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VALIDATION OF FPINNOVATIONS BiOS APP IN COAL HARBOUR, BC:
METHODOLOGY AND RESULTS

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ABSTRACT:

FPInnovations completed the fifth validation of the FPBiOS app in the winter of 2022. A cutblock located in the CWHvm1 near Coal Harbour, BC was chosen. This validation required researchers to measure available biomass in the field, including dispersed volume and residual pile volume left on site after the secondary harvest. After measurements were completed, the values collected were compared with the outputs predicted by BiOS. Differences between the BiOS predicted values and the measured values indicate the need for follow up validation of the CWHvm1 timber type.

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INTRODUCTION

Background

The BiOS mobile application project is a key part of a larger initiative within the Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) aiming to develop a Forest Residual Biomass Geographic Information System for the development of the British Columbia (BC) forest bioeconomy (Forest BioGIS). The interactive map developed by FLNRORD will show location, type and amount of residual fibre generated by harvest activities, and economic feasibility to utilize them to produce advanced bio-materials. Forest BioGIS will improve area planning and support decision makers by having a better understanding of the fibre potential located in each Timber Supply Area (TSA). As a key feature of the BC Forest BioGIS interactive map, the BiOS app will help to serve the purpose of developing the forest bioeconomy cluster(s) for advanced biomaterial manufacturing in BC and may support other related government key priorities like GHG targets.

The need for such an interactive tool comes from the BC commitment to reducing greenhouse gas emissions to 80% below 2007 levels by 2050. The forest harvest levels in BC are massive, with an average annual harvest from 2005 to 2015 of 67 M m3 (42% of Canada's harvest). The harvest of this merchantable roundwood generates logging residues to the amount of about 10 million oven-dry tonnes (odt) per year (assuming 0.15 odt/m3). The BC Wildfire Act and Wildfire Regulation stipulate that the forest industry dispose of leftover slash and wood residues to abate fire hazards. The most common practice for reduction of fuel loading by forest tenure holders is to pile and burn. In 2015, it is estimated that 2.5 M odt of forest fibre was piled and burned in BC. The emissions generated by this practice are equivalent to those from 1 M cars (1/3 of all BC cars).

The BiOS app was introduced to both iOS and Android platforms in February 2018. This first version of the app utilized the core of the BiOS and Carbon modules of FPInterface to present a full biomass flow and carbon accounting of supply chain operations. The BiOS app serves foresters to quantify the amount of logging residues generated following logging operations and measure the supply chain cost and carbon footprint. Data collected by the app to update Forest BioGIS will mainly come from users such as logging contractors, secondary users of harvest residual fibre and FLNRORD field technicians. The BiOS mobile app will be utilized in a larger information system (Forest BioGIS) to provide data to industry which will help to improve biomass utilization and support the bio-economy and mitigate GHG emissions from existing slash burning operations.

BiOS application validation – Coal Harbour, BC

A series of development activities are required to bring the app from a base tool to a more complete and validated asset. For this reason, in-field validation trials to assess roadside pile volume and density are required. These field trials should be done in cooperation with industry leaders that show an interest in the Forest BioGIS platform.

FPInterface is a validated tool with multiple productivity studies performed across Canada over the last 40 years used to build machine productivity equations for various stand types and operating conditions. BiOS has also been validated in the Boreal forest across Canada and is well calibrated to perform TSA-level estimates. Given the variability of ecosystems in BC, FPInnovations suggests completing at least one validation trial per forested Biogeoclimatic (or ecological) zone according to the Biogeoclimatic Ecosystem Classification (BEC) program. There are 14 recognized forested zones in BC. Some zones (e.g. Coastal Western Hemlock) may need more than one validation trial to capture the variance. Therefore, at least 20 trials are recommended to fully validate the BiOS app for BC conditions. Two less comprehensive trials were completed in Powell River (2011) and Williams Lake (2011). Fully comprehensive first, second, third and fourth trials were recently completed in Mackenzie (2019), Powell River (2020), Topley (2020) and Williams Lake (2020), respectively.

This document will outline the methodology utilized in the 2022 Coal Harbor trial and present the field results compared to the BiOS App results.

METHODOLOGY

Note: Many parts of the Methodology section will reference the BiOS App in terms of the data entry tabs and the data fields required to create the app's report in order to compare the App's results and the field trial results. For a full list of values entered in the BiOS App for this trial, please see Appendix I.

Site and operation description

Site characteristics

Location

The 12.7-hectare cutblock chosen for the validation was located near Quatse Lake and is approximately 66 km from the Atli Chip Limited Partnership (Atli CLP) chipping plant near Beaver Cove, BC (Figure 1).

Figure 1. Map for cutblock 63943.

Biogeoclimatic zone

Cutblock 64943 is located in the Coastal Western Hemlock (CWH) biogeoclimatic zone, submontane very wet maritime (vm1) variant (Figure 2). According to the government of BC 's BCWEB website "The CWHvm1 Variant is the most extensive biogeoclimatic unit in the Vancouver Forest Region. It occurs on the windward slopes of Vancouver Island as far south as Jordan River, and on both sides of Vancouver Island north of Kelsey Bay. Its northern limit on Vancouver Island occurs just north of Port Hardy."

"The CWHvm1 has a wet, humid climate with cool summers and mild winters featuring relatively little snow. Growing seasons are long. Although precipitation is high, it can vary considerably, from lower values in the local rain shadow of northeastern Vancouver Island (Port Hardy, Port Alice, Coal Harbour, and Alice Lake 58 areas), to the highest values where air masses lift over steep mountains."

"Forests on zonal sites are dominated by Hw (western hemlock), Ba (amabalis fir), and lesser amounts of Cw (western red cedar)."

Figure 2. Biogeoclimatic zone map. Block location is denoted by the red star.

Stand description

The cutblock was timber cruised to FLNRORD standards (1.1 plots/ha, 4.5 trees per plot) in April 2021 and was harvested late in 2021. The stand was mainly composed of second growth western hemlock with minor components of western red cedar, amabalis fir, Sitka spruce and red alder (Table 1). The cruise compilation summary can be found in Appendix IV.

Table 1. Stand description from timber cruise results

Species	Gross merchantable volume (m^3/ha)	Stems per hectare	Gross merchantable volume per tree (m^3)	% of stand (by volume)
Western hemlock	866.0	688.8	1.26	76
Amabalis fir	171.1	66.2	2.59	15
Western red cedar	53.1	128.6	0.41	5
Sitka spruce	35.1	17.4	2.02	3
Red alder	16.5	15.7	1.05	1

Operational characteristics

Primary harvest

The cutblock was felled in 2021 using a feller buncher and then hoe-chucked to roadside with a log loader. Processing occurred at roadside with a danglehead processor. All merchantable sized (diameter at breast height > 12.0 cm) trees were harvested. The residues at roadside were left in the oriented pile formation, meaning that residual tops were left roughly aligned during processing (Figure 3). No piling for burning was performed during the primary harvest as the secondary harvest for this cutblock was planned in advance.

Figure 3. Residue pile located in validation cutblock.

Secondary harvest

The secondary harvest occurred in February 2022. Machinery included a Hitachi Zaxis 370 log loader and a Hitachi Zaxis 225 excavator. (Figure 4 and 5, respectively). Both machines were equipped with single-tine log loading attachments.

Figure 4. Hitachi log loader.

Figure 5. Hitachi excavator.

The excavator's primary role was to move debris to roadside from the processing residue piles and from the dispersed area of the cutblock. The excavator also piled the residual debris for burning after the pulp logs were loaded. The log loader prepared and moved the roadside residue closer to the road in between loading trucks. If trucks were not available for loading the log loader also cleaned up residual debris for burning.

Tridem drive trucks with quad-axle trailers were used to transport the residual logs and tops. (Figure 6).

Figure 6. Tridem drive truck with quad-axle trailer.

Tandem trucks with 45ft bins were used to transport the shorter residual pieces. (Figure 7).

Figure 7. Tandem truck with bin.

Stand and residue measurements

In order to compare and validate the theoretical results from the BiOS App to the field validation results, all portions of stand fibre needed to be measured in the field including standing residual volume (if any), volume located in the dispersed area of the cutblock, residue pile volume, secondary harvest volume and volume left at roadside after the secondary harvest.

Standing residual trees

BiOS entry

The BiOS App calculates the volume of trees left standing after the primary harvest based on initial inputs by the user. In this trial all volumes were set to 100% harvest removal for all species (Figure 8).

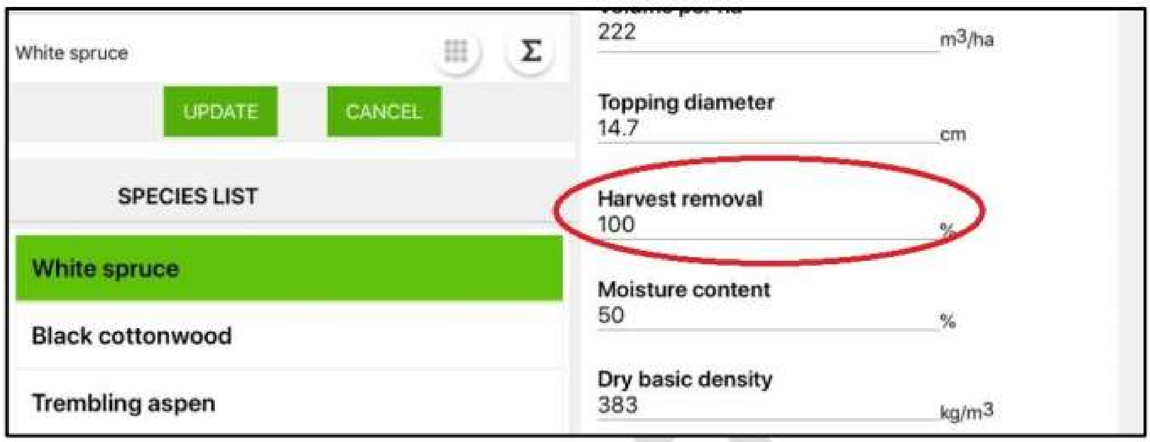

Figure 8. Species Operations data entry page; specifically harvest removal entry field.

Field measure

No trees of any species were left standing in this cutblock; therefore no field measurements were performed for standing residual coniferous trees.

