures_&_Engineering/external/!publish/Engineer/rsa-bibliography-wrp-restorat.doc.

Much of the practices suggested in this document owe their standing to the work of those authors. The annotated bibliography also provides a list of useful web references and a brief description of each. It is recommended that readers refer to the annotated bibliography and to the original sources for clarification and additional information.

McLennan (2002 in prep.) provides a wide-ranging review of riparian restoration in British Columbia stressing ecological functioning in hydroriparian ecosystems. McLennan (2002 in prep.) should be considered as a companion document to this guideline document as it provides the ecological framework, assessment procedure examples and an historical perspective for riparian silviculture treatments in B.C. It will soon be available on the web.

Additionally there are other excellent references (e.g., Murphy 1995) that will be mentioned within this document that provide additional background and guidance.

The document is set up in four sections to help the practitioner link treatments to achieving specific objectives within the riparian area:

1. **Section 1 – Introduction**: provides an introduction to set the context of the guidelines; it provides an overview of Riparian Function and links to Watershed level assessment procedures. It also provides an overview of Riparian Functional elements.
2. **Section 2 – Stream types and objectives**: provides an overview of stream classes and the relative importance of riparian functional elements. This section is meant to provide a context for treatment based on stream type.
3. **Section 3 – Objectives by Riparian Vegetation Type**: provides a summary of stand structures (Riparian Vegetation Types - RVTs) that are commonly found in previously harvested or disturbed riparian areas. A list of treatment options is provided. The options are linked to the Management Practices (MPs) treatments section where guidance for treatment implementation is provided.
4. **Section 4** - Management Practices: provides a description of the MPs, they are organized somewhat chronologically by treatment timing into the following categories:

In the electronic version of this guideline, hypertext links are provided to take you to related and relevant sections. If using a text version, the reader will need to go to the section manually.

Table of Contents

1.0 Introduction

This is a living document, in such it is subject to change as knowledge and skills improve. Riparian restoration is a relatively young and vital field where new information and ideas are constantly emerging. This document is meant to provide a conceptual framework and background information for use in choosing suitable treatments in the restoration of streamside vegetation. It keys in on repeatable vegetation patterns (Riparian Vegetation Types – RVTs) found in riparian areas to focus treatment options.

Riparian restoration is a field that should die out over time as current and future forest practices address the links between land and water and water and land (McLennan 2002 in prep.). The present situation of dysfunctional riparian systems is the result of past management practices that were insensitive to their effects on the entire land/water system, for example, logging to the stream edge and cleaning large woody debris from streams.

1.1. Types of riparian restoration

When any type of riparian restoration is considered it is prudent to solve upstream problems first. Murphy (1995) breaks out three main components for Riparian Restoration:

- upland restoration to control erosion,
- riparian restoration to restore the function of streamside vegetation, and
- instream restoration to improve habitat structure by physically modifying stream channels or their flood plains.

This document focuses on the second component - restoration of streamside vegetation.

1.2. Pre-treatment Assessment

Prior to implementing a restoration strategy an assessment of some type is needed to determine what if any problems exist. Numerous authors recommend and promote the use of a watershed level assessment (e.g., Prichard et al.1995, Koning 1999, McLennan 2002 in prep.).

In British Columbia a Watershed Assessment Procedure (WAP Guidebook 1999) is available to assess hydrological impacts of past harvesting on the potential impacts of future harvesting. Specifically:

- the potential for changes in peak stream flows

- the potential for accelerated landslide activity
- the potential for accelerated surface erosion
- channel bank erosion and changes to channel morphology as a result of logging the riparian vegetation
- the potential for change to the stream channel and
- the interaction of all of these processes, an evaluation of which indicates the sensitivity of the watershed to further forest development

These results can be used to prevent or mitigate impacts or to be used to guide watershed restoration activities. Overall the procedure can provide some guidance on impacts related to loss of riparian vegetation. The detail will vary; depending on how much field sampling versus aerial photo interpretation was done. It is a good starting point for assessing the entire watershed, highlighting issues that require immediate attention, such as points two and three above.

> To address upland restoration the reader is guided to the comprehensive document: (Atkins et al. 2001) *Best Management Practices Handbook: Hillslope Restoration in British Columbia*, November 2001, at:
>
> http://www.for.gov.bc.ca/RTE/engineering/wrp-pub.htm

1.2.1 Riparian Assessment and Prescription Procedure

Koning (1999) provides a riparian assessment and prescription procedure designed for assisting practitioners in identifying riparian functional deficits and their options. It was created as a component of a set of procedures for the Watershed Restoration Program of BC.

It provides clear step-by-step direction on planning watershed restoration projects, specifically those relating to vegetation management in the riparian zone. The document is based on earlier works by McLennan and Johnson (1997) and includes background materials on the ecological functions of riparian vegetation and an assessment procedure to assess the level of riparian functioning. It also provides a Riparian Assessment and Prescription Procedure (RAPP), designed to help priorize activities and opportunities as they relate to riparian function.

The RAPP procedure has three distinct phases to help identify areas in need of restoration. The three phases are:

- Office based overview assessment from air photos, maps, forest data files.

- Level 1 – Field based reconnaissance
- Level 2 – Field based assessment and prescription development.

The procedure focuses on previously harvested areas and on the area adjacent to fish streams larger than 1.5 m wide (considered as Riparian Reserve Zones under the Forest Practices Code Act of BC 1995).

1.2.2 US Bureau of Land Management Approach

Another approach for assessing riparian functioning was created by the US Bureau of Land Management as outlined in Prichard et al. (e.g., 1995, 1998a, 1998b). This approach uses a team of experts who answer a list of questions from a checklist of proper functioning. This process has been refined over time and evolves as new information becomes available. For detailed information on the approach consult the above references.

1.2.3 Use of a watershed assessment to set treatment priorities

Riparian restoration is a relatively new field, with many as of yet untested approaches. The information provided here is meant to capture the best management practices of the day; recognizing that these could change as more information becomes available. The key is to recognize that you are working in a dynamic environment and assess options in a watershed context.

> To promote cost effective treatments, activities should be in sync with a watershed scale assessment to establish the level of riparian functioning and to set priorities prior to treatment implementation.

1.3. Proper Functioning Condition is defined as:

Level of function needs to be determined prior to treatment.

The Operational Planning Regulation (Section 52) defines "proper functioning condition" to mean the ability of a stream, river, wetland or lake, and its riparian area, to:

• withstand normal peak flood events without experiencing accelerated soil loss, channel movement

or bank movement;

• filter runoff; and

• store and safely release water.

Pritchard et al (1999) further define proper functioning condition as:

Riparian Wetland areas are functioning properly when adequate vegetation, landform or large woody debris is present to dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality; filter sediment, capture bedload and aid floodplain development; improve food-water retention and ground-water recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and support greater biodiversity.

The functioning condition of riparian-wetland areas is a result of the interaction among geology, soil, water, and vegetation.

Level of Functioning is described in Koning (1999) as:

High (Proper Functioning condition[1]:) – functioning well, improvement not needed.

Medium (Function – at risk) – functioning moderately, improvement may help.

Low (Nonfunctional) – riparian vegetation is functioning poorly – improvement needed.

Additionally trends for function can be assessed and rated as Upward, Downward or Not Apparent (e.g., Prichard et al. 1995)[2].

Another objective of riparian ecosystems is to maintain habitat diversity for the maintenance of species diversity. Proper function can be extended to include whether the area provides suitable structure. Douglas (2002) provides a list of habitat enhancement activities designed to increase habitat values (see McLennan 2002 in prep.).

See also Silviculture Guidelines and Practices for Maintaining or Recruiting Key Habitat Objectives (Manning et al. 2002 in prep.) for in-depth direction on managing for key habitat objectives.

[1] The US Department of the Interior/Bureau of Land Management terms are provided in brackets for the level of functioning. They propose a fourth class as well – Unknown (Prichard et al. 1995).

[2] The BC Ministry of Forests Range Section uses a similar set of descriptors (Proper Functioning Condition, At Risk and Non-functional), see the Range Manual Chapter 12 for examples of the assessment procedure http://www.for.gov.bc.ca/hfp/range/Manual/ch12-ap-e-25.htm#TopOfPage

Riparian vegetation forms a continuum from the waters edge to upland conditions; it benefits fish and wildlife and provides significant diversity (e.g., Figure 1).

Watershed photo taken in 1886, note the LWD in the stream, BC Archives D-04677

Figure 1. The functioning stream, note the range of stand structure and level of wood in the River.

Former management has, in many cases, simplified the structure; it is the objective of Riparian Silviculture to restore the more varied conditions, promoting functional fish and wildlife habitat.

It is recommended that McLennan (2002 in prep.) be used to provide an overview of riparian restoration and to acquaint the practitioner with the ecological fundamentals of hydroriparian systems and watershed level assessment methodology.

Gayton (2001) provides an overview of ecological restoration and includes steps for setting up a project and adaptive management along with a list of potentially useful references.

1.4. *Ecological Functions of Riparian Vegetation.*

What follows is a brief overview of the contribution of various riparian elements for providing proper functioning condition.

Figure 2 shows diagrammatically the various vegetation functions within the riparian area. Note the range of desirable structures and attributes. When these are missing, riparian functions may be compromised. Riparian silviculture treatments may be available to help restore the riparian area to a greater functionality.

Note the ecological functions relate to upland habitats as well as stream function.

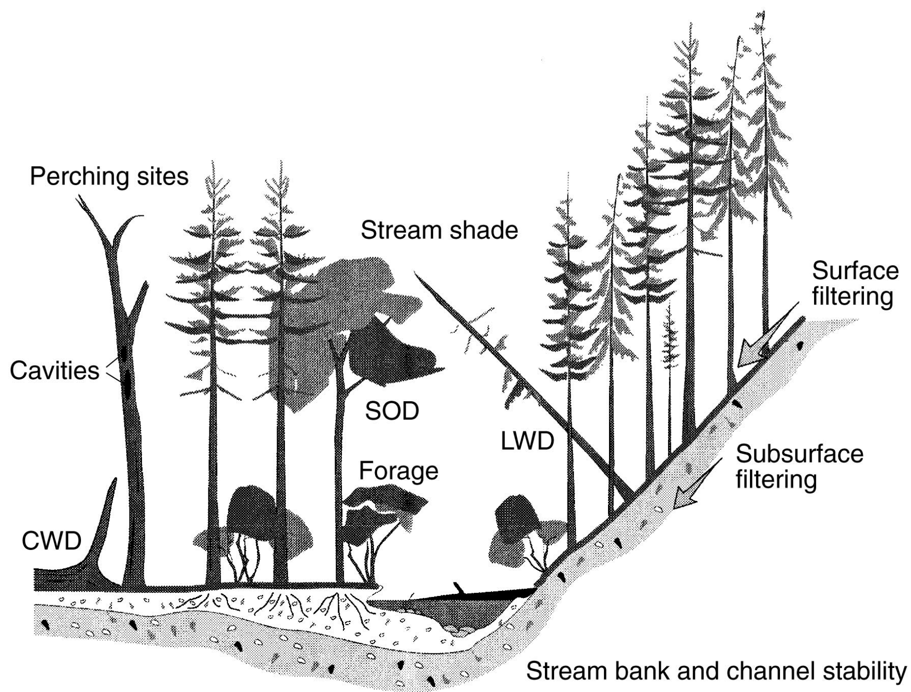


Figure 2. Illustrates the various Ecological Functions of Riparian Vegetation (after Koning, W. 1999. Riparian Assessment and Prescription Procedures, Watershed Restoration Technical Circular No. 6).

1.5. Large Woody Debris[3]

Large Woody Debris (LWD) is defined as pieces of dead wood, having a diameter of 10 cm or larger over a minimum 2 m length that intrudes into the stream channel (Fox 2002).

LWD is particularly important to salmonids as it been found to provide 80-90% of pools in valley bottom streams (Heifetz et al. 1986).

LWD also provides an important source of cover. In winter the need for cover is the most important of all habitat needs. Cover can increase a stream's carrying capacity for juvenile salmonids by providing security from predators and floods. (Murphy 1995).

1.5.1. Effects of logging

Significant reduction of LWD inputs occurs where logging has occurred to the stream edge. Murphy and Koski (1989) model LWD inputs from areas harvested to the streamedge showing instream LWD would be reduced by 70% in 90 years and would take more than 250 years to fully recover.

