ESTABLISHING COARSE WOODY DEBRIS BENCHMARKS IN THE PRINCE GEORGE TIMBER SUPPLY AREA

Final Report Prepared by:

Manning, Cooper, and Associates Ltd.
Northern Interior Office
#211 – 154 Quebec Street
Prince George, B.C. V2L 1W2
CONTACT: Aaron M. Deans, RPBio

Prepared for:

Canadian Forest Products Ltd.
5162 Northwood Pulpmill Road
Prince George, B.C. V2L 4W2
ATTN: Kerry Deschamps, RPF

March 31, 2007

EXECUTIVE SUMMARY

Coarse woody debris (CWD) plays an important role in the ecology of forests (Harmon et al. 1986; Stevens 1997), the provisions of shelter, habitat and food for plant and wildlife species (Bunnell et al. 1999; Bull 2002), and in forest ecosystem nutrient cycling (LeFroth 1998). In order to set targets for CWD retention in managed forest landscapes, it is necessary to first have "benchmark" understandings of CWD quantities and qualities that naturally occur in late successional forest stands.

To establish benchmarks for CWD retention in the Prince George Timber Supply Area, 40 sites in 3 different BEC zones were sampled for CWD volumes. Volumes in the Sub-boreal Spruce (SBS), Interior Cedar-Hemlock (ICH), and Engelmann Spruce-Subalpine Fir (ESSF) BEC zones tended to be quite variable, with the highest volumes occurring in the ESSF and the lowest volumes occurring in the SBS. Volumes were analyzed in 3 classes, total volume, volume 7.5 – 30 cm in diameter, and volume >30 cm in diameter.

We offer preliminary targets for CWD volume retention within these BEC zones based on the data collected in this study. The small sample size of this study (only 40 sites across 3 BEC zones) is important to note when applying these targets. To ensure that targets reflect naturally occurring levels of CWD and capture the inherent variation in them, it is highly recommended that additional sampling of forest stands be undertaken to refine targets and ranges presented in this report.

ACKNOWLEDGMENTS

Kerry Deschamps initiated this project and provide guidance and datasets for candidate site selections. Karl Bachmann, Allan Carson, Aaron Deans, Nathan Hentze, and Dan Stevens all in part collected field data contained within the report. Report was written by Karl Bachmann and Aaron Deans.

Project was funded by Forest Investment Account (FIA) and administered by Canadian Forest Products Ltd.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICIES

1.0 INTRODUCTION

Coarse-woody debris (CWD) is a key structural element in forested landscapes and recognized as important stand-level habitat features for a diversity of species in managed forests (Harmon et al. 1986; Hansen et al. 1991; Machmer and Steeger 1995; Bunnell et al. 1999 and 2004; Manning et al. 2005; Fenger et al. 2006). Standing dead and dying trees are also important structural elements for habitat (i.e., wildlife trees), and future recruitment of CWD into the understorey. One-quarter of the vertebrate species (birds, small mammals, amphibians, and furbearers) in British Columbia depend upon wildlife trees (Stevens 1997; Bunnell et al. 1999; Bunnell et al. 2004; Fenger et al. 2006), and CWD for nesting, roosting, foraging, and shelter or as travel routes throughout their respective territories (e.g., Proulx and Kariz 2000; Keisker 2000; Bull 2002). CWD also provides a substrate for diverse species of invertebrates, fungi and lichen, and as it decomposes it returns elements back into the nutrient cycle of the soil and forest floor (Stevens 1997; Lofroth 1998).

Not all pieces of CWD are of equal value, or perform all ecological functions. Larger pieces of CWD tend to persist longer in the environment and maintain their function over longer time periods (Stevens 1997). Additionally, larger pieces tend to be more useful to a greater suite of wildlife species (Adams 2002). Large pieces are also the most difficult to create or retain in a managed forest landscape, as the larger merchantable trees are removed from the site or burned as slash. Decay class also influences the ecological value of CWD (Densmore et al. 2004). For example, southern red-backed voles (*Clethrionomys gapperi*) tend to be associated with more decayed CWD (Bowman et al 2000).

While a substantial amount of work looking at the ecological role and naturally occurring levels of CWD in B.C. has been undertaken (e.g., Stevens 1997), many areas still lack baseline data on CWD levels. Caza (1993) noted that there was a paucity of information on naturally occurring levels of CWD. Because naturally occurring levels of CWD are influenced by many factors (e.g., fire return interval, forest type, moisture), management targets should be specific to appropriately scaled ecological units.

1.1 Project Objectives

Given the role of CWD in the maintenance of biodiversity, the objectives of this project were to:

1. Establish CWD benchmark data by Biogeoclimatic Ecological Classification Zone in various Natural Disturbance Units in the Prince George Timber Supply area. This included data on total volume, volume by diameter class, number of pieces, and decay class.
2. Set preliminary targets for post-harvest coarse woody debris retention
3. Offer recommendations on future data requirements for further refining coarse woody debris targets

2.0 STUDY AREA

The study area for this project was contained by supply blocks C, D, G, and H of the Prince George Timber Supply Area (TSA). This corresponds to portions of the Fort St. James, Vanderhoof, and Prince George Forest Districts (**Figure** 4**1**).

