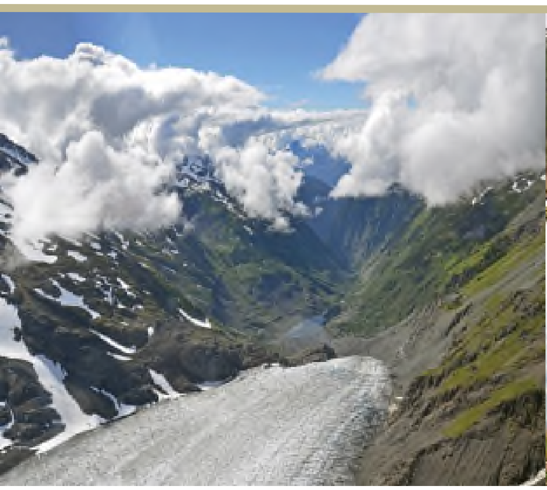
Wood Waste Feedstock Assessment – Haines Junction and Watson Lake, YT



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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was contracted by the Government of Yukon (YG) Forest Management Branch (FMB) in January 2017 to complete an assessment of wood waste as feedstock in Haines Junction and Watson Lake, YT. The scope of work for the project was to review and assess industrial activities which generate wood in Yukon, provide an estimate of timber volume held by YG slated for clearing activities which will generate wood, including the volume and opportunities within 150 km of Haines Junction and Watson Lake, and create a study design to quantify wood waste generated by forestry operations.

The industrial activities assessed include:

- Gravel extraction
- Forestry (including sawmill) residuals
- Agriculture
- Mining
- Private land/lot development
- Fire smart projects
- Highway improvement and maintenance
- Yukon Energy projects.

Timber volumes were generated using the total land base summary (merchantable and unmerchantable areas) and average conifer volume per hectare predicted for harvest for the Coal, Liard and Kluane Forest Management Units (FMUs) in the Timber Supply Analysis for the Southern Yukon (TSA; Henry 2000). In order to compensate for data deficiencies, for example known rates of clearing for gravel pits, agricultural land, and mining projects, Tetra Tech used current available data provided from local government and industry to augment broader estimates, used available published data and tools, such as the Natural Resources Canada Biomass and Nutrient Calculator (Natural Resources Canada 2017), and applied professional judgement to generate estimated values to apply to the average stand volume available for biomass harvest. The estimate is limited by available data at the time of assessment. Future land developments were not included in the assessment. Anticipating future development will be an important component of future biomass assessment projects.

In Yukon, gravel extraction ranks highest in the greatest opportunity for biomass harvest, based on the community-level results, and the lack of Yukon-wide data. Forestry residuals are ranked second, as the volume harvested is approximately equal to the estimated volume for agriculture, and there are existing markets for biomass harvest in this industry. Ranked third is agriculture if the maximum potential harvest is attained, although there is no direct mechanism to sell biomass harvested through agriculture. Similarly, FireSmart projects are ranked fourth, although there is no mechanism at present to sell biomass harvested through FireSmart projects. Without estimated areas, mining has been ranked fifth, as small to moderate volumes of biomass has potential to be produced, followed by Yukon Energy Projects and Yukon highway improvement, as they have smaller individual projects that are anticipated at future dates, providing local biomass, followed by private land development where areas are small and amounts to be cleared are variable.

Gravel extraction is ranked first for all three distance categories from Haines Junction, followed by private land development nearest Haines Junction, and agriculture and mining beyond 50 km away. Forestry residuals are ranked third near Haines Junction, then fourth or fifth beyond 50 km away. Agriculture is ranked fourth nearest Haines Junction, but second 50-100 km away. Overall, within 150 km of Haines Junction, gravel extraction is ranked first, followed by agriculture, private land development, forestry residuals, and mining.

Gravel extraction is ranked first within all categories of Watson Lake. Within 50 km of Watson Lake, private land development ranks second, followed by forestry residuals. Further from the community, forestry residuals and mining are ranked second. Agriculture ranks fifth in all distance categories. Overall, within 150 km of Watson Lake, gravel extraction is ranked first, followed by private land development, then forestry residuals, mining, and agriculture.

The main driver of economical biomass projects is the cost to transport biomass to its receptor site. Considering the current price of fuel and labour, economical biomass projects are restricted to the areas closely surrounding urban or commercial centres, or harvesting associated with existing commercial harvest. Tetra Tech recommends that future biomass projects consider assessing the economical and feasible distance to harvest biomass from a community centre, and if this changes if biomass is harvested as roundwood (logs or firewood) or chips generated using portable chippers.

Tetra Tech developed a design for wood waste from commercial sawlog harvest (forestry operations) in Yukon, as follows:

- Sample 1 plot/ha with 50% of plots as accumulated biomass area and 50% of plots as dispersed biomass per cutblock with a minimum of 5 plots per block
- Plot size is 100 m^2 (circular using 5.64 m plot cord, or rectangular, as long as plots are consistent), randomly located
- Plots will measure safely accessible biomass 8 cm and over inside bark
  - Logs, branches, etc. will measure median area ($A = \pi r^2$) diameter times length
  - Tops will measure butt area times length divided by three ($V = \pi r^2 h/3$) to account for taper
  - Where plots cannot safely access all biomass, or where biomass is piled such that the bottom of the pile cannot be measured, the safely accessible biomass % in the plot will be estimated, and divided by the safely accessible % to generate a 100% estimate of the accumulated biomass.
    - Alternatively, if safe access is not available, estimates of biomass volume for piles may follow the biomass estimate by pile size and shape outlined in Section 5.1.1.
- The sum of biomass volume per plot (m^3/100m^2 (plot size)) and multiplied by 100 (m^3/ha) to determine wet m^3/ha.
- Wet m^3/ha will be multiplied by median dry density (374 kg/m^3) estimate dry tonnes of wood waste per hectare (kg/ha).

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

LIST OF FIGURES IN TEXT

APPENDIX SECTIONS

FIGURES

APPENDICES

ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
BC	British Columbia
dbh	diameter at breast height
FMB	Forest Management Branch
FMUs	Forest Management Units
ha	hectares
ibid.	in the same place. Used to repeat immediately preceding citation.
kg	kilogram
Tetra Tech	Tetra Tech Canada Inc.
THP	Timber Harvest Plan
TSA	Timber Supply Analysis
YEC	Yukon Energy Corporation
YG	Government of Yukon
yr	year

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the Government of Yukon and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the Government of Yukon, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech Canada Inc.'s Services Agreement. Tetra Tech's General Conditions are provided in Appendix A of this report.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was contracted by the Government of Yukon (YG) Forest Management Branch (FMB) in January 2017 to complete an assessment of wood waste as feedstock in Haines Junction and Watson Lake, YT.

Regulated forest management began in Yukon in the late 1990's, through the Federal Government, although experimental forests have been in place in Yukon since the 1960's (Kirk Price, pers. comm. February 20, 2017). The 2002 Tough Report defined the need for forest management planning in Yukon, recommending regional forest management plans (Alsek Renewable Resources Council (ARRC) 2004). Forest management plans were generated for the Champagne and Aishihik Traditional Territory surrounding Haines Junction in 2004 (ibid), for Teslin, and for Dawson in 2013 (FMB 2017). There is currently no forest resources management plan for Watson Lake; however, there is an Integrated Landscape Plan for the Champagne and Aishihik Traditional Territory, including guidelines for landscape planning, and resource assessment (ibid). The forest management plans provide strategic management planning at the forest level to guide forest resources management in the area. In 2011 the *Forest Resources Act* and Regulations were implemented in Yukon, formally regulating forest management in Yukon to promote the sustainable use of forest resources for future generations (FMB 2017). Timber harvest plans are laid out within forest management plan areas (where available) at the landscape unit level to identify areas of forest resource harvesting. Within timber harvest plan areas are operating units with site plans identifying stand-level management activities, methods and standards (FMB 2015).

Biomass studies, discussions, and charettes have been completed for the Yukon. These include the Biomass Energy Background Paper, which states that based on a growth rate of 1.1 m^3/(ha yr) an area of approximately 1 km^2 would supply approximately 50 tonnes of wood per year for biomass (Preto 2011), developed in support of a Biomass Workshop/Charette developed by Yukon Energy Corporation (YEC 2011). The Energy Strategy for Yukon was developed in 2009, setting out YGs priorities, strategies and actions (YG 2016). The Yukon Biomass Energy Strategy was released in 2016 and was developed as part of the Renewable Energy priority action to develop a wood based biomass energy industry in Yukon (ibid). The intent of the Strategy is to reduce Yukon's dependence on imported fossil fuels by optimizing the use of Yukon-harvested wood to meet the territory's hearing needs using modern biomass energy systems. There are six key action areas proposed within the strategy for the development of biomass energy in Yukon. They include (ibid):

- Commit to using biomass energy in government infrastructure.
- Develop regulations, policies and programs for biomass energy industry, as required.
- Manage biomass facility emissions to protect public/environmental health and safety.
- Facilitate private sector development in biomass energy.
- Manage and regulate Yukon forests sustainably.
- Ensure biomass fuel security and quality.

