



Morice & Lakes Innovative Forest Practices Agreement

Epidemic Mountain Pine Beetle Curve Adjustments

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1.0 Introduction

This document details the methods used for adjusting yield curves in the Morice IFPA Decision Scenario and the Lakes IFPA Base Case Scenario. This methodology was used in the Morice IFPA Recreation and Forest Productivity scenarios to account for non-recoverable volume losses. The foundations of these adjustments are the projections of the British Columbia Mountain Pine Beetle (BCMPB) project. The basic method is to apply the BCMPB projections in reducing yield curves as precisely as possible according to a stand's age, landscape unit, and pine component class. These adjustments were conducted in January and February of 2005.

2.0 Basic Assumptions

- Consistent with the IFPA approach of carrying high resolution, stand specific yield-functions, these epidemic related volume loss adjustments were implemented at the highest resolution supported by the available data.
- Stands are allowed to increase in volume following epidemic induced losses according to rates of growth previously determined for those stands. Those growth rates are moderated by the projected proportion of residual live pine.
- For strata with some pine component, the pine component is assumed to remain constant prior to epidemic loss adjustments being made.
- The Mountain Pine Beetle (MPB) epidemic ends when the BCMPB project's projections end in 2013.
- Beetle killed pine volume dead no longer than 5 years is viable for saw-logs and is added back to the yield function.

3.0 Generalized Description of Epidemic Loss Yield Curve Modifications

1. Select stands that require adjustments for MPB epidemic related mortality.
2. Isolate the pine volume component.
3. Determine depletion amounts using BCMPB data.
4. Determine the proportion of live pine remaining during and after the epidemic based on the BCMPB projections.
5. If a specific stratum crosses stands of significantly different ages and/or landscape units, then split the stratum along the stand boundary to form 2 separate strata.
6. Determine pine rates of growth or annual increments for each yield curve data point.
7. Generate new data points on yield curves for years 2003, 2008, and 2013.
8. Apply depletion amounts specific to the year, landscape unit and percent pine component class of each strata.
9. Grow the residual live pine component according to the previously determined annual increment moderated by the proportion of live pine remaining.
10. Determine the amount of pine volume dead no longer than five years and add this saw-log volume back to the stand's pine volume.
11. Add the modified pine volume to the non-pine volume previously separated.

4.0 Details of Epidemic Loss Yield Curve Modifications

All stands with a pine component and a projected time zero age of 45 years or older were selected to have epidemic loss adjustments applied to them. The projected loss amounts that were developed in the BCMPB project provided the basis of the adjustments. These initial figures were supplied for both the Lakes TSA and Morice TSA at the resolution of Landscape Units subdivided into percent of pine component classes (pcpClasses). According to these initial figures, all stands with a pine component at least 60 years old would experience mortality due to MPB. Stands having an age of 45 years were selected to be modified since they would reach an age of 60 years by 2013 – the assumed end of the epidemic.

The next step in the process was to determine the pine component of each stand and to use these components to assign stands to percent pine component classes (pcpClasses) according to the same class breaks that were used in the BCMPB Project.

pcpClass = 0 where PineComponent=0
pcpClass = 10 where PineComponent >0 And <=10
....
pcpClass = 100 where PineComponent >90 And <=100

Pine component curves were derived by subtracting the non-pine component volume. The assumption was that a stand composed of 50% pine would have exactly half its volume in pine at all times in its development prior to the epidemic loss adjustments. The annual pine increment was then determined for each data point (m³/ha/yr).

In cases where a yield curve was originally intended to be used by similar stands of significantly different ages then that strata was split. This was necessary to maintain a high level of resolution, since in this methodology yield curve modifications for a 60 year old stand begin at a different point on the yield curve than yield curve modifications for a 120 year old stand.

Similarly in cases where a yield curve was originally intended to be used by similar stands in different landscape units then that strata was split into two strata. Again the BCMPB projections indicate different percentages of pine killed in different landscape units. Therefore strata duplication was done to maximize the spatial resolution of the epidemic loss modifications being made to the yield curve functions.

The effort to maintain the highest resolution possible was facilitated by added new data points to the yield curves to represent the years 2003, 2008 and 2013. This allowed yield curve adjustments to occur in years where the BCMPB projections apply. The annual pine increment figures previously determined were used to derive interpolated volumes (i.e. y-values) for these new data points prior to any epidemic loss adjustments being made.

