

# **Worksheets for Assessing Backlog Treatment Costs Relative to Expected Gains**

## **Basic Principles and Instructions For Use**

**May 24, 2001**

**B.C. Ministry of Forests  
Forest Practices Branch**



**This document and the accompanying Excel spreadsheets are intended for exploratory use during the 2001 field season. For subsequent years, it may be superceded by newer versions.**

# Table of Contents

<b>Introduction .....</b>	<b>1</b>
<b>Basic Description and Framework for Application .....</b>	<b>2</b>
<b>Comments on the Cost Cap .....</b>	<b>2</b>
<b>Yield Calculations .....</b>	<b>3</b>
<b>Stocking Assumptions .....</b>	<b>5</b>
<b>Limitations on Current Stand Age .....</b>	<b>8</b>
<b>Volume Gains vs. Value Gains .....</b>	<b>8</b>
<b>Accuracy of Predictions .....</b>	<b>9</b>
<b>Known Limitations .....</b>	<b>9</b>
<b>Impacts of Forest Health Issues .....</b>	<b>10</b>
<b>Cost/Benefit vs. NPV .....</b>	<b>11</b>
<b>Instructions For Use .....</b>	<b>11</b>
<b>Appendix I: Growth reduction and mortality tables .....</b>	<b>14</b>
<b>Appendix II: Impacts of option selections .....</b>	<b>17</b>

## Introduction

A great deal of uncertainty exists in making decisions about the value of treating backlog sites. Guidance on this issue comes from the Provincial Backlog Management Policy, which establishes the following objective:

*“to ensure that backlog areas are brought to free-growing status to achieve a free-growing or otherwise acceptable stand”.*

Within this context, however, the policy also acknowledges

*“that certain areas will never reach the current free-growing standards under present economic or biological constraints, and that **further investments cannot be justified or may not be appropriate**”.*

In an attempt to help assess situations in which the qualification to the Provincial Backlog Management Policy as stated above may or may not apply, a decision support tool in the form of interactive tables has been developed to help quantify potential treatment gains. The purpose of this document, then, is to outline the philosophy and construction assumptions for the Backlog Assessment Tables, and to provide some basic instructions for use. It is assumed that persons using these tables have some rudimentary understanding of the Microsoft Excel computer program, different measures of forest “stocking”, the dynamics of different brush communities that compete with conifer crop trees, and even-aged forest stand dynamics.

These guidelines are intended for application to the following categories of backlog land:

- Backlog NSR that is either not under an SP or is under an SP but the commencement date as defined in FPC Act section 70(d) has not yet been initiated.
- Impeded backlog areas that are not under an SP.

The Backlog Assessment Tables should not be applied to backlog areas being managed under SP’s where the commencement date has been initiated, as the SP holder is required to establish a free growing stand in accordance with the requirements of FPC Act section 70(4)

**Note:** for the purposes of this document, the term *backlog* refers to both *backlog areas* as defined by the Forest Practices Code (FPC) Act and *impeded areas* as defined by the provincial Backlog Management Policy. This matches the usage of the term *backlog* as employed by FRBC in their funding of silviculture treatments on non-free-growing areas harvested prior to Oct. 1, 1987.

## Basic Description and Framework for Application

The Backlog Assessment Tables consist of a set of Excel spreadsheets intended to help determine cost feasibility of treating backlog sites. Output from the tables provides important information for rationalizing spending decisions for backlog harvest units, particularly where costs are high relative to the expected benefits. The tables use a set of generalized stand descriptions to predict yield gains from treatment, and apply a threshold cost/benefit ratio (\$/m<sup>3</sup>), or cost cap value, to determine a maximum per hectare regime cost:

$$\begin{aligned} \text{Maximum Regime Cost (\$/ha)} \\ = \text{Expected Volume Gain (m}^3\text{/ha)} \times \text{Cost Cap (\$/m}^3\text{)} \end{aligned}$$

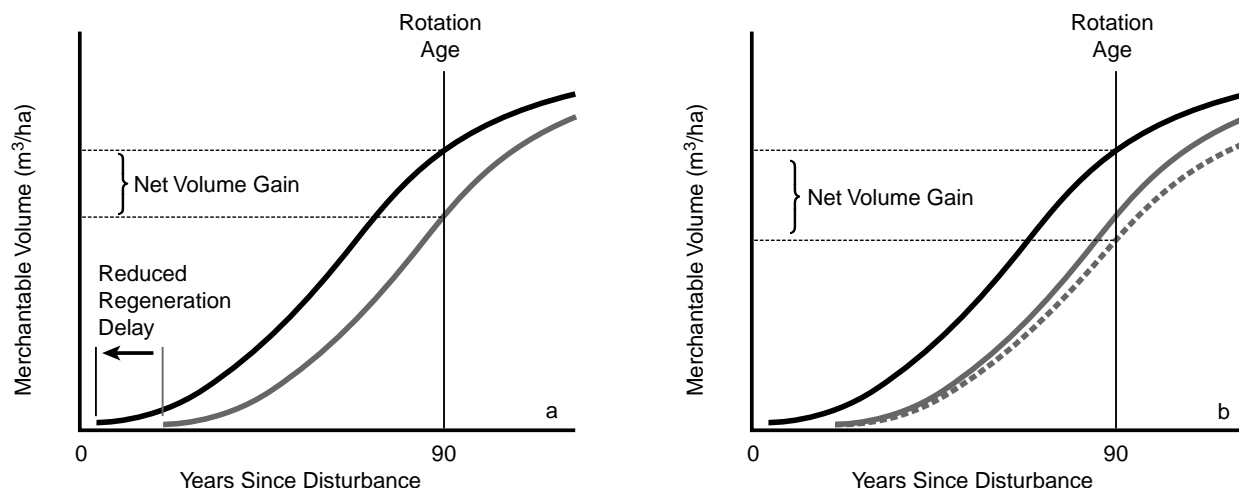
The intent of this assessment is to screen out stands for which treatment costs are excessively high relative to the expected gains. The predicted yield gains from these tables can also be used in determining actual expected cost/benefit ratios or net present values, which in turn will be useful for prioritizing stands for treatments in the face of a limited budget.