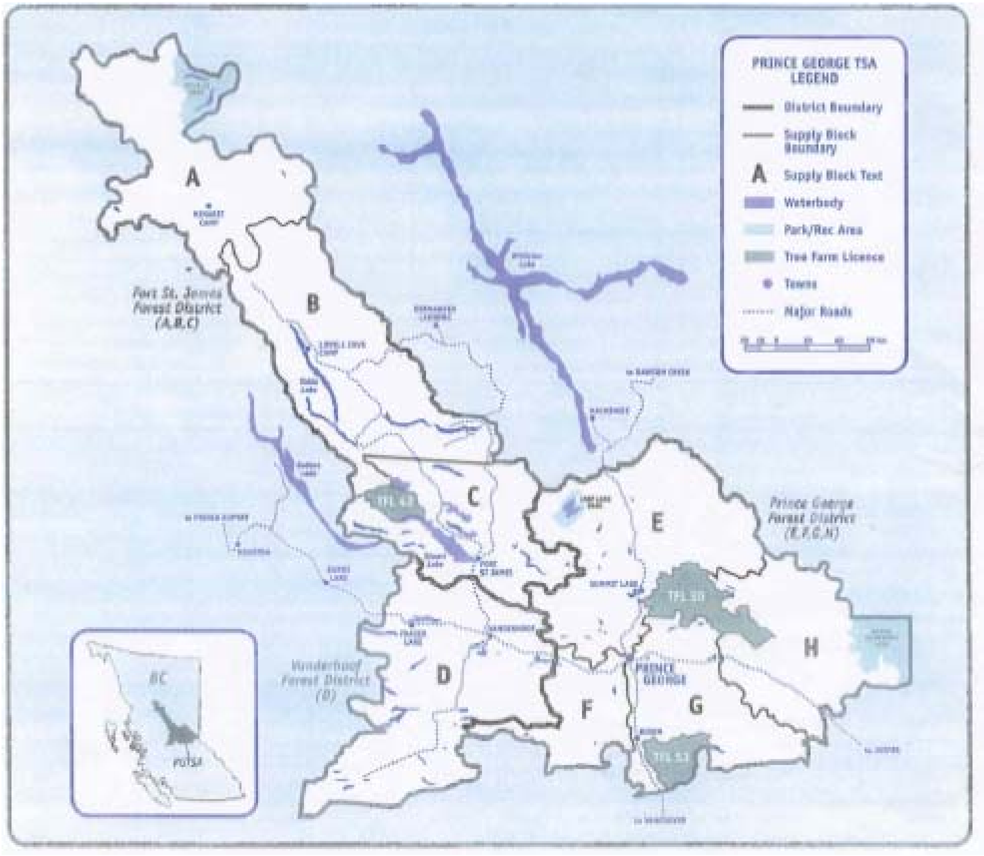


Figure 1. The Prince George timber supply area (TSA).

Biogeoclimatic Ecological Classification (BEC) zones selected for this study included: the Engelmann Spruce – Subalpine-fir (ESSF) zone, the Interior Cedar-Hemlock (ICH) zone, and the Sub-boreal Spruce (SBS) zone (Meidinger and Pojar 1991). The ESSF occurs at the highest forested elevations, generally between 900 m and 1700 m (Coupe et al. 1991). A continental climate dominates, with long snowy winters and cool, moist summers. Climax tree species are Engelmann spruce (*Picea engelmannii*) and subalpine Fir (*Abies lasicarpa*), with lodgepole pine (*Pinus contorta var. latifolia*) being the dominant seral species. The ICH occurs in valley bottom and mid-slope locations in the wetter portions of the B.C. interior from approximately 400 m to 1500 m (Ketcheson et al. 1991). It has high precipitation year round, with mild summers and cool, wet winters. Climax trees species are generally western red-cedar (*Thuja plicata*) and western hemlock (*Pseudotsuga heterphylla*), although many other trees species can occur in climax stands, including subalpine fir and interior hybrid spruce. The SBS occupies the drier plateau and montane areas of central interior B.C., usually between 1100 m and 1300 m in elevation (Meidinger et al. 1991). Climate is continental, with short, hot and dry summers, and long, cold winters. Climax tree species are hybrid white spruce (*Picea engelmannii x glauca*) and subalpine fir, with Lodgepole pine and Trembling aspen (*Populus tremuloides*) being the most common seral species.

Our study area covers 2 different Natural Disturbance Units (NDUs, DeLong 2002), the Moist Interior (contains SBSdk, dw, mc, mk and ESSFmv) and the Wet Trench (contains ICHwk and vk, ESSFwk) (**Figure 2**).

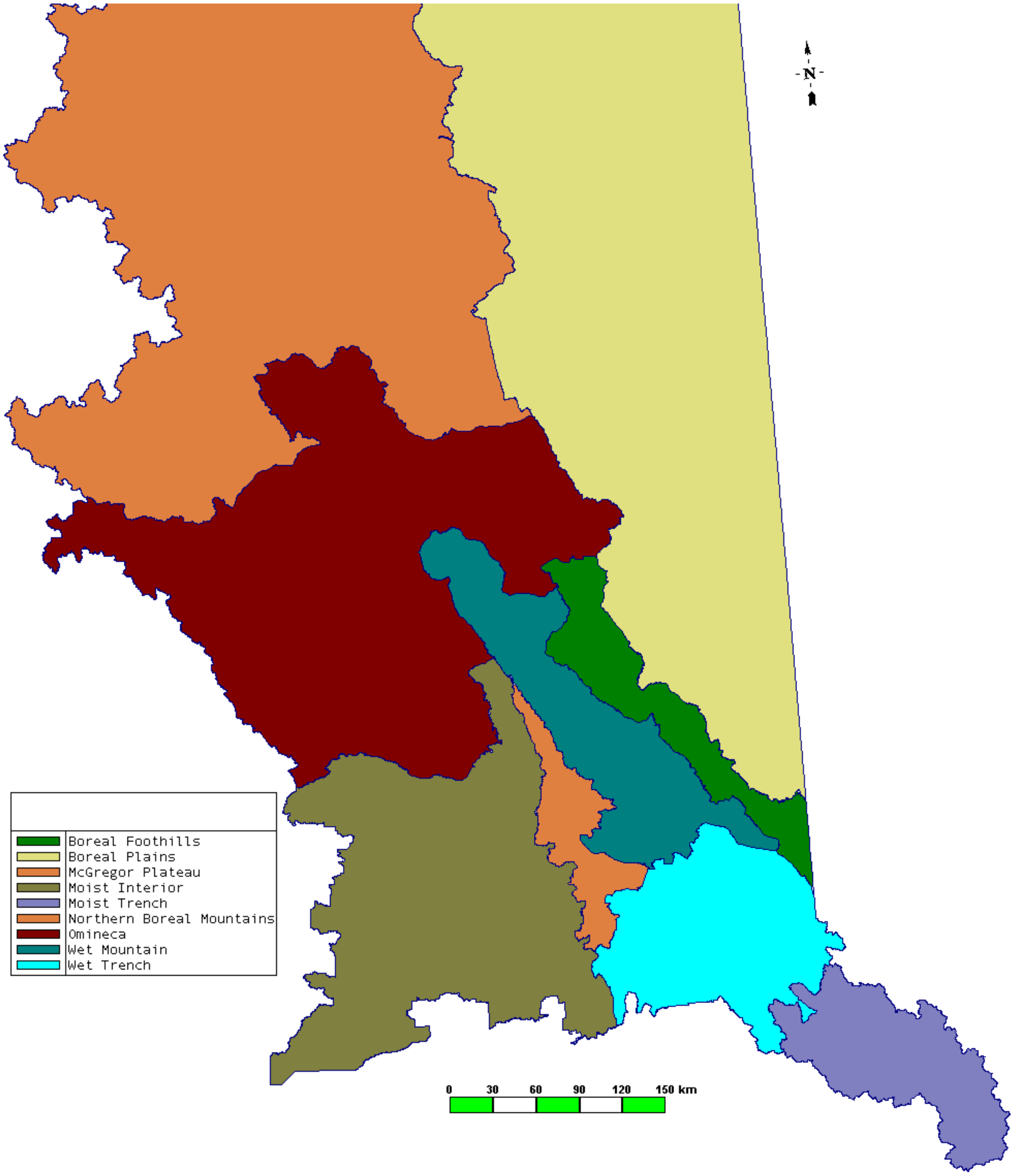


Figure 2. Natural Disturbance Units of the Prince George Forest Region (map from DeLong 2002).