If there are no LWD sources in the stand, it could take over well over 100 years for natural levels to recover.

Figure 3 shows how LWD can influence water flow in a stream.

Figure 3. Inputs of high quality large woody debris (LWD) with low decay rates are an important feature for the natural functioning of many streams.

The absence of large conifer LWD can result in channel erosion resulting in downcutting as LWD from hardwoods is inadequate for structuring the stream channel that can result in lower local

[3] Also described as LOD – Large Organic Debris – the terms can be used interchangeably.

water tables. Storage and moisture recharge may be reduced and base streamflow can decline, which could be a serious issue in areas with summer drought. Downcutting can also reduce the potential for natural disturbance on the floodplain, as flows follow the channel and do not go over their banks during peak events which formerly provided conditions suited to the establishment of conifers, the lack of it promotes shrubs (Murphy 1995).

Once the LWD is in the stream it can promote favorable fish habitat through a range of functions (particularly in lower gradient riffle-pool-bar channel types) where it aids in the retention of spawning gravels, creation of pools and the provision of cover and nutrients (Fox 2002).

LWD may or may not be a critical element – it depends upon the channel type.

It should be noted that LWD has different roles to play in different types of channels, it is not critical everywhere, for example in block-step pool channels. Not all channels are dysfunctional due to a lack of LWD (P. Tschaplinski, pers. comm., May 2002).

Input of LWD varies by stream type. Unconstrained streams in valley bottoms can meander across the floodplain, obtaining LWD from the immediate streambank, undercutting trees along the banks. Over time the channel can meander resulting in undercutting trees far from its present channel (Murphy 1995). However Murphy (1995) points out that most LWD is recruited from within a tree length from the stream edge, and the tree height is a function of productivity.

LWD can come from local sources through bank undercutting or from upstream through mass wasting.

In constrained channels (e.g., those in bedrock) where there is little chance of undercutting the bank, the stream often has steep forested areas above that provide pulses of LWD through mass wasting (Murphy 1995). These stochastic disturbance events can deliver large quantities of mixed sediment and LWD from hillslope failures and debris torrents initiated along headwater stream channels (e.g., Swanson et al. 1987; Hogan and Schwab 1991 in Murphy 1995). When this type of disturbance occurs after logging has removed the trees, sediment is transferred to the stream without the LWD.

LWD once in the channel, is depleted though decay, breaking up into fragments and being swept downstream. The rate of depletion depends on the size and species of the LWD and the type of stream.

Not all LWD is created equally. Deciduous LWD will decompose rapidly (< 10 years), while cedar will remain for decades, even centuries if underwater. Spruce and western hemlock will also provide long term LWD with depletion rates in the order of 1-3% in valley bottom streams (Murphy 1995). Recruitment of LWD begins at about 30 to 35 years for deciduous and 65 years for conifers (P. Bisson USDA Forest Service, pers. comm. March, 2002).

Size of functional LWD has been linked to channel width. Form of LWD is also important. Key pieces of LWD with rootwads are often preferred since they are less likely to move during peak flow periods. For more information on functional sizes of LWD see Bilby and Ward (1989).

1.5.2. For more information

For an overview of how much LWD is considered suitable for various areas in the Pacific Northwest see the Center for Streamside Studies (CSS) website at: http://depts.washington.edu/cssuw/Publications/publications.html and click on the Fact Sheet for Large Woody Debris.

The amount suited to your reach may vary from the information provided. Use the local watershed assessment to provide local guidance. Remember LWD sources may be adjacent to the reach or upslope depending upon the situation.

1.6. Bank stability

Roots of vegetation in the riparian zone can play an essential role in stabilizing stream banks and adjacent deposited materials (e.g., sediment bars). Vegetation removal can result in increased channel instability, bank erosion and sediment input. This is likely most common in small floodplains and braided channel reaches along small and medium sized streams.

Bank stability issues need to be identified at the watershed level using input from relevant specialists.

Bank stability needs to be addressed at the watershed level and may require active instream works backed up by silvicultural treatments.

Figure 4. Photo of young vegetation along a meandering stream, rooting strength of young vegetation is not optimal for maintaining bank integrity.

Lateral or bank erosion is a natural process and may be unrelated to removal of riparian vegetation, especially along larger streams with well-developed benches. The ability of roots to protect stream banks from erosion and maintain stability is not only a function of stream size but also a function of root size, increasing with larger root systems (Koning, 1999). Therefore selected treatments to increase the size of individual trees will often result in larger root systems that may aid in long-term bank stabilization on selected reaches.

1.7. Shading (temperature control)

Temperature management is a challenging topic with no simple answers. Seasonally harmful temperatures can be an issue almost anywhere where sensitive species such as bull trout, occur or where the right conditions of slope, aspect, elevation, groundwater, drainage connectivity, etc. occur (P. Tschaplinski, pers. comm., May 2002). Shade may be important or not depending upon a range of factors.

Shading can be more critical in hot dry climates and streams with low seasonal flows and minimal southern topographic shading.

Vegetation along riparian areas provides shading that can help decrease summer stream temperatures and light levels in some systems. Loss of streamside shading may negatively affect stream ecology and fish movement. In British Columbia, this may be especially critical in warmer portions of the province, such as in portions of the Interior Douglas-fir, Interior Cedar Hemlock, Ponderosa Pine, Coastal Douglas Fir, and Bunchgrass Biogeoclimatic zones.

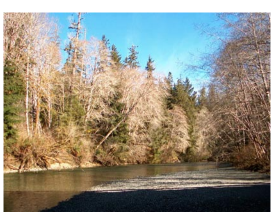
Consult your local resource management agencies and experts for direction.

Shading is a function of the topography as well as channel width. Smaller streams can be shaded by shorter vegetation; temperature in large streams may not be influenced by shading instead may be influenced more by flow rate and depth. Additionally some stream's temperature is regulated by underground springs, moderating the temperature, creating a situation where local management of riparian shade may not be effective.

To determine where temperature issues exist the manager should consult BC Ministry of Water Air and Land Protection and the Department of Fisheries and Oceans for specific information on local watersheds. Where critical, it may be desirable to manage to increase the amount of shading immediately.

1.8. Nutrient inputs – Small Organic Debris (SOD)

Nutrient inputs through contributions of SOD provide needed food sources for aquatic organisms. SOD occurs as coniferous and deciduous litterfall.



Deciduous leaf fall provides important nutrient input into the riparian system.

Deciduous inputs generally have higher levels of nutrients and are used more rapidly by decomposers than conifer needles. While deciduous litter is an important energy source for stream invertebrates and is often a preferred substrate for aquatic *microbes and insects, conifer input provides a more year round* source complementing the seasonal deciduous input (McLennan 2002 in prep.).

SOD input is thought to be important in all stream classes, but more so in smaller streams as the impact of vegetation on larger streams diminishes.

1.9. Terrestrial wildlife habitat

Riparian areas are often structural diverse providing habitat elements for a range of species.

Where the structure has been simplified, management can help restore those attributes.

Riparian systems are known to contain a range of structural and species diversity. They are used by a significant number of vertebrate species and uncounted numbers of insects and other invertebrates.

Important features include herbs and shrubs for foraging, and hiding cover, large trees for roosting and nesting, and overstories for shelter from snow and cold. A strength of the riparian zone is its heterogeneity and its ability to provide for a range of attributes over a relatively confined area.

Past harvesting practices have often resulted in simplified uniform stand structures that do not have the range of structures, habitats and niches that were created through the frequent disturbances of floods and windthrow that created the heterogeneous riparian vegetation communities preharvest. Where past practices have simplified the structure, there is an opportunity to look to unharvested riparian areas to observe ranges of vertical and horizontal variability.

Management can promote maintaining structural legacies such as wildlife trees and restoring structural variability over time.

2.0 Stream types, key riparian attributes and possible options

Riparian function has been described as part of the stream/river continuum beginning in the headwaters and moving down stream (Vannote et al. 1980). What follows is a brief description of the stream types and some key riparian functions vegetation may provide by stream type.

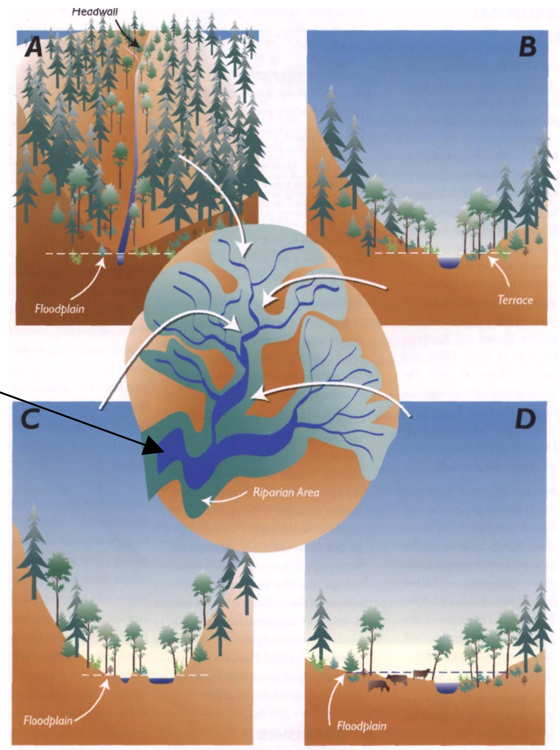


Figure 5. Different portions of the stream-river continuum and how they relate to stream types. Diagram used with permission from Emmingham et al. 2000. Silviculture practices for riparian forests in the Oregon Coast Range. Research Contribution 24. Oregon State University, Forest Research Laboratory, College of Forestry.

This section is meant as a link between stream types and potential treatments by vegetation types found on site. A brief description of the functional role of vegetation in the stream type and a link to the commonly encountered Riparian Vegetation Types (RVT) is provided. For a full description of RVTs see Section 3 page 23.

Specific recommendations need to be done on a case-by-case basis with a clear understanding of what is the intent of the treatment for the area to be treated.

More detailed channel structure and function information is available in the Channel Assessment Procedure Guidebook (1996) found at:

http://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/CHANFLD/CFLD-TOC.HTM

which describes geomorphic channel types, their functions and linkages to hillslopes, floodplains and identifies where LWD is critically important.

2.1. Headwater streams – mainly S5 - S6 (possibly S4)

Headwater streams are important sources of nutrients and energy for the entire stream–river system and may be important LWD sources in some situations.

However, their role is not fully understood and additional learning is needed.

Source streams including headwater steams, often steep and without fish, are important parts of the stream river continuum, as described in Vannote et al. (1980) where they form the starting point for inputs of bedload elements, energy and nutrients that are carried throughout the system. The riparian vegetation contribution will depend upon many factors, including the climatic zone and the type and size of watershed. Headwater riparian areas are often conifer dominated. The stands are often not 'wet' or 'saturated' as is the common conception of riparian vegetation. Instead they are often 'mesic' or medium moisture regimes and respond to treatment, as would much of the upland forest.

Treatments that reduce stocking may be suitable for riparian areas along these streams to create desired conditions sooner. However, present information on the role of vegetation along these stream types is incomplete, as more information becomes available treatments may vary. Presently some concepts to consider include:

2.1.1. Key Riparian Attributes and RVTs of potential concern.

LWD

Conifer LWD recruitment may be important for future headwall failures and downstream effects. Otherwise LWD is not usually a factor in the stream morphology, instead it provides a long-term source for downstream jams.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 2 – overstocked conifer stands – most likely RVT

SOD

The contribution of nutrients through SOD leaf litter and detritus to downstream segments is high for these streams, making retention or restoration of vegetation along these streams a priority. In many cases nature will rapidly provide suitable cover after a disturbance, such as logging. Where significant vegetation removal has occurred, such as from a slump or landslide, active revegetation may be desirable. See the planting section in the Hillslope Restoration BMP for guidance.

Potential conditions of concern:

RVT 2 – overstocked conifer stands

Bank Stability

Usually not an issue as banks relatively confined.

2.2. Lower Gradient streams – S2 and S3 (S4, S5, S6)

Treatments to promote conifer LWD recruitment, SOD inputs, bank stability, shading and the provision of riparian habitat for terrestrial organisms are all candidates in these reaches.

Photo credit – R. Muller.

These streams are often dependent upon the contribution of nutrients and LWD. A balance of deciduous and coniferous with unstocked gaps was often the original unharvested condition. Previous harvesting to the stream edge has reduced LWD sources and modified the Small Organic Debris (SOD) sources. Bank stability and shading may have been reduced as well. Since many of these streams are fish bearing (including the smaller S4 category), it is important to identify at the watershed level what functions have been compromised and to determine what options are available to restore them on a site-specific basis.