Table 1 outlines how the depletion and proportion of residual live pine were calculated using data from the BCMPB project.

**Table 1. Example Depletion Amounts and Proportion of Pine Remaining
(based on BCMPB projections)**

	Example A	Example B	Description
Landscape Unit	Babine East	Intata	
pcpClass	40	100	
PV03	115,200	3,136,272	Total Pine Volume in 2003
PV08	115,194	3,136,269	Total Pine Volume in 2008
PV13	115,196	3,136,271	Total Pine Volume in 2013
VK03	12,070.40	2,044,194.40	Volume Killed as of 2003: D1:VK2003
VK08	51,432.55	2,881,130.75	Volume Killed as of 2008
VK13	81,534.05	2,968,748.55	Volume Killed as of 2013
R1	103,129.60	1,092,078.00	Residual LIVE Volume in 2003: PineVolume-volumeKilled in 2003
D2	39,362.15	836,936.40	VOLUME KILLED SINCE 2003 AS OF 2008 : VK03- VK08
R2	63,767.45	255,141.30	Residual LIVE Volume in 2008: R1-D2
D3	30,101.50	87,617.80	VOLUME KILLED SINCE 2008 AS OF 2013: VK08-VK13
R3	33,665.95	167,523.50	Residual LIVE Volume in 2013: R2-D3
T0_DEPL	0.10	0.65	PCT OF RESIDUAL LIVE VOLUME KILLED AS OF 2003
T5_DEPL	0.38	0.77	PCT OF RESIDUAL LIVE VOLUME KILLED SINCE 2003 AS OF 2008
T10_DEPL	0.47	0.34	PCT OF RESIDUAL LIVE VOLUME KILLED SINCE 2003 AS OF 2008
PPR_2003	0.90	0.35	proportion of pine remaining: (1-VK03/PV03)
PPR_2008	0.55	0.08	proportion of pine remaining: (1-VK08/PV08)
PPR_2013	0.29	0.05	proportion of pine remaining: (1-VK13/PV13)

The sequence of steps shown in Table 2 was applied to reduce pine volumes according to the BCMPB projections and subsequently grow the residual live pine volume components during and shortly after the assumed ten years of the MPB epidemic. After each depletion step the residual live pine volume increased according to the previously determined pine rate of growth factor moderated by the proportion of residual live pine remaining.

The dead wood volumes were calculated and then any volume dead for 5 years or less was added back to the pine volume component to contribute to saw-log volume. This phase is also detailed in Table 2.

Table 2. Example Pine Component Curve Adjustments Sequence

VARIABLE LABEL	VALUE	DESCRIPTION
Example Curve	A	
	Intata	Landscape Unit
	95%	Pine Component
pcpClass	100	Percent component pine class
T0	74	Time zero age (2003)
Delta	4	Difference between previous data point and time zero age: used in determining transitional rates of growth for new data points.
PrevDP	70	Previous Data Point: Beginning of transition period where epidemic loss volume adjustments occur and merchantable dead volume amounts are determined. Original Curve Data
PrevDP_Y	89.09	Y Value of yield curve at PrevDP. Original Curve Data