3.0 METHODS

3.1 Site Selection

We used a randomized block sampling design to select a total of 40 sites from candidate sites identified within the 3 different BEC zones. Each zone was subdivided by moisture regime, using BEC subzone as a surrogate (**Table 1** and **Figure 3**).

Table 1. Breakdown of CWD benchmark sample sites by BEC Subzone in the Prince George Timber Supply Area.

BEC ZONE	BEC SUBZONE	MOISTURE	NO. OF SAMPLE SITES
ESSF	mv	Moist (M)	5
	wk	Wet (W)	5
ICH	vk	Very Wet (V)	5
	wk	Wet (W)	5
SBS	dk and dw	Dry (D)	10
	mc and mk	Moist (M)	10

Spatially explicit candidate sites were initially identified through a coarse filter analysis of Predictive Ecosystem Modeling (PEM) in combination with Vegetation Resource Inventory (VRI), and harvest history datasets provided by Canfor Ltd. Late successional forest areas were considered in each of the above BEC subzones. Mature stands that exhibited little or no anthropomorphic disturbance were given priority. All candidates sites identified with inadequate road access were excluded from the selection process. Wherever possible, benchmark study sites were established in groupings so as to maximize operational efficiencies.

Figure 3. CWD representative sample stands in SBS, ICH, and ESSF BEC units of the PG TSA.

Study sites were delineated in eleven separate areas throughout the Prince George TSA (**Figure 4**; and **Appendix 1**).

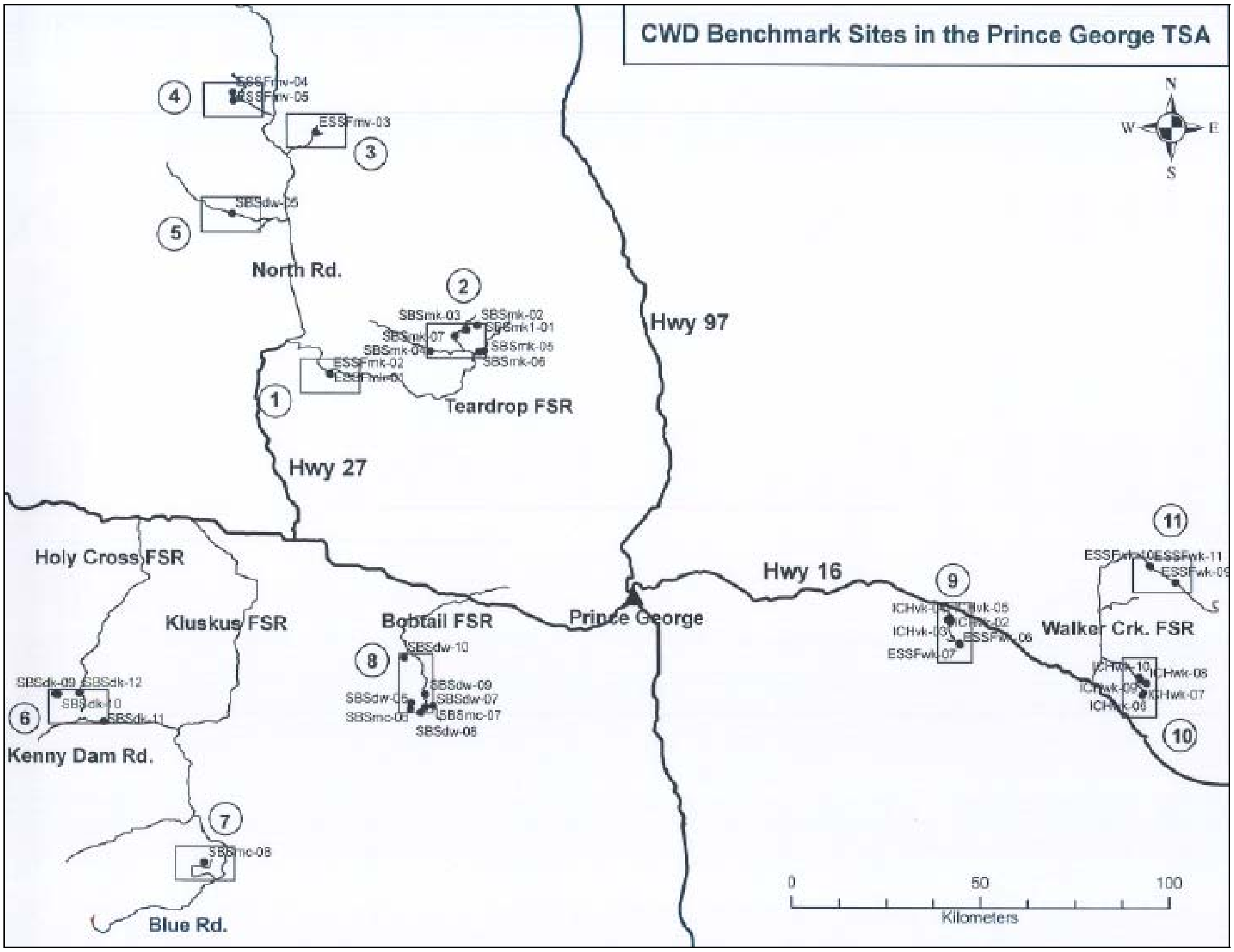


Figure 4. Map of CWD benchmark sampling sites in the Prince George Timber Supply Area.

3.2 Site Set-up

Sites were situated a minimum of 200 m from a road or other edge (e.g., cutblock) to negate the influence of edge effects on CWD recruitment. A minimum of 400 m was maintained between any two IPCs to avoid pseudoreplication.

An integrated plot centre (IPC) was established and a unique tag identifier, UTM coordinates, elevation, and plot name was recorded at each sample site. Garmin 76 handheld Global Positioning System (GPS, Olathe KS) was used to determine geo-reference data. Photo images of the IPC and a representative picture of the stand were taken with a digital camera. Aspect was recorded in degrees. Stand age was derived from Vegetation Resource Inventory (VRI) data provide by Canfor Ltd., forward aged to 2006.

3.3 Data Collection

An 11.28 m fixed radius plot was delineated at each IPC and stand structure data was recorded on all trees > 7.5 cm diameter at breast height (dbh). Data was recorded on species, dbh, and decay class. Additionally, the heights of 3 representative canopy layer trees were determined using a clinometer and tree cores were extracted for tree aging using an increment borer. All trees < 7.5 cm dbh were classified as saplings and tallied by species.

CWD data was recorded along 150 m of line-sampling transect, which was laid out as an equilateral triangle. One corner of the triangle was situated on the IPC and the direction of the initial trajectory from the IPC was determined by random bearing (**Figure 5**). A compass and hip chain was used to lay-out the transect during sampling. A diameter tape was used to measure the diameter of each piece of CWD.

