A Mountain Pine Beetle Retrospective Analysis for the Cranbrook Timber Supply Area

DRAFT

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1.0 Introduction

A retrospective analysis based on historic information on spatial and temporal characteristics of MPB outbreaks and responses by forestry permit insights to be gained into current and future outbreaks and effective management responses to mitigate MPB impacts on economic and social values derived from the land base. As part of *A Strategic Analysis Framework for Managing Forests under the Mountain Pine Beetle Outbreak* this report addresses one component of Objective 2 (*provide guidance to managers for addressing current MPB-impacted landscapes based on an evaluation of historic data on a previous MPB infestation and forward looking projections*) and details 1) the methods used to reconstruct the historic MPB outbreak that occurred in Cranbrook Timber Supply Area (TSA) in the late 1970's, 2) the scenarios used to assess previous management responses to the outbreak and to explore alternative management responses, and 3) analytical results.

2.0 A Historic Account of MPB in the Flathead

At the time, the MPB outbreak in British Columbia's Flathead valley[1] in the late 70's, was one of the most significant MPB infestations to have occurred in the province. It coincided with a series of MPB outbreaks in southwest Alberta, the north-western United States (US) and in the Nelson and Caribou regions of BC. Immediately south of the Flathead in Montana, Glacier National Park (GNP) and the Flathead National Forest (FNF) were also experiencing significant MPB outbreaks. Inaction by US park officials and few access roads in the FNF were believed to have facilitated the US outbreak. Within the Flathead valley, the outbreak rapidly progressed from an observation of pitch tubes on a few trees in 1975 to 7 million red trees in 1980. The outbreak subsequently collapsed suddenly in the early 80's, likely due to a combination of susceptible host depletion, harsh weather conditions, and perhaps, increased resistance by host trees. By that time, 20,600 ha had been impacted and the beetle had clearly demonstrated its destructive potential and its ability to not just impact trees, but also people.

The stage for the MPB outbreak in the Flathead was set in the first 40 years of the 20th century. Extensive wildfires burned over the landscape resulting in abundant, naturally regenerating immature pine stands throughout the valley bottom and extending up the slopes into the ESSF. Major infestations of spruce beetle in the Flathead had occurred in the mid-50s and late 60s, however, MPB outbreaks over this time period had been sporadic, isolated outbreaks of short duration. Forestry in the early 70's focused on spruce harvest related to the beetle outbreaks and in conjunction with oil and coal exploration had resulted in a lightly roaded landscape.

Management response to the Flathead outbreak was influenced by competing land objectives among user groups and adjacent jurisdictions. The Akamina and Kishinena, side drainages of the Flathead, had long been the subject of conservation interests due to their wilderness characteristics, their adjacency to GNP and Waterton Lakes National Park (WLNP), and their contribution to the maintenance of sensitive trans-boundary wildlife populations. While the Forest Service wanted to salvage-log the MPB impacted stands in these drainages so as to recover economic value, put beetle-killed forest land back into productivity, and reduce impacts to the Annual Allowable Cut, conservation interests supported a no-harvest policy that was consistent with that of WLNP and GNP. In response, the Forest Service prepared a Coordinated Land Use Plan to address the conflicting agendas of user groups. The plan, accepted by the Environment and Land Use Committee (ELUC), stressed logging only of currently impacted and susceptible

[1] This section is a summary of: Young, C. 1988. Coming of Age in the Flathead: How the British Columbia Forest Service Contended with the Mountain Pine Beetle Infestation of Southeastern British Columbia 1976 – 1986. Pest Management Report Number 10. Ministry of Forests, BC.

pine stands, maintenance of wilderness and recreational values, and road closures following the completion of logging. Concerns expressed by the US government further led to cooperative arrangements and long-standing agreements on a number of forestry-related issues. Ultimately, the resulting road network from salvage operations was the major public concern and prompted the appointment of a public involvement coordinator. A Coordinated Access Management Plan was completed in 1982 with broad public support; however, funding was unavailable until 1986.

Logging operations in the early years were driven by a sense of crisis with the licensee holding timber rights for the Flathead directed to concentrate its operations there. A road infrastructure was established and planning, harvesting and land use decisions with long-term ramifications were made on the ground by Forest Service and company personnel, following the issuance of a large cutting permit for the Flathead. Adherence to the ELUC directive for the Akamina and Kishinena was followed and in general, care was taken throughout the valley to address wildlife, recreational and aesthetic values. Harvesting became a year-round activity and was preferentially directed at mature stands of pure pine followed by those that were at least 30% pine. Islands of non-merchantable pine were retained as buffers and wildlife habitat, selective harvesting retained other wind-firm species, spruce was harvested only when it was a small proportion of the pine stand, and pure spruce stands were left untouched.

However, the ability of the licensee to conduct operations so focused on pine was limited. Salvage stumpage rates were only applied after a stand was standing dead for a year and the smaller pine, being a less valuable species at the time, did not generate sufficient economic return. From the licensee's perspective, including more spruce in the harvest made economic sense. Unable to meet prescribed harvest rates, the licensee eventually felt it was too small to meet the obligations placed on it and argued that there were too many constraints and that salvage should have proceeded quicker and on a larger scale. A decline in the lumber market in 1981 combined with high overhead costs and marginal quality of the salvaged wood forced the licensee to pull out of the Flathead.

Unable to find a licensee willing to continue operations in the Flathead valley the Forest Service put beetle-killed timber up for auction. This approach required a suspension of regulations on raw log exports and incentives to maintain salvage operations, including permission to harvest spruce and subalpine fir. Approximately 55% of all timber harvested between 1981 and 1985 were species other than pine. With the cessation of the salvage operation in 1985, the contractors opted to pay small penalties rather than meet site rehabilitation obligations, leaving the Forest Service to complete the task. Over all, substantial benefits in terms of encouraging rapid regeneration and reducing fire hazard were gained from the salvage program, and most economically viable mature pine stands were salvaged.

The original silvicultural response to MPB in the Flathead was on mixed species planting on salvage logged sites to prevent a pine monoculture from re-establishing. However, this focus switched in the early 80's to rehabilitating unsalvaged stands of small diameter trees. Harvest plans for the Flathead now promote harvesting of all future pine stands before they reach an age susceptible to MPB.

Although the Flathead valley suffered the severest impacts from MPB, the entire southeast portion of the province was affected. Early on, managers realized that a regional response to beetles was required. This invigorated the East Kootenay Insect and Disease Control Committee which was composed of government and industry managers. The Committee streamlined procedures such that salvage operations on beetle impacted timber could begin quickly through expediting cutting permits and easing the transfer of allowable cuts between TSAs. In 1980, the

Committee created a 5-year master salvage plan for the Cranbrook TSA that incorporated requirements for licensees to direct 70% of their cut to bark beetle susceptible stands. The Committee continues to functions as a lobby for funding and policy revisions to promote bark beetle control.

