FORCORP Solutions Inc.

Enhanced Mountain Pine Beetle Decision Support Tool Application Development

Prepared for: Foothills Growth and Yield Association

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EXECUTIVE SUMMARY

This report describes the detailed procedures of the Enhanced Mountain Pine Beetle (MPB) Decision Support Tool (DST) application development.

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1. Project Objectives

The Foothills Growth and Yield Association (FGYA) is implementing an important project to develop Decision Support Tools for forest management in a mountain pine beetle (MPB) environment. The project is sponsored by the Forest Resource Improvement Association of Alberta (FRIAA), the Foothills Research Institute and Alberta Environment and Sustainable Resource Development (ESRD).

The objective of the FGYA MPB project is to identify the most common pine dominated stand structures across Alberta ecosites' range, modify their characteristics to emulate an MPB attack and potential subsequent management interventions, and project them forward in time using growth and yield models such as GYPSY and MGM.

The existing Mountain Pine Beetle Environment Decision Support Tool was developed in 2010 (The Forestry 2010). The received user feedback indicated that the 18 Stand Types did not encompass all of the important stand conditions encountered by FGYA members. FGYA members also suggested it would be much preferred for a user to be able to input specific starting conditions directly into the DST.

The following DST Improvements were defined and proposed by FGYA Members:

1. Incorporate additional level of MPB attack (75%)

2. Incorporate additional Stand Types to account for presence of Balsam Fir (Fb) understories

3. Incorporate adjustment of Overstory/Understory Mean Density to allow users to specify the use of either of the mean, the 25th percentile, or the 75th percentile of density for projection starting conditions.

The objective of this project is to develop the enhanced DST to meet the needs identified above.

2. DST Background

2.1 Stand Types

2.1.1 Stand Types in the Existing DST

The stratification scheme for DST stand types was adopted from the FGYA Regenerated Lodgepole Pine study, and included 8 strata as per the following table (Table 1).

Table 1. Stratum summary.

Ecosite (and Edatopic) Type	Ecosite[1]	NSR[2]	Stratum Number
1. Bearberry / lichen/hairy wild rye (submesic / subxeric, medium - low)	b, c	Any	1
2. Labrador tea - mesic (mesic - poor)	d (c)	UF	2
	d (c)	LF	3
3. Billberry / cranberry / sarsaparilla / rhododendron (mesic - medium)	e (d)	SA/UF	4
	e (d)	LF	5
4. Honeysuckle / fern (subhygric rich)	f (e)	UF	6
	f (e)	LF	7
5. Labrador tea - hygric (hygric - poor)	h (f)	Any	8

1. Ecosites as classified by *Field guide to ecosites of west-central Alberta* , J.D. Beckinhham, I.G.W. Corns and J.H. Archibald, Can. For. Serv. Special Report 9, 1996. Equivalent classifications for southwestern Alberta are shown in brackets (*Field guide to ecosites of* southwestern *Alberta* , J.D. Beckinhham, G.D. Klappstein, and I.G.W. Corns, Can. For. Serv.)
2. Natural sub-regions (NSR): UF = Upper Foothills, LF = Lower Foothills, SA = Sub-alpine

Plot data from the 149 PSP's being monitored by FGYA for MPB activity, as well as data from the Field Guide to Ecosites of West-Central Alberta, were used to characterise 'typical'

mensurational conditions for each Stratum. This yielded 18 Stand Types that were used in the existing DST (Table 2).

Table 2. Matrix summarizing the most probable stand types and stand structures by stratum.

Stratum	Age_Class	Stand Structure	Overstory	Understory	Stand Type
1	1, 2, 3	1 Layer	Pl		1
	1, 2, 3	1 Layer	Pl+Aw		2
	1, 2, 3	2 Layers	Pl	Sb	3
	1, 2, 3	2 Layers	Pl+Aw	Sb	4
2	1, 2, 3	1 Layer	Pl		5
	1, 2, 3	2 Layers	Pl	Sb	6
3	1, 2, 3	1 Layer	Pl		7
	1, 2, 3	2 Layers	Pl	Sb	8
4	1, 2, 3	1 Layer	Pl		9
	1, 2, 3	1 Layer	Aw+Pl		10
	1, 2, 3	1 Layer	Sw+Pl		11
5	1, 2, 3	1 Layer	Pl		12
	1, 2, 3	1 Layer	Aw+Sw+Pl		13
6	1, 2, 3	1 Layer	Pl		14
	1, 2, 3	1 Layer	Pl+Aw+Sw		15
7	1, 2, 3	1 Layer	Pl		16
	1, 2, 3	1 Layer	Aw+Sw+Pl		17
8	1, 2, 3	1 Layer	Sb+Pl		18

2.1.2 Stand Types in the Enhanced DST

Additional Stand Types to account for Fb understories were added in the enhanced DST. These were identified as being highest priority in *'e'* ecosites, and lower priority in *'d'* and *'f'* ecosites. Adding Fb understory Stand Types for only the *'e'* ecosites added an additional 5 Stand Types to the existing DST, i.e., 9a, 10a, 11a, 12a, and 13a (Table 3).

Table 3. Proposed Stand Types for Enhanced DST.

Stratum	Age_Class	Stand Structure	Overstory	Understory	Stand Type
1	1, 2, 3	1 Layer	Pl		1
	1, 2, 3	1 Layer	Pl+Aw		2
	1, 2, 3	2 Layers	Pl	Sb	3
	1, 2, 3	2 Layers	Pl+Aw	Sb	4
2	1, 2, 3	1 Layer	Pl		5
	1, 2, 3	2 Layers	Pl	Sb	6
3	1, 2, 3	1 Layer	Pl		7
	1, 2, 3	2 Layers	Pl	Sb	8
4	1, 2, 3	1 Layer	Pl		9
	1, 2, 3	1 Layer	Aw+Pl		10
	1, 2, 3	1 Layer	Sw+Pl		11
5	1, 2, 3	1 Layer	Pl		12
	1, 2, 3	1 Layer	Aw+Sw+Pl		13
6	1, 2, 3	1 Layer	Pl		14
	1, 2, 3	1 Layer	Pl+Aw+Sw		15
7	1, 2, 3	1 Layer	Pl		16
	1, 2, 3	1 Layer	Aw+Sw+Pl		17
8	1, 2, 3	1 Layer	Sb+Pl		18
4	1, 2, 3	2 Layers	Pl	Fb	9a
	1, 2, 3	2 Layers	Aw+Pl	Fb	10a
	1, 2, 3	2 Layers	Sw+Pl	Fb	11a
5	1, 2, 3	2 Layers	Pl	Fb	12a
	1, 2, 3	2 Layers	Aw+Sw+Pl	Fb	13a

This resulted in 23 Stand Types (18 original + 5 additional for Fb understories for ‘e’ only) in total in the Enhanced DST.

2.2 MPB Attack Levels

2.2.1 MPB Attack Levels in the Existing DST

Four levels (0%, 25%, 50%, and 100% kill) of MPB attack were defined in the existing DST.

2.2.2 MPB Attack Levels in the Enhanced DST

An additional level of MPB Kill 75% option was added to the enhanced DST. Three additional scenarios, similar in specification as 25% and 50%, for the new 75% MPB Kill Option were added. Therefore, there are now 14 Scenarios vs. the original 11 Scenarios (refer to Section 4.1.5).

2.3 Starting Condition - Densities

2.3.1 Starting Condition - Densities in the Existing DST

Mean densities for both overstory species and understory species were calculated by stratum and age class based on the 149 sampled PSPs and were used in the existing DST.

2.3.2 Starting Condition - Densities in the Enhanced DST

For overstory species, three starting conditions - high, medium, low density were defined in the enhanced DST. The previous "mean" condition used in the existing DST was used as medium.

Similarly, three starting conditions - high, medium, low density for the understory species were defined in the enhanced DST.