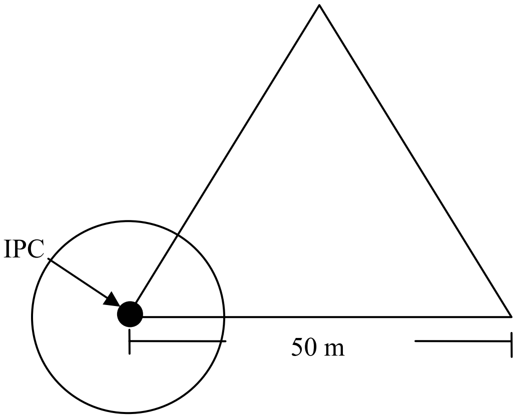
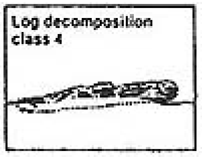


Figure 5. CWD sampling scheme for baseline data collection in the Prince George Timber Supply Area.

Standard National Forest Inventory (NFI) Ground Sampling guidelines for CWD sampling were utilized (NFI 2004; BC MSRM 2005). Data collection procedures were compatible to B.C. Ministry of Forests protocols for Describing Terrestrial Ecosystems and sampling CWD (BCMOF 1998). CWD was considered as downed wood > 7.5 cm in diameter and data was recorded for all pieces that intercepted the line transect. Along the length of the sampling transect CWD data was recorded on species (if possible to determine), diameter, decay class (1-5, **Table 2**), piece shape, as well as an estimation of length into 3 classes (1 = <2m, 2 = 2-10 m, 3 = >10m).

Table 2. Decay classes for coarse woody debris (source: BC Ministry of Forests 1998).

	CLASS 1	CLASS 2	CLASS 3	CLASS 4	CLASS 5
					

WOOD TEXTURE	Intact, hard	Intact, hard to partially decaying	Hard, large pieces partially decaying	Small blocky pieces	Many small pieces, soft portions
PORTION ON GROUND	Elevated on support points	Elevated but sagging slightly	Sagging near ground, or broken	All of log on ground, sinking	All of log on ground, partly sunken
TWIGS <3CM (IF ORIGINALLY PRESENT)	Present	Absent	Absent	Absent	Absent
BARK	Intact	Intact, or partly missing	Trace	Absent	Absent
SHAPE	Round	Round	Round	Round to oval	Oval
INVADING ROOTS	None	None	In sapwood	In heartwood	In heartwood

3.4 Data Analysis

All data was entered into an Access database, and exported to Excel for exploratory analysis. Statistix 8.0 (Tallahassee, FL) was used for all statistical analyses reported.

Volume of CWD (cubic metre per hectare, m^3/ha.) was calculated using Van Wagner's (1968) equation for a site using the line intersect method:

$$V = \frac{\pi^2 * \Sigma(d^2)}{8 \times L}$$

Where: V is volume per unit area (m^3/ha),
d is piece diameter at intersection (cm),
L is slope-corrected length of sample line (m).

Volume of CWD by site was tallied into 3 different volume classes: total volume, 7.5 – 30 cm volume, and > 30 cm volume. We followed other studies (e.g., Adams 2002) in defining a 'large' piece of CWD as > 30 cm in diameter. Average volumes and standard error by BEC zone were calculated for all 3 BEC zones in the study.

Data normality was tested using probability plots and the Shapiro-Wilk statistic. A one-way ANOVA was used to detect differences in volumes among BEC zones. The assumption of equal variances was tested using Bartlett's Test of Equal Variances. Tukey's HSD All-pairwise Comparisons Test was used to test for specific difference between CWD volumes in distinct BEC zones. Where the assumptions of normality were not met for an ANOVA, we used the Kruskal-Wallis One-way non-parametric method. We looked at differences between moisture regimes within BEC zones using 2-sample T-tests (we report the *t* statistic), using the *F* test to test for equality of variances. When this test was not appropriate due to non-normality of the data, we used the non-parametric Wilcoxon Rank Sum Test (we report the *U* statistic). Relationships between leading species and volumes were examined using Pearson correlations. An α of 0.05 was used for all statistical tests.

4.0 RESULTS

A total of 40 CWD sampling sites were established in 3 different BEC zones and 9 different sub-zones (**Figure 4** and **Appendix 1**). Moist and dry SBS sub-zones were not pooled for analysis since they were considered to be sufficiently ecological distinct from each other. The range of CWD volume calculated for each volume class was determined to be quite variable as seen in the difference between maximum and minimum values reported for all BEC zones (**Table 3**).

Table 3. Average volumes of CWD by volume class in 3 BEC zones of the Prince George TSA.

BEC ZONE	*n*	TOTAL VOL (m^3/ha.)[1]	MAX., MIN.	7.5 – 30 cm VOL (m^3/ha.)[1]	MAX., MIN.	> 30 cm VOL (m^3/ha.)[1]	MAX., MIN.
ESSF	10	159.57 (±24.87)	29.79, 264.79	73.76 (±14.68)	29.79, 164.35	85.80 (±24.90)	0.00, 199.89
ICH	10	139.45 (±15.80)	66.23, 209.20	50.23 (±8.21)	16.47, 94.08	89.21 (±14.33)	23.33, 168.58
SBS moist	10	107.80 (±18.05)	23.09, 189.86	102.85 (±16.94)	23.09, 173.53	4.92 (±2.07)	0.00, 16.30
SBS dry	10	56.86 (±13.43)	3.38, 137.86	53.67 (±13.45)	3.38, 130.46	3.20 (±1.71)	0.00, 14.51

[1] Volumes presented are combined replicate averages ± standard error.

Overall, total volumes of CWD were found to be similar between BEC units except for the dry SBS sub-zone, which was found to be significantly less then ESSF and ICH BEC zones (*F*=5.83, *p*=0.0024). The volume of CWD in the smallest size class (7.5 – 30 cm) was found highest in moist SBS study sites, and significantly greater than comparable volumes in ICH zone (*F*=3.11, *p*=0.0383) (**Table 4**). The >30 cm volume class showed similar volumes in ESSF and ICH sites, however, both had significant greater amounts of large CWD compared to moist and dry SBS sub-zones (*F*=16, *p*=0.0001). Total volume and > 30 cm volume groupings appear to follow a moisture gradient with the wet and very wet ESSF and ICH zones having significantly greater volumes.

Table 4. Homogeneous groupings by volume class and BEC zone in the Prince George TSA.

BEC ZONE	TOTAL VOL (m^3/ha.)[1]	7.5 – 30 cm VOL (m^3/ha.)[1]	> 30 cm VOL (m^3/ha.)[2]
ESSF	A	AB	A
ICH	A	B	A
SBSm	AB	A	B
SBSd	B	AB	B

[1] Tukey HSD All-Pairwise Comparisons
[2] Kruskal-Wallis All-Pairwise Comparison Test

There was no correlation found between total volume and number of pieces of CWD at a site (R^2= 0.13, **Figure 6**).