Lessons learned from the Flathead MPB outbreak:

- Salvage operations must be accompanied by a comprehensive monitoring plan
- Salvage contracts need to incorporate clearly specified responsibilities for forest management and site rehabilitation and be accompanied by the posting of performance bonds by contractors that are reflective of the true costs of rehabilitation
- Be vigilant – forests should monitored for indications of bark beetle or other forest pest infestations followed by a control response
- Be proactive – the primary management tool is harvesting of infested and susceptible stands and is facilitated by pro-active development of access into susceptible pine stands rather than reactive development.
- Licensees must be able to move operations quickly to respond to sanitation logging needs.
- Maintain appropriate staffing – the Flathead outbreak led to appointments of a pest management coordinator, a forest entomologist, and a forest pathologist in each of BC's forest regions.
- MPB outbreaks impact people as well as trees – a failure to address the social consequences of salvage operations through a coordinated and cooperative approach can lead to long-term administrative issues.
- Conduct cost-benefit-risk analyses – must every outbreak be met with salvage logging operations?
- Compare the Flathead with adjacent areas that were not salvage logged to determine long-term differences in forest recovery.

3.0 Current MPB Management Initiatives

The current MPB outbreak in BC is the largest ever recorded in North America[2]. With the total merchantable inventory of mature lodgepole pine approximating 1.8 billion m^3, and a current MPB mortality of over 400 million m^3 spread over 8 million ha of forest land, the outbreak has reached catastrophic proportions. The MPB infestation continues to progress through the central interior, the Kootenay and Thompson-Okanagan regions, and is making inroads in the Peace River region where it is being met with aggressive suppression management. Projections indicate that 80% of the merchantable pine may be killed by 2013. Impacts from the outbreak will be widespread reflecting the importance of pine, not only economically and socially, but also ecologically.

Maximizing the economic return from the beetle-killed stands must be balanced with other resource values and objectives that are identified in regional land-use plans, and be sensitive to economic and social consequences. Broadly, the Province's strategic goal is to sustain economic and environmental values over the long-term while addressing short and mid-term impacts.

[2] This section summarizes information from:
British Columbia's Mountain Pine Beetle Action Plan 2006-2011
Cranbrook TSA Forest Health Strategy 2006
Cranbrook TSA Type 1 Silviculture Strategy 2006

Objectives identified by the Provincial MPB Action Plan include:

> **1. Encourage immediate and long-term economic sustainability for communities.**
> **2. Maintain and protect worker and public health and safety.**
> **3. Recover the greatest value from dead timber before it burns or decays, while respecting other forest values.**
> **4. Conserve the long-term forest values identified in land use plans.**
> **5. Prevent or reduce damage to forests in areas that are susceptible but not yet experiencing epidemic infestations.**
> **6. Restore the forest resources in areas affected by the epidemic.**
> **7. Maintain a management structure that ensures effective and coordinated planning and implementation of mitigation measures.**
>
> Source: *British Columbia's Mountain Pine Beetle Action Plan 2006-2011*

Important forest level initiatives derived from the Action Plan include: 1) adjustments to the Annual Allowable Cut (AAC) in MPB-impacted areas and issuing of licenses to expedite salvage; 2) prompt detection and removal of 'green-attack' trees in areas proximal to the leading edge of the epidemic; 3) the establishment of an Emergency Bark Beetle Management Area within which Emergency Management Units are identified and classified as either aggressive or sanitation management; 4) the development of innovative approaches to reforestation and stand management to enhance stand resistance to infestation and to account for long-term risks and climate trends; 5) increases in the long-term timber supply by establishing stands on currently non-sufficiently restocked lands and through identification and prompt reforestation of the most productive sites; 6) an emphasis on surveying, site preparation and planting supported at the strategic level by timber supply analyses, silvicultural strategies such as fertilization, thinning and brushing, and seed supply planning for resistant or fast growing species; 7) development of an ecological restoration strategy for areas not zoned as timber producing lands but that enhance other values; and 8) identification of constraints and policy issues to these initiatives that may necessitate Forest Policy revisions.

On the Cranbrook TSA, lodgepole pine dominates ≈47% of the timber harvesting land base. Between 1999 and 2005, the cumulative areal impact of MPB totaled 63,990 ha with the majority of this impact (43,801 ha; 68%) recorded in the 2005 survey. Approximately 70,000 ha are currently rated as moderate to high hazard for MPB attack. Current attack tends to scattered in single trees or in small spots rather than large polygons due to weather conditions during the 2005 flight, but retains the potential for rapid spread and complicates the management response. The TSA is designated as an Emergency Bark Beetle Management Area.

Following strategic direction from the Draft Provincial Forest Health Strategy, the MPB management response focuses on identifying MPB management units and prescribed strategy, tactical planning for detection and treatment, and planning MPB monitoring such that it incorporates factors to aid in identifying required future uplifts to the AAC. On the ground activities include pheromone baiting in conjunction with harvesting, single tree treatments for small spot infestations in moderate to highly susceptible stands, and heli-logging in inoperable stands in sensitive areas such as community watersheds.

Broadly, management of bark beetles includes monitoring of beetle populations and spread, reducing population levels to minimize future volume losses and rate of spread, reducing the susceptibility of stands that are at high risk through promoting a mosaic of diverse forest species and age classes, and to quantify long-term impacts on timber volume and wood quality. Each landscape unit on the TSA constitutes a Beetle Management Unit (BMU) that is reviewed annually to assess assignment into one of four of management and treatment strategies:

1. Suppression - addresses all current attack within two years (80% + target of brood kill per year) with the intent to reduce bark beetle populations and terminate spread.
2. Holding - maintains beetle populations at a level that can be addressed under the current AAC by responding to 50-80% of current attack.
3. Salvage – minimizes loss of timber value in areas where suppression or holding actions are not feasible through salvage of previously attacked timber.
4. Monitor – requires no action except monitoring and recording.

BMUs are also assigned to provincial zones (aggressive and containment) to support high-level resource allocation through application of special harvest operations and regulations.

Suppression BMUs are biologically ranked according to importance by procedures outlined in the Provincial Bark Beetle Management Technical Guidelines. The ranking procedure considers both the outbreak's relative severity and the amount of remaining area that is susceptible. Impacted BMUs that contain community watersheds are assigned a high priority outright so that measures to reduce long-term consequences are available.

In conjunction with harvest of spot attacks and block harvesting of infested or susceptible stands, single tree treatments are proposed for Suppression BMUs on the TSA as follows:

1. Perform detailed aerial surveys of all red-attack (including inoperable stands) identified in MOFR Aerial Overview Surveys.
2. Conduct ground surveys of detailed aerial survey sites as well as moderate to highly susceptible stands where risk of spread is deemed high.
3. Conduct single tree disposal (fall & burn or peel) with efforts focused in remote or inoperable areas along the BC – Alberta border.
4. Use pheromone baiting to reduce beetle aggregations in high value stands and as a single tree disposal clean-up.
5. Funnel Trap Monitoring and Mortality Surveys.
6. Track treatment activities and annually update the TSA Forest Health Strategy.