2.2.1. Key Riparian Attributes and RVTs of potential concern.

LWD

Sources of future functional LWD may be seriously compromised. All RVTs may be encountered and have opportunities for treatment.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 2 - overstocked conifer stands

RVT 3 - conifers overtopped by deciduous trees

RVT 4 – Deciduous dominated stands lacking conifers

SOD

The contribution of nutrients through SOD leaf litter and detritus to downstream segments is important for these streams, making retention or restoration of vegetation along these streams a priority.

Potential conditions of concern:

RVT2 – overstocked conifer stands

Bank Stability

Maintenance of bank stability through conifer rooting may be important, and may require LWD recruitment strategies.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 2 - overstocked conifer stands

RVT 3 - conifers overtopped by deciduous trees

RVT 4 – deciduous dominated stands lacking conifers

2.3. Floodplains along S1 and S2 streams

Riparian areas are often thought of as having high watertables. These are floodplain sites in the deposition zone of steams and rivers. Floodplains are often associated with S1 and S2 stream types and may contain much smaller channels within them, including wetlands. Three classes of floodplains have been described based on flooding frequency and intensity: High, Medium and Low Bench (e.g., Green and Klinka 1994).

2.3.1. Larger streams S1 - S2s - High Bench

A key indicator of high bench sites is that the forest floor is developing but is only a few centimeters thick, as compared to thicker forest floors from upland sites and less developed in more frequently flooded sites.

High benches are the highest and most infrequently flooded portions of a floodplain with generally more than a 5-year return period with short periods of growing season flooding (Green and Klinka 1994). These sites are formed from the deposition of sediments during flooding after major precipitation events (McLennan 2002 in prep.). They are often rich, good growing sites, with a high potential for brush competition.

2.3.2. Key Riparian Attributes and RVTs of potential concern.

The importance of LWD recruitment varies by river and size. Large wood supply is important in S2 high bench floodplains to provide instream LWD.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 2 - overstocked conifer stands

RVT 3 - conifers overtopped by deciduous trees

RVT 4 – Deciduous dominated stands lacking conifers

SOD is of moderate importance in most cases, except where instream work has taken place, where its importance may be elevated due to its removal. Sources of native seed (e.g., red alder) should be assessed prior to any treatment to increase SOD inputs. Where lacking, planting of native whips may be an option.

Potential conditions of concern:

RVT2 – overstocked conifer stands

Maintenance of Bank Stability through conifer rooting is often important and may require LWD recruitment strategies.

See LWD above.

NOTE:

Treatments to promote conifer growth, such as overstorey removal and spacing of dense stands are considered preferred treatments. Planting to augment conifer stocking is a somewhat risky due to the potential for brush competition, therefore a brushing regime to promote survival and growth should be part of any regeneration plan.

2.3.3. Larger streams S1-S2s - Medium Bench

Medium bench sites have thin poorly developed forest floor layers, often composed of only litter.

Medium benches are intermediate in height above the stream channel between high and low benches, generally flooding at least every 5 years and often annually (Green and Klinka 1994). . Mature stands are dominated by deciduous species, conifers are often at low densities, restricted to elevated microsites. This is due to the flooding intervals and extent. Annual flood levels are often close to the soil surface, resulting in saturated rooting conditions for weeks at a time, as well flooding occurs during the growing season. Thus plants adapted to saturated conditions dominate. Conifers are restricted to mounded microsites within the stand (McLennan 2002 in prep.).

2.3.4. Key Riparian Attributes and RVTs of potential concern.

Conifer LWD recruitment can be extremely important for fish habitat. Large wood supply and log jams collect on nick points along the reach margins providing the primary fish producing areas in S1 streams (e.g., Slaney et al. 1994). Watershed assessments are needed to make judgments on LWD requirements.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 2 - overstocked conifer stands

RVT 3 - conifers overtopped by deciduous trees

RVT 4 – deciduous dominated stands lacking conifers

SOD has a moderate importance for S1 streams and is highly important for S2 medium benches. As is the case for high benches, look for local seed sources prior to active treatment.

Potential conditions of concern:

Bars lacking any vegetation.

Bank Stability is considered as moderately important for S1s and important for S2s. Managing onsite conifer stocking to promote growth is seen as a preferred strategy. Planting is often risky due to the potential of flooding.

Potential conditions of concern:

RVT 1 – understocked with conifers and brush sites

RVT 3 - conifers overtopped by deciduous trees

RVT 4 – deciduous dominated stands lacking conifers

2.3.5. Low Bench – range of stream sizes – including fans

Restoration of desired structure in the low bench areas, requires a clear understanding of the intensity of hydrogeomorphic activity – i.e., flood or debris flow frequency and size before any action should be taken. A team of specialists needs to be involved in prescription development. Many situations present a major restoration challenge where doing nothing is often a reasonable option (see Wilford et al. *(2002) for a discussion of Fan restoration).*

Low bench sites are flooded annually (Green and Klinka 1994). Forest floor layers are absent or made up of fresh litter. Mature stands are dominated by deciduous species conifers are rare and may not be suited to establishment, due to the high watertable. Willow is a common component.

No generalizations are provided. **Determine** prescriptions based on site-specific conditions. The amount and type of treatment will be based on risk and functional condition of the area. Because low bench sites are extremely dynamic, it is not possible to make generalizations about the importance of attributes and priorities. An interdisciplinary approach is required.

With interdisciplinary input (e.g., geomorphologists, foresters, biologists and engineers), active treatments may be identified to stabilize the floodplain. Woody debris treatments may be appropriate (active input to the area) causing deposition of silt and fine sands to promote re-vegetation. Planting of deciduous whips may be desirable to help stabilize these sites**.**

This type of restoration is usually a long-term undertaking (possibly decades)with a high degree of uncertainty, proceed with caution and informed input.

Recognize that maintaining structure may be more suited to providing long-term function, than silvicultural treatment options that may destabilize intact vegetation.

The do nothing option is one that should be looked upon seriously unless a well thought out interdisciplinary strategy is agreed upon.

3.0 Links to treatments by Riparian Vegetation Type

Past logging practices have modified riparian structure by removing conifers from the site and often created conditions that promoted deciduous and shrub establishment.

Poulin and Simmons (1999) outline five riparian vegetation types commonly encountered in riparian areas after harvest. These vegetation types have specific treatment options associated with them.

The following section is set up to provide linkages to the Recommended Management Practices by Riparian Vegetation Type. RVT types after Poulin and Simmons (1999) are:

RVT 1 – Understocked with conifers and brush sites.

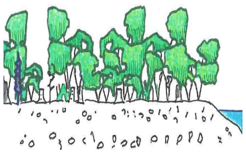
RVT 2 – Overstocked conifers.

RVT 3 – Conifers overtopped by deciduous trees.

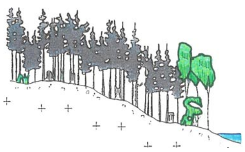
RVT 4 – Deciduous dominated stands lacking conifers.

RVT 5 – Mature stands or those not requiring restoration

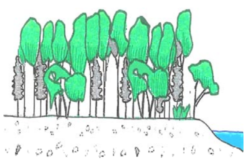
RVT 1



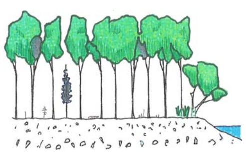
RVT 2



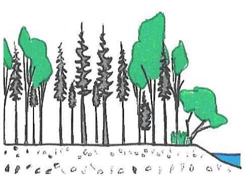
RVT 3



RVT 4



RVT 5



Diagrams of RVTs 1 -5

(after Poulin and Simmons, 1999. Restoration of fish habitat and water quality requires riparian silviculture. In Watershed Restoration Technical Bulletin, Streamline, Volume 4, No. 1.

Reference stands – what does a desired stand type look like?

When contemplating a treatment of RVT 1 through 4 sites, look for RVT 5 sites in the area. These natural riparian stands can be described and used as ‘references” to guide treatment standards to achieve desired future conditions.

In areas with infrequent disturbance regimes, look at old stands for their structure, species, size, distribution and especially variability. These old stand conditions can help focus treatment intensities to move your younger stands toward those desired conditions.

Remember nothing is static and the old stands offer one set of desired conditions. An intermediate or alternative set of desired conditions may better suit the local situation if natural functioning has been severely compromised. For example no conifers exist within a sea of deciduous. An interim desired condition may be to increase the size of individual deciduous, something not found in the older stands.

Remember - The key is to restore normal riparian function.

It is important to recognize that reference stands may not be available in your area due to past management practices (e.g., extensive logging, fire suppression, etc.). Use knowledge of the key functional elements and input of experts to help derive desired future stand goals.

An example RVT 5 – widely spaced conifers (300 – 400 sph) with a dense understorey of shrubs.

Title: Copley Crossing the Mouth of Fall River

Figure 6. An example of a reference stand – historical photos may help where few old stands remain in an area.

This photo was taken in 1913 by Frank Swannell in the Bulkley-Nechako area. BC Archive I-33960.

Care must be taken to match treatments to the stand and site conditions to provide for long-term structural objectives.

Care must be taken in choosing treatments that will stand the test of time. In some cases staged treatments may be required to reduce the risks associated with taking a stand to the desired conditions too quickly. For example planning a two pass thinning system where the stocking is taken to an intermediate level first to 'windfirm' the stand, then at some later date take the stand to the desired density.

3.1. RVT1 Understocked with conifers and brush sites

Treat only if needed as identified in a watershed assessment.

The reason – costly with a high level of commitment (i.e. risky) – & it provides useful structural diversity.

While adding conifers to an area may be an important step in restoring riparian function, it is considered a high maintenance option, often requiring up to 5 years of brushing and browse protection. Use this treatment wisely, since some brushy gaps in the riparian forest are desirable to provide habitat for a variety of organisms. Base your treatment decision on a watershed assessment that shows a clear need to add more conifers. An issue that needs to be addressed is that this approach will take a long time to create usable LWD. Active in-stream riparian treatments may be needed to restore function in the short and medium term.

Potential Objectives

- When identified at the watershed level as necessary - Increase the conifer component to provide for long term LWD and bank stability through long lived rooting structure.

Often RVT1 occurs as a minor component of the vegetation complexes, thus the no treatment option is suitable for promoting structural diversity along the reach.

RMPs

- Increase the conifer component – see the Regeneration RMP (page 41)– for a description of site preparation, planting and maintenance options.

  NOTE – Treatment of this RVT is often a lower priority than treatment in RVT 2-4, due to high levels of risk and cost factors.

- Leave portions intact to maintain and provide structural diversity.

3.2. RVT 2 Dense / Overstocked Conifer Stands

Issues *–*

What is the expectation of treatment?

What age and height are most suited for treatment?

What densities and configurations should be left?

When is commercial thinning an option?

Overstocked or dense conifer stands compete for light, moisture and nutrients resulting in tall thin trees with relatively small root masses. During this stage they have very little structural diversity. While these stands will provide some level of riparian functionality, they are lacking gaps and opportunities for more individual trees to grow faster and create larger diameter trees and root systems.

These overstocked stands, within the riparian zone, if left untreated, could result in excessive LWD inputs as a pulse destabilizing the streambed and increase sediment production, both undesirable for restoration of fish habitat (Poulin and Simmons 1999). Thinning creates conditions that result in larger stems faster. The stand should be more windfirm allowing options for future harvesting adjacent to these future Riparian Reserves.

Potential Objectives

- Increase the rate in which long term LWD will be produced by providing the remaining conifers with more growing space.
- Provide more varied structure, e.g., increased gappiness for shrub and other plant growth.

RMPs

- See Variable Density Spacing in the Riparian Zone (page 34) for details on size of stands to treat, post spacing density options, safety.
- Maintain desirable non-crop species (i.e., shrubs for browsing deciduous for leaf input).
- Note that in some cases commercial thinning (CT) may be an option that could help defray costs while enhancing the functional condition. See Commercial Thinning in the Riparian Zone (page 40) for more detail.

3.3. RVT 3 Conifers overtopped by deciduous trees

Conifer release provides understorey conifers more light and opens up the stand promoting structural diversity.