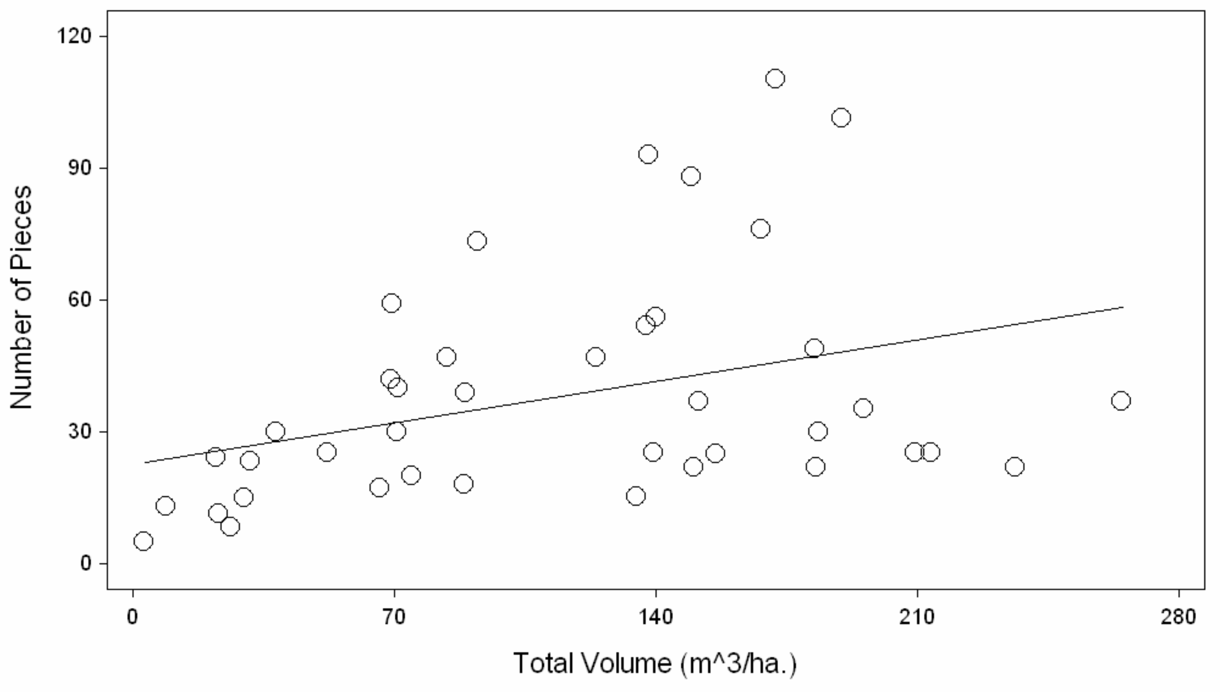


Figure 6. Graph of number of pieces of CWD vs. total volume for 40 sites in the Prince George Timber Supply Area.

Volume of CWD by diameter class was further considered by moisture regime and BEC zone (**Figure 7**, **Figure 8**, **Figure 9**). The SBS zone revealed significant differences between dry and moist moisture regimes in all but the >30 cm volume class (Total Vol.: *t*= -2.26, *p*=0.0362; 7.5-30 cm Vol.: *t*= -2.27, *p*=0.0354; and, >30 cm Vol.: *U*= 42.00, 58.00, *p*=0.4613).

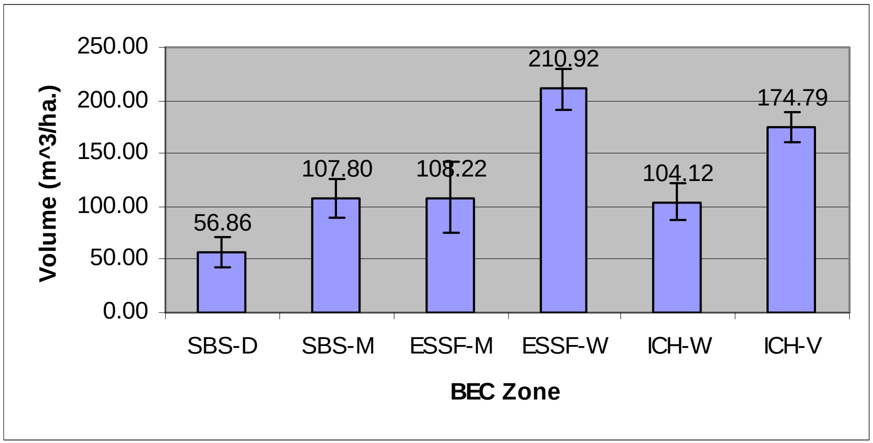


Figure 7. Total volume of CWD averaged by moisture regime and BEC zones in the PG TSA. Values are above each bar. Error bars indicate ± standard error.

Similarly, the ESSF also exhibited a difference in 2 of 3 volume classes (Total Vol.: *t*= -2.28, *p*=0.0278; 7.5-30 cm Vol.: *t*= 0.83, *p*=0.4314; >30 Vol.: *t*= -4.63, *p*=0.0017). The ICH showed the same pattern as the ESSF, with no difference in the 7.5-30 cm volume between the 2 moisture regimes (Total Vol.: *t*= 3.16, *p*=0.0133; 7.5-30 cm Vol.: *t*= 0.17, *p*=0.8692; >30 Vol.: *t*= 3.62, *p*=0.0068).

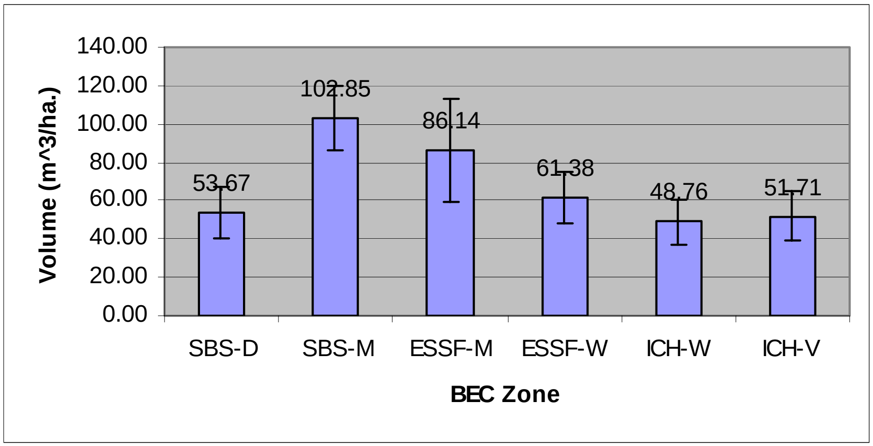


Figure 8. Graph of average 7.5 – 30 cm volume of CWD by moisture regime within BEC zone for the Prince George Timber Supply Area. Values are above each bar. Error bars are ± standard error.