Uplifts to the AAC are an important component of management response to MPB in order to capture value from impacted stands and to subsequently return stands to productivity. Uplift to the AAC is triggered by four factors, collectively assessed pre- and post-flight annually, as determined by the TSA's Forest Health sub-committee:

Factor 1 – Landscape level outbreak:

- Current to red-attack ratios are increasing
- Trend to more patch or less spot infestations
- Mortality surveys predict continuation of exponential beetle population increase
- Chance of reducing or maintaining beetle populations is decreasing even with aggressive management

Factor 2 – Unattainable BMU Treatment Targets:

- Failure to achieve treatment targets resulting in a management shift from suppression to containment BMUs
- An increase in non-recoverable losses beyond 6% of the AAC

Factor 3 – Unacceptable proportion of AAC composed of impacted timber volume that will not be addressed before next beetle flight:

- Pre-flight (June): Carry-over of biological ranking priority 1 and 2 volume exceeds 25% of AAC
- Post-flight (September): 75 to 125% of AAC contains infested volume

Factor 4 – Determining proportion of Priority 1 & 2 volume that is unconstrained

Between 1996 and 2005, the AAC for the Cranbrook TSA has increased from 850,000 m^3/year to 974,000 m^3/year. Increases represent additions from marginally economic sites, temporary uplifts to address wildfire salvage, and an increase in the conventional AAC primarily to support restoration of stands in the NDT4. It is envisioned that additional short-term uplift will be required to incorporate MPB-killed stands.

4.0 Retrospective Analysis Methods

The previous MPB outbreak that occurred on the Cranbrook TSA was characterized by creating GIS data layers of the pre-outbreak forest and road network conditions, and historic wildfires, cut-blocks, and bark beetle infestation sites. These data layers were used to assess, via scenario analysis, the previous management responses to beetle outbreaks and to explore and evaluate how alternative management responses may have altered landscape conditions from those that exist currently.

Our primary data sources for the retrospective analysis included the Cranbrook TSR3 spatial dataset and matching FIP history and layer tables, TRIM road data for the Cranbrook TSA, Tembec's spatial dataset and history tables for private grant MF27, and Nelson Forest Region spatial bark beetle polygon layers maintained by the Pacific Forestry Center. We used these data sources to generate GIS data layers as follows:

4.1 Combined Forest Cover Dataset

The Cranbrook TSR3 spatial dataset is composed of a grid (1 ha resolution) of values that link to a table of forest cover (FIP) and landscape attributes such as landscape units, BEC units, NDTs etc. Extensive private crown grants exist on the Cranbrook TSA and forest cover attributes for these areas were not incorporated into the TSR3 dataset (although landscape attributes covered the entire TSA). We acquired spatial (vector) forest cover layers and associated data tables in E00 format from our project partner Tembec for their private grants MF27, MF72 and St Mary. The Tembec vector data were imported into ArcView (3.2) and overlaid on the TSR3 grid to assess alignment and projection. Comparison of the two datasets indicated that only the MF27 data were required to update the Cranbrook TSR3 dataset.

All individual Tembec vector tiles (62) for MF27 were merged together into a single unified shape file and were gridded on the Mapstand field to the same resolution and extents as the TSR3 grid. Development of data tables for the Tembec data was conducted in Access as follows:

1) import the Value Attribute Table (VAT) generated during gridding of the unified shape file
2) import the Polygon Attribute Table (PAT) generated during merging of shape files
3) merge the VAT and PAT tables together
4) import all 62 individual Layer tables and append together
5) import all 62 individual forest Species tables and append together

6) generate cross-tabulation tables of species data (Species Code, Species Percent, and Species VolumeU1) from the unified Species table
7) update the unified Layer table with forest species data from the cross-tabulation tables
8) generate from the updated Layer table a new Layer table of only Forest Cover Rank 1 records
9) generate a spatially linked attribute table for the Tembec by merging the Layer Rank 1 table with the merged VAT and PAT table

The Cranbrook TSR3 data and Tembec data for MF27 were selectively merged together on a grid cell by grid cell basis under the following criteria:

- TSR3 forest cover data was missing (i.e., classified as NTA or else null for SPC_1_CD, NPD_DESCRP and NF_DESCRP), and
- MF27 data was not classified as NTA.

This approach favored retaining TSR3 data in areas where there was overlap between the two datasets and maintained an ability to assess scenarios against TSR3 projections for the crown forest base. Additionally, the TSR3 data incorporated landscape attributes not included in the Tembec data that had to be retained in the final dataset. To accomplish this selective merging of data and retention of landscape attributes the following steps were taken:

1) import from ArcView into Access the TSR3 and Tembec grids, assigning on import an ID field based on grid row and column (since both grids had the same resolution and extents the ID fields allow grid alignment within Access)
2) align and link grids to their respective attribute tables and generate a table of selected cells to be merged with Tembec data based on above criteria
3) update table of selected cells with FC_TAG from Tembec data and collapse table into unique records
4) update the unique records with Tembec forest cover attributes (see Table A1 of Appendix)
5) assign a globally unique grid value to the unique records
6) append the unique records to the existing TSR3 attribute table to create a unified forest and landscape attribute table
7) generate a new spatial resultant grid that incorporates original grid values for non-merged cells and new grid values for merged cells

4.2 Pre-Outbreak Forest Conditions

Based on historic MPB outbreaks in the Cranbrook TSA we established 1973 as the last year prior to significant impacts from the 1970's MPB outbreak. To characterize the pre-outbreak state of the forest we rolled back the combined forest cover dataset to 1973 with a SELES program that makes a simple reversion of the forest to the desired year. For stands that are currently older than the number of years to revert back to, the program reduces the stand age by the number of reversion years. For stands currently less than or equal to the number of years to revert back to, the program diffuses stand ages from older forest patches. Patches not reached by the diffusion algorithm are assigned the mean age of older forest.

We made two refinements of the SELES model for this application:

1) for all stands that were re-aged by diffusion from older stands the program was modified to also diffuse the spatial resultant grid values that link to the forest and landscape attribute table. This permitted us to assign the forest cover attributes of the stand contributing the diffused age to the stand receiving the diffused stand age.

2) we restricted diffusion of ages and attributes such that the contributing and receiving stands were within the same BEC units. This eliminated spreading stand compositions that are typical for one BEC unit into a BEC unit for which the composition would be atypical.

Five input grids were generated from the dataset to support application of the SELES model:

1) *Study Area*: defined as all grid cells within the boundaries of the Cranbrook TSA.
2) *Forested*: defined as the currently forested land-base (all forest cover polygons with a recorded forest species) and the potential forest bearing land-base (all forest cover polygons without a recorded forest species but coded as NSR).
3) *Current Age*: defined as the current age (≥ 0) for all forested cells. To account for different stand age projection dates in the dataset we brought all ages of forested cells forward to 2005 by simply adding the appropriate number of years to the projected age (NSR stands with a projected age of 0 remained unchanged).
4) *BEC*: defined as the six BEC zones that occur on the Cranbrook TSA.
5) *Spatial Resultant Grid*: defined as the grid values that link to the unified forest and landscape attribute table.