Dispersed and roadside volume

BiOS

The BiOS app estimates dispersed residues using a default, at the stump, recovery factor which is applied to the total amount of residues generated by the logging operation. This is based on data entered into the app in the Biomass Operations tab. Most of the time, dispersed volume is not targeted by secondary users due to the prohibitive cost associated with harvesting it. However, in this instance, due to the high value of the residual pulp logs, an effort was made to scour the entire cutblock for residual logs. The default value of 30% was used for the 'Technical losses at-the-stump' on the Biomass Operations tab for the default scenario and was reduced to 15% for the sensitivity analysis to better represent the actual activities performed by the secondary harvester.

Field measure

The line transect method was used to collect dispersed volume data in the field (see Appendix II for full method).

The dispersed area was split into two stratums. A roadside stratum of 4.4 hectares was established within 30 metres of the road centerline in order to capture volume from long butts in the oriented piles left at roadside due to their small and difficult to handle sizes. The rest of the area in the cutblock, 8.3 hectares, was kept as the traditional dispersed area. Total dispersed volume for the stratums was then calculated by multiplying the average volume derived in the dispersed and roadside plots by the area of the stratums.

Roadside pile measurement

In previous validation trials, four different methods of residue pile volume calculation were used and then compared to derive the best method of pile data collection. Unfortunately, proximity to the Coal Harbour Water Drome prevented the use of the UAV to collect apparent (geometric) pile volumes. For this validation, the section on UAV pile measurement has been removed. For those interested in the UAV method, please reference the Mackenzie, Powell River or Topley validation trial reports. The following sections describe how each method works.

I. Manual Measurement Method (3M)

The manual measurement method, or 3M, requires the following steps:

1. Measure width of pile in metres
2. Measure length of pile in metres
3. Measure height of pile in metres. If height is irregular, determine average of multiple heights.
4. Determine a shape of the pile from the following list (Note: all piles for this trial were windrows)
   a. Cone (haystack),
   b. Windrow,
   c. Oriented pile
5. Determine a factor for each pile based on pile shape. Pile shape factors are as follows:
   a. Cone (haystack) – 0.4
   b. Windrow – 0.6
   c. Oriented pile - 0.5

Note: These are the factors that have consistently been used in past FPI reports and projects.

6. To determine apparent volume of the pile (Note: this is not fibre volume), multiply the length, width, height and pile shape factor.

The calculated apparent volume in conjunction with the measured average pile density will then be used to determine total pile volume. (Discussed in the Pile density section of the Methodology).

II. GPS Measure Method (GMM)

The GPS Measure Method, or GMM, is similar to the 3M except that a GPS is used to determine the area or footprint of the pile. The GMM requires the following steps:

1. Set GPS track feature to one point per second.
2. Walk around the pile, holding the GPS above the pile edge.

3. When the pile has been circumnavigated, create a waypoint with a pile name.
4. Measure height of pile in metres. If height is irregular, determine average of multiple heights.
5. Determine a shape of the pile from the following list (Note: all piles for this trial were windrows):
    a. Cone (haystack),
    b. Windrow,
    c. Oriented pile
6. Determine a factor for each pile based on pile shape. Pile shape factors are as follows:
    a. Cone (haystack) – 0.4
    b. Windrow – 0.6
    c. Oriented pile - 0.5
7. To determine apparent volume of the pile (Note: this is not fibre volume), multiply the area of the pile derived by GPS, height and pile shape factor.

The calculated apparent volume in conjunction with the measured average pile density will then be used to determine total pile volume. (Discussed in the Pile density section of the Methodology).

III. BiOS Pile Volume Visual Estimator Method (VEM)

The BiOS Pile Volume Estimate Method, or VEM, is an automated derivative of the 3M method, located in the BiOS app. To use the VEM method, users need to follow these steps:

1. In the Visual Estimator function, click 'Add Pile' (Figure 9).

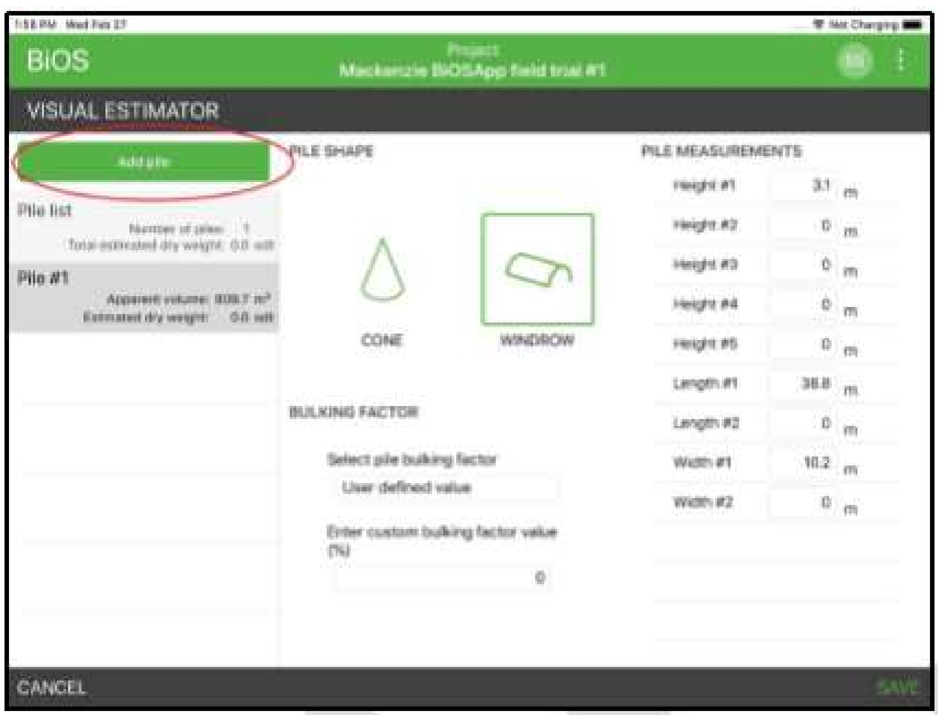

Figure 9. Add pile button in BiOS visual estimator.

2. Select a pile shape. Note: currently there are only two shapes (conical and windrow) available (Figure 10). More shapes are planned for future versions.

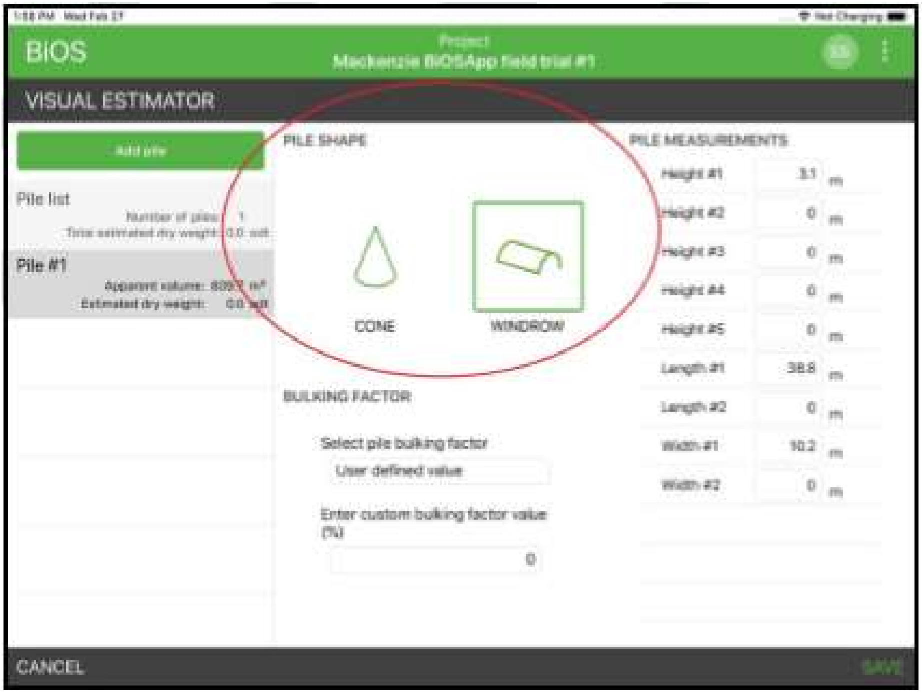

Figure 10. Pile shape buttons in BiOS visual estimator.

3. Enter the height, length and width values collected in the field. The cone shape requires a height and diameter (Figure 11).

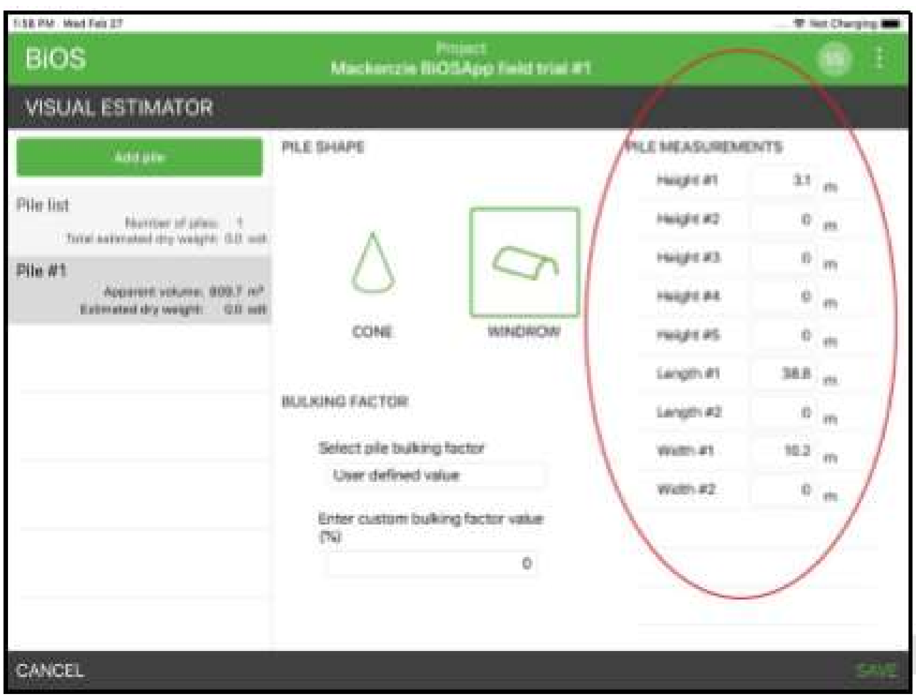

Figure 11. Pile measurement entry fields in BIOS visual estimator.