Sites with conifers (> 100 sph) beneath deciduous provide a range of options. Conifers established under significant deciduous overstories compete for light and other site resources often resulting in slow growing spindly saplings. Options for treatment include overstorey removal for conifer release, overstorey spacing to provide conditions for larger deciduous stems, and in some cases planting if conifer levels are low.

Potential Objective:

- To reduce light competition from above to enhance conifer diameter growth to increase the rate in which long term LWD will be produced.

RMPs

- See Conifer Release – overstorey reduction (page 29) for more details on the characteristics for trees to be released and desired structural outcome.

3.4. RVT 4 Deciduous stands without a conifer understorey

Sites with low levels of conifers (generally < 100 sph) are often considered as having low or moderate risk for riparian function (nonfunctional, or functional at risk) for future LWD sources. But remember the risk function is from a fish perspective and should be assessed at the watershed level to bring in terrestrial habitat needs.

Options exist to space out the deciduous overstorey to provide conditions for accelerated diameter growth of the remaining deciduous stems. Another option is to follow the regeneration strategy, which may include falling, site preparation, planting and follow up brushing.

Issues:

- Deciduous stems are in place that provide nutrient inputs and short term LWD and SOD and to a limited extent bank stability.
- Conifers may be needed to provide longer-term sources of LWD, wildlife trees and added bank stability.

Potential Objectives

- Increase the conifer component of the stand to provide for long term LWD and bank stability through long lived rooting structure.
- Increase deciduous piece size.

RMPs

- See the Regeneration RMP (page 41) for information on site preparation, planting and maintenance options.
- Thin out the deciduous to increase piece size.

4.0 Recommended Management Practices

This section contains recommended management practices based on experience in British Columbia and neighboring areas. It is split into subsections as follows:

- conifer release
- variable density spacing
- regeneration
- link to range management information
- general considerations.

Within each subsection, a set of potential objectives is provided along with a description of the practice, a set of prescription indicators, or situations that would trigger the prescription, suggestions for implementation, cost factors and where applicable additional information is provided.

For general guidance on use of the document, as provided by the B.C. Ministry of Forests please refer to the preface page i.

4.1. Conifer Release – overstorey reduction

4.1.1. Potential Objectives:

- To reduce competition from overtopping deciduous species to promote conifer survival and increase conifer growth rates within the riparian area.
- To promote structural diversity and provide long term sources of LWD and promote large conifer rooting structures to maintain bank stability.
- To maintain a component of deciduous stems as a source of habitat diversity and as a source of nutrients for both stream and uplands.

4.1.2. Description:

On many riparian areas harvested to the stream edge, deciduous species dominate. On the coast the main species found are red alder, cottonwood and big leaf maple. In the interior they are often aspen and or birch.

These areas can be identified on air photos but require ground truthing to determine the conifer stocking in the understorey. Conifer stocking is often clumpy or patchy. Depending upon the time since disturbance the conifers may have relatively low vigour with small crowns and high height to diameter ratios.

4.1.3. Prescription Indicators:

Dense areas of deciduous stocking, with existing conifers in the understorey.

- **Conifer candidates for release should have the following characteristics**:
    - be species suited to the site and desired for the objectives for the area;
    - have a minimum of 30% live crown;
    - have a height diameter ratio of < 80;
    - have no serious forest health concerns[4];
    - be abundant enough to provide the desired future condition – could be measured/estimated as number of trees per length of stream or as a minimum number of stems per ha.;
    - be above understorey vegetation (in order to respond to overstorey reduction).

Released conifer in riparian zone released from a deciduous overstorey.

4.1.4. Suggestions

4.1.4.1. Opening size

A common problem with conifer release from a deciduous overstorey is leaving too many overstorey stems, limiting light penetration. The key is to reduce crown closure significantly.

- Treat only areas with desired understorey trees.

  On good growing sites, Hibbs and Chan (1997) found that with 85% of red alder removed the canopy closed back within seven years. Emmingham et al. (2000) recommend reducing overstorey spacing of alder or maple to a least 9 m spacing or 6 m if a second thinning is planned within a decade, or in concert with gaps of 0.2 ha or greater. A 0.20 ha gap results in an effective gap of 0.12-0.10 ha if the crown radius of the remaining trees are in the normal range of 4.5 – 7.5 m (Emmingham et al. 2000).

  Where there is a range of deciduous tree sizes an alternative approach is to treat 80% (± 10%) of all overstorey deciduous within 10 m of a potential crop tree. Treat the largest stems first and leave the smallest untreated. This will provide a deciduous component for structural diversity while reducing competition for light.

[4] May with to contact forest health specialist for treatment in areas of high spruce terminal weevil activity.

Open canopy for effective ground level light penetration.

- Emmingham et al. (1998) recommend drastic reduction in overstorey densities for satisfactory growth of understorey conifers. They suggest a minimum of 40% full sunlight is needed to promote vigorous tree growth. Note that light is still restricted from the sides of openings making opening size critical for significant release. Remember that leave trees will add crown reducing the amount of light penetration over time.

- If treating large areas with a relatively uniform conifer understorey, vary treatment intensity to provide varied conditions. This will provide a range of understorey light conditions, resulting in increased or slower growth to some conifers, staging their availability as future LWD. It will also provide a range of retained deciduous stocking and shrub and herb cover.

- Maintain desirable structural attributes when found, such as wildlife tree classes 3-8. Create no work zones around danger trees where necessary.

4.1.4.2. Gap production – cutting versus girdling:

Choose the method most suited to your situation, in some cases some of each will work the best.

Cutting - Advantages

- No further seed-in.
- No safety concerns regarding future snags.
- Rapid opening of the canopy.
- Can visually gauge post treatment canopy closure.
- Can maintain root growth if hinge cuts or cutting above the lowest live limb is used.

Cutting - Disadvantages

- Stems under approximately 20 cm will resprout from the root collar (red alder).
- May be difficult to fall without damaging understorey stems.
- May have hang ups that are difficult to fall safely.
- Slash may create a fire hazard.
- May require bucking and limbing to reduce slash loading (costly).
- May limit ungulate movement.
- Loose slash may shift and crush seedlings in flood conditions – where flooding is expected, leave high stumps, or anchor some slash to minimize movement.

Girdling - Advantages

- Opens up the canopy slowly allowing acclimation of understorey stems from shade to sun conditions.
- Can be done without the use of chainsaws and their inherent danger.
- Can create short-term wildlife trees for smaller woodpeckers.

For effective girdling the entire cambium must be severed and wide enough to prevent bridging (flow of nutrients)

Girdling - Disadvantages

- Creates snags that may be danger trees in the future. Do not girdle stems in areas of backcountry use (e.g., along streams frequented by fishers).
- Cannot be sure where and when the trees will fall, stems or parts of the stem could land on understorey trees (but will be lighter than if felled).
- Cannot observe the amount of future canopy opening at the time of treatment.

4.1.5. Cost factors:

Treatment costs will vary by contractor availability, access, size and difficulty of the treatment. Costs can vary from $200 to $3000 per ha depending upon the situation.

4.1.6. Additional Comments:

Mark on the ground desired features, e.g., clumps or individual large deciduous stems, individual trees with high wildlife use, etc that are to be left untreated. Alternatively, brief crews on what features are to be maintained and monitor their work.

Keep slash out of waterways, unless specifically prescribed for.

In areas with high flooding potential, leave high stumps or girdle stems to avoid slash, crushing conifers.

Some level of habitat enhancement may be desirable, such as creation of bat flanges, bat boxes, or other nesting boxes, depending upon the needs identified for the area.

4.2. Variable Density Spacing in the Riparian Zone[5]

4.2.1. Potential Objectives:

Models show LWD inputs to take over 100 years in many cases.

Juvenile spacing may help accelerate the process.

- To manage the mix of species to promote more desirable riparian species such as Cw, Sx, and Fd.
- To create larger diameter stems faster, than if left untreated. Spacing can provide additional area for individual trees to grow added diameter faster than if left untreated. The amount of growth on the remaining stems will depend upon their vigour, species and their post spacing density.
- To create gaps in the canopy to provide space for shrubs and herbaceous vegetation.

4.2.2. Description:

Previous harvesting was often done to the bank edge in a number of riparian settings. In some cases dense conifer regeneration has occurred in the upland riparian zone.

4.2.3. Prescription Indicators:

Dense conifer stands between 10 to 20 m tall on the coast and 4- to 8 m in the interior. The level of stocking that is considered as dense relates to the objectives for the stand. For riparian areas densities above 2000 sph are often considered overstocked.

4.2.4. Suggestions:

4.2.4.1. Treated area

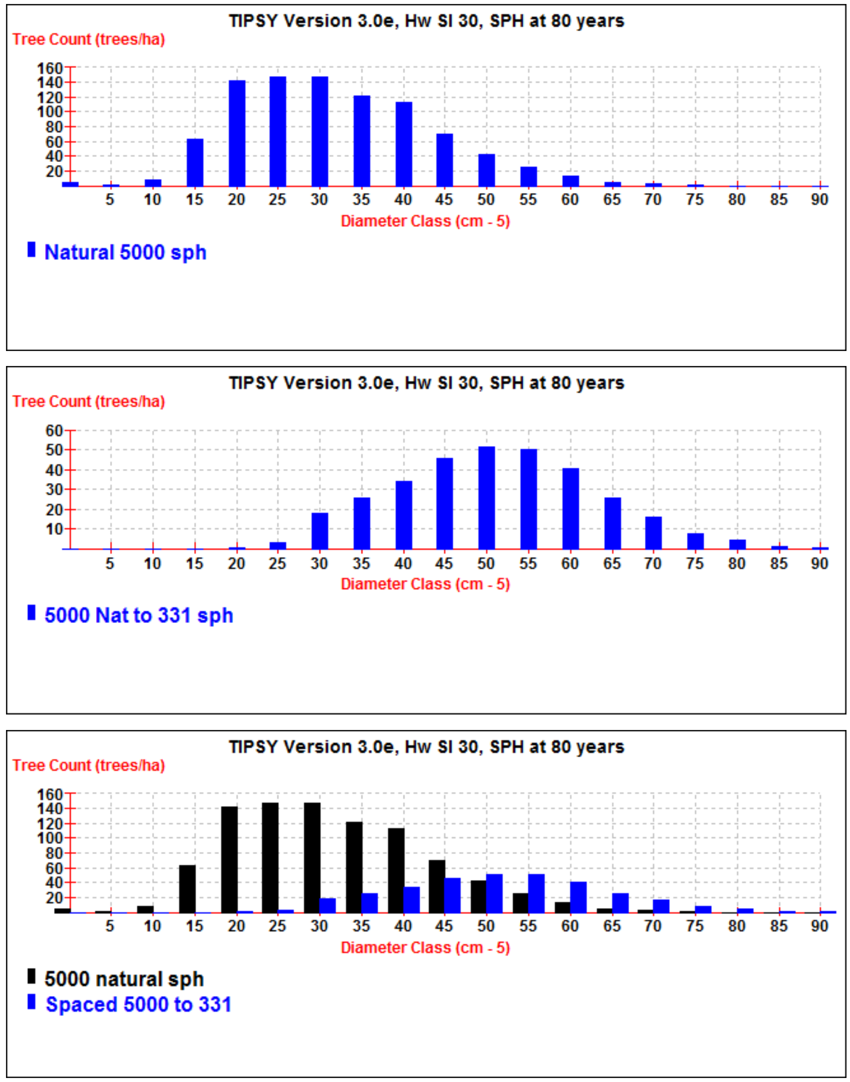
- The treatment area needs to be clearly defined. Studies suggests that most of the LWD comes from within one tree length from the bank edge (e.g., Murphy 1995). Therefore treatments should encompass that distance or fit with a regulatory riparian management zone of a similar size.
- The distance out from the streamedge to be treated needs to be identified on the ground – i.e., flagged.

4.2.4.2. Post treatment densities

- Stand density after spacing should provide enough space for enhanced diameter growth of the remaining trees. Use growth models to indicate desired post treatment densities to achieve local objectives. See an example treatment using TIPSY output below.

[5] For a general overview and guidelines pertaining to juvenile spacing for timber production and maintenance of stand level biodiversity see the Spacing Guidebook at http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/space/spa-toc.htm

Use growth models to help choose treatment intensity – remember to use site factors in making the final decision, as the model will not predict such things as windthrow.



TIPSY 3.0e output for Hw, Site Index 30 BHA^{50} (no OAFs).