Biomass as a primary product from the forest is currently the primary industry in Yukon, with approximately 10,600 m^3/yr harvested for personal fuel wood (Gavin Dyshoorn, pers. comm. February 13, 2017). There is a growing market for wood chips used for heat energy, including to support the objectives of the Yukon Biomass Strategy. For example, the combustion wood boiler at Raven Recycling in Whitehorse uses approximately 200 m^3 of wood chips per year (Myles Thorp, pers. comm. February 26, 2017) and the Dawson Infrastructure Heating Plant uses chips to heat the Dawson Wastewater Treatment Plant.

The scope of work for the project was to review and assess industrial activities which generate waste wood in Yukon, provide an estimate of timber volume held by YG slated for clearing activities which will generate waste wood, including the volume and opportunities within 150 km of Haines Junction and Watson Lake, and create a study design to quantify wood waste generated by forestry operations.

The industrial activities assessed include:

- Gravel extraction
- Forestry (including sawmill) residuals
- Agriculture
- Mining
- Private land/lot development
- Fire smart projects
- Highway improvement and maintenance
- Yukon Energy projects.

2.0 YUKON WOOD WASTE VOLUMES BY ACTIVITY

Each industrial activity is reviewed in the following sections, including current and immediate known planned activities for the Yukon, estimated areas of clearing, identified wood use, and estimated wood waste available to YG for feedstock. Wood waste has been considered available if it is within two kilometres of a maintained highway. Table 2-1 shows the summary of industry activities, and anticipated ranking of areas of clearing and anticipated wood waste volumes, providing a relative rank for potential for sourcing wood waste for feedstock.

Each section describes the industry in Yukon and discusses the anticipated projects that would generate wood waste. Each industry is assessed, in general, for the opportunities and constraints involved with using waste generated from industrial activities.

The wood waste volumes have been ranked from 1-8 to indicate the best (1) to worst (8) potential for biomass fibre sourcing by industry. The ranking of biomass by industry considered potential volume that has the potential to be produced if economical (i.e., if an industry existed to drive private tenure holders to sell chips or roundwood for biomass.

Sources of information were:

- Geomatics Yukon, Yukon Lands and Mining viewers
- Interviews and discussions with YG Environment, Lands, EMR
- FMB GIS and CADD data
- Timber Supply Analysis for the Southern Yukon (TSA; Henry 2000)
- Timber Harvest Plans (THPs) for Haines Junction and Watson Lake (FMB 2016).

2.1 GRAVEL EXTRACTION

Quarrying refers to extracting and removing topsoil, sand, gravel, or rock materials from a pit or site (YG 2015). Quarrying activities are administered through leases, designated public pits, highway pits, and private pits under Quarry Permits. Gravel reserves are determined for use by YG for long-term maintenance and construction projects (YG 2015a). As of 2015, there were 650 gravel pits throughout Yukon for construction and maintenance of highways and airports. Most of the gravel reserves in Yukon were developed with the development of Yukon's highway and airport systems; however, new pits are being developed and existing pits are being expanded to support ongoing maintenance and road improvements.

YG does not track gravel reserve development on an annual basis, and it is unknown how much new gravel reserve development is anticipated in Yukon in the next few years, including pit development for highway improvements on the North Canol Road and the Silver Trail (Justine Scheck, pers. Com. February 23, 2017). Where pits are developed in future for large road improvements it is assumed that sufficient biomass would be available for economical harvest; however, small pit expansions are assumed to be uneconomical for biomass production. Community level assessment of gravel pits ranked them first with areas of robust data and the assumption that 80% of disposition areas would be cleared within the next 10 years. Given the lack of data for Yukon, the community-level ranking was used for Yukon gravel extraction.

2.2 FORESTRY RESIDUALS

Timber harvesting occurs in a small scale in Yukon, near Haines Junction, Watson Lake, Whitehorse, and Dawson, with small volumes reported for other areas (Gavin Dykshoorn pers. comm. January 30, 2017). Typically, standing trees are harvested in cutblock areas (often standing dead wood is targeted), and yarded to a landing at roadside in the cutblock. Merchantable stems are loaded onto trucks on the landing, and remaining waste wood is typically piled and burned.

Biomass harvest occurs to fuel local commercial heating projects in Dawson and Burwash, among others. In Dawson, biomass is harvested from residual wood waste from sawmill harvest. Where timber harvesting occurs, there is the opportunity to harvest residual biomass from harvest waste. Residual biomass harvest for sawlog operations increase total logged volume by approximately 15%, including tops, rotten stems, and smaller sized stems (Louise Blanchard, pers. comm. February 20, 2017). Other harvesters estimate 25% of biomass left as residual wood from harvest operations, not all of which will be economical and feasible to process for biomass (Myles Thorp, pers. comm. February 23, 2017). Uneconomical and in-feasible biomass residual volume is estimated to be 10% using these estimates.

Currently in Yukon biomass is primarily harvested as roundwood, then dried and chipped at a central location (Louise Blanchard, pers. comm. February 20, 2017). Portable chippers are being introduced to the Yukon (e.g., in Dawson, Teslin, and Haines Junction), and biomass is harvested at roadsides processing residual material from logging beetle and fire killed timber near Haines Junction (Myles Thorp, pers. comm. February 26, 2017). The increase in numbers of portable chippers may lead to stands being harvested solely for biomass in the future; however, at present it is more economic to combine sawlog and biomass harvest (ibid).

The TSA estimates merchantable volumes of average stands, and estimates the number of hectares (ha) of harvest per year. The average commercial harvest for the past three years is 19,731 m^3/yr (Gavin Dykshoorn pers. comm. January 30, 2017). Assuming that in an average Yukon harvesting operation there would be an additional 15% of economically feasible waste wood biomass for harvest during commercial operations (as discussed above), an estimated 2,960 m^3/yr of biomass could be generated in an average commercial harvest year across Yukon.

The TSA does not estimate the volume of wood to be harvested from beetle-killed stands, but Spruce Bark Beetle has affected timber around Haines Junction and in other parts of the Yukon (ARRC 2004, FMB 2017). Since 1990 the Spruce Bark Beetle has killed more than half of the mature Spruce forest over approximately 400,000 ha (FMB 2016a). The Forest Management Resource Zones and Timber Harvest Plan areas around Haines Junction focus on areas with highest Spruce tree mortality, as well as highest timber volumes and closest areas to existing access (Anonymous 2017). Harvesting dead wood is challenging due to stem breakage in harvesting, and challenges in processing, such as rapidly dulling blades (Preto 2011). Where fires occur near highways (for example near Fox Lake and Carmacks), locals are preferentially harvesting biomass for use as firewood (Myles Thorp, pers. comm. February 26, 2017). Liard River Burn THP, False Canyon Creek Fire THP, and Barney Lake Fire Salvage THP target forest-fire damaged stands around Watson Lake (FMB 2016).

There is a demand for biomass to provide fuelwood for personal wood stoves, typically sourced from standing beetle-killed wood. The volume harvested for personal use is often harvested in dispersed areas throughout the forest around communities. This harvesting occurs in mature stands with dead and down timber the primary target (Myles Thorp, pers. comm. February 26, 2017). This demand (volume) depends on the population of the community. Approximately 10,600 m^3/yr (7-9 m^3/permit x average number of permits) is harvested as personal fuelwood biomass annually, with most permits issued in Whitehorse or Haines Junction (Gavin Dykshoorn pers. comm February 13, 2017). In areas where timber harvesting is occurring commercially, harvesting mill or cutblock residuals for personal fuelwood biomass already occurs as part of commercial operations and sales (e.g., at Dimok Timber in Otter Falls, Haines Junction). There are two firewood manufacturing and distribution yards in Whitehorse, Hurlburt Enterprises and Beron Placer, which purchase round logs and process them using cord wood machines (e.g., cord king) that cut to length and split the wood (Myles Thorp, pers. comm. February 26, 2017). This demand places constraints on commercially available biomass for chips; however, due to differences in harvest area locations and scales this constraint is mitigated by the available volume of biomass overall and the relatively limited combined demand.