4. Choose a pile bulking factor from the list or enter a value manually (Figure 12).

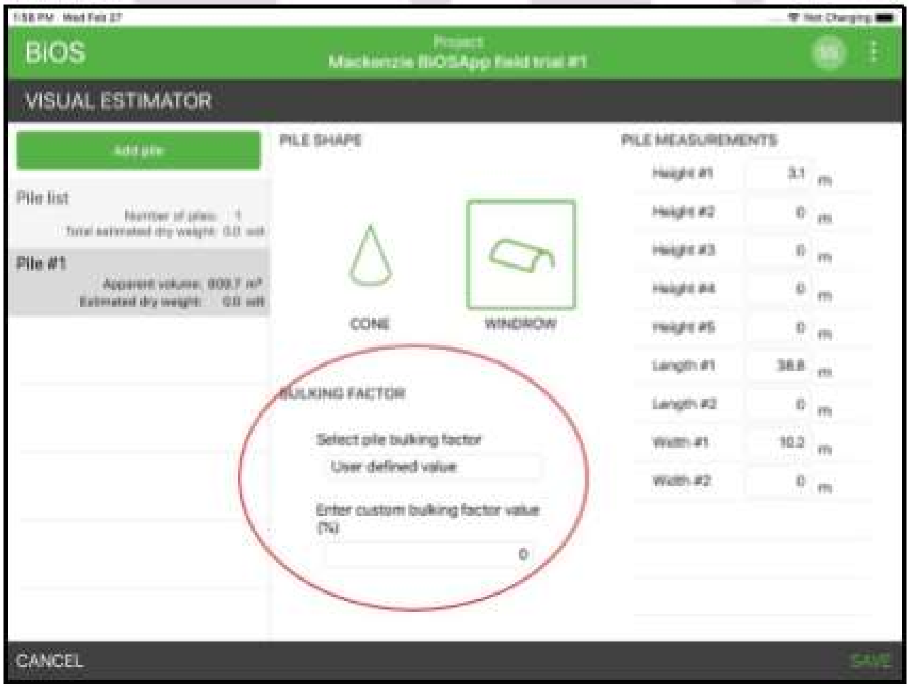

Figure 12. Bulking factor choice via drop-down in BiOS visual estimator.

For each pile, the visual estimator will calculate the apparent volume and estimate an oven dry weight of the fibre in the pile. A summary with the number of piles and the total estimated oven dry weight of the piles is calculated and located in the upper left corner of the screen (Figure 13).

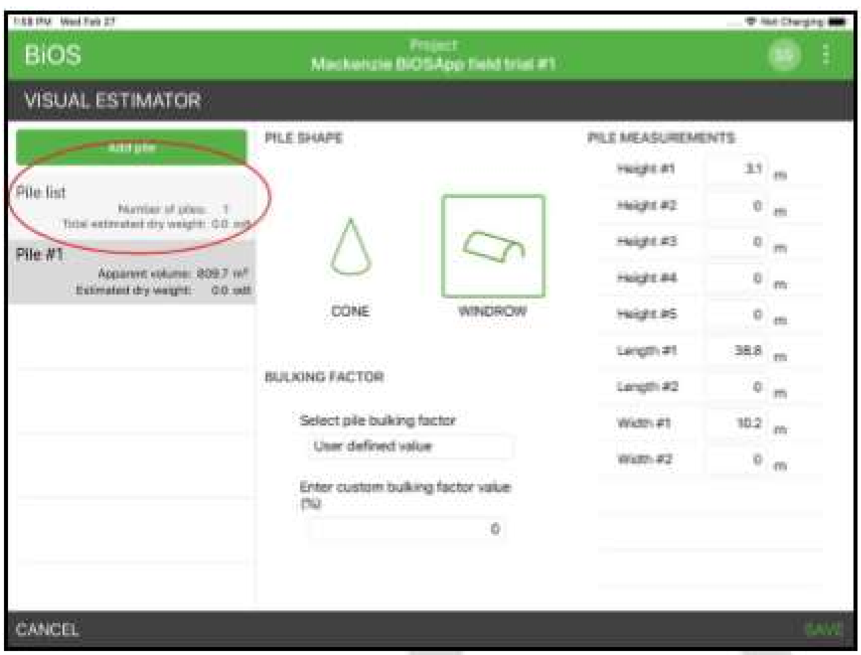

Figure 13. Pile counter and dry weight calculation.

Pile density

Brush piles were created after the secondary harvest in order to meet fire abatement commitments within the cutblock. After the viable pulp material was collected, loaded and hauled from the cutblock, the loader and excavator operators piled the brushy material in haystack shapes to facilitate burning of the residue (Figure 14 and 15).

To determine an average density for the residue piles created after the secondary harvest, researchers deconstructed an 'average' pile and weighed the volume found within it. Due to the intensive labor required in deconstructing piles only one pile was weighed.

Figure 14. Residual pile chosen for deconstruction.

Figure 15. Residual pile location after deconstruction.

First, the apparent volume of the pile was measured using the GMM method described in the sections above. Next, a scale was setup with a large pot to collect and weigh the residue. Over a period of two days, researchers slowly pulled the pieces out of the pile and placed them into or carefully balanced on top of the pot for weighing. Moisture content for the pile was determined by collecting samples from the pile. Once the total green weight of the pile was determined, the moisture content was used to determined the overall dry weight of the pile. The oven dry weight was divided by the apparent volume to determine the density of the pile in oven dry kilograms per cubic metre of apparent volume.

Pulp log collection

Load slips recording the green weight of each load were provided by Kurt Leroy Trucking and Atli Chipping and were cross referenced with the load times recorded in the field (although a portion of the cutblock was harvested before researchers arrived). Sample 'cookies' were cut and weighed for each day of hauling and moisture content analysis was performed in the FPInnovations Vancouver lab. For a detailed explanation of moisture content analysis methodology, please see Appendix III.

Post-harvest measurement

After the residual logs and chunks were moved to roadside and loaded onto the trucks, leftover volume within the roadside pile footprint was quantified using line transect surveys performed every 50 metres along the active roadside. For description of line transect survey methodology, please see Appendix II.

BiOS comparison

The BiOS reporting phase tabulates the results generated from the inputs entered by the user. These results are displayed in five sections including:

- Biomass recovery
    - Area
    - Recovered biomass (odt)
    - Average moisture content (%)
    - Biomass yield (odt/ha)
    - Biomass / merchantable (odt/m^3)
    - Low heating value (MJ/kg)
    - Fuel consumption (L/odt)
    - GHG emissions (tonnes)
- Biomass transport
    - Distance to end use (km)
    - Operational road length (km)
    - Primary road length (km)
    - Public or paved road length (km)
    - Fuel consumption (L/odt)
    - GHG emissions (tonnes)
- Biomass supply cost
    - Recovery – stump to roadside ($/odt)
    - Transport – roadside to mill ($/odt)
- Species breakdown chart
    - Carbon delivered (tonnes)
    - Avoided GHG (tonnes CO2eq)
    - Odt of biomass
    - Odt/m^3
    - Odt/ha
- Biomass flow diagram
    - Total fibre (odt)
    - Merchantable volume harvested (odt)
    - Available biomass (odt)
    - Natural losses (odt)
    - Uncut trees (odt)
    - Cutover residues (odt)
    - Roadside volume (odt)
    - Roadside volume not recovered (odt)
    - Net roadside volume (odt)
    - Visual estimator volume (odt)
    - Recovered (%)
    - Biomass ratio (%)

The comparison in this report will focus only on the results displayed in the Biomass Flow Diagram of the report created by BiOS as these were the measurable outputs.

Due to discrepancies found between the BiOS results populated with BiOS default inputs and the actual harvest results as well as further discrepancies between the cruise prediction and the actual harvest volumes, a sensitivity analysis was completed using the actual harvest results paired with cruise data piece sizes as inputs. This sensitivity analysis was completed in order to attempt to determine what caused the discrepancies and aid in future validation work.

BiOS calculates greenhouse gas, or GHG, emissions for the biomass recovery and transport phase of an operation. It also calculates the volume of carbon delivered and the volume of avoided GHG by not burning the residue hauled to roadside. As there was not a viable way to measure greenhouse gas during the trial, the BiOS results for GHG's were not validated.

RESULTS AND DISCUSSION

Cruise data was provided by Western Forest Products and a summary can be viewed in Table 1 (Page 4). A more comprehensive version can be found in Appendix IV.

Standing residual trees

In the primary harvest, no merchantable trees were left standing within the harvest area. Therefore, no measurements were made after the primary harvest.

Dispersed volume

Sixteen plots were completed in the dispersed area of the cutblock after the excavator forwarded the residual chunks and logs to roadside. Dispersed volume results for each plot can be found in Table 2. The total volume in the dispersed area of the cutblock was 160.6 oven dry tonnes (19.4 oven dry tonnes per hectare multiplied by 9.3 hectares of dispersed area). Average dry density for the stand was 408.7 oven dry kg per cubic metre based on the species proportions from the timber cruise.

Table 2. Dispersed area volume

Plot	m^3/ha	odt/ha
5B	42.1	17.2
10	55.6	22.7
11	23.7	9.7
13	28.0	11.4
18	68.2	27.9
19	89.5	36.6
20	23.6	9.6
50	66.6	26.8
51	51.8	21.2
52	32.0	13.1
100	43.4	17.8
101	32.4	13.2
102	14.7	6.0
103	37.5	15.3

104	78.7	32.2
105	70.9	29.0
Average	47.3	19.3

Pile measurements

As described in the Methodology section of this report, there were three methods of pile measurement used to determine geometric volume of residual piles.

I. Manual Measurement Method (3M)

Total apparent volume for the 3M method was 982.4 m^3 (Table 3).