Crop tree species covered by the tables include white spruce and lodgepole pine. For each of these species, there is a set of four Excel worksheets to describe different initial conditions. These conditions include not satisfactorily restocked (NSR), and satisfactorily restocked (SR) but impeded by one of three competing brush communities: herbs and low shrubs, tall shrubs, and deciduous trees.

It is important to recognize that the initial conditions used to describe stands are highly generalized, and any one set of stand descriptors will be used to represent a fairly wide range of actual conditions. Several of the stand descriptors are categorical variables that are quite coarsely defined, which has important implications for output precision.

## Comments on the Cost Cap

A provincial default cost cap of \$10/m<sup>3</sup> was determined based on subjective assessment of a number of criteria. These included the moral responsibility to reforest disturbed areas, expectations of the public as interpreted by our political leaders, and actual historic costs experienced to reforest both current and backlog areas. It is expected that the \$10/m<sup>3</sup> default value will be applicable in most cases, but that variations based on local conditions may occasionally be required. Such adjustments should be District or TSA level decisions, and should be made based on criteria such as impacts of backlog treatment on future timber supplies (as reflected in the Timber Supply Review process) or local demand for job creation programs.



**Figure 1.** Volume gains are calculated for impeded stands by assuming the period of reduced growth can be simulated using a regeneration delay (a). Both the treated (black) and untreated (grey) stands have volume/age curves with the same shape, but the treated stand reaches each volume milestone sooner. The addition of mortality (b) in the untreated stand further drops the expected yields (dashed line), resulting in slightly larger gains from treatment.

## Yield Calculations

Based on a set of user inputs, a current stand structure (species, stocking, current age and competing brush complex) is inferred and a set of TIPS<sup>1</sup>Y-based yield curves is accessed. Yields are calculated for both treated and untreated stands, and the difference at final harvest is the expected gain. As TIPS<sup>1</sup>Y does not directly model impacts of competing vegetation, the following assumptions and effects had to be incorporated in the spreadsheet calculations:

1. For stands with competing vegetation complexes that last only a portion of the rotation (all situations except untreated deciduous tree complexes), conifer growth losses were assumed to have similar yield impacts as a regeneration delay (Figure 1). Inherent in this assumption is that volume growth patterns after release are similar to those of an unsuppressed stand, but the same yield milestones occur at older ages. Expressed in terms of a volume over age curve, the effect is simulated by shifting the curve to the right on the time (“x”) axis. Vegetation complexes with heavier cover and/or longer duration impacts are assumed to result in larger and/or longer duration growth losses, the effects of which are simulated with longer regeneration delays.
2. For treated stands, the magnitude of simulated temporary growth losses (regen delays) is calculated as a percentage of current stand age; heavier

1. TIPS<sup>1</sup>Y: Table Interpolation Program for Stand Yields. Developed by the BC Ministry of Forests, Research Branch, for providing access to managed stand yield tables.

competing vegetation communities have higher associated percentage values (see also Appendix I). For instance, a stand overtopped by a shrub community with a high percent cover might be growing at only 70% of its potential (a 30% growth loss). A stand treated at 30 years of age would be simulated using a regen delay of 9 years (30% of 30 years), while a 10-year old stand would be simulated using a regen delay of 3 years. Longer regen delays are associated with heavier percent coverage of brush species.

3. Crop trees are assumed to respond well to reduced competition after treatment, returning to the growth potential for the site within a relatively short time period (> 2-3 years).
4. For untreated stands, regeneration delays used to simulate growth losses are determined solely based on the type, height ratio and percent cover of the competing vegetation (see also Appendix I).
5. Mortality effects from overtopping vegetation were assumed to have a similar effect as a reduced establishment density. For spruce, mortality rates vary from 0 to 15%, with the highest rate experienced only under the most extreme brush conditions. For pine, mortality rates for the most commonly encountered conditions range from 0 to 30%, again with the highest rates being associated with taller and more dense brush cover. Allowance has been made for lodgepole pine mortality rates as high as 60%, but the necessary types of brush communities would rarely be observed in conjunction with lodgepole pine.
6. Yields for treated stands can be simulated using current density as an establishment density value (this results in a bias toward slightly pessimistic yield values for treated stands).

Other factors affecting yields include:

1. All volumes from TIPSYS incorporate the following:
  - OAF1 = 15%, OAF2 = 5%
  - Existing NSR and all impeded stands projected as “natural”; treated NSR stands projected as “planted”
  - Merchantability limits for all species set at 12.5 cm dbh, 10 cm top and 30 cm stump
2. Density for spruce NSR stands is assumed to be 1300 trees/ha after treatment, and 1800 trees/ha for pine.
3. An option exists to incorporate increases in yield resulting from planting of genetically improved stock. Default yield gains are 8% for pine and 15% for

spruce. These gains will apply only to treated NSR stands. Gains are pro-rated for the percentage of the final crop that originated from improved stock (the existing stock is assumed have similar genetic potential as the natural population).