- To estimate the response of any spacing treatment the use of a stand growth model or interpolation table such as TIPSY is recommended. The above example is for Hw at a site index of 30 m at 50 years with initial conditions of 5000 sph naturals compared to a stand of the same starting conditions spaced to 331 sph (5.47 m spacing). The top graph shows the range of diameter distribution at 80 years with 5000 sph naturals without treatment. Most of the stems are less than 35 cm in diameter. The middle graph shows 5000 naturals spaced to 331 sph, where most of the stems are over 50 cm. The bottom graph compares the two options showing a similar number of 50 cm stems with both options but with much higher levels of smaller stems in the untreated and more larger stems in the treated. The spaced stand results in more larger stems sooner. The use of variable density spacing will likely result in greater variability.

- MoF research branch will perform specific runs if requested, contact Ken Polsson at Ken.Polsson@gems5.gov.bc.ca

- McLennan (2000 in prep.) provides an example where thinning is prescribed to achieve a mean diameter stem of 75 cm for spotted owl habitat. Model runs indicate the desired size is reached within 150 years with a stand thinned to 250 stems per ha, while the unthinned stand had not reached the desired average diameter by 300 years.

- Link to TIPSY on the web. http://www.for.gov.bc.ca/research/gymodels/TIPSY/

Stand density management diagrams help visualize treatment options and effects

- Note there are other models such as STIM http://www.for.gov.bc.ca/research/gymodels/STIM/ that can be used for Hw and aspen thinning estimates as the hemlock model has been calibrated for both natural and thinned stands based on data from coastal British Columbia, Washington and Oregon. The aspen model has been calibrated for both natural and thinned stands based on data from across Canada.
- The mixedwood model MGM is a stand growth model developed for the boreal forests of Alberta and northeastern British Columbia. MGM is calibrated for white spruce and trembling aspen, typically growing together in varying degrees of mixture, it is located at: http://www.for.gov.bc.ca/research/gymodels/MGM
- The use of Stand Density Management Diagrams may help

  See the following link for more information: visualize and select treatment densities. http://www.for.gov.bc.ca/hfp/pubs/standman/SDMD_yld.pdf
- Another model available for working with diverse stand structures is PrognosisBC. It is an adaptation of the U.S. Forest Service Forest Vegetation Simulator (FVS) developed in North Idaho. PrognosisBC versions 1.02 (April 1998) and 2.0 (July 2000) are applicable in British Columbia's Nelson and Kamloops forest regions. It is found at: http://www.for.gov.bc.ca/research/gymodels/progbc/index.htm
- By reducing the number of stems, you are reducing the potential for smaller (intermediate and suppressed) stems from becoming short term LWD, as they will have been cut. Be sure to think through the prescription before implementation, some untreated areas may be desirable.

- *Option* - Leave some areas untreated to allow for staging of LWD over time from density dependant mortality input of smaller LWD in the short to mid term.

- *Option* - An objective may be to create an uneven aged structure, where recruitment of young stems to create a multi story structure is desirable for long-term LWD recruitment. This approach may require some form of site preparation or planting to promote recruitment. A well thought out plan is recommended for this objective. See http://www.for.gov.bc.ca/hfp/pubssilvsystems.htm and choose the Silvicultural Systems handbook for BC for guidance on setting up an uneven-aged prescription.

4.2.4.3. Post treatment densities – multi pass

- In dense stands (especially those dominated by Hemlock and *Abies* species), a multi pass approach may be desirable to promote windfirmness. Higher post treatment densities than those found in RVT 5 reference stands may be desirable after the fist pass, e.g., 600 to 800 sph.

4.2.4.4. Post treatment densities – habitat objectives

To enhance gaps, focus spacers on cutting out perimeter trees from gaps present in the stand.

The table on the right provides examples of intertree distance for a range of post spacing densities using square spacing.

In many cases varying intertree distance may be desirable to create a varied structure.

- A secondary objective may be to provide open space for enhanced shrub growth. When this is an objective vary spacing to create canopy gaps (e.g., 20 by 20 m gaps).
- In most areas, final densities should be variable ranging from 150 to 800 sph with varying distances between individuals and clumps (150 to 250 in gaps, 350 – 750 in the matrix).

Example intertree distances:

SPH	Intertree distance (m)	
	Square	Triangular
100	10	10.8
150	8.2	8.8
250	6.3	6.8
400	5	5.4
600	4.1	4.4
700	3.8	4.1

4.2.4.5. Treatment timing

- In general treat stands prior to 40 years of age (5 to 20 m tall, 10 to 20 cm dbh). Stands should be old enough to promote selection of individuals with desired characteristics. Taller and larger stands may be candidates for commercial harvest. See Commercial Thinning section p 40.

4.2.4.6. Species selection and flexibility

Leave trees with desired characteristics, e.g., healthy preferred species, large crown, well rooted..

As a rule of thumb try and keep all species found.

Build in flexibility

- For all prescriptions list the order of preference by species and size.
  - For example protect/select dominant trees as 1st priority. However you may wish to build in flexibility to select species other than the dominant species. For example in predominantly Hw stands Cw, Fd, and Ss may be preferred – leave if they are > 2/3rds the height of the Hw.
  - Provide guidance on inter-stem spacing and numbers to be left per clump if clumps of trees are to be maintained.
  - Intertree spacing should be kept low to provide options in choosing suitable leave trees, a range is suggested – e.g., target spacing of 5 m (0.1 m to 7 m range).
- **As a guide keep all species that are found on site – but manage percentages to create desired conditions.**
- For any prescription there needs to be guidance on what to cut and what to leave and to identify the level of flexibility. The key is timely supervision. Due to the variability of riparian areas, there will likely be a number of treatment units identified along the reaches. It is then desirable to have alternative treatments identified when stand structure changes.
  - For example there may be patches of red alder in a relatively dense Hw matrix. The intent is to thin the Hw to decrease time for LWD production. But within the alder patches there are young Cw and Ss beneath. The intent is to open up the alder canopy to release the Cw and Ss and to provide additional shrubs and diversity to the area. The crews will need to know when to switch treatments and what that treatment should be.
  - Where the strata are mappable, an effective approach is to stratify and map using a walk through. Where the strata are too small to map and variability is high, the use of an If statement can be built into the prescription, if it is clear what treatments match which pre treatment structure. This requires clear communication and adequate supervision.

4.2.4.7. Untreated areas

- For areas with an extensive length of treatable area along a reach, it is recommended to leave uncut corridors (5 to 10 m or more) perpendicular to the stream within the area of the riparian zone that is being thinned. This allows for travel corridors for wildlife (and safety trails for workers) without slash. Anchor the untreated areas on game trails if found or other natural features such as ridges or depressions (desirable shrub species, short snags – stand with attributes that you are trying to create…). The untreated areas do not need to be straight they can follow the feature. One rule of thumb is an untreated 5 to 10 m strip every 60 to 150 meters

- Maintain snags where possible – soft inside and hard outside are good for cavity nesters. If there is an abundance of snags in one area, they could be used as an anchor for an untreated corridor or patch.
- A no treatment zone on the edge of the stream edge may be left to maintain bank stability and to minimize disturbance.
- At this time no recommended distance is provided. It depends upon which bank, inside or outside is being treated (inside less susceptible to scouring allowing treatment to the edge). There may be an issue of trees falling into the stream, it should be determined whether there is a benefit to the stream, if not what the cost of removal is versus leaving a buffer untreated. No treatment buffers of 1 m to 1 tree width have been suggested. The proper choice will depend upon the site conditions and the treatment intensity to achieve the desired future condition. In some cases hinging trees or girdling above the lowest live limb will provide increased light while maintaining intact roots.
- Use local judgment on what is needed to avoid bank disruption.
- Goals of a no treatment zone could be:
    - Maintaining roots for bank stability,
    - Maintenance of streamside vegetation as SOD input sources,
    - Debris management,
    - Worker efficacy – as edge trees may be leaning into the stream, requiring wedging or other techniques to minimize input into the stream (if undesirable).
    - Maintenance of conifers if present as their rooting is preferred over deciduous.

When is a no treatment zone along the bank desirable?

Almost always unless there are very few conifers to release and they are found on the bank.

4.2.5. Cost Factors:

Treatment costs will vary by contractor availability, access, size and difficulty of the treatment.

Cost of treatment, in some cases may be covered by commercial harvest. See the following discussion.

4.2.6. Additional Comments

4.2.6.1. Workers Compensation Regulations

- WCB – has distance criteria for workers away from transportation – be aware of the regulations and follow them.
- WCB web link. http://www.worksafebc.com/Default.asp

4.2.6.2. Commercial Thinning in the Riparian Zone[6]

Some stands may be candidates for CT while restoring Riparian Function.

- In some cases Commercial Thinning (CT) in 2nd growth Riparian Reserve zones may be desirable to restore riparian functions.
- For example in areas where extensive harvesting or fires occurred 40 years ago or more, dense conifer forests have grown to the bank edge. These stands may be merchantable in size but are lacking structural variability. A planned commercial harvest can provide for diversity and restoration of functional attributes while paying for the treatment.
- In stands of 20 cm plus average diameter, assess the feasibility for removal of some or all thinned stems.
- Where removal is to occur, it should not detract from the purpose of the treatment.
- In most cases the largest most windfirm trees should be left on site, including good wildlife trees.
- A recommendation is for tops to be bucked and left on site as CWD without penalty.
- Where the level of CWD is low, some larger trees could be left to provide habitat (e.g., for amphibians).
- In all cases where commercial harvest occurs in the Reserve Zone, clear objectives for Riparian Restoration are a key component to achieving the desired objectives.
- **Where in stream works are occurring concurrently, cooperation in providing wood for structures should be promoted**.

[6] See also http://www.for.gov.bc.ca/hfp/PUBS/CT/CT0726.pdf for general guidelines for Commercial Thinning.

4.3. Regeneration[7]

Questions that need to be asked.

How important is it to establish new conifers? Can we work with what we have?

Regeneration can be risky and costly to achieve in some riparian zones.

Because of the potential high costs and risk of regenerating some riparian areas, it is important to clarify the intent and issues before you embark. Some important questions follow.

- What do you want the regeneration to do and over what time frame?
  - Provide future LWD?
  - Provide bank stability?
  - Provide shade?
  - Whatever you wish to achieve needs to be clearly defined and put into perspective with what is on site already and where it is likely to go without treatment.
- What vegetation is already established?
- Will it provide for the desired future condition if left untreated?
  - If yes, will it be in a timely fashion? Can it be accelerated?
  - If not, what is established, what are the options?
- Are some conifers already established?
  - Are there enough?
    - If so is brushing recommended for release?
    - Is overstorey removal of deciduous needed for release?
    - If not, can we plant and expect success – why or why not?
    - If we are going to plant what should we consider?

Suppressed seedling – will it provide for the desired conditions without treatment?

Regeneration in the riparian zone can be difficult if vegetation is already established, or in ecosystems with a high brush potential.

[7] For an overview of regeneration issues and treatment selection pertinent to various plant complexes see Operational summaries for Vegetation Management at http://www.for.gov.bc.ca/hfp/pubsvegmngt.htm

To be successful a well thought-out plan is needed and must be followed.

- To be successful a series of well thought out and timed treatments is needed.
  - Site preparation – is it needed?
    - Is it an option yes or no?
    - What methods are available?
  - Planting – species selection and size are important.
  - Brushing – what methods are available, how often over what time period?

Be clear on the objectives as well as the area to be treated, RRZ, RMZ or RMA. Be clear of what the desired future condition is, are conifers needed, if so in what sort of distribution. What are the essential steps for maximizing the potential for success?

Treatments should be guided by the Watershed Overview Assessment along with a commitment for success over time.

4.3.1. Site preparation

4.3.1.1. Potential Objectives:

- Site preparation may be needed to provide suitable conditions for initial conifer establishment. Where vegetation is in place, conifers may not be able to compete for light and below ground resources without the creation of favorable microsites. Site preparation can remove unwanted vegetation and rearrange slash loads creating plantable spots with improved planter access reducing the time taken for planting spot selection, thereby reducing costs.
- Specifically to create elevated microsites in areas with high water tables.
- To minimize disturbance of LWD and other functional elements already in place.

4.3.1.2. Description:

Site preparation is any activity whereby plantable spots are created and planter access is improved. Methods include falling/brushing, scalping, mixing or inverting the forest floor.

4.3.1.3. Prescription Indicators:

Heavy vegetation established in Riparian area

Any of the following site indicators may require site preparation

Any area with high levels of established brush competition, specifically shrubs or aggressive herb complexes that are in place.