VARIABLE LABEL	VALUE	DESCRIPTION
ROG_1	2.63	Rate of growth in m ³ /ha/yr from PrevDP to NextDP. Derived
NextDP	80	Ten years after prevDP. Original Curve Data
NextDP_Y	115.42	Y Value of yield curve at NextDP. Original Curve Data
ROG_2	2.47	Rate of growth in m ³ /ha/yr from NextDP to ThirdDP. Derived
ThirdDP	90	Data point on yield curve twenty years into the transition period wherein epidemic loss volume adjustments occur. Original Curve Data
ThirdDP_Y	140.17	Y Value of yield curve at ThirdDP_Y. Original Curve Data
ROG_3	2.32	Rate of growth in m ³ /ha/yr from ThirdDP to T_fin. Derived
T_Fin	100	Time Final: End of transition period wherein epidemic loss volume adjustments occur and merchantable dead volume amounts are determined. Original Curve Data
T_FinY_Orig	163.40	Original Y Value of yield curve at T_Fin: without epidemic loss adjustments. Original Curve Data
T0	74	New Data Point on Yield Curve: Time zero age (2003)
T0_Y	99.62	Original Y Value of yield curve at T0 without epidemic loss adjustments applied; = PrevDP_Y + delta * ROG1: Derived
T0_Depl	0.65	Time zero depletion ratio: PCT OF RESIDUAL LIVE VOLUME KILLED AS OF 2003:(Total Pine Volume 2003 - pine volumeKilled in 2003) / Total Pine Volume 2003: Derived from AllForestAllAges BCMPB loss projections provided by Marvin Eng: data resolution by LU and by pcpClass
T0_DeplY	34.69	Epidemic loss adjusted Y Value of yield curve at T0: = T0_Y * (1-T0_Depl)
T0_DeadLT5	64.93	Difference between T0_Y and T0_DeplY
T0_DeadLT10	64.93	volume per hectare of pine beetle killed wood dead less than 10 years: same as T0_DeplY
T0_TotalDead	64.93	Total volume per hectare of pine beetle killed wood: same as T0_DeplY
T5	79	New Data Point on Yield Curve: Time zero age plus five (2008)
T5_Y_Orig	112.79	Original Y Value of yield curve at T5 without epidemic loss adjustments applied; = T0_Y + 5*ROG1
T5_Y	39.27	T0_DeplY + 5*ROG1*PPR_03: Residual live pine volume at T0 plus 5 years of growth adjusted for the proportion of pine remaining after epidemic losses as of 2003
T5_Depl	0.77	PCT OF RESIDUAL LIVE VOLUME KILLED SINCE 2003 AS OF 2008: Derived from AllForestAllAges BCMPB loss projections provided by Marvin Eng: data resolution by LU and by pcpClass
T5_DeplY	9.18	Epidemic loss adjusted Y Value of yield curve at T5: = T5_Y *(1- T5_Depl)
T5_DeadLT5	30.10	T5_Y minus T5_deply
T5_DeadLT10	95.03	T5_DeadLT5 plus T0_DeadLT5
T5_TotalDead	95.03	same as T5_DeadLT10
T10	84	New Data Point on Yield Curve: Time zero age plus ten (2013)
T10_Y_Orig	125.32	Original Y Value of yield curve at T10 without epidemic loss adjustments applied; = T5_Y + 5*TROG1
T10_Y	10.19	T5_DeplY + 5*TROG1*PPR_2008: Residual live pine volume at T5 plus 5 years of growth adjusted for the proportion of pine remaining after epidemic losses as of 2008
T10_Depl	0.34	PCT OF RESIDUAL LIVE VOLUME KILLED SINCE 2008 AS OF 2013: Derived from AllForestAllAges BCMPB loss projections provided by Marvin Eng: data resolution by LU and by pcpClass
T10_DeplY	6.69	Epidemic loss adjusted Y Value of yield curve at T10: = T10_Y * (1-T10_Depl)
T10_DeadLT5	3.50	T10_y minus T10_DeplY
T10_DeadLT10	33.60	T5_DeadLT5 + T10_DeadLT5
T10_totalDead	98.53	T0_DeadLT5 + T5_DeadLT5 + T10_DeadLT5