Deciduous tree yields cannot be determined using TIPSY, and a different methodology was employed. Potential yields for fully stocked deciduous stands are inferred using a multiplier that is applied to the conifer yields (Deciduous Yield = Conifer Yield \* x). The value of this multiplier varies with stand age and conifer species (Figure 2), and was determined using the relative yields of aspen and the conifer species in question (with SI = 20 for pine & aspen and SI=18 for spruce) as predicted using VDYP. The ratio of potential conifer to deciduous yield was assumed to be independent of site.

To determine conifer and deciduous yields in untreated mixed stands (Figure 3), volumes are pro-rated based on expected canopy occupancy at harvest (as supplied by the user). Minor adjustments have been made to this relationship to reflect the relative heights of the conifer and deciduous trees at the time of assessment, with lower deciduous/conifer height ratios resulting in increased conifer volumes at harvest.

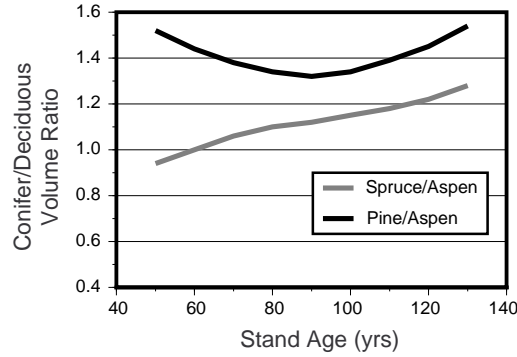
This method of volume calculation for mixed conifer/deciduous stands is relatively crude from a number of perspectives, and the results should be used with caution (see known limitations below). Still, it is difficult to conceive of a better approach that can be incorporated into a spreadsheet style presentation such as that being used here. The complexities and range of outcomes resulting from various combinations of site, species and successional dynamics requires an individual tree growth model such as MGM<sup>2</sup>. At the time of writing, MGM cannot reliably be used for such purposes. A new release is expected soon which hopefully can be used to test the magnitude and range of gains included in these tables.

## Stocking Assumptions

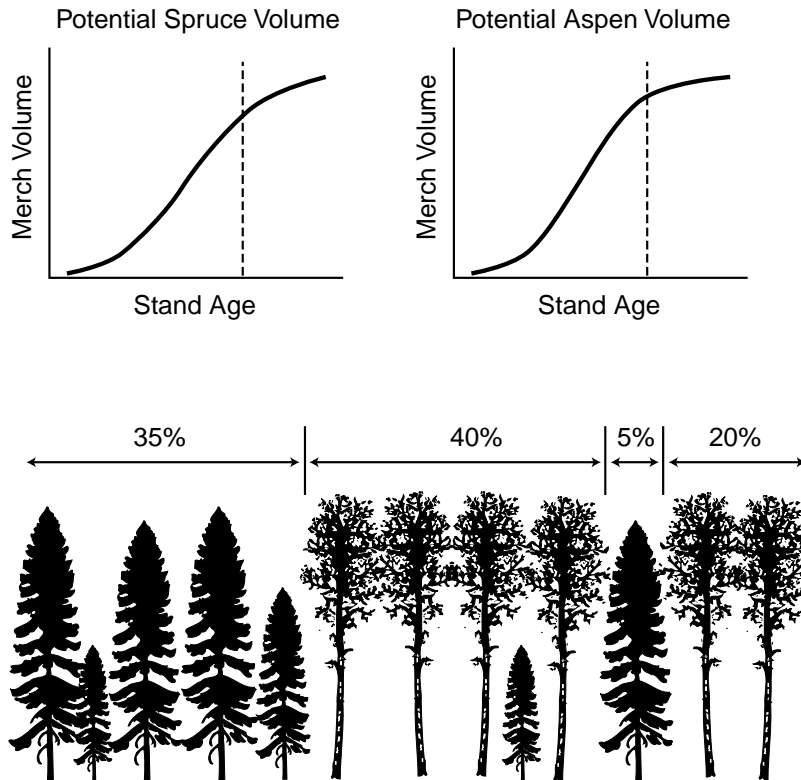
While TIPSY uses the total number of trees per hectare as the initial measure of density for simulating stand growth, the Backlog Assessment Tables use the concept of *well spaced* trees. The base assumptions for converting well spaced trees to total trees for the TIPSY runs are provided in Figure 4. Using well spaced trees instead of total trees provides a more stable prediction of yield, as it eliminates much of the variability caused by changes in spatial distribution that would arise if total trees were instead used. The *well spaced* concept does a much better job than *total trees* of representing site occupancy (the proportion of an area that is stocked with trees), to which yield is quite sensitive. Note that all well spaced tree values are assumed to be “capped” using a maximum tally in each 50 m<sup>2</sup> plot of 6 trees (M=6).

---

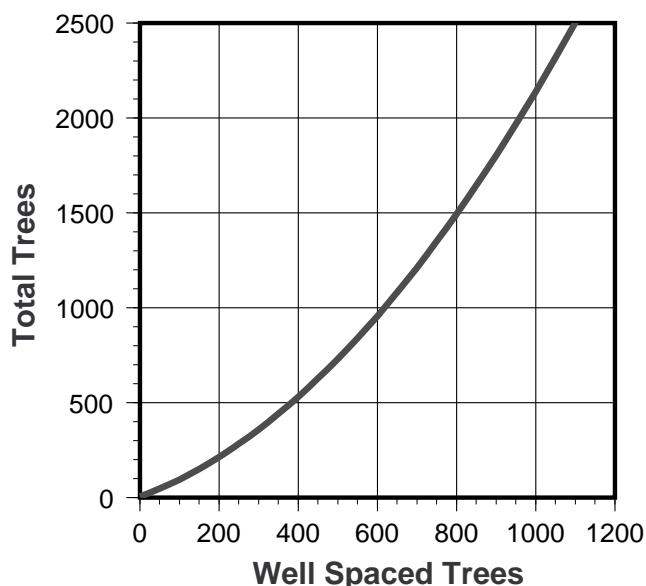
2. Mixedwood Growth Model: an individual tree growth model designed by Dr. Steve Titus at the University of Alberta for use in boreal mixedwood stands.