Table 3. Pile dimensions using the Manual Measurement Method

Pile name	Radius (m)	Height (m)	Shape	Shape factor	Pile area (m^2)	Apparent volume (m^3)
50	2.5	2.0	Haystack	0.4	19.6	15.7
51	1.5	2.2	Haystack	0.4	7.1	6.2
52	2.5	2.0	Haystack	0.4	19.6	15.7
53	2	2.7	Haystack	0.4	12.6	13.6
54	3.5	3.4	Haystack	0.4	38.5	52.3
55	3	3.1	Haystack	0.4	28.3	35.1
56	3	3.1	Haystack	0.4	28.3	35.1
57	3	2.9	Haystack	0.4	28.3	32.8
58	1.3	2.2	Haystack	0.4	5.3	4.7
59	2.1	2.2	Haystack	0.4	13.9	12.2
60	2.0	2.2	Haystack	0.4	12.6	11.1
61	3.5	4.3	Haystack	0.4	38.5	66.2
62	3.3	2.8	Haystack	0.4	34.2	38.3
63	3.0	1.7	Haystack	0.4	28.3	19.2
64	3.7	2.5	Haystack	0.4	43.0	43.0
65	3.0	3.5	Haystack	0.4	28.3	39.6
66	1.5	2.5	Haystack	0.4	7.1	7.1
67	2.7	3.2	Haystack	0.4	22.9	29.3
68	3.4	4.5	Haystack	0.4	36.3	65.4
69	1.5	2.8	Haystack	0.4	7.1	7.9
70	2.8	2.8	Haystack	0.4	24.6	27.6
71	4.0	3.4	Haystack	0.4	50.3	68.4
72	2.5	2.2	Haystack	0.4	19.6	17.3
Q5	L-21.5, W-18.5	1.1	Oriented	0.5	397.8	218.8
Q200	2.25	2.3	Haystack	0.4	15.9	14.6
Q201	2.0	2.0	Haystack	0.4	12.6	10.1
Q202	1.25	1.5	Haystack	0.4	4.9	2.9
Q203	1.85	2.3	Haystack	0.4	10.8	9.9
Q204	2	2.1	Haystack	0.4	12.6	10.6
Q205	2.25	2.0	Haystack	0.4	15.9	12.7
Q206	1.2	0.8	Haystack	0.4	4.5	1.4

Q300	1.4	2.3	Haystack	0,4	6.2	5.7
Q301	1.4	1.8	Haystack	0.4	6.2	4.4
Q302	1.1	1.7	Haystack	0.4	3.8	2.6
Q303	1.3	1.6	Haystack	0.4	5.3	3.4
Q304	1.5	1.6	Haystack	0.4	7.1	4.5
Q305	1.8	2.4	Haystack	0.4	10.2	9.8
Q306	1.6	2.3	Haystack	0.4	8.0	7.4
Total						**982.4**

II. GPS Measure Method (GMM)

Total apparent volume for the GMM method was 1478.0 m^3 (see Table 4).

Table 4. Pile dimensions using the GPS Measure Method

Pile name	Height (m)	Shape	Shape factor	Pile area (m^2)	Apparent volume (m^3)
50	2.0	Haystack	0.4	26.0	20.8
51	2.2	Haystack	0.4	9.3	8.2
52	2.0	Haystack	0.4	26.0	20.8
53	2.7	Haystack	0.4	16.6	17.9
54	3.4	Haystack	0.4	48.0	65.3
55	3.1	Haystack	0.4	47.4	58.8
56	3.1	Haystack	0.4	79.5	98.6
57	2.9	Haystack	0.4	37.4	43.4
58	2.2	Haystack	0.4	7.0	6.2
59	2.2	Haystack	0.4	18.3	16.1
60	2.2	Haystack	0.4	16.6	14.6
61	4.3	Haystack	0.4	51.7	88.9
62	2.8	Haystack	0.4	51.5	57.7
63	1.7	Haystack	0.4	37.4	25.4
64	2.5	Haystack	0.4	69.6	69.6
65	3.5	Haystack	0.4	55.7	78.0
66	2.5	Haystack	0.4	26.0	26.0
67	3.2	Haystack	0.4	42.2	54.0
68	4.5	Haystack	0.4	54.7	98.5
69	2.8	Haystack	0.4	36.8	41.2
70	2.8	Haystack	0.4	55.9	62.6
71	3.4	Haystack	0.4	92.8	126.2
72	2.2	Haystack	0.4	69.7	61.3
Q5	1.1	Oriented	0.5	158.5	87.2
Q200	2.3	Haystack	0.4	21.0	19.3
Q201	2.0	Haystack	0.4	16.6	13.3
Q202	1.5	Haystack	0.4	6.5	3.9
Q203	2.3	Haystack	0.4	14.2	13.1
Q204	2.1	Haystack	0.4	16.6	14.0
Q205	2.0	Haystack	0.4	21.0	16.8
Q206	0.8	Haystack	0.4	6.0	1.9
Q300	2.3	Haystack	0,4	27.9	25.7

Q301	1.8	Haystack	0.4	28.0	20.2
Q302	1.7	Haystack	0.4	19.9	13.5
Q303	1.6	Haystack	0.4	23.0	14.7
Q304	1.6	Haystack	0.4	22.7	14.5
Q305	2.4	Haystack	0.4	30.8	29.6
Q306	2.3	Haystack	0.4	33.0	30.4
Total					**1478.0**

III. BiOS Pile Volume Estimate Volume (VEM)

Total apparent volume for the VEM method was 789.0 m^3 (see Table 5) uses a default bulking factor of 20% was used for volume calculations and provided an estimated total dry weight of 54.1 oven dry tonnes.

Table 5. Pile dimensions using the BiOS Pile Volume Estimate Method

Pile name	Radius (m)	Height (m)	Shape	Apparent volume (m^3)	Bulking factor (%)	Estimated dry weight (oven dry tonnes)
50	2.5	2.0	Haystack	13.1	20	1.1
51	1.5	2.2	Haystack	5.2	20	0.4
52	2.5	2.0	Haystack	13.1	20	1.1
53	2	2.7	Haystack	11.3	20	0.9
54	3.5	3.4	Haystack	43.6	20	3.6
55	3	3.1	Haystack	29.2	20	2.4
56	3	3.1	Haystack	29.2	20	2.4
57	3	2.9	Haystack	27.3	20	2.2
58	1.3	2.2	Haystack	3.9	20	0.3
59	2.1	2.2	Haystack	10.2	20	0.8
60	2.0	2.2	Haystack	9.2	20	0.8
61	3.5	4.3	Haystack	13.8	20	1.1
62	3.3	2.8	Haystack	31.9	20	2.6
63	3.0	1.7	Haystack	16.0	20	1.3
64	3.7	2.5	Haystack	35.8	20	2.9
65	3.0	3.5	Haystack	33.0	20	2.7
66	1.5	2.5	Haystack	5.9	20	0.5
67	2.7	3.2	Haystack	6.1	20	0.5
68	3.4	4.5	Haystack	54.5	20	4.5
69	1.5	2.8	Haystack	6.6	20	.5
70	2.8	2.8	Haystack	23.0	20	1.9
71	4.0	3.4	Haystack	57.0	20	4.7
72	2.5	2.2	Haystack	14.4	20	1.2
Q5	L-21.5, W-18.5	1.1	Oriented	218.8	10	8.9
Q200	2.25	2.3	Haystack	12.2	20	1.0
Q201	2.0	2.0	Haystack	8.4	20	0.7
Q202	1.25	1.5	Haystack	2.5	20	0.2
Q203	1.85	2.3	Haystack	8.2	20	0.7
Q204	2	2.1	Haystack	8.8	20	0.7
Q205	2.25	2.0	Haystack	8.8	20	0.7

Q206	1.2	0.8	Haystack	1.2	20	0.1
Q300	1.4	2.3	Haystack	4.7	20	0.4
Q301	1.4	1.8	Haystack	3.7	20	0.3
Q302	1.1	1.7	Haystack	2.2	20	0.2
Q303	1.3	1.6	Haystack	2.8	20	0.2
Q304	1.5	1.6	Haystack	3.8	20	0.3
Q305	1.8	2.4	Haystack	8.1	20	0.7
Q306	1.6	2.3	Haystack	1.5	20	0.1
Total				**789.0**		**54.2**

Pile volume method comparison

The apparent volumes derived from each pile measurement method can be found in Table 6.

The total apparent volume for the 3M and VEM were similar. This is due to the similar methodology used in apparent volume calculation. The total apparent volume for the GMM method was significantly higher than that of the other two methods. This is due to the assumption used in the 3M and VEM calculations that a pile is perfectly circular. The GMM method with its GPS footprint calculates the 'actual' shape of the pile which is usually more oval and rarely perfectly circular.

Table 6. Apparent volumes of residue measurement methods

Apparent volumes of residue measurement methods							
Pile name	**3M**	**GMM**	**VEM**	**Pile name**	**3M**	**GMM**	**VEM**
50	15.7	20.8	13.1	69	7.9	41.2	6.6
51	6.2	8.2	5.2	70	27.6	62.6	23.0
52	15.7	20.8	13.1	71	68.4	126.2	57.0
53	13.6	17.9	11.3	72	17.3	61.3	14.4
54	52.3	65.3	43.6	Q5	218.8	87.2	218.8
55	35.1	58.8	29.2	Q200	14.6	19.3	12.2
56	35.1	98.6	29.2	Q201	10.1	13.3	8.4
57	32.8	43.4	27.3	Q202	2.9	3.9	2.5
58	4.7	6.2	3.9	Q203	9.9	13.1	8.2
59	12.2	16.1	10.2	Q204	10.6	14.0	8.8
60	11.1	14.6	9.2	Q205	12.7	16.8	8.8
61	66.2	88.9	13.8	Q206	1.4	1.9	1.2
62	38.3	57.7	31.9	Q300	5.7	25.7	4.7
63	19.2	25.4	16.0	Q301	4.4	20.2	3.7
64	43.0	69.6	35.8	Q302	2.6	13.5	2.2
65	39.6	78.0	33.0	Q303	3.4	14.7	2.8
66	7.1	26.0	5.9	Q304	4.5	14.5	3.8
67	29.3	54.0	6.1	Q305	9.8	29.6	8.1
68	65.4	98.5	54.5	Q306	7.4	30.4	1.5
				Total	**982.4**	**1478.0**	**789.0**

As stated in the previous validation reports, when residue piles are measured, care should be taken to describe the method used as there is significant variance of area and apparent volumes between the measurement methods.