4.3 Pre-Outbreak Road Network

To estimate road conditions in 1972, we estimated conditions when industrial logging began (about 1949). We assumed that the only roads existing at the time were the main paved highways in the area (clearly a coarse assumption, since other roads surely existed). We then "replayed" historic logging patterns from 1949 to 1972, allowing the model to "activate" the road network segments required to access the harvested areas. This resulted in a road map for 1972 conditions, with some of the present road network as "active" and some of it as "future"

4.4 Historic Wildfires

We acquired all 1:20 000 FIP files from map sheets 082F, 082G, and 082J that matched the TSR3 dataset (124 tiles) and extracted the History tables to DBF format with the Forest Cover Attribute Processing program. All History tables were imported in Access and appended together. We also imported into Access all History tables (also DBF format) from the Tembec data and appended them to the unified History table.

Within the unified History table we identified all records that linked via FC_TAG to the unified forest and landscape attribute table and were coded as DI (disturbance) for the Attribute field and B (wildfire) for the Activity field. From this subset of History records we extracted a table of unique FC_TAGs and for each FC_TAG identified all stand layers for which there was a History record. In the case of more than one stand layer record in the History table we assigned a priority stand layer (in order 1, 2, V, and S) to use to extract records from the History table. We also determined, for each FC_TAG and its respective priority stand layer instances of more than one record in the History table (these denote stands that burned more than once). Finally we generated a Fire History table for the Cranbrook TSA by extracting one History record for each unique FC_TAG and its respective priority layer. For stands (2) that burned more than once, we extracted the earliest fire record.

We created two output grids within Access to represent historic fires on the TSA: 1) a grid of wildfires coded by year of the fire, and 2) a grid of wildfires coded by the percent area of the stand that was burned.

4.5 Historic Cut-Blocks

Starting with the unified History table created for the wildfire analysis, we followed a similar procedure as with wildfires to generate a Cut Block History table for the TSA. We identified all History records that linked via FC_TAG to the unified forest and landscape attribute table and were coded as DI (disturbance) for the Attribute field and L (logging) for the Activity field. From this subset of History records we extracted a table of unique FC_TAGs and for each FC_TAG identified all stand layers for which there was a History record. In the case of more than one stand layer record in the History table we assigned a priority stand layer (in order 1, 2, V, and S) to use to extract records from the History table. We also determined, for each FC_TAG and its respective priority stand layer instances of more than one record in the History table (these denote stands that have more than one entry for Activity_Year1). Finally we generated a Cut Block History table for the Cranbrook TSA by extracting one History record for each unique FC_TAG and its respective priority layer. For stands (233) that have more than one entry for Activity_Year1, we extracted the record with the earliest activity.

We generated within Access annual grids of cut blocks from 1970 to 1998 coded by percent of the block that was harvested, and two multi-annual grids of cut blocks for the period between 1999 and 2003 where one grid was coded by year of harvest (if known) and one grid was coded by percent of the block that was harvested.

4.6 Historic Bark Beetle Infestations

We obtained multi-annual shape files in Albers Equal Area Conic projection for bark beetle infestations (Mountain pine beetle, Spruce beetle, Douglas-fir beetle, and Western Balsam bark beetle) in the Nelson Forest District from the Pacific Forestry Centre. For each species the shape files were clipped to the MOFR boundary file for the Cranbrook TSA and re-projected to NAD83 UTM Zone 11N, updated for area and perimeter fields, and had a unique polygon identifier (UNI_ID) added to the table. We used ArcView's query builder to select annual sets of polygons and generated a shape file for each beetle species by year. We gridded each shape file on UNI_ID to the same resolution and extents as the TSR3 grid. We used the UNI_ID value of the grids as a relational link back to the data table so as to be able to determine the severity code of each polygon.

4.7 Scenarios

Starting in 1972, we projected landscape conditions forward to 2004 with an aim of exploring the range of possible outcomes. These represent a range of "real options" available for managers during that period.

- *Historic logging (HistLog1973_2003)*

This scenario simply replays historic logging, fire and MPB to provide a simple baseline comparison and to verify that the model ends up with conditions close to 2004 conditions.

- *No management (NoMgmt1973_2003)*

This scenario simply replays natural disturbance over this time period, to provide a baseline of how the forest conditions may have evolved in the absence of logging.

- *Default management (SQLog1973_2003)*

This scenario applies the "status quo" management regime assumed in TSR 3 over this time frame, with an additional priority for salvage of disturbed stands.

- *No salvage (NoSalvage1973_2003)*

This scenario is the same as above, except no salvage was applied.

- *Susceptibility focus (SuscFocus1973_2003)*

This scenario applied a priority to focus harvest as much as possible in stands susceptible to MPB, based on an approximation of the Shore and Safranyik MPB susceptibility rating. This scenario aims to quantify the degree to which susceptibility may have been reduced over this time frame.

- *Minimize roads(MinRds1973_2003)*

This scenario harvests the same volume, but with a focus on minimizing the amount of road constructed to access stands. The aim was to quantify the minimum amount of road that could have been built to harvest wood.

5.0 Retrospective Analysis Results

5.1 Combined Forest Cover Dataset

We added 23,785 records to the final forest cover and landscape attribute table to account for Tembec's private grant MF27. A total of 95,322 ha (6.4%) of the Cranbrook TSA land base were updated with Tembec forest cover data.

5.2 Pre-Outbreak Forest Conditions

We reverted back the forest land base (1,049,146 ha) of the Cranbrook TSA 32 years from its current status (as of our reference year 2005) to represent the land base in 1973. A total of 110,904 ha (10.6%) of the forest land base were ≤32 years of which 110,566 ha were re-aged by diffusion with the remaining 338 ha that were not reached by the diffusion algorithm assigned to the mean age of forest stands >32 years old in 2005 (114 years). Reversion to 1973 resulted in a mean forest age of 86.9 years compared to a mean age of 103.9 years for the reference year of 2005.

Diffusion of spatial resultant grid values from stands contributing a diffused age to the receiving stands resulted in changes to stand attributes from current conditions and 1973 (Table 1). With the exception of NSR stands without forest species, changes in percent representation by lead species were small.

Table 1. Hectares (Ha) and percent representation of forest stands by lead species currently versus 1973.

SPC_1_CD	Ha Currently	Percent Currently	Ha in 1973	Percent in 1973
null	25442	2.43	152	0.01
AC	5488	0.52	7386	0.70
AT	14739	1.40	14406	1.37
B	25559	2.44	26914	2.57
BA	374	0.04	374	0.04
BL	120024	11.44	108515	10.34
CW	3717	0.35	4047	0.39
E	194	0.02	194	0.02
EP	2205	0.21	1573	0.15

SPC_1_CD	Ha Currently	Percent Currently	Ha in 1973	Percent in 1973
F	16	0.00	0	0.00
FD	166006	15.82	177317	16.90
H	66	0.01	66	0.01
HW	2691	0.26	3216	0.31
L	2172	0.21	2196	0.21
LA	4999	0.48	5072	0.48
LW	77734	7.41	86252	8.22
PA	33286	3.17	36317	3.46
PL	396329	37.78	391206	37.29
PW	68	0.01	66	0.01
PY	21003	2.00	22304	2.13
S	30839	2.94	34367	3.28
SE	116195	11.08	127206	12.12
Total	**1049146**	**100**	**1049146**	**100**

5.3 Pre-Outbreak Road Network

The inventory file indicates a current total of about 18,810 km roads of all classes, with about 930 km of highways, 16,420 km of primary logging roads, and 1,460 km of secondary roads. The estimated 1972 conditions resulted in approximately 3,940 km of roads or 21% of the current total (Figure 1).

