Haida Gwaii Timber Supply Review

DRAFT Data Package

Timber Supply Review Technical Working Group report for the Haida Gwaii Management Council

2019

Date
November 2019

Citation
Technical Working Group. 2019. Haida Gwaii Timber Supply Review Data Package. Report for the Haida Gwaii Management Council. Old Massett, Haida Gwaii, B.C.

Acknowledgements

Andrew Fall, Wenli Xu, Roman Bilek, Rene DeJong, Sari Saunders, Allen Banner, Pam Dykstra, Peter Ott, James Wang, Xiaoping Yuan, Tim Salkeld, Bill Floyd, Dave Waddell, Gordon Nigh, Graham Hawkins, Nyssa Temmel, Mark Salzl, Anya Reid, Sheena Duncan, Aline Lachapelle, Carissa Logue, Jason Smith, Mike Davenport, Lisa Hartnup Mei-Ching Tsoi, Margaret Penner, Derek Debiasio, Ken McPhail, Diana Cooper, Glynnis Horel, Irene Weiland, Keta Kosman, Owen Jones, Sean Brennan, Robert Kennedy, Sarah Good, Jeremy Calhoun, Laurie Whitehead, Rob Sandberg, Tom Johnson, Daryl Sherban, Jeff Mosher, Ken Briggs, Jonathan Fane, Cam Brown, Keith Moore, Joe Thorley, Marty Kranabetter, Richard Kabzems.

The Technical Working Group (TWG) was co-chaired by Nick Reynolds, RPF (CHN) and Christine Fletcher, RPF (Forest Analysis and Inventory Branch), and included members David Stuart, RPF (Forest Analysis and Inventory Branch) and Sean Muise, RPF (Haida Gwaii Natural Resource District) and Ted McRae (Forest Analysis and Inventory Branch). The TWG received substantial and invaluable support from Dr. Andrew Fall (Gowlland Technologies).

Contents

Glossary

Base case :	
CHN	Council of the Haida Nation
CMAI:	Culmination Mean Annual Increment
ECA	Equivalent Clearcut Area
EMS:	Existing Managed Stands
FAIB:	Forest Analysis and Inventory Branch
FGS:	Free growing stems
FMS:	Future Managed Stands
FPPR:	Forest Planning and Practices Act
FRPA:	Forest and Range Practices Act
HGLUOO:	Haida Gwaii Land Use Objectives Order
HGMC:	Haida Gwaii Management Council
LEFI	LiDar Enhanced Forest Inventory
LIDAR	Light Detection and Ranging
MFLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development
MHA:	Minimum harvest age
MHV:	Minimum harvest volume
NSYT	Natural Stand Yield Table
RESULTS:	The Reporting Silviculture Updates and Land Status Tracking System
SPH:	Stems Per Hectare
TASS:	Tree and Stand Simulator
THLB	Timber Harvesting Land Base
TIPSY:	Table Interpolation Program for Stand Yields
TWG	Technical Working Group
VDYP	Variable Density Yield Projection
VLI:	Visual Landscape Inventory
VQO:	Visual Quality Objectives
VRI	Vegetation Resource Inventory

Chapter 1 Introduction

1.1 Authority of a Timber Supply Review

This timber supply review (TSR) has been directed under the authority of the Haida Gwaii Management Council (HGMC), which in turn was established as a result of the Kunst'aa guu- Kunst'aayah or Haida Gwaii Reconciliation Protocol (2009), which set out terms for joint and shared decision making for resource management on Haida Gwaii. The HGMC was delegated legal authority for setting the Allowable Annual Cut (AAC) on Haida Gwaii under the Haida Nation's *KaayGuu Ga ga Kyah ts'as - Gin 'inaas 'laas 'waadluwaan gud tl'a gud giidaa* (Haida Stewardship Law) and the Province of BC's *Haida Gwaii Reconciliation Act*. The authority to set an AAC is meant to include all forestry-tenures on Haida Gwaii (not including private lands). While the HGMC sets an AAC for all of Haida Gwaii, the *Haida Gwaii Reconciliation Act* requires that the determination for specific management units (Tree Farm Licences, Timber Supply Area, woodlots) not exceed the overall level determined by the HGMC. Information on the Haida Gwaii Management Council can be found at www.haidagwaiimanagementcouncil.ca. More information on BC's TSR process can be found at here[1].

This data package and appendices represent the inputs and approaches that were used in the timber supply modelling and that are key to informing the AAC determinations on Haida Gwaii. While the authority for establishing the overall AAC (HGMC) and the AAC by management units (Chief Forester for the Timber Supply Area and Tree Farm Licences and Minister or delegate for First Nation Woodland Licence, Community Forest Agreement, and Woodlots) and further determinations at a TSA licence level (Minister), this data package is meant to act as a reference at all levels of decision making.

The Haida Gwaii Management Council mandated a Technical Working Group (TWG), made up of technical representation from the Council of the Haida Nation and the Province of BC to oversee the technical processes associated with this TSR[2]. This involved enlisting support (both inside and outside of the governments) to complete the analyses for informing an AAC determination.

1.2 Overview of concepts and process

TSRs include the technical analyses and reporting, consultations (public, stakeholders, licensees) as well as the determination process. **This data package is only that part of the TSR that involves the explanation of the technical analysis.**

Other key documents that support the TSR process include:

(i) The Analysis Report: summaries and interpretation of findings that result from the timber supply modelling described in this data package;
(ii) A Public Discussion Paper: An amalgamation of key timber supply inputs, approaches and findings, as well as a description of the TSR process and timelines;
(iii) A Socio-Economic Analysis Report: a detailed socio-economic evaluation of the forest industry on Haida Gwaii;
(iv) The AAC rationales: The final determination document by decision makers that sets the AAC.

Timber supply analysis involves collating and analysing information to characterize:

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[1] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/timber-supply-review-and-allowable-annual-cut

[2] The Technical Working Group (TWG) includes Nick Reynolds, RPF (CHN), Christine Fletcher, RPF (Forest Analysis and Inventory Branch), David Stuart, RPF (Forest Analysis and Inventory Branch) and Sean Muise, RPF (Haida Gwaii Natural Resource District) and Ted McRae (Forest Analysis and Inventory Branch). The TWG had critical support from Dr. Andrew Fall (Gowlland Technologies).

- Where there are forests and the attributes of those forests (species, age, stand heights etc.) (inventory);
- How the forests grow over time (growth and yield);
- What forests are available for commercial logging (defining the Timber Harvesting Land Base);
- Applying current resource management practices (e.g., Land Use Objectives Orders; regulations under the Forest and Range Practices Act, etc.).

The data and assumptions for each of these factors are detailed in this data package.

This particular TSR applies important principles for estimating a sustainable rate of cut:

- Use the best available data;
- Where possible, utilize local empirical data;
- Utilize a spatially explicit timber supply model;
- Report on timber supply as an evenflow or non-declining flow over a 400-year time horizon.

Appendix 8 of this data package provides a summary of the technical inputs that have informed this TSR.

1.3 Spatial Timber Supply Modelling

This section describes the software platform used to conduct the timber supply modelling. The following is sourced from (Fall & D., 2006).

1.3.1 SELES Spatial Modelling Tool

A number of tools are available for performing spatio-temporal analysis at broad scales. The Spatial Timber Supply Model built using the SELES (Spatially Explicit Landscape Event Simulator, Fall and Fall 2001) modeling language was the tool chosen for making spatial analyses to support this TSR[3].

SELES is suited to support the TSR because it can operate at the different scales required (management units, landscape units, watersheds, broad ecological scales) and can easily transfer information between scales. SELES is a raster (grid) based tool, and so one important aspect is that all spatial data must be represented in raster format. It is fairly straightforward to export spatial information from a GIS (e.g. ArcGIS) in a raster form usable by SELES, and conversely to import spatial raster outputs from SELES back into a GIS as needed.

1.3.2 SELES Spatial Timber Supply Model

The SELES Spatial Timber Supply Model (STSM) is the underlying timber supply model used in many projects (e.g. the decision support tools developed for the North Coast LRMP and Haida Gwaii LUP). For more details of STSM, see Fall (2002).

The STSM consists of a linked set of sub-models of landscape change that include forest growth, forest harvesting and roading. The inputs consist of digital raster maps describing the land base and parameter files that control model behaviour. The outputs include text files that record various aspects of the land base (e.g. growing stock, age class distribution) and time series raster maps of landscape conditions (e.g. stand age) during the simulation. Output is used both to verify correct model behaviour and to provide indicators for values of interest. Via the user interface of SELES, the model landscape can also be viewed during model runs. The "process" portion applies to the sub-models that simulate ecological and management-induced change (e.g. stand aging, harvesting). The model projects initial landscape conditions (described by input

[3] SELES is provided freely at www.gowlland.ca..

maps) forward through time, using processes represented in the sub-models (and controlled partially by input parameters) to create a model of landscape dynamics and to estimate future landscape conditions (summarised in output files and spatial maps). Users create new scenarios primarily by modifying maps of management zones and parameters affecting management and natural processes.

The STSM has some stochastic elements regarding the location and shape of cutblocks, controlled by parameters. Although each model run may produce different results, the variation between runs is usually low when harvesting is specified as a deterministic preference (e.g. stand age relative to culmination age). The overall model design is shown in Figure 1.3.2.1. All data layers are derived from inventory information provided. Management zones include landscape units, visual quality zones and resource management zones (protected areas, private land, forest tenures, etc.). Species are represented using forest stand type groups, based on leading species, and forest productivity groups.

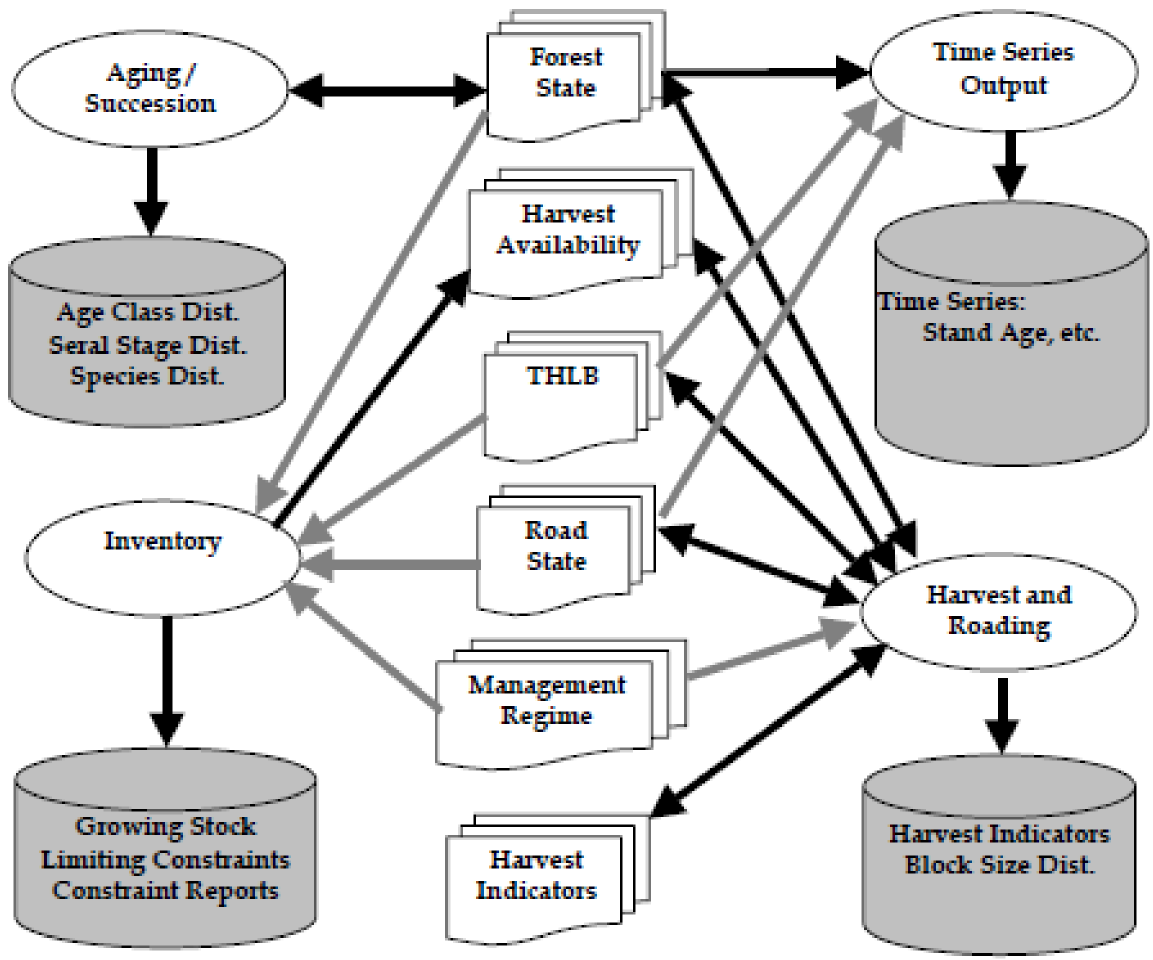

Figure 1.3.2.1 Elements of the Spatial Timber Supply Model

Each main modeled process is shown as an oval, while the main parts of the landscape state (represented as spatial data layers and tables) are shown in the centre, and output files are shown as grey drums. Arcs indicate that a process depends on and/or modifies the connected landscape state.

The forest is represented using species and age. Harvest availability indicates which cells are available for harvesting according to harvest policy and rules as specified for the base case analysis. The timber harvesting land base (THLB) is modeled spatially as a portion of each cell (e.g. road reductions are captured as partial netdowns of non-forest within cells). Growth and yield information was generated as described in Chapter 5. The road state tracks current and developed roads.

In addition to the spatial information above, a variety of non-spatial parameters are included, such as the harvest level, minimum harvest age, management objectives, and forest cover constraints.

Chapter 2 Forest Management Overview (practice, policy and regulation)

2.1. Current forest policies

Forest management on Haida Gwaii has changed dramatically over the last several decades. The underpinnings of how much forest can be logged, where it can be logged and how it can be logged can be traced back to various forest and land use policies. The TSR is meant to represent current forest and land use policies as opposed to create policy. In other words, TSR timber supply analyses are meant to reflect current policy and practice as opposed to dictating what they should or will be. An exception to this rule is where decision makers (Haida Gwaii Management Council, Chief Forester, Minister) determine that a partition is required to best sustainably manage the forests, which in turn may affect current practices.

The Province of BC has numerous Acts and Regulations that inform timber supply, however there are also important laws and policies under the Haida Nation that have equal effect on timber supply on Haida Gwaii. The most notable policy regarding the effect on timber supply on Haida Gwaii is the Haida Gwaii Strategic Land Use Agreement (2007) signed by both governments, proposed to bring the level of protection up to approximately 50% of Haida Gwaii in some form of protection, and stipulated that the rest of the Forest Management Land Base be managed under an Ecosystem Based Management (EBM) framework.

The following laws and policies inform this TSR:

- Kunst'aa Guu-Kunst'aayah Reconciliation Protocol
- The *Haida Gwaii Reconciliation Act*
- The *Forest Act* and its regulations, principally
    - *Section 8, Allowable Annual Cut*
- *The Forest and Range Practices Act* and its regulations, principally
    - *Part 2, Forest Stewardship Plans*
    - *Forest Planning and Practices Regulation;*
- The *Land Act* and its regulations, principally:
    - *The Haida Gwaii Land Use Objectives Order*
- *The Wildlife Act*
- *Parks Act* (for defining the THLB);
- *Ecological Reserve Act* (for defining the THLB);
- *Conservancy Act* (for defining the THLB);
- *Indian Act* (under Aboriginal Affairs and Northern Development Canada, for defining the THLB),
- *Public Lands Grants Act* (under the federal Department of Defence, for defining the THLB);
- *KaayGuu Ga ga Kyah ts'as - Gin 'inaas 'laas 'waadluwaan gud tl'a gud giidaa* or Stewardship Law (Haida Nation)
- The *Haida Nation Constitution*, principally section *A.8.S6* (Haida Nation)
- The *Cedar Stewardship Area Management Plans* (Haida Nation)
- Haida Nation *House of Assembly Resolutions*
- *The Cultural Feature Identification Standards Manual* (Haida Nation).

Chapter 3 Timber Harvesting Land Base

3.1 Spatial data- overview

The Haida Gwaii TSR is based on spatially-explicit inputs for defining: (1) where forests can be logged; (2) what types of trees are where; (3) how fast trees are predicted to grow, and; (4) how forests are managed and harvested.

A series of spatial files incorporates these key elements into timber supply modelling. They include administrative boundaries (ex. resource tenures, protected areas), biophysical boundaries (ex. forest inventory, lakes, wetlands, rivers), and boundaries that represent management strategies for objectives set by the Council of the Haida Nation (CHN) and/or BC (e.g., buffers on streams, Wildlife Habitat Areas, etc.).

Some of these inputs are informative – for example an inventory layer maps a stand of trees – while some inputs have prescriptive management implications – their occurrence inherently influences timber supply (e.g., a protected area boundary). Those inputs that have prescriptive management implications go on to form the basis of the Timber Harvesting Land Base.

3.1.1 Spatial inputs towards defining a Timber Harvesting Land Base (THLB)

This section provides a description of the inputs, including the sources of the information, and a summary of each inputs' effect on timber supply. For the purpose of this data package, inputs are divided into the following categories:

1. *Administrative areas* that do not contribute to forestry (see 3.1.2 below);
2. *Inventory data*, which include Vegetation Resource Inventory (VRI), Ecosystem Mapping and LiDAR enhanced forest inventory (LEFI) (see chapter 4);
3. *Resource management data*, which includes spatially explicit delineation of all resource management factors (see chapter 6).

Together, these spatial data help define the Forest Management Land Base.

3.1.2 Forest Management Land Base (FMLB)

The Forest management Land Base represents the area that contributes in some way to forest management, whether it is for timber or other types of forest values. The inventory designation describes whether an area (polygon) is forested or has been forested and is capable of producing a stand of trees.

Data used to define forested areas included:

Hydrologic features

Terrestrial Resource Information Management *(TRIM)* data was used to identify wetlands (e.g., swamps, marshes, bogs, fens), lakes, and double-line rivers (e.g., wide rivers). This data was mapped using 1:20,000 aerial photo interpretation on Haida Gwaii in 1985-86 with updates to the coastline in 2005-2006[4]. This mapping followed specifications developed by the BC Ministry of Environment, Lands and Parks (BC MELP, 1997).

Non-forest areas

Non-forested areas are defined through the BC Land Cover Classification Scheme (RIC, 2002) as attributed within the VRI standards and product. These include non-treed (any wetland, upland or alpine area with less than 10% crown closure) and non-vegetated units (<5% vegetation cover). Note that these do not include

[4] GeoBC *TRIM updates by year* retrieved Dec.12, 2018
https://www2.gov.bc.ca/assets/gov/data/geographic/topography/trim/trim_updates_by_year.pdf

low-productivity forested stands (these exclusions, including minimum harvest volume limitations, are defined in section 7.1).

An additional filter applied to define non-forested areas was where the inventory site index from the VRI had a value less than or equal to 5.

Roads
Roads were grouped into three main categories: Permanent (paved), mainlines, and branches. Existing roads were mapped using a variety of sources, including TRIM, historic licensee road data (TFL 39), road segments from the RESULTS dataset[5], as well as roads from a mapping gap analysis conducted by the CHN's Heritage and Natural Resource Department using high resolution imagery. Buffers of 10m and 20m (total) were put along branch roads and permanent/mainline roads respectively and excluded from the Forest Management Land Base. See section 6.9 for a more detailed description of roads, trails and landings.

3.1.3 Timber Harvesting Land Base (THLB)

The Timber Harvesting Land Base (THLB) represents areas that are estimated to be available for logging. It excludes areas that have been administratively removed from eligibility for logging, such as areas protected under the Haida House of Assembly which coincide with protection under BC's legislation such as under the *Parks Act*, *Ecological Reserve Act*, or *Conservancy Act*. The THLB excludes other administrative classes such as 'crown grants', which include private or 'fee simple' lands, and federal crown grants. The THLB also accounts for a host of other spatially explicit laws and policies, such as areas under the Haida Gwaii Land Use Objectives Order or Wildlife Habitat Areas that may limit logging. Beyond legal, other policy or administrative removals, the THLB also accounts for operational factors, such as unstable terrain, that renders areas inaccessible or somehow restricts logging.

Being a 'spatially explicit' dataset, each component is mapped, and the inputs, which together define the THLB, form some of the most influential elements affecting timber supply.

A thumbnail map of the THLB can be seen in figure 3.1.3.1, and THLB inputs are available in map form (appendix 11), or part of a GIS geo-database available through the HGMC[6].

3.1.3.1 Inclusion factors

Inputs into the THLB include a broad range of factors, some that restrict industrial logging absolutely, others that may partially restrict logging. An 'inclusion factor' is a common approach to assigning the proportion of an area that contributes to timber supply. For example, Protected Areas do not contribute at all to timber supply, so have an inclusion factor of '0'. 'Crown grants' that are classed as 'private land' also do not contribute to timber supply, therefore have an inclusion factor of '0'. If raster only partially overlaps an area that is not available for harvest, the inclusion factor would be between 0 and 1, depending on the extent of overlap.

Figure 3.1.3. Illustrative example of THLB inclusion factors and scaling data up to 1 hectare spatial units

[5] WHSE_FOREST_TENURE.FTEN_ROAD_SECTION_LINES_SVW
[6] Some inputs have restrictions due to sensitivity (ex. archaeological sites, wildlife denning or nesting etc.) and may be restricted to data sharing/ confidentiality agreements.

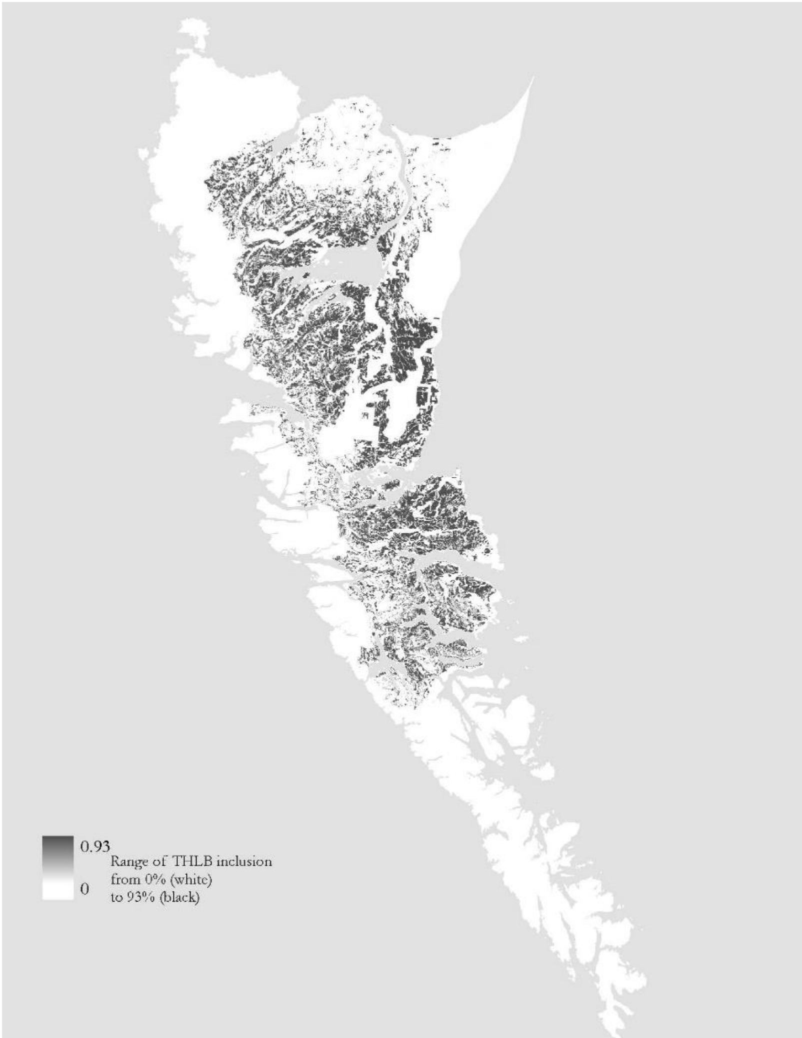

Figure 3.1.3.1. Map of the Timber Harvesting Land Base used for the base case reference scenario.

Where there are overlapping elements within each hectare (ex. wetland and road) there is assumed to be no overlap between the elements, but each element's contribution to the hectare is area-weighted and summed. To illustrate this, in the 1 hectare example in figure 3.1.3, 15% of the area is wetland (0% THLB), 15% of the area is a mainline road (0% THLB) and the remaining 70% of the area is forest (100% THLB), therefore the THLB for this 1 hectare unit would be ($0.15x\,0 + .15x0 + .7x1$) and amounts to a THLB inclusion factor for the entire hectare of 70%. Where multiple elements overlap the same area (e.g., monumental AND riparian area), then that element with the lowest THLB inclusion is used.

3.1.3.2 Overlaps

Inputs into the THLB often geographically overlap each other. For example, there may be a reserve zone for a Culturally Modified Tree within the area of a Saw Whet Owl nesting reserve, or a boundary to protect a research permanent sample plot within a riparian reserve. The total effect of each input on the THLB is recorded as the gross area, and its overlap with other inputs is accounted for in defining net effect on the THLB (net area). The THLB tables below summarize each input or factor. The factors are reported ranging from most restrictive to logging (absolute exclusion) to least restrictive to logging (partial exclusion).

3.1.4 Administrative areas that do not contribute to forestry

3.1.4.1 Municipal boundaries

Three communities have formal municipal boundaries under section 12 of the *Municipal Act*: Queen Charlotte, Port Clements and Masset.

The Kunst'aa Guu- Kunst'aayah Reconciliation Protocol (CHN; Province of BC, 2009) excludes municipalities from the Haida Gwaii Management Council's Allowable Annual Cut determination. This exclusion is further defined (as *management areas*) within the 2010 *Haida Gwaii Reconciliation Act* (HGRA). However, section 8 of the *Forest Act* mandates the Chief Forester to determine an Allowable Annual Cut for the Timber Supply Area on Haida Gwaii, which includes some areas within municipal boundaries, while meeting the constraint that all individual AACs on Haida Gwaii must sum to at most the AAC set by the HGMC, as defined by the HGRA.