Secondary harvesting

Load volumes

Load slips were collected by the Atli Chipping plant for the secondary harvest of pulp logs. Loads weights were collected in green tonnes and then converted to oven dry tonnes using an average moisture content derived from collected moisture samples. A total of 923.3 green tonnes at 58% moisture content or 387.8 oven dry tonnes were hauled from the cutblock in the secondary harvest. Average load size for the hayrack trailers was 42.2 green tonnes at 58% moisture content or 17.7 odt. Average load size for the bin trailers was 16.5 green tonnes at 58% moisture content or 6.9 odt.

Recovered pulpable material was classified as 'recovered biomass' for the default BiOS comparison because in theory, the pulpable material available at roadside consisted only of the decay-waste-breakage volume and the volume of the tops past the 14.3cm topping diameter.

In the sensitivity analysis, based on visual estimates and experience from previous trial work, researchers estimated that 50% of the volume would fall under the 'merchantable' category in BiOS (logs larger than the 14.3cm topping diameter) and 50% would be considered 'available biomass' (pieces less than 14.3cm diameter and decay-waste-breakage volume).

Moisture content

Over the course of the trial, moisture samples were derived by collecting wood samples from random piles throughout the trial period. Average moisture content throughout the trial was 58% for the solid wood pieces and 66% for the green needles and small branches. 58% was entered as the moisture content in BiOS for both the default BiOS run and the sensitivity analysis run.

Post-harvest measurement

Roadside volume

Twenty-seven plots were completed in the roadside area of the cutblock. Roadside volume results for each plot can be found in Table 7. The total volume in the dispersed area of the cutblock was 180.1 oven dry tonnes (40.9 oven dry tonnes per hectare multiplied by 4.4 hectares of the roadside stratum). As with the dispersed strata data calculations on average dry density of 409 oven dry kilograms per cubic metre was used to convert m^3/ha to odt/ha. As expected, volumes left at roadside were higher than those found in the dispersed area.

Table 7. Roadside stratum volume

Plot	m^3/ha	odt/ha
R1	109.2	44.6
R2	23.1	9.4
R3	37.8	15.4
R4	156.6	64.0
R5	79.6	32.5
R6	124.1	50.7
R7	143.6	58.7
R8	238.2	97.4

R9	295.8	120.9
R10	36.5	14.9
R11	35.2	14.4
R12	153.6	62.8
13	102.3	41.8
14	100.1	40.9
15	48.0	19.6
16	195.7	80.0
17	143.0	58.4
18	64.3	26.3
300	3.5	1.4
301	16.9	6.9
302	123	50.3
303	81.8	33.4
304	18.3	7.5
305	134.7	55.1
306	75.9	31.0
307	39.0	15.9
308	124.4	50.8
Average	100.1	40.9

Pile density

Pile density for this trial was calculated by deconstructing and weighing the material found in an average pile. Density for that pile was 159.4 green kg/m3 at 60% moisture content or 63.8 oven dry kg/m3.

The average pile density was used to populate the residue piles left after the secondary harvest. Table 8 shows a summary and compilation of the volume left in these piles.

Table 8. Residual pile volume

Pile name	Apparent volume (m^3)	Pile density (odkg/m3)	Estimated dry weight (oven dry tonnes)
50	20.8	63.8	1.3
51	8.2	63.8	0.5
52	20.8	63.8	1.3
53	17.9	63.8	1.1
54	65.3	63.8	4.2
55	58.8	63.8	3.8
56	98.6	63.8	6.3
57	43.4	63.8	2.8
58	6.2	63.8	0.4
59	16.1	63.8	1.0
60	14.6	63.8	.9
61	88.9	63.8	5.7
62	57.7	63.8	3.7
63	25.4	63.8	1.6
64	69.6	63.8	4.4

65	78.0	63.8	5.0
66	26.0	63.8	1.7
67	54.0	63.8	3.5
68	98.5	63.8	6.3
69	41.2	63.8	2.6
70	62.6	63.8	4.0
71	126.2	63.8	8.1
72	61.3	63.8	3.9
Q5	87.2	63.8	5.6
Q200	19.3	63.8	1.2
Q201	13.3	63.8	0.9
Q202	3.9	63.8	0.3
Q203	13.1	63.8	0.8
Q204	14.0	63.8	0.9
Q205	16.8	63.8	1.1
Q206	1.9	63.8	0.1
Q300	25.7	63.8	1.6
Q301	20.2	63.8	1.3
Q302	13.5	63.8	0.9
Q303	14.7	63.8	0.9
Q304	14.5	63.8	0.9
Q305	29.6	63.8	1.9
Q306	30.4	63.8	1.9
Total		63.8	**94.3**

BiOS comparisons #1 – Cruise data inputs and default settings

The BiOS App creates a report which is summarized in a flowchart format (Figure 16). The information in the flowchart was the focus of the Coal Harbor BiOS validation. This section of the report depicts a comparison of the BiOS results to actual measured field results using cruise data as BiOS inputs. The entire list of BIOS inputs for comparison one, in the order they were entered into the app, can be found in Appendix IA.

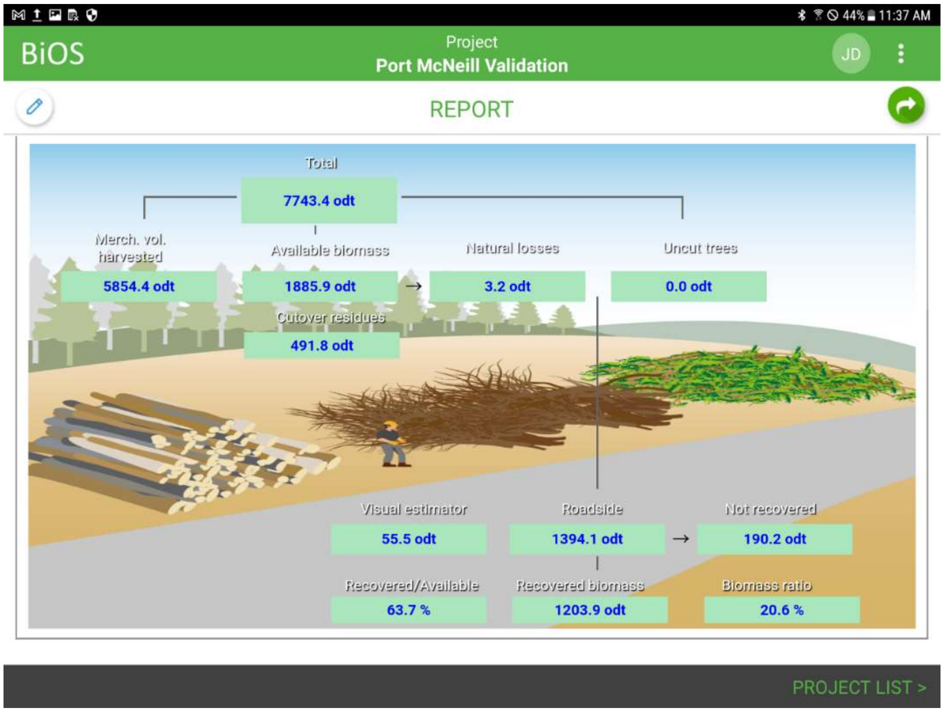

Figure 16. Biomass flowchart produced by the BiOS app for Coal Harbour cutblock for default comparison.

In order to compare the data in the flowchart with the actual results found in the field, Table 9 was created to ease analysis. Each line in the table describes one aspect of the flowchart except for Line 1, which depicts topping diameter (arguably one of the biggest influences on BiOS calculations).

Table 9. Comparison of BiOS calculated results and field trial results

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	14.3	14.3	n/a
2	Total fibre (odt)[a]	7743.4	5681.2	36%
3	Merchantable volume harvested (odt)	5854.4	4855.2	21%
4	Available biomass (odt)	1885.9	822.8	129%
5	Natural losses (odt)	3.2	3.2	n/a
6	Uncut trees (odt)	0.0	0.0	n/a
7	Cutover residues (odt)	491.8	160.6	206%
8	Visual estimator (odt)	54.2	94.3	43%
9	Roadside (odt)	1394.1	662.2	111%

10	Recovered biomass (odt)	1203.9	387.8	210%
11	Not recovered (odt)	190.2	274.4	31%

[a] Standing tree (merchantable stem + tops, branches and leaves)

Line 1 – Topping diameter

Line 1 displays the topping diameter used by BiOS and was measured during the field analysis. Topping diameter is used in BiOS to determine the proportion of the volume of total fibre in the cutblock that is considered merchantable or within merchantable size specifications. Topping diameter was entered as 14.3 cm in BiOS to match the average butt diameter of 'top' pieces measured in the residue piles.

Line 2 – Total fibre

'Total fibre' in Line 2 is the total volume of woody fibre in the cutblock. This includes merchantable fibre, available biomass, natural losses (needles and leaves) and uncut trees. The BiOS app predicted volume of 7743.4 oven dry tonnes is 36% higher than the actual total volume 5681.2 oven dry tonnes derived from the field results.

Line 3 – Merchantable volume harvested

Merchantable volume describes the proportion of total woody fibre considered merchantable by the BiOS app after entering the inputs for the Species Operations Tab. BiOS estimated merchantable volume for the trial cutblock to be 5854.4 oven dry tonnes. Merchantable volume harvested was 4855.2 oven dry tonnes and represents the actual volume hauled during the primary harvest. The BiOS result was 21% higher than the cruise estimate.

Line 4 – Available biomass

BiOS calculates the 'Available biomass' located in Line 4 of Table 9 by subtracting the merchantable volume, natural losses and uncut trees from total fibre. To determine available biomass in the actual results column, the leftover ('not recovered' in the flowchart), recovered and cutover residues were added together. The BiOS result, 1885.9 oven dry tonnes and the actual result, 822.8 oven dry tonnes, were 129% different. Potential reasons for this difference will be discussed in the Overall Analysis section below.