VARIABLE LABEL	VALUE	DESCRIPTION
T15	89	New Data Point on Yield Curve: Time zero age plus fifteen (2018)
T15_Y_Orig	137.70	Original Y Value of yield curve at T15 without epidemic loss adjustments applied; = $T10_Y + 5*ROG2$
T15_Y	7.35	$T10_DeplY + 5*ROG2*PPR_2013$: Residual live pine volume at T10 plus 5 years of growth adjusted for the proportion of pine remaining after epidemic losses as of 2013
T15_DeadLT5	0.00	all dead wood has been dead longer than 5 years
T15_DeadLT10	3.50	same as T10_DeadLT5
T15_TotalDead	98.53	same as T10_TotalDead
T20	94	New Data Point on Yield Curve: Time zero age plus twenty (2023)
T20_Y_Orig	149.46	Original Y Value of yield curve at T20 without epidemic loss adjustments applied; = $T15_Y + 5*TROG2$
T20_Y	7.98	$T15_Y + 5*TROG2*PPR_2013$: Residual live pine volume at T15 plus 5 years of growth adjusted for the proportion of pine remaining after epidemic losses as of 2013
T20_DeadLT5	0.00	0
T20_DeadLT10	0.00	0
T20_TotalDead	null	same as T10_TotalDead
T_Fin	100	Final Data Point = PrevDP plus 30: end of transition
T_FinY_Orig	163.40	Original pine volume component
T_FinY	8.06	$T20_Y + 5*ROG3*PPR_2013$: Residual live pine volume at T20 plus (10 minus delta) years of growth adjusted for the proportion of pine remaining after epidemic losses as of 2013
T_Fin_TotalDead		same as T10_TotalDead
TROG_1	2.51	Transitional Rate of Growth: In this case used for growth from T_5 to T_10: $(5-Delta)/5*ROG1 + Delta/5*ROG2$. Derived
TROG_2	2.35	Transitional Rate of Growth: In this case used for growth from T_15 to T_20: $(5-Delta)/5*ROG2 + Delta/5*ROG3$. Derived
ROG_Fin	2.17	Rate of pine Growth in m3/ha/yr associated with T_fin. Derived
PPR_2003	0.96	proportion of pine remaining: $(1-Pine\ Volume\ Killed\ as\ of\ 2003/Total\ Pine\ Volume\ in\ 2003)$
PPR_2008	0.55	proportion of pine remaining: $(1-Pine\ Volume\ Killed\ as\ of\ 2008/Total\ Pine\ Volume\ in\ 2008)$
PPR_2013	0.18	proportion of pine remaining: $(1-Pine\ Volume\ Killed\ as\ of\ 2013/Total\ Pine\ Volume\ in\ 2013)$

For each modified yield curve the volume adjustment had to be carried through to the last data point. In the period after the adjustment outlined in Table 2, the residual live pine component was grown according to the annual increments previously determined and moderated according to the proportion of pine remaining in 2013.

At this stage, the yield curves have been updated to account for the MPB epidemic. Finally, the original non-pine components that were previously separated were added back in to complete the transformation. Table 3 shows example results, but only for a thirty year period.

Table 3. Adding Back Original Non-Pine Volume Components

Curve	Age	PineVol (m ³ /ha)	NonPineVol (m ³ /ha)	Final YValue (m ³ /ha)
B	110	87.24	130.86	218.10
B	111	87.99	131.98	219.97
B	116	82.12	137.59	219.70
B	121	52.83	143.15	195.98
B	126	28.94	148.52	177.46
B	131	29.93	153.61	183.53
B	140	30.06	160.68	190.74

Table 4 shows Example Yield Curve A and Example Yield Curve B both before and after the MPB mortality yield curve adjustments were applied. Figures 1 and 2 graphically display these two examples.

Table 4. Final Results of Epidemic Loss Curve Adjustments

Example Curve A from Intata Landscape Unit				Example Curve B from Babine East Landscape Unit			
95% pine component, pcpClass = 100				40% pine component, pcpClass = 40			
Curve	Age	Epidemic Loss Adjusted Volume (m ³ /ha)	Original Volume (m ³ /ha)	Curve	Age	Epidemic Loss Adjusted Volume (m ³ /ha)	Original Volume (m ³ /ha)
A	0	0	0	B	0	0	0
A	10	0	0	B	10	0	0
A	20	0	0	B	20	0	0
A	30	0	0	B	30	0	0
A	40	0	0	B	40	14.33	14.33
A	50	30.71	30.71	B	50	54.43	54.43
A	60	60.78	60.78	B	60	90.05	90.05
A	70	89.09	89.09	B	70	121.7	121.7
A	74	99.622		B	80	149.9	149.9
A	79	39.27343		B	90	175	175
A	80		115.42	B	100	197.6	197.6
A	84	10.19499		B	110	218.1	218.1
A	89	7.354945		B	111	219.97	
A	90		140.17	B	116	219.709	
A	94	7.983474		B	120		236.8
A	100	8.057923	163.4	B	121	195.9813	
A	110	11.84792	185.11	B	126	177.4602	
A	120	12.88576	205.67	B	130		254.7
A	130	13.59992	225.1	B	131	183.5323	
A	140	14.16985	238.47	B	140	190.744	267.8
A	150	14.57527	249.14	B	150	198.6192	278.4
A	160	14.83005	256.73	B	160	204.2288	286.6
A	170	14.94009	261.5	B	170	208.2013	292.5
A	180	14.89896	263.56	B	180	210.5849	296.2
A	190	15.02395	262.79	B	190	211.834	297.6
A	200	15.15908	265.13	B	200	214.3431	301.1
A	210	15.29422	267.66	B	210	216.8405	304.6