**Figure 2.** Assumed ratios of conifer to deciduous yields used to calculate potential full stocking deciduous volumes relative to potential full stocking conifer volumes.



**Figure 3.** Deciduous and conifer volumes are pro-rated based on proportion of canopy occupancy. In the example above, the yield curves for each species assume full stocking with a single species stand, with the harvest age indicated by the dotted line. Since aspen is occupying 60% of the canopy area with 40% left for the spruce, the volume for the mixed stand is assumed to be 60% of the potential aspen yield plus 40% of the potential spruce yield.



**Figure 4.** Assumed relationship between well spaced trees per hectare and total trees per hectare for stands with a “natural” or random tree distribution as expressed in the TIPSY program, and using a minimum inter-tree distance of 2.0 m in a silviculture survey.

Using well spaced trees as a descriptor of initial condition, however, is not without its problems. The well spaced statistic is not a fixed value for any given stand: the numbers of well spaced trees tallied will vary depending on survey parameters. The two largest factors here are the minimum inter-tree distance (MITD) and the criteria for determining acceptable crop trees.

As MITD decreases, the number of well spaced trees tallied for any given stand will increase (more “crop trees” can be tallied within a given fixed area plot). To account for these effects, both a measure of spatial distribution (for pine only) and MITD have been included as an input values. Based on these values, the number of well spaced trees for each reference stand in the tables is adjusted to reflect the different survey parameters. The magnitude of the adjustments is based on relationships found in Bergerud (2001)<sup>3</sup> and Bergerud et al. (1999)<sup>4</sup>.

Survey assumptions around acceptable crop trees may also be important, but have not been explicitly included in the Backlog Assessment Tables. In assessing stands for which the survey has tallied a large number of less-than-ideal trees, highly inaccurate estimation of yields is a distinct possibility. In cases where tree growth is impeded by factors other than competing vegetation (i.e. pest or environmental damage, poor micro-site), results derived from the Backlog Assessment Tables in most cases will be excessively optimistic.

---

3. Bergerud, W. 2001. The statistical properties of the silviculture survey and corresponding yield projections. BC Ministry of Forests, Research Branch. Internal draft report.

4. Bergerud, W., MacDonald, R., Harper, G. and Mitchell, K. 1999. The statistical properties of the Ministry’s silviculture surveys and expected rotation at harvest. BC Ministry of Forests, Research Branch. Internal draft report.

## Limitations on Current Stand Age

The tables for impeded stands are based on the assumption that at least 7 years have past since stand establishment. The reason for this is that the FPC Act came into force 7 years ago in 1994 and created the requirement for an SP if it was known or anticipated that a treatment other than planting will be required on a backlog area. Therefore it is assumed that backlog areas requiring brushing that have treatment commencement dates of 1994 or later are being managed under an SP.

It is important to recognize that this assumption implies that the optimum window for brushing of the herbaceous complex is past, and this is reflected in the assumptions regarding yield impacts on untreated stands (particularly as impacted by mortality). Applying the tables to stands with less than 7 years old may lead to underestimating net volume gains.

## Volume Gains vs. Value Gains

Not all treatment benefits in the tables are reported in terms of “Net Volume Gain”. In some cases, a simple calculation of volume differences would be insufficient to adequately reflect all the benefits of treatment. In these cases, the value of logs from treated and untreated stands is different, with a major portion of the treatment benefits arising from increased log values. Where a stand that without treatment would produce low value logs is modified through treatment to produce higher value logs, the volume of the untreated stand is adjusted downward to reflect its lower value, and a “Value Gain Index” is reported instead of a “Net Volume Gain”.

One such case is with deciduous tree vegetation complexes. Here the untreated stand has deciduous volume at final harvest, but the deciduous timber may have a lesser value than an equal volume of conifer logs. By treating the stand, we are sacrificing the deciduous volume in order to make gains in the more valuable coniferous volume. To account for this, the deciduous volume of the untreated stand is reduced to match the volume of conifers that would have equal value. For example, an untreated mixed stand is predicted to have 250 m<sup>3</sup>/ha conifer volume and 100 m<sup>3</sup>/ha of deciduous volume at harvest. The corresponding treated stand is expected to have 375 m<sup>3</sup>/ha of coniferous volume. In this case:

$$\text{Net Volume Gain} = 375 \text{ m}^3/\text{ha} - (250 \text{ m}^3/\text{ha} + 100 \text{ m}^3/\text{ha}) = 25 \text{ m}^3/\text{ha}$$

However, it is assumed that the deciduous volume has only one quarter the value of the conifer volume. Using a value ratio of 0.25, the deciduous volume is reduced to the volume of conifer logs of equivalent value (i.e. 25 m<sup>3</sup> of conifer logs is of equal value to 100 m<sup>3</sup> of deciduous logs):

$$\text{Volume Gain Index} = 375 \text{ m}^3/\text{ha} - (250 \text{ m}^3/\text{ha} + 0.25 \cdot 100 \text{ m}^3/\text{ha}) = 100 \text{ m}^3/\text{ha}$$

Note that the term “Volume Gain Index” is used in such cases to reflect that gains are no longer purely based on volume differences.