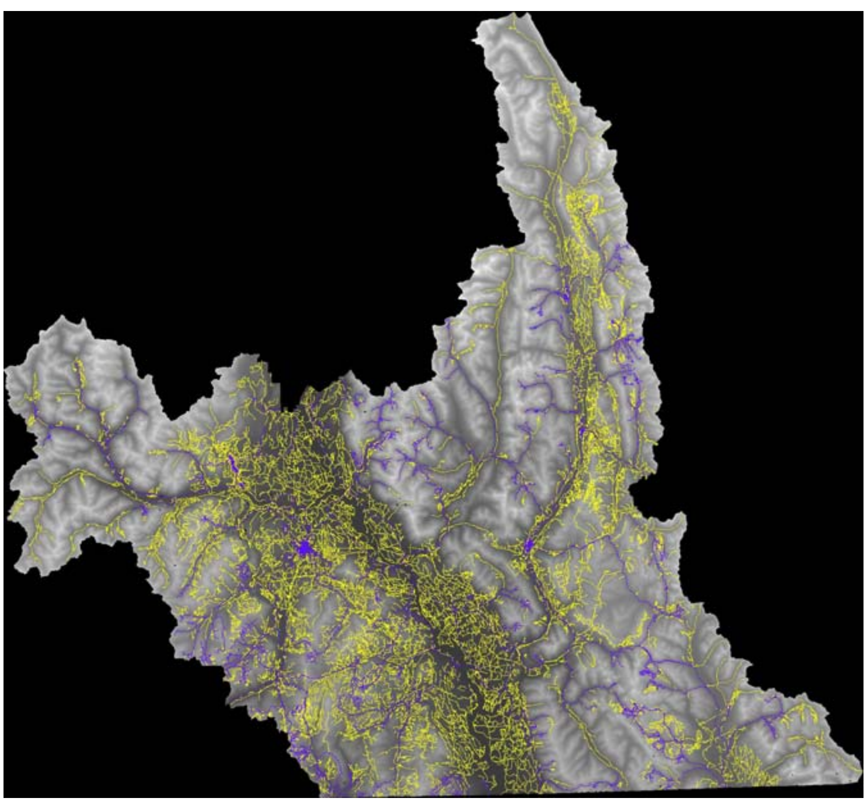

Figure 1. Estimated existing (blue) and future (yellow) roads in 1972 conditions.

5.4 Historic Wildfires

A total of 60,672 ha of wildfire burned stands were extracted for the History tables between 1928 and 2001 with another 15,832 ha of wildfire burned stands that lacked an Activity Year (Table A2 of Appendix). Large fires burned an additional 22,434 ha of Crown Forest Land Base on the Cranbrook TSA in 2003 but were not included in the History table. Wildfires burned more absolute and relative area in NDT 3 followed by NDT 4, NDT2 and NDT 5 (Table 2).

Table 2. Total hectares (Ha) burned and percent area burned by NDT.

NDT	Total Ha	Total Ha Burned	Percent Burned
2	158283	5504	3.5
3	977398	59609	6.1
4	234634	10926	4.7
5	113396	465	0.4
Totals	**1483711**	**76504**	**5.2**

Based on the current forest stand composition over the entire Cranbrook TSA, the area burned by lead species was greatest for lodgepole pine (PL) leading stands, followed by Engelmann spruce (SE) leading stands, Alpine fir (BL) leading stands, and Douglas fir (FD) leading stands (Table 3).

Table 3. Total hectares (Ha), total hectares burned, and percent burned by lead species. Note that for stands with null values for forest species that the total area includes NSR stands and all other non-forested polygons such as rangeland, urban areas and water.

SPC_1_CD	Total Ha	Total Ha Burned	Percent Burned
null	460007	23602	5.1
AC	5488	196	3.6
AT	14739	1295	8.8
B	25559	1251	4.9
BA	374	110	29.4
BL	120024	6606	5.5
CW	3717	22	0.6
E	194	0	0.0
EP	2205	20	0.9
F	16	0	0.0
FD	166006	6164	3.7
H	66	0	0.0
HW	2691	81	3.0
L	2172	0	0.0
LA	4999	0	0.0
LW	77734	1346	1.7
PA	33286	516	1.6
PL	396329	23015	5.8

SPC_1_CD	Total Ha	Total Ha Burned	Percent Burned
PW	68	0	0.0
PY	21003	1419	6.8
S	30839	2613	8.5
SE	116195	8248	7.1
Total	**1483711**	**76504**	**5.2**

5.5 Historic Cut-Blocks

A total of 182,197 ha of cut blocks were extracted from the History table of which 26,426 ha (14.4%) did not have an Activity Year recorded. For all other blocks, the Activity Year represents the first year of logging (Table 4) although for some blocks logging continued for several years.

Recorded annual harvested area was low for 1999 on, and there were only Tembec cut block records for 2000 on (Table 4). The 10 year average of harvested area for 1989 – 1998 was 4,502 ha/year and the expectation of harvested area for the five year period from 1999 to 2003 totaled 22,510 ha versus the 3,447 ha from the History file. We assumed that most cut blocks without an Activity Year were recent blocks that were harvested between 1999 and 2003.

Table 4. Harvested hectares (Ha) extracted from the History table by first year of activity in the cut block.

Ha	HISTORY RECORD SOURCE	ACT_YEAR1_GROUP
26426	MOF & TEMBEC	No activity year recorded
22969	MOF & TEMBEC	1969 or earlier
2283	MOF & TEMBEC	1970
2532	MOF & TEMBEC	1971
4416	MOF & TEMBEC	1972
5726	MOF & TEMBEC	1973
3755	MOF & TEMBEC	1974
2061	MOF & TEMBEC	1975
3191	MOF & TEMBEC	1976
4317	MOF & TEMBEC	1977
4441	MOF & TEMBEC	1978
3998	MOF & TEMBEC	1979
3176	MOF & TEMBEC	1980
3535	MOF & TEMBEC	1981
2735	MOF & TEMBEC	1982
6196	MOF & TEMBEC	1983
6617	MOF & TEMBEC	1984
4444	MOF & TEMBEC	1985
8573	MOF & TEMBEC	1986
6689	MOF & TEMBEC	1987
5653	MOF & TEMBEC	1988

Ha	HISTORY RECORD SOURCE	ACT_YEAR1_GROUP
4113	MOF & TEMBEC	1989
4026	MOF & TEMBEC	1990
6190	MOF & TEMBEC	1991
5152	MOF & TEMBEC	1992
4718	MOF & TEMBEC	1993
3951	MOF & TEMBEC	1994
4373	MOF & TEMBEC	1995
5117	MOF & TEMBEC	1996
3622	MOF & TEMBEC	1997
3755	MOF & TEMBEC	1998
1456	MOF & TEMBEC	1999
405	TEMBEC	2000
646	TEMBEC	2001
400	TEMBEC	2002
540	TEMBEC	2003

5.6 Historic Bark Beetle Infestations

Annual vector layers of bark beetle infested polygons were created for all years where data were available between 1967 and 2005 (Table 5). Summed area totals by beetle species over the annual vector layers (table 5), however, over-estimate the total area of the Cranbrook TSA impacted by bark beetles due to overlapping polygons within beetle species across years. Such overlaps represent annual estimates of the percent stand mortality (Severity Codes 1, 2, and 3) where the infestation continued for more than one year.