The HGMC tasked the Technical Working Group (TWG) to develop a timber supply analysis that could facilitate a simple transition between the HGMC's AAC and the subsequent AACs determined by the Chief Forester (HGMC, 2016). As such, the TWG accounted for and tracked the amount of THLB that contributes to the overall AAC within municipalities for respective decision makers to consider.

The three municipalities all have Official Community Plans (OCP) under section 875 of the *Local Government Act* and all three include mapped restrictions to industrial forestry operations in specific zones. The Village of Port Clements OCP designates *Resource Management Land Use* as areas open to forestry activities (Village of Port Clements, 2012) amounting to 307 hectares out of a municipal boundary of 575 hectares.

The Village of Queen Charlotte established an OCP under Bylaw 50-2011 in 2011 which, under sec. 10.3 designates areas within the municipal boundaries for *Industrial Land Use* which includes primary forestry activities, amounting to 2849 hectares out of a municipal boundary of 3595 hectares (Village of Queen Charlotte, 2011).

The Village of Masset adopted the *Village of Masset Integrated Official Community Plan* under Bylaw 628 in 2017 (Village of Masset, 2017), and while there are designations for light and heavy industrial areas, these are targeted towards manufacturing sites as opposed to primary forestry activities. Forested areas are otherwise designated under *Parks and Green Space* zonation for passive and active recreation and leisure. Masset's municipal boundary encompasses 2149 hectares.

3.1.4.2 Crown grants/private land

Crown grants, or 'fee simple lands' are lands that have been granted by the Province of BC and are considered private land. All private lands are excluded from this Timber Supply Review (i.e., do not contribute to the FMLB or THLB). Data sources for private land were based upon the *Integrated Cadastral Information Society* (ParcelMap BC), sourcing data through a partnership with the Land Title and Survey Authority of British Columbia (LTSA), in turn minimizing data discrepancies between multiple information sources through a dynamic database. Further review was conducted in conjunction with the HG Natural Resource District and cross-referenced with *BC Assessment* and updated LTSA data. A total of 17,300 hectares are included within this administrative category.

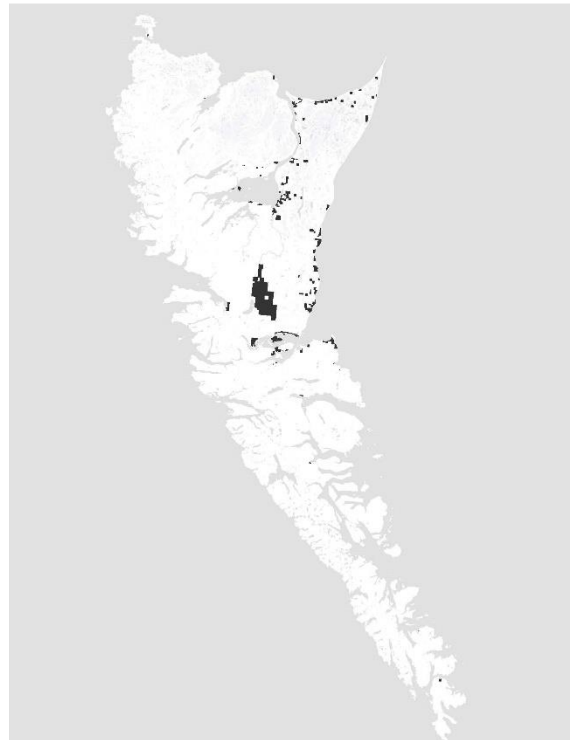

Figure3.1.4.2. Private lands (black)

3.1.4.3 Federal Reserves

Federal reserves were excluded from the THLB. These include reserves under *Indian Act* (under Aboriginal Affairs and Northern Development Canada), military reserves under the *Public Lands Grants Act* (under the Department of Defence) and miscellaneous reserves under the *Navigation Protection Act* (e.g., under Transport Canada). These amount to 2,631 hectares. Reserves under the *Indian Act* constitute the largest removal from the THLB for Federal Reserves (outlined in table 3.1.4.3 and listed in appendix 10) and amount to 1,631 hectares.

3.1.4.4 Protected Areas

All Federal and Provincial protected areas on Haida Gwaii were excluded from the THLB:

Protected Area	Area (Hectares)
Gwaii Haanas National Park and Heritage site	145,753
Daawuuxusda	70,295
Damaxyaa	822
Drizzle Lake	814
Duu Guusd	144,762
Duu Guusd - ER	8,684
K'uuna Gwaay	2,105
Kamdis	1,894
Kunxalas	3,344
Naikoon Provincial Park	67,268
Nang Xaldangaas	6,897
Pure Lake Provincial Park	142
SGaay Taw Siiwaay K'adjuu	597
Tlall	16,208
Tow Hill Ecological Reserve	451
Yaaguun Gandlaay	2,450
Yaaguun Suu	7,970

These areas encompass a total of 478,008 hectares, which is 48% of the total area (including surface water) of Haida Gwaii.

3.1.4.5 Tenures

Non-Forestry Tenures

'Tenures' broadly refer to licences, permits, leases, reserves or other authorizations that confer rights, responsibilities, or restrictions to the use of land. A number of tenures on Haida Gwaii negate forestry activities over an extended period and as such were removed from the THLB. These include:

- Section 15 Land Act Reserves (MFLNRO, 2011);
- Section 16 Land Act withdrawals from disposition (MFLNRO, 2011);
- Crown land permits (licences of occupation that preclude long-term commercial forestry, e.g., gravel pits, airports, community institution, etc.);
- Designated recreation sites or recreation reserves (including Shields Bay, Rennell Sound, Riley Creek, Bonanza Creek, Hangover Creek Spirit lake, Onward Point, Marie Lake, Mosquito Lake, Moresby Camp, Tarundl Creek, Stanely Lake, Lawnhill, Ship Island, Maast Island),

Collectively these tenures amount to a gross exclusion of 3,637 hectares.

Forestry Tenures

Forestry tenures include the volume based and area-based licences under the *Forest Act* (excluding Timber Sale Licences which are short-term, generally non-renewable licences sold through BC Timber Sales). While the HGMC's mandate is to set an AAC for the entirety of Haida Gwaii, this TSR includes analysis of individual management units and then aggregates results up to the entire archipelago. The forestry tenures included in this TSR are:

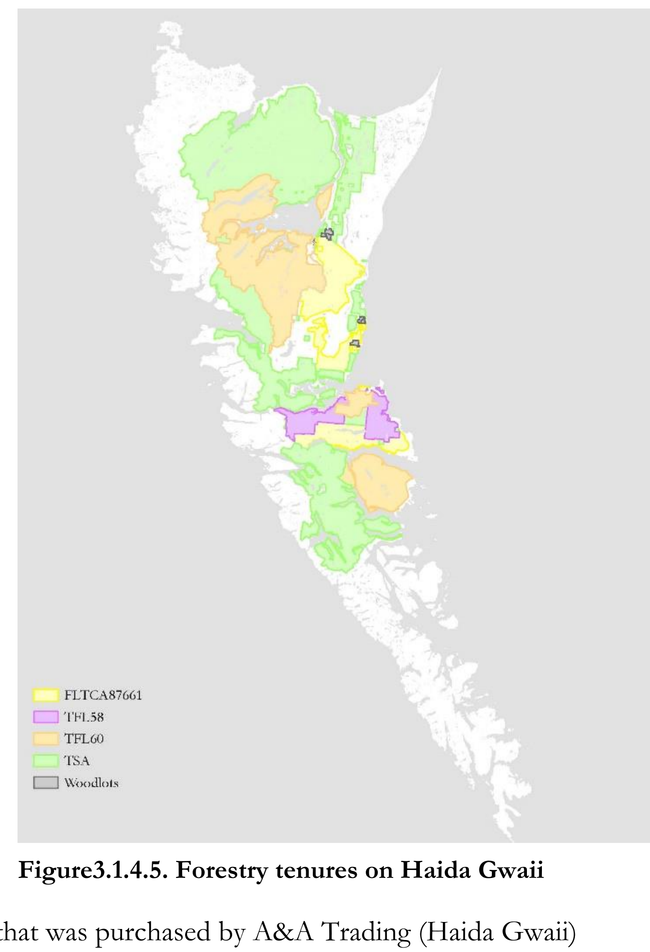

Figure3.1.4.5. Forestry tenures on Haida Gwaii

TFL 60

Tree Farm Licence 60 is a replaceable area-based licence that was purchased by Taan Forest Products in 2012 from Western Forest Products. The original licence was acquired by the Powell River Company in 1961 as part of TFL 39, but in 2010 it was deleted from TFL 39 and became TFL 60 (Brash & West, 2012). The total area of the TFL is 134,507 hectares (including non-forested areas) and includes most of central Graham Island, a small portion of northern Moresby Island, as well as Louise Island and some area in the Chadsey Creek drainage. It is the largest area-based tenure on Haida Gwaii and is currently certified under Forest Stewardship Council sustainable forest management standard for British Columbia.

TFL 58

Tree Farm Licence 58 is a replaceable area-based licence that was purchased by A&A Trading (Haida Gwaii) in 2016 from Teal Cedar Products Ltd. The original licence was the result of an amalgamation of TFL 2 and TFL 12 into TFL 47 in 1985, then owned by Crown Forest Industries Ltd. (Pederson, 1996). This tenure was eventually transferred to TFL Forest Ltd. (a subsidiary of TimberWest). In late 2006, the Moresby Block was deleted from TFL 47 to create TFL 58, which was transferred in 2007 to Teal Cedar Products. The licence includes four parcels of fee simple private lands or "Schedule B" lands that are subject to the terms of the Tree Farm Licence (District Lots 1362, 167, 2143 and 2854). The total area of the TFL is 27,873 hectares and is entirely contained within north Moresby Island.

Forest Licence to Cut (FLTC) A87661
FLTC 87661was awarded as a non-replaceable volume-based licence to Taan Forest Products in 2012 as part of the fulfillment of the Strategic Land Use Agreement and subsequent Kunst'aa guu- Kunst'aayah Reconciliation Protocol (CHN; Province of BC, 2009) for the management of 120,000m^3 per year by the Haida Nation. The area is technically within the Timber Supply Area, however a 'chart' area has been designated for management of the volume. The area is primarily located on the central east coast of Graham Island, along with a supply area on north Moresby Island and covers 58,606 hectares.

Woodlots
There are four woodlots on Haida Gwaii. W1841 is managed by Old Massett Village Council and covers approximately 478 hectares just south of Port Clements. W1840 is managed by Skidegate Band Council and includes 422 hectares near Jungle Creek. W0161 is managed by Dave Younger and covers 477 hectares just east of Port Clements. W0162 is managed by Gerald Lavoie and is 465 hectares within the Lawn Hill area.

Timber licences
Timber licences are the oldest form of forestry tenure in BC, having originated in the 1860s. These grant exclusive right to harvest timber in a specified area. This right however is reverted to a licence holder (if the timber licence is in a TFL) or back to the TSA after the mature or natural stand is cut (e.g., they represent rights to one-time harvests). As such, these licences are not considered as individual long term timber supply units, but rather contribute to the broader unit which they are contained within (e.g., TFL or TSA). It is common practice in provincial TSRs that the initial Timber License harvests are not include in TSA projections until after the initial harvest. However, the majority of Timber Licences on Haida Gwaii are within the TFLs (owned by the TFL holders) and therefore do not constrain or reduce timber supply for those units. As such, Timber Licences were not tracked as supply units within this TSR.

Timber Supply Area
All the area outside of the aforementioned tenures or administrative units (e.g., protected areas) is considered the Timber Supply Area. Within this unit the majority of the volumes currently are allocated to a series of replaceable Forest Licences (Husby's A16869, Dawson Harbour Logging Co.Ltd's A75084, A&A Trading's A16870). In addition the area charted for Taan Forest Product's Forest Licence to Cut of 120,000m^3 also comes out of the Timber Supply Area as well as the area allocated to BC Timber Sales Timber Sale Licences.

3.2 THLB tabular summaries

The THLB is generated using vector-based spatial data (polygons) that get integrated into a raster based one-hectare grid (see appendix 1 meta data).

The resulting THLB for the HGMA is estimated at 147,746 hectares with a long-term THLB (after future roads are built) to be approximately 138,290 hectares. This is not entirely an administrative unit (legally defined area) but rather an amalgamation of legally defined areas and outputs from analyses described in this data package. The sum of all three management units (TSA, TFL 58 and TFL 60) is slightly less than the total reported in section 3.2.1 as that total includes woodlot areas.

3.2.1 THLB for all of Haida Gwaii

Spatial net downs	Gross Removal	Net Removal	After Net Removal	Net % Haida Gwaii
HaidaGwaii			**1,004,982**	
Protected Areas (CHN/Federal)	145,735	145,735	859,247	15%
Protected Areas (CHN/Provincial)	332,273	332,273	526,974	33%
Surface water (TRIM waterbodies)	64,685	37,428	489,546	4%
Non-forest	86,940	19,454	470,092	2%
Current roads	9,100	8,768	461,324	1%
Federal Reserves (IR)	1,541	1,433	459,891	0%
Federal Misc (Military/other)	1,026	865	459,026	0%
Provincial Reserves/non-timber tenures	6,259	3,003	456,023	0%
Private (crown grants-40N)	17,300	15,833	440,190	2%
Municipal	3,092	1,055	439,135	0.1%
AFU	36,353	20,502	418,634	5%
Type 1 Fish Habitat	93,149	32,774	385,860	7%
Type 2 Fish Habitat	58,108	28,140	357,720	6%
Forested Swamps	15,331	1,960	355,760	0.4%
FPPR Riparian	24,143	1,452	354,308	0.3%
Red listed Ecosystems	13,567	823	353,485	0.2%
Blue listed Ecosystems	62,444	15,566	337,920	4%
Karst	7,179	2,572	335,348	1%
Forest Reserves (Marbled Murrelet, Rare Ecosystems)	31,201	20,467	314,881	5%
Marbled Murrelet reserves	116	64	314,817	0.0%
Northern Goshawk nesting	3,661	2,116	312,701	0%
Saw Whet Owl nesting	730	327	312,374	0.1%
Black Bear denning (current in-block)	62	43	312,331	0.0%
Wildlife Habitat Areas	623	178	312,153	0.0%
Heritage (HTHH, CMTs, Arch Sites)	27,946	5,937	306,217	1%
Cedar Stewardship Areas	25,303	15,372	290,845	4%
Monumentals (current in-block)	442	251	290,593	0.1%
Monumentals (future)	77,615	44,584	246,009	4.4%
Haida Traditional Forest Features	281	137	245,872	0.0%
Yew (current in-block)	212	51	245,822	0.0%
Trails (current in-block)	1,693	279	245,542	0.1%
Permanent Sample Plots	1,010	360	245,182	0.1%
Landslides	1,209	686	244,497	0.2%
Class IV Terrain	16,816	10,962	233,535	2%
Class V Terrain	30,987	17,802	215,732	4%
Rare Ecosystems	12,019	4,840	210,892	1%
LUOO in block retention	85,353	23,356	187,536	5%
Low productive forest	79,652	39,541	147,995	4%
Small islands	3,123	249	147,746	0%
Future Roads/Trails/Landings (6.4%)		9,456	138,290	2%

3.2.2 THLB by management unit

TSA 25

Spatial netdowns	Gross Removal	Net Removal	After Net Removal
TSA			**339,063**
Surface water (TRIM waterbodies)	30,776	30,762	308,301
Non-forest	29,311	16,476	291,825
Current roads	4,163	4,148	287,677
Provincial Reserves/non-timber tenures	768	712	286,964
Municipal	1,265	1,009	285,955
AFU	13,838	12,990	272,965
Type 1 Fish Habitat	33,801	24,752	248,213
Type 2 Fish Habitat	21,183	18,580	229,633
Forested Swamps	1,976	1,007	228,625
FPPR Riparian	7,739	1,808	226,817
Red listed Ecosystems	4,379	649	226,168
Blue listed Ecosystems	16,539	9,843	216,325
Karst	1,966	1,277	215,048
Forest Reserves (Marbled Murrelet, Rare Ecosystems)	18,834	12,635	202,413
Marbled Murrelet reserves	116	64	202,349
Northern Goshawk nesting	2,190	1,517	200,832
Saw Whet Owl nesting	141	75	200,756
Black Bear denning (current in-block)	32	24	200,732
Wildlife Habitat Areas	379	141	200,591
Heritage (HTHH, CMTs, Arch Sites)	6,645	3,999	196,591
Cedar Stewardship Areas	11,962	6,744	189,847
Monumentals (current in-block)	340	203	189,644
Monumentals (future)	54,412	32,336	157,308
Haida Traditional Forest Features (current in-block)	191	82	157,225
Yew (current in-block)	189	44	157,182
Trails	1,014	271	156,910
Permanent Sample Plots	306	191	156,719
Landslides	773	449	156,270
Class IV Terrain	11,632	7,508	148,763
Class V Terrain	22,682	13,019	135,744
Rare Ecosystems	6,464	2,276	133,467
In block retention (LUOO and WTRA)	29,224	15,687	117,780
Low productive forest	71,344	34,544	83,237
Small islands	157	17	83,219
Future Roads/Trails/Landings (6.4%)		5,326	77,893

TFL 58

Spatial netdowns	Gross Removal	Net Removal	After Net Removal
TFL58			**23,933**
Surface water (TRIM waterbodies)	189	189	23,744
Non-forest	175	165	23,578
Current roads	762	762	22,816
Provincial Reserves/non-timber tenures	40	36	22,780
Municipal	0	-	22,780
AFU	1,285	1,199	21,581
Type 1 Fish Habitat	2,513	1,657	19,925
Type 2 Fish Habitat	1,932	1,797	18,128
Forested Swamps	73	8	18,120
FPPR Riparian	398	171	17,949
Red listed Ecosystems	226	5	17,945
Blue listed Ecosystems	553	363	17,582
Karst	270	238	17,344
Forest Reserves (Marbled Murrelet, Rare Ecosystems)	1,166	567	16,777
Marbled Murrelet reserves	0	-	16,777
Northern Goshawk nesting	0	-	16,777
Saw Whet Owl nesting	0	-	16,777
Black Bear denning (current in-block)	1	1	16,776
Wildlife Habitat Areas	0	-	16,776
Heritage (HTHH, CMTs, Arch Sites)	636	393	16,383
Cedar Stewardship Areas	309	259	16,124
Monumentals (current in-block)	0	-	16,124
Monumentals (future)	1,827	1,160	14,964
Haida Traditional Forest Features	2	1	14,963
Yew (current in-block)	0	-	14,963
Trails	0	-	14,963
Permanent Sample Plots	16	12	14,952
Landslides	22	17	14,935
Class IV Terrain	537	400	14,535
Class V Terrain	1,264	779	13,756
Rare Ecosystems	1,459	1,094	12,662
In block retention (LUOO and WTRA)	1,828	1,260	11,402
Low productive forest	652	301	11,101
Small islands	1	-	11,101
Future Roads/Trails/Landings (6.4%)		710	10,390

TFL 60

Spatial netdowns	Gross Removal	Net Removal	After Net Removal
TFL60			**134,526**
Surface water (TRIM waterbodies)	4,431	4,431	131,932
Non-forest	2,913	2,594	128,724
Current roads	3,210	3,208	128,580
Provincial Reserves/non-timber tenures	146	144	128,580
Municipal	0	-	122,360
AFU	6,653	6,220	116,118
Type 1 Fish Habitat	9,774	6,242	108,431
Type 2 Fish Habitat	8,582	7,687	108,163
Forested Swamps	470	268	108,025
FPPR Riparian	895	138	107,857
Red listed Ecosystems	1,476	168	102,623
Blue listed Ecosystems	11,205	5,234	101,571
Karst	1,673	1,052	94,317
Forest Reserves (Marbled Murrelet, Rare Ecosystems)	11,015	7,255	94,317
Marbled Murrelet reserves	0	-	93,719
Northern Goshawk nesting	1,096	598	93,477
Saw Whet Owl nesting	571	241	93,460
Black Bear denning (current in-block)	23	18	93,423
Wildlife Habitat Areas	243	37	92,041
Heritage (HTHH, CMTs, Arch Sites)	2,227	1,382	83,737
Cedar Stewardship Areas	12,791	8,305	83,689
Monumentals (current in-block)	100	48	72,607
Monumentals (future)	21,185	11,082	72,553
Haida Traditional Forest Features	86	54	72,546
Yew (current in-block)	23	7	72,546
Trails	0	-	72,394
Permanent Sample Plots	273	153	72,173
Landslides	357	220	69,119
Class IV Terrain	4,646	3,054	65,115
Class V Terrain	7,040	4,004	63,649
Rare Ecosystems	3,248	1,466	62,183
In block retention (LUOO and WTRA)	11,237	6,265	55,918
Low productive forest	7,576	4,642	51,276
Small islands	0	-	51,276
Future Roads/Trails/Landings (6.4%)		3,282	47,994

Chapter 4 Inventory

Forest Inventory

This section describes forest inventory evaluated and used during this TSR. While many iterations are described here, the main forest inventory used in this TSR consisted of: VRI (species, age, site index for natural stands); LiDAR enhanced Forest Inventory (basal area, heights) for natural stands; RESULTS (silviculture records) updates and 2017 depletion (remotely sensed) data for existing managed stands.

4.1 VRI and Inventory Audits

A VRI was completed for all of Haida Gwaii between mid-2011 and 2013 (Sandvoss, 2014). VRIs describe the characteristics of vegetation, primarily trees, and provide information such as tree species, height, age, basal area, stems per hectare and other attributes that support forest management and analysis. The Haida Gwaii VRI had two general stages: (1) Phase 1, estimation of vegetation characteristics based on aerial photographs along with 283 ground and 547 air calibration points; and (2) Phase 2, measurement of field plots located using a statistical design, and use of the resulting ground data to calculate statistics on the accuracy of the photo-interpreted estimates. In many areas and where the audits show statistically significant differences, the Phase 2 statistics can be used to adjust the photo-interpretation (Phase 1) inventory information for use in timber supply analysis.

4.1.1 Photointerpretation VRI (Phase 1)

Work on the photo-interpretation Haida Gwaii VRI commenced on July 28, 2011 and was completed in December, 2013. A comparison of the new Phase 1 inventory with the amalgamation of inventories used in the previous (2011-12) TSR showed that the total volume in the Phase 1 was about 22% lower than the previous TSR on the total forest area, and almost 25% lower on a rough approximation of the THLB. The comparison also showed that the Phase 1 inventory contained substantially less area in very old forest (over 250 years old) and more area in mature forest (141-250 years old), and generally that height estimates were lower than in the inventory used in the previous TSR. These differences reinforced the need to do a Phase 2 ground-based inventory audit.

4.1.2 Mature Audit and Young-Stand Monitoring (Phase 2)

Two types of ground studies were done in Phase 2 of the Haida Gwaii VRI: a mature stand volume audit of stands with an age over 50 years old; and a young stand monitoring (YSM) project, applicable to stands in the 15-50 year old range. This section summarizes the mature stand audit. A subsequent section will cover the YSM study.

The Phase 2 inventory audit results [7]indicated that the Phase 1 photo-interpreted ages matched ground samples very well; that ground-measured heights were slightly lower (about 5%) than in the photo-interpreted inventory; and that ground-measured basal area (BA) and number of trees per hectare were substantially greater than in the Phase 1 inventory, by 21.5% and 63.8% respectively. The differences between the Phase 1 and Phase 2 led to an overall Phase 2 ground volume, based on local loss factors, that was 22.8% higher than estimated from the Phase 1 inventory (Penner, 2018).

About two-thirds of the difference in volumes was due to "attribute bias" – specifically to the larger BA noted in the Phase 2 ground sampling. This bias resulted because photo-interpreters were unable to see some of the larger stems through the forest canopy, which is a common issue with coastal inventories in particular.

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[7] Haida Gwaii. Documentation of Vegetation Resources Inventory Analysis – Volume Audit (Mature), March 16, 2018. Prepared for: Forest Analysis and Inventory Branch, FLNRO.

The other third of the difference was due to "model bias" which refers to differences in the manner in which volumes are determined from the inventory data. The Phase 1 estimates were based on the VDYP yield model, which uses a database of stand-level yield data, while for the Phase 2 ground estimates, individual tree-level taper equations were used. The taper equation approach is generally believed to provide more accurate yield estimates than the stand-level model.

The volume difference between the photo-interpreted and ground-plot-based inventory of 22.8% noted above, was the average for all species. However, the differences were 54.4% for redcedar and yellow cedar, and 0.4% for other species (primarily hemlock and spruce). The cedars were placed in a separate category because of their economic importance on Haida Gwaii (cultural and traditional values are generally assumed to be protected through the LUOO and are not part of the THLB), and because the difference was so significant. Species other than cedar were combined because the sample size was small for spruce, and hence the sampling error for that species alone was very large.

4.1.3 Inventory and volume bias ratios

Table 4.1.3.1 shows the ground plot over Phase 1 ratios from the mature inventory audit. The strata ratios are based on Table 8 of "Haida Gwaii Documentation of Vegetation Resource Inventory Analysis-Volume Audit (Mature)", revised March 16, 2018) for the VDYP7 adjustment processes. For reference, the full table of ratios and sample errors is reproduced in Table 4.1.3.2, below.

Table 4.1.3.1 Mature stand audit ratios (sampling errors in parentheses)

	Leading species Strata	
Attributes ratios	**Cw/Yc**	**Hw/Hm & SS+**
Leading Species matched age	1.037 (8.8%)	0.996 (15.9%)
Leading Species matched height	1.057 (9.5%)	0.941 (13.1%)
Basal area	1.282 (12.8%)	1.135 (18.8%)
Trees/ha	1.425 (18.3%)	2.057 (41.3%)
Lorey Height	0.977 (9.7%)	0.887 (13.7%)
Volume net Dwb (Local Loss Factors) (m^3/ha) 17.5 cm+	1.544 (22.9%)	1.004 (23.8%)

Table 4.1.3.1 shows that some of the sampling errors, particularly for net volume, are large. For this reason, the ratios were not used for the base case in the analysis. The ratios were applied to the photo-interpreted attributes for exploratory analysis, as described in section 5.8. However, for most part, LiDAR enhanced inventory information was used where available for the timber supply analysis, including the base case.