Because plot data are insufficient for calculating understory species (Sb and Fb) density percentiles (or standard deviations), a simple method was used for understory densities as below.

1. Medium = mean
2. High = mean adjusted 25% up
3. Low = mean 25% adjusted down

The same method was used for overstory species densities in order to be consistent. The densities for all species were adjusted up (or down) at the same rate when there were more than one species in the overstory.

3. Data and Input Matrix

3.1 Data Description

3.1.1 Surveyed PSPs in 2008

Based on a set of comprehensive criteria, a total number of 240 PSPs were selected for this project. From the total number of PSPs selected, 149 plots from 8 companies were surveyed in 2008. The number of plots surveyed for each company is presented in Table 4.

Table 4. Number and percent frequency of plots surveyed in 2008 by company.

Company	N Plots	Frequency %
BRL	5	3.4
CAN	4	2.7
HWP	13	8.7
MWF	4	2.7
SDA	4	2.7
SFP	5	3.4
SLS	3	2.0
SRD	111	74.5
Total	149	100.0

3.1.2 Variables Collected

Both quantitative and qualitative variables were collected during the 2008 field season. The collected data included measurements for trees (DBH ≥ 9.1 cm), saplings (trees < 9.1 cm in DBH and > 1.3 m in height), regeneration (trees < 1.3 m and ≥ 0.1 m in height), ecosite, non-tree vegetation, quantification of mountain pine beetle attack, arboreal lichens, and cone serotiny.

The tree information was obtained from the last re-measurement of the PSP. The plot size was represented by the actual PSP size. Age data by species were also obtained from previous PSP re-measurements. All other information was collected during the 2008 field season.

Sapling information was collected from a circular sub-plot centered on the PSP center with a radius of 5.64 m (100 m^2). Species, DBH, height, as well as the condition codes were recorded for each sapling.

Regeneration information as well as non-tree vegetation were collected from four circular 1.78 m radius plots (10 m^2) located in the four PSP quadrants. The count by five height classes was recorded for each species present in the plots.

All dead trees were recorded. The trees attacked by MPB were recorded in the entire PSP as well as the stage of the attack (green/red). The numbers of pitch tubes below and above 1.3 m were recorded.

In each quadrant, four trees closest to the center were used to assess the arboreal lichens and cone serotiny. One or two additional trees were added in some cases in order to include trees with evidence of MPB attack.

For non-tree vegetation, modal height, species, and percent cover were collected in the 4 regeneration plots.

3.2 Stand Classification

3.2.1 Strata Assignment

Stratum was determined as a function of ecosite and natural subregion (refer to Table 1). The ecosite used in the stratification was the ecosite assessed in the field. Eight strata were defined in this project based on the ecosite and the natural subregion. Each of the sampled PSPs was assigned to one of the eight strata.

3.2.2 Age Classification

Age class was determined based on the lodgepole pine total age from the PSPs data. Age class "1_50-100" was assigned to a plot if the pine total age was greater or equal to 50 years and smaller or equal to 100 years. If the pine total age was between 101 years and 140 years then age class "2_100-140" was assigned to the plot, while age class "3_140+" was assigned if the pine total age was greater than 140 years and smaller than 180 years.

3.2.3 Stand Structure

Based on the AVI field call, the sampled PSPs were grouped into single story (only overstory AVI field call) and two story stands (overstory and understory AVI field calls).

3.3 Input Matrix Framework

For each stratum, three age classes were defined as 50 to 100 year, 101 to 140 years and greater than 140 years. Growth model inputs were developed for the mid-point of each age class: 75 years, 120 years and 160 years.

There were 149 permanent sample plots sampled in 2008 across all the 8 strata and all three age classes. The sampled data were not evenly distributed across the 8 strata and did not represent a random sample of what the stands susceptible to mountain pine beetle attack might look like. Table 5 presents the distribution of the plots by strata, age class, and stand type (single or two story stands).

Table 5. Number of plots by stratum, age class, and stand type (single or two storey).

Stratum Soil	Age Class	Layers	N Plots	Percent
1	1_50-100	1	5	71
		2	2	29
	2_100-140	1	1	7
		2	13	93
	3_140+	1	5	83
		2	1	17
2	2_100-140	1	14	82
		2	3	18
	3_140+	1	5	100
3	1_50-100	1	2	100
	2_100-140	1	9	82
		2	2	18
	3_140+	1	1	100
4	1_50-100	1	10	100
	2_100-140	1	6	67
		2	3	33
	3_140+	1	1	33
		2	2	67
5	1_50-100	1	2	40
		2	3	60
	2_100-140	1	21	53
		2	19	48
6	2_100-140	1	2	50
		2	2	50
7	2_100-140	1	5	100
8	2_100-140	2	1	100

*Age classes not listed had no PSPs in the sample.

Since the actual sampled data were deemed insufficient to characterize the strata – age class combinations, the following approach was taken to develop the range of inputs required by the project. A Conceptual Framework and a Data Based Framework were both developed and were used to create the growth model input matrix.

3.3.1 Conceptual Framework

The process of defining stand types was based on the 'Field Guide to Ecosites of West-central Alberta'. The guide was used to determine, by frequency of occurrence, the most common stand types in each of the 8 strata, and whether the stands in the 8 strata were single story or two story stands. Table 3 (in Section 2.1.2) presents the developed matrix describing the most probable stand types in each stratum for the enhanced DST.

23 unique 'Stand Types' across the 8 Strata were determined and represent the most common 'typical' stand types and species compositions found in the 8 project strata.

An input matrix was developed to characterize the species composition in each stratum*age class*stand_structure combination. The matrix presents the species associations most likely to be found in any of these combinations, as well as the vertical distribution of the trees (single layer or two layers). The matrix was based on both the actual plot data and the 'Field Guide to Ecosites of West-Central Alberta'. When the data conflicted with the guide and the sample size was too small (1-4 plots) the species association described in the guide prevailed in the matrix building.

The actual data were compiled and summarized as a 'Data Based Framework' and used in generating the pre-attack inputs.

3.3.2 Data Based Framework

1. **PSP Compilations**

Data from 149 PSP plots surveyed in 2008 were compiled and used in generating the pre-attack inputs.

- Breast Height or Stump Height Age by Species

The breast height age or stump height age was recorded differently for each company according to the particular protocol used. The age measurements (breast or stump height) were taken within the plot or in the PSP's buffer at plot establishment. There are cases where age was measured at plot establishment and at re-measurements. Because of multiple age measurements, in each plot and for each species, the latest age measurements were used to calculate the mean breast height or mean stump height age.

Not all measured ages were used in the mean age calculations. The range of ages was restricted by species and plot as follows: if the individual age was smaller than the maximum age minus 20 years, that age was not used for the mean age calculations.

There were no conversions between breast height and stump height ages. For some plots, both mean stump age and mean breast height age were calculated where data were available. However, in the site index calculations, the mean stump age was used with one exception, plot 101-1, black spruce.

The mean age (stump or breast height) was grown from the year of age measurement to the year of the last PSP re-measurement to match the year of the calculated top height. The same method was applied for the FRIAA GYPSY validation project when the mean age of the PSP was compiled.

- Top Height

Only live trees (DBH ≥ 9.1 cm) were included in the top height calculation. The largest 100 trees by DBH per species and per hectare were used to calculate the top height. The exact number of trees in each plot is dependent on the PSP size.

- Site Index

Site index was calculated using GYPSY 2006 plot based equations. The mean breast height or mean stump height age together with the top height by species were used to calculate the site index. The mean age (breast or stump height) was grown forward in time until the last re-measurement when height was recorded. Where available, mean stump age was used to calculate site index. Where mean stump age was not available, breast height age was used to calculate the site index.

- Density

Based on the AVI field call, the sampled PSPs were grouped into single story (only overstory AVI field call) and two story stands (overstory and understory AVI field calls). The individual species were grouped into four species groups, similar to GYPSY groupings (Aw, Pl, Sb, and Sw).