The benefit to timber residual biomass is that it has been demonstrated to be economical paired with commercial timber harvest, and systems are in place for timber harvesting. The economy is growing for biomass generation from residual harvest, and residual harvest volumes will grow in volume as the market grows. Examples of residual volume harvest are: utilizing waste piles at landings and roadside, harvesting non-timber species or smaller stems, and harvesting whole trees so that tops can be processed for biomass at sawmills. While there is overlap in biomass harvest with firewood harvesters (as discussed above), harvest area locations and harvest scales differ sufficiently to avoid significant conflict. Constraints for biomass harvest are Annual Allowable Cuts and merchantable and feasible limits to harvest distances, which will increase as commercial forestry operations move further from communities.

2.3 AGRICULTURE

Agriculture projects in Yukon focus on developing a growing industry (YG 2011). Yukon has 13,500 ha of land devoted to agriculture, with 40% cropland, 20% (approximately 2,700 ha) under development for future agricultural use, and 40% non-cropland agriculture (ibid, David Murray pers. comm. March 22, 2017). In the next three to seven years approximately 192 ha (up to 360 ha) will be cleared for agricultural development (David Murray pers. comm. Feb 2, 2017).

Many areas under agricultural development have lower timber volumes, as these areas are less expensive to develop for agriculture. Assuming that lower timber volume areas have half the volume of feasible and economical biomass from commercial timber harvest areas (derived using comparisons of biomass for Stands with Site Index 20 and Site Index 10; Natural Resources Canada 2015), the estimated volume of timber potentially available for biomass development, assuming that all areas being developed will be within 2 km of a highway, that 30% of wood harvested will be used by the farmer, and that development occurs over five years, is 1,590 to 4,200 m^3/yr (if 192 or 360 ha are harvested).

Under development, the timber biomass is under the ownership and management of the project proponent (farmer). Farmers are responsible to ensure that all timber resources are utilized (David Murray pers. comm. Feb 2, 2017). Currently, no biomass volume is removed from agriculture projects for non-local use (e.g., local firewood or agriculture). If an economy existed for sale of biomass chips, an opportunity exists for biomass harvest from agricultural clearing.

2.4 MINING

Mineral exploration and mining form a large part of Yukon's economy, contributing over 11% of total real GDP in 2015 (mining, quarrying and oil and gas extraction; YG 2016a). Most quartz mining areas tend to be focused in mountainous regions, and does not occur within 2 km of a highway, whereas placer mining occurs along drainages, which may occur within 2 km of highways. The level of clearing in mining varies from claim to claim, as miners may own many claims and work only a few at a time, in the instance of placer mining, and as quartz mines move from early exploration through development and operation. Mining projects clear timber from mined areas, and this biomass could be available for energy uses (FMB 2017).

2.5 PRIVATE LAND/LOT DEVELOPMENT

Private land development occurs within 2 km of Yukon highways, on land owned or leased by the landowner. Timber is typically used on site, for building or fuelwood. If an economy existed for sale of biomass chips, limited biomass may be available for energy production through private land/lot development.

YG does not track private land and lot development on an annual basis, and it is unknown how much new private lot development is anticipated in Yukon in the next few years (Justine Scheck, pers. comm. February 23, 2017). The area cleared by an individual land developer will depend on the size of development and the interests of the landowner in their home or business layout and design, and wood harvested may be used for home building or other private uses. Larger subdivisions in Whitehorse (e.g., Whistle Bend) have disposed of timber biomass as waste, or provided it as free firewood to Whitehorse residents (Myles Thorp, pers. comm. February 26, 2017). Private land/lot development is not anticipated to generate significant biomass unless large areas are being developed within community boundaries.

2.6 FIRESMART PROJECTS

FireSmart projects in Yukon are aimed at reducing the risk of loss of life and property from fire in the wildland/urban interface (Partners in Protection 2017). Among other recommendations, FireSmart recommends thinning trees and understory within 30 m of residences (Partners in Protection 2003). FireSmart projects in Yukon are carried out in Yukon communities, with no formal reporting of areas thinned, or biomass removed. From 2012 to 2016 390 ha have been thinned in 133 areas, averaging approximately 3 ha per FireSmart thinning area (Caleb Tomlinson pers. comm. February 2, 2017). The estimated volume removed through FireSmart projects in Yukon is 30% of stand volume (although this varies considerably, Caleb Tomlinson pers. comm. February 13, 2017). Using a 30% estimate for volume removal to account for an increased focus on the harvest of smaller stems and an increased rate of harvest of stems smaller than what is considered economically feasible biomass, and the wood waste volume calculations discussed in Section 3.0, approximately 2,800 m^3 is removed annually. The biomass volume is piled for local firewood use, chipped, or burned. No biomass volume is currently removed for use outside of the local area. FireSmart treatment prescriptions allow chipped biomass to be removed from site (Caleb Tomlinson pers. comm. February 2, 2017).

2.7 HIGHWAY IMPROVEMENT AND MAINTENANCE

Maintenance and improvement of Yukon's highways mainly comprises brushing small diameter stems from the existing Right of Way, which generates negligible biomass for commercial production. Highway improvements and realignments are a possible source of biomass in the future, such as along the Silver Trail and North Canol Highways. The highway widening project near McCrae in Whitehorse provided cleared timber as firewood for local residents (Myles Thorp, pers. comm. February 26, 2017). Where highway improvements are planned, relatively small areas of highway would be re-routed through timbered areas, generating relatively small amounts of biomass, which may be feasible for harvest on a local scale.

2.8 YUKON ENERGY PROJECTS.

Yukon Energy Corporation (YEC) has studied available biomass for the Haines Junction area (YEC 2013), and discussed biomass in a 2011 workshop/charrette (YEC 2017). The Front End Engineering Design study included estimates of available biomass near Haines Junction, estimating 7,600 green (wet) metric tonnes of biomass available per year and discussion of feedstock harvest cost (YEC 2013). Powerline projects such as the recent improvements to from Stewart Crossing to Keno have generated biomass used for firewood, although the quantity is not published. Future powerline projects will also generate biomass; however, the area of development or future timing is not known.

2.9 DISCUSSION

Biomass is typically harvested in the Yukon as roundwood (logs or firewood), although portable chippers are being introduced for biomass processing (Kirk Price, pers. comm. February 20, 2017; Louise Blanchard, pers. comm. February 20, 2017). Harvested biomass is typically chipped using dry wood (depending on boiler demand), which requires harvested material to be stockpiled for a season (approximately one year) to dry sufficiently for chipping (Louise Blanchard, pers. comm. February 20, 2017) or harvesting standing dead (e.g., beetle killed) wood. Forest harvesting operations typically occur in winter months in Yukon, as determined by the harvesting requirements under Soil Conservation Standards and Guidelines (Kirk Price, pers. comm. February 20, 2017). Winter harvest is favoured because logs are cleaner yarded over snow, with less contamination from dirt or rocks (Myles Thorp, pers. comm. February 26, 2017). There may be challenges to stockpiling biomass material on the land, such as bark beetle loading, and landing sizes. Current biomass operators chip stockpiled material at sawmill sites or log yards (Louise Blanchard, pers. comm. February 20, 2017). One limitation of chipping wood in the forest is chip volume, which is approximately 2.5 times the volume of stacked roundwood (ibid).

Feasible and economical piece size for biomass harvest is an important consideration for biomass estimates in Yukon. Biomass may include tree stems, branches, and needles, but harvest is limited to feasible and economical pieces. Uniformity of chip size is important to some boilers (Louise Blanchard, pers. comm. February 20, 2017). In addition, deciduous species and coniferous needles burn hotter and generate more ash, which may require additional maintenance for smaller boiler systems (ibid). Combustion boilers are able to handle more diverse fuel than gasification systems (Myles Thorp, pers. comm. February 26, 2017). Different tree species have different forms, some of which may require additional volume for transport (for example Aspen trees with crooked stems or branches). If chipped in the field, this becomes a smaller issue, depending on the capacity of the chipper (ibid). Arctic Inland harvests to a 10 cm coniferous top size (Kirk Price, pers. comm. February 20, 2017) and below a 12.5 cm dbh is considered waste wood for agricultural projects (David Murray pers. comm. Feb 2, 2017).