Line 5 – Natural losses

'Natural losses' from Line 5 in Table 9 describes the volume of leaves or needles in the cutblock that have fallen off due to season of harvest (no leaves in winter), or time from initial harvest (after one year, 70% of needles and 100% of leaves fall off). As the secondary harvest occurred less than one month after the primary harvest, naturals losses were 3.2 odt. This consists of the leaves for the alder trees which fell off in the previous fall. Conifer needles were still attached to the branches at the time of the trial. Data collection for natural losses is virtually impossible, even when needles and leaves are attached to branches, so the BiOS value was utilized for both the BiOS and field trial results.

Line 6 – Uncut trees

In BiOS, 'Uncut trees' is the volume attributed to trees left standing after the primary harvest. No trees were left standing in this cutblock so both the BiOS value and the actual value was 0.0 odt.

Line 7 – Cutover residues

'Cutover residue' described in Line 7 of Table 9 describes the volume of fibre that is left in the dispersed area of the cutblock and is not usually harvested. This volume is calculated based on the 'Technical losses at the stump' value found on the Biomass Operations data entry tab. The default for this value is set at 30%. The BiOS predicted value of 491.8 odt was 206% higher than the measured field results of 160.6 odt. Potential reasons for this difference will be discussed in the Overall Analysis section below.

Line 8 – Visual estimator

The visual estimator calculated volume is independent of the rest of the BiOS flow calculations. This indicator is useful to assess the volume per pile and was compared with the field result's total pile volume. The visual estimator predicted 54.2 oven dry tonnes of volume within the residue piles at roadside. This was 43% lower than the 94.3 oven dry tonnes of roadside volume measured in the piles. The difference between these two values is likely a result of the difference between the actual packing value of the piles versus the 20% default value for loose slash available in BiOS. For future applications, if the value were consistently found to be lower in future cutblocks of similar profiles, the user could manually reduce the packing ratio to better reflect the actual conditions.

Line 9 - Roadside

The BiOS calculation for roadside volume in Line 9 of Table 9 consists of all the volume that is hauled to roadside in the primary harvest. To determine roadside volume for the actual field results, total hauled volume was added to the leftover pile volume to get 662.2 oven dry tonnes. This was different from the BiOS calculation of 1394.1 oven dry tonnes by 111%. Potential reasons for this difference will be discussed in the Overall Analysis section below.

Line 10 – Recovered biomass

The BiOS calculation for recovered biomass in Line 10 of Table 9 consisted of the roadside biomass volume that was comminuted and transported during the secondary harvest. The BiOS calculation for recoverable biomass of 1203.9 oven dry tonnes was 210% different than the measured field result of 387.8 oven dry tonnes. Potential reasons for this difference will be discussed in the Overall Analysis section below.

Line 11 – Not recovered

The not recovered value in Line 11 of Table 9 consists of the volume left at roadside after the secondary harvest including both volume from the roadside stratum and the residue piles. BiOS calculates this using the Recovered Technical Efficiency Value found in the pre-piling and comminution functions of the Biomass Operations Tab. In the field, line transect surveys were completed to determine volume. The BiOS volume for 'not recovered' was 190.2 oven dry tonnes and was 31% lower than the value of 274.4 oven dry tonnes calculated in the field.

Overall analysis of comparison

Unlike the four other validations completed previous to the Coal Harbour validation, the measured values varied significantly from those forecasted by the BiOS App. There are number of potential reasons for this:

1. The form of this validation differed from the previous four.
    a. The secondary harvester was focused entirely on harvesting only pulpable material and left all loose and piled residue at roadside. This volume was measured with line transect surveys and pile deconstruction. In the previous validations, all loose or piled residue was ground into trucks and weighed.
    b. The operator also forwarded all potentially pulpable material from the dispersed area, whereas the previous validations harvested only the volume available at roadside. This will have reduced the volume found in the dispersed area versus the default calculation of 30% volume left at the stump.
2. The timber cruise over forecasted the volume of merchantable volume available in the cutblock by approximately 1900 cubic metres. The overestimation over actual merchantable volume likely also contributed to the overestimation by the app of the volume of biomass available at roadside.
3. No validation has been completed in this timber type previously, which could mean that the allometric equations are ill-suited to the tree form of the species found within the cutblock in this area. Specifically, the amabalis fir and Sitka spruce had very large piece size (2.59 m3 and 2.06 m3 per piece, respectively) and were likely outside the allometric equations maximum and minimum size recommendations. Western hemlock height and diameter was also well outside the average size used in the formation of the equations.

In response to the large discrepancies between the actual, cruise and BiOS values a sensitivity analysis was completed by the author in an attempt to more adequately represent the actual harvest practices and harvest volumes for this cutblock, and to try an isolate the potential cause of the discrepancies.

BiOS comparisons #2 – Sensitivity analysis - Actual harvest inputs

As reported in the last section, there were severe discrepancies between the values predicted by BiOS and the actual measured values in the field, including the volume harvested from the cutblock. To discern the cause of these discrepancies, the following changes to the BiOS inputs were implemented:

- Gross merchantable volume inputs were changed to reflect the actual harvest volume reported for the cutblock by the primary harvester. All other values, including decay-waste-breakage, and gross merchantable volume per tree were kept the same.

- On the Logging Operations tab, the primary harvest date was changed to December 1st, 2019, so that the value of natural losses (or needle volumes) could be removed from the available biomass and provide a better understanding of potential discrepancies.
- On the Biomass Operations page:
    - The 'Technical losses at-the-stump' value was reduced from 30% to 15% to better reflect the secondary harvester's activity in which additional volume was collected from the dispersed area.
    - The 'Recovery technical efficiency' value was changed from 65% to 0% because only pulpable volume was collected and force volume into the 'not recovered' category where it more accurately represented the field practices.

Input values for this section can be found in Appendix IB. Those values changed from the BioS defaults are highlighted in yellow.

The author also modified the measured values to better represent the pulp harvest by splitting the secondary harvest to 50% pulp (merch) and 50% biomass (volume smaller than merchantable volume as well as decay-waste-breakage). The 50% values were determined by visual estimation in the field as loads were typically split between large, merchantable sized pieces and smaller tops (considered biomass by BiOS).

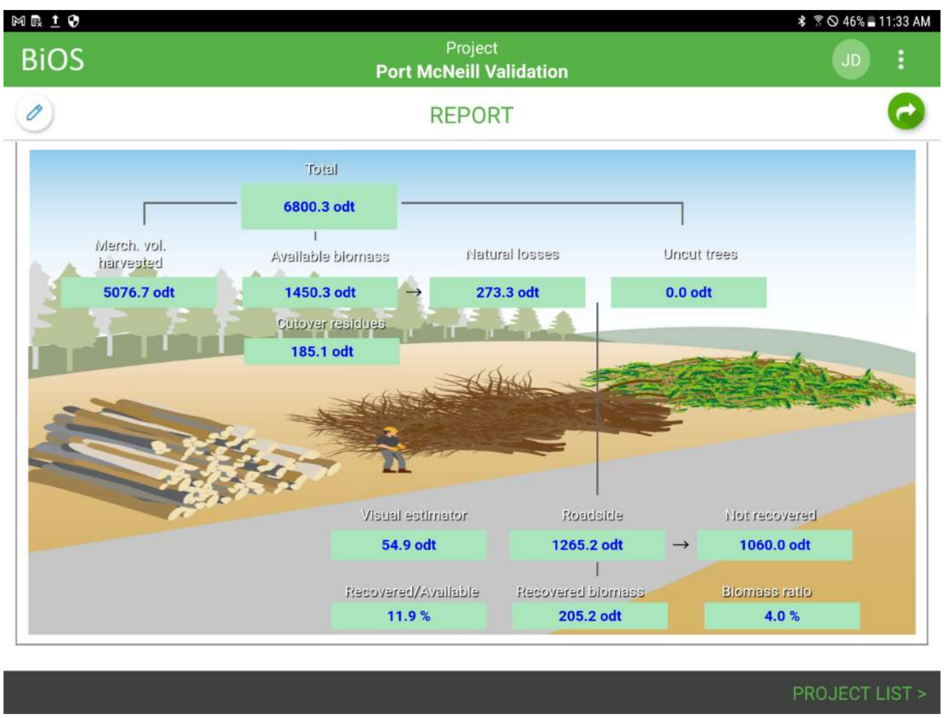

Figure 18. Biomass flowchart produced for the sensitivity analysis by the BiOS app for Coal Harbour cutblock.

As with the default comparison, in order to compare the data in the flowchart with the actual results found in the field, Table 11 was created to ease analysis. Each line in the table describes one aspect of the flowchart except for Line 1, which depicts topping diameter.

Table 10. Comparison of BiOS calculated results and field trial results

Reference line	BiOS flowchart field	BiOS calculated results	Field trial results	Difference between BiOS and field trial results
1	Topping diameter (cm)	14.3	14.3	n/a
2	Total fibre (odt)[a]	6800.3	5951.1	14.3%
3	Merchantable volume harvested (odt)	5076.7	5049.1	0.5%
4	Available biomass (odt)	1450.3	628.3	130.6%
5	Natural losses (odt)	273.3	273.3	n/a
6	Uncut trees (odt)	0.0	0.0	n/a
7	Cutover residues (odt)	185.3	160.6	15.4%
8	Visual estimator (odt)	55.5	94.3	41%
9	Roadside (odt)	1265.2	468.3	170.2%
10	Recovered biomass (odt)	205.2	193.9	5.9%
11	Not recovered (odt)	1203.9	274.4	286.3%

[a] Standing tree (merchantable stem + tops, branches and leaves)

Line 1 – Topping diameter

Line 1 displays the topping diameter used by BiOS and was measured during the field analysis. Topping diameter is used in BiOS to determine the proportion of the volume of total fibre in the cutblock that is considered merchantable or within merchantable size specifications. Topping diameter was entered as 14.3 cm in BiOS to match the average butt diameter of 'top' pieces measured in the residue piles.

Line 2 – Total fibre

'Total fibre' in Line 2 is the total volume of woody fibre in the cutblock. This includes merchantable fibre, available biomass, natural losses (needles and leaves) and uncut trees. The BiOS app predicted volume of 6800.3 oven dry tonnes is within 14.3% of the actual total volume 5951.2 oven dry tonnes derived from the field results. Unlike in the default scenario, the difference between the two values in this sensitivity analysis is within acceptable parameters.