The two story stands were split using the midpoint height between the overstory and understory AVI heights as taken from the AVI field call. For the two story stands, trees and saplings above the midpoint height were used to calculate overstory density, while trees and saplings below the midpoint height were used to calculate the understory density.

Mean densities were calculated by stratum and age class. For the two story stands, they were calculated for both the overstory and the understory layers.

Total age and site index were also compiled for each plot and species group with available data, and they were averaged by stratum and age class.

Due to missing age or stratum information, only 140 PSPs were used to compile the Data Based Framework.

2. Additional PSP for Understory Fb/Sb Compilations

Five companies (Weyerhaueser Grande Prairie, Blue Ridge Lumber, Millar Western, West Fraser Hinton Wood Products, West Fraser Sundre Forest Products) provided data compilation summaries as described below from their existing database for the 5 additional stand types (i.e.,

9a, 10a, 11a, 12a, and 13a in Table 3) to account for Fb understories as well as for the existing Sb understories.

(1) Stratification

Each plot was stratified by Stratum, Age Class, Stand Structure, and Stand Type using the same definitions in Section 3.2.

Strata are defined using the method described in section 3.2.1 and by Stratum Number (1-8) as in Table 1.

Age classes are defined based on the AVI Overstory Ages, by Age Class Number (1-3) as either 1 (50 – 100), 2 (101 – 140), or 3 (140 +) as described in section 3.2.2.

For the Stand Structure definition, the plots were grouped into single story and two story stands based on the AVI field call using the same method as described in section 3.2.3.

Stand Types were defined as Stand Type Numbers (1-18, and 9a-13a) and assigned to each plot as described in Table 3 in Section 2.1.2.

(2) Compilation Variables

For all plots with Fb understories (Stand Types 9a, 10a, 11a, 12a, and 13a), the following were summarized by Age Class and Stand Type:

- Number of Plots
- Understory Fb Mean Density, 25th and 75th percentile Densities
- Understory Fb Mean Height, Std Deviation of Height, 25th and 75th percentile Heights
- Understory Fb Mean DBH, Std Deviation of DBH

For those plots with Sb understories (Stand Types 3, 4, 6, and 8), the following were summarized by Age Class and Stand Type:

- Number of Plots
- Understory Sb Mean Density, 25th and 75th percentile densities
- Understory Sb Mean Height, Std Deviation of Height, 25th and 75th percentile Heights
- Understory Sb Mean DBH, Std Deviation of DBH

3. Pre-Attack Stand Conditions

To avoid dealing with multiple growth trajectories within the same matrix row, that might potentially lead to completely different stand types for the same matrix row, the following approach was taken to create pre-attack inputs (Table 6):

- From the Data Based Framework the matrix row mean inputs (density, site index, total age) for the age class with the most plots measured was selected.
- Site index from the actual data was checked against the Ecosite Guide's site index and adjusted to match the range of productivities described by the guide.
- Densities were checked against Phase 3 Pl density tables and in some cases adjusted to match the Phase 3 densities.
- The density projections were compared with actual plot data to ensure that they were reasonable.

For the newly added FB understory Stand Types ('9a', '10a', '11a', '12a', '13a'), the information for overstory species from the corresponding original Stand Types were used as their overstory inputs. For example, the overstory inputs from Stand Type 9 were used for Stand Type 9a.

Table 6. Modified GYPSY inputs used to create the pre-attack stand conditions.

Stand		Age	Stand					Data Based Inputs			Modified Inputs for GYPSY		
Type	Stratum	Class	Structure	Overstory	Understory	N Plots	Species	Density	SI	Total Age	Density	SI	Total Age
1	1	1_50-100	1 Layer	Pl		5	PL	1,107	14.9	80.5	1,800	14.9	80.5
2	1	1_50-100	1 Layer	Pl+Aw		5	AW		13.9	65.5	540	13.9	65.5
							PL	1,107	14.9	80.5	1,260	14.9	80.5
3	1	2_100-14(	2 Layers	Pl	Sb	13	PL	663	19.7	120.2	663	14.9	120.2
							SB	274	14.3	110.5	381	14.3	50.0
4	1	2_100-14(	2 Layers	Pl+Aw	Sb	13	AW	64	19.3	132.3	64	19.0	132.3
							PL	663	19.7	120.2	663	14.9	120.2
							SB	274	14.3	110.5	274	14.3	60.0
5	2	2_100-14(	1 Layer	Pl		14	PL	1,085	14.9	113.6	1,200	14.9	113.6
6	2	2_100-14(	2 Layers	Pl	Sb	3	PL	983	14.9	113.6	983	14.9	113.6
							SB	100	7.4	98.0	1,500	7.4	40.0
7	3	2_100-14(	1 Layer	Pl		9	PL	996	15.4	115.8	1,200	15.4	115.8
8	3	2_100-14(	2 Layers	Pl	Sb	2	PL	100	15.4	115.8	1,000	15.4	115.8
							SB	70	14.9	118.5	1,000	14.9	50.0
9	4	1_50-100	1 Layer	Pl		10	PL	1,312	19.0	78.7	1,800	15.0	78.7
10	4	1_50-100	1 Layer	Aw+Pl		10	AW				600	18.0	78.7
							PL	1,312	19.0	78.7	1,000	15.0	78.7
11	4	1_50-100	1 Layer	Sw+Pl		10	PL	1,312	19.0	78.7	1,000	15.0	78.7
							SW	346	10.7	79.0	650	10.7	79.0
12	5	2_100-14(	1 Layer	Pl		21	PL	1,022	18.2	113.3	1,022	18.2	113.3
13	5	2_100-14(	1 Layer	Aw+Sw+Pl		21	AW	468	20.6	106.6	468	18.0	106.6
							PL	1,022	18.2	113.3	700	18.2	113.3
							SW	600	9.8	112.0	600	15.0	112.0
14	6	2_100-14(	1 Layer	Pl		2	PL	1,186	17.9	110.7	1,186	17.9	110.7
15	6	2_100-14(	1 Layer	Pl+Aw+Sw		6	AW				600	17.0	110.0
							PL	1,186	17.9	110.7	800	17.9	110.7
							SW	200			200	16.0	110.0
16	7	2_100-14(	1 Layer	Pl		5	PL	494	16.3	118.5	700	18.0	118.5
17	7	2_100-14(	1 Layer	Aw+Sw+Pl		5	AW	488	15.6	106.0	488	18.0	106.0
							PL	494	16.3	118.5	494	18.0	118.5
							SW	178	11.8	114.0	178	18.0	114.0
18	8	2_100-14(	1 Layer	Sb+Pl		1	PL		15.2	107.7	1,200	15.2	107.7
							SB				1,200	11.0	107.0
9a	4	1_50-100	2 Layers	Pl	Fb	10	PL	1,312	19.0	78.7	1,800	15.0	78.7
						6	FB	677			700	10.7	30.0
10a	4	1_50-100	2 Layers	Aw+Pl	Fb	10	AW				600	18.0	78.7
							PL	1,312	19.0	78.7	1,000	15.0	78.7
						5	FB	365			400	10.7	30.0
11a	4	1_50-100	2 Layers	Sw+Pl	Fb	10	PL	1,312	19.0	78.7	1,000	15.0	78.7
							SW	346	10.7	79.0	650	10.7	79.0
						6	FB	455			500	10.7	30.0
12a	5	2_100-14(	2 Layers	Pl	Fb	21	PL	1,022	18.2	113.3	1,022	18.2	113.3
						10	FB	1,541			1,500	15.0	40.0
13a	5	2_100-14(	2 Layers	Aw+Sw+Pl	Fb	21	AW	468	20.6	106.6	468	18.0	106.6
							PL	1,022	18.2	113.3	700	18.2	113.3
							SW	600	9.8	112.0	600	15.0	112.0
						10	FB	1,541			1,500	15.0	40.0

The modified inputs in Table 6 were projected forwards and backwards using GYPSY and localized at 3 ages: 75 years, 120 years, and 160 years. These localized projection outputs (such as site index, density, BA, and top height) represent the pre-attack stand conditions at each age (midpoint of the age class). The pre-attack stand conditions were used to obtain Post Attack Stand inputs for GYPSY projections through modifications appropriate for various combinations of MPB attack, salvage treatments and regeneration options as defined in the following section.