A benefit to feasible and economical limitations to biomass harvest is retaining some coarse woody debris on site. Woody biomass is important for forest ecology (Roach and Berch 2014, Harmon et. al. 1986, Stevens 2997, Stewart et al. 2010). In Alberta, biomass is supplied through agreements with commercial timber harvesters to produce harvest residues as feedstock. Haul costs of biomass are only affordable using hog fuel/mill residues in Alberta (Roach and Berch 2014).

In Yukon, gravel extraction ranks highest in the greatest opportunity for biomass harvest, based on the community-level results, and the lack of Yukon-wide data (Table 2-1). Forestry residuals are ranked second, as the volume harvested is approximately equal to the estimated volume for agriculture, and there are existing markets for biomass harvest in this industry. Ranked third is agriculture if the maximum potential harvest is attained, although there is no direct mechanism to sell biomass harvested through agriculture. Similarly, FireSmart projects are ranked fourth, although there is no mechanism at present to sell biomass harvested through FireSmart projects. Without estimated areas, mining has been ranked fifth, as small to moderate volumes of biomass has potential to be produced, followed by Yukon Energy Projects and Yukon highway improvement, as they have smaller individual projects that are anticipated at future dates, providing local biomass, followed by private land development where areas are small and amounts to be cleared are variable.

Table 2-1: Anticipated Wood Waste Yukon

Industrial Activity	Anticipated Volume of Biomass Available if Economical (m^3/yr)	Anticipated Dry Biomass Available If Economical (kg/ha)	Rank
Gravel Extraction	moderate -high	moderate-high	1
Forestry Residuals	2,960	130,658,057	2
Agriculture	2,985	131,759,537	3
FireSmart	2,781	122,759,915	4
Mining	small-moderate	small-moderate	5
Yukon Energy	small	small	6
Highway Improvement/Maintenance	small	small	7
Private land/lot development	very small	very small	8

The main driver of economical biomass projects is the cost to transport biomass to its receptor site. Considering the current price of fuel and labour, economical biomass projects are restricted to the areas closely surrounding urban or commercial centres, or harvesting associated with existing commercial harvest. Tetra Tech recommends that future biomass projects consider assessing the economical and feasible distance to harvest biomass from a community centre, and if this changes if biomass is harvested as roundwood (logs or firewood) or chips generated using portable chippers. Economical and feasible biomass calculations may include:

- Using available data to postulate an economically feasible distance to transport biomass to local communities, considering fuel pricing, costs of trucking, costs of biomass harvest
- Reviewing available information about biomass available for local supply of biomass within the economically feasible distance using available transportation corridors
- Factoring in ability and willingness of local harvesters to harvest and transport biomass to target facility sites
- Generating a local feedstock supply curve, indicating the availability of biomass feedstock at various price points at various distances from the target facility site, determining the optimal feedstock supply range for the project.
- Considering local feedstock supply and potential energy to be sustainably generated at the target facility.

3.0 WOOD WASTE VOLUME CALCULATIONS

The timber volumes in Table 2-1 were generated using the total land base summary (merchantable and unmerchantable areas) and average conifer volume per hectare predicted for harvest for the Coal, Liard and Kluane Forest Management Units (FMUs) in the Timber Supply Analysis for the Southern Yukon (TSA; Henry 2000).

3.1 WOOD WASTE VOLUME CALCULATIONS

Wood waste volume calculations were generated as follows:

- Average merchantable volumes were determined by averaging the volume per ha in the TSA predicted for 250 years for the Coal and Liard FMUs to represent Watson Lake, and for Kluane FMU to represent Haines Junction (Henry 2000). Average merchantable volumes were multiplied by 1.15 to accommodate feasible and economic biomass harvest, and averaged for Yukon forests (discussed in Section 2.2).
- Estimated merchantable forest area was determined from the total land forest summary of the TSA, and compared to average losses to fire per year to determine the % losses of fire/ha/TSA/yr. This is less than 1% and was discounted from further analysis.
- Yukon biomass areas cleared within 2 km of a highway by industry were provided by various government agencies as noted in Section 2.0.
- Watson Lake and Haines junction biomass areas cleared within 2 km of a highway by industry were derived using available GIS data for land dispositions (viewed using the Yukon Lands Viewer). All forestry tenures within the 150 km radius (modified for Haines Junction as discussed in Section 4.1) were included in the available biomass area, as directed by FMB via email February 13, 2017.
  - Gravel pit land dispositions, point locations, and individual CADD files of development to date were used for gravel resources
  - Timber harvest plan operating unit areas were used for forestry resource areas
  - Agricultural land dispositions and active applications were used for agriculture
  - Placer and Quartz claim areas were used for mining
  - Land applications (active), land dispositions (leases), land use permits and land licenses were used for land use.
- Weighted species mixes in each FMU from the TSA forest strata area summary, total land base (not including strata with deciduous as leading species, and averaged for Coal and Liard) were used to generate a weighted average wood density (kg/m^3) for Watson Lake and Haines Junction. These were averaged to generate a weighted average for Yukon forests. Dry densities were provided for White spruce and Lodgepole Pine (Miles and Smith 2009).

3.2 ASSUMPTIONS AND DISCUSSION

The method used included the following assumptions:

- Timber volumes available for biomass in Yukon are predominantly located near communities and urban centres.
  - The majority of timber available for biomass harvest is located in Southern Yukon (i.e., the TSA for Southern Yukon (Henry 2000) is applicable for use)

  - More detailed forest volume data is not available for macro-level analysis of Yukon biomass
- Timber volumes and available areas around Haines Junction and Watson Lake were determined using Operating Unit net and/or target areas and volumes identified in the Timber Harvest Plans for their areas. Where gross areas and volumes were only available, 50% of gross area and volume was considered available to account for reserves, roads, unmerchantable areas, etc. Fuel abatement THPs for Haines Junction and Silver City, and the Watson Lake fuelwood THP were not included, as fuelwood harvest is anticipated to be on a small scale, and is not anticipated to leave residual waste sufficient for biomass harvest.
  - Haines Junction Operating Units under THPs are those associated with: Mackintosh East, Building Logs, Marshal Creek, Bear Creek, Pine Canyon, Quill Creek, and Kluane Lake East.
  - Watson Lake Operating Units under THPs are those associated with: Liard River Burn, Dodo Lakes, False Canyon Creek Fire, King Creek, East Hyland, Barney Lake, Watson Lake Small Volume, and Junction 37.
- Averaged 250 year yield and area predictions in the TSA, using the Variable Density Yield Prediction System, and corrected using Yukon sample plot volumes, are used to estimate merchantable volume biomass estimates per hectare
  - Annual harvest in the TSA is generated from clearcutting (i.e., limited harvest volumes from thinning or other harvest methods are not included in conifer volume) merchantable stands meeting the minimum harvest age criteria set out in the TSA
  - Economical biomass harvest areas would include non-merchantable timber harvest areas (identified in the total land base summary) and non-merchantable volumes of timber harvested stands, estimated to be 15% of merchantable stand volume.
  - The minimum feasible and economic piece for biomass harvest is 8 cm in diameter at breast height (dbh) or in diameter (if a branch, top, etc.)
  - Low volume stands for agriculture were 50% of average merchantable volume for Yukon
  - Agriculture farmers used 30% of harvested biomass internally (i.e., for fences, firewood, etc.)
  - Low volume stands for mining, either gravelly riparian areas for Placer Mining or high elevation mountainous areas for Quartz mining were 66% of average merchantable volume for Yukon. Miners have multiple claims, and work in 5% of the total area per year, clearing 20% annually, resulting in 1% of total clearing per claim per year.
  - FireSmart projects removed 30% of average merchantable volume for Yukon, through thinning smaller understory stems and leaving larger ones
  - Gravel and borrow pits (even closed pits) will be cleared to 80% of the extent of the disposition. This assumption is limiting because disposition boundaries are administrative and do not follow the boundaries of economical gravel or rock resources. While volume remaining in each disposition has been accounted for, it is not known if 100% of the extent will be cleared, or in what timeframe.
  - Land Use holders will harvest 30% of timber within the disposition.
- Forest fire affected wood was disregarded from volume determinations, as less than 1% of volume useable for biomass is lost to fire annually, as calculated using Wildland fire reporting (YG 2015b) and the TSA (Henry 2000), and as the majority of fire areas are more than 2 km from a Yukon highway
- Dry biomass was calculated using average oven dry weight on green volume basis (kg/m^3) as cited by Miles and Smith (2009) applied to the weighted average wood density by leading conifer species in each Forest

Management Unit near Haines Junction and Watson Lake (Henry 2000). Mixed conifer species class Spruce/Pine 4G used the average oven dry weight on green volume basis of both species. Deciduous wood density was not considered, as targeted deciduous harvest is not yet commonplace in Yukon.