Volumes were defined based on close utilization volume net of decay, waste and breakage (DWB). Volumes were calculated using local taper functions developed from destructive sampling of approximately 813 trees on Haida Gwaii in the 1990s (Flewelling, 2001), and subsequent Haida Gwaii specific taper equations developed by Kozak (1997)Utilization standards were 17.5 cm dbh for all species except for pine, for which the minimum dbh was 12.5 cm. See appendix 5 for a description of the Haida Gwaii specific taper equations.

Table 4.1:3.2 Reproduction of Table 8 from "Haida Gwaii Documentation of Vegetation Resource Inventory Analysis-Volume Audit (Mature)", revised March 16, 2018

Attribute	Cw/Yc	Hw/Hm	SS+	Hw/Hm & SS+	THLB	Non THLB	All
Leading Species Age (years)	1.043 (8.8%)	1.051 (19%)	0.827 (14.1%)	0.995 (15.9%)	1.054 (10.9%)	0.985 (10.5%)	1.027 (7.8%)
Leading Species matched Age (years)	1.037 (8.8%)	1.053 (19%)	0.827 (14.1%)	0.996 (15.9%)	1.052 (10.9%)	0.978 (10.7%)	1.023 (7.8%)
Second Species matched Age (years)	0.978 (17%)	1.328 (34.8%)	1.043 (0%)	1.321 (34.1%)	1.066 (17.4%)	1.096 (39.6%)	1.074 (16%)
Leading Species Height (m)	1.054 (9.5%)	1.056 (12.1%)	0.697 (22.8%)	0.935 (12.9%)	0.973 (10.4%)	1.035 (12.8%)	0.996 (7.2%)
Leading Species matched Height (m)	1.057 (9.5%)	1.066 (12.2%)	0.697 (22.8%)	0.941 (13.1%)	0.979 (10.5%)	1.037 (12.8%)	1.001 (7.3%)
Second Species matched Height (m)	1.031 (17.4%)	1.044 (25.2%)	1.018 (0%)	1.041 (22.4%)	0.994 (14.4%)	1.138 (30.9%)	1.036 (13.9%)
Basal area (m2/ha) 7.5 cm+	1.282 (12.8%)	1.189 (23%)	1.011 (30.4%)	1.135 (18.8%)	1.284 (12.6%)	1.104 (19.7%)	1.215 (10.8%)
Trees/ha 7.5 cm+	1.425 (18.3%)	1.821 (56%)	2.957 (27.9%)	2.057 (41.3%)	1.759 (29.9%)	1.465 (22.9%)	1.638 (20.1%)
Lorey Height (m)	0.977 (9.7%)	0.984 (14.7%)	0.676 (22.6%)	0.887 (13.7%)	0.932 (11.2%)	0.932 (12.5%)	0.932 (7.8%)
Volume net Dwb (m^3/ha) 17.5 cm+ **NVAF**	1.635 (22.3%)	1.208 (26.5%)	0.708 (46.2%)	1.03 (24%)	1.385 (20.3%)	1.118 (31.2%)	1.282 (15.9%)
Volume net Dwb (m^3/ha) 17.5 cm+ **LF**	1.544 (22.9%)	1.17 (25.8%)	0.702 (47.8%)	1.004 (23.8%)	1.323 (19.8%)	1.078 (32%)	1.228 (16%)
Leading Species Site index (m) age 10-120	1.121 (19.3%)	1.102 (13.9%)	0.85 (27.8%)	0.998 (14.9%)	1.001 (14.9%)	1.081 (21.3%)	1.029 (11.1%)
Leading Species Site index (m) All ages	1.061 (8.5%)	1.123 (8.6%)	0.833 (22.9%)	1.018 (10.8%)	1.022 (8.5%)	1.063 (12.4%)	1.037 (6.4%)
Leading Species matched Site index (m) age 10-120	1.245 (20.8%)	1.104 (13.7%)	0.923 (29.4%)	1.041 (13.8%)	1.027 (15.4%)	1.234 (14.9%)	1.09 (11.1%)
Second Species matched Site index (m)	1.652 (68.2%)	0.892 (8%)	0.993 (0%)	0.916 (7.5%)	0.918 (8.9%)	1.243 (61.8%)	1.011 (16.6%)
Leading Species matched Site index (m) All ages	1.121 (7.9%)	1.11 (8.7%)	0.855 (31.6%)	1.04 (11%)	1.042 (8.7%)	1.155 (10.7%)	1.078 (6.3%)
Site index (m) PSPL	0.78 (20.2%)	0.962 (18.9%)	0.892 (25.2%)	0.945 (15.7%)	0.899 (16.6%)	0.875 (19.4%)	0.892 (12.7%)

Note: Top number in each cell is the ratio; the value in parentheses is the sampling error at a 95% confidence level.

4.2 Young stand monitoring study

Young stand monitoring (YSM), a FLNR Forest Analysis and Inventory Branch initiative, was designed to provide information useful for evaluating stand development in the young and intermediate age range (15-50 years) (DeJong, 2017b). Given sufficient sampling over time these data can be used to assess if adjustments to inventory attributes, relative to photo-interpreted information, are warranted in stands in this age range.

YSM has five specific objectives:

1. Characterize the young stand population, including composition, structure, mortality, growth, yield, and health.
2. Assess the accuracy of some Phase I Vegetation Resources Inventory (VRI) photo-interpreted polygon attributes (e.g., age, height, density and site index) for young stands.
3. Assess the accuracy of site index estimates in the Provincial Site Productivity Layer (PSPL).
4. Compare observed stand yields (e.g., basal area/ha and trees/ha) to predictions generated from TIPSY.
5. Compare observed growth to forecasts from growth and yield models for the young stand population once remeasurements are available.

Since remeasurements are not yet available for Haida Gwaii, the 2017 YSM study focuses on the first four objectives only.

In Haida Gwaii, the YSM population consists of polygons that are currently 15-50 years old, which cover approximately 100,000 ha. Forty-three ground samples were established in 2016. The YSM population is dominated by hemlock (48% by basal area) followed by spruce (42%) with minor amounts of alder, cedar, yellow cedar and pine. Of the 43 YSM plots 24 were in hemlock-leading stands, 13 were in spruce-leading stands, 3 were in stands dominated by cedar, and 3 were in stands with other leading species.

The photo-interpreted (Phase I) inventory was used as the baseline for comparison of basal area, age, and height. The provincial site productivity layer (PSPL) was the comparison baseline for site index. TIPSY using Phase 1 forest cover estimates was the baseline for volume estimates.

Table 4.2 summarizes the results of the YSM study.

Table 4.2. Summary of comparison of ground plots to the inventory and to the YSM assumptions. A p-value < 0.05 is generally considered to indicate a statistically significant difference (or bias). Volume estimates do not include residual trees. All attributes are at the 7.5 cm utilization level.

Attribute	N	Baseline estimate	Ground mean	Inventory mean	Difference (grnd – inv)	Difference as % of grnd mean[1]	p-value
Basal area (m^2/ha)	43	VRI	31.4	27.0	4.4 ± 2.2	14%	0.053
Species matched age (years)	43	VRI	39.6	32.5	7.1 ± 2.7	18%	0.011[2]
Species matched height (m)	43	VRI	15.4	16.3	-0.9 ± 0.7	-6%	0.208
Site index (m)	41	PSPL[3]	23.3	25.4	-2.2 ± 1	-9%	0.042
Whole stem volume (m^3/ha)	40	TIPSY	219.6	189.9	29.7 ± 29.2	14%	0.314
Volume model bias (m^3/ha)	40	TIPSY	—	—	38.7 ± 13.2	18%	0.006
Volume attribute bias (m^3/ha)	40	TIPSY	—	—	-9 ± 22.1	-4%	0.687

Notes:
(1) The YSM report table 1 shows differences as the percent of the ground mean, but in the text uses the inventory as the reference. For example, the report text says that the ground BA is about 14% higher than the inventory BA, but in fact, the inventory BA is 14% lower than the ground BA.
(2) Shaded values are statistically significant at a p-value of less than 0.05
(3) PSPL is provincial site productivity layer

While the difference in BA shows as not statistically significant in Table 4.2 (i.e., > 0.05), in fact the BA difference in stands in the 15-30 year range is larger and statistically significant, while the difference in the 31-50 year range is smaller and not statistically significant.

The analysis has a number of complications. These are young samples and the trees are small. Small changes in age and height can have relatively large effects on SI. The age, height, site index and basal area biases are smaller in the older age class (31 – 50) than the younger age class (15 – 30).

Since this was the first YSM analysis for Haida Gwaii, the results were not used to adjust attributes and volumes for this TSR. YSM information will have greater utility for future TSRs once remeasurements have been done.

4.3 LiDAR and Enhanced Forest Inventory

Light Detection and Ranging (LiDAR) was completed on Haida Gwaii between 2015-2017 through various partners and projects. LiDAR is an airborne survey method that uses laser pulses from an aircraft to measure distances to an object below (a point density of 8 pulses/m^2 on Haida Gwaii). Its applications in resource management are wide ranging, however the most common products include a digital elevation model, digital terrain model (both to 1m resolution on Haida Gwaii), contours and canopy height models. The ground returns (e.g, point clouds) can be used to model a series of forest attributes (described below). The table summarizes the approximate extent of the projects flown on Haida Gwaii.

Table 4.3.1 LiDAR project proponents and area coverage

MoE (parks/protected areas)	786 km²
FLNRO (TSA)	1350 km²
FLNRO (TSA)	1900 km²
TAAN (operating areas)	1930 km²
Island Timberlands (operating areas)	104 km²
GWAII HAANAS	1470 km²
BCTS (TSA)	500 km²

These LiDAR data were used extensively for this TSR for derived mapping projects to enhance terrain stability mapping (see section 6.8) and mapping active fluvial units (see section 6.11.4), but most notably for enhancing forest inventory attributes, or LiDAR Enhanced Forest Inventory (LEFI).

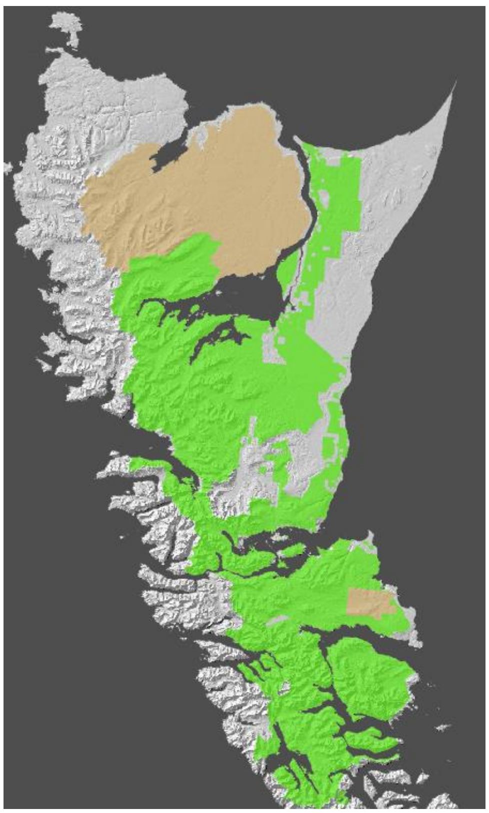

Figure 4.3 LiDAR coverage (light green) and no coverage (brown) within the Haida Gwaii operating areas.

The Forest Analysis and Inventory Branch (FAIB) developed an area-based parametric prediction model that was based upon metrics sourced from the LiDAR canopy point cloud data and ground tree measurements (Yuan & Wang, 2017). A total of 84 ground plot tree measurements were used from the VRI audit inventory plots (35 Young Stand Monitoring, 3 Change Monitoring, 46 VRI audit plots). Final inventory parameters that were produced include top height, Lorey height, diameter, basal area, crown cover and whole stem/net volumes and delivered as a 20m x 20m raster product. Height (actual LiDAR output) and basal area/quadradic mean diameter (derived LiDAR outputs from parametric modelling) were computed through FAIB's ground compiler which utilizes the 2002 'QCI' decay, waste and taper equations to calculate volume (see section 4.1.3 for more information on DWB).

The initial LEFI project was completed in 2017, however the same methodology was later applied to new LiDAR acquisitions of approximately 500km² (BCTS). The following table summarizes key statistics from the prediction equations, indicating a reasonable correlation (R-squared values) between the prediction model and ground samples.

Table 4.3.2. Statistics of the LEFI prediction equations (Yuan & Wang, 2017)

Variable (in log)	Adjusted R-squared	Root MSE	p-value
Lorey height	0.8995	3.364	<0.0001
Top height	0.9013	3.202	<0.0001
Basal area	0.8651	0.3208	<0.0001
Quadratic mean diameter	0.7608	0.3320	<0.0001
Whole stem volume	0.9148	0.3896	<0.0001
Net waste/breakage volume	0.9208	0.5010	<0.0001

4.4 Ecosystem Mapping

Ecosystem mapping is made up of tenure specific projects on Haida Gwaii. From 1994-2017, there were 17 ecosystem mapping projects on Haida Gwaii (Madrone Environmental Services Ltd., 2017): Nine projects were collated from TFL 39[8] (now TFL 60) where Terrestrial Ecosystem Mapping (TEM) was undertaken to a survey intensity level (SIL) 4 between 1995-1999. That overall project (approximately 270,500 ha) had quality assurance completed by B.Beese and D.Meidinger (exceeding 65% accuracy threshold). Other Ecosystem Mapping projects include:

a. Five projects completed to a Survey Intensity Level 5 in the Timber Supply Area[9] between 2004-2007, covering approximately 437,200 ha. Quality assurance was completed by Timberline Natural Resource Group in 2008 (dominant entity correct with and without alternate calls was 45%/59% respectively (see discussion below);
b. A pre-TEM (before Resource Inventory Committee published standards) mapping project was completed for TFL 25[10], covering approximately 52,900 ha. Q/A not available;
c. A pre-TEM project for TFL 58 (formerly TFL 2 and 47) was done by T. Lewis. Approximately 27,300 ha. Q/A not available;
d. A TEM project (including quality assurance) was completed for a portion Louise and north Moresby Islands in 2015-6 by Madrone as part of a strategic re-inventory and updating of TEM for Haida Gwaii (Tripp, J.McEwen, H.Williams, & R.Adams, 2017).
e. A TEM project completed for Skidegate Lake Landscape Unit by Blackwell Consulting. This mapping overlapped and replaced the pre-TEM project described in (c) above;
f. Gwaii Haanas biophysical mapping project was completed in 1994 (not using a BEC basis);
g. A Predictive Ecosystem Mapping project was completed in 2002 by EBA Engineering Consultants for the north/central coasts and Haida Gwaii to support Land and Resource Management Planning (EBA Engineering Consultants Ltd., 2002);
h. The Reporting Silviculture Updates and Land Status Tracking System (RESULTS) provides site series mapping at the Standard Unit scale.

For the Timber Supply Review, projects described were collated to provide a complete coverage of Haida Gwaii, as detailed in Figure 4.4 and Table 4.4.

BEC Classification updates

In 2014 the Biogeoclimatic Ecological Classification system for Haida Gwaii was updated from the previous classification published in1994 (Green & Klinka, 1994). The update incorporated results from newer

[8] Mapping in 1994-1998 for MacMillan Bloedel
[9] Mapping in 2005-2006 led by Husby Forest Products
[10] Mapping revised in 2003 to TEM attribute standards by T.Lewis Ph.D, P.Ag, P.Geo

ecological research plots and analysis into the Land Management Handbook 68 (Banner A. P., 2014). The new classification led to a number of changes at the BEC variant level and site series level (e.g., the change from CWHvh2 to CWHvh3, etc.). In addition, new BEC variant mapping was published by the Ministry in 2014 that adjusted boundaries, particularly for the very wet hypermaritime zone (CWHvh2/3).

The application of the new classification is confounded by the fact that the HGLUOO's ecosystem representation targets (HGLUOO Schedule 10) and red/blue ecosystem targets (HGLUOO Schedule 13) and the majority of the ecosystem mapping are based upon the 1994 BEC classification. Currently the HG Natural Resource District and the Council of the Haida Nation are undertaking an initiative to update (re-map or cross-walk) all the ecosystem mapping on Haida Gwaii, in accordance with a Strategic Plan that was developed in 2017 (Tripp & Temmel, 2017).

Therefore, for all elements of the TSR that use ecosystem mapping (e.g., site productivity estimates, spatial net downs, etc.), both classifications were used (where applicable). The cross-walk table (table 4.4.2 below) was applied (Banner, W. MacKenzie, MacKinnon, Saunders, & H.Klassen, 2014).

Table 4.4.1 Area of ecosystem mapping projects used in this TSR.

Project	Hectares
Gwaii Haanas Ecosystem Mapping	147,013
Madrone 2016 (TEM)	17,892
RESULTS Ecosystem Mapping	41,800
SS Predictive Ecosystem Mapping	78,779
TFL 25 (TEM)	40,109
TFL 39 (TEM)	214,393
TSA (TEM)	416,957
Blackwell (2019)	48,700

Table 4.4.2. Relationship between site unit numbers used in Green and Klinka (1994) and those presented in Allen et. al (2014)

Current site unit	Current biogeoclimatic unit (presented in this guide)[a]			
	CWHvh3	CWHwh1	CWHwh2	MHwh
101	vh2/01, vh2/03	wh1/01	wh2/01, wh2/02	wh/01, wh/04[b]
102	vh2/02	wh1/02	N/A[c]	wh/02[b]
103	vh2/14, vh2/16	wh1/13, wh1/15	N/A	N/A
104	vh2/15	wh1/14	N/A	N/A
105	vh2/04	wh1/03, wh1/16	N/A	N/A
106	vh2/05, vh2/17	N/A	N/A	N/A
110	vh2/06	wh1/04	wh2/03	wh/03[b]
111	vh2/08	wh1/05	wh2/05	wh/05, wh/06, wh/07, wh/09[b]
112	vh2/09	wh1/07	wh2/04, wh2/06	N/A
113	vh2/10	wh1/08	N/A	N/A
114	vh2/07	wh1/09	N/A	N/A
115	vh2/11	wh1/10	N/A	N/A
116	vh2/18, vh2/19	wh1/06	N/A	N/A
117	vh2/13	wh1/17, wh1/18	N/A	N/A
118	N/A	wh1/12	N/A	N/A
Wb51	N/A	wh1/11	N/A	N/A
Wb53	vh2/12	N/A	NPE[d]	wh/08[b]
Wb54	NPE	N/A	NPE	wh/08[b]
Wf51	NPE	NPE	N/A	N/A

a See Appendix 4 of MacKenzie and Moran (2004) for crosswalk to other nonforested and wetland units.

b Includes both the MHwh1 and MHwh2, which were lumped as MHwh in Klinka and Green (1994).

c Not applicable — site unit does not occur in the current classification for this biogeoclimatic unit presented in this guide.

d No previous equivalent — site unit did not occur in previous published classification for Haida Gwaii (Green and Klinka 1994).

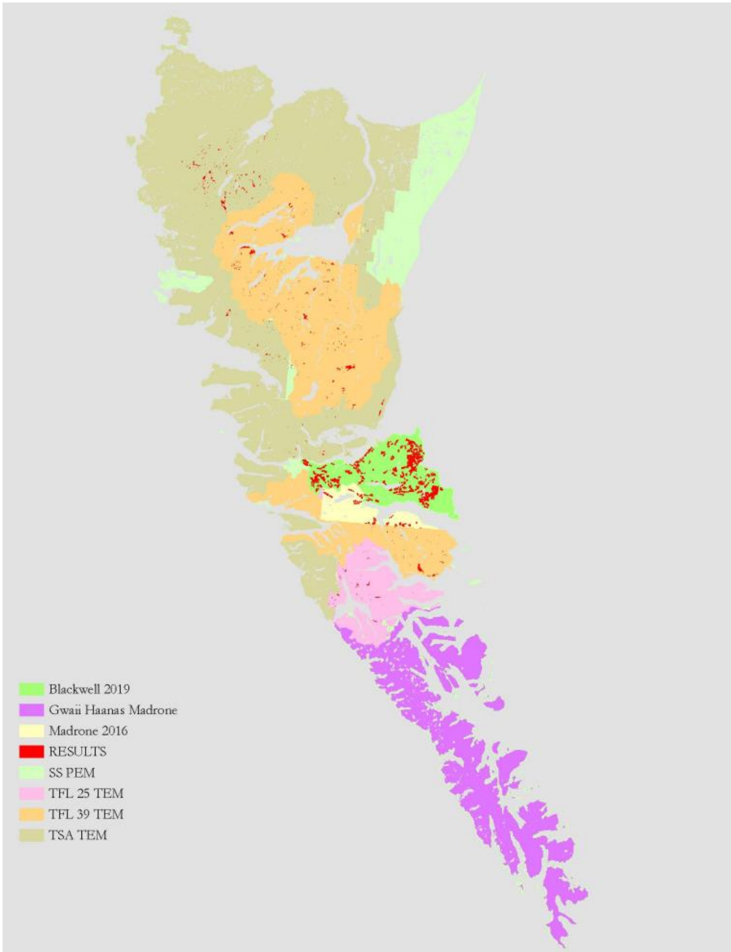

Figure 4.4. Ecosystem mapping sources used within this TSR

Chapter 5 Growth and Yield

5.1 Site Productivity

Site productivity, or the capacity of an area for growing trees, is often measured using site index. Site index (SI) is the average height in metres (m) that the tallest trees in a stand are expected to achieve at age 50 (e.g., a site index of 25 means that a site is expected to grow a stand to a height of 25 metres in 50 years).

SI is an important input for growth and yield models, which are used to project the estimated timber volume of different types of forest stands over time. Site index is a key input into the managed stand growth and yield model (TIPSY) and the natural stand growth and yield model (VDYP), discussed in detail in section 5.6 and 5.9 respectively.

Various methods can be used to estimate site index, including the growth intercept method, site index curve method, or Site Index by Biogeoclimatic Ecological Classification (SIBEC) (Mah & G.Nigh, 2015). Studies on Haida Gwaii[11] and throughout BC have demonstrated that inventory information from old-growth forests tends to under-estimate site productivity. This, in part, is because most trees in old stands, which tend to be uneven-aged and multi-layered, have grown under substantial competition and suppression, and often have broken tops. Therefore, it is important when generating growth and yield estimates for managed stands to use SIs that to the extent possible realistically reflect anticipated growth, rather than rely on inventory information on old forests to estimate site productivity.

For this timber supply analysis, the primary source of SIs was the SIBEC database, which is described in more detail below. Since ecosystem mapping is required to apply SIBEC, where ecosystem mapping is unavailable the SI from the provincial site productivity layer – also described below - was used.

5.1.1 SIBEC

The SIBEC project began in 1994 as scientists and foresters recognized strong correlations between site factors (e.g. temperature, soil moisture and nutrients) and site productivity. As a result, standards were developed in 1997 to develop estimates for site index for each ecosystem 'site series' for each BEC unit across the province, with a second version coming out in 2009 (B.C. Ministry of Forests and Range, 2009). SIBEC plots, which are 100m^2 in size, are established in homogeneous site series with trees between 20-120 years of age, with site trees (healthy, largest trees in the plot) measured to estimate height at breast height age 50.

SIBEC approximations aim to report on the mean site index and standard error of the mean (if there are at least 7 plots)[12] by site series and tree species. Estimates are updated based upon the availability of new information that meets the SIBEC standards. The last publication for Haida Gwaii was in 2013 (MFLNRO, 2013).

During the TSR, forest mensuration field plots from a variety of sources were collated to increase the SIBEC samples for Haida Gwaii. One dataset was created by the Forest Analysis and Inventory Branch to amalgamate all forest mensuration plots from Haida Gwaii. This dataset, which is supplementary to the SIBEC dataset, consists of 685 field plots ranging from 1945-2016. The following projects were included:

- Growth Natural Permanent Plots (subjectively located)
- Research-based untreated control plots
- VRI Phase II (mature audit) 5-point clusters (PPSWR-based selection)

[11] (Hardy K. , 2005); (Hardy K. , Remeasurement of 2nd growth permanent sample plots on Moresby Island. Project Report SFM15-05., 2006); (Hardy K. , Queen Charlotte Islands stump-site index study, 2007)
[12] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/ecosystems/sibec

- Change Monitoring Inventory
- Silvicultural Treatment Program (discontinued)
- Intensive Forestry Program (discontinued)
- Research Branch Experimental Projects
- Site Index Adjustment Project

The TWG compiled these supplementary data, along with the SIBEC plots and additional Provincial research plot data[13] into one dataset. In this dataset, a total of 1,170 plots contained specific site index information and site series designation allowing for comparison of site index estimates from various sources. See appendix 2 for a detailed description of findings.

See section 5.4 below for the documented use of site index in the base case in this TSR.

5.2 Alternative sources of site index assignments to inventories
Site index can be estimated and spatially assigned using a number of methods. The following summarizes both the approach used for the base case, as well as methods considered but not applied. See appendix 3 for the evaluation of alternative sources of site index assignments.

Ecosystem mapping
Ecosystem mapping provides a direct link between field-based SIBEC estimates of productivity by site series and the spatial representation of those site series across the land base. While not all ecosystem mapping projects have been independently assessed for accuracy, all existing mapping is being used on the premise that it provides superior site productivity information compared to using site index derived from inventory attributes of old growth stands.

TSA TEM calibration study
The TSA TEM project had a final accuracy assessment completed in 2008 (Timberline Natural Resource Group, 2008), the result being that the product did not pass the Provincial standards for inclusion in the TSR. In 2011, through coordination with the FLNRORD Regional Ecologist (Dr. Andy MacKinnon), the accuracy assessment data was used to analyze error trends and make adjustments to the inventory (Ran, 2011). Error trends were calculated based on the site series proportions of the unbiased accuracy assessment plots sampled in the field. The following error trends were found:

a. CWHwh1: The TEM has over-mapped site series 01 and under-mapped site series 04 and 10. The TEM has also over-mapped site series 05 and 06;
b. CWHwh2: The TEM has over-mapped site series 01 and 03 but under-mapped 02 and 05;
c. CWHvh2: The TEM has over-mapped site series 01 and 04, but under-mapped site series 06, 07, and 13.