4. Post Attack Stand Inputs

This section describes the methods used to obtain the input matrix by stratum, age class, MPB attack levels, and treatment combinations to be used as starting conditions in a growth and yield model - GYPSY. The inputs were built to describe a range of possible treatments following different levels of mountain pine beetle attack.

4.1 Projection Scenarios

4.1.1 Defining Levels of MPB Attack

Five levels of MPB attack were defined (0%, 25%, 50%, 75%, and 100% kill), and were assumed to occur in one unique kill-event.

4.1.2 Defining Salvage Treatment

Two levels of salvage treatment were defined:

- No: No removal of trees, no matter the degree of attack.
- Yes: Removal of all attacked trees, no matter the degree of attack.

4.1.3 Defining Regeneration Assumptions

The following assumptions were defined for regeneration:

- There is no pre-existing lodgepole pine natural regeneration in the stand prior to the attack

- All new regeneration of lodgepole pine following MPB attack is limited to those cases where some level of salvage is undertaken. The disturbed areas recruit natural Pine at rates observed in the FGYA RLP study; recruitment rates vary by stratum.

- In areas undisturbed by salvage, pre-existing regeneration (if present) continues to grow, but no new regeneration is recruited into the stand.

- Optional supplemental planting of pine is done where the MPB attack is followed by salvage operations.

4.1.4 Defining Silviculture Treatments

Optional scarification and site preparation to promote additional natural regeneration are available only after salvage in 100% MPB attack.

4.1.5 Projection Scenario

Based on combinations of 5 levels of MPB attack, 2 levels of salvage, 2 levels of planting, and 2 levels of site preparation, 14 scenarios were created for each stand type, age class and stratum combination selected for modeling (Table 7).

Table 7. Projection Scenarios.

Scenario Number	MPB Kill	Salvage	Natural Regen	Fill Plant	Site Prep	Scenario Type
1	0	No	No	No	No	1
2	25	No	No	No	No	2
3	25	Yes	Yes	No	No	3
4	25	Yes	Yes	Yes	No	3
5	50	No	No	No	No	2
6	50	Yes	Yes	No	No	3
7	50	Yes	Yes	Yes	No	3
8	75	No	No	No	No	2
9	75	Yes	Yes	No	No	3
10	75	Yes	Yes	Yes	No	3
11	100	No	No	No	No	2
12	100	Yes	Yes	No	No	3
13	100	Yes	Yes	Yes	No	3
14	100	Yes	Yes	Yes	Yes	3

* See section 3.2.2 for definition of Scenario Type.

The existing matrix with 23 stand types (refer to Table 3) localized at three ages 75, 120, and 160 years representing three age classes: 50-100 years, 101-140 years, and over 140 years was considered appropriate as the basis for the projections.

There are 14 stand types with 1 Layer Stand Structure and 9 Stand Types with 2 Layer Stand Structure (i.e., 4 Sb understories + 5 Fb understories.) among the total 23 Stand Types.

For 1 Layer Stand Structure, the overstory density was adjusted "up" (i.e., 25% up) and "down" (i.e., 25% down) from the mean to obtain 3 Overstory Starting Conditions (high, medium, low). This generated 1764 (=14 Stand Types X 3 Age Classes X 3 Overstory Starting Conditions X 14 Scenarios) unique stands available for model projections.

For 2 Layer Stand Structure, the overstory density was adjusted "up" (i.e., 25% up) and "down" (i.e., 25% down) from the mean to obtain 3 Overstory Starting Conditions (high, medium, low), and the understory density was adjusted "up" (i.e., 25% up) and "down" (i.e., 25% down) from the mean to obtain 3 Understory Starting Conditions (high, medium, low). This generated 3402 (=9 Stand Types X 3 Age Classes X 3 Overstory Starting Conditions X 3 Understory Starting Conditions X 14 Scenarios) unique stands available for model projections.

At the result, 5166 (1764+3402) unique stands in total were generated and available for model projections.

4.2 Starting Conditions

4.2.1 Starting Conditions

The pre-attack stand inputs obtained from GYPSY projections and from the compiled regeneration data were modified using the intensity of the MPB attack and presence/absence of salvage operations to obtain the post-attack stand conditions.

1. Overstory and Understory

For Overstory and Understory, the pre-attack stand conditions were used to obtain Post Attack Stand inputs for GYPSY projections after modifications to account for the MPB attack levels and salvage operations.

2. Regeneration

- Existing Regeneration

The existing regeneration densities for Aw, Sb and Sw were estimated based on the PSP data, Ecosite Guide, single or two story type of stand, and stand age. The density of black spruce natural regeneration was considered to increase with the age of the stand. The black spruce density in a two layers 75 years old stand was estimated at 1500 stems per hectare (spha) and at 4000 spha in a 120 and 160 years old stand. The white spruce and aspen densities were considered 3000 spha for all three age classes.

- New Natural Pine Regeneration

The natural Pine regeneration recruitments were determined at the rates observed in FGYA RLP study. Natural regeneration densities post-salvage were calculated to reflect site preparation and no site preparation, and are stratum specific.

- New Pine Planting

Planted Pine density was estimated at 2000 spha 10 years after the MPB attack and the salvage operations.

4.2.2 Input Modifications and Area Reductions

The 14 scenarios in Table 7 can be grouped into three types. Each type involves a series of assumptions and model projections. The three types of scenarios identified are presented below:

1. Type 1 – no kill, no salvage, no planting, no new natural regeneration (1 scenario)

2. Type 2 – MPB kill (25%, 50%, 75%, 100%), no salvage, no planting, no new natural regeneration (3 scenarios)

3. Type 3 – MPB kill (25%, 50%, 75%, 100%), salvage, site preparation or no site preparation, planting or no planting, and new natural regeneration (7 scenarios)

The post-attack stand inputs were calculated differently for each combination.

1. Type 1 Scenarios

Type 1 scenarios represent stands with no kill, no salvage, no planting, no new PL natural regeneration. The pre-attack inputs were used for the post-attack stand inputs.

2. Type 2 Scenarios

Type 2 scenarios represent stands that were attacked by MPB (25%, 50%, 75%, 100%), but there was no salvage, no planting, and therefore no new regeneration.

Only pre-attack overstory Pl density and BA were reduced to reflect the MPB kill levels and used as post-attack stand inputs.

- N_PLpost-attack = (1-%MPB kill)*N_PLpre-attack

- BA_PLpost-attack = (1-%MPB kill)* BA_PLpre-attack

No adjustments were made for post-attack density or BA for non-pine overstory species, or any understory or regeneration layer species.

3. Type 3 Scenarios

Type 3 scenarios are represented by stands affected by MPB kill (25%, 50%, 75%, 100%), salvage, site preparation or no site preparation, planting or no planting, and new natural regeneration. The area of these stands is split into the remnant stand area and the salvaged stand area.

The following assumptions were made:

- For the remnant stand portion (i.e. not attacked by MPB), the overstory pine input basal area and density were reduced with a percentage equal to the percent kill, with no further adjustments from MPB attack for any other species or layers. The projected Remnant Stand volumes were applied to the remnant portion of the stand.

- The Salvaged Stand Area was calculated based on the Post-Attack Densities. This is the area that is grown as a clear cut and it is represented by the area formerly occupied by the MPB killed and salvaged pine.