Similar value differences may also be experienced with low density lodgepole pine stands. In this case, the value of pine logs is reduced when grown at low stand densities as a result of frequent coarse knots, a high degree of taper and a high percentage of juvenile wood. Further discussion of value differences for pine and the resultant effects on “Volume Gain Index” calculations is provided in Appendix II under the heading “Value Ratio for Low Density Pine”.

## **Accuracy of Predictions**

Without any adjustments applied, conifer volumes in these tables would accurately reflect those from managed stand yield tables produced by TIPSY. Many adjustments to those yields have been made, however, often based on the author’s perceptions tempered with peer review input from other field foresters and researchers. This has certainly affected accuracy of the volume estimates provided, but there is little if any hard data available against which to test the magnitude and direction of any bias.

Given untested bias, it is left to the judgement of the user to assess whether the tables have value. To some degree, a level of confidence can be provided through testing against the user’s perceptions and experience, but it must always be recognized that those perceptions may also be biased. To facilitate such a process, matrices of adjustment factors used in the tables have been included in Appendix I. It is still recognized, however, that such testing is less than ideal.

To partially reflect the level of confidence in predicted volumes, all reported values have been rounded to the nearest 10 m<sup>3</sup>/ha, and maximum expenditure values to the nearest \$100/ha.

## **Known Limitations**

The following caveats must be recognized when using these tables:

1. There is only limited data on which to base growth losses resulting from competing vegetation. Existing monitoring data bases such as those belonging to the NIVMA cooperative in the northern interior and resulting from the PROBE program in the southern interior are relatively young and cannot yet assess the impact of long term competitive effects. Existing research trials produce highly precise data for specific sites and vegetation complexes, but have limited scope of inference to other sites and variants of brush communities.
2. The tables assume a relatively quick (<3 yrs) response of crop trees to release. There are many situations in which this assumption will be false. In particular:
  - sites on which competing vegetation is not the only growth limiting factor such as those with climatic extremes (high elevations and frost pockets) or cold, wet soils (such as wet alder complexes on depressional sites)

- stands where there is a high degree of treatment related damage to crop trees
  - sites where treatment induces increased risk of other growth limiting factors such as pests, sunscald or frost stress
  - stands where extreme levels of brush competition have resulted in crop trees with limited crown volume such that response is limited while the crop trees rebuild their crowns
3. The tables may not work well for sites where competition is primarily for resources other than light, or where treatment ameliorates other growth limiting conditions. This applies particularly to cases such as grass competition for moisture on droughty sites. In these cases, the % brush cover and particularly the brush/conifer height ratios may not adequately reflect the degree of growth limiting competition that is being experienced.
4. The coarse assumptions for yields of mixed deciduous/conifer stands have a number of potential flaws including:
- aspen is an imperfect surrogate for other deciduous species such as birch and cottonwood.
  - pine and aspen will not always have equivalent site indices on the same site, and spruce will not always have a site index 2 m lower than aspen
  - the shape of the curve representing the ratio of conifer to deciduous volume may not be consistent over a wide range of site indices.
  - the shape of the curve representing the ratio of conifer to deciduous volume assumes a single pattern of mixedwood succession, with a constant pattern of deciduous decline with increasing age. In fact, this pattern has been observed to vary dramatically with geographic region.

## **Impacts of Forest Health Issues**

Impacts of stand damaging agents are not explicitly incorporated into the Backlog Assessment Tables. It is therefore up to the user to assess the impact of a particular damaging agent based on specific stand conditions and knowledge of the impact of that agent on stand development.

Stand damage resulting from biotic or abiotic agents will usually have some degree of impact on stand yields. Where the impacts are relatively light and similar for both treated and untreated stands, the impact on expected yield gains will be minimal. In cases where yield impacts are heavier but unaffected by treatment, there will be a similar reduction in treatment related yield gains as for total volume on a percentage basis. Where proposed brushing treatments are likely to affect the impact of the damaging agents, yield gains may be dramatically increased (if treatment reduces pest impacts) or decreased.

## Cost/Benefit vs. NPV

The backlog assessment tables facilitate the evaluation of cost-effectiveness in treating backlog sites primarily by helping to estimate treatment gains. In addition, they directly facilitate evaluation of those gains relative to the cost of treatment.

One method of contrasting treatment benefits from different regimes or options, widely touted as the most powerful and informative, is the calculation of net present values (NPVs). Other than providing expected yield gains, however, these tables do not support such calculations. Additional required information for such calculations includes assumed harvest timing for different management regimes, treatment costs, expected harvest revenues and a realistic discount rate. Many of these are either unavailable or difficult to evaluate in the context of preparing backlog treatment prescriptions. For these reasons, this method will not be expanded upon here.

In the evaluation method directly supported by the Backlog Assessment Tables, a threshold cost benefit ratio ( $\$/m^3$ ) is used coupled with the yield gains to determine a maximum expenditure permitted in order to achieve the expected yield gains. Alternatively, a silviculture planner can use the expected yield gains from these tables coupled with an estimate of actual total regime costs to determine unique cost/benefit ratios for treating each individual stand. These then can be used to prioritize stands for treatment in the presence of a limited budget.

The use of cost/benefit ratios in this context is partly flawed as it compares *present costs* with *future benefits*. If future harvest timing varies for each block, this may lead to inappropriate conclusions regarding comparisons to the threshold value (cost cap) or to ranking priority. In the absence of any knowledge about future harvest queues, however, this method will not be particularly biased even though it may lack precision.