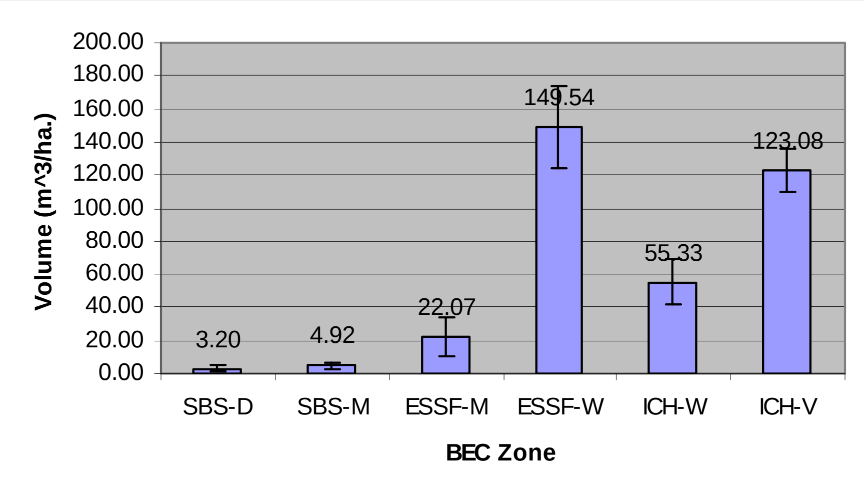


Figure 9. Graph of average > 30 cm volume of CWD by moisture regime within BEC zone for the Prince George Timber Supply Area. Values are above each bar. Error bars are ± standard error.

Out of 20 sites in the SBS, 18 were Lodgepole Pine (Pl) leading and 2 were Spruce (Sx) leading. In the ESSF, 5 sites were Sub-alpine fir (Bl) leading, 3 were spruce leading, and 2 were Douglas-fir (Fd) leading. In the ICH, 6 sites were Western Hemlock (Hw) leading and Western Red-cedar (Cw) leading. The only correlation between leading species and volume of CWD were slight negative correlations between Pl and total volume (-0.5657) and between Pl and > 30 volume (-0.5320). Overall, poor quality of tree cores prevented aging of many of the trees sampled, thus not allowing a correlation between age and CWD volumes.

5.0 DISSCUSSION

Measured volume data from this study was comparable in most cases to values reported in the literature in the same BEC subzones (**Table 5**). Our average total volume value for the ESSF fell within the range of all of these studies, as did the same values for both the moist and dry SBS zones. Our average total volume for the ICH, however, was below the range of 3 out of 4 of the studies we looked at.

Table 5. Means and ranges (in parentheses) of CWD volume by BEC zone and subzone from studies relevant to B.C. forests.

STUDY	BEC ZONE / SUBZONE	TOTAL CWD VOLUME (m^3/ha.)
Harrison et al. 2002	ESSFwk	243 (60 – 425)
Feller 2003	ESSFwk	145 (4 – 373)
Feller 2003	ESSFmv	74 (5 – 201)
Stevens 1997	ESSFmv / mk	212.07 (3.92 – 373.38)
Feller 2003	ICHwk	327 (158 – 557)
Harrison et al. 2002	ICHwk	255 (144 – 658)
Densmore et al 2004	ICHvk / wk	232.73 (87.66 – 486.32)
Stevenson et al. 2006	ICHvk / wk	303.5 (220 – 387)
Feller 2003	SBSdk	55 (2 – 473)
Feller 2003	SBSdw	116 (0-468)
Feller 2003	SBSmc	151 (2 – 661)
Feller 2003	SBSmk	26 (7 – 36)
Clark et al. 1998	SBSmc	60
Densmore et al 2004	SBSmk	145.04 (22.84 – 390.41)
DeLong 2002	SBSmk	192.6 (38.6 – 286.0)
Lloyd 2005	SBSdk	81
Lloyd 2005	SBSmc	160
Stevens 1997	SBSdk / dw	120.54 (4.17 – 387.08)
Stevens 1997	SBSmk / mc	222.78 (1.37 – 932.14)

The ESSF zone had the highest volume of CWD in our study area, similar to several studies that have also found the ESSF has the highest relative volumes of CWD (e.g. Adams 2002, Harrison et al. 2002). The ICH had lower overall volumes than the ESSF, but a higher volume of >30 cm pieces. Given the common occurrence of large Cw in the ICH, this agrees with Stevenson et al. (2006) who found a strong relationship between tree size and CWD. Overall, the SBS had the lowest volume of CWD. The > 30 volume for both the dry and moist SBS zones was not normally distributed. Because all our sites in the SBS were dominated by Pl, inputs of > 30 cm diameter CWD were relatively rare, skewing the distribution leftwards. Looking at literature from areas dominated by Pl stands, Proulx and Vergara (2001) found that the median diameter for CWD was 28 cm, suggesting the patterns we have observed are generally consistent across the SBS.

It has been noted the CWD volumes generally increase with increasing elevation (Adams 2002), a rough surrogate for BEC zone. Our results reflect this pattern on average, although there is considerable overlap in volume between individual sites within BEC zone. This relationship breaks down, however, when volume is separated into 7.5-30 cm and >30 cm divisions. Tree species associations with BEC zones likely explain this pattern. For example, Cw is a common species in the ICH, and tends to be larger in diameter in mature stands than either Pl or Sx. CWD inputs from this species would result in a higher volume of >30cm pieces (e.g., Stevenson et al. 2006).

Logging of our sample sites (indicated by old stumps or skid trails) previous to detailed records being kept may influence our results. Generally, CWD volumes (Adams 2002) and/or decay class distribution and piece length (Stevenson et al. 2006) are altered post-harvest. While we avoided sites with overt signs of harvesting, some logged stands may have had enough time post-disturbance to regain mature status. Such stands would have lower levels of CWD in addition to slower inputs of CWD from the young regenerating stand. This may explain why some of our average volumes are lower than those studies reported in **Table 5**.

The ranges in **Table 5** are quite broad, suggesting that natural levels of CWD are quite variable. Given that the full range of variables contributing to CWD inputs and retention is not fully understood, some caution should be used in applying CWD volumes to targets in other areas. Clearly, there is a high degree of variability in total CWD volumes on the landscape. This suggests that any operation targets set for the retention of CWD post-harvest should be based on sampling at the BEC subzone level rather than the zone level to capture the range of natural variation (Feller 2003).

Our sample sizes within BEC zones by moisture regime were relatively small, yet we still detected a significant difference in volumes. This indicates that moisture regime probably does significantly influence either the inputs and/or retention of CWD within a BEC zone. Further sampling stratified by BEC and moisture zone will allow these patterns to be teased apart. Given that forest harvesting is usually defined by BEC subzone and variant, having good information on CWD volumes by moisture zone is particularly germane to forest management.