Table 5. Impacted hectares (Ha) by year and bark beetle species, summed over Severity Codes, for the Cranbrook TSA. Results are derived from annual vector layers of bark beetle polygons. Column totals do not reflect the true area on the TSA impacted by each beetle species due to overlap in polygons across years.

Year	Ha MPB	Ha DFB	Ha BBB	Ha SB
1967	0.00	4.01	0.00	0.00
1968	0.00	272.47	360.18	5999.09
1969	10.71	0.00	863.12	13595.94
1971	0.00	0.00	0.00	100.98
1974	63.24	0.00	0.00	0.00
1977	500.80	0.00	36.08	0.00
1978	2600.56	0.00	0.00	8.56
1979	8170.70	0.00	0.00	0.00
1980	15257.68	0.00	0.00	0.00
1981	14536.70	8.54	40.81	1677.58
1982	9577.78	29.68	281.96	1724.85
1983	111.74	1.53	4.50	21.51
1984	3561.90	0.00	50.44	515.25
1985	3734.71	0.00	5.61	0.00

1986	3739.26	0.00	192.68	29.12
1987	3247.62	0.00	160.12	0.00
1988	5260.64	0.36	0.00	0.00
1989	7912.18	76.82	0.00	0.00
1990	6667.58	26.66	0.00	0.00
1991	8383.30	12.03	167.34	0.00
1992	2142.89	0.00	0.00	0.00
1993	437.02	3.79	1275.49	0.00
1994	160.35	20.92	1579.32	2.02
1995	363.83	16.28	417.52	11.53
1996	149.06	9.04	344.80	2.76
1999	2339.28	119.10	552.42	0.00
2000	1411.82	282.61	220.57	83.42
2001	534.38	792.12	873.61	0.00
2002	7603.56	284.06	277.84	48.89
2003	6345.79	447.03	1015.91	35.51
2004	21014.96	402.26	1050.74	332.03
2005	53923.77	976.88	10974.25	0.00
Totals: 1967 – 2005	**189763.81**	**3786.19**	**20745.31**	**24189.04**
Totals: 1974 – 2005	**189753.10**	**3509.71**	**19522.01**	**4493.03**

For each beetle species we estimated the total area of the TSA impacted between 1974 and 2005, regardless of infestation severity, by deleting earlier years and dissolving overlapping polygons in the multi-annual shape files with ArcView. Total hectares impacted by each beetle species over the period of interest were: Mountain pine beetle (MPB) 151,262.1 ha, Douglas-fir beetle (DFB) 3,282.1 ha, Western Balsam bark beetle (BBB) 17,051.2 ha, and Spruce beetle (SB) 4,405.7 ha.

Severity Codes for bark beetle infestations represent the percent of the stand killed annually and are expressed as ranges (1 = 1 – 10% of trees killed; 2 = 11 – 29% of trees killed; and 3 = 30%+ of trees killed). For each cell on the landscape grid we estimated the cumulative severity of attack for each bark beetle species by summing the mid-points of the annual Severity Codes (mid-points are 5.5%, 20%, and 65%, for Severity Codes 1, 2, and 3, respectively) recorded for that cell over the period of interest (1974 – 2005; Table 6).

Table 6. Cumulative severity and hectares (Ha) of bark beetle attacks over the period of 1973 – 2005 on the Cranbrook TSA.

Cumulative Severity (% of stand killed)	**MPB** Ha; (%)	**DFB** Ha; (%)	**BBB** Ha; (%)	**SB** Ha; (%)
1 – 20	95925; (63.5)	2702; (82.3)	15283; (89.4)	3963; (89.8)
21 – 40	9222; (6.1)	80; (2.4)	960; (5.6)	27; (0.6)
41 – 60	764; (0.5)	4; (0.1)	125; (0.7)	0; (0.0)
61 – 80	30113; (19.9)	490; (14.9)	573; (3.3)	376; (8.5)
81 – 100	15132; 10.0)	8; (0.2)	150; (0.9)	47; (1.1)
Totals	**151156; (100.0)**	**3284; (100.0)**	**17091; (100.0)**	**4413; (100.0)**

Note: Analyses are derived from grids of the annual vector layers which accounts for small discrepancies in the total area of the TSA impacted by each beetle species from that reported above based on dissolved vector layers.

Using the forest age structure reverted to 1973 as a starting point, we examined the age distribution of stands impacted by MPB between 1974 and 2005 (in comparison, the other bark beetle species had minor impacts on the Cranbrook TSA over the period of interest and were excluded from further analyses). MPB infestation polygons represent the red-attack stage that occurs one year after the actual infestation. We combined each annual grid of MPB infestation with the 1973 reverted stand age grid, adjusted stand ages forward for the year of infestation lagged by one year, and tallied the infested area by age groups (table 7).

Table 7. Age distribution of forest stands, at time of infestation by MPB, between 1974 and 2005 on the Cranbrook TSA. Results are derived from grids created from annual vector layers.

Infestation Year	Stand Age Group						
	1 – 20	21 – 40	41 – 60	61 – 80	81 – 100	101 – 140	140+
1974	21	1	15	0	1	0	18
1977	129	2	141	115	29	37	28
1978	256	50	646	606	317	366	173
1979	509	200	2354	1491	1049	710	1149
1980	794	323	4982	2283	1760	1846	1970
1981	565	771	2940	627	952	1718	4671
1982	318	443	2300	139	235	1221	3892
1983	2	3	35	1	15	5	34
1984	49	205	770	297	701	541	675
1985	83	138	924	325	627	845	617
1986	55	74	532	545	774	1007	564
1987	5	49	508	374	620	904	654
1988	38	196	1088	912	799	1202	835
1989	54	170	1726	1051	1225	1487	1518
1990	16	138	1438	1529	1143	921	655
1991	6	135	1486	1570	1942	1605	804
1992	0	69	285	273	495	550	327
1993	0	7	53	59	86	137	58
1994	0	2	7	26	46	54	18
1995	0	7	34	42	125	86	40
1996	0	6	11	18	38	35	13
1999	0	30	93	382	639	738	256
2000	0	25	60	226	317	353	324
2001	0	22	14	51	87	171	106
2002	0	95	356	681	607	3515	1745
2003	0	36	178	947	664	2690	1323
2004	0	158	731	3897	3125	8024	3629
2005	0	551	2192	11897	7033	15817	12639
Total Ha (%)	**2900 (1.7)**	**3906 (2.2)**	**25899 (14.9)**	**30364 (17.5)**	**25451 (14.6)**	**46585 (26.8)**	**38735 (22.3)**

Note: Total hectares are exclusive of non-forested inclusions within the MPB-impacted area.