The percentages of Salvage Stand Area and Remnant Stand Area are calculated based on the overstory species specific densities as below:

- %Salvage Stand Area = N_PLpre-attack* %MPB_kill/SUM (N_PLpre-attack, N_SBpre-attack, N_SWpre-attack, N_AWpre-attack)

- %Remnant Stand Area = 1 – %Salvage Area

An additional 15% mortality was assumed for all species and all the layers as a result of salvage operation impacts in the Remnant Stand Area.

The area and the salvage adjustment were applied only to the Type 3 scenarios. Figure 1 shows an example of how the Remnant and Salvage Area were calculated in a hypothetical two story stand affected by 25% MPB kill.

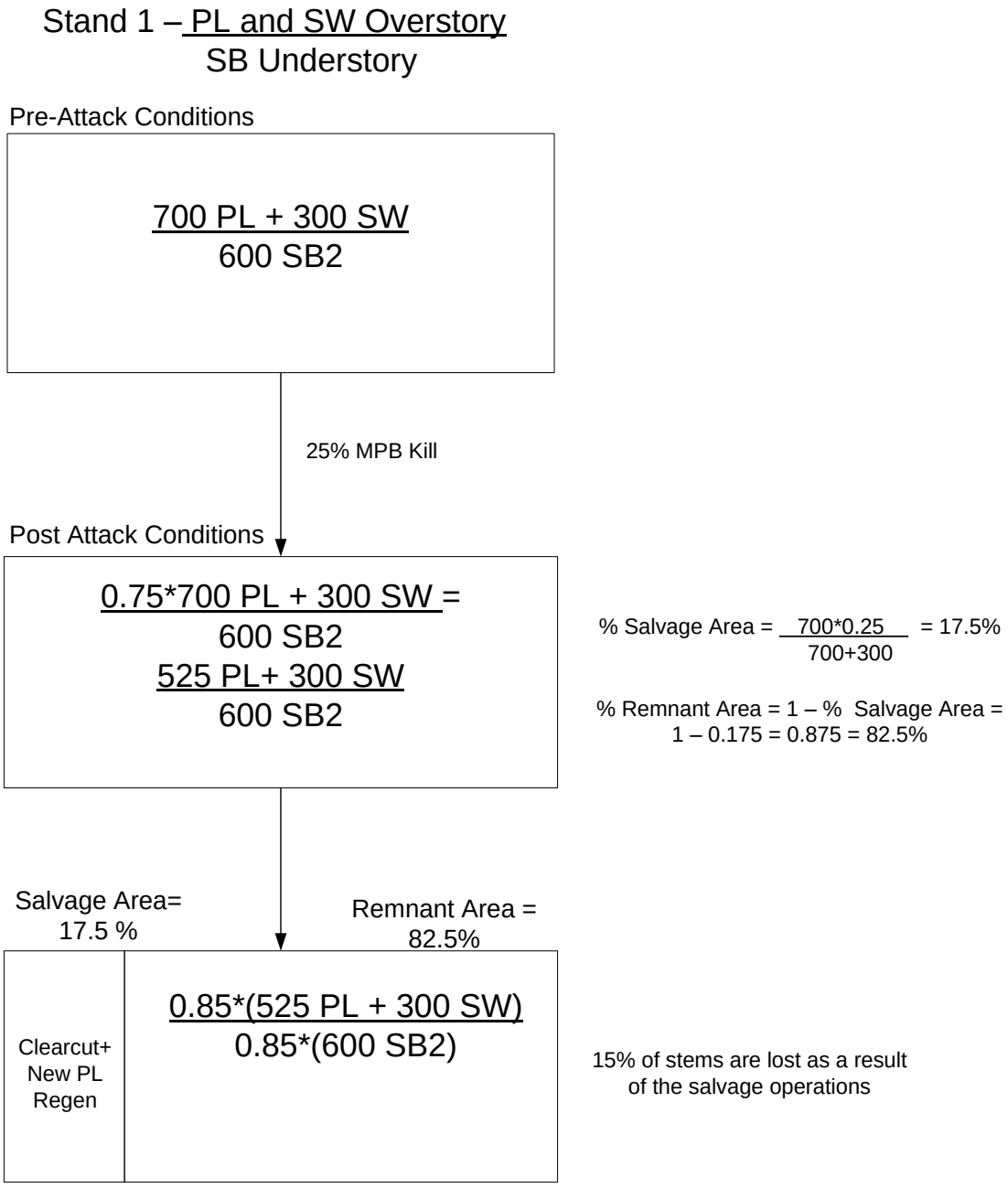


Figure 1. Example of Remnant and Salvage Areas calculations for the DST reporting.

4.2.3 Post Attack Stand Inputs

The 14 projection scenarios for each of 23 stand types at each of 3 ages and at each of 3 Overstory/3 Understory Starting Conditions produced 5166 unique scenarios for stand projections using the Growth Models.

The Excel workbook provided in a CD with this document details the variables used as inputs as well as the pre-attack/post-attack values for each of the 5166 unique scenarios used to create growth projections with GYPSY.

5. Stand Projections

Projections from the growth and yield models describe future stand conditions post mountain pine beetle attack. Two growth and yield models - GYPSY and MGM were used in the existing DST project.

In this enhanced DST, only GYPSY was used for growth projections due to two reasons: (1) GYPSY is widely acknowledged as being the most applicable model for lodgepole pine in Alberta. Therefore it is most applicable in the MPB world. (2) MGM is very unwieldy for 'batch processing' of large numbers of projections.

5.1 GYPSY Projections

GYPSY (short for Growth and Yield Projection System) is a forest growth model composed of a number of sub-models or functions.

5.1.1 GYPSY_Layers3

Shongming Huang at SRD provided The Forestry Corp with a new version of GYPSY - GYPSY_Layers3, capable of handling data from 4 species groups located in three layers: layer1 – overstory, layer2 – understory, and layer3 – regeneration.

The following species groups can now be included in the input dataset to be projected with the model: AW, SB, SW, PL representing the overstory, AW2, SB2, SW2, PL2 to represent the understory, and AW3, SB3, SW3, PL3 to represent the regeneration layer. The stand density factor (SDF) functions for each of the twelve components have been modified to accommodate the interactions between the 12 components. Understory FB was treated as SW2 in GYPSY.

The SDFs for AW, AW2, AW3, SB, SB2, and SB3 are independent of each other and of any other species. The other six SDFs are dependent on other species' SDFs as follows:

SDFSW = *f*(SDFAW)

SDFSW2 = *f*(SDFAW, SDFAW2)

SDFSW3 = *f*(SDFAW, SDFAW2, SDFAW3)

SDFPL = *f*(SDFAW, SDFSB, SDFSW)

SDFPL2 = *f*(SDFAW, SDFAW2, SDFSB, SDFSB2, SDFSW, SDFSW2)

SDFPL3 = *f*(SDFAW, SDFAW2, SDFAW3, SDFSB, SDFSB2, SDFSB3, SDFSW, SDFSW2, SDFSW3)

The species composition for the overstory layer is calculated as the ratio between the species overstory density and the sum of the species in the overstory (Example 1).

Example 1 – Layer1 (Overstory, AW)

SC_AW = den_AW/sum(den_SB, den_AW, den_PL, den_SW)

The species composition for the understory layer is calculated as the ratio between the species understory density and the sum of densities from the overstory and understory (Example 2).

Example 2 – Layer2 (Understory, AW)

SC_AW2 = den_AW2/sum(den_SB2, den_AW2, den_PL2, den_SW2, den_SB, den_AW, den_SW, den_PL)

The species composition from the regeneration layer is calculated as the ratio between the species regeneration density and the sum of densities from all three layers: overstory, understory, and regeneration (Example 3).

Example 3 – Layer3 (Regeneration, AW)

SC_AW3 = den_AW3/sum(den_SB3, den_AW3, den_PL3, den_SW3, den_SB2, den_AW2, den_PL2, den_SW2, den_SB, den_AW, den_SW, den_PL)

5.1.2 GYPSY Inputs

For each projected species, GYPSY requires the following variables as inputs: density (N), BA (optional), site index (SI), total age.