6.0 CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Stevens (1997) concluded that naturally occurring levels of CWD make good targets for retention in harvested areas. Additionally, she notes that natural levels vary considerably both spatially and temporally, allowing flexibility in setting targets. This echoes the Biodiversity Guidebook (BCMOF and BCMOE 1995) principle of ensuring managed forests emulated natural forests as closely as possible to conserve biodiversity.

Any strategy to manage CWD must also recognize that maintaining CWD levels within the range of natural variation on the managed landscape must address more than just post-harvest volumes.

The full range of techniques for long-term planning for CWD retention is beyond the scope of this report; however, ensuring within-cutblock retention of live trees and retention of snags are two of the most important (Bunnell et al. 2003). Live trees and snags retained within a cutblock area will be the basis for future CWD inputs into managed stands once the CWD retained post-harvest has totally decayed (Lofroth 1998).

Based on the results of this study, we recommend:

1. The CWD retained post-harvest should meet the following targets to emulate natural CWD volumes (**Table 6**). The suggested ranges are preliminary, based on plus/minus twice the standard error presented in this study. Targets were not established for specific moisture regimes within BEC zones due to small sample sizes, and are intended for coarse-scale targets only.

Table 6. Preliminary total volume targets and acceptable ranges for CWD in BEC zones within the Prince George Timber Supply area.

BEC SUBZONE	TARGET (m^3/ha.)	ACCEPTABLE RANGE (m^3/ha.)
ESSF	160	110 – 210
ICH	140	110 – 170
Dry SBS	55	30 - 85
Moist SBS	100	70 – 145

2. Because of the high variability in CWD volumes and relatively small sample size of this study, it is important that additional sampling should be conducted within specific subzones for each BEC zone. Based on this, the targets above can be refined in each BEC subzone to ensure that CWD volumes retained through post-harvest falls within the naturally occurring range.

3. Additional sampling should focus on developing separate targets for both 7.5 - 30 cm and > 30 cm volumes. This will ensure that the ecologically more valuable large CWD pieces are retained. Having targets set exclusively with respect to total volumes may allow targets to be achieved entirely by retention of smaller diameter pieces, which may lead to an ecologically undesirable condition with an overall lower value to CWD dependant species.

4. To emulate the variability inherent in CWD volumes and distributions, CWD volume targets do not necessarily have to be met on every cutblock. As long as the average CWD volume retained over all cutblocks (within some appropriately size planning or ecological unit) meets the target, variations on individual cutblocks will emulate natural variation.

7.0 LITERATURE CITED

Adams, I. 2002. Coarse woody debris in the East Kootenay region. Final Report for Tembec Industries, B.C. Division, Cranbrook, B.C.

BC Ministry of Forests and BC Ministry of Environment, Lands, and Parks. 1995. Forest practices code biodiversity guidebook. British Columbia Ministry of Forests and Ministry of Environment, Lands, and Parks, Queen's printer, Victoria, British Columbia, Canada.

BC MOF. 1998. Field Manual for Describing Terrestrial Ecosystems. BC Ministry of Forests, Land Management Handbook Number 25.

BC MSRM. 2005. National Forest Inventory – British Columbia. Change Monitoring Procedures for Provincial and National Reporting. Prepared by Ministry of Sustainable Resource Management (MSRM), Resource Information Branch for the Resources Information Standards Committee. Version 1.4. March 31, 2005. 222pp. See url: http://ilmbwww.gov.bc.ca/risc/pubs/teveg/nficmp05/nfi_cmp_2k5.pdf

Bowman, J.C., D. Sleep, G.J. Forbes, and M. Edwards. 2002. The association of small mammals with coarse woody debris at log and stand scales. Forest Ecology and Management 129: 119-124.

Bull, E.L. 2002. The value of coarse woody debris to vertebrates in the Pacific Northwest. USDA Forest Service Gen. Tech. Rep. PSW-GTR-181. La Grande, Oregon.

Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environ. Rev. **7**: 97-146.

Bunnell, F.L., G. Dunsworth, D. Huggard, and L. Kremsater. 2003. Learning to sustain biological diversity on Weyerhaeuser's coastal tenure. Report for Weyerhaeuser Ltd.

Caza, C.L. 1993. Woody debris in the forests of British Columbia: a review of the literature and current research. British Columbia Ministry of Forests Land Management Report 78.

Clark, D.F., D.D. Kneeshaw, P.J. Burton, and J.A. Antos. 1998. Coarse woody debris in sub-boreal spruce forests of west-central British Columbia. Can. J. For. Res. 28: 284.290 (1998).

Coupe, R., A.C. Stewart, and B.M. Wikeem. 1991. Chapter 15: Engelmann spruce – subalpine fir zone. In: Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forests. 330 pp.

DeLong, C. 2002. Natural disturbance units of the Prince George Forest Region: guidance for sustainable forest management. Unpublished report, B.C. Ministry of Forests, Prince George Region.

Densmore, N., J. Parminter, and V. Stevens. 2004. Coarse woody debris: Inventory, decay modelling, and management implications in three biogeoclimatic zones. BC Journal of Ecosystems and Management 5(2): 14–29. URL: www.forrex.org/jem/2004/vol5/no2/art3.pdf

Feller, M.C. 2003. Coarse woody debris in the old-growth forests of British Columbia. Environmental Review 11: 135-157.

Fenger, M., T. Manning, J. Cooper, S. Guy, and P. Bradford. 2006. Wildlife and trees in British Columbia. Lone Pine Publishing. 336pp.

Hansen, A. J., Spies, T. A., Swanson, F. J., and Ohmann, J. F. 1991. Conserving biodiversity in managed forests: lessons from natural forests. *BioScience* 41: 382-392.

Harmon, M.E., Franklin, J.F., Swanson, F.J., Sollins, P., Gregory, S.V., Lattin, J.D., Anderson, N.H., Cline, S.P., Aumen, N.G., Sedell, J.R., Lienkaemper, G.W., Cromack, K., Jr., and Cummins, K.W. 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. **15**: 133–302.

Harrison, M., DeLong, S.C., & Burton P. J. 2002. A comparison of ecological Characteristics in Stands of Differing Age Class in the ICHwk3, ESSFwk2, ICHmm and ESSFmm: Development of An Index to Assess Old Growth Features. Ministry of Forests, Prince George, B.C. Final report for Roboson Valley Enhanced Forest Management Pilot Project.

Ketcheson, M.V., T.F. Braumandl, D. Meidinger, G. Utzig, D.A. Demarchi, and B.M. Wikeem. 1991. Chapter 11: Interior cedar – hemlock zone. In: Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forests. 330 pp.

Lloyd, R.A. 2005. Results of operational trials to manage coarse woody debris in the Northern Interior. Unpubl. rep. prepared for Morice and Lakes Innovative Forest Practices Agreement, Prince George, BC. 27 pp. + appendices.