The resulting analysis was applied through a biophysical model, informed by an expert review[14], to adjust mainly the second and third deciles of the mapped TEM (no linework was adjusted) in order to utilize the mapping for the previous timber supply review. A 2011 review of the adjustment to the inventory specific to the Forest Management Land Base[15] showed a weighted average site index increase of 0.7 metres (TSR Joint Technical Working Group , 2012).

[13] Research plots include SIBEC data stored and managed using VPRO software,from P.Dykstra; and Ecoysystem Recovery Plots data from A.Banner.
[14] Model parameters were reviewed by ecologists Andy MacKinnon, Sari Saunders and Alan Banner.
[15] FMLB are those areas remaining after non-forest areas and areas not administered for forest management are excluded from the land base.

RESULTS

The Reporting Silviculture Updates and Land Status Tracking System (RESULTS) reports site index derived from silviculture surveys in the field. A variety of methods are acceptable under BC's Silviculture Survey Standards (MFLNRORD, 2018), which include growth intercept method, height-age reference curves, SIBEC and others. On Haida Gwaii, the majority (52%) of all site index estimates from RESULTS use the SIBEC method whereby a forester classifies a 'standard unit' (part of a harvest opening) based on BEC, and then refers to the published SIBEC estimates. However, since SIBEC estimates are updated over time with new information, the growth intercept method (using the in situ height and age of trees) is considered the most reliable. Site index in RESULTS was assigned using growth intercept on approximately 6,020 hectares on Haida Gwaii.

Provincial Site Productivity Layer (PSPL)

The Provincial Site Productivity Layer is a well-documented spatially explicit database that consists of site index for commercial tree species. Site indexes were derived primarily in one of two ways. The first is by linking published SIBEC estimates with an ecological map or a biophysical model (Cloverpoint, 2016). Ecological maps, such as TEM or Predictive Ecosystem Mapping (PEM) are used if they meet the Provincial protocols for accuracy assessments of ecosystem maps (D.Meidinger, 2003). The second approach is used if TEM/PEM is not available. In that case, a biophysical model is used to predict site index based on BEC zone, slope, aspect, elevation and climate variables (Nigh G. , 2012). The PSPL dataset has been validated using a variety of independent ground plots, such as Growth Natural Permanent Sample Plots and Vegetation Resources Inventory plots, comparing predicted and observed site index in order to provide a measure of confidence (Nigh & deJong, 2015). The PSPL dataset covers all of Haida Gwaii, using a biophysical model to derive site index in conjunction with the 'TFL 39' TEM data (linking SIBEC estimates to leading ecosystem type in TEM).

Site Index based on inventory attributes

Site Tools is a software platform for making site index calculations that was developed and made available through MFLNRORD[16]. It integrates site index models for 24 species throughout BC. The software benefits from four types of site index models including height-age models, growth intercept models, juvenile height growth models and species conversion models. Site Tools is incorporated into the Forest Analysis and Inventory Branch TASS, TIPSY and VDYP growth and yield programs. As a result, Site Tools calculations form the basis of site index attributes within the Vegetation Resource Inventory.

The problem with using inventory height and age as inputs to Site Tools (or any other SI generating application) is that for older stands in particular, those attributes may not reflect actual site potential given competition and damage to trees.

Paired plot studies

In the late 1990's, regional studies were conducted for a number of major commercial tree species to derive adjustments for old growth site indices. Paired plots were installed in old growth stands adjacent to logged and regenerated (LAR) stands of the same site type/productivity (Nussbaum, 1998). However, none of the adjustment equations are applicable to Haida Gwaii.

Site index adjustment (SIA) studies

A Site Index Adjustment study was completed in Haida Gwaii's TSA in 2010, involving sampling young stands between the age of 9-61 years old (Timberline Natural Resource Group Ltd., 2010). The primary objective of the study was to test a proprietary biophysical model to map site productivity across Haida Gwaii. The resulting site index adjustments were based on site index derived from field samples (young

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[16] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/site-index-tools-sitetools

spruce and hemlock in the TSA) and site index derived from the biophysical model. While the study report provided adjustment equations, expert review indicated that there was not a statistically significant relationship[17]. The results of the SIA were not applied in the Haida Gwaii base case.

Stump site index

The stump site index work was conducted by researchers from the Ministry of Forests and Range in 2005-2007 (Hardy K. , 2007). The work provided statistically valid site index adjustments for western hemlock and Sitka spruce stands on Haida Gwaii. Localized taper equations and existing cruise data were used to estimate tree heights from stumps, which were compared to site indexes measured from a regenerating stand. Statistically significant regression equations were developed by using a growth intercept method to estimate site index for spruce and hemlock in Logged-And-Recovered stands. While the sampling for the stump site index project was specific to what was then TFL 39 (now TFL 60), the findings have been considered applicable to the entire operating area of Haida Gwaii. The stump site index model uses the Vegetation Resource Inventory attributes of leading species and age as model parameters to derive site index. The accuracy of leading species has since been the subject of the Phase II VRI ground audits (Penner, 2018), resulting in relatively low agreement for hemlock and spruce leading stands[18]. In addition, the stump SI adjustments were broad-scale, that is, applied across Haida Gwaii. Therefore, localized SIBEC estimates applicable to site series were used in the timber supply analysis rather than stump site index adjustments.

5.3 Site Index application in the base case for managed stands

SIBEC applied through ecosystem mapping, as well as the Provincial Site Productivity Layer (PSPL) were used in the base case for existing and future managed stands (managed stands). Where ecosystem mapping was available, species composition from RESULTS was paired with SIBEC site indices for managed stands. Where there were gaps in the ecosystem mapping coverage, the Provincial Site Productivity Layer was used, in conjunction with VRI leading species[19]. The following table details the hectares of site index source used across the FMLB for the TSR for managed stands.

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[17] Personal communication, Peter Ott, Senior Biometrician at Forests, Lands and Natural Resource Operations and Rural Development.

[18] The accuracy of species composition in VRI increases when the all species are considered (i.e not just leading species). The Phase II result had a 52% and 50% agreement between VRI attributes and field observations for western hemlock and Sitka spruce respectively.

[19] Note that PSPL filled gaps for generally low-productive/inoperable areas where ecosystem polygons were missing.

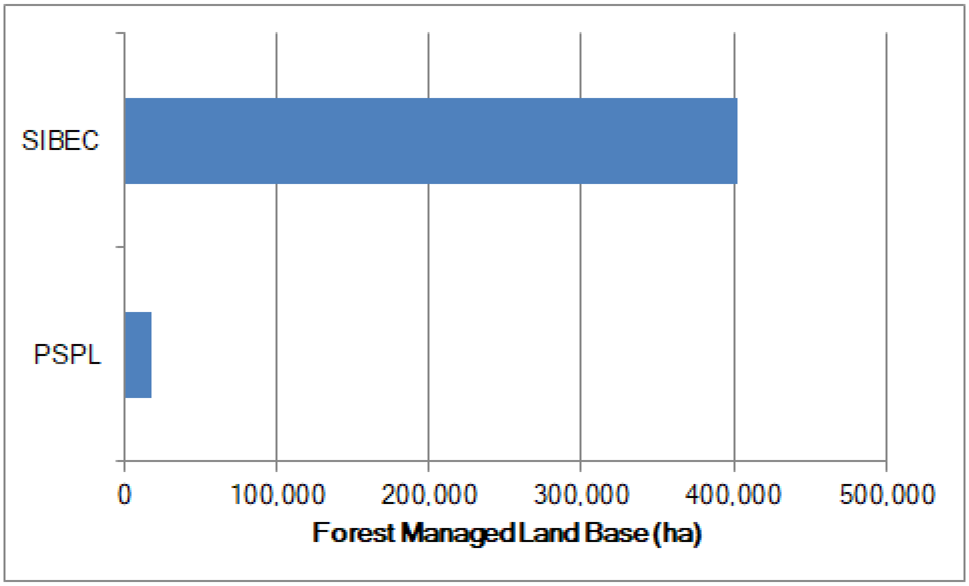


Figure 5.3.1 . Application of SIBEC vs. PSPL in the base case

SIBEC links ecosystem types (site series) to productivity based on field studies on Haida Gwaii. Ecosystem mapping delineates site series by complex polygons, whereby each polygon may represent between one and three different site series (represented as 'deciles'). As tree species grow at varying rates in different site series, assigning site index for each species components in a polygon is considered a reasonable way to estimate site productivity.

Where ecosystem mapping and species combinations produced units not otherwise represented in the SIBEC look up table, site indices were applied based on expert opinion (Dr. Allan Banner, ecologist) that considered site productivity of adjacent edatopic units within the same biogeoclimatic (BGC) variant[20].

The complete SIBEC look up table for this Timber Supply Review is shown in table 5.3.3. The following figures detail the site index by soil moisture regime (SMR) and soil nutrient regime (SNR) for the major commercial tree species and three main biogeoclimatic units within the THLB.

[20] See table 5.3.1, where *no. plots* is null.

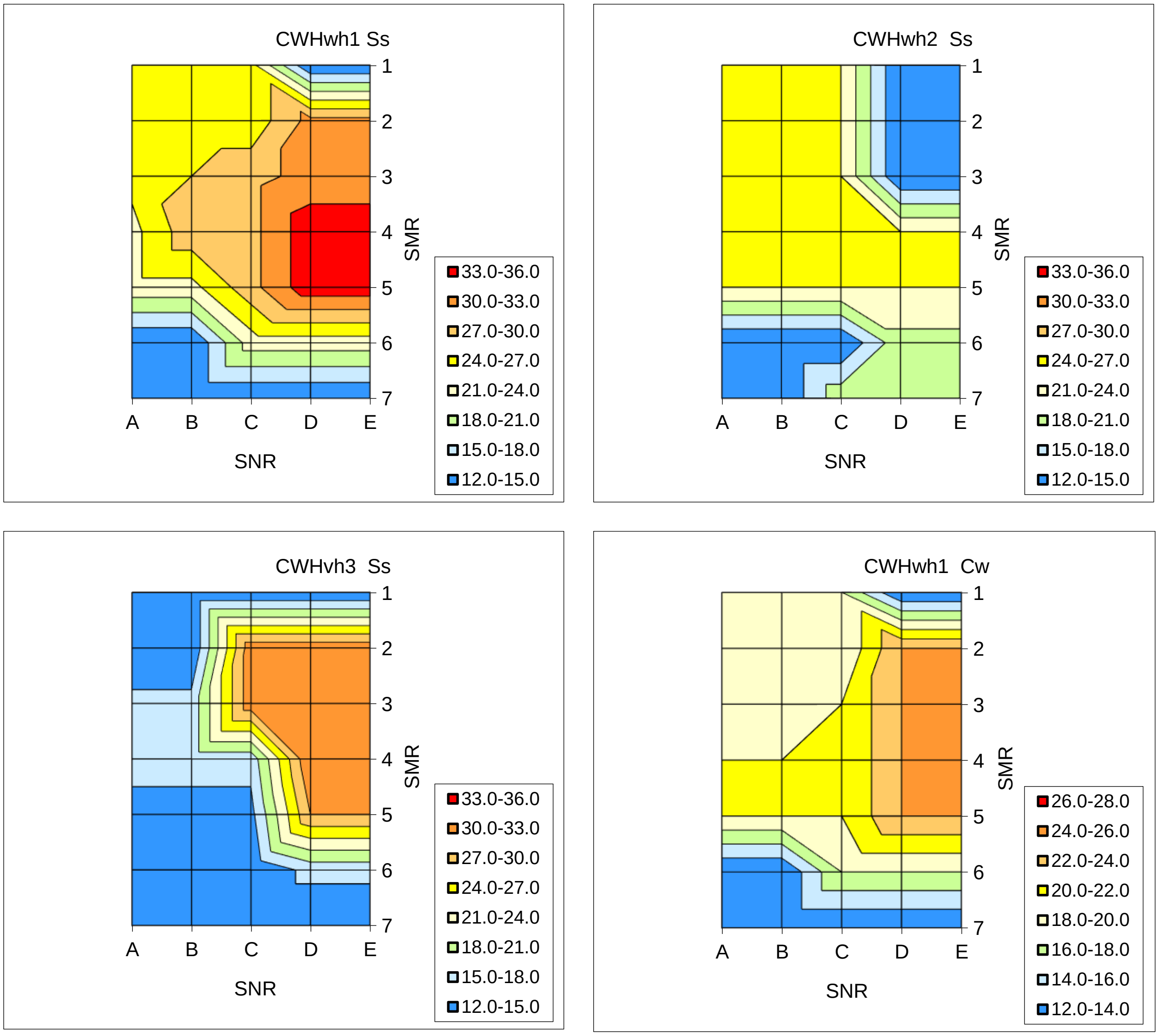


Figure 5.3.2Site index by soil moisture regime (SMR) and soil nutrient regime (SNR) for the major commercial tree species and three main biogeoclimatic units within the THLB

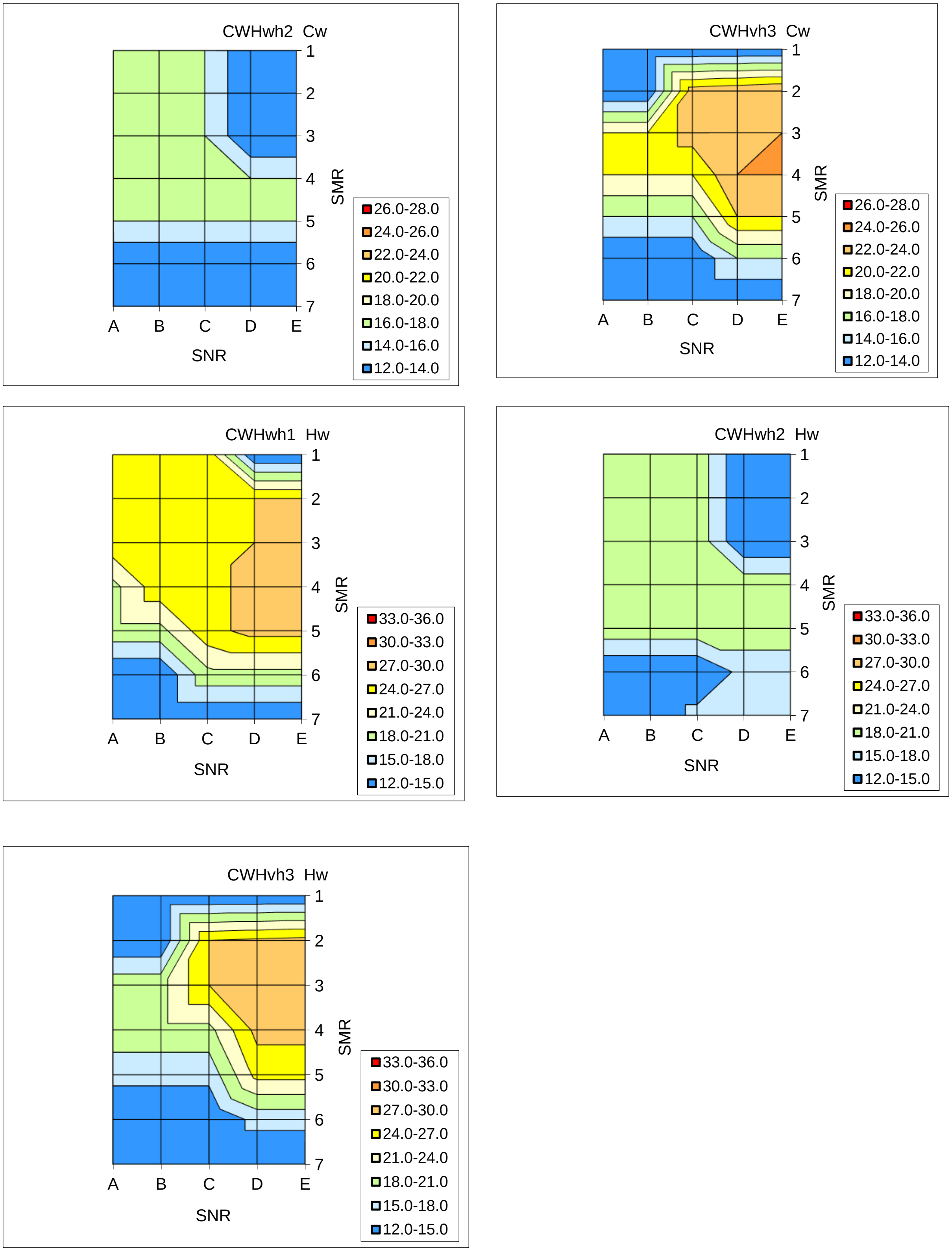


Figure 5.3.2Site index by soil moisture regime (SMR) and soil nutrient regime (SNR) for the major commercial tree species and three main biogeoclimatic units within the THLB (cont.)

Table 5.3.3. Enhanced SIBEC look up table (rounded) for species by site series.

BGC_Unit	*n* plots	Site Series	Cedar	Western Hemlock	Mountain Hemlock	Lodgepole Pine	Sitka spruce	Yellow cedar
CWHvh3		12	8			12		8
CWHvh3	2	11	12	12		16		12
CWHvh3		14	12	12			16	
CWHvh3		16	12	12			16	
CWHvh3	6	13	16	16			16	16
CWHvh3		15	16	16			20	
CWHvh3	2	3	16	16		16		16
CWHvh3	22	1	20	20		20	16	16
CWHvh3	9	8	24	24			32	
CWHvh3	41	7	22	25			30	
CWHvh3	143	4	23	27			32	
CWHvh3		17	24	28			32	
CWHvh3	17	5	24	28			32	
CWHvh3		9	24	28			32	
CWHvh3	70	6	24	28			33	
CWHwh1	4	11	8			12		8
CWHwh1		17	16				20	
CWHwh1	26	10	12	12		16	12	12
CWHwh1	2	13	12	12			16	
CWHwh1		15	12	12			16	
CWHwh1	8	12	16	16			16	
CWHwh1		14	16	16			20	
CWHwh1		4	20	20		20	23	
CWHwh1	21	6	20	24			29	
CWHwh1	132	2	18	26		20	25	
CWHwh1	156	1	20	26			29	
CWHwh1	7	16	24	27			30	
CWHwh1	152	3	24	27			31	
CWHwh1	84	5	24	28			35	
CWHwh1	2	7	24	28			32	
CWHwh1	2	8	24	28			32	
CWHwh2		5	8	8	8			8
CWHwh2		6	12	12	12		16	16
CWHwh2		2	16	16	16		16	16
CWHwh2	2	4	12	16			20	16
CWHwh2	13	1	16	20	16		24	16
CWHwh2	8	3	16	20			24	16
MHwh		2		8	8		8	8
MHwh		5		8	8		8	8

BGC_Unit	*n* plots	Site Series	Cedar	Western Hemlock	Mountain Hemlock	Lodgepole Pine	Sitka spruce	Yellow cedar
MHwh		6		8	8		8	8
MHwh		7		8	8		8	8
MHwh		9		8	8		8	8
MHwh		1		12	12		12	12
MHwh		3		12			12	12
MHwh		3		12	12		12	12
MHwh		4		12	12		12	12

5.4 Site Index application in the base case for natural stands
For natural stands (e.g. unmanaged stands), site index was sourced from the Vegetation Resource Inventory Phase I (adjusted) attributes. VRI does not use photo interpretation to estimate site index for stands greater than 30 years old (MSRM, 2002), but rather derives site index from inventory attributes using SiteTools within the VDYP7 growth and yield program.

Section 5.8.7 provides further a chart on the distribution of site index classes across the THLB.

5.5 Height-Age (site index) curves
Growth curves estimate stand attributes (primarily height over age) and are based on empirical field plots from a variety of growing conditions and species types. These mathematical models predict height from site index and age, based on how the species grows within ranges of nutrient availability.

The following summarizes the sources of site index models that were used for all stand types (unmanaged/natural stands, existing managed stands, future managed stands) based on TIPSY and VDYP7 to derive the growth and yield curves for the timber supply analysis[21]. Figure 5.5 summarizes the proportion of volume, by species and age class across the THLB to illustrate the importance of these various curves to timber supply.

[21] Some descriptions are sourced from *Site Tools 4.1*

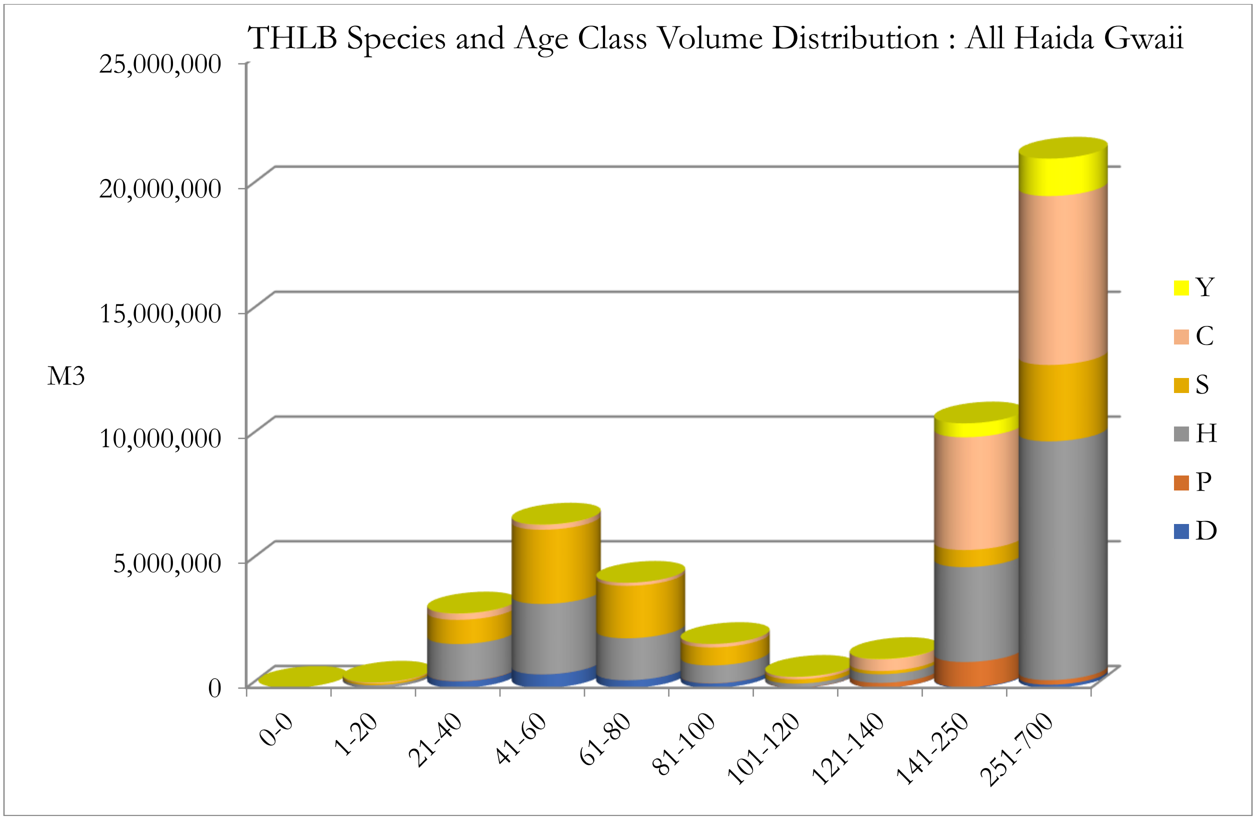
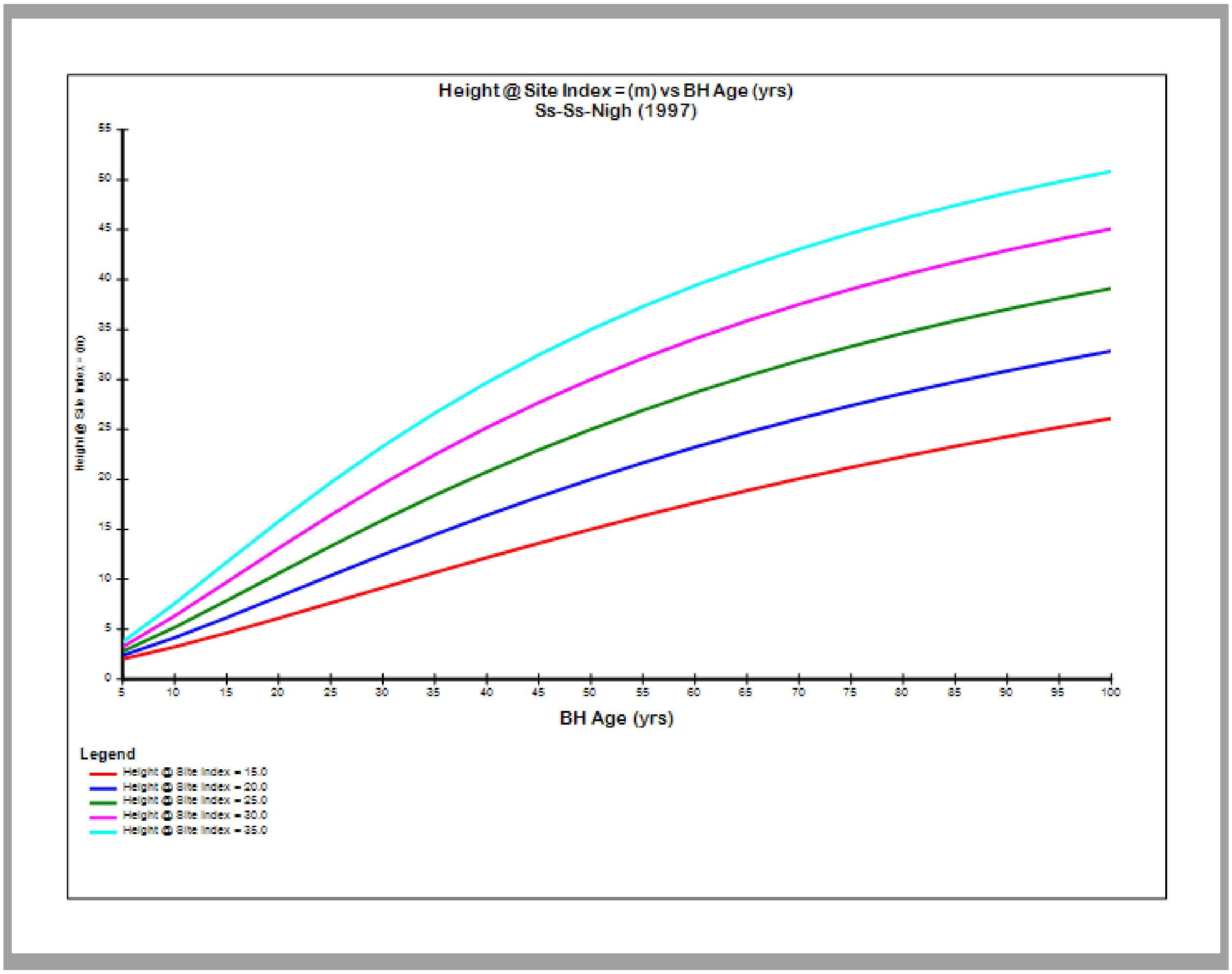


Figure 5.5 Volume distribution by species and age class within the THLB (Y= yellow cedar, C= red cedar, S= Sitka spruce, H= western hemlock, P=lodgepole pine, D= red alder).