5.1.3 GYPSY Projections

A detailed description of the GYPSY runs is presented below.

1. Type 1 Scenarios

The post-attack inputs (N, BA, SI, Total Age) for all the stand type components (all layers and species groups) were used to do the stand projections using GYPSY_Layers3. The post-attack inputs are equal to the pre-attack inputs. The outputs represent the baseline scenario, no attack and no salvage operations and they were applied to 100% of the stand area.

2. Type 2 Scenarios

In this Scenario, the modified overstory PL density and basal area, plus the pre-attack stand conditions for all other species and layers, were used to do the stand projections using GYPSY_Layers3. The outputs represent the results for these scenarios and were applied to 100% of the stand area.

3. Type 3 Scenarios

Step 1. Project the Remnant Stand

The modified overstory PL density and basal area, plus the pre-attack stand conditions for all other species and layers, were used to do the stand projections using GYPSY_Layers3. The GYPSY projections (volumes, density, and BA) were adjusted downwards by 15% to account for the salvage damage. The reduction was applied to all species and all the layers as a result of salvage operations in Remnant Stand Area.

Step 2. Project the Salvage Area (New Regeneration and Planting)

The New Natural Regeneration and the New Planted Regeneration were used to do the stand projections using GYPSY_Layers3. In the Salvage Area there is only pine growing similar to the pine in a clear cut. Pine densities in the Salvage Area reflect natural pine recruitment, variable by stratum, plus supplemental planting if specified.

Step 3. Summarize Volumes for Type 3 Projections

On an area-weighted basis, the Remnant Stand volume gets applied to the %Remnant Stand Area, while the volume grown in the Salvage Area gets applied to the %Salvage Stand Area.

6. Wood Quality Parameter

6.1 Parameter Lists

The following four wood quality parameters (Non-Mensurational Response Variables) were required for the first 10 years of projection in DST Application.

1. MPB Killed Trees Standing;
2. MPB Killed trees with checks;
3. MPB Killed trees with saprot;
4. MPB Killed trees with woodborer damage.

For each Stratum X Species/Stand Structure X Age Class combination, there are 14 projection scenarios (see section 4.1.5) as follows:

1. No MPB Kill
2. 25% MPB Kill, no salvage
3. 25% MPB Kill + Salvage
4. 25% MPB Kill, + Salvage + Planting
5. 50% MPB Kill, no salvage
6. 50% MPB Kill + Salvage

7. 50% MPB Kill, + Salvage + Planting
8. 75% MPB Kill, no salvage
9. 75% MPB Kill + Salvage
10. 75% MPB Kill, + Salvage + Planting
11. 100% MPB Kill, no salvage
12. 100% MPB Kill + Salvage
13. 100% MPB Kill, + Salvage + Planting
14. 100% MPB Kill, + Salvage + Planting + Site Prep

Wood quality parameters were required for Projection Scenario Numbers 2, 5, 8 and 11 (MPB Kill in the absence of salvage). Wherever there is salvage, it is assumed that all MPB Killed trees are salvaged and harvested, therefore no MPB killed trees are left for which to report wood quality parameters.

6.2 Parameter Calculations

6.2.1 Fall Down Rate

All trends are based on Lewis and Thompson, 2009 (Change in wood quality and fall rate of trees up to ten years after death from mountain pine beetle. 2009. Lewis, K.J.; Thompson, D. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Mountain Pine Beetle Working Paper 2008-30).

It is assumed that there is 0 fall-down of MPB killed trees for years 1 to 5. Fall-down begins in year 6, and is equal annually for years 6 to 10, with final fall-down proportions by year 10 that are Stratum-specific as follows:

Stratum 1 (dry): 50% of MPB killed stems are down by year 10

Strata 2, 3, 4, 5 (mesic): 25% of MPB killed stems are down by year 10

Strata 6, 7, 8 (wet): 18% of MPB killed stems are down by year 10

Fall-down applies only to the MPB killed portion of the PL density, and not to any other species.

6.2.2 MPB Killed Trees Standing

For years 1 to 5, because of 0 fall-down of MPB killed trees, the number of MPB Killed Trees Standing is equal to MPB killed stems.

For years 6 to 10, the number of MPB Killed Trees Standing is calculated using the equation below:

# of MPB Killed Trees Standing = MPB killed stems*(1- Fall Down Rate*(Year-5)/5).

For Example:

Assume Stratum 1 (dry), pre-attack PL density = 2000, 50% kill, therefore post-attack live PL density = 1000 and post-attack standing dead PL density = 1000.

Years 1 to 5: Standing Dead PL density = 1000

Year 6: Standing Dead PL density = 900

Year 7: Standing Dead PL density = 800

Year 8: Standing Dead PL density = 700

Year 9: Standing Dead PL density = 600

Year 10: Standing Dead PL density = 500

That is, for year 6 to 10, the annual fall-down is equal, and such that the year 5 standing dead PL density is reduced by 50%.

6.2.3 MPB Killed Trees with Checks

The proportion of standing MPB killed trees with checks increases by year, and the rate of increase is the same for all projections (no difference by stratum, age class or stand structure) as follows:

Year	% trees with checks
0	0
1	30
2	70
3	70
4	70
5	70
6	80
7	90

8	90
9	100
10	100

The number of Standing MPB Killed trees with checks is calculated as:

# of Standing MPB Killed trees with checks = # of MPB Killed Trees Standing*Check Rate

6.2.4 MPB Killed Trees with Saprot

The proportion of standing MPB killed trees with saprot increases by year, and the rate of increase is the same for all projections (no difference by stratum, age class or stand structure) as follows:

Year	% trees with saprot
0	0
1	30
2	50
3	50
4	80
5	80
6	80
7	90
8	100
9	100
10	100

The number of Standing MPB Killed trees with saprot is calculated as:

# of Standing MPB Killed trees with saprot = # of MPB Killed Trees Standing* Saprot Rate

6.2.5 MPB Killed Trees with Woodborer Damage

The proportion of standing MPB killed trees with woodborer damage increases by year, and the rate of increase is the same for all projections (no difference by stratum, age class or stand structure) as follows:

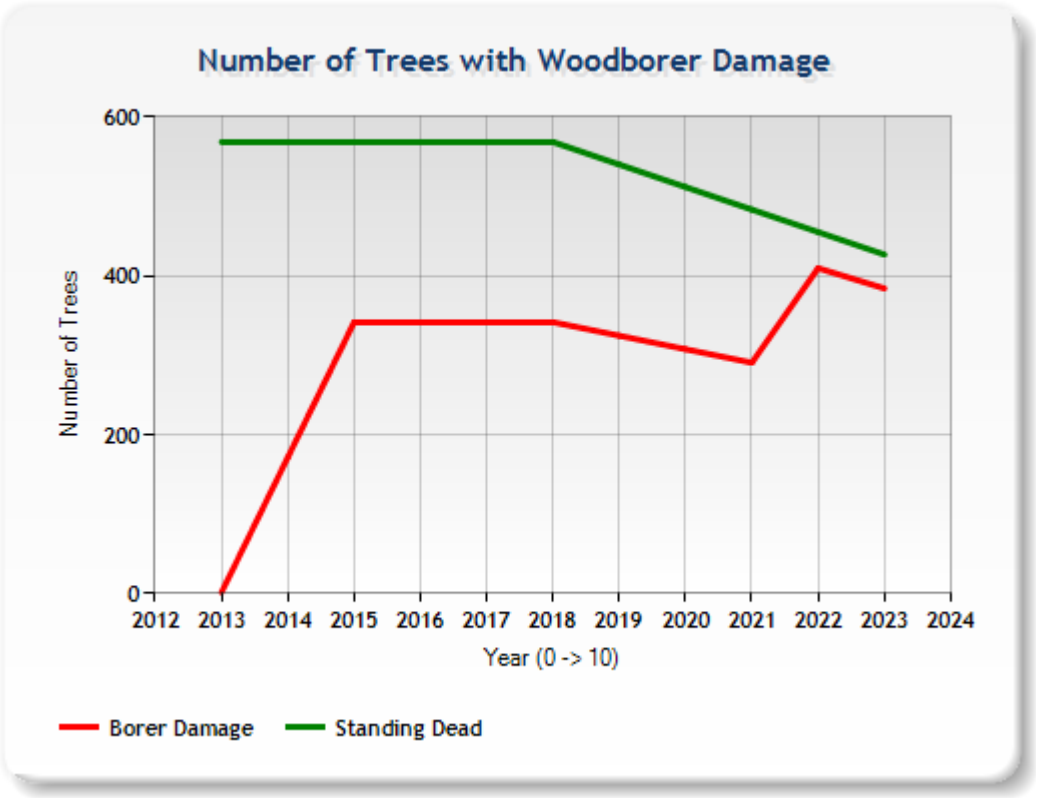
Year	% trees with woodborer
0	0
1	30
2	60
3	60
4	60
5	60
6	60
7	60
8	60
9	90
10	90