Line 3 – Merchantable volume harvested

Merchantable volume describes the proportion of total woody fibre considered merchantable by the BiOS app after entering the inputs for the Species Operations Tab. When using the actual harvest volumes as inputs, BiOS estimated merchantable volume for the trial cutblock to be

5076.7 oven dry tonnes. The merchantable volume was 5049.1 oven dry tonnes and represents the actual volume hauled during the primary harvest and 50% of the pulp volume hauled during the secondary harvest (as stated in the beginning of this section). The BiOS result was 0.5% more than the cruise estimate. This minimal difference in values when actual harvest values are used as inputs indicates that the BiOS calculations to determine merchantable fibre were very accurate in this instance.

Line 4 – Available biomass

BiOS calculates the ‘Available biomass’ located in Line 4 of Table 10 by subtracting the merchantable volume, natural losses and uncut trees from total fibre. To determine available biomass in the actual results column, the leftover (not recovered in the flowchart), recovered and cutover residues were added together. The BiOS result, 1450.3 oven dry tonnes and the actual result, 628.3 oven dry tonnes, were 131% different. This is similar to the 161% overage in the default scenario. The absolute difference in the sensitivity analysis scenario at 821.5 odt is less than the absolute difference in the default scenario, 1163.4 odt. This is likely a result of re-designating 50% of the harvested volume as pulp (merch).

Line 5 – Natural losses

‘Natural losses’ from Line 5 in Table 10 describes the volume of leaves or needles in the cutblock that have fallen off due to season of harvest (no leaves in winter), or time from initial harvest (after one year, 70% of needles and 100% of leaves fall off). In order to determine the volume of leaves and needles and remove this volume from the available biomass categories, the primary harvest date was moved back two years. Natural losses volume for the sensitivity scenario was 273.3 odt.

Data collection for natural losses is virtually impossible even when needles and leaves are attached to branches, so the BiOS value was utilized for both the BiOS and field trial results.

Line 6 – Uncut trees

In BiOS, ‘Uncut trees’ is the volume attributed to trees left standing after the primary harvest. No trees were left standing in this cutblock so both the BiOS value and the actual value was 0.0 odt.

Line 7 – Cutover residues

‘Cutover residue’ described in Line 7 of Table 10 describes the volume of fibre that is left in the dispersed area of the cutblock and is not usually harvested. This volume is calculated based on the ‘Technical losses at the stump’ value found on the Biomass Operations data entry tab. The default for this value is set at 30% but for this sensitivity analysis the value was reduced to 15%. The BiOS predicted value of 185.3 odt was 15.4% higher than the measured field results of 160.6 odt. This is an improvement over the default scenario, which predicted 206% more volume than was measured.

Line 8 – Visual estimator

The visual estimator calculated volume is independent of the rest of the BiOS flow calculations. This indicator is useful to assess the volume per pile and was compared with the field result's total pile volume. There was no change in visual estimator values between scenarios.

Line 9 - Roadside

The BiOS calculation for roadside volume in Line 9 of Table 10 consists of all the volume that is hauled to roadside. To determine roadside volume for the actual field results, 50% of the hauled volume was added to the leftover pile volume to get 468.3 oven dry tonnes. This was different from the BiOS calculation of 1265.2 oven dry tonnes by 170%. Although the proportion between actual and the BiOS prediction was higher in the sensitivity scenario, the absolute difference volume was approximately 500 odt lower with the actual harvest volume inputs.

Line 10 – Recovered biomass

The BiOS calculation for recovered biomass in Line 10 of Table 10 consisted of the roadside biomass volume that was comminuted and transported during the secondary harvest. The BiOS calculation for recoverable biomass of 205.2 oven dry tonnes was 5.9% higher than the measured field result of 193.9 oven dry tonnes. The difference between these two values is significantly lower than in the default scenario and is a result of the 50% transfer of hauled volume to the merchantable fibre category and the reduction of the grinder recovery technical efficiency.

Line 11 – Not recovered

The not recovered value in Line 11 of Table 10 consists of the volume left at roadside after the secondary harvest. BiOS calculates this using the Recovered Technical Efficiency Value found in the pre-piling and comminution functions of the Biomass Operations Tab. The BiOS volume for 'not recovered' was 1203.9 oven dry tonnes and was significantly higher than the value of 274.4 oven dry tonnes calculated in the field.

Overall analysis of comparison

Overall, the changes made to the input for the sensitivity analysis improved some of the differences between some of the categories, specifically the merchantable fibre, total fibre and recoverable fibre categories, which are arguably the most important categories, as they are of the most interest to secondary pulp harvesters. However, this came at the expense of the available biomass and not recovered categories which were made less accurate by the changes.

Based on the changes to inputs made for the sensitivity scenario and the assumption that if the merchantable fibre has been correctly estimated, yet the biomass estimations are still significantly higher than measured values, the allometric equations for the species present are likely overestimating the biomass volumes. This also indicates that the cruise data is likely not the cause of the differences, although reinforces the value of accurate cruise data for more accurate BiOS results.

It is recommended that a second validation be completed in this area or timber type to determine whether the results can be replicated with the assumption that if the same results occur, the allometric equations may need to be updated to improve accuracy.

CONCLUSION

FPInnovations completed a field validation of the FPBiOS App in February 2022. A cutblock located in the CWHvm1 biogeoclimatic zone near Coal Harbor, BC was chosen. This validation required researchers to measure available biomass in the field, including dispersed volume, residual pile volume and volume left over on site after the secondary harvest. After measurements in the field were completed, the values collected were compared with the outputs calculated by BiOS.

Of the three pile measurement methods that were attempted, the GPS measure method was considered to have the most accurate shape and apparent volume methodology. Discussions should occur regarding the addition of more pile bulking factor options to better improve estimator volume predictions.

Unlike the other four validations performed to date, there were significant differences between the measured values for each category and the predicted BiOS values. A sensitivity analysis was performed to determine the source of the differences.

Based on the changes made for the sensitivity scenario and the assumption that if the merchantable fibre has been correctly estimated, yet the biomass estimations are still significantly higher than measured values, the allometric equations for the species present are likely overestimating the biomass volumes. However, it is recommended that a second validation be completed in this area to determine whether the results can be replicated with the assumption that if the same results occur, the allometric equations may need to be updated to improve accuracy.

REFERENCES FOR ALLOMETRIC EQUATIONS

Lambert, M.-C., Ung, C.-H., and F. Raulier, 2005. Canadian national tree aboveground biomass equations. Can. J. For. Res. 35: 1996-2008.

Ung, C.-H., Bernier, P. and Guo, X.J. 2008. Canadian national biomass equations: new parameter estimates that include British Columbia data. Can. J. For. Res. 38: 1123-1132.

Standish, J.T., Manning, G.H. and Demaerschalk, J.P. 1985. Developement of biomass equations for British Columbia tree species. Information report BC-X-264. Pacific Forest Research Center. 48 p.

APPENDIX IA – BIOS APP DATA ENTRY, DEFAULT

Run	Tab	Area
1	Project Informatio	12.7

Run	Tab	Data source	Species	Volume/ha	Top dia	Harvest remove	Decay waste break	MC	Dry basic density	Green density	Value m3/ton
1	Species Operations	Cruise + Field	Cw	53.1	14.3	100	5	58	329		0.41
			Hw	866.0	14.3	100	4	58	423		1.26
			Ba	171.1	14.3	100	4	58	377		2.59
			Ss	35.1	14.3	100	4	58	347		2.02
			Dr	16.5	40	100	6	58	373		1.05

Run	Tab	Average Skid	Harvest Date	Harvest Method
1	Logging Operations	50	12/01/2021	Full tree with roadside processing

Run	Tab	chnical Losses at the Stu	Recovery Date	Pre-pilin	Comminution
1	Biomass Operations	30%	02/10/2022	On (30%)	Grinder 65%

Run	Tab	Truck Configuration	Destination	Distance
1	Transport	Bin Truck	Beaver Cove Chip Plant	User defined (1km operational, 2.5km primary, 63.3km public)

Run	Tab	Piles	Pile Type	Ht1	L1 (or diameter)	W1	Bulking	Apparent	Est Dry
1	Visual Estimator	1	Cone	2.0	5.0		20%	13.1	1.1
		2	Cone	2.2	3.0		20%	5.2	0.4
		3	Cone	2.0	5.0		20%	13.1	1.1
Number of piles -		4	Cone	2.7	4.0		20%	11.3	0.9
		5	Cone	3.4	7.0		20%	43.6	3.5
		6	Cone	3.1	6.0		20%	29.2	2.4
		7	Cone	3.1	6.0		20%	29.2	2.4
		8	Cone	2.9	6.0		20%	27.3	2.2
		9	Cone	2.2	2.6		20%	3.9	0.3
Total estimated dry weight:		10	Cone	2.2	4.2		20%	10.2	0.8
		11	Cone	2.2	4.0		20%	9.2	0.7
		12	Cone	4.3	3.5		20%	13.8	1.1
		13	Cone	2.8	6.6		20%	31.9	2.6
		14	Cone	1.7	6.0		20%	16.0	1.3
		15	Cone	2.5	7.4		20%	35.8	2.9
		16	Cone	3.6	6.0		20%	33.0	2.7
		17	Cone	2.5	3.0		20%	5.9	0.5
		18	Cone	3.2	2.7		20%	6.1	0.5
		19	Cone	4.5	6.8		20%	54.5	4.4
		20	Cone	2.8	3.0		20%	6.6	0.5
		21	Cone	2.8	5.6		20%	23.0	1.9
		22	Cone	3.4	8.0		20%	57.0	4.6
		23	Cone	2.2	5.0		20%	14.4	1.2
		24	Oriented	1.1	21.5	18.5	10%	218.8	8.8
		25	Cone	2.3	4.5		20%	12.2	1.0
		26	Cone	2.0	4.0		20%	8.4	0.7
		27	Cone	1.5	2.5		20%	2.5	0.2
		28	Cone	2.3	3.7		20%	8.2	0.7
		29	Cone	2.1	4.0		20%	8.8	0.7
		30	Cone	2.1	4.0		20%	8.8	0.7
		31	Cone	0.8	2.4		20%	1.2	0.1
		32	Cone	2.3	2.8		20%	4.7	0.4
		33	Cone	1.8	2.8		20%	3.7	0.3
		34	Cone	1.7	2.2		20%	2.2	0.2
		35	Cone	1.6	2.6		20%	2.8	0.2
		36	Cone	1.6	3.0		20%	3.8	0.3
		37	Cone	2.4	3.6		20%	8.1	0.7
		38	Cone	2.3	1.6		20%	1.5	0.1