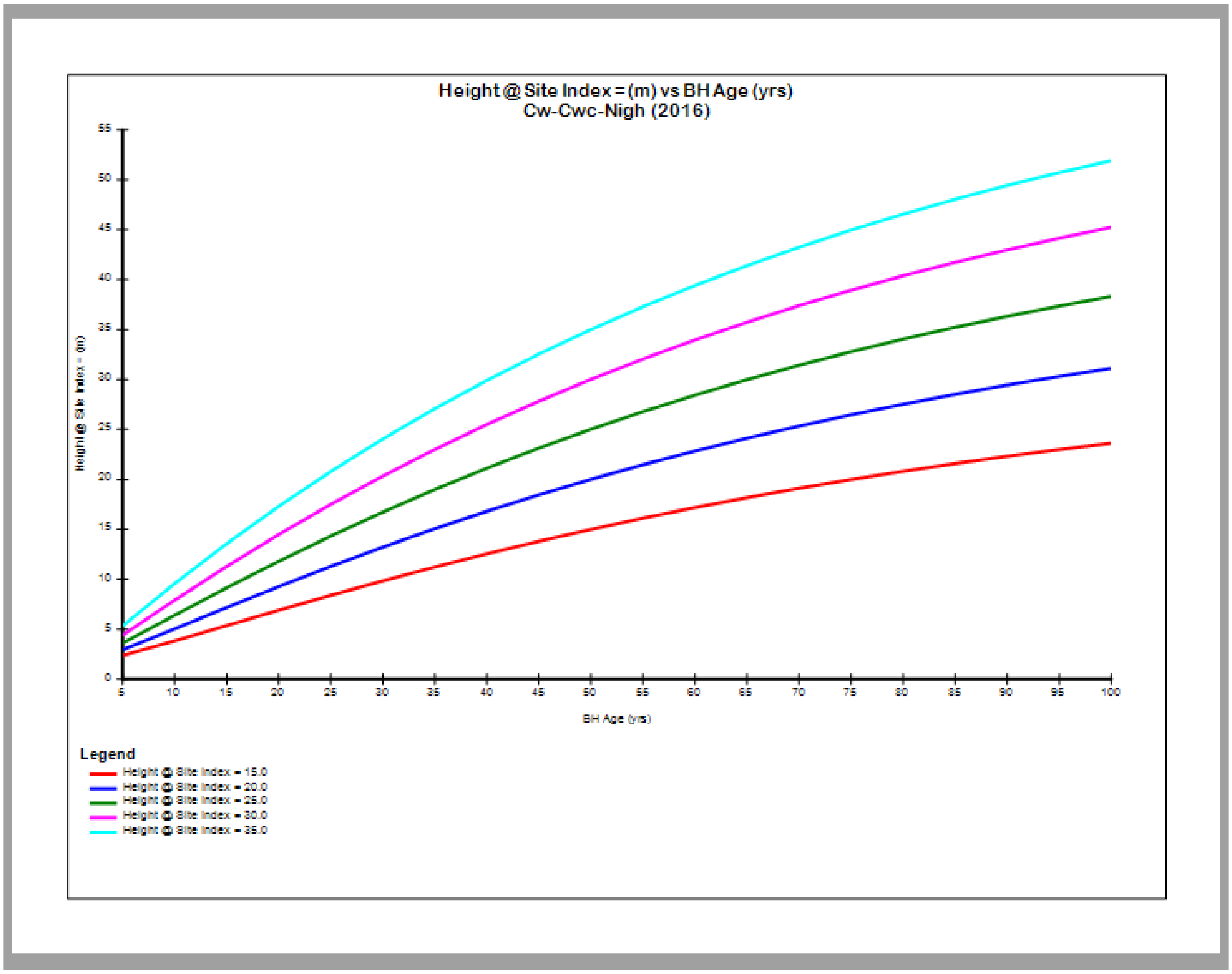
5.5.1 Sitka spruce

The primary purpose of this model is to estimate stand heights over time for immature Sitka spruce stands. The height-age (site index) curves for Sitka spruce were developed from 40 stem analysis plots established in edaphically uniform areas of Sitka spruce stands on Haida Gwaii (Nigh G. , 1997) and include revisions from newer growth intercept modelling techniques (Nigh G. , 1998). All plots were in the sub-montane wet hypermaritime Coastal Western Hemlock (CWHwh1) biogeoclimatic variant (Banner, et al., 2014). Plot ages ranged from 50 to 121 years at breast-height and site index from 13.6 to 40.3 m.



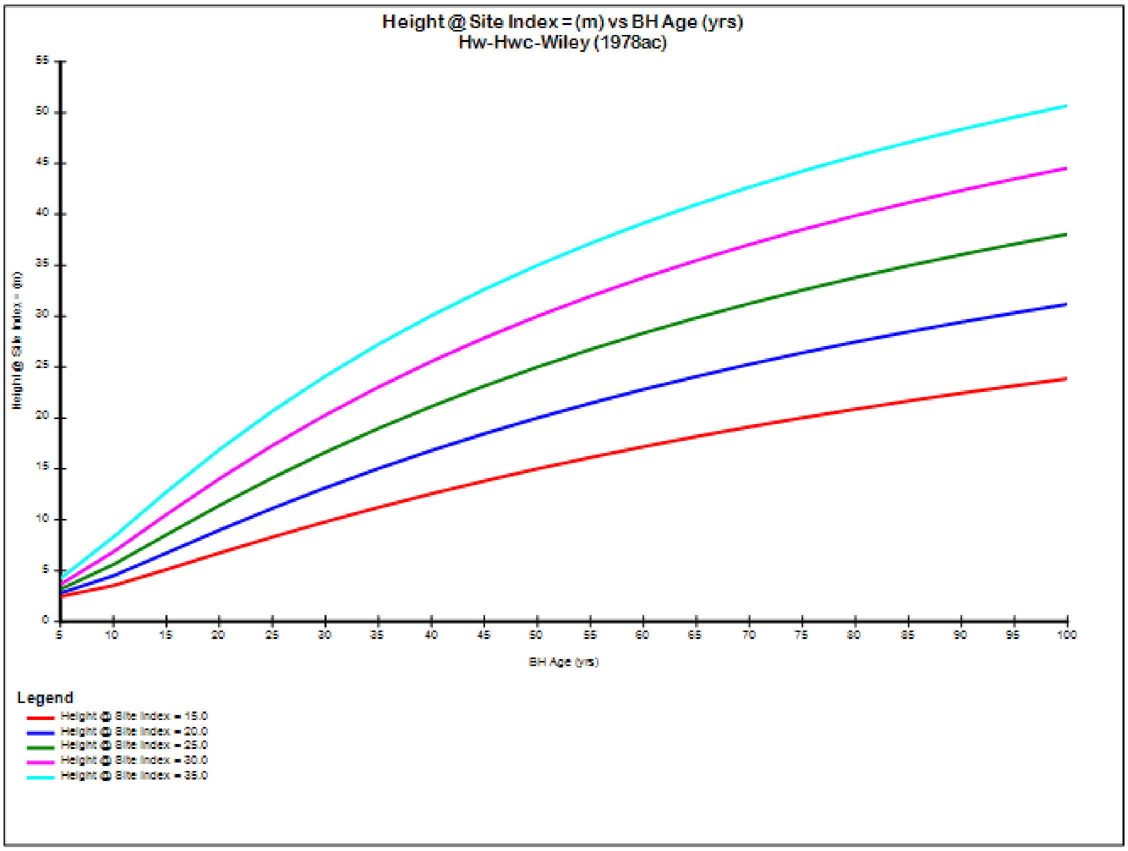
5.5.2 Western redcedar

An original site index model was developed for coastal western redcedar by MacMillan Bloedel Ltd in 1978 (Kurucz, 1978). This model used stem analysis from approximately 50 stands throughout Vancouver Island and the mid-coast and included trees ranging in age from 33-285 with site indices ranging from 10 to 40. In 2016, the Ministry of Forests, Lands and Natural Resource Operations updated the Western redcedar site index model to improve estimates of heights and site index predictions for old trees, and to use newer statistical techniques. In this case a "grounded-generalized algebraic difference approach was applied to a Chapman-Richards function to derive a base-age invariant site index model" (Nigh G. , 2016). The updated model used data from four sources, including the 1978 MacMillan Bloedel samples, as well as wood quality and foliar nutrient analysis samples from other coastal research projects. Note that there currently is not a height-age model for yellow cedar. As such, the Nigh (2016) curves are used for yellow cedar.



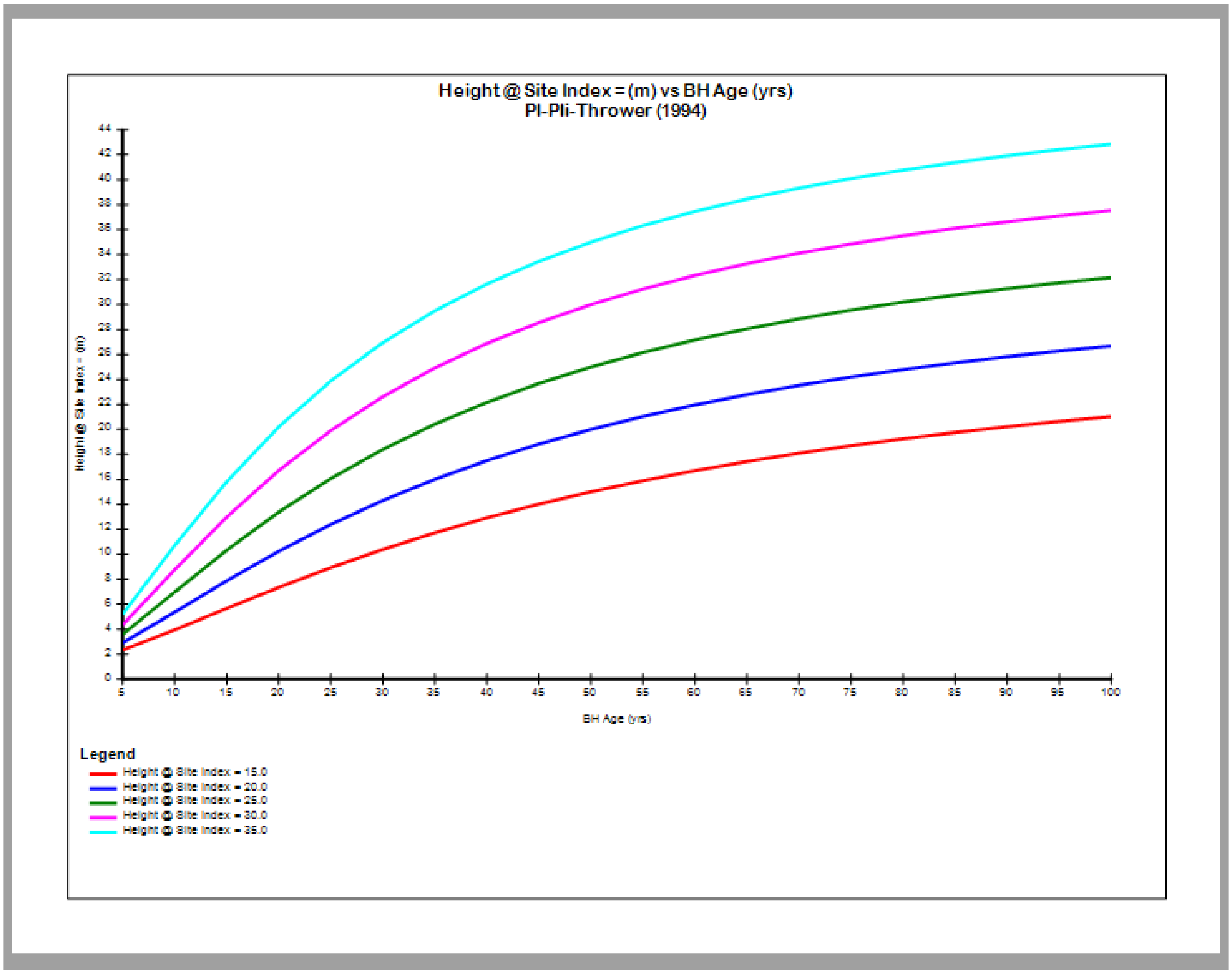
5.5.3 Western hemlock

The site index (height-age) curves were developed from stem analysis data collected from 90 plots in Washington and Oregon (Wiley, 1978). The plots ranged from site index 18 to 40m and from about 60 to 130 years breast-height age. MacMillan Bloedel Ltd. calibrated these curves to better represent the local growing conditions. Growth intercept curves were then developed from 46 stem analysis plots established in ecologically uniform areas throughout the CWH biogeoclimatic zone. Plot ages ranged from 50 to 173 years at breast-height and site index from 7.7 to 38.1m these models were updated to reflect changes in the growth intercept modelling technique (Nigh G. , 1999).



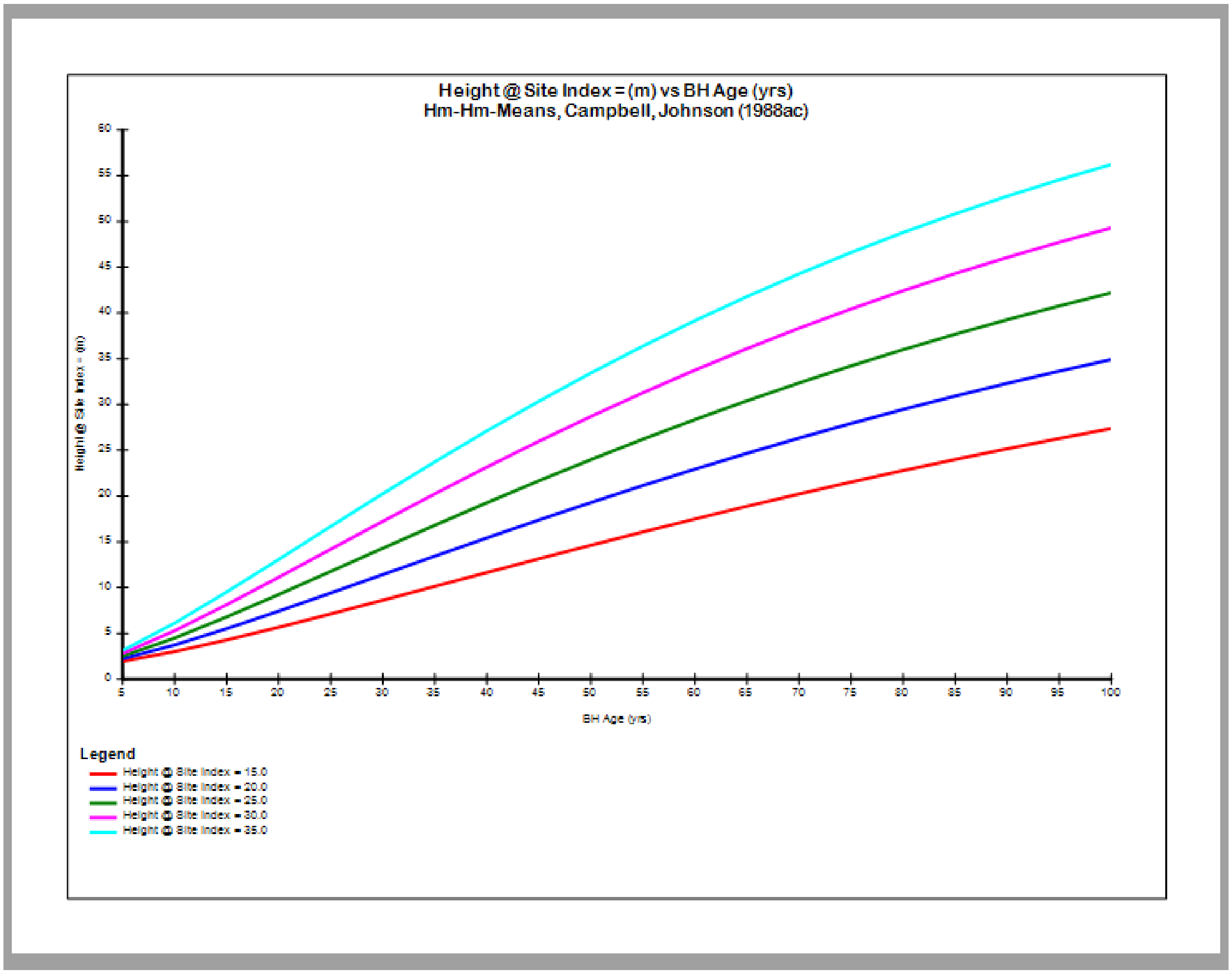
5.5.4 Lodgepole pine

The height-age models were developed from 106 plots established throughout the interior of British Columbia (Thrower, 1994). Ages ranged from 50 to 130 years at breast height. The site indices of the plots ranged from 6 to 27 m at breast height age 50. A years-to-breast-height model was also developed. These curves replace the ones by Goudie (1984) and utilize data collected in British Columbia.



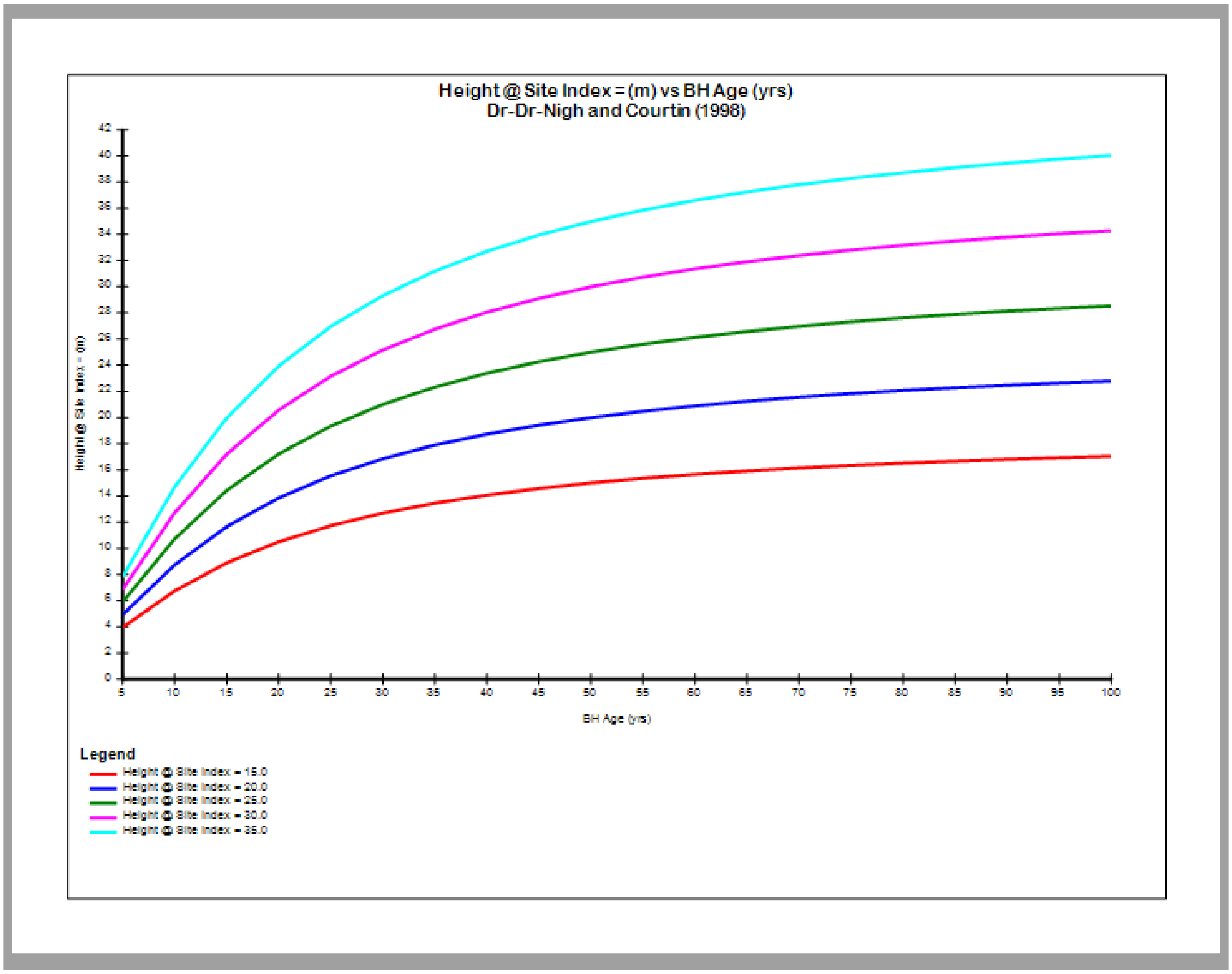
5.5.5 Mountain hemlock

The height-age curves for mountain hemlock were developed from 95 trees sampled in the Cascade Mountains in Washington and Oregon (Means, Campbell, & Johnson, 1988). The stands from which the trees were sampled were unmanaged, and the trees were dominant or co-dominant with no signs of stem breakage or suppression. Most of the sample trees were between 150 and 350 years of age and the site index ranged from 3 to 15m (mean 8m). The years-to-breast-height function for coastal western hemlock is being used for mountain hemlock.



5.5.6 Red alder

The height-age equation was developed from stem analysis of 30-0.04 hectare plots from natural red alder stands in the CWH biogeoclimatic zone in British Columbia (Nigh & Courtin, 1998). Breast height ages ranged up to 54 years and site index ranged from about 15 to 28 m. Conversions from a breast height age 25 site index to a breast height age 50 site index are derived from the height-age model.



5.6 Existing and Future Managed Stand Analysis Units - TIPSY inputs

The following section describes the inputs for modelling growth and yield for existing and future managed stand analysis units. A description of existing unmanaged (natural) stands is provided in section 5.8. Inputs such as species composition, site index and densities of spatially delineated stands are run through the *Table Interpolation Program for Stand Yields* (TIPSY). TIPSY is a growth and yield program that reports managed stand yield tables generated by the *Tree and Stand Simulator* (TASS) program (Di Lucca, 1999), which in turn is based on over 15,000 Permanent Sample Plot measurements throughout BC. Growth projections are based upon pure (single species) even-aged stands. Growth for multiple species stands (e.g., the majority of Haida Gwaii stands) are not biologically modelled in TASS (e.g., interspecies interactions are not accounted for), but growth is prorated based upon species composition and site index. TIPSY reports growth curves, starting at age zero, for each spatial unit used in the timber supply analysis.

For this timber supply analysis two separate sets of growth and yield curves were generated for existing and future managed stands (collectively referred to as *managed stands*). A total of 4,542 curves were generated for existing stand analysis units, and a total of 807 curves were generated for future managed stand analysis units (see descriptions below).

Figure 5.6.1 is a conceptual diagram of key inputs that go into TIPSY for existing and future managed stands.