The number of Standing MPB Killed trees with woodborer is calculated as:

# of Standing MPB Killed trees with woodborer = # of MPB Killed Trees Standing* Woodborer Rate

6.2.6 Wood quality Charting Anomalies

Wood quality parameters are expressed as the number of standing trees with a certain condition (checks, saprot, wood borer damage). These 'numbers' are calculated as a proportion of the trees still standing, over time, after MPB attack. Because of this, the numbers of standing trees with a certain condition after MPB attack can appear to decrease, and then to increase again (see example for Woodborer Damage in the figure below). This is a function of the changing proportions of standing trees with a given condition over time (as described and listed above), and how those proportions are applied against the changing numbers of standing dead trees. As a result, caution is advised in user interpretation of these trends.


Number of Trees with Woodborer Damage
600
400
200
0
Number of Trees
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year (0 -> 10)
Borer Damage
Standing Dead

7. Decision Support Tool Application

7.1 Decision Support Tool Description

Enhanced Mountain Pine Beetle (MPB) Decision Support Tool (DST) is a Web-based application. The DST is designed to help users assess the impacts of different levels of MPB infestation, and various silviculture interventions, on post-attack stand development.

Enhanced DST can provide stand level projections of pre- and post-attack conditions, by assimilating growth model outputs, monitoring assessments and domain knowledge expertise such that forest planners can incorporate appropriate management strategies to mitigate the medium and long term impacts on timber supply.

The user may undertake the following using Enhanced DST:

- Quantify the impacts of different levels of lodgepole pine mortality that leave varying residual structures of live trees following MPB attack
- Quantify the impact of different regeneration assumptions following varying degrees of MPB attack
- Identify and project differences in secondary structure and regeneration observed or hypothesized in different stand types (ecosites)

Intended users are forest planners at the compartment, operating area or FMA level. Users are given User ID's and Passwords by the System Administrator. The archived 'Answer Database' contains the results from all GYPSY projections.

7.2 Method to Use

Users can define simulation scenarios by specifying growth model, ecosite, stand structure, species composition, stand age, MPB severity, silviculture intervention, overstory density adjustment, and understory density adjustment. For each defined scenario, the application searches the pre-populated 'Answer Database' and reports stand growth projections.

Users can specify:

- Model preference (GYPSY only)
- Stratum (one of 8 possible)
- Stand Structure (pre-defined for each Stratum)
- Current Age Class (75, 120, 160)
- MPB Mortality Level (0, 25, 50, 75, 100%)
- Intervention (determined by MPB kill level %)
    - No Salvage (Base Run)
    - Salvage (implies Natural Pl Regen)
    - Salvage + Supplemental Planting
    - Salvage + Supplemental Planting + Site Preparation (only for 100% Kill and Salvage)
- Overstory Density Adjustment (25% up, mean, 25% down)
- Understory Density Adjustment (25% up, mean, 25% down)

The application queries the 'Answer Database' for Scenarios specified by the user.

7.3 Simulation Results

The results are reported from the run that projects the Scenario specified by the user.

Simulation results include tabular and graphical reports of standard mensurational stand growth attributes, and post-MPB wood quality metrics, for 100 years and 10 years post-attack, respectively.

Tabular and graphic outputs include:

1. Mensurational stand growth parameters for 100 year projection period:

Layer	Species Reported	Ave. Ht (m)	Basal Area (m2/ha)	Merch Vol. (cu.m./ha) @ 15/10, .30 m stump	Density (stems/ha)
Overstory	All present	√	√	√	√
Pre-Existing Understory	SB and FB only	√	√	√	√
Pre-Existing Regeneration	All present	√	√	√	√
New Regeneration	PL only	√	√	√	√

- Overstory merchantable volume (15/10, stump ht=30 cm) by species.
- Understory SB merchantable volume (15/10, stump ht=30 cm). (where applicable)
- Understory FB merchantable volume (15/10, stump ht=30 cm). (where applicable)
- Regen merchantable volume (15/10, stump ht=30 cm) by species.
- Overstory total density by species.
- Understory SB total density. (where applicable)
- Understory FB total density. (where applicable)
- Regen total density by species.
- Overstory total BA by species.
- Understory SB total BA. (where applicable)
- Understory FB total BA. (where applicable)
- Regen total BA by species.
- Overstory average height by species.
- Understory SB average height. (where applicable)

- Understory FB average height. (where applicable)
- Regen average height by species.

2. Wood quality parameters for first 10 years of projection:
   - MPB Killed Trees Standing.
   - MPB Killed trees with checks.
   - MPB Killed trees with saprot.
   - MPB Killed trees with woodborer damage.

Table 8 lists the species reported in the DST's outputs for mensurational stand growth parameters and wood quality parameters for each stand type.

Table 8. Species reporting specification.

Stand Types	Stratum	Stand Struct.	Over Sp. Comp	Under Sp. Comp	Pre-Existing Overstory				Pre-Existing Understory	Pre-Existing Regen			New Regen
					PL	AW	SB	SW	SB or FB	AW	SB	SW	PL
1	1	1 layer	Pl		X								X
2	1	1 layer	Pl+Aw		X	X							X
3	1	2 Layers	Pl	Sb	X				X		X		X
4	1	2 Layers	Pl+Aw	Sb	X	X			X		X		X
5	2	1 layer	Pl		X								X
6	2	2 Layers	Pl	Sb	X				X		X		X
7	3	1 layer	Pl		X								X
8	3	2 Layers	Pl	Sb	X				X		X		X
9	4	1 layer	Pl		X								X
10	4	1 layer	Aw+Pl		X	X				X			X
11	4	1 layer	Sw+Pl		X			X				X	X
12	5	1 layer	Pl		X								X
13	5	1 layer	Aw+Sw+Pl		X	X		X				X	X
14	6	1 layer	Pl		X								X
15	6	1 layer	Pl+Aw+Sw		X	X		X					X
16	7	1 layer	Pl		X								X
17	7	1 layer	Aw+Sw+Pl		X	X		X					X
18	8	1 layer	Sb+Pl		X		X						X
9a	4	2 Layers	Pl	Fb	X				X				X
10a	4	2 Layers	Aw+Pl	Fb	X	X			X	X			X
11a	4	2 Layers	Sw+Pl	Fb	X			X	X			X	X
12a	5	2 Layers	Pl	Fb	X				X				X
13a	5	2 Layers	Aw+Sw+Pl	Fb	X	X		X	X			X	X

X: denotes attributes for that species need to be reported

Users can:

1. View results (tabular)
2. Report results (tabular + graphic)
3. Save Scenario specifications
4. Export results to Excel

5. Print results report to PDF

All MPB attack events, and subsequent management interventions, if any, are assumed to occur simultaneously in the year 2013. Projection results are presented in tables and graphs starting in the year 2023, ten years after the occurrence of MPB attack and subsequent treatments. In 2023, any new regeneration from ingress and/or planting will be ten years old, the earliest age at which it is reasonable for GYPSY to begin forward stand development projections.