Sources of possible error in the method were:

- Extrapolating the average stand volume available for biomass harvest from the average volume harvested per ha in the TSA.
- Extrapolating Operating Unit areas and volumes where only Gross areas and volumes were provided.
- Data deficiencies with stand volumes (i.e., the TSA is dated from 2000)
- Data deficiencies in the area-based data, dated mostly from 2013/2014
- Estimating amounts of clearing for unknown industrial uses, and the amounts that would be used by land holders or farmers. Altering these estimates changes the outcomes of the timber volume analysis considerably. The estimates were made using best available data at the time but may not be accurate.
- Estimating minimum feasible and economic biomass piece size. This will change depending on proximity to the chipping location, price, chip size, chipper design and capability, and the individual biomass harvester.

In order to compensate for the data deficiencies, Tetra Tech used current available data provided from local government and industry to augment broader estimates, used available published data and tools, such as the Natural Resources Canada Biomass and Nutrient Calculator (Natural Resources Canada 2017), and applied professional judgement to generate estimated values to apply to the average stand volume available for biomass harvest.

This estimate is limited by available data at the time of assessment. Future land developments were not included in the assessment. Anticipating future development will be an important component of future biomass assessment projects.

4.0 WOOD WASTE AVAILABILITY NEAR HAINES JUNCTION AND WATSON LAKE

Tetra Tech has completed a targeted study of the anticipated volumes of wood waste to be generated in the immediate future within a 150 km radius of Haines Junction (Figure 4-1) and Watson Lake (Figure 4-2). The tables below show a more precise estimate of wood waste to be generated by activity, using the methods outlined in Section 3.0. The wood waste volumes have been ranked from 1-5 to indicate the best (1) to worst (5) potential for biomass fibre sourcing by industry. Industries with no designated areas available for Haines Junction and Watson Lake (FireSmart, YEC projects, and highway development projects) are not ranked. Wood waste has been considered available if it is within two kilometres of a maintained highway, excepting forestry tenures which are considered available within the 150 km radius.

4.1 OPPORTUNITIES NEAR HAINES JUNCTION

The anticipated volumes of wood waste to be generated in the immediate future (1 to 3 years) within a 150 km radius of Haines Junction are outlined below (Figure 4-1). The study area does include highways leading north from Whitehorse, given that hauling biomass from northern highways through Whitehorse to Haines Junction will be uneconomical. Dispositions on the section of the Alaska Highway between Haines Junction and Whitehorse were only evaluated if they are less than 100 km away from Haines Junction. Tables 4-1 to 4-4 identify the wood waste by activity area and project (where known) as follows:

- Table 4-1: Potential volumes 0-50 km away from the community
- Table 4-2: Potential volumes 51-100 km away from the community
- Table 4-3: Potential volumes 101-150 km away from the community
- Table 4-4: Total anticipated wood waste near Haines Junction within 150 km of the community.

Gravel development has been estimated using Gravel Pit land disposition and point data provided by YG. Assuming that 80% of disposition areas will be developed in the next 10 years, the annual area has been assumed to be 10% of the available (80%) area. Available area near Haines Junction is 2,155 ha, with 247,868 m^3 of available for biomass harvest, totaling 92,451,066 dry kg of biomass. If this area is developed over 10 years, 9,245,107 dry kg would be available annually for biomass.

Near Haines Junction 68,444 ha are tenured with timber harvest plans within the study radius for forestry operations. Operating Units within Timber Harvest Plans within those areas total 4,470 ha available for harvest, considering reserve areas and other withdrawals from harvest. The available volume in the Operating Units is 549,334 m^3. Assuming that commercial operations will remove commercially merchantable stems, and that 15% of commercial volume is available for biomass, 82,400 m^3 of volume is available as wood waste in the tenure area, totaling 30,729,686 dry kg of biomass. Assuming that the harvest levels in Haines Junction for 2015/2016 (11,896 m^3, Gavin Dyshoorn, pers. comm. February 13, 2017) represent typical harvest volumes for the area, the existing Operating Unit target areas could be harvested over 50 years to maintain typical annual volumes. If the area was harvested over a 50 year planning horizon, 614,594 dry kg of biomass would be available annually.

Agriculture development has been estimated using Agricultural Permits and Leases in the Lands Viewer. Assuming that 50% of the area is already developed, 100% of disposition areas will be developed in the next 10 years, and farmers will use 30% of wood for internal purposes, the wet volume/ha is 35% of the total ha. The annual area has been assumed to be 10% of the available area. Available area near Haines Junction is 618 ha, with 36,690 m^3 of available for biomass harvest, totaling 13,684,984 dry kg of biomass. If this area is developed over 10 years, 1,368,498 dry kg would be available annually for biomass sale.

Mining development has been estimated using Quartz and Placer mining tenures in the Lands Viewer. As many mining tenures are not developed in any given year, 1% of the tenure area was assumed to be cleared annually. Available area for mining near Haines Junction is 914 ha, with 69,353 m^3 of available for biomass harvest, totaling 25,867,265 dry kg of biomass. If this area is developed at 1% per year, 258,673 dry kg would be available annually for biomass.

Private land/lot development has been estimated using land applications (active), land dispositions (leases), land use permits and land licenses in the Lands Viewer. Because of the variability of uses under land use permits, 30% of the disposition areas were assumed to be cleared in the next 5 years. Available area near Haines Junction is 256 ha (30% of 855 ha), with 29,496 m^3 of available for biomass harvest, totaling 11,001,366 dry kg of biomass. If this area is developed over 5 years, 648,441 dry kg would be available annually for biomass.

Gravel extraction is ranked first for all three distance categories from Haines Junction, followed by private land development nearest Haines Junction, and agriculture and mining beyond 50 km away. Forestry residuals are ranked third near Haines Junction, then fourth or fifth beyond 50 km away. Agriculture is ranked fourth nearest Haines Junction, but second 50-100 km away. Overall, within 150 km of Haines Junction, gravel extraction is ranked first, followed by agriculture, private land development, forestry residuals, and mining.

Table 4-1: Anticipated Wood Waste Near Haines Junction 0-50 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	80	3,437,733	1
Private land/lot development	46	1,974,631	2
Forestry Residuals	88	608,955	3
Agriculture	15	232,075	4
Mining	2	57,885	5

Table 4-2: Anticipated Wood Waste near Haines Junction 50-100 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	95	4,090,798	1
Agriculture	73	1,136,424	2
Mining	5	145,010	3
Private land/lot development	3	126,626	4
Forestry Residuals	2	5,639	5

Table 4-3: Anticipated Wood Waste near Haines Junction 100-150 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	40	1,716,575	1
Private land/lot development	2	99,017	2
Mining	2	55,777	3
Forestry Residuals	0	0	4
Agriculture	0	0	5

Table 4-4: Total Anticipated Wood Waste near Haines Junction within 150 km of the Community

Industrial Activity and Project	Available Area (ha)	Wet volume (m³)	Dry Mass (kg) total	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	2,155	247,868	92,451,066	9,245,107	1
Agriculture	882	36,690	13,684,984	1,368,498	2
Private land/lot development	256	29,496	11,001,366	648,441	3
Forestry Residuals	4,470	82,400	30,729,686	614,594	4
Mining	914	69,352	25,867,265	258,673	5

4.2 OPPORTUNITIES NEAR WATSON LAKE

The anticipated volumes of wood waste to be generated in the immediate future (1 to 3 years) within a 150 km radius of Watson Lake are outlined below (Figure 4-2). The study area excluded portions of highway that are outside Yukon, such as the portion of the Alaska Highway that travels through British Columbia to the southeast of Watson Lake. Tables 4-5 to 4-8 identify the wood waste by activity area and project (where known) as follows:

- Table 4-5: Potential volumes 0-50 km away from the community
- Table 4-6: Potential volumes 51-100 km away from the community
- Table 4-7: Potential volumes 101-150 km away from the community.
- Table 4-8: Total anticipated wood waste near Watson Lake within 150 km of the community.

Gravel development has been estimated using Gravel Pit land disposition and point data provided by YG. Assuming that 80% of disposition areas will be developed in the next 10 years, the annual area has been assumed to be 10% of the available (80%) area. Available area near Watson Lake is 1,764 ha, with 213,031 m³ of available for biomass harvest, totaling 80,097,989 dry kg of biomass. If this area is developed over 10 years, 8,009,799 dry kg would be available annually for biomass.