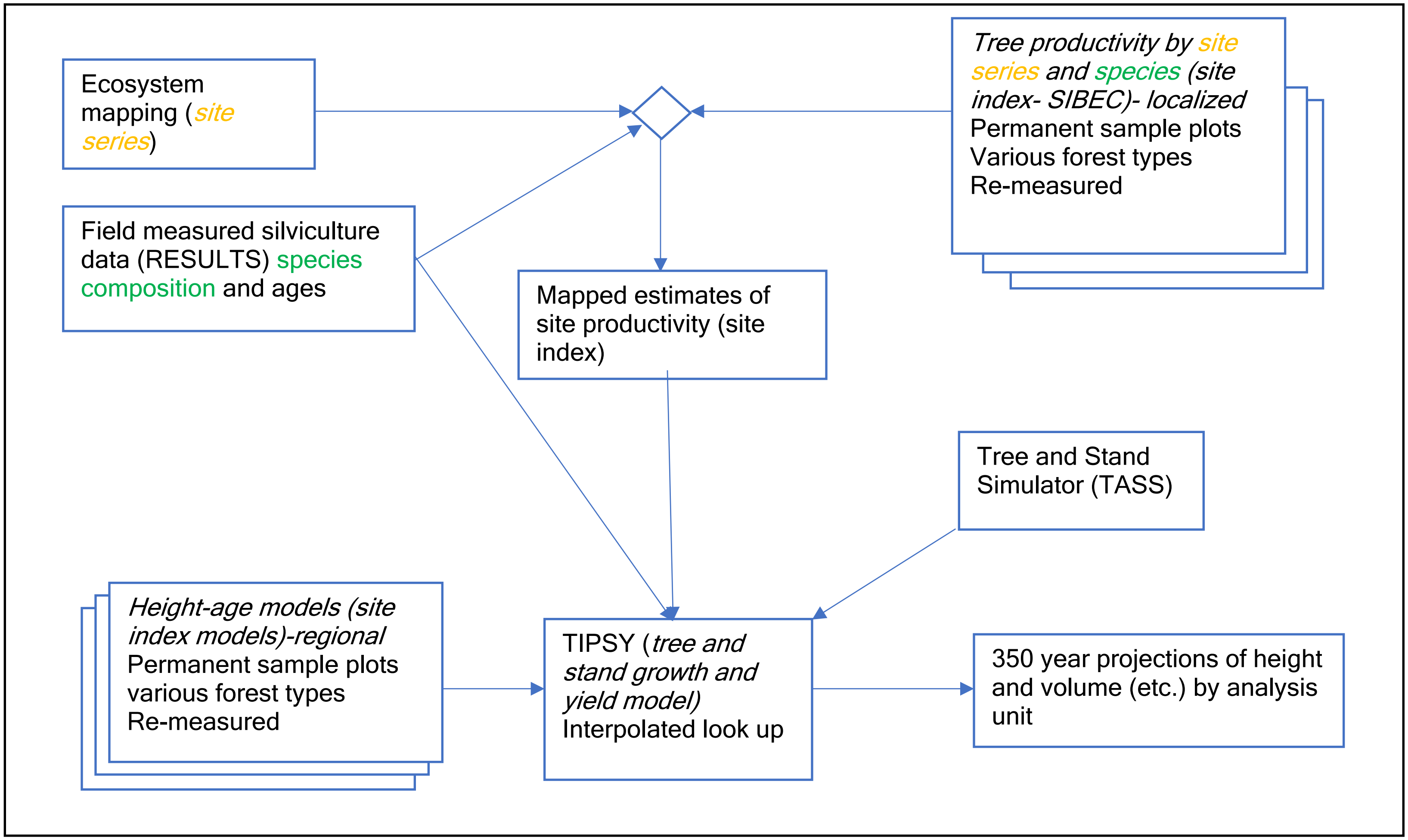


Figure 5.6.1 Conceptual diagram of key inputs and sources into the growth and yield model *TIPSY* for this TSR

The source of both the existing and future managed stand inputs into TIPSY for age, species composition, site series (linked to SIBEC site index) and density is the RESULTS forest cover silviculture layer (WHSE_FOREST_TENURE.RSLT_FCSLV dataset (Resource Practices Branch, 2017)). RESULTS silviculture records can date back to 1987, when the requirement for silviculture prescriptions was legislated[22]. Haida Gwaii digital spatial silviculture records go back to 1991 and include 39,426 hectares (up to 2017) of existing managed stand data. Each individual standard unit (with site specific silviculture classifications and prescriptions for site series and stocking) forms the basis of inputs for existing managed stand analysis units. Future managed stands use the attributes from RESULTS averaged to the site series. Together there are 5,349 managed stand yield curves for this TSR. All stands established after 1986, but without RESULTS silviculture records, are regenerated on TIPSY future managed stand curves. The inputs for existing and future managed stands are the same unless otherwise noted in this section.

5.6.1 Species composition

Existing Managed Stands (EMS)

All species composition data (up to 5 species) are sourced from RESULTS. Units are at the Standard Unit scale, which is the unit delineated during a silviculture prescription. VRI standards also incorporate RESULTS silviculture data, however data are generalized to the block, or Feature ID scale. Using the Standard Unit scale was preferable to using the Feature ID scale (blended block) for the following reasons:

- Blocks have a variety of Standard Units, each may be a separate ecosystem (site series) with different species compositions and productivity.
- In the CHWwh1 Queen Charlotte Lowlands ecosection, Cw-Hw salal-deer fern sites (04 or 110) are often a secondary ecosystem to zonal sites. Generalizing species composition to the zonal site would misrepresent (e.g., underestimate) cedar composition by leaving out the 04 site series. Given the importance of quantifying cedar stocks for this TSR, a higher resolution product was considered the best available data.
- Maintaining the Standard Units provides a closer representation of what is in the field. The use of Batch TIPSY software facilitates an increased number of growth curves enabled by higher resolution data sets.

The existing managed stands were comprised of a total of 4,542 units from RESULTS (e.g., 4,542 separate growth curves).

Future Managed Stands (FMS)

TSR analyses sometimes assume that future managed stands will have the same species composition as current unmanaged forest inventory. For this timber supply analysis, FMS species composition was based on data that are sourced from the WHSE_FOREST_TENURE.RSLT_FCSLV dataset (Resource Practices Branch, 2017) and has been compiled to provide estimates for inputs into TIPSY. An analysis was completed to determine what the species composition was, by site series, in second growth stands, based on the time a stand was declared as free growing. Free growing stems (FGS) are a subset of well-spaced trees that are not constrained by the competition from shrubs or other trees, meet a well-spaced definition, and meet the requirements for free growing height (Resource Practices Branch, 2016). Free growing stems best correlates with ‘crop trees’ (pers. com. Craig Wickland, RPF, section head- Forest Stewardship Branch, MFLNRORD).

A weighted area analysis by species and site series only included records where the reference year (REF_YR) was after the year 2009. This was to acknowledge the change in the HG Forest District cedar policy in 1995 and 1998 where minimum stocking standards were required. Major licensees began planting to the new standards in the spring of 1999 (pers. com. Ken Briggs, RFT), and free growing takes between 8-12 years from the date of planting (therefore the reference year was set to 2009).

[22] *Bill 70- Forest Amendment Act No. 2, 1987*

Based upon expert review (K.Briggs, RFT and Mark Salzl, RPF) it was concluded that the main change in stocking standards after both the 1998 District policy change and the 2011 LUOO was for zonal site series in the CWHwh1. In this case it is anticipated that FGS for western redcedar (Cw) will be between 200-225 SPH, from a total of 700-800 FGS (approximately 25-32% Cw content). To account for this adjustment, the RESULTS species composition was pro-rated (species were proportionately reduced) to account for the increase in Cw, however to remain pre-cautionary about the degree to which cedar will become established, the lower FGS estimate (25%) was used. This assumption is in part underwritten by Haida Gwaii Natural Resource District planting records (RESULTS) that show the proportion of the total planted for redcedar ranged from 25% in both 1988-1995 (pre-district cedar policy), and 1995-2011 (post- district cedar policy), to 28% from 2012-2017 (post-LUOO), see figure 5.6.2. This small increase may be concentrated within the CWHwh1 zonal site series (as suggested by licensee silviculturalists).

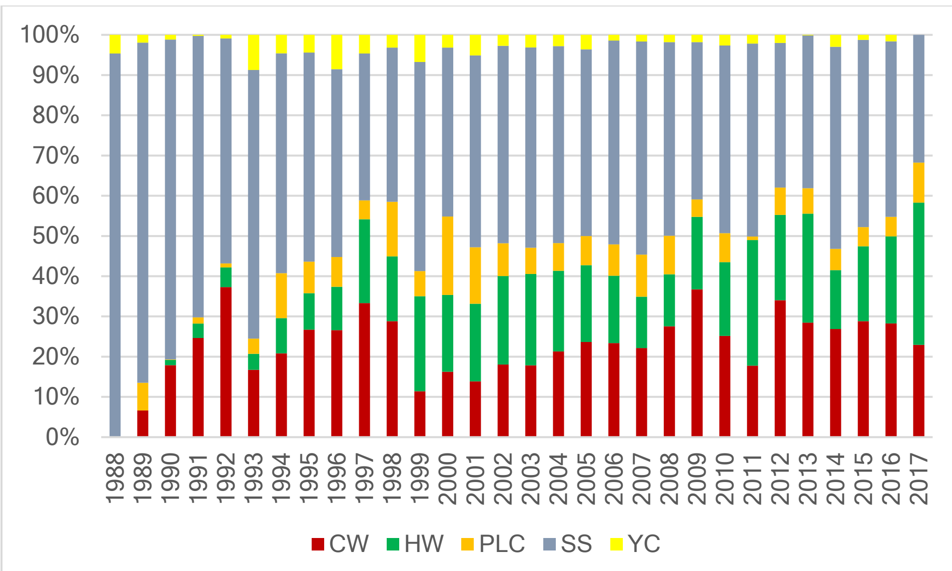


Figure 5.6.2 . Proportion of planted species from 1988-2017 on Haida Gwaii

Shifts in species composition over a rotation period is a legitimate concern. Western redcedar is of specific interest during this TSR and given the higher site index for western hemlock in the most common cedar-leading stands, managers (and modellers) would like to know how much species composition changes between 'initial condition' and harvest. A composition change analysis was conducted with 65 Permanent Sample Plots (PSPs) where re-measurement data existed for leading western redcedar stands. The percent change (±) in composition was calculated between first and last measure (earliest from 1964, latest from 2012). The results were that 90% of the Cw leading species within the plots changed by ±8.46% over the course of the re-measurements (with Cw remaining as a leading species). The average change in leading species (Cw) composition between initial measurement and last re-measurement within the plots was 2.5%. The average time between re-measures for this dataset was 18 years (min 5, max 41 years) which suggests that leading species composition (for pole sapling to understory re-initiation succession) does not change significantly over this period.

Where there were gaps in the ecosystem mapping coverage with RESULTS, the PSPL was used in conjunction with VRI leading species.

Table 5.6.3 Future managed stand species proportion (%) and density (sph) inputs into TIPSY

Site Series	Cw	Hw	Hm	Ss	Yc	Pl	Dr	Free Growing density
CWHwh1 01	25	44		29		1		1315
CWHwh1 02	32	51				17		835
CWHwh1 03	3	44		49			3	1840
CWHwh1 04	33	51		3	1	11		1107
CWHwh1 05	4	34		54		1	7	1251
CWHwh1 06	15	46		34	3	2		817
CWHwh1 10	35	51		2	1	11		1021
CWHwh1 11	33	28				39		375
CWHwh2 01	2	62	2	33	1			1172
CWHwh2 02	9	72	2	11	5			1090
CWHwh2 03	2	50		48	1			1398
CWHwh2 04	4	51	1	41	4			1035
CWHwh2 05	11	57	7	1	13	11		720
CWHwh2 06	11	66		17	4		1	1121
CWHvh2 01	21	59	1	14	5			975
CWHvh2 03	27	66		1	6			907
CWHvh2 04	6	45	48				1	2003
CWHvh2 05	6	53		42				748
CWHvh2 06	7	42		51				802
CWHvh2 07	2	60		38				580
CWHvh2 11	14	55		26	5			856
MHwh 01		34	31	35				907
MHwh 02					100			494
MHwh 03		85	15					1107
MHwh 04		34	31	35				1107
MHwh 05	50		13	25	12			1107
MHwh 06	50		13	25	12			984
MHwh 07	50		13	25	12			1107
MHwh 09	50		13	25	12			984

5.6.2 Site Index

Site index was derived from the enhanced SIBEC table and the Provincial Site Productivity Layer, as described in section 5.3. Site index was assigned to each species component therefore site index conversion equations were not used[23].

5.6.3 Regeneration method

Not all stems that reach free growing are from planted stock, as natural regeneration is a common and important part of silviculture strategies. An analysis of 933 opening ID's using RESULTS planting records[24] compared planted stems (initial establishment) to free growing stems. In Figure 5.6.3 points to the left of the diagonal reference line represent opening IDs in which there are more trees in the free growing surveys than were planted. This difference is a result of natural ingress. TIPSY however does not provide an option to initiate a curve with planted *and* natural stock. While there is some modelling uncertainty introduced, it was considered reasonable for all existing and future managed stands to be treated as *planted* within TIPSY for the base case.

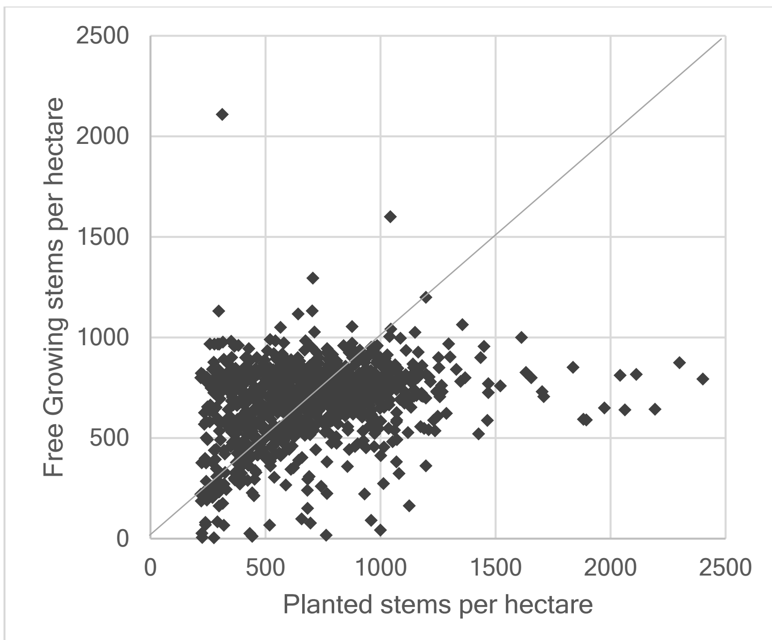


Figure 5.6.3 Planted versus free growing stems per hectare for 933 opening IDs (90th percentile of all openings with planting and free growing records).

5.6.4 Utilization limit

Utilization limit, also known as merchantability limits, defines the minimum diameter at breast height that a tree must achieve to be included in TIPSY stand attributes reports. For this TSR, utilization limits are 12.5 cm, which is the minimum diameter that stumpage is applied to second growth stands in B.C., as outlined in the Coast Merchantability Specification of the Provincial Logging Residue and Waste Procedures Manual (Timber Pricing Branch, 2018).

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[23] Site index conversion equations are often used for stands with multiple-species to predict the site index of an additional (e.g. secondary, etc.) species through statistical regression based on the site index of a reference species with a known site index.

[24] Haida Gwaii Natural Resource District planted trees tracked in RESULTS, sourced from Mei-Ching Tsoi, Oct 30, 2017.

5.6.5 Operational Adjustment Factor 1[25] (OAF1)

OAF1 is designed to capture gaps or non-uniformity of stands as they reach harvest age. OAF1 is a constant multiplier applied uniformly at all ages. The ministry default is 0.85, which was used for this analysis (assumes that 15% of the area of a stand is not occupied by commercial trees). OAF1 is used to reduce yields for various abiotic and biotic factors not accounted for in the data that underlie TIPSY. Small, unmapped non-productive area (NP, e.g., rock and wetland) is normally the dominant abiotic factor, but it can also include weather-related stocking loss (e.g., wind, snow, ice). Biotic factors include competition-related stocking gaps on otherwise productive ground, e.g., growing space occupied by non-commercial species or brush, and other endemic losses, e.g., forest health impacts, etc.

5.6.6 Operational Adjustment Factor 2[26] (OAF2)

OAF2 is a progressive multiplier; the value and impact increases with age. The ministry default is 0.95, which was used for this analysis (5% loss at 100 years). The default is generally assumed to account for merchantable volume losses due to decay, waste, and breakage (DWB). However, OAF2 can also be used for endemic biotic factors (e.g., forest health impacts) with yield effects that increase over time.

An OAF2 value is indexed to age 100, such that its specified value (e.g., 0.95) equals its yield impact at age 100. The impact increases by a constant amount per year ((1-OAF2)/100 yrs) reaching the specified value at age 100 and continues increasing by the same percentage per year thereafter. For example, for an OAF2 of 0.90, yields are multiplied by 0.999 at age 1, 0.95 at age 50, 0.90 at age 100 (the index year), and 0.80 at age 200, etc.

Young Stand Monitoring plot results indicated that tree-level forest health factors affected 7% of live trees (not including windthrow[27] or forks/crooks), including 1% for dwarf mistletoe (western hemlock), 1% broken tops, 2% logging wounds and 3% unknown damage (DeJong, 2017b). Not all of these forest health factors will affect merchantable volume (DWB). Similarly, a review of 10 years (2008-2017) of blocks from the Harvest Billings System second growth blocks (*n*=175) listed avoidable waste as 8.4% of total volume scaled. This is slightly higher than the OAF2 applied, however is reasonable when considered in tandem with both OAFs (e.g., 20% reduction).

See sections 4.1.3 and 5.8.5 for a description of decay, waste and taper inputs for unmanaged/natural stands in this timber supply analysis.

5.6.7 Regeneration Delay

Regen delay is the number of years from disturbance (e.g. harvesting) to the beginning of the stand establishment period. For all planted stands the default used in this timber supply analysis was 1 year, which assumes all stands are planted 1 year after logging. Note that planted stock assumes 1-year old stock, effectively moving the regeneration delay to zero.

5.6.8 Genetic worth

Genetic worth is an indication of the quality of genetically improved seed, as represented by a percentage volume increase expected near harvest age. The MFLNRORD's Forest Genetics Program develops genetically improved seed through selective breeding programs of seed collected from superior natural (wild) trees. The Seed Planting and Registry System (SPAR) tracks seedlot information used within different Natural Resource Districts across the province and includes information on genetic worth (by seed class) and selection age.

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[25] sourced from TIPSY 4.4

[26] (sourced from TIPSY 4.4)

[27] Note that windthrow is treated as a natural disturbance factor as described in section 7.4.

An analysis of the genetic worth of seedlings from the SPAR system for the Haida Gwaii Natural Resource District is provided below. The weighted average of select seed used (from which genetic gain is estimated) over a 15-year period on Haida Gwaii amounts to 71% of all seed. Of that select seed, the majority has a genetic worth of 2% (SPWR003(v2), 2018). When accounting for the weighted average (select seed vs. non-select seed) genetic worth for each species over that 15-year period, Cw has 2.06%, Hw has 1.99% and Ss has 1.4% genetic gain, with a total weighted-average (all species) of 1.8%. Accounting for the proportion of select seed (71%) this lowers the genetic worth to 1.27%. In a similar analysis, the Haida Gwaii Young Stand Monitoring project found that 50% of its randomly established plots (post 1987) were made up of natural stands (DeJong, 2017b). The uncertainty of planted crop trees *versus* natural crop trees at harvest age further dilutes the confidence in increased genetic gain. As such, genetic gain was not included in TIPSY growth curves.

5.6.9 Stock height

Planted tree stock heights used in this timber supply analysis are defaults used within TIPSY, which in turn are sourced from Forest Practices Branch (1998). All stock ages are assumed to be 1-year old.

Table 5.6.9. Planted tree stock heights used in TIPSY. Note bold heights have been weighted by the planting frequency of different stock types (e.g, PSB415B, PSB 410, BSB 313B, PSB/PCT 415B).

Species	Stock heights (cm)
Western hemlock	**22**
Western redcedar	**27**
Sitka spruce	26
Yellow cedar	27
Lodgepole pine	**13**
Mountain hemlock	22

5.6.10 Density

Density is the initial stocking condition in the TIPSY model, in other words the number of established trees within the stand expressed in stems per hectare (SPH). RESULTS silviculture planting data and free growing data from silviculture surveys was summarized by BEC site series. Stands are typically a mix of natural and planted trees, whereby planted stocking targets range between a minimum of 500 stems per hectare to a maximum of 900 stems per hectare (Taan Forest Ltd & Limited Partnership, 2018), but may be as low as 200-400 SPH on very wet sites. Free growing surveys are a measure of well-spaced trees that are anticipated to become crop trees (Resource Practices Branch, 2018). Free growing is a requirement under section 97(7) of the *Forest Planning and Practices Regulation*, including declaration of a regeneration date. Regeneration is qualified by a site-specific strategy (species composition, heights and SPH). Competition pressures from naturals (e.g. western hemlock) are often highest ahead of free growing. Therefore, data from free growing surveys is a more useful indicator of species composition than planting data as trees move into older successional stages (e.g. pole sapling). However free growing surveys tend to occur between 8-12 years after the initial stocking condition.

To account for this, free growing survey SPH was compared to TIPSY SPH (initial condition) at age 10 for zonal sites for the CWHwh1, CWHwh2, CWHvh3 and MHwh. The objective was to determine what TIPSY density input (initial condition) would produce outcomes closest to the RESULTS free growing numbers at age 10 for zonal sites for all BEC zones on Haida Gwaii.

For example, the weighted-area average density for zonal (01 or 101) site series within the CWHwh1 is 1315 SPH at free growing. An adjustment factor of 1.22 in TIPSY (1315 x 1.22) sets an initial condition (age 0) of 1604 SPH in TIPSY, coming closest to the 1315 target at age 10 (due to the reverse J-Curve theory of diminishing stems over time). Table 5.6.10 lists the density adjustment factors applied to the RESULTS-based density figures. Note that table 5.6.1 provides the RESULTS density figures by site series that were inputs into TIPSY.

Table 5.6.10. Density adjustment factors applied to RESULTS free growing stems per hectare data to set initial (stocking) condition in TIPSY

BEC zone	Density adjustment factor
CWHwh1	1.22
CWHwh2	1.19
CWHvh2	1.23
MHwh	1.23

Note that TIPSY does not allow for initial densities to be lower than 494 SPH, therefore a limited number of records were adjusted to meet this criterion.
Where there were gaps in the ecosystem mapping coverage, and PSPL was used, the density was set to TIPSY default of 1600 stems per hectare.

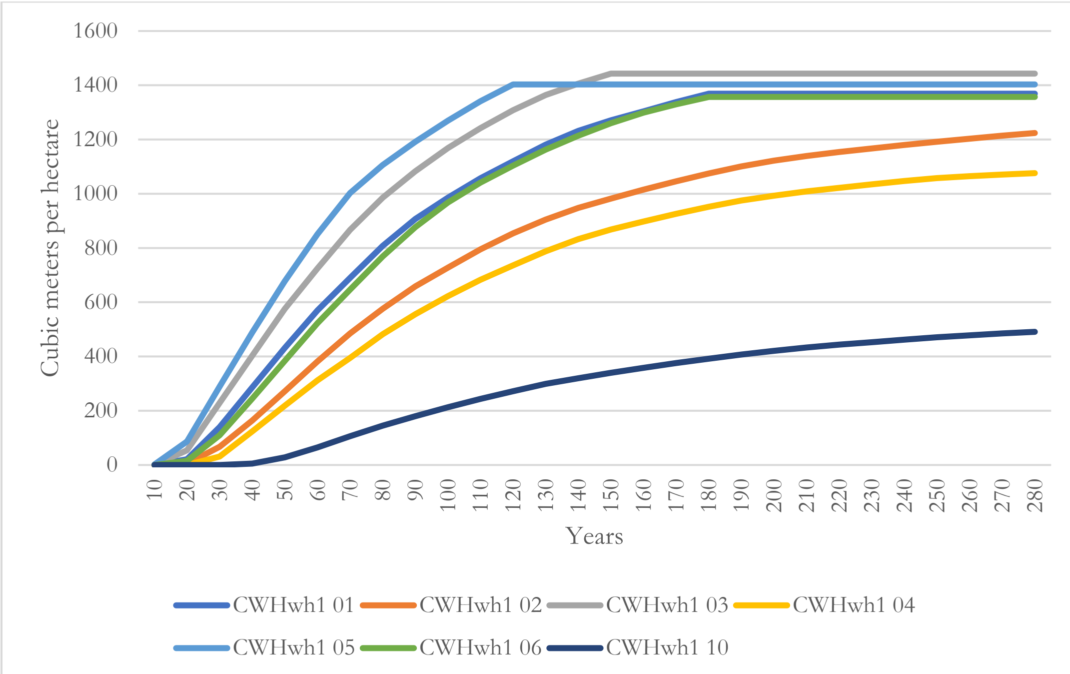
5.7 Growth Curves

The following graphs illustrate the growth curves of the most common analysis units (site series) for future managed stand tables on the THLB. It is impractical to graph the individual curves of the existing managed stand tables as each standard unit/silviculture record has its own curve. Note however that, as the future managed curves are derived as averages from the existing managed stand data (RESULTS), the curves by site series are very similar. Note that units are presented in the Green et al (1994) classification format, as this is the format of most of the ecosystem mapping on Haida Gwaii (including within RESULTS)[28].

Appendix 4 provides a detailed evaluation that compares future and existing managed stand growth and yield curves using Haida Gwaii Permanent Sample Plot (PSP) re-measurement data by BEC site series.
Whereas Analysis Units generally move from a natural stand curve to a future managed stand curve after harvesting in the timber supply model, a small amount of area does not have a corresponding future managed stand curve, as a result of data gaps in ecosystem mapping or the Provincial Site Productivity Layer. In these instances that harvested areas regenerate again on the same natural stand curves.

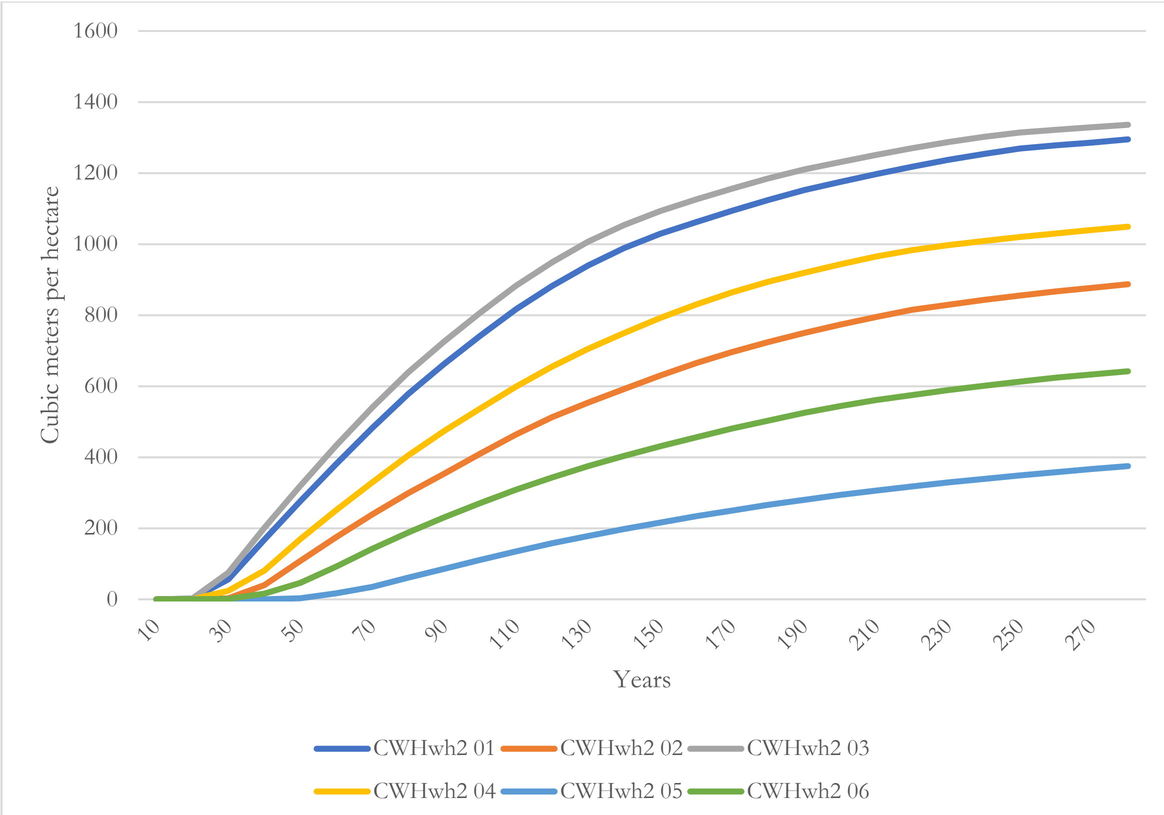
[28] Section 4 provides a crosswalk table between the current BEC format (2014) and the old format (1994).