Lofroth, E. 1998. The dead wood cycle. *In* Conservation biology principles for forested landscapes. J. Voller and S. Harrison (eds.). UBC Press, Vancouver, BC. pp. 185-214.

Machmer, M.M. and C. Steeger. 1995. The ecological roles of wildlife tree users in forest ecosystems. Land Management Handbook 35. British Columbia Ministry of Forests, Victoria, BC. 54pp.

Manning, E.T., W.J. Golding, J. Baker, and A.M. Deans. 2005. Silviculture guidelines and practices for maintaining or recruiting key habitat objectives in area affected by large-scale salvage logging for mountain pine beetle. Report prepared for BC Ministry of Water, Land and Air Protection, Biodiversity Branch. Victoria, B.C. 96pp.

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forests. 330 pp.

Meidinger, D., J. Pojar, and W.L. Harper. 1991. Chapter 14: Sub-boreal spruce zone. Page 209-221 In: Meidinger, D. and J. Pojar. (Eds.) Ecosystems of British Columbia. B.C. Ministry of Forests. 330 pp.

NFI. 2004. Canada's National Forest Inventory: Ground sampling guidelines. Prepared by Canadian Forest Inventory Committee. Version 4.1. February 13, 2004. 97pp. See url: https://nfi.nfis.org/documentation/ground_plot/Gp_guidelines_v4.1.pdf

Proulx, G., and R. Kariz. 2000. Coarse woody debris and small mammal populations in clearcuts and unharvested forests in the sub-boreal spruce biogeoclimatic zone of Fort St. James Forest District, British Columbia. Alpha Wildlife Research & Management Ltd. report submitted to Canadian Forest Products, Prince George, British Columbia.

Proulx, G, and V. Vergara. 2001. Wildlife habitat attributes for wildlife tree patch quality assessments in Canfor's managed landscapes. Report prepared for Canadian Forest

Products Ltd., Prince George, British Columbia by Alpha Wildlife Research and Management Ltd. Sherwood Park, Alberta.

Stevens, V. 1997. The ecological role of coarse woody debris. Working Paper 30. Ministry of Forests Research Program. B.C. Ministry of Forests.

Stevenson, S.K., M.J. Bull, and B.J. Rogers. 2006. Abundance and attributes of wildlife trees and coarse woody debris in the Interior Cedar-Hemlock zone, British Columbia. Forest Ecology and Management 233: 176-191.

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. Forest Science 14(1): 20-26.

8.0 APPENDICIES

Appendix 1. Summary of CWD benchmark sample site location details in the Prince George TSA.

Sample Plot	FSR Access[2]	UTM Co-ordinates		Elevation (m)	Aspect	BEC Zone[3]	BEC Sub-zone	VRI Age[4]
		Easting	Northing					
ESSFMV-01	Teardrop	436246	6029457	1058.0		ESSF	mv	163
ESSFMV-02	Teardrop	436036	6029807	1012.6		ESSF	mv	163
ESSFMV-03	Rainbow	432507	6092976	1190.0		ESSF	mv	193
ESSFMV-04	Witch	410864	6103622	1261.0	NE	ESSF	mv	295
ESSFMV-05	Witch	410952	6101459	1256.0	NE	ESSF	mv	215
ESSFWK-06	Hungary Creek	602536	5958583	1271.0	SW	ESSF	wk	228
ESSFWK-07	Hungary Creek	602387	5958982	1285.0	SW	ESSF	wk	228
ESSFWK-08	Walker Creek	659521	5975087	1020.1	NE	ESSF	wk	157
ESSFWK-09	Walker Creek	652876	5979496	1035.0	NE	ESSF	wk	229
ESSFWK-10	Walker Creek	653094	5979264	1034.3	NE	ESSF	wk	229
ICHVK-01	Hungary Creek	600059	5964478	1118.0	W	ICH	vk	109
ICHVK-02	Hungary Creek	600183	5964933	1145.0	W	ICH	vk	259
ICHVK-03	Hungary Creek	599469	5964926	997.0	W	ICH	vk	159
ICHVK-04	Hungary Creek	599389	5965339	980.0	W	ICH	vk	159
ICHVK-05	Hungary Creek	599986	5965583	992.0	N	ICH	vk	259
ICHWK-06	Morkill	650823	5945507	577.2	W	ICH	wk	208
ICHWK-07	Morkill	651176	5946046	796.8	N	ICH	wk	178
ICHWK-08	Morkill	651923	5948538	810.5	SW	ICH	wk	188
ICHWK-09	Morkill	650445	5949397	789.4	W	ICH	wk	198
ICHWK-10	Morkill	649933	5950229	798.7	SW	ICH	wk	228
SBSDK-01	Marilla Main	363585	5944991	980.0	N	SBS	dk	110
SBSDK-02	Marilla Main	364298	5944940	983.0	NW	SBS	dk	110
SBSDK-03	500 Road	376026	5937756	894.0	N	SBS	dk	84
SBSDK-04	Marilla Main	369855	5945181	811.0	SE	SBS	dk	110
SBSDW-05	Germansen-Hat	410570	6071551	836.0	N	SBS	dw	114
SBSDW-06	Grizzly-22	457052	5941336	1008.0	SW	SBS	dw	140
SBSDW-07	Grizzly	463099	5942169	900.0	N	SBS	dw	145
SBSDW-08	Grizzly-25	459845	5940328	998.0	N	SBS	dw	145
SBSDW-09	Grizzly	461033	5945192	964.0	W	SBS	dw	100
SBSDW-10	Grizzly-5	455450	5954757	956.0	S	SBS	dw	165
SBSMK-01	428 Road	472255	6041373	896.5		SBS	mk	165
SBSMK-02	428 Road	475042	6042420	888.1		SBS	mk	138
SBSMK-03	428 Road	472062	6041523	898.5		SBS	mk	165
SBSMK-04	400 Road	462740	6035743	850.0	NW	SBS	mk	182
SBSMK-05	Teardrop	476835	6035853	869.0	SW	SBS	mk	162
SBSMK-06	Teardrop	475549	6035585	820.0	SE	SBS	mk	155
SBSMK-07	428 Road	469169	6039734	829.0	N	SBS	mk	165
SBSMC-08	Grizzly-22	457299	5942971	1186.0	S	SBS	mc	150
SBSMC-09	Grizzly-22	461058	5941785	991.7	NE	SBS	mc	140
SBSMC-10	Blue 6000	402656	5900562	1118.0	SW	SBS	mc	125

[1] Treatment: E=Early Successional; I=Intermediate (mid-seral); L=Late Successional; P=Wildlife Tree Patch

[2] Forest service road (FSR) access to study plots

[3] Biogeoclimatic ecosystem classification (BEC) sub-unit and variant

[4] Vegetation resource inventory (VRI) map data corrected to year of study (2006)