Near Watson Lake 49,484 ha are tenured with timber harvest plans within the study radius for forestry operations. Operating Units within Timber Harvest Plans within those areas total 4,016 ha available for harvest, considering reserve areas and other withdrawals from harvest. The available volume in the Operating Units is 515,052 m³. Assuming that commercial operations will remove commercially merchantable stems, and that 15% of commercial volume is available for biomass, 77,258 m³ of volume is available as wood waste in the tenure area, totaling 29,048,294 dry kg of biomass. Harvest levels in 2015/2016 for Watson Lake were 790 m³ (Gavin Dyshoorn, pers. comm. February 13, 2017) which would allow 650 years of harvest in existing operating units at current rates. If the area was harvested over a 50 year planning horizon, as in Haines Junction, 580,966 dry kg of biomass would be available annually.

Agriculture development has been estimated using Agricultural Permits and Leases in the Lands Viewer. Assuming that 50% of the area is already developed, 100% of disposition areas will be developed in the next 10 years, and farmers will use 30% of wood for internal purposes, the wet volume/ha is 35% of the total ha. The annual area has been assumed to be 10% of the available area. Available area near Watson Lake is 36 ha, with 1,517 m³ of available for biomass harvest, totaling 570,233 dry kg of biomass. If this area is developed over 10 years, 57,023 dry kg would be available annually for biomass sale.

Mining development has been estimated using Quartz and Placer mining tenures in the Lands Viewer. As many mining tenures are not developed in any given year, 1% of the tenure area was assumed to be cleared annually. Available area for placer mining near Watson Lake is 1,683 ha, with 134,111 m^3 of available for biomass harvest, totaling 50,424,732 dry kg of biomass. If this area is developed at 1% per year, 504,247 dry kg would be available annually for biomass.

Private land/lot development has been estimated using land applications (active), land dispositions (leases), land use permits and land licenses in the Lands Viewer. Because of the variability of uses under land use permits, 30% of the disposition areas were assumed to be cleared in the next 5 years. Available area near Watson Lake is 71 ha (30% of 238 ha), with 8,623 m^3 of available for biomass harvest, totaling 3,242,204 dry kg of biomass. If this area is developed over 5 years, 648,441 dry kg would be available annually for biomass.

Gravel extraction is ranked first within all categories of Watson Lake. Within 50 km of Watson Lake, private land development ranks second, followed by forestry residuals. Further from the community, forestry residuals and mining are ranked second. Agriculture ranks fifth in all distance categories. Overall, within 150 km of Watson Lake, gravel extraction is ranked first, followed by private land development, then forestry residuals, mining, and agriculture.

Table 4-5: Anticipated Wood Waste Near Watson Lake 0-50 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	70	3,194,474	1
Private land/lot development	14	629,325	2
Forestry Residuals	28	275,979	3
Mining	6	188,875	4
Agriculture	4	57,023	5

Table 4-6: Anticipated Wood Waste near Watson Lake 50-100 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	78	3,537,794	1
Forestry Residuals	51	296,449	2
Mining	9	273,393	3
Private land/lot development	0	9,275	4
Agriculture	0	0	5

Table 4-7: Anticipated Wood Waste near Watson Lake 100-150 km away from the Community

Industrial Activity and Project	Anticipated Area to be Cleared (ha/yr)	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	28	1,277,530	1
Mining	1	41,979	2
Private land/lot development	0.2	9,841	3
Forestry Residuals	1	8,538	4
Agriculture	0	0	5

Table 4-8: Total Anticipated Wood Waste near Watson Lake within 150 km of the Community

Industrial Activity and Project	Available Area (ha)	Wet volume (m3)	Dry Mass (kg) total	Anticipated Dry Mass of Wood Waste (kg/yr)	Rank
Gravel Extraction	1,764	213,031	80,097,989	8,009,799	1
Private land/lot development	71	8,623	3,242,204	648,441	2
Forestry Residuals	4,016	77,258	29,048,294	580,966	3
Mining	1,683	134,111	50,424,732	504,247	4
Agriculture	36	1,517	570,233	57,023	5

4.3 SUGGESTED NEXT STEPS TO BIOMASS DEVELOPMENT IN HAINES JUNCTION AND WATSON LAKE

The main driver of economical biomass projects is the cost to transport biomass to its receptor site. Considering the current price of fuel and labour, economical biomass projects are restricted to the areas closely surrounding Haines Junction or Watson Lake, or harvesting associated with existing commercial harvest. Tetra Tech recommends that future biomass projects consider assessing the economical and feasible distance to harvest biomass from a community centre, and if this changes if biomass is harvested as roundwood (logs or firewood) or chips generated using portable chippers, as discussed in Section 2.9.

5.0 WOOD WASTE STUDY DESIGN

Tetra Tech has generated the following study design to quantify the amount of wood waste generated by Yukon forestry operations. The objective of the study design is a simple design for determining biomass from timber harvesting operations. The study design is based upon existing designs for wood waste in similar boreal forest areas.

Wood waste in British Columbia (BC) is calculated using waste and residue surveys, directed by the Provincial Logging Residue and Waste Measurements Procedure Manual (BC 2016). Waste measurements began in BC in the 1960s and utilization policies for coastal and interior forests were implemented in the early 1990s (ibid). The policies prescribe minimum cutting specifications, log grade utilization, and cut control requirements. In 1999 waste benchmarks were established to allow a volume of waste biomass to be left on site without monetary billing, allowing harvesters to recover merchantable timber to their economic margins (ibid). The onsite biomass is left as course woody debris or harvested as biomass for local use. In 2003 BC implemented the Forestry Revitalization Plan eliminating species and log grade requirements from harvest specifications. In 2015 the BC Forest Fibre Action Plan implemented a pre-harvest waste assessment and amended the Provincial Logging Residue and Waste Measurements Procedure Manual, including five methods of waste and residue survey measuring dispersed and accumulated (e.g., piled) biomass (BC 2016):

- The full sampling intensity survey – measuring dispersed and accumulated biomass by individual piece in plots
- A reduced sampling intensity survey – used when the estimated disbursed biomass volume is lower than a tabulated number (20 m^3/ha in similar forests to Yukon – Boreal White and Black Spruce Biogeoclimatic Zone), and includes 400 m^2 plots (including transects)
- The parent block survey – applying the biomass of one cutblock to another small cutblock
- The ocular estimate survey – used when the maximum avoidable sawlog waste is lower than a tabulated number (10 m^3/ha in similar forests to Yukon – Boreal White and Black Spruce Biogeoclimatic Zone), and includes smaller (50 m^2) plots (including transects)
- The pre-harvest waste assessment – used for biomass harvest, this is a pilot project in the BC interior.

Best management practices for plot locations (approximately 1 plot/ha for smaller blocks up to 20 ha) include (BC 2016):

- Placing plots in areas that reasonably cover the different waste types on the cutblock
- Placing transect lines to provide good sample coverage of the stratum, traverse back and forth from the road at an angle, and measure all pieces within 2-5 m from the transect line
- Record the volume of the piece within the plot boundary only
- Where a plot cannot be measured safely, it should be moved to a safe, nearby location
- Use circular 400 m^2 plots for open slash, and 50 m^2 plots for accumulations.

Wood waste in Alberta is managed to reduce fire hazard under the Forest and Prairie Protection Regulations Part II and Alberta Harvest Planning and Operating Ground Rules Framework for Renewal (Roach and Berch 2014). The Debris Management Standards for Timber Harvest Operations provide standards for debris management in timber harvesting operations. Sample plots should be large enough to include local variability in type and density of waste present (e.g., 100 m^2; WHRC 2016).

There are several tools available to measure biomass of forest ecosystems for fuel loading and carbon measurement (for example Woodall & Monleon 2008, Reinhardt et. al. 2006). Most of these are more complex than are envisioned to be useful for Yukon application. One example is the Forest Inventory and Analysis program of the USDA Forest Service, which inventories timber and non-timber attributes, including estimates of slash or residual piles based on shape categories and size (Woodall & Monleon 2008). FuelCalc similarly estimates fuel loading in forest stands, including estimating surface fuels through transects and through pile shape, size, packing ratio, and fuel density (Reinhardt et. al. 2006).

Estimating surface biomass based upon pile size and shape has been developed for fire prediction, and has software developed to aid in calculations (US Forest Service 2017). The biomass surface estimates are derived from research completed by Hardy on estimating volume and biomass from piled slash, and Wright on hand-piled fuels (Wright et. al. 2009, Hardy 1996). Details of estimating biomass based upon pile size are presented in Section 5.1.1.