Table 5.7.1 TIPSY growth curves for key site serieswithin the CWHwh1 (Green, 1994)



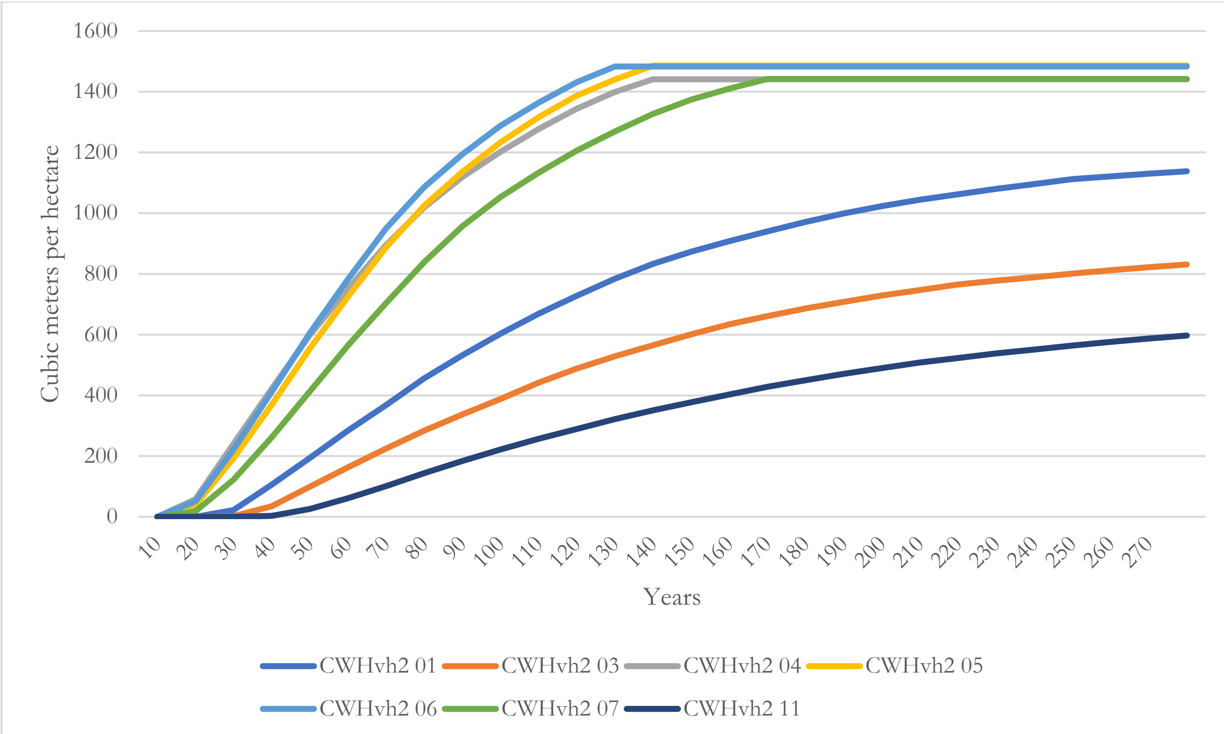
Site Series	Culmination Mean Annual Increment (CMAI)	Age at CMAI (rounded)
CWHwh1 01	10.1	80
CWHwh1 02	7.3	90
CWHwh1 03	12.4	70
CWHwh1 04	6.2	100
CWHwh1 05	14.3	70
CWHwh1 06	9.7	90
CWHwh1 10	2.3	130

Table 5.7.2 TIPSY growth curves for key site series within the CWHwh2 (Green, 1994)



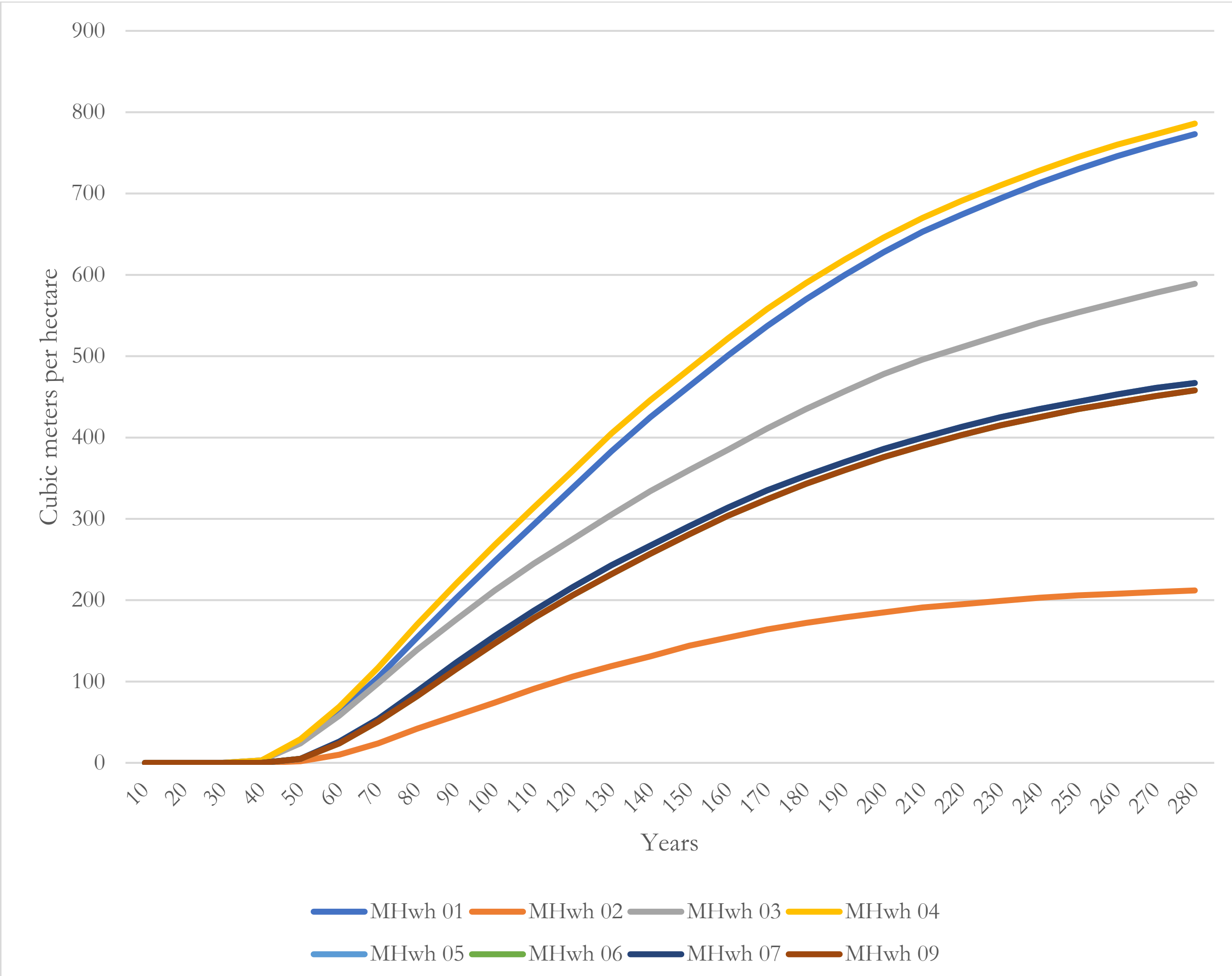
Site Series	Culmination Mean Annual Increment (CMAI)	Age at CMAI (rounded)
CWHwh2 01	7.4	110
CWHwh2 02	4.3	120
CWHwh2 03	8.0	100
CWHwh2 04	5.5	120
CWHwh2 05	1.5	180
CWHwh2 06	2.9	140

Table 5.7.3 TIPSY growth curves for key site series within the CWHvh2 (Green, 1994)



Site Series	Culmination Mean Annual Increment (CMAI)	Age at CMAI (rounded)
CWHvh2 01	6.1	110
CWHvh2 03	4.1	130
CWHvh2 04	12.8	70
CWHvh2 05	12.8	80
CWHvh2 06	13.6	80
CWHvh2 07	10.6	90
CWHvh2 11	2.5	160

Table 5.7.4 TIPSY growth curves for key site series within the MHwh (Green, 1994)



Site Series	Culmination Mean Annual Increment (CMAI)	Age at CMAI (rounded)
MHwh 01	3.2	180
MHwh 02	1.0	170
MHwh 03	2.4	170
MHwh 04	3.3	170
MHwh 05	2.0	170
MHwh 06	1.9	170
MHwh 07	2.0	170
MHwh 09	1.9	170

5.8 Natural Stand Growth and Yield

Variable Density Yield Projection version 7 (VDYP7, hereafter called VDYP) is the provincial empirical growth and yield prediction program specialized for updating and projecting attributes in the otherwise static VRI beyond the initial year of interpretation, through the VRIMS (Vegetation Resources Inventory Management System). Independent of the VRIMS, VDYP is also used to create natural stand yield tables for timber supply analyses. It is based on 52,000 permanent field plots and 9300 temporary sample plots province-wide (FAIB, 2007). VDYP7 projects stand heights, diameters, basal area, stems per hectare and volumes at various utilization levels and stand ages and bases its projections on forest inventory attributes such as age, height, species composition, density of stems, basal area, and site index, and BGC Zone.

In this Haida Gwaii TSR, all the natural stands have height and volume curves generated using VDYP. Natural stands are defined as those stands that have no history of silviculture and established before 1986. Most of these natural stands have not been felled commercially and therefore are old stands, but some have been harvested and were naturally regenerated prior to the time when stocking standards were applied in FRPA and FPPR.

A progression of several sets of VDYP7 curves were developed for this analysis to help assess the implications of the various data sources and models, on the way to deciding which to use in the base case:

1. Phase 1 VDYP curves: from VRI Phase 1 (photo-interpretation) inputs.
2. Phase 2 VDYP curves: Phase 2 (mature ground audit) attribute adjustments made to VDYP inputs.
3. LEFI-based VDYP curves: LiDAR Enhanced Forest Inventory (LEFI) curves from a combination of VRI Phase 1 and LEFI inputs.
4. LEFI-based analysis unit curves: The LEFI-based VDYP curves were aggregated into 66 analysis units (AUs).
5. LEFI volume adjustments made to analysis unit curves: The LEFI-based VDYP curves were adjusted based on LEFI net merchantable volumes. This set of 66 AU curves is used in the base case.

The following sections provide specifics related to each of these sets of volumes curves.

To help illustrate the different outcomes among these types of curves, two charts showing the existing timber volumes are presented below; one for western red cedar leading, and one for hemlock leading stands. These charts plot the average volumes in cubic metres per hectare of stands of the same age based on the various yield estimates listed above. The inventory volumes matching the Phase 1 VDYP are shown in black. Phase 2 adjusted VDYP volumes are shown in red. LEFI-based VDYP volumes are green. LEFI net merchantable volumes are in purple.

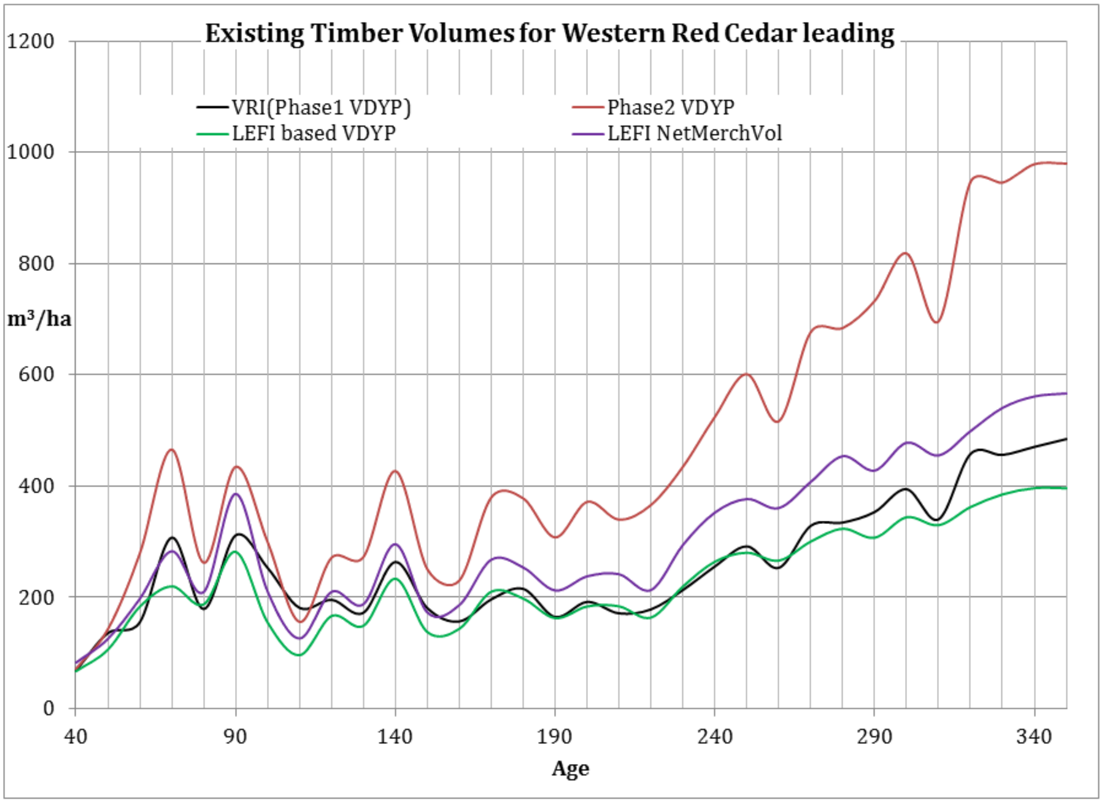


Figure 5.8.1: Existing Timber Volume Comparisons for Western Red Cedar Leading Stands

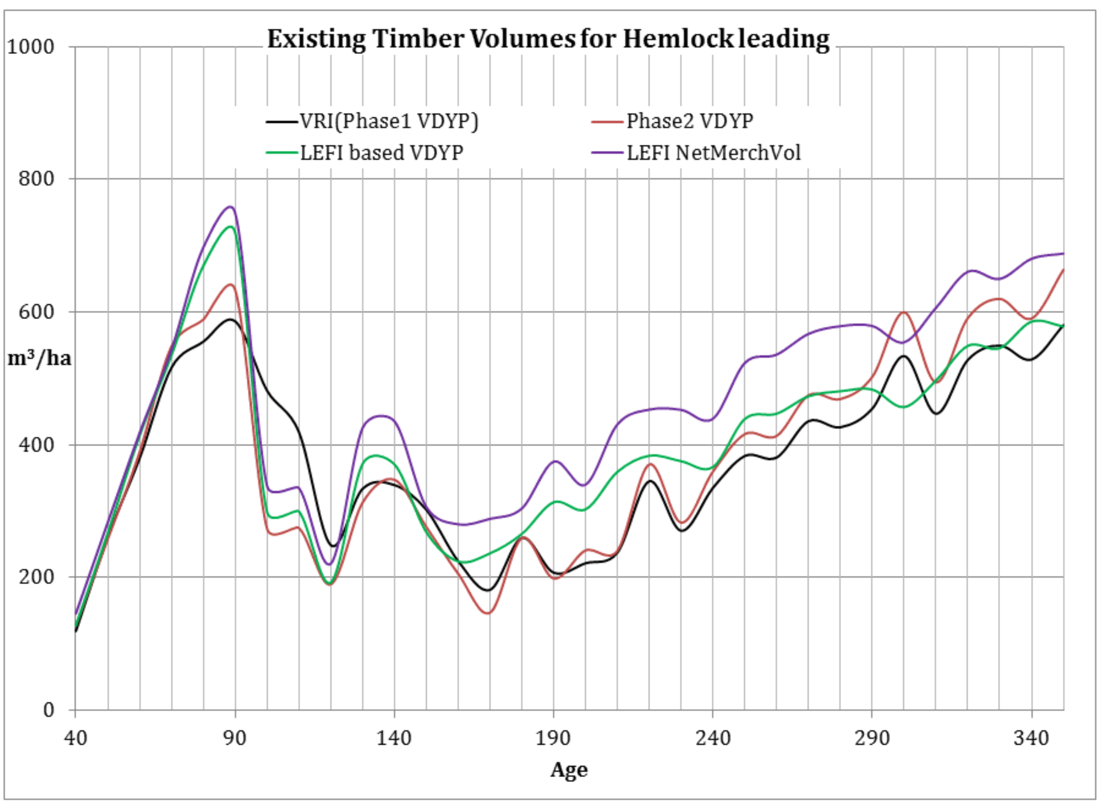


Figure 5.8.2: Existing Timber Volume Comparisons for Hemlock Leading Stands

5.8.1 Phase 1 VDYP Curves

The first set of natural stand yield tables (curves) generated for this TSR from VDYP was the Phase 1 VRI curves. These curves are specific to each VRI polygon and are consistent with the VRIMS which means that the current volume of stands on these curves matches the value found in the VRI. All the required VDYP7 inputs were available in the Phase 1 VRI which is based on air photo interpretation. They were prepared for initial modeling and comparison purposes only, and were not used in the base case.

5.8.2 Phase 2 VDYP Curves

A second set of curves was produced using the results of the Phase 2 assessment of the accuracy of the Haida Gwaii Phase 1 inventory. Such a ground-plot based study is a standard method following a Phase 1 inventory and the findings can be used to verify and enhance the Phase 1 inventory attributes used as VDYP inputs. The details of this Phase 2 VRI program are provided in the Haida Gwaii Vegetation Resources Inventory Analysis – Volume Audit (Mature) report by Penner (2018). The Phase 2 adjustments were made in creating the set of Phase 2 VDYP curves which ended up being an interim step, given concerns about the confidence about the adjustments, as discussed immediately below. These were also VRI polygon specific curves.

The Phase 2 study resulted in very large bias estimates for cedar. However, the sampling error associated with that estimate was also largely due to a limited sample size. Figure 5.8.1 above shows the differences between the curve sets discussed here in the cedar leading stands. The very high volume estimates from the Phase 2 adjustments for red cedar is obvious. Figure 5.8.2 shows the effect on the growth and yield of hemlock leading stands.

The Phase 2 study suggests that there were biases associated with the Phase 1 inventory, which needed to be addressed. However given the large sampling errors associated with the Phase 2 adjustments, particularly for cedar, the TWG evaluated the potential of another data source for natural stand growth and yield refinements.

5.8.3 LEFI-based VDYP Curves

Fortunately, a new forest inventory technology product is also available for a large proportion of Haida Gwaii including the majority of the THLB: LiDAR enhanced forest inventory or LEFI. The LEFI model generates 20 metre raster grids of six inventory attributes: basal area, Lorey height, top height, stems per hectare, quadratic mean diameter, and net merchantable volume. The LEFI combines information from ground plots and from LiDAR to derive forest attributes that can be used with a high degree of confidence.First, correlations between the compiled field plot data and the LiDAR are created for all the available field plots. Those correlations are then extrapolated to the rest of the LiDAR extent on a 20m raster grid using least difference parametric equations. The LiDAR Enhanced Forest Inventory (LEFI) Haida Gwaii Summary Report 2016/2017 by Yuan and Wang (2017) contains further information.

Having LiDAR and LEFI available meant having a viable option for Natural Stand Yield Table (NSYT) inputs and led to a recommendation from FAIB inventory specialists to use LEFI-based NSYTs in the base case as the best available information, instead of the Phase 2 adjustment-based curves. All of the LEFI attributes were used as VDYP inputs except for LEFI net merchantable volumesince VDYP does not use volume estimates from other sources as input. However, the LEFI volumes were used later for ratio adjusting the VDYP curves (see 5.8.4 below).

It was necessary to combine LEFI and VRI attributes for a complete set of VDYP inputs because LEFI does not provide all of the input required for VDYP. VDYP also requires species composition, stand age and site productivity inputs which are available for each polygon from the VRI Phase 1. This need to combine LEFI and VRI attributes led to the decision to produce LEFI attribute averages for each VRI polygon.

So, the inputs for this third set of VDYP curves are:

- VRI polygon averages for the following LEFI values
  - basal area,

    - Lorey height,
    - top height,
    - stems per hectare,
    - quadratic mean diameter
- VRI polygon values from Phase 1
    - age,
    - species composition, and
    - site index (from Site Tools).

This third set of curves was created for all VRI polygons with LiDAR data coverage since that is also the LEFI extent. For the area that was lacking LiDAR and LEFI, aggregated analysis unit curves were used, as described in the next step (Section 5.8.4).

5.8.4 Analysis Units for LEFI-based VDYP Curves

Creating the fourth curve set involved aggregating the VRI polygon-specific LEFI-based curves in the third set together into much larger analysis units. Advantages of creating aggregated analysis units include:

i. It is easier to report, display and discuss a few dozen curves than 84,000, which is the approximate number of VRI polygons.
ii. Aggregating has the effect of cleaning up a minority of odd shaped curves and other anomalies that resulted with the mix of the algorithm-based inputs from LEFI and the attributes based on photo-interpretation, which came from VRI.
iii. The forest cover information at the polygon level, at least for the Phase 1 inventory, is subject to uncertainty. Averaging over many similar polygons combines information for the class which evens out the polygon-level uncertainty.
iv. LEFI (same extent as LiDAR) is not available for all of Haida Gwaii. With the area weighted aggregation of curves, it became straightforward to extend the LEFI-based curves to the non-LEFI extent of Haida Gwaii.

The VRI polygon-specific LEFI curves were aggregated into 66 analysis unit curves. These were created by area-weighting polygon curves according to:
1. Biogeoclimatic Zone
2. leading species (single letter species codes C, D, H, P, S, Y)
3. site index classes: 00, 01 to 05, 06 to 10, 16 to 20, 21 to 25, 26 to 30, 31 to 45.

The 66 AU curves were distributed to the non-LEFI extent of the forest management land base. This was also done according to BGC Zone, leading species and site index class. Once these analysis units were identified across the entire FMLB, even where there is no LiDAR, the yield tables based on Phase 1 VRI and LiDAR/LEFI information were available for the entire land base. No information from the VRI Phase 2 was used in these VDYP curves or other analysis inputs.

5.8.5 LEFI net volume adjustments of LEFI-based VDPY curves

LEFI net merchantable volumes, like the other LEFI attributes, were generated using information from ground plots and from LiDAR and can be used with a high degree of confidence. The TWG considers the LEFI volumes (which are net of decay waste and breakage at a utilization level of 12.5 cm) the best available information on the current volume of stands. These LEFI net volumes averaged to the VRI polygon are not yield curves. Instead, they represent current volumes. They are useful for adjusting the magnitude of the LEFI-based VDYP curves for two reasons.

Firstly, the ground plot volume calculations on which the LEFI volumes are based are compiled using Haida Gwaii specific taper factors and Haida Gwaii specific loss factors for decay, waste and breakage. In contrast, the VDYP7 model uses taper factors and loss factors that are generalized to the entire area of the provincial BGC zones. The forests outside Haida Gwaii are not exactly the same even if in the same BGC zone and so the factors do not match. In this sense the LEFI net volumes are more specific to Haida Gwaii than the LEFI-based VDYP curves.

Secondly, in attaining the LEFI net volumes, the LEFI model uses parametric equations to extrapolate from these ground measurements and locally specific compilations. This is a high-resolution extension of the ground data that does not involve combining LEFI information with VRI information. In contrast, the LEFI-based VDYP curves (described in section 5.8.3) are produced using VDYP inputs from two very different sources: air photo interpretation and ground plot measurements distributed by the LEFI model. Using the two different sources of information is a creative and carefully considered approach intended to make the best use of the available information, and an improvement over Phase 2 adjustment (section 5.8.2). Using the detailed LEFI information provides a way of verifying and calibrating the yield estimates based on LEFI and VRI inputs and the VDYP model.