The age distribution of forest stands match expectations with >95% of stands >40 years of age at time of infestation. While stands as young as 20 years of age have been observed to be attacked by MPB in the current infestation, the validity of apparent attacks on such young stands between 1974 and 1991 (Table 7) is questionable. The occurrence of young stands within beetle polygons is not the consequence of age diffusion by the stand reversion model as minimum ages diffused by the model were 69 years. The abrupt cessation of beetle attack on young stands starting in 1992 may suggest that these results are an artifact of early data collection technologies that inadvertently included young stands peripheral to older attacked stands. However, the inclusion of young stands in beetle polygons from recent years would not be observable in the above analysis due to the stand reversion model and the results may be an artifact of the model itself.

Using the 1973 pre-outbreak forest base, we examined forest types, indexed by Inventory Type Groups (ITG), within the area of MPB infestation and tallied the total hectares by ITG, and hectares by percent cumulative infestation severity and ITG (Table A3 of Appendix). In general, ITGs within the MPB-impacted area were consistent with those that would be susceptible to MPB outbreaks with ≈71,000 ha (≈47%) of the impacted area composed of pine-leading stands and ≈52,000 ha (≈35%) composed of stand types where pine could be expected as a secondary species. Additionally, pine-leading stands tended to correspond with those stands experiencing higher percent cumulative infestation severities (Table A3 of Appendix).

Some potential discrepancies were noted in that there were ≈5000 ha each of ITGs 24 (SB) and 33 (LFd) in the MPB-impacted area, and that ITG 34 (L) tended to support higher percent cumulative infestation severities (Table A3 of Appendix) than would be expected for non-pine-leading stands. We investigated whether the diffusion of stand types as part of our forest reversion model contributed to these discrepancies (Table A4 of Appendix) due to a bias towards older non-susceptible stand types that survived and contributed to the diffusion. Only 18034 ha (≈12%) of the MPB-impacted area were subjected to diffusion of ages and stand types in the reversion to 1973 pre-outbreak forest conditions (Table A4 of Appendix) with ≈20% of the area of ITGs 24 and 33, and ≈16% of the area of ITG 34 due to diffusion of stand types.

5.7 Scenarios

All scenarios harvest an average of about 500,000 m^3/year. Area harvested per year varies from about 1990 ha/year to 2360 ha/year, while mean age varies from about 112 years to about 160 years (Table 8).

Table 8. Base metrics for retrospective scenarios.

Scenario	Area harvested (ha/yr)	Mean volume/ha harvested (m^3/ha)	Mean age harvested (years)	Mainline roads built (km)	Mean susceptibility harvested (0-100)
Historic logging	2,360	219	122	5,390	20
Default management	1,950	263	160	3,410	20
No salvage	1,990	258	159	2,430	20
Susceptibility focus	2,260	226	112	4,560	47
Minimize roads	2,040	251	145	2,230	24

The area of forest with susceptibility of at least 40% would have been reduced by about 30,000 ha if harvest had focused on reduction of such stands from 1972 to 2003 (Table 9). Other management scenarios reduced susceptible stands by about 20,000 ha over the no harvest scenario. The main susceptibility harvested is about 20 to 24 for all scenarios, except Susceptibility focus, where it is 47 (Table 8).

The amount of road built varies considerably between scenarios, with a low of just over 2,400 km built over period (minimize roads scenario) to a high of over twice that level (Table). The scenario the aims to reduce susceptibility leads to relatively high levels of roading. The historic logging scenario does not re-create all currently mapped roads (there are over 18,000 km in the inventory file, but the historic logging scenario ends with about 9,300 km). This is due in part to roads created historically for reasons other than harvest access, but may suggest that the CLM produces a less compact road network than historically.

Table 9. Area with susceptibility rating of at least 40% from different retrospective scenarios starting in 1973 and running to 2003. Note that the historic logging scenario does not define a THLB (since it simply replays past harvesting).

Scenario	**Susceptibility ≥ 40 total (ha)**	**Susceptibility ≥ 40 THLB (ha)**
No management	143,400 ha	104,200 ha
Historic logging	124,400 ha	N/A
Default management	126,400 ha	89,000 ha
No salvage	127,800 ha	89,800 ha
Susceptibility focus	92,100 ha	58,300 ha
Minimize roads	123,000 ha	85,600 ha

Appendix

Table A1. Tembec forest cover fields used to update the forest cover and landscape attribute table for the Cranbrook combined forest cover dataset. Original values from the TSR3 data set were retained for all other fields.

TSR3 Data Table Field	Updated with Tembec Rank = 1 Data Field (or default values)
MAP_ID	MAP_ID (note that Tembec records have an extra [1 – 4] digit)
POLYGON_ID	POLYGON_ID
FC_TAG	Constructed from MAP_ID and POLYGON_ID
FEATURE_ID	Set to null values
NPD_DESCRP	NPFORESTDESC
NPD_CD	NPFORESTCODE
NF_DESCRP	NFORESTDESC
SPC_1_CD	SPC_1_CODE
SPC_2_CD	SPC_2_CODE
CROWN_CLOS	INVCROWNCLOS
PROJ_AGE	PRJAGE
PROJ_HT	PRJHEIGHT
SITE_INDEX	CALSITEIDX
SI_ESTIMAT	INVSITEIDXEST
INV_TYPGRP	CALINVTYPEGROUP
CON_VOL_HA	Set to zero for Tembec records – available from supplied data, but compatibility with TSR data uncertain
ESA1	ESAHIGH
ISLOGGED	Set to zero for Tembec records
INCLFACT	Set to zero for Tembec records – not available from data
CONTCLAS	Set to X for Tembec records – not available from data
CFLB	Set to zero for Tembec records – not available from data
THLB	Set to zero for Tembec records – not available from data
AREAHA	Set to zero for Tembec records – not available from data
THLBAREA	Set to zero for Tembec records – not available from data
NCLBAREA	Set to zero for Tembec records – not available from data
AU	Set to null values for Tembec records – definitions available from TSR3 document
PRJ_AGE_CL	PRJAGECLS

Table A2. Hectares (Ha) of wildfire extracted from the History table and year of burn on the Cranbrook TSA.