## Instructions For Use

There are 4 basic steps to using the backlog assessment tables:

1. Select the worksheet that best fits your stand type.

There are 8 sheets in the workbook: 4 for lodgepole pine stands and 4 for interior spruce. For each species, there is one worksheet for NSR stands, and three for impeded stands with different competing vegetation complexes. Less generalized vegetation complexes such as those described by Newton and Comeau (1990)<sup>5</sup> have been grouped to reflect their height growth potential and ultimately their duration of impact on crop trees. The herbaceous complex, for example, includes vegetation communities with predominantly low growing shrubs such as thimbleberry, twinberry and elderberry. The tall shrub complex is intended to

---

5. Newton, N. and Comeau, P. 1990. **Control of competing vegetation**. In: Lavender, D.P., Parish, R., Johnson, C.M., Montgomery, G., Vyse, A., Willis, R.A., and Winston, D. (eds). Regenerating B.C.'s forests. Univ. of BC Press, Vancouver BC. pp. 256-265.

cover competing vegetation communities reaching heights of 4-15 m (primarily alders and willows), while the deciduous tree complex is intended to cover vegetation that could potentially form part of the final crop.

The impeded stand worksheets include some stocking levels for which stands would normally be considered as NSR. These have been included for assessment of poorly stocked stands where further planting is not being considered, but where brushing to improve growth of existing trees is an option.

2. Describe your stand in terms of the required input parameters:

- site index: this is an extremely important parameter which has a large impact on both total yields and yield gains from treatment. The best possible estimate of site index is therefore essential,
- well spaced conifer stocking, along with spatial distribution (for pine) and minimum inter-tree distance (MITD) used to assess well spaced trees,
- predominant height ratio of competing vegetation to conifer crop trees, including only those species that have the potential to overtop crop trees,
- for herbaceous and tall shrub complexes, current percent cover of competing vegetation. Again, include only those species with the potential to overtop crop trees. Use total brush cover for the stratum. In strata with highly clumped brush cover, you may wish to split the strata into two substrata, one with low brush cover and one with high brush cover. In such cases, the two resultant gain predictions would be area-weighted to reflect a single value for the whole stratum.
- for deciduous trees, expected proportion of the canopy (at final harvest) that will be occupied by deciduous trees, expressed in percent. This value is based on that which would be interpreted using the visible portion of the canopy in a 1:15,000 aerial photo.
- current stand age.

For the competing vegetation descriptors, select the appropriate categories from the drop-down lists provided. Enter the stand age in the indicated cell (the age range limit is 7 to 30 years).

3. Determine an expected harvest timing (use a common age for all stands being evaluated – 80 years is a good place to start in the absence of better information) and:

- for pine stands determine the value of low density pine (established below 500 well spaced trees/ha) relative to that established at densities above 900 well spaced trees/ha. Assuming a 3/5 ratio of value between pulpwood and sawlogs, a value ratio of 0.6 would be appropriate. If there is no expected difference, use a value of 1.0. In most cases, you should use either the default value of 0.6 or a value set by the MoF District Office.

- for deciduous tree complexes, determine the value of deciduous logs relative to an equal volume of coniferous logs. If there is no expected difference, use a value of 1.0. In most cases, you should use either the default value of 0.3 or a value set by the MoF District Office.
  - for NSR stands, determine whether or not genetically improved seed will be used.
  - maximum cost in  $\$/m^3$ , where the volume is the expected gain due to treatment. In most cases, you should use either the default value of  $\$10/m^3$  or a value set by the MoF District Office.
4. Once the required entries have been made, read off the “Net Volume Gain” or “Volume Gain Index” values, and if needed the “Maximum Treatment Cost ( $\$/ha$ )”. Where site indices and stocking conditions do not match perfectly with those listed in the first two columns of the table, interpolation is appropriate.
  5. Where a proposed treatment regime has costs that are within 20% of the “Maximum Future Regime Cost”, some sensitivity testing is appropriate. For each of the input parameters, test a slightly higher and lower setting to test the impacts of an inaccurate estimator of stand condition. Include site index and stocking levels in the sensitivity testing (use +/- 10% for both values).

Further information on the effects that each entry parameter has on calculations can be found in Appendix II.

## Appendix I: Growth reduction and mortality tables

The following tables contain the mortality and growth loss (regen lag) assumptions for untreated stands (herbaceous and tall shrub brush communities):

### Lodgepole Pine – Herbaceous

Expected Mortality (%) (untreated stands)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	5	5
	26 to 50%	0	10	15	15
	51 to 75%	0	20	25	30
	76 to 100%	5	30	45	60

Effective Regen Delay (yrs) (untreated stand)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	0
	26 to 50%	0	5	5	5
	51 to 75%	0	5	10	10
	76 to 100%	0	10	15	15

### Interior Spruce – Herbaceous

Expected Mortality (%) (untreated stands)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	5
	26 to 50%	0	0	5	5
	51 to 75%	0	5	5	10
	76 to 100%	0	10	10	15

Effective Regen Delay (yrs) (untreated stand)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	0
	26 to 50%	0	5	5	5
	51 to 75%	0	5	5	10
	76 to 100%	0	5	10	15

**Lodgepole Pine – Woody Shrub**

Expected Mortality (%) (untreated stands)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	5
	26 to 50%	0	5	5	10
	51 to 75%	0	10	15	35
	76 to 100%	5	20	40	60

Effective Regen Delay (yrs) (untreated stand)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	5
	26 to 50%	0	5	5	10
	51 to 75%	0	10	15	20
	76 to 100%	5	15	25	30

**Interior Spruce – Woody Shrub**

Expected Mortality (%) (untreated stands)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	0
	26 to 50%	0	0	5	5
	51 to 75%	0	5	10	10
	76 to 100%	0	10	10	10

Effective Regen Delay (yrs) (untreated stand)		Brush to Crop Tree Height Ratio			
		< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
Percent Brush Cover	0 to 25%	0	0	0	5
	26 to 50%	0	5	5	10
	51 to 75%	0	10	15	20
	76 to 100%	5	15	25	30

The following tables contain the assumptions for growth losses (regen lags) resulting from brush competition in treated stands for the period prior to treatment.