Sites where overstorey trees have been felled, some form of slashing or piling may be needed to provide plantable spots and planter access.

Sites with saturated soils with a limited number of natural elevated microsites.

4.3.1.4. Suggestions:

4.3.1.4.1. Methods:

Available treatments to create suitable microsites and reduce vegetation competition.

- Mechanical methods are suitable such as a hoe or an excavator to mix or invert/mound the soil. These mechanical methods are most cost effective when used in conjunction with in-stream work (for machine availability).
    - Options are to use a brush rake on the excavator or hoe to remove vegetation and to create elevated mounds, or mixed mineral/humus to provide plantable spots.
    - Mixed mineral mounding (mineral + organics) is the preferred approach in wetter ecosystems to provide warm unsaturated soils for early root establishment and growth. Raised planting spots improve drainage and aeration on wet sites that can result in improved seedling performance. Well-drained soil warms faster than waterlogged soil. For more information on site preparation see and use of microsites see: http://www.for.gov.bc.ca/hfp/pubs/silvman/siteprep/2-Mech-02.htm#P134_13537
    - Special brush heads such as the Hy-test Tiller or VH Mulcher can be used to create mixed mineral conditions and can be used to make elevated microsites to provide warmer unsaturated soil conditions.
    - A necessary requirement for hoe work is access - you have to be able to get the machine into the riparian area - so there will have to be a usable road or trail nearby. Also, the hoe should be able to work in the riparian area without causing excessive soil disturbance, compaction and damage to the stream structure.

Hoe with various head attachments, VH mulcher on the ground in front of the hoe

- Manual brushing using brush saws or chain saws provides for planter accessibility. It does not create favorable microsites other than to remove the brush competition temporarily. Follow up brushing will often be required.

- To increase planter efficiency, create more diversity and promote varying growth rates in the conifers, create the plantable spots for clusters of seedlings rather than individual seedlings – use 'reference' stands to help space out clusters – often 8 – 15 m apart.

4.3.1.4.2. Treatments not recommended or require special permitting:

- Manual spot scarification using a Power Scalper – found to be ineffective see:

  http://www.for.gov.bc.ca/hfp/pubs/silviculture_notes/silvnote18.pdf for trial results.

- Herbicides can provide effective site preparation. In British Columbia a pesticide use permit or a Forest Vegetation Pest Management Plan must be approved prior to the use of herbicides on Crown Land. For more information see:

  http://wlapwww.gov.bc.ca/vir/pp/ipmweb/pup/pup.htm

  http://wlapwww.gov.bc.ca/epd/epdpa/eripm/pmp/gfdafvpmp.html

  See the link for the BC Ministry of Forests Silviculture Manual – for overall direction; it has links to legislation and cost ranges for many treatment types.

  http://www.for.gov.bc.ca/hfp/pubs/silvman/index.htm

4.3.1.5. Cost factors:

Mounding - $550 to over $1000 per ha depending upon machine availability, number of sites prepared and the starting condition.

4.3.1.6. Additional Comments:

Use existing microsites when available. If there are insufficient natural microsites, ask yourself why before choosing an active treatment (may just be too wet and flood too often for conifer establishment).

Where suitable seed trees (sources of desirable seed) are in the area, screefing and or mixing of the soil could provide suitable conditions for establishment. These trees may be considered as longer term recruits as they may fill in over time to provide diversity and staged entry into larger size classes.

See Species selection (p.47) section for seedbed requirements by species.

See also the following link for site preparation and response information.

http://www.for.gov.bc.ca/hfp/pubs/silviculture_notes/sn05.pdf

4.3.2. Planting conifers

4.3.2.1. Potential Objectives:

- To increase conifer stocking within the riparian area where watershed level direction has shown riparian function for LWD or bank stability is lacking or at risk.
- To increase the conifer component within a tree length of the stream edge (for example in areas with less than 100 sph. Planting is recommended only where a clear strategy for success is in place.

4.3.2.2. Description:

Planting should focus on utilizing available microsites.

Cluster planting is recommended.

Planting below Cottonwoods is an option, to create nurse tree shelterwoods.

4.3.2.3. Prescription Indicators:

Where stream banks and riparian zones are lacking conifer cover.

Where steep unvegetated slopes adjacent to streams require woody cover to slow the movement of materials downslope.

In areas behind instream structures to promote long term rooting strength.

In areas with cottonwood cover lacking conifers in the understorey.

4.3.2.4. Suggestions for planting conifers:

Be clear on the objectives of the treatment and the desired future stand characteristics. For example inputs of LWD in 100 years with enhanced grizzly bear habitat now and into the future. This translates into clumpy distributions with open space, using species suited for long term LWD.

Choose species ecologically suited for the site by Biogeoclimatic unit (using Field Guides for Site Identification and Interpretation and Establishment To Free Growing guides). Identify the site limiting factors (e.g., excessive moisture, frost, vegetation competition, forest health issues…).

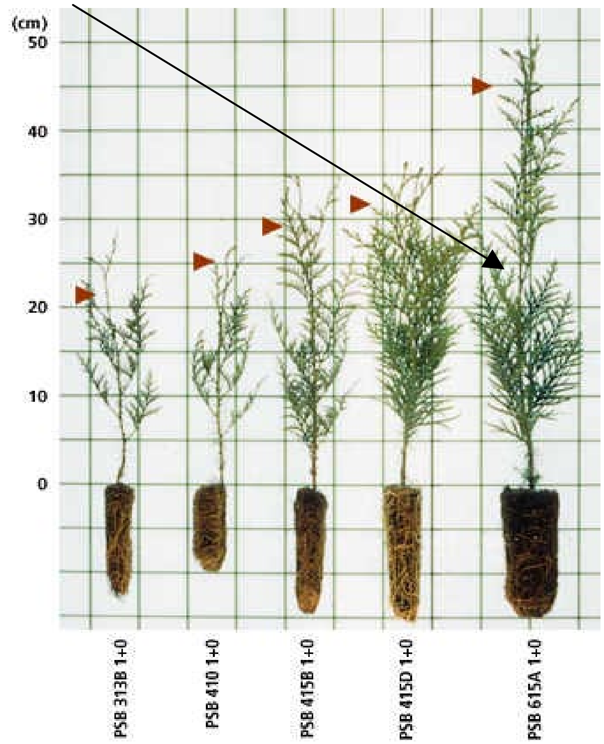
Local experience is a key to successful regeneration. Ask questions and look at similar sites for successes and failures. Ask why regeneration was successful or not.

Nursery links –Pacific Regeneration Technologies provides a link to a range of forest nursery references, along with other useful forestry references at http://www.prtgroup.com/search_prt.html. – select seedlings for a list of references.

For Brushy riparian sites with some seasonal saturation – size can make a difference.

- Use as large and healthy stock as available.
    - For example use large stock such as PSB 615 1+ 0

In some cases seedlings found on road edges (wildings) can be dug up and used in riparian areas.



From MOF 1998 (Provincial seedling stock type selection and ordering guidelines) see http://www.for.gov.bc.ca/nursery/stockselection/poster/factor.htm for stock selection information.

Large Cw stock used in mid bench setting (PSB 1015).

Photo credit Reinhard Muller.

- Stock larger than 615s may be desirable for brush prone sites such as PSB1015 1+0 that have a plug diameter of 10 cm with a 15 cm depth. (1+0 means the seedling is grown in the plug for 1 year and 0 means no outplanting).
- Large potted conifers can be used in areas with high brush competition – these may be difficult to obtain through traditional sources – nurseries should be contacted with sufficient lead time to set aside stock (1 to 2 years lead time).

4.3.2.5. Species Selection

- **Species selection** – use the appropriate sections of the Establishment to Free Growing guides (ETFG) for the riparian ecosystems to be treated.

  http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm is the link to FPC guidebooks, choose the relevant region for your area.

  - Generally Cw is desired as it rots slowly. Other species may be desired as well (e.g., Fd and Lw) – use the local ETFG guide for guidance. Choose shade tolerant species if competition is going to be an issue.
  - For information on tolerances see: http://www.for.gov.bc.ca/hfp/PUBS/silvsystems/Silvic.pdf.

4.3.2.6. Stock type

- Bare root or plug transplants are difficult to plant into manually prepared sites (i.e. hand cut vegetation) as the roots are difficult to plant through the intact roots and vegetation. Direct supervision is needed, or use plug stock. Planting bareroot stock into sandy soils is appropriate.
- In some areas local seedlings are available along road cuts that can be transplanted. Success will be enhanced if transplanted outside of the active root-growing phase (i.e., other than spring and fall).
- For more information on seedling stock type selection, see the Provincial seedling stock type selection and ordering guidelines (MOF 1998) found at http://www.for.gov.bc.ca/hfp/pubs/stocktype/index.htm

4.3.2.7. Timing of planting

- Summer plant where possible to promote rapid root establishment and summer drought is not an issue – summer planting will promote root establishment prior to bud-burst the following year.

4.3.2.8. Planting spot selection

- Where possible use raised microsites and cluster plant to reduce brushing costs and to provide open areas for other vegetation. The site should help dictate the number of seedlings per cluster, in general the number should be between 5 and 30 with a minimum intertree distance of 0.5 m. See

  http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/FREE/EFG-Van-web.pdf

  for recommendations stocking standards for Grizzly bear management. Note the grizzly bear guidelines are meant to provide grizzly bear habitat while growing a timber crop, riparian management is meant to provide riparian function, often with limited future options for timber extraction.

- The importance of microsite selection for planters cannot be understated. The following sites are useful for identifying planting options.

  http://www.for.gov.bc.ca/hfp/pubs/silviculture_notes/sn01.pdf

  http://www.for.gov.bc.ca/hfp/planting/Microsite_presentations/microsite.htm

  Remember in most cases follow up brushing will be required to provide conditions for survival and growth.

4.3.2.9. Fertilization at time of planting[8]

- Not recommended as a blanket treatment, be familiar with information on efficacy prior to use.

- Fertilization at time of planting, by placing fertilizer near the planted trees roots, has shown a range of response. Operational trials have shown extremely variable results with the net benefit on conifer growth being low, non-existent, or negative. However, one example where benefits have been consistent is on sites with chlorotic, slow-growing Sitka spruce, western hemlock, and western redcedar (refer to SCHIRP Research Update #1, Influence of Density, Scarification and Fertilization at Planting on Growth of Cedar and Hemlock on CH and HA Sites) for details.

[8] See the Fertilization Guidebook for additional details http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/fert/ferttoc.htm .

- Seedlings planted on rehabilitated sites may also show a positive response. Fertilization at time of planting on these sites may provide an immediate but temporary release of growth check. See the following for details.

  http://www.for.gov.bc.ca/hfp/pubs/silviculture_notes/sn13.pdf

4.3.2.10. Cost factors

Planting costs include stock and planting. Large stock costs more to purchase and to plant, but has a greater chance of survival in areas of high competition. Contact local nurseries and planting contractors for price estimates (seedling costs vary from $0.10 for very small plug stock to over $1.00 per seedling for larger stock, this range is valid for planting as well).

4.3.3. Planting deciduous and shrubs[9]

4.3.3.1. Potential Objectives:

- To increase deciduous or shrub stocking to provide for SOD.
- To create vegetative barriers to build up flood debris on bars or along banks.
- To provide deeper soil stability by planting shrubs and/or trees on landslides or disturbed sites.
- To accelerate soil development, provide habitat for wildlife, mitigate visual impact.

4.3.3.2. Description:

Areas that are lacking vegetation, such as recently eroded banks, disturbed areas adjacent to instream works, sand bars in rivers, etc.

Look for natural seed sources and germinants before treating. In many cases freshly disturbed areas will already have small germinants of aggressive colonizers, such as red alder established. Where there are no obvious seed sources or germinants proceed to assess for revegetation options.

[9] See section 6.3 Soil Bioengineering pp 138 – 163 in the Hillslope Restoration in British Columbia: Best Management Practices, November, 2001 for a thorough coverage of regeneration using live cuttings. http://www.for.gov.bc.ca/ftp/Branches/Resource_Tenures_&_Engineering/external/!publish/Engineer/bmp-handbk-final-mar-2002.pdf

4.3.3.3. Prescription Indicators:

Where stream banks and riparian zones are lacking vegetative cover, this includes banks that have been identified as candidates for revegetation at the watershed assessment stage.