Users may see apparent 'wobbles' in the projection lines in some output graphs. These are the result of a smoothing function used to produce graphic output from the output tables, and do not reflect 'real' trends in the years between sequential ten-year projection periods. For exact values at ten-year projection intervals, users are referred to tabular output results, and are cautioned against graphic interpolation between projection intervals.

The following legend explains the symbols used for graphical output:

OS = Pre-Existing Overstory
US = Pre-Existing Understory
PR = Pre-Existing Regeneration
NR = New Regeneration

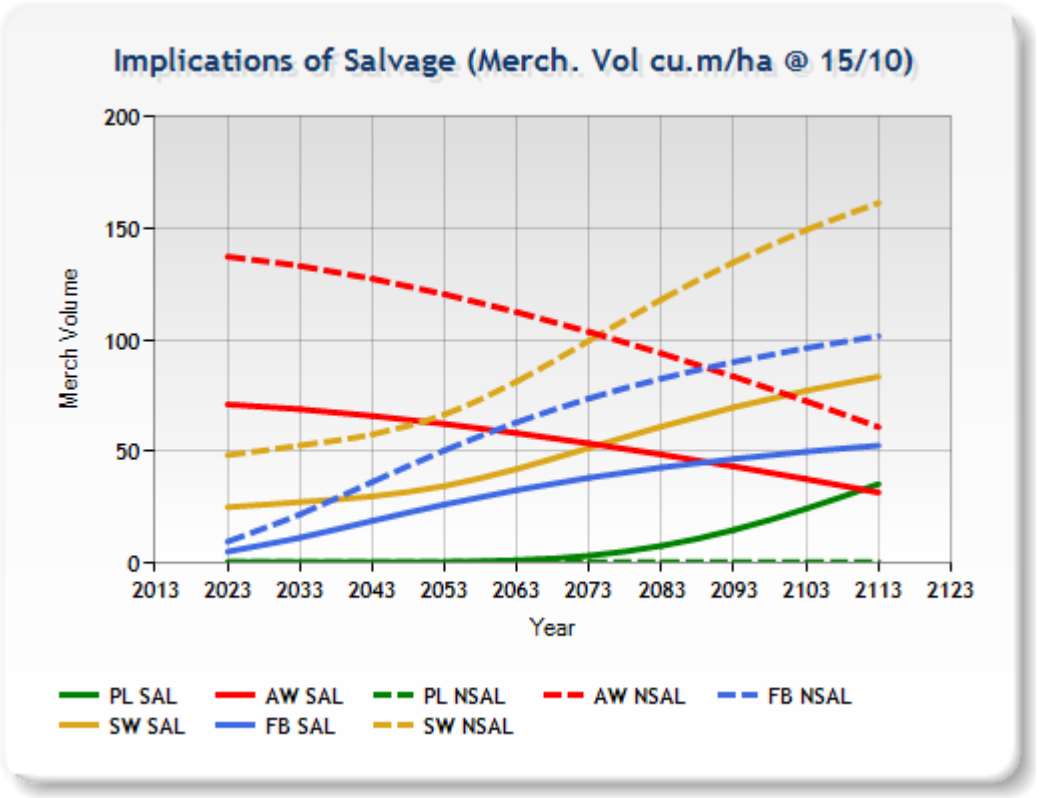
Each of these prefixes is followed by a species group label as appropriate for the species group cohort being described in the graph. New Regeneration is a combination of natural regeneration and planted regeneration as appropriate for the management interventions specified by the user.

For projection scenarios that contemplate salvage of MPB killed stems, the final output graph presented is labelled Implications of Salvage (Merch. Vol cu.m/ha @ 15/10). This graph is intended to illustrate the long term effects of salvaging MPB killed stems versus not salvaging those stems and letting the resultant stand develop and grow in the absence of any post-attack intervention. Therefore, it compares, for a given set of stand, MPB attack and intervention prescriptions, the forecast stand development when salvaged, and when not salvaged.

For the example below, all chart lines with a suffix of "NSAL" describe the long term projection for the stand, after MPB attack, if the stand is not salvaged. Similarly, all lines with the suffix "SAL" describe the long term stand development of the same stand, after MPB attack, where all MPB killed stems are removed in a salvage operation.

Note, in this example, the stand specification was for 100% MPB Kill, therefore there is no line for PL NSAL, since all PL stems are assumed to have been killed, none remain living, and in the absence of any salvage, there is no natural or artificial regeneration assumed to occur. Where MPB-killed stems are salvaged under the same scenario, a new cohort of PL is established, as shown by the green line labelled "PL SAL".

Each of the other species groups project less volume, long term, under salvage vs non-salvage, because some of the existing non-PL stems are assumed to be removed and/or damaged during the salvage operation, leaving less residual growing stock for those species to produce volume after the salvage operation.


Implications of Salvage (Merch. Vol cu.m/ha @ 15/10)
Merch Volume
200
150
100
50
0
2013
2023
2033
2043
2053
2063
2073
2083
2093
2103
2113
2123
Year
PL SAL
AW SAL
PL NSAL
AW NSAL
FB NSAL
SW SAL
FB SAL
SW NSAL

8. GYPSY Projection Issues

In the course of DST development, and related GYPSY projections, a number of issues were identified related to challenges of using GYPSY for the projection of post-MPB attack stands. These are described below.

Early Regeneration Densities of Lodgepole pine

GYPSY was designed, and is useful for, the forward projection of stands from "*about ten years of age*", and for that reason, the results presented in the DST begin ten years after MPB-attack and subsequent stand intervention. The inappropriate backwards-projection of densities from year ten to year one using GYPSY mortality functions results in infeasible very early densities.

Data from FGYA Regeneration of Lodgepole Pine trials provide reasonable ranges of early regeneration densities that can be expected for the various strata in the DST. These early density trends (from year one to year ten) are at odds with those from backwards extrapolations in GYPSY (from year ten to year one).

A useful revision of GYPSY, to include reasonable estimates of very early (< 10 years) stand densities, will give managers the ability to compare observed early stand densities with those projected by GYPSY, in order to decide if actual early stands are 'on-line' to achieve the later stand development trends projected by the model.

Inclusion of Balsam Fir in the White Spruce Species Group

GYPSY does not explicitly model the development of balsam fir, a potentially important cohort of many lodgepole pine dominated stands susceptible to MPB attack. Rather, balsam fir is included in the white spruce species group.

In order for long term projections of balsam fir understories after MPB attack to be more robust, it would be useful for balsam fir to be explicitly included in its own species group. Data

limitations will likely limit this possibility for GYPSY in the near term, but the recognition of this issue should influence the design of ongoing monitoring efforts.

Unvalidated Version of GYPSY Layers 3

All DST stand projections were undertaken with an "*un-approved*" version of GYPSY provided by AESRD. This version was provided in an attempt to be able to project the multi-layered stands contemplated in the DST.

Validation of the GYPSY Layers 3 version used here will serve to support the acceptance of the stand projections currently incorporated in the DST.

Non-spatial GYPSY

Area-partitioning of post-MPB attack stands was used in the DST to approximate the effects of partial MPB kill, and of salvage of MPB-killed stems, on subsequent stand development. This was necessitated because GYPSY was not able to model directly the spatial implications of partial MPB attack and of salvage. Admittedly, this is a complex issue, and is one not easily solved.

The value and utility of a spatial version of GYPSY, and the effort and commitment to produce the same, should be carefully considered prior to a decision to pursue the incorporation of spatial effects into GYPSY.

9. References

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Appendix I Post Attack Stand Inputs Tables

1. Post Attack Stand Inputs Table for GYPSY

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