Example Curve A from Intata Landscape Unit				Example Curve B from Babine East Landscape Unit			
95% pine component, pcpClass = 100				40% pine component, pcpClass = 40			
Curve	Age	Epidemic Loss Adjusted Volume (m ³ /ha)	Original Volume (m ³ /ha)	Curve	Age	Epidemic Loss Adjusted Volume (m ³ /ha)	Original Volume (m ³ /ha)
A	220	15.42349	270.19	B	220	219.2429	308
A	230	15.54794	272.61	B	230	221.4535	311.1
A	240	15.66172	274.94	B	240	223.5808	314.1
A	250	15.76534	277.07	B	250	225.553	316.9
A	260	15.86362	279.01	B	260	227.3218	319.4
A	270	15.94588	280.85	B	270	228.9473	321.7
A	280	16.02333	282.39	B	280	230.4411	323.8
A	290	16.0901	283.84	B	290	231.8398	325.8
A	300	16.14672	285.09	B	300	233.0468	327.5
A	310	16.198	286.15	B	310	234.1705	329.1
A	320	16.23325	287.11	B	320	235.1624	330.5
A	330	16.2637	287.77	B	330	236.071	331.8
A	340	16.2888	288.34	B	340	236.8362	332.9
A	350	16.2888	288.81	B	350	237.3762	333.8

Figure 1. Epidemic vs Original Yield Curve Comparison: Example Curve A

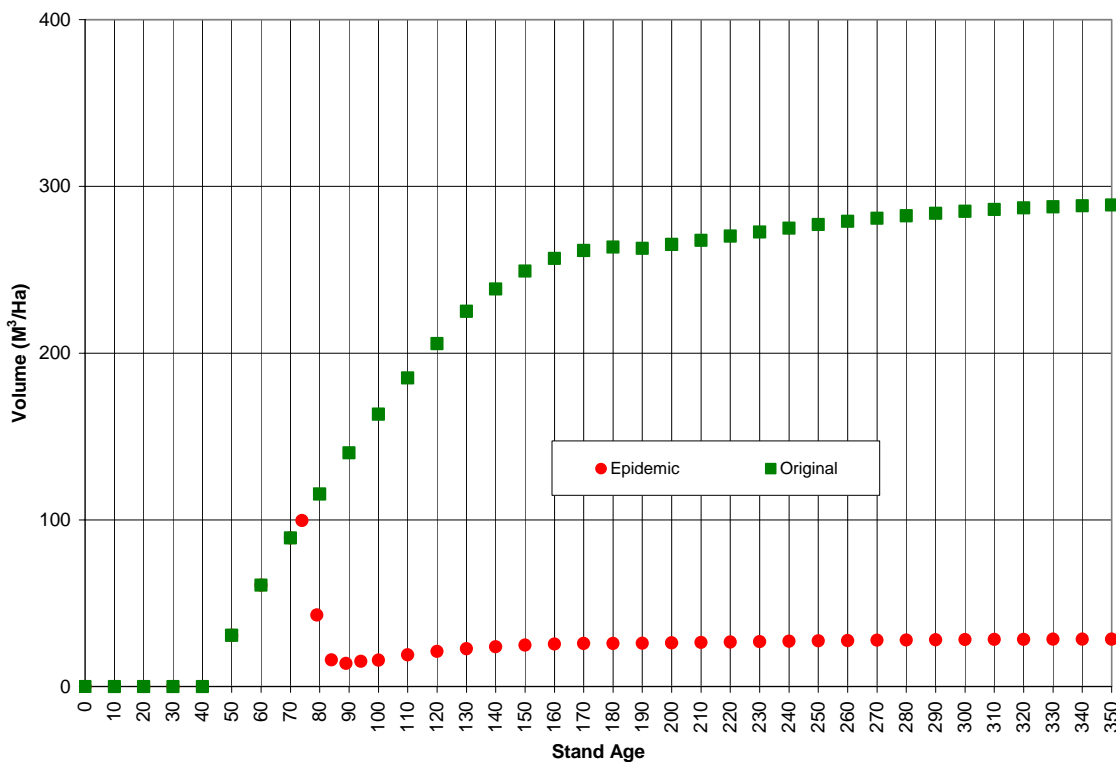


Figure 2. Epidemic vs Original Yield Curve Comparison: Example Curve B