4.3.3.4. Suggestions for planting cuttings and bare root plants:

See footnote above, for a link to Hillslope Restoration In BC BMP that provides detailed suggestions for use of live cuttings to promote bank stability, create silt fences, provide for live shade and other bioengineering options.

4.3.3.4.1. Some direction from Western Washington[10]

Describe the planting site – learn about the soil conditions: sandy, rocky, a mix? Is the site sunny? Will it likely dry out? What kind of vegetation is now on site? Will it provide the functions we are after? What type of vegetation is on undisturbed sites?

When creating a revegetation plan choose the species that are suited to the site conditions. Use local sources and discuss with nursery personnel to help choose species for various locations.

When revegetating an area it is often wise to establish a variety of species, for both their anchoring effectiveness and desirability for wildlife. Often a varied structure with a mix of conifers, deciduous and shrubs provides a diversified habitat for a range of wildlife species.

4.3.3.4.2. Spacing

Shrubs and small trees can be spaced approximately 1 m apart, willow cuttings closer together, about 60 cm, with taller trees approximately 2 m apart.

4.3.3.4.3. Soil substrate

Rocky soils – use cuttings or plugs designed for use in rocky soils. Use willow over cottonwood, as cottonwood is often damaged in gravelly soil causing rot.

Sandy soils –cuttings or rooted seedlings can be used.

10 Suggestion provided in: Restoring the Watershed, A citizen's guide to riparian restoration in Western Washington. Washington Department of Fish and Wildlife, 1/95. A well-designed overview of revegetation using cutting and shrubs found on line at: http://www.wa.gov/wdfw/outreach/volunter/riparian.pdf. See also for shrub species tolerances.

4.3.3.4.4. Hardwood Cuttings[11]

Willow cuttings established on bar.

- Suited species include – e.g., willow, cottonwood.
- Collect cuttings during the dormant season (late fall), winter or early spring from wood of the previous season's growth.
- Take cuttings from healthy vigorous plants that have been growing in full sunlight.
- Use the middle and basal part of the stem, discard the tip as they are often low in stored energy, with a minimum caliper of 1 cm with no upper limit, length varies from 30 cm to over 1 m, depending upon the substrate it is to be planted.
- A minimum of two nodes is needed per cutting, with the basal cut below a node, and the top cut 2 cm above a node.
- Store materials so they will not dry out and keep them cool. Bundles can be buried outdoors in sandy soil, upside down to keep the basal ends warmer – this may help promote root initiation when outplanted, right side up.
- If buds are developing during storage, reduce the storage temperature.

4.3.3.4.5. Planting Hardwood Cuttings

- Set cuttings with the top end up pointing downstream at an angle of 45 to 60 degrees.
- Completely bury or expose a few centimeters of the top of the bud.
- Use a planting spade or probe (of rebar or the like) to make the hole, press the soil adjacent to the cutting with your foot to secure it in place (as in tree planting).
- Plant where there is soil moisture available, it is not required to reach ground water if planted early in the season.
- Use a small excavator or hoe if planting large stock (e.g., > 1m, see (Muller and Muller, 1999) for an example.

4.3.3.4.6. Species selection

- Willow cuttings are suited to streambank stabilization. Plant before March where possible.
- Cottonwood is not recommended for bank stabilization as they do not create the same level of rootmass as willows, they are prone to toppling, which may create further bank instability.

[11] Guidance taken from Holzworth and Batchelor, No Date, Techniques of tree and shrub propagation by hardwood stem techniques. Plant Materials Technical Note no. 29, USDA, Soil Conservation Service.

They can be used in more upland conditions, in sandy substrates, to provide SOD and potential mid term LWD.

4.3.3.4.7. Cost factors:

- Availability and location of stock will affect cost, as will the size of cuttings, larger cuttings may require mechanical planting. The range of cost per planted cutting is between $0.30 to over $1.00 per planted cutting (e.g., $0.46 Muller and Muller 1999).

4.3.3.4.8. Additional comments:

- Planting of deciduous cuttings may be done in conjunction with instream LWD placement for Bar stabilization.
- Favour willows on the bars planting into sand where possible. Mix in a small percentage of cottonwood (e.g., 10%) away from the bank edge and not into coarse substrates (e.g., cobbles or gravel).
- Rooted cuttings are also an option in sandy and gravely soils. Suitable species are red osier dogwood (*Cornus stolonifera*), pacific ninebark (*Physocarpus capitatus*), and hardhack (*Spirea douglasii*). Discuss with local nurseries suitable microsite selection.
- Palmate coltsfoot (*Petasites palmatus*) provides a rapid below ground rhizome system, useful in stabilizing soft substrates such as sandy bars (Muller and Muller 1999).
- See the Hillslope Restoration in British Columbia BMP for a discussion on willow structures http://www.for.gov.bc.ca/ftp/Branches/Resource_Tenures_&_Engineering/external/!publish/Engineer/bmp-handbk-final-mar-2002.pdf.

4.3.4. Animal Damage

Animal damage will vary by area and species being regenerated. It should be expected to some extent due to the preference by many species for riparian habitats.

Browsed Cw from QCI trial, J Henigman /M. Martinz (2001) photo

Use local expertise to help identify, species and areas of significant concern.

- Damaging agents and options:
  - Deer or elk - Protect seedlings with browse protection. Protection needs to be tall enough to allow full establishment. Over 1 m for deer, 1.5 m for elk. Yearly maintenance is required for up to three years. Protection brands available include: Sinclair® tree shelter tube, the Sinocast® tree shelter cone, the Sweetwood® metal cage, Vexar® mesh tube, Freegro® Plant Shelter,

Tubex® or other containment devices. Each has specific advantages and disadvantages [12]

- Treatment is costly and comes with a commitment to maintenance. However no protection may be more costly than seedling mortality. Cost of installation and maintenance varies. A range of costs for all aspects from transportation, installation and maintenance in the remote Queen Charlotte Islands ranged from $3 to over $8 per seedling (Henigman and Martinz, 2001). Plan for at least two years of maintenance.

- Porcupine or beavers–chicken wire cages around planted conifers may be required.
- Voles – keep vegetation low, maintain raptor perches, cottonwood may require plastic vole collars.

4.3.5. Brushing Options

4.3.5.1. Potential Objectives:

- To reduce competition from brush species to promote conifer survival and increase conifer growth rates within the riparian area.
- To manipulate species composition.
- To promote new alternative species or enhance suckering growth.

4.3.5.2. Description:

Depending upon the ecosystem and the level of disturbance, brush competition may vary from non-existent in some upland riparian areas, to very high in lush high bench floodplain sites. Brushing may be required in areas where non-crop vegetation overtops the seedlings for prolonged periods.

Where intact vegetation is on site, knowledge of the Autecology of competing species is needed. This includes species, growth rates, rates of spread, means of regeneration and response to control (e.g., Haeussler et al. 1990).

[12] Contact John.Henigman@gems1.gov.bc.ca for a report comparing a number of the above brands against deer browse in the Queen Charlotte Islands.

4.3.5.3. Prescription Indicators:

Vegetation – complexes have a mix of species use local field guides for help identifying potentially brushy sites.

Vegetation competition can be predicted to some extent and observed in other cases.

The likelihood of vegetation competition can be predicted by identifying the Biogeoclimatic Site Series for your site in conjunction with the competing vegetation section of regional Field Guides for Site Identification and Interpretation to determine the likelihood of brush competition within the wide range of riparian associated ecosystems.

For example, in the Vancouver Forest Region on floodplain sites, all site series have a Very High competing vegetation potential rating for vegetation complex number 1 – Cottonwood Alder – with the following major species (Green and Klinka 1994):

Cottonwood
Red Alder
Salmonberry
Red-osier dogwood
Devil's club
Red elderberry
Thimbleberry

It is important to recognize competing species in the field and to understand their growth characteristics and responses to determine their potential for competition. See the references section at the end of the document for useful plant identification sources and Field Guides for Site Identification and Interpretation.

4.3.5.4. Suggested approaches:

Simple tools that can be used for girdling larger stems.

Brushing approaches can be as simple as cutting stems, to using heavy equipment for site preparation to modify the growing site, to reducing seed sources preharvest through felling or girdling, to using herbicides to spot or broadcast treat competing vegetation.

Because of the sensitivity around herbicide use near water sources, most brush control that has been done near streams has been non-chemical. However, herbicides are often more effective at reducing shrub competition, and when used judiciously as a spot or single stem treatment, may provide a safe, cost effective approach to provide the conditions to repair riparian function.

In British Columbia a pesticide use permit or a Forest Vegetation Pest Management Plan must be approved prior to the use of herbicides on Crown Land. For more information see:

http://wlapwww.gov.bc.ca/vir/pp/ipmweb/pup/pup.htm

http://wlapwww.gov.bc.ca/epd/epdpa/eripm/pmp/gfdafvpmp.html

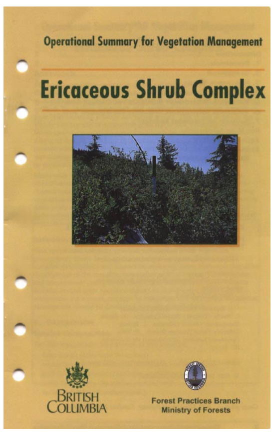
4.3.5.4.1. Shrub competition[13]

Shrub species often resprout rapidly after cutting (some can grow more than 2 m per year).

- Manual Brushing – is often the main option, where herbicide use is not an option due to proximity to waterbodies or local concerns.
- Manual brushing includes all treatments that are non-chemical but are done by hand, including the use of chainsaws, brushsaws, axes, Sandviks, girdling tools (See Boateng and Ackerman 1990. A guide to Vegetation Control Equipment, FRDA handbook 005, for a listing of tools and methods of operation).
- Many shrub species are renowned for their ability to resprout after cutting, an effective evolutionary response to disturbance and browsing. However, this translates to multiple manual treatments to reduce competition effectively.
    - Due to the high brush growth in many riparian zones, a concerted effort is required to control brush, this translates to assessing seedling performance at least every two months (more if brush mats are not used and sprouting shrubs are the competitive threat).

[13] For treatment of deciduous competition see section 4.1 p. 41,Conifer Release.

- Treat brush control as you would in a backlog prescription. Plan on multiple manual treatments in the first year clearing brush away from the crop tree to at least:
  - The yearly height growth of the competing species – for example salmonberry can grow up to 2 m in one year, therefore create, at a minimum, a 2 m radius clearing around the crop tree.
- During the growing season (i.e., June through early July), assess and treat second time if needed at the end of the growing season to minimize vegetation press (August through September). Continue multiple treatments yearly until the crop trees are above the competing vegetation. Assume three years of treatment will be needed, plan funding accordingly.



See operational Summaries for Vegetation Management for guidance.

See the operational summaries by vegetation complex for more detail on treatment regimes and efficacy, located at:

http://www.for.gov.bc.ca/hfp/pubsvegmngt.htm

These summaries are available for the following Vegetation Complexes:

Reedgrass, Willow, Ericaceous shrub, Fireweed, Mixed Shrub, Pinegrass, Wet and Dry Alder.

For established vegetation of the various complexes refer to the vegetation management strategies for Backlog sites found in the summary documents.

4.3.5.4.2. Herbaceous competition

- Manual brushing has limited effectiveness due to regrowth of most herbaceous competitors, but can reduce the level of press damage when treatment occurs late enough in the season to minimize regrowth.
- See operational summaries for guidance.
- Brush mats have been used in riparian areas with limited effectiveness – they may reduce vegetation press if established effectively and are useful for finding the seedlings for subsequent brushing treatments.
  - They are applied at the time of planting, when the vegetation is minimal.
  - A minimum size of 90 cm by 90 cm can be used to reduce the amount of initial encroachment of competing vegetation.

Brush mats have some but limited potential for managing vegetation – they usually require manual follow-up treatments.

- Larger mats may provide more vegetation control, the key is to secure the mats both on the edges and at the slit.
- Assume that the mat will only provide the first summer of control, plan on a fall treatment in areas of high competition potential.
- Mats are most useful on herbaceous complexes, they are not effective on Salmonberry or other fast sprouting shrubs.

Dense Riparian complex that would require multiple manual treatments to promote seedling growth

Selective herbicide can provide longer-term vegetation control than manual cutting, but its use may be limited in and around riparian areas.