**Lodgepole Pine – Herbaceous**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Brush to Crop Tree Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	25	50	50

**Interior Spruce – Herbaceous**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Brush to Crop Tree Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	10	20	40

**Lodgepole Pine – Woody Shrub**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Brush to Crop Tree Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	15	30	40

**Interior Spruce – Woody Shrub**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Brush to Crop Tree Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	10	20	30

**Lodgepole Pine – Deciduous Tree**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Deciduous/Conifer Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	25	50	75

**Interior Spruce – Deciduous Tree**

"Regen Lag" for brush effects to date (yrs) (% of current age)

Deciduous/Conifer Height Ratio			
< 1.0	1.0 to 1.5	1.5 to 2.0	> 2.0
0	5	15	25

## Appendix II: Impacts of option selections

The following descriptions highlight the general trends that will be observed as different input values and selections are made from the options at the top of each table.

**Crop Tree Distribution:** This parameter applies only to pine stands, and permits inclusion of the differences in yields expected from otherwise equivalent stands as reflected in the TIPSY program. To be represented by the same yield curve, a clumped stand needs up to 100 more well spaced trees per hectare than does a stand with a random tree distribution.

**Current Crop overtopped?:** This parameter applies only to NSR stands. A “yes” response triggers a uniform regen lag of 5 years. It is assumed that when the stand is treated (fill planted) the treatment regime will include sufficient brushing treatments so that the stand will reach free growing status.

**Current Stand Age:** This parameter is used in several calculations. It is added to the Harvest Timing value to get total stand age at harvest, which in turn is used as the input parameter for each yield function (volume/age curve). It is also used to determine the degree of growth loss experienced by a stand prior to treatment – older stands will have undergone a longer period of suppression with resultant greater growth losses. Age is multiplied by a percentage value from the “Regen Lag for brush effects to date” table (see Appendix I) to determine the absolute magnitude of the growth loss. The relative magnitude of growth loss as expressed in the “Regen Lag for brush effects to date” table is affected by tree species and brush to crop tree height ratio.

**Deciduous/Conifer Height Ratio:** This parameter applies only to the deciduous tree complex. It is used to determine growth reductions to date for treated stands. It is also used to adjust the apportionment of conifer and deciduous volumes in the final harvest (see also “Percent Decid. Cover at harvest (untreated)”).

**Decid./Conifer Value Ratio:** This parameter applies only to the deciduous tree complex. With this complex, it is assumed that the deciduous trees if left untreated will generate some revenue in the future, but less than an equivalent volume of conifer logs. The act of treating these stands, then, is an exercise in sacrificing some deciduous volume in order to increase the more valuable conifer volume. In the gain calculations, the lost volume of deciduous must be accounted for (we may, for example, be giving up 120 m<sup>3</sup>/ha of deciduous volume to gain 130 m<sup>3</sup>/ha of coniferous volume). In this example, the absolute volume gain is only 10 m<sup>3</sup>/ha, but this does not reflect the expected gains from treatment. If the deciduous logs are worth only half of the same volume of coniferous logs, the deciduous volume should be reduced to match that of the volume of conifer logs that would generate the same revenue (in this case 0.5 x 120 m<sup>3</sup>/ha = 60 m<sup>3</sup>/ha). The resultant gain index would then be 70 m<sup>3</sup>/ha (130 m<sup>3</sup>/ha – 60 m<sup>3</sup>/ha) instead of the absolute gain of 10 m<sup>3</sup>/ha.

**Genetic Gain for Treated Stands?:** This parameter applies only to NSR stands. A “yes” response triggers a yield multiplier for the treated portion of the stand (fill planted

trees) to reflect their increased growth potential. The default multipliers are 8% for pine and 15% for spruce. These values cannot easily be changed by the user, but a custom variation of the tables can be quickly and easily produced for specific Districts/TSAs if needed.

**Harvest Timing (years from present):** This value is added to current stand age to get total stand age at harvest, which in turn is used as the input parameter for each yield function (volume/age curve). Prior to use in the yield functions, actual harvest age is adjusted by various “regen lag” values to get effective harvest age based on various degrees of suppression experienced based on different tree species and brush communities.

When generating yield gains for a number of stands for use in cost/benefit ratios for prioritizing stand treatments, it is best to select a single “Harvest Timing” and stick with it regardless of species and current age. This will help ensure that all benefits (yield gains) are calculated for the same time period in the future. If there is a broad range of ages and site indices in the stands being tested, it will be a good idea to test two or three different harvest ages to see if the ranking is altered.

**Maximum Cost (\$/m<sup>3</sup>):** This parameter has no effect on growth predictions, and no effect on ranking of stands based on yield gains. This factor simply multiplies the predicted gain by a dollar value to produce a value that reflects the maximum per hectare cost of treatment. Stands for which treatment costs exceed the calculated maximum should be considered for classification either as free-growing in their present condition or as NP Brush.

**Minimum Inter-tree Distance:** This parameter is used to account for different tallies of well spaced trees that can be derived from the same stand using different MITD’s in the silviculture survey. Altering this value has no effect on the yield curves, but changes the reference number of well spaced trees for a particular yield curve.