Yukon timber harvesting typically accumulates biomass on the road or landing as tops and unmerchantable residual pieces cut from sawlogs (due to rot, for example; Myles Thorp, pers. comm. Feb 23, 2017). Unmerchantable stems, such as trees too small to be efficiently handled by a feller buncher or other logging equipment, and unmerchantable species are left dispersed in cutblocks, or standing (ibid). Biomass accumulated at landings or roadsides will be the most economical to access for biomass harvest. Sufficient volume of dispersed biomass would be required to make salvaging dispersed biomass economical from forest cutblocks.

5.1 YUKON WOOD WASTE STUDY DESIGN

Tetra Tech recommends the following design for wood waste from commercial sawlog harvest (forestry operations) in Yukon:

- Sample 1 plot/ha with 50% of plots located in accumulated biomass area and 50% of plots located in dispersed biomass per cutblock with a minimum of 5 plots per block
- Plot size is 100 m^2 (circular using 5.64 m plot cord, or rectangular, as long as plots are consistent), randomly located
- Plots will measure safely accessible biomass 8 cm and over inside bark
  - Logs, branches, etc. will measure median area ($A = \pi r^2$) diameter times length
  - Tops will measure butt area times length divided by three ($V = \pi r^2 h/3$) to account for taper
  - Where plots cannot safely access all biomass, or where biomass is piled such that the bottom of the pile cannot be measured, the safely accessible biomass % in the plot will be estimated, and divided by the safely accessible % to generate a 100% estimate of the accumulation biomass.
    - Alternatively, if safe access is not available, estimates of biomass volume for piles may follow the biomass estimate by pile size and shape outlined in Section 5.1.1.
- The sum of biomass volume per plot ($m^3/100m^2$ (plot size)) and multiplied by 100 (m^3/ha) to determine wet m^3/ha
- Wet m^3/ha will be multiplied by median dry density (397 kg/m^3) estimate dry tonnes of wood waste per hectare (kg/ha).

5.1.1 Biomass Estimate by Pile Size and Shape

Where pile volume cannot be safely assessed by direct measurement, biomass may be estimated by pile size and shape as follows (Hardy 1996). Consume software can also be used to calculate biomass through field measurements (US Forest Service 2017).

- Select a representative pile shape (Figure 5-1)
- Calculate the gross volume of the pile within the plot (wet $m^3/100m^2$; Table 5-1)
- Multiply the gross volume by the packing ratio (removing the air space volume from the pile gross volume) to determine wood wet volume. The estimated packing ratio for Yukon biomass is 10% (wet $m^3/100m^2$; Hardy 1996).

- Multiply by 100 (m^3/ha) to determine wet m^3/ha
- Wet m^3/ha will be multiplied by median dry density (397 kg/m^3) estimate dry tonnes of wood waste per hectare (kg/ha).

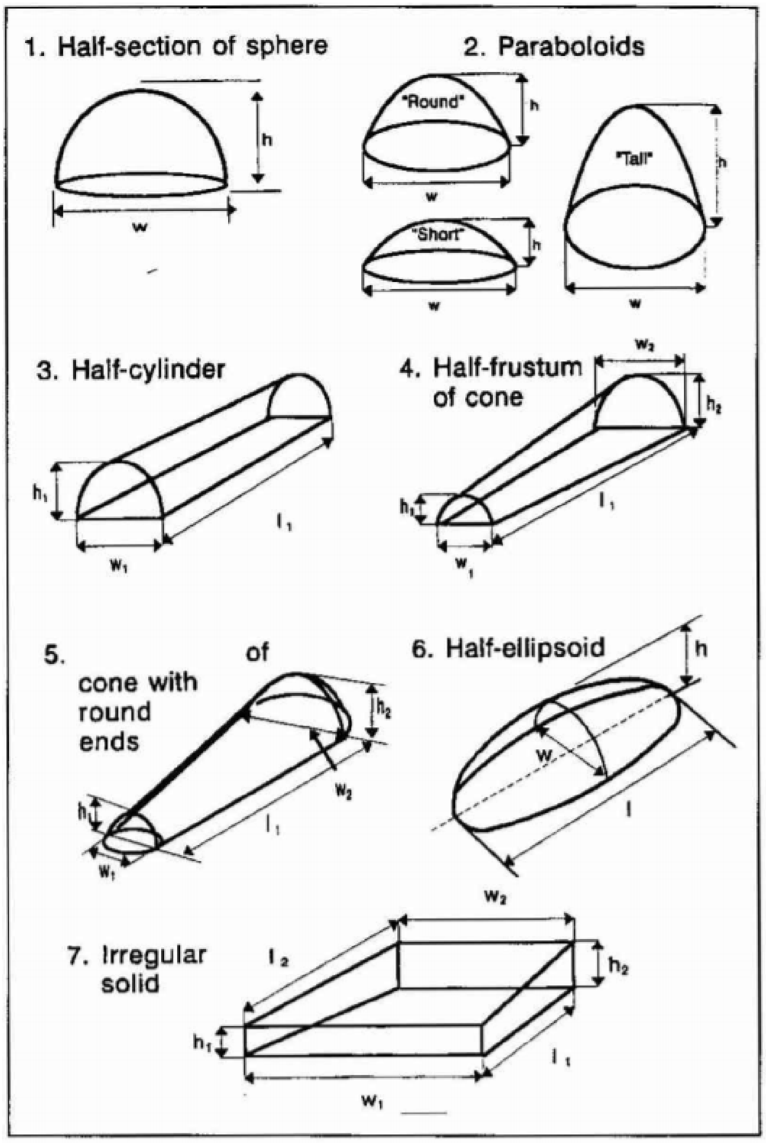

Figure 5-1: Generalized Pile Shapes

Table 5-1: Slash Pile Shape Volume Equations

Pile Shape	Volume Formula
Half-Sphere	$V=2\pi h^3/3$ or $V=\pi hw^2/6$
Paraboloids	$V=\pi hw^2/8$
Half-Cylinder	$V=\pi wlh/4$
Half-Frustum of Cone	$V=\pi l1[h12 + h22+(h1h2)]/6$ if using heights $V= \pi l1[w12 + w22+(w1w2)]/24$ if using widths
Cone with Round Ends	$V= \pi\{l1[w12 + w22+(w1w2)]+ w13 + w23\}/24$
Half Ellipsoid	$V=\pi wlh/6$
Irregular Solid	$V=(l_1+l_2)(w_1+w_2)(h_1+ h_2)/8$

Note: V= volume
l=length
w=width
h=height

6.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

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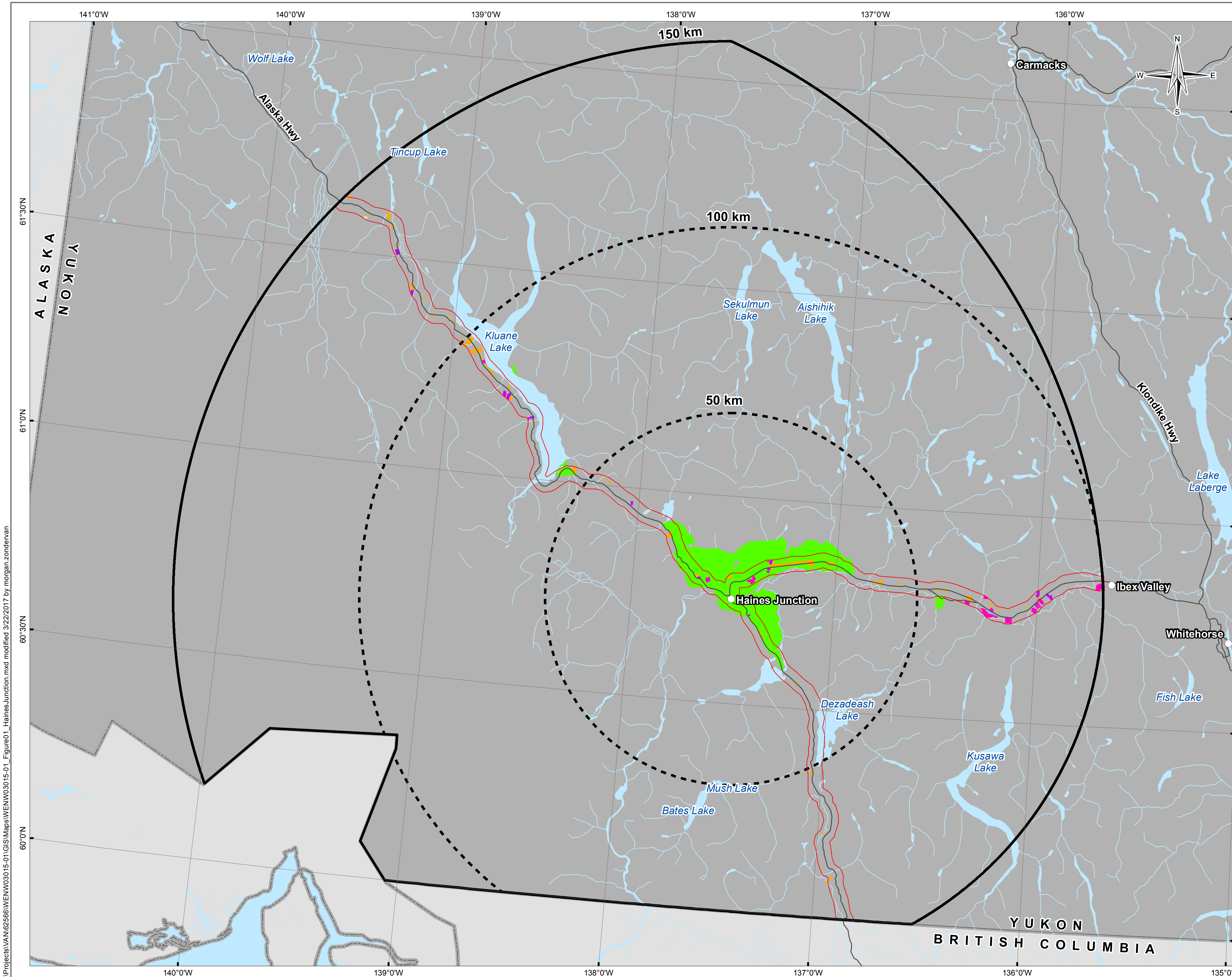
FIGURES