APPENDIX IB – BIOS APP DATA ENTRY, SENSITIVITY ANALYSIS

Run	Tab	Area
1	Project Informatio	12.7

Run	Tab	Data source	Species	Volume/ha	Top dia	Harvest remov	Decay waste break	MC	Dry basic densit	Green density	Volumes/tom
1	Species Operations	Cruise + Field	Cu	90.5	14.3	100	5	58	329		0.41
			Hu	714.2	14.3	100	4	58	423		1.26
			Ba	135.5	14.3	100	4	58	377		2.59
			Sr	44.6	14.3	100	4	58	347		2.02
			Dr	16.5	40	100	6	58	373		1.05

Run	Tab	Average Skid	Harvest Date	Harvest Method
1	Logging Operations	50	01/01/2019	Full tree with roadside processing

Run	Tab	chnical Losses at the Stu	Recovery Date	Pre-pilin	Comminution
1	Biomass Operations	15%	02/10/2022	On (0%)	Grinder 0%

Run	Tab	Truck Configuration	Destination	Distance
1	Transport	Bin Truck	Beaver Cove Chip Plant	User defined (1km operational, 2.5km primary, 63.3km public)

Run	Tab	Piles	Pile Type	Ht1	L1 (or diameter)	W1	Bulking	Apparent	Est Dry
1	Visual Estimator	1	Cone	2.0	5.0		20%	13.1	1.1
Number of piles -		2	Cone	2.2	3.0		20%	5.2	0.4
		3	Cone	2.0	5.0		20%	13.1	1.1
		4	Cone	2.7	4.0		20%	11.3	0.9
		5	Cone	3.4	7.0		20%	43.6	3.5
		6	Cone	3.1	6.0		20%	29.2	2.4
Total estimated dry weight:		7	Cone	3.1	6.0		20%	29.2	2.4
		8	Cone	2.9	6.0		20%	27.3	2.2
		9	Cone	2.2	2.6		20%	3.9	0.3
		10	Cone	2.2	4.2		20%	10.2	0.8
		11	Cone	2.2	4.0		20%	9.2	0.7
		12	Cone	4.3	3.5		20%	13.8	1.1
		13	Cone	2.8	6.6		20%	31.9	2.6
		14	Cone	1.7	6.0		20%	16.0	1.3
		15	Cone	2.5	7.4		20%	35.8	2.9
		16	Cone	3.6	6.0		20%	33.0	2.7
		17	Cone	2.5	3.0		20%	5.9	0.5
		18	Cone	3.2	2.7		20%	6.1	0.5
		19	Cone	4.5	6.8		20%	54.5	4.4
		20	Cone	2.8	3.0		20%	6.6	0.5
		21	Cone	2.8	5.6		20%	23.0	1.9
		22	Cone	3.4	8.0		20%	57.0	4.6
		23	Cone	2.2	5.0		20%	14.4	1.2
		24	Oriented	1.1	21.5	18.5	10%	218.8	8.8
		25	Cone	2.3	4.5		20%	12.2	1.0
		26	Cone	2.0	4.0		20%	8.4	0.7
		27	Cone	1.5	2.5		20%	2.5	0.2
		28	Cone	2.3	3.7		20%	8.2	0.7
		29	Cone	2.1	4.0		20%	8.8	0.7
		30	Cone	2.1	4.0		20%	8.8	0.7
		31	Cone	0.8	2.4		20%	1.2	0.1
		32	Cone	2.3	2.8		20%	4.7	0.4
		33	Cone	1.8	2.8		20%	3.7	0.3
		34	Cone	1.7	2.2		20%	2.2	0.2
		35	Cone	1.6	2.6		20%	2.8	0.2
		36	Cone	1.6	3.0		20%	3.8	0.3
		37	Cone	2.4	3.6		20%	8.1	0.7
		38	Cone	2.3	1.6		20%	1.5	0.1

APPENDIX II – LINE TRANSECT SURVEY METHODOLOGY

- Volume leftover after the secondary harvest was assessed using line transect methodology
- Starting location within the pile footprint should be chosen randomly. Number of plots within the footprint should be determined in the field to adequately represent the size of the footprint.
    - At least two 10 m transects per plot.
    - The transect bearing selection should be done by spinning the compass wheel and randomly stopping on a given bearing.
    - The minimum length of pieces that cross the transect to be measure is 30 cm.
- Tallied pieces over 5 cm in diameter can be identified by species or group (softwood & hardwood) depending on site conditions and relevance to study (species was not collected for this trial). Pieces with a diameter less than 5 cm (down to 1 cm) are only to be tallied (counted) regardless of species or group.
- Not to be tallied:
    - Non-commercial species or brush species that won't become a full-grown tree.
    - Roots
    - Stumps
    - Trees with root ball (roots in the ground) attached counts as standing and not as slash on the ground
    - Slash height (site assessment factor)
    - Pieces with more than 50% rot (it breaks apart easily)

[1]**Van Wagner. 1968.** The Line Intersect Method in Forest Sampling. Forest Science.

APPENDIX III – MOISTURE CONTENT ANALYSIS

Analyzing the Moisture Content of Biomass Samples

Objective: to find the moisture content percentage *mc* (%) (% by weight, wet basis) of a biomass sample.

Work space: This procedure should be performed in laboratory conditions.

Materials and equipment:

- Digital scale with a capacity of at least 2000 g and accuracy of 0.1g
- Drying oven
- Clean sample weighing tray, able to hold at least 300 g of biomass
- 6 L (>1 kg) of biomass sample (3 replicates of at least 300 g each)

Procedures:

Step 1
Follow the procedures for *Separating Biomass Samples* to separate 3 replicates of at least 300 g each from one sample of at least 1 kg of biomass.

Step 2
Weigh the empty sample tray and record its weight (tare) m_t.

Step 3
Load the material of a replicate into a weighing tray. Weigh the loaded tray and record the weight m_{we}.

Step 4
Load the tray into the oven and set to 105°C.
Keep the tray in the oven until constant mass is obtained[2].

Step 5
Weigh the loaded tray and record the weight of the dry material m_{dry}.

Step 6
Calculate moisture content *mc* (%) according to the following formula:
$mc\ (\%) = [(m_{we} - m_{dry}) / (m_{we} - m_t)] \times 100$

Step 7
Analyze the 3 replicates and report the average.

[2] Mass constancy is obtained when the mass lost between two weights taken 60 minutes apart is not exceeding 0.2% of the total lost in mass (EN-TS 14774-1:2009). The drying time will depend on the particle size and the thickness of the sample in the tray, and may vary between 5 and 24 hours (overnight).

APPENDIX IV – CRUISE COMP SUMMARY

Net Area: [TFL6 : 12.7]
Gross Area: [Grand Total : 12.7]

		Total	Conifer	Decid	C	H	B	S	D
Utilization Limits									
Min DBH	cm (I)				12.0	12.0	12.0	12.0	12.0
Stump Ht	cm (I)				30.0	30.0	30.0	30.0	30.0
Top Dia	cm (I)				10.0	10.0	10.0	10.0	10.0
Log Len	m				10.0	10.0	10.0	10.0	10.0
Volume and Size Data									
Gross Merchantable	m3	14501	14291	209	674	10998	2173	446	209
Net Merchantable	m3	13890	13694	196	640	10540	2086	428	196
Net Merch - All	m3/ha	1094	1078	15	50	830	164	34	15
Distribution	%	100	99	1	5	76	15	3	1
Decay	%	0	0	1		0			1
Waste	%								
Waste(billing)	%								
Breakage	%	4	4	5	5	4	4	4	5
Total Cull (DWB)	%	4	4	6	5	4	4	4	6
Basal Area / Ha	m2/ha	81.3	80.0	1.3	6.5	60.6	10.3	2.6	1.3
Net VBAR	m3/m2	13.456	13.480	11.963	7.812	13.686	15.913	13.073	11.963
Stems/Ha (Live & DP)		916.8	901.0	15.7	128.6	688.8	66.2	17.4	15.7
Avg DBH (Live & DP)	cm	33.6	33.6	32.3	25.3	33.5	44.6	43.5	32.3
Snags/Ha									
Avg Snag DBH	cm								
Gross Merch Vol/Tree	m3	1.25	1.25	1.05	0.41	1.26	2.59	2.02	1.05
Net Merch Vol/Tree	m3	1.19	1.20	0.98	0.39	1.20	2.48	1.94	0.98
Avg Weight Total Ht	m	36.8	36.9	30.2	22.8	37.1	39.7	39.9	30.2
Avg Weight Merch Ht	m	30.6	30.7	23.8	16.9	30.5	35.0	34.7	23.8
Net Merch Vol/Log	m3	0.49	0.49	0.34	0.26	0.48	0.72	0.62	0.34
Gross Merch Vol/Log	m3	0.49	0.49	0.35	0.26	0.48	0.72	0.62	0.35
Avg # of Logs/Tree		2.55	2.54	3.00	1.60	2.60	3.59	3.26	3.00
Net Immature	%	98.6	100.0		100.0	100.0	100.0	100.0	
Net 2nd Growth	%		100.0						
Average Slope	%	9							
Algorithm Grades %									
#2 Sawlog	H	16	17			13	35	27	
#3 Sawlog	I	4	4			4	4	18	
#4 Sawlog	J	60	61		69	64	50	37	
#5 Utility	U	15	14	62	27	14	11	17	62
#6 Utility	X	4	4		4	5			
#7 Chipper	Y	1		38				1	38
Statistical Summary									
Coeff. of Variation	%	42.3	45.2	374.2	230.4	67.5	167.6	261.8	374.2
Two Standard Error	%	24.4	26.1	216.0	133.0	38.9	96.7	151.1	216.0
Number and Type of Plots		MP = 14							
Number of Potential Trees		63							
Plots/Ha		1.1							
Cruised Trees/Plot		4.5							

FLAGS: Full Volumes, Normal Cruise, All Trees Compiled, Measure Plots Only, Damage,

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