Year of Fire	Ha Burned
No year recorded	15832
1928	18
1929	617
1930	45
1931	10486
1932	517
1933	3145
1934	2548
1936	6798
1938	14
1940	6700
1941	14
1943	152
1944	124
1945	537
1946	2
1950	145
1951	2456
1952	231
1953	716
1955	6
1958	173
1960	7556
1961	671
1962	17
1964	463
1965	5
1966	17
1967	2067
1968	32
1969	387
1970	2248
1971	571
1973	3154
1974	281
1975	9
1976	366

Year of Fire	Ha Burned
1978	229
1979	909
1980	22
1982	533
1984	54
1985	2963
1986	577
1987	99
1988	701
1989	20
1991	23
1992	1
1994	1130
1995	21
1997	17
1999	12
2000	2
2001	71

Table A3. Distribution of stand types (Inventory Type Groups) within the MPB-impacted area of the Cranbrook TSA, based on the 1973 pre-outbreak forest conditions.

Inv. Type Group	Name	First Species	Second Species	Total Ha	Ha by Percent Cumulative Infestation Severity				
					1 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
0				13012	8394	577	33	2957	1051
1	Fd	Fd > 80%	Any	7334	5335	573	36	813	577
2	FdCw	Fd	Cw or Yc	74	55	8	0	0	11
3	FdH	Fd	H or B	293	168	0	0	98	27
4	FdS	Fd	S	1481	996	114	12	205	154
5	FdPl	Fd	Pl	7427	4995	651	60	935	786
6	FdPy	Fd	Py	2336	1992	110	8	216	10
7	FdL	Fd	L, Pw	8639	6826	844	58	676	235
8	FdDecid	Fd	Decid	288	220	10	1	48	9
9	Cw	Cw/Yc > 80%	Any	13	13	0	0	0	0
10	CwFd	Cw/Yc	Fd, L, Py, Pw, Pl, or Decid	130	74	9	4	34	9
11	CwH	Cw/Yc	H, B, or S	263	231	19	2	6	5
12	H	H > 80%	Any	22	16	0	0	0	6
13	HFd	H	Fd, L, Py, Pw, or Pl	147	146	0	0	1	0
14	HCw	H	Cw or Yc	150	149	0	0	1	0
15	HB	H	B	100	92	0	0	4	4
16	HS	H	S	80	79	1	0	0	0
18	B	B > 80%	Any	653	417	13	0	122	101
19	BH	B	H, Cw, or Yc	10	10	0	0	0	0
20	BS	B	S, Fd, Pw, Pl, L, Py, or Decid	5661	3644	94	8	1410	505
21	S	S > 80%	Any	1476	799	112	17	372	176
22	SFd	S	Fd, L, Pw, or Py	2545	1546	225	13	507	254
23	SH	S	H, Cw, or Yc	264	237	14	1	4	8
24	SB	S	B	4999	2873	157	13	1457	499
25	SPl	S	Pl	3846	1953	283	29	947	634
26	SDecid	S	Decid	948	463	54	2	295	134
27	Pw	Pw	Any	6	6	0	0	0	0
28	Pl	Pl/Pa > 80%	Any	28220	15594	1707	133	6862	3924
29	PlFd	Pl	Fd, Pw, L, or Py	23654	16073	1795	153	3670	1963

Inv. Type Group	Name	First Species	Second Species	Total Ha	Ha by Percent Cumulative Infestation Severity				
					1 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
30	PIS	Pl	S, B, H, Cw, or Yc	15857	8588	445	42	4307	2475
31	PlDecid	Pl	Decid	1441	769	157	30	319	166
32	Py	Py	Any	1646	1321	111	29	180	5
33	LFd	L <= 80%	Fd	4855	3339	347	25	824	320
34	L	L	Any	10659	6784	582	39	2305	949
35	AcConif	Ac	Conif	406	161	15	1	181	48
36	AcDecid	Ac	Decid	334	272	11	0	41	10
40	E	E	Any	352	278	28	2	36	8
41	AtConif	At	Conif	1124	720	117	11	231	45
42	AtDecid	At	Decid	398	288	38	2	46	24
TOTALS:				**151143**	**95916**	**9221**	**764**	**30110**	**15132**

Table A4. Distribution of stand types (Inventory Type Groups) diffused over the MPB-impacted area of the Cranbrook TSA by the forest reversion model.

Inv. Type Group	Name	First Species	Second Species	Total Ha	Ha by Percent Cumulative Infestation Severity				
					1 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
0				0	0	0	0	0	0
1	Fd	Fd > 80%	Any	1158	854	132	3	106	63
2	FdCw	Fd	Cw or Yc	0	0	0	0	0	0
3	FdH	Fd	H or B	19	13	0	0	3	3
4	FdS	Fd	S	235	188	10	0	19	18
5	FdPl	Fd	Pl	1162	780	144	11	160	67
6	FdPy	Fd	Py	387	293	25	0	66	3
7	FdL	Fd	L, Pw	1472	1176	141	8	104	43
8	FdDecid	Fd	Decid	10	5	1	0	4	0
9	Cw	Cw/Yc > 80%	Any	3	3	0	0	0	0
10	CwFd	Cw/Yc	Fd, L, Py, Pw, Pl, or Decid	24	10	1	0	8	5
11	CwH	Cw/Yc	H, B, or S	56	43	11	1	1	0
12	H	H > 80%	Any	0	0	0	0	0	0
13	HFd	H	Fd, L, Py, Pw, or Pl	9	9	0	0	0	0
14	HCw	H	Cw or Yc	8	8	0	0	0	0
15	HB	H	B	1	1	0	0	0	0
16	HS	H	S	1	0	1	0	0	0
18	B	B > 80%	Any	17	11	3	0	2	1
19	BH	B	H, Cw, or Yc	0	0	0	0	0	0
20	BS	B	S, Fd, Pw, Pl, L, Py, or Decid	398	253	3	0	91	51
21	S	S > 80%	Any	455	199	28	7	128	93
22	SFd	S	Fd, L, Pw, or Py	775	446	79	5	150	95
23	SH	S	H, Cw, or Yc	13	12	0	0	1	0
24	SB	S	B	978	385	23	6	413	151
25	SPl	S	Pl	873	388	35	3	250	197
26	SDecid	S	Decid	384	163	39	1	117	64
27	Pw	Pw	Any	0	0	0	0	0	0
28	Pl	Pl/Pa > 80%	Any	1929	1271	184	20	232	222
29	PlFd	Pl	Fd, Pw, L, or Py	2533	1693	224	25	359	232

Inv. Type Group	Name	First Species	Second Species	Total Ha	Ha by Percent Cumulative Infestation Severity				
					1 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
30	PIS	Pl	S, B, H, Cw, or Yc	1812	892	62	5	495	358
31	PlDecid	Pl	Decid	84	58	10	2	5	9
32	Py	Py	Any	163	148	6	0	9	0
33	LFd	L <= 80%	Fd	976	608	89	3	206	70
34	L	L	Any	1663	928	93	8	459	175
35	AcConif	Ac	Conif	133	52	2	0	63	16
36	AcDecid	Ac	Decid	173	157	8	0	7	1
40	E	E	Any	60	43	12	1	1	3
41	AtConif	At	Conif	50	33	4	1	11	1
42	AtDecid	At	Decid	20	17	1	0	0	2
TOTALS:				**18034**	**11140**	**1371**	**110**	**3470**	**1943**