LEGEND

- Area within 2 km of a Highway
- Study Area
- Community
- Road
- Watercourse
- Waterbody
- Provincial/State Boundary

Areas of Potential Clearing

- Forestry
- Agriculture
- Mining
- Land Disposition/Land Application/Land Use

NOTES
Base data source:
CanVec 1:1M
Areas of potential clearing assembled from various Geomatics Yukon and client supplied datasets (accessed February 2017)

STATUS
ISSUED FOR USE

WOOD WASTE FEEDSTOCK ASSESSMENT HAINES JUNCTION AND WATSON LAKE, YT

Areas of Potential Clearing within the Haines Junction Study Area

PROJECTION	DATUM	CLIENT
Yukon Albers	NAD83	Yukon Government

Scale: 1:1,000,000
20 10 0 20
Kilometres

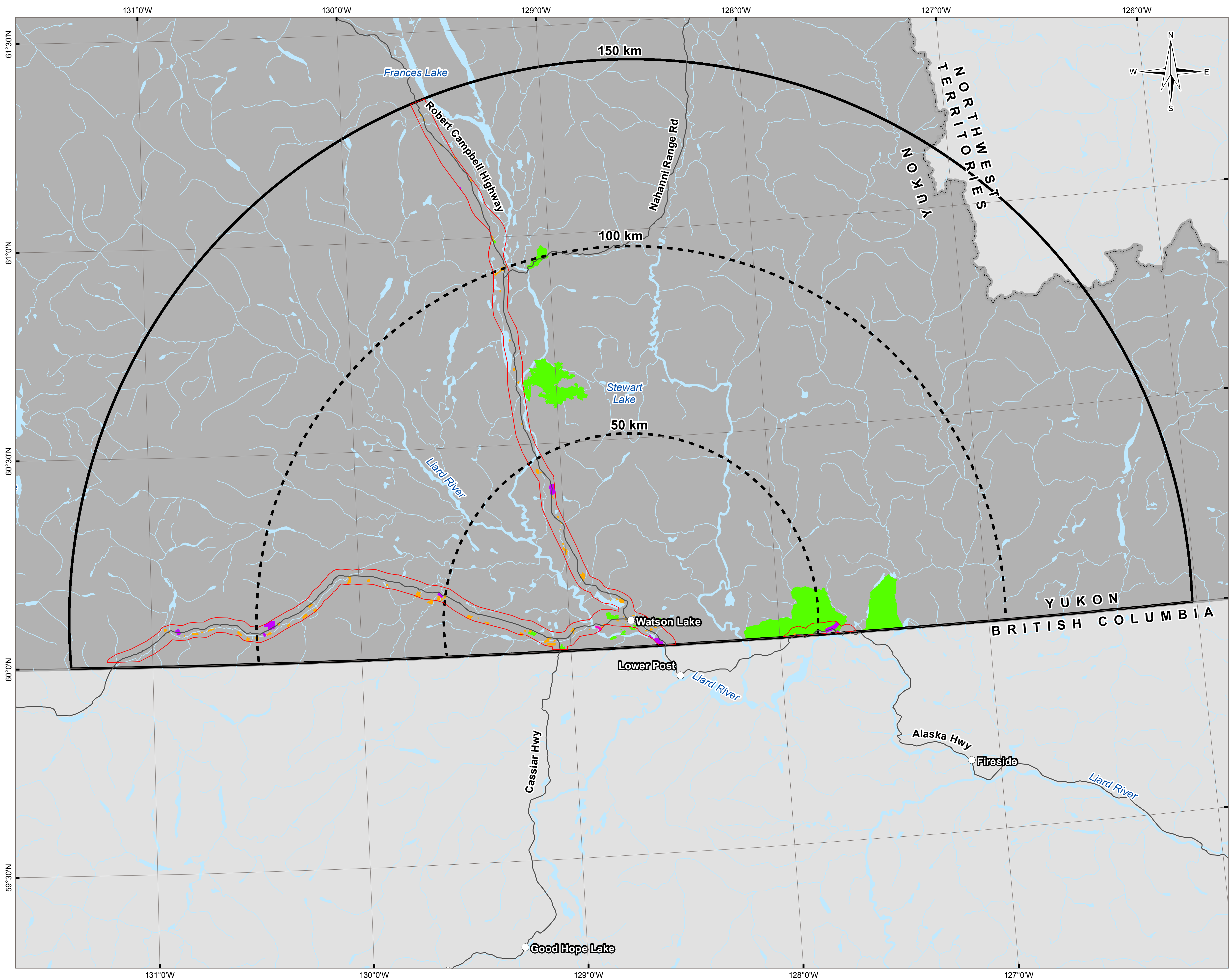
TETRA TECH

FILE NO.
WENW03015-01_Figure01_HainesJunction.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MEZ	SL	KG	0

DATE	PROJECT NO.
March 22, 2017	ENW.WENW03015-01

Figure 1



LEGEND

- Area within 2 km of a Highway
- Study Area
- Community
- Road
- Watercourse
- Waterbody
- Provincial Boundary

Areas of Potential Clearing

- Forestry
- Agriculture
- Mining
- Land Disposition/Land Application/Land Use

NOTES
Base data source:
CanVec 1:1M
Areas of potential clearing assembled from various Geomtaics Yukon and client supplied datasets (accessed February 2017)

STATUS
ISSUED FOR USE

WOOD WASTE FEEDSTOCK ASSESSMENT HAINES JUNCTION AND WATSON LAKE, YT

Areas of Potential Clearing within the Watson Lake Study Area

PROJECTION	DATUM	CLIENT
Yukon Albers	NAD83	Yukon Government

Scale: 1:1,000,000
20 10 0 20
Kilometres

FILE NO.
WENW03015-01_Figure02_WatsonLake.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MEZ	SL	KG	0

DATE	PROJECT NO.
March 22, 2017	ENW.WENW03015-01

Figure 2

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APPENDIX A

TETRA TECH'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOENVIRONMENTAL REPORT – GOVERNMENT OF YUKON

This report incorporates and is subject to these “General Conditions”.

1.1 USE OF REPORT AND OWNERSHIP

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of TETRA TECH’s client. TETRA TECH does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than TETRA TECH’s Client unless otherwise authorized in writing by TETRA TECH. Any unauthorized use of the report is at the sole risk of the user.

1.2 ALTERNATE REPORT FORMAT

Where TETRA TECH submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed TETRA TECH’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by TETRA TECH shall be deemed to be the original for the Project.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

1.3 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by TETRA TECH in its reasonably exercised discretion.

1.4 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of the report, TETRA TECH may rely on information provided by persons other than the Client. While TETRA TECH endeavours to verify the accuracy of such information when instructed to do so by the Client, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information which may affect the report.