**Percent Brush Cover:** This variable is one of two used to determine mortality rates and growth reductions (expressed as “regen lags) in untreated stands resulting from overtopping by deleterious brush. Both mortality rates and growth reductions increase with increasing percent brush cover (see also Appendix I).

**Predominant Brush/Crop Tree Height Ratio:** This variable applies only to herbaceous and tall shrub communities. It is one of two variables used to determine mortality rates and growth reductions (expressed as “regen lags”) in untreated stands resulting from overtopping by deleterious brush. Both mortality rates and growth reductions increase with increasing height ratios (see also Appendix I). The height ratio is also used alone to determine growth losses to date experienced by treated stands. Again, the growth losses increase with increasing height ratio.

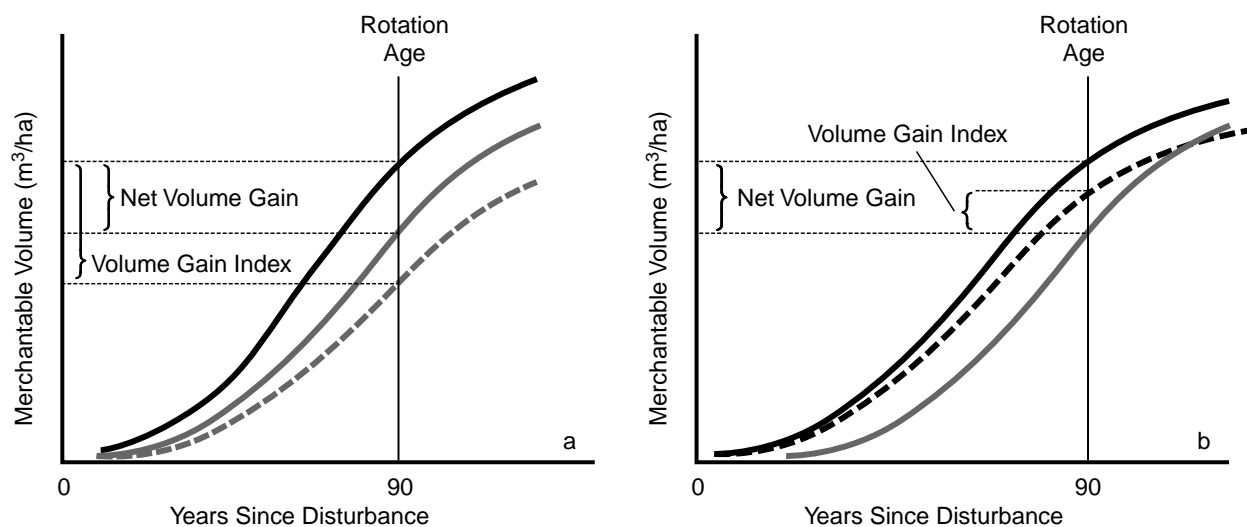
**Proportion Decid. Cover at harvest (untreated):** This parameter applies only to the deciduous tree complex. It is used to apportion the total volume in the untreated stand to deciduous and coniferous components. Volume of each at final harvest is assumed to

be primarily a function of their relative percent covers. The apportionment is also adjusted based on the deciduous/conifer height ratio, with conifer apportionment increasing as the deciduous/conifer height ratio decreases.

**Value Ratio for Low Density Pine:** This parameter applies only to lodgepole pine stands. The entered ratio ( $0 < x \leq 1$ ) reflects the monetary value of logs as it varies with wood quality. Pine grown at low densities typically has frequent coarse knots, a high percentage of juvenile wood and a high degree of taper, all of which decrease quality and value. The value ratio decreases the effective volume in a low density stand (Figure 5) to the point where its monetary value matches that of wood grown at higher densities (i.e. 100 m<sup>3</sup> of low density pine may be equivalent in value to 60 m<sup>3</sup> of pine grown at higher densities).

In the case of NSR units, a treated (fill planted) stand might have a yield of 300 m<sup>3</sup>/ha, where the untreated stand has a yield of 200 m<sup>3</sup>/ha, resulting in an absolute gain of 100 m<sup>3</sup>/ha. The wood in the untreated stand is of lower quality, however, and is equivalent in value to only 120 m<sup>3</sup>/ha of wood in the treated stand. Instead of reporting the absolute gain, the tables report a gain index, calculated as the yield of the treated stand minus the adjusted yield of the untreated stand ( $300 \text{ m}^3/\text{ha} - 120 \text{ m}^3/\text{ha} = 180 \text{ m}^3/\text{ha}$ ).

The entered value ratio is not applied equivalently to all low density stands. Below 600 well spaced trees/ha, the full ratio is applied. Between 800 and 1000 well spaced trees/ha, the value ratio is reduced to zero based on a linear function. Above 1000 trees/ha, the value ratio has no impact.



**Figure 5.** Differences between Net Volume Gain and Volume Gain Index for lodgepole pine stands that are either NSR (a) or impeded (b). In both cases, the dashed line represent a volume of good quality sawlogs that has the same value as the actual predicted volume of low quality sawlogs resulting from a low density stand.

The impact of the value ratio is also affected by certain brush communities. Tall shrub and deciduous tree communities will reduce the quality impacts of low density pine by inducing self-pruning (minimizing knot size and the percentage of juvenile wood) and reducing stem taper, particularly in the lower bole. The degree of reduction increases with increasing brush height and percent cover. In this case, a reduced value ratio for low density pine will decrease rather than increase the expected gains from treatment, as it is the treated stand for which the value is reduced.