- Herbicides may be available if permits are approved for their use. Herbicides will provide longer control than most manual treatments and are often less expensive.
  - Check for a local Forest Vegetation Pest Management Plan, if available, for direction. If the use of herbicides is an option, assess feasibility using Boateng (1998) Herbicide Field Handbook for detailed information on treatment selection and efficacy.

4.3.5.5. Costs factors:

Brushing costs will depend upon the method chosen, contractor availability, logistics (location, terrain, size of vegetation, searching time for seedlings…), and the number of treatments required.

Expect costs to be between $200 and $800 per ha per entry.

4.4. Range Management

4.4.1. Links to Ministry of Forests Range Section references:

Livestock in riparian areas, management is the key.

Range management is a discipline in its own right. Managing livestock to maintain functioning ecosystems is an objective in most jurisdictions. In British Columbia, the BC Ministry of Forests Range Section has produced a suite of pamphlets and brochures on the subject found at http://www.for.gov.bc.ca/hfd/pubs/Bro.htm. specifically pamphlets 64-67 and brochures 68-69, 71-74

Additionally the range manual provides a methodology for assessing Proper Functioning Condition and can be found at http://www.for.gov.bc.ca/hfp/range/Manual/TablCont.htm#TopOfPage Chapter 12.

An assessment on the Effect of Cattle Grazing Near Streams, Lakes and Wetlands was done by the Forest Practices Board, they used a slightly different approach to assess proper functioning condition, it is described in the Special Report found at: http://www.fpb.gov.bc.ca/SPECIAL/reports/SR11/sr11s.htm

4.5. General Considerations for all treatments

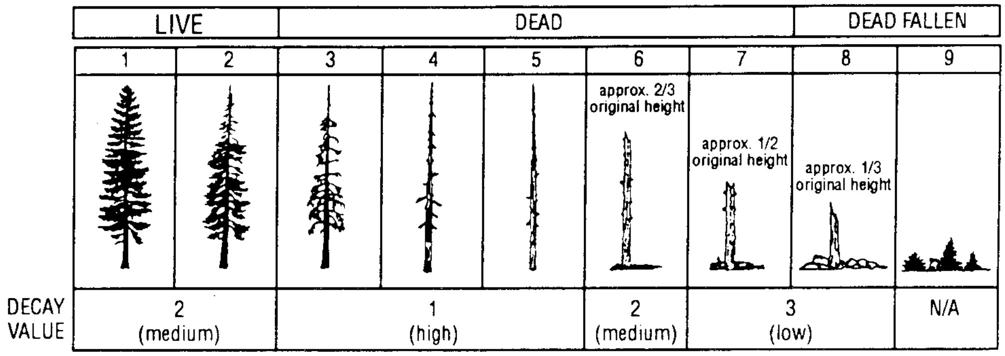
The general theme for riparian silviculture treatments is to create long-term solutions for riparian functioning. Riparian silviculture treatments are part of the continuum of opportunities from permanent upland solutions to temporary in-stream approaches. Overtime, with adequate stream protection and management, riparian silvicultural treatments will be phased out. Until then the previous suggestions are meant to help create the desired conditions for functioning riparian areas.

What follows are some general considerations when treating riparian areas.

4.5.1. Retention of wildlife trees[14]

- Where possible retain all high value wildlife trees by incorporating them into no work zones when designated as danger trees.
    - Characteristics of high value wildlife trees include:
        - Greater than 50 cm dbh
        - > 20 m tall,
        - Wildlife tree classes 3 – 5 for their decay characteristics

[14] See also Manning et al. 2002 in prep for additional guidance on maintaining habitat structures.



        - Loose bark
        - Wildlife use, such as open nests, recent feeding, denning, cavity nests, perching or a squirrel cache.
    - For information on dead wood attributes see http://www.for.gov.bc.ca/research/deadwood

- Maintain a proportion of the area under prescription untreated to provide for established successional pathways as well as habitat corridors. As a rule of thumb a minimum of 5% untreated area is recommended.
    - This can be located as a no work zone on the edge of the riparian feature, and or
    - As untreated patches or strips throughout the treatment area.
    - In areas of difficult to regenerate shrub patches in a matrix of treatable areas.
    - Where there is low risk of downstream effects leave low value wildlife trees or danger trees that must be felled due to safety issues, left on site for CWD.
- Where significant simplification of stand structure has been created, consider actively creating habitat. This could include creating snags by topping or injection of heart rot fungus (cheap and effective), wounding trees to attract rot and insects, creation of habitat features in trees (e.g., bat flanges) introduction of bird and bat nest boxes.

4.5.2. Monitoring

Monitoring is a key part of successful riparian restoration.

Murphy (1995) identifies seven steps for a comprehensive monitoring program for Best Management Practices (BMPs)[15]. They are:

- *Determine whether critical problem areas are recognized and appropriate practices are specified;*
- *Determine whether BMPs are adequately applied through implementation monitoring of site plans;*

[15] Taken from the California Board of Forestry 1993 as outlined in Murphy 1995 p 65.

- *Determine whether BMPs are effective at meeting their intent (effectiveness monitoring)*
- *Determine whether properly implemented BMPs meet water quality standards where applicable (compliance monitoring);*
- *Determine whether BMPs for given projects protect the stream's beneficial uses (project monitoring);*
- *Provide results to the regulatory agency and public for review; and*
- *Provide means for improving monitoring procedures and BMPs.*

Some specific monitoring suggestions for riparian silviculture treatments are:

- For planting, monitor after the first growing season and until desired stocking is achieved to determine fill planting needs and what stock is required.
- Conduct maintenance of animal controls as needed.
- Recommend brushing schedules based on site conditions.
- For other treatments, implementation monitoring is needed to ensure treatments were followed as planned.
- Set up your treatments to allow for Adaptive Management, for information on the subject see: http://www.for.gov.bc.ca/hfp/amhome/amhome.htm

The key is follow-up:

- Lack of follow-up on recommendations of the monitoring will result in less than desired results.
- Poor record keeping, problems with relocating treated areas has been identified as a common problem, indicating that clear up front planning and record keeping are important for success.
- For a list and description of Watershed Restoration projects in BC for 2000-2001 see Cleary and Underhill (2001).

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Abbreviations

BMP	Best Management Practice
Cw	Western redcedar
CWD	Coarse woody debris
DBH	Diameter at breast height
DFO	Department of Fisheries and Oceans, Canada
Fd	Douglas-fir
Hw	Western hemlock
LWD	Large Woody Debris (also known as LOD – Large organic debris)
MOF	B.C. Ministry of Forests
MSRM	B.C. Ministry of Sustainable Resource Management
WLAP	B.C. Ministry of Water Land and Air Protection
RMA	Riparian management area
RMP	Recommended Management Practice
RMZ	Riparian management zone
RRZ	Riparian reserve zone
RVT	Riparian Vegetation Type
SPH	Stems per ha
SOD	Small organic debris
SPH	Stems per ha
Sx	Spruce - hybrids
USFS	United States Forest Service

Glossary[17]

Best Management Practices (BMPs): a practice or combination of practices that are determined to be the most technologically or economically feasible means of preventing or managing potential impacts.

Alluvial: (see fluvial)

Bareroot seedling: stock whose roots are exposed at the time of planting (as opposed to container or plug seedlings). Seedlings are grown in nursery seedbeds and lifted from the soil in which they are grown to be planted in the field.

Biogeoclimatic classification: a hierarchical classification system of ecosystems that integrates regional, local and chronological factors and combines climatic, vegetation and site factors.

Canopy closure: the progressive reduction of space between crowns as they spread laterally, increasing canopy cover.

Coarse woody debris (CWD): sound and rotting logs and stumps that provide habitat for plants, animals, and insects and a source of nutrients for soil development.

Fisheries-sensitive zones: side and back channels, valley wall ponds, swamps, seasonally flooded depressions, lake littoral zones and estuaries that are seasonally occupied by over- wintering anadramous fish.

Floodplain: a level, low-lying area adjacent to streams that is periodically flooded by stream water. It includes lands at the same elevation as areas with evidence of moving water, such as active or inactive flood channels, recent fluvial soils, sediment on the ground surface or in tree bark, rafted debris, and tree scarring.

Fluvial processes: all processes and events by which the configuration of a stream channel is changed; especially processes by which sediment is transferred along the stream channel by the force of flowing water.

Large Organic Debris (LOD): entire trees or large pieces of trees that provide channel stability or create fish habitat diversity in a stream channel.

Large woody debris (LWD): a large tree part, conventionally a piece greater than 10 cm in diameter and 1 m in length.

Plug: a seedling grown in a small container under carefully controlled (nursery) conditions. When seedlings are removed from containers for planting, the nursery soil remains bound up in their roots.

Restoration: the return of an ecosystem or habitat to its original community structure, natural complement of species and natural functions.

Riparian: an area of land adjacent to a stream, river, lake or wetland that contains vegetation that, due to the presence of water, is distinctly different from the vegetation of adjacent upland areas.

[17] For a complete list of definitions see: http://www.for.gov.bc.ca/PAB/PUBLCTNS/GLOSSARY/R.htm

Riparian Habitat: vegetation growing close to a watercourse, lake, swamp, or spring that is generally critical for wildlife cover, fish food organisms, stream nutrients and large organic debris, and for streambank stability.

Riparian Management Area (RMA): defined in the Forest Practices Code of British Columbia Act Operational Planning Regulation as an area, of width determined in accordance with Part 10 or the regulation, that is adjacent to a stream, wetland or lake with a riparian class of L2, L3 or L4; and, consists of a riparian management zone and, depending on the riparian class of the stream, wetland or lake, a riparian reserve zone.

Riparian management zone (RMZ): defined in the Forest Practices Code of British Columbia Act Operational Planning Regulation as that portion of the riparian management area that is outside of any riparian reserve zone or if there is no riparian zone, that area located adjacent to a stream, wetland or lake of a width determined in accordance with Part 10 or the regulation.

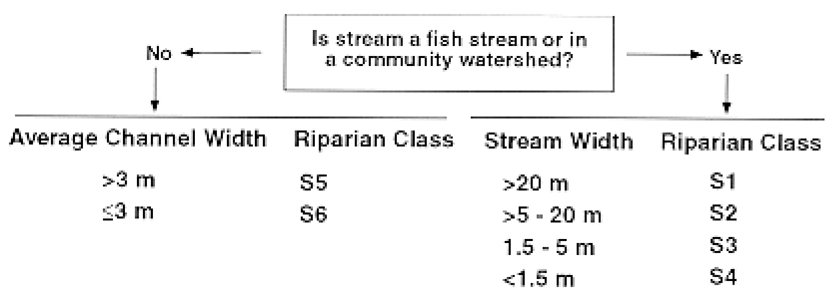
Riparian Reserve Zone (RRZ): defined in the Forest Practices Code of British Columbia Act Operational Planning Regulation as that portion, if any, of the riparian management area or lakeshore management area located adjacent to a stream, wetland or lake of a width determined in accordance with Part 10 of the regulation.

Riparian vegetation type (RVT): classification of vegetation based on stand structure and species composition.

Silviculture: the art and science of controlling the establishment, growth, composition, health and quality of forests and woodlands. Silviculture entails the manipulation of forest and woodland vegetation in stands and on landscapes to meet the diverse needs and values of landowners and society on a sustainable basis.

Small organic debris (SOD): organic material such as leaves, detritus, terrestrial insects, twigs that enter the stream and become part of the aquatic food chain.

Stream class: method of classifying streams based on size, gradient and presence of fish. The classification of S1-S6 is described in the Forest Practices Code of BC Act.



From the Riparian Management Area Guidebook 1995

Watershed: an area of land that collects and discharges water into a single main stream through a series of smaller tributaries.

Watershed assessment: evaluates the present state of watersheds and the cumulative impact of proposed development on peak flows, suspended sediment, bedload, and stream channel stability within the watershed.

Wetland: a swamp, marsh or other similar area that supports natural vegetation that is distinct from adjacent upland areas.

Wildlife tree: defined in the Forest Practices Code of British Columbia Act Operational Planning Regulation as a tree or group of trees that are identified in an operational plan to provide present or future wildlife habitat.

A wildlife tree is a standing live or dead tree with special characteristics that provide valuable habitat for the conservation or enhancement of wildlife. Characteristics include age diameter and height for the site, current use by wildlife declining or dead condition, value as a species, valuable location and relative scarcity.

Wildling: a seedling naturally reproduced outside of a nursery, used in reforestation.

Windthrow: uprooting by the wind. Also refers to a tree or trees so uprooted.