5.8.6 LEFI net volume adjustments of LEFI-based VDPY7 curves: Magnitude and Method

With the above justification for making adjustments, the methods and magnitude of the adjustments are described next. The current volumes of stands on the LEFI-based VDYP curves were compared to the LEFI net volumes in scatter plots created for each leading species (C, P, S, and Y, and for H younger than 250 years, and H at least 250 years). For each case, a line of best fit through the origin and a co-efficient of determination (R^2) were generated using MSExcel. There is a distinct pattern in each case. The cedar leading example is shown below (see figure 5.8.6); the remainder are in appendix 9

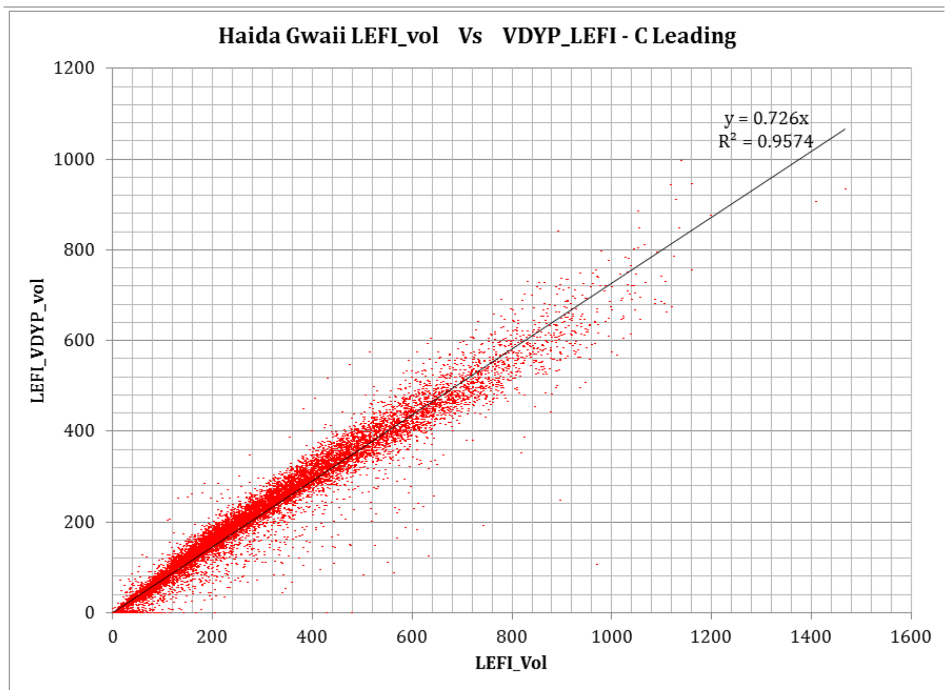


Figure 5.8.6Comparison between LEFI-based VDYP curve volumes and LEFI net volumes for cedar.

These equations of best fit have very high coefficient of determination or R^2 values. This statistic indicates the percentage of the variance in the dependent variable that the independent variable explains. In these cases, depending on the leading species, between 89 and 98 percent of the relationship between the points is described by the line of best fit through the origin (shown in the table below).

Table 5.8.6 Line of best fit ratio- LEFI-based VDYP / LEFI net volume

Line of best fit ratio - LEFI based VDYP / LEFI net vol

Sp1_1	U_O_250	Ratio (current volume LEFI based VDYP / LEFI net vol)	R^2	reciprocal (1/Ratio)
C		0.726	0.957	1.377
H	250 years and over	0.831	0.954	1.203
H	under 250	0.905	0.895	1.105
S		0.875	0.891	1.143
P		0.808	0.951	1.238
Y		0.751	0.980	1.332

Two sources for the difference are proposed. First, VDYP7 does not include the Haida Gwaii specific taper factors and decay and waste factors. Second, the LEFI-based VDYP curves have input from VRI as well as LEFI, and this has an effect of unknown direction and magnitude.

The slopes of those lines of best fit were used to adjust the magnitudes of existing unmanaged stand yield curves; specifically the LEFI-based VDYP curves that are aggregated into 66 analysis units. The reciprocal of these ratios was used as a multiplier.

At this stage, the 66 LEFI-based VDYP curves that were based on LEFI inputs and Phase 1 species, age and SI, as discussed in section 5.8.4, are adjusted using current net merchantable LEFI volume.

5.8.7 Utilization Adjustment

The LEFI net volumes are based on a 12.5 cm diameter utilization limit, whereas the VDYP curves discussed are based on 17.5 cm diameter utilization limit for all species except pine and alder at 12.5 cm. Therefore, a final adjustment was necessary to correct for the difference between 17.5 cm and 12.5 cm utilization. The ratio of the difference between the two utilization limits was found along the analysis unit volume curve using the LEFI-based VDYP curves, then it was applied to the LEFI-based VDYP curves with the LEFI net volume adjustment. The equation used is shown here, followed by a chart (5.8.7) highlighting an example analysis unit; CWH_C_10to15.

A = Volume at 17.5 cm utilization.

B = Volume at 12.5 cm utilization

LV = LEFI-based VDYP volume curves

LVL = LEFI-based VDYP volume curves adjusted using LEFI net volume (12.5 cm utilization)

$$A_{LVL} = A_{LV} * B_{LVL}/B_{LV}$$

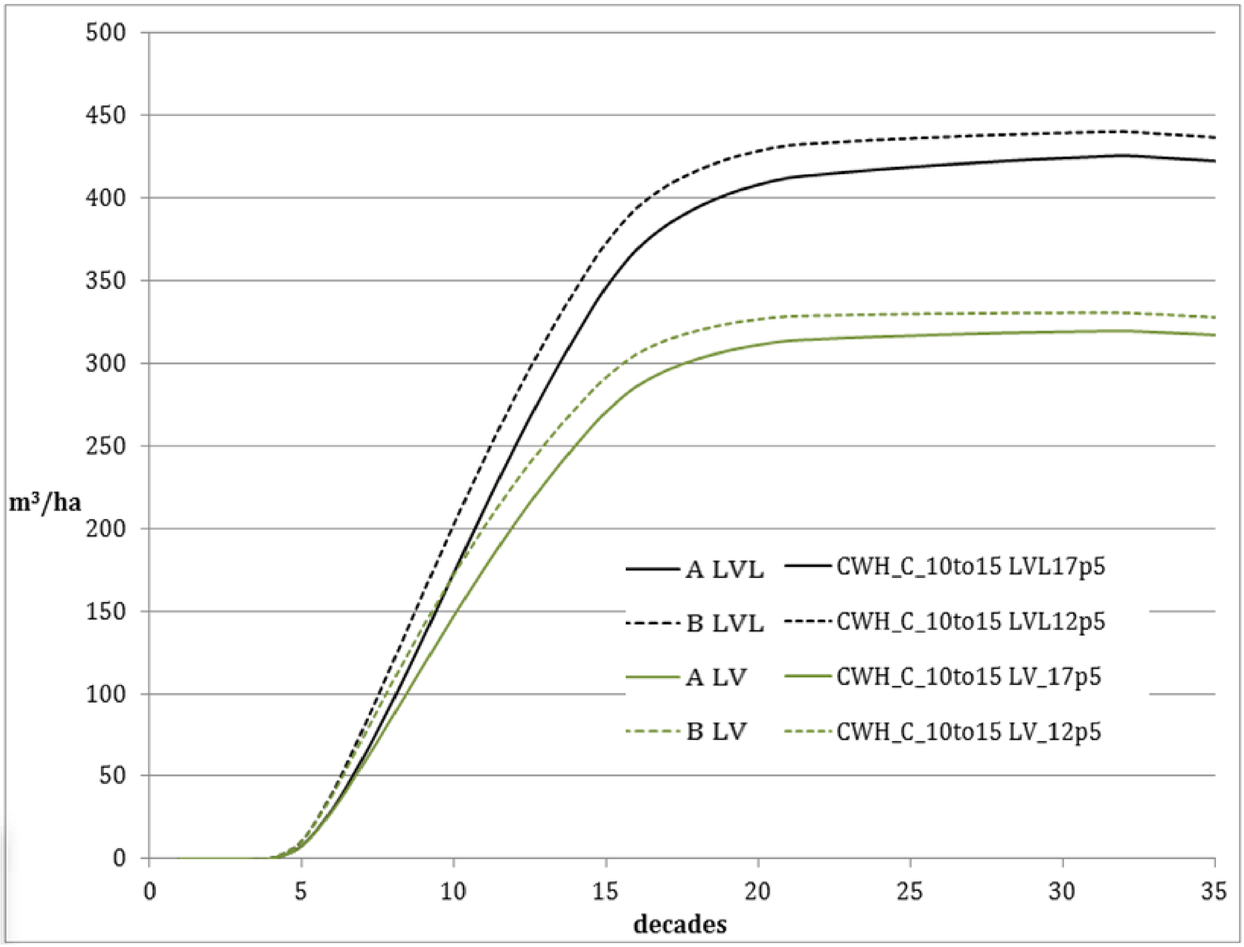


Figure 5.8.7 Differences between 12.5cm and 17.5cm utilization using LEFI-adjusted VDYP curves

The following table summarizes the utilization differences for CWH analysis units covering the majority of the THLB. To reduce the size of the table, it does not include:

- Red Alder AUs,
- AUs not expected to reach 250 m^3/ha,
- AUs with less than 20 ha THLB, or
- Any of the MH AUs – most of them have very little THLB, and the trend is like CWH AUs.

Some trends are apparent in the table:

1. High SI stands are not affected by the utilization change.
2. The difference is greater at younger ages, which is moderated by the time stands achieve the minimum harvest volume (MHV) of 250 m^3/ha. Values that are below minimum harvest volume (MHV) of 250 m^3/ha are struck through to emphasize that the larger differences found at younger ages are not realized in the harvest.
3. Spruce leading AUs are affected the least. Cedar leading and Pine leading are affected more.

Table 5.8.7 Impact of utilization-level change (12.5 cm dbh to 17.5 cm dbh)

					Volume at Util 17.5 cm dbh					Volume at Util 12.5 cm dbh					Util Dif					Util Dif %				
Ha	THLB	CurveSet / Age			50	100	200	300	350	50	100	200	300	350	50	100	200	300	350	50	100	200	300	350
3,534	1,368	CWH	Y	11 to 15	~~28~~	~~178~~	338	352	351	~~35~~	~~204~~	354	363	362	~~7~~	~~26~~	16	11	11	~~21.3%~~	~~12.7%~~	4.5%	3.2%	3.0%
72,759	26,665	CWH	C	11 to 15	~~29~~	~~176~~	314	319	316	~~39~~	~~201~~	329	331	327	~~10~~	~~25~~	15	11	11	~~25.0%~~	~~12.5%~~	4.5%	3.4%	3.3%
17,012	4,762	CWH	C	16 to 20	~~61~~	291	476	475	470	~~79~~	318	486	482	476	~~18~~	27	11	7	7	~~23.1%~~	8.6%	2.2%	1.5%	1.4%
1,841	986	CWH	C	20 to 25	~~241~~	676	877	835	814	~~271~~	681	877	835	814	~~30~~	5	0	0	0	~~11.0%~~	0.7%	0.1%	0.0%	0.0%
327	177	CWH	C	25 to 30	356	891	1,154	1,099	1,075	388	892	1,154	1,099	1,075	32	2	0	0	0	8.2%	0.2%	0.0%	0.0%	0.0%
24,245	9,288	CWH	H	06 to 10	~~19~~	~~168~~	367	359	353	~~25~~	~~194~~	381	369	362	~~7~~	~~26~~	15	10	10	~~26.5%~~	~~13.4%~~	3.9%	2.8%	2.7%
59,502	16,889	CWH	H	11 to 15	~~40~~	292	571	547	534	~~53~~	326	582	553	541	~~14~~	33	11	7	6	~~25.9%~~	10.2%	1.9%	1.2%	1.1%
25,454	11,438	CWH	H	16 to 20	~~157~~	549	809	749	731	~~184~~	564	811	750	732	~~27~~	15	3	2	1	~~14.8%~~	2.6%	0.3%	0.2%	0.2%
35,251	17,758	CWH	H	20 to 25	292	785	1,036	947	923	320	789	1,037	947	923	28	5	0	0	0	8.8%	0.6%	0.0%	0.0%	0.0%
17,204	8,036	CWH	H	25 to 30	418	990	1,255	1,153	1,125	441	992	1,255	1,153	1,125	23	2	0	0	0	5.3%	0.2%	0.0%	0.0%	0.0%
5,184	2,258	CWH	H	06 to 10	509	1,106	1,381	1,267	1,237	525	1,108	1,381	1,267	1,237	16	2	0	0	0	3.1%	0.2%	0.0%	0.0%	0.0%
3,061	1,184	CWH	P	11 to 15	~~56~~	~~191~~	265	254	248	~~61~~	~~200~~	273	262	256	~~5~~	~~10~~	8	7	7	~~8.7%~~	~~4.8%~~	3.0%	2.8%	2.8%
913	330	CWH	P	20 to 25	~~97~~	259	334	319	311	~~105~~	269	341	325	317	~~8~~	10	7	6	6	~~7.5%~~	3.8%	2.1%	1.9%	2.0%
101	64	CWH	P	25 to 30	~~85~~	~~196~~	245	234	229	~~93~~	~~202~~	250	239	233	~~8~~	~~6~~	4	4	4	~~8.2%~~	~~3.1%~~	1.7%	1.7%	1.8%
1,950	471	CWH	S	06 to 10	~~13~~	241	609	577	571	~~17~~	264	617	584	577	4	23	8	6	6	~~24.7%~~	8.7%	1.3%	1.1%	1.0%
5,480	1,016	CWH	S	11 to 15	~~18~~	302	700	661	652	~~24~~	326	706	666	656	~~6~~	24	6	5	4	~~23.5%~~	7.4%	0.8%	0.7%	0.6%
5,870	1,457	CWH	S	16 to 20	~~105~~	511	877	818	805	~~120~~	529	881	821	808	~~16~~	18	4	3	3	~~12.9%~~	3.5%	0.4%	0.4%	0.3%
9,067	3,744	CWH	S	20 to 25	332	914	1,192	1,092	1,075	358	920	1,193	1,093	1,075	26	6	1	1	1	7.2%	0.7%	0.1%	0.1%	0.1%
13,269	5,032	CWH	S	25 to 30	462	1,078	1,317	1,194	1,176	479	1,080	1,318	1,194	1,176	17	2	0	0	0	3.6%	0.2%	0.0%	0.0%	0.0%
15,550	5,260	CWH	S	30 to 45	553	1,187	1,413	1,274	1,256	563	1,187	1,413	1,275	1,256	11	1	0	0	0	1.9%	0.1%	0.0%	0.0%	0.0%

This final set of curves is the set of analysis unit curves used in the base case. These 66 analysis units have LEFI-based VDYP curves adjusted based on the LEFI net volumes, and also the impact of moving from 12.5 to 17.5 cm utilization. These adjustments are applied across the LEFI and the non-LEFI extent of Haida Gwaii.

5.8.8 Example Analysis Unit Charts

The following three charts each show three volume curves; 1) Phase 2 VDYP curves, 2) LEFI-based VDYP curves, and 3) LEFI volume adjusted LEFI-based VDYP curves. All three charts, representing a large portion of the THLB, are focused on an analysis unit within the CWH zone where the SI is between 10 and 15 and each looks at a different leading species: C, H, and S.

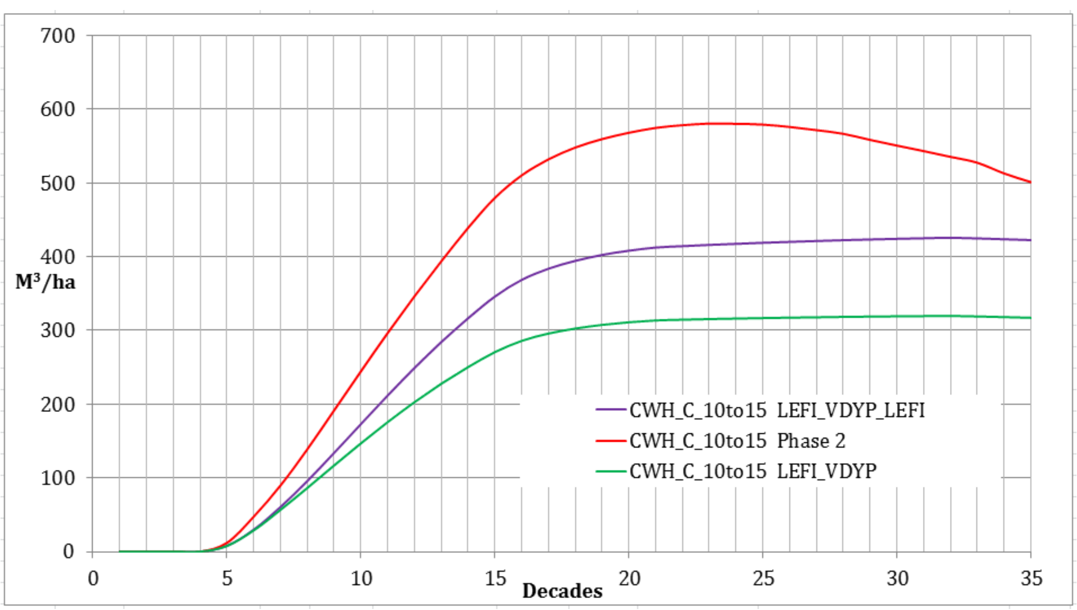


Figure 5.8.8.1: CWH Cedar Leading with SI between 10 and 15.

Figure 5.8.8.1 shows volume curves for the analysis unit containing cedar-leading stands in the CWH zone, with site index 10-15. The Phase 2 curve in red is much higher than the LEFI-based VDYP curve in green, and the curve resulting from the LEFI volume adjustment, in purple, is intermediate between the others. The adjusted curve is used in the base case.

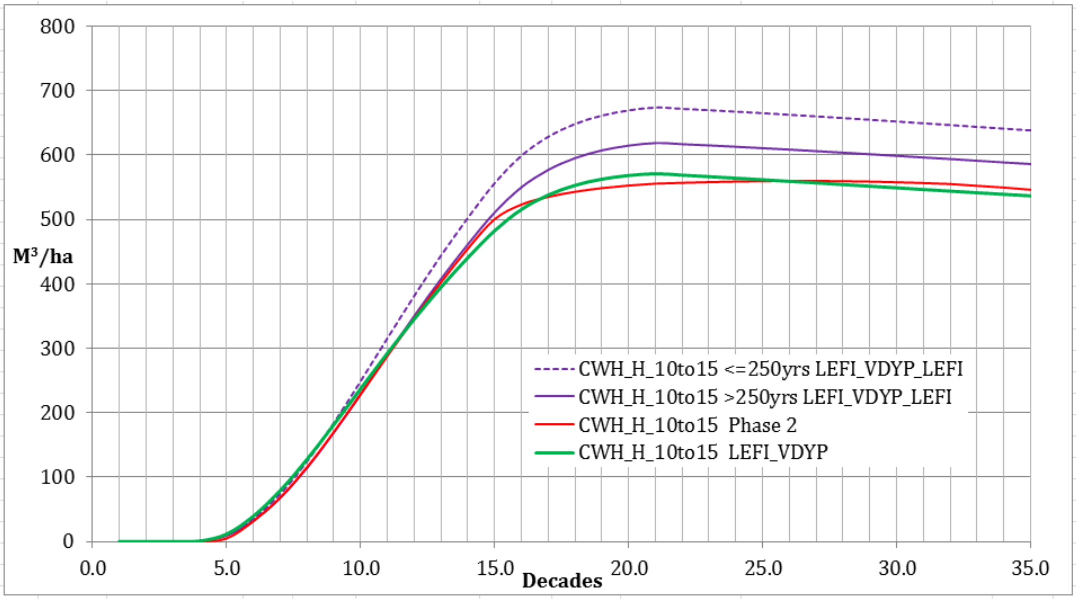


Figure 5.8.8.2: CWH Hemlock Leading with SI between 10 and 15.

Figure 5.8.8.2 compares curves for the hemlock leading CWH, site index 10 to 15 analysis unit. The Phase 2 curve in red is has very similar magnitude as the LEFI base VDYP curve in green. The LEFI volume adjustment depends on the age bracket of the stands. For stands 250 years and older, the green curve is adjusted creating the dashed purple curve. For stands younger than 250, the result is the solid purple line. These higher purple lines mean that the base case curves for hemlock-leading stands (with LEFI volume adjustment) are higher than the Phase 2 curve or the unadjusted LEFI-based VDYP curve.

Figure 5.8.8.3 below compares the spruce leading CWH, site index 10 to 15 analysis unit. The Phase 2 curve is shown in red. Its magnitude for stands older than 300 years is nearly identical to that of the purple LEFI Volume adjusted curve. The LEFI-based VDYP curve in green has less volume at all ages than the Phase2 VDYP curve. The LEFI volume adjustment of the green curve creates the purple curve which is used in the base case.

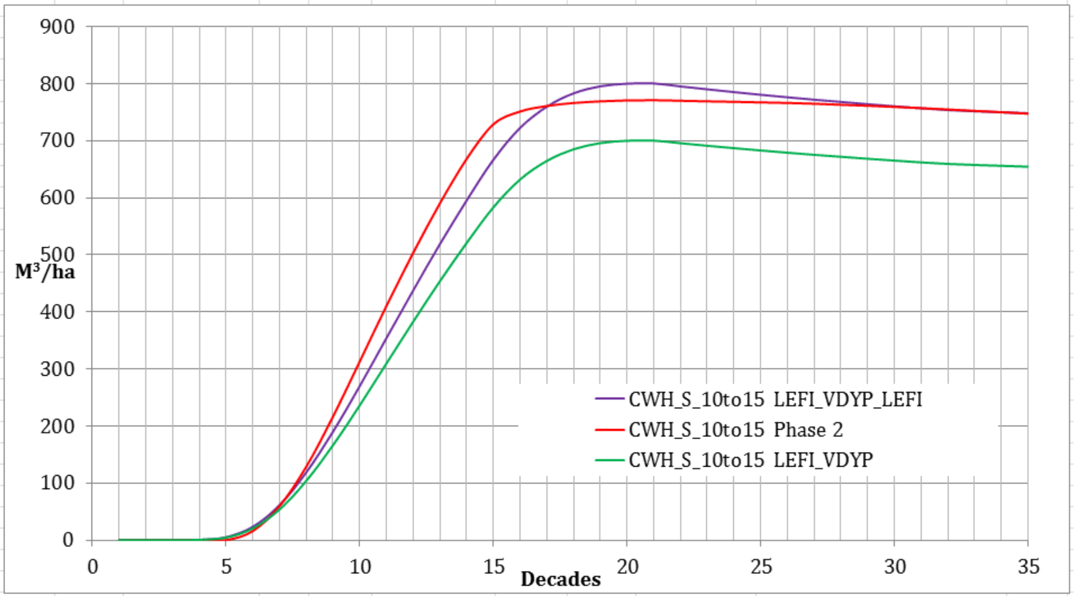


Figure 5.8.8.3.CWH Spruce Leading with SI between 10 and 15.

The following charts show base case volume curves (LEFI volume adjusted) for the most common analysis units. Note the very high site index curves are somewhat anomalous given the small areas they represent (see figure 5.8.8.10 below for the distribution of site index classes in the THLB).

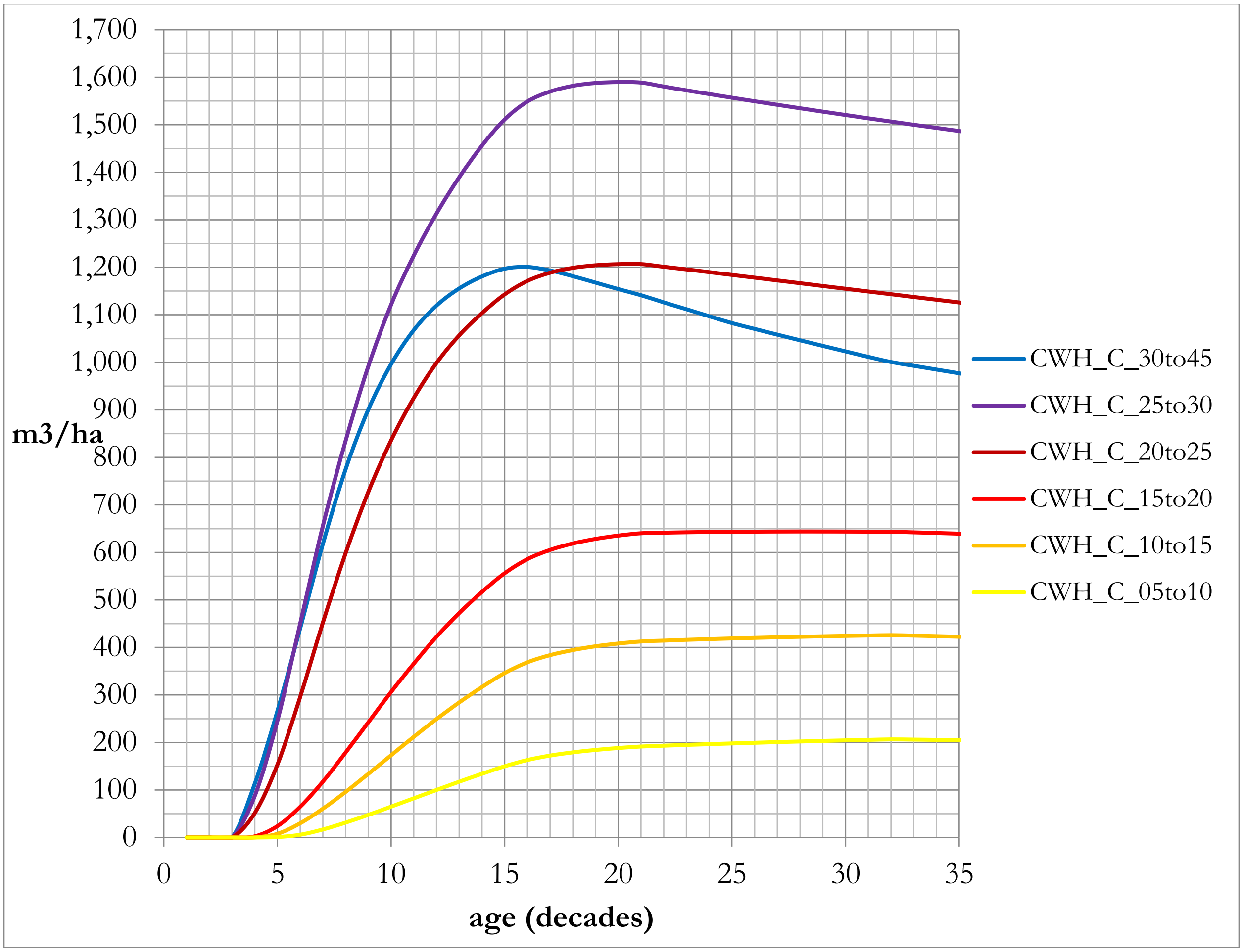


Figure 5.8.8.4. Red cedar leading natural stand analysis units by BEC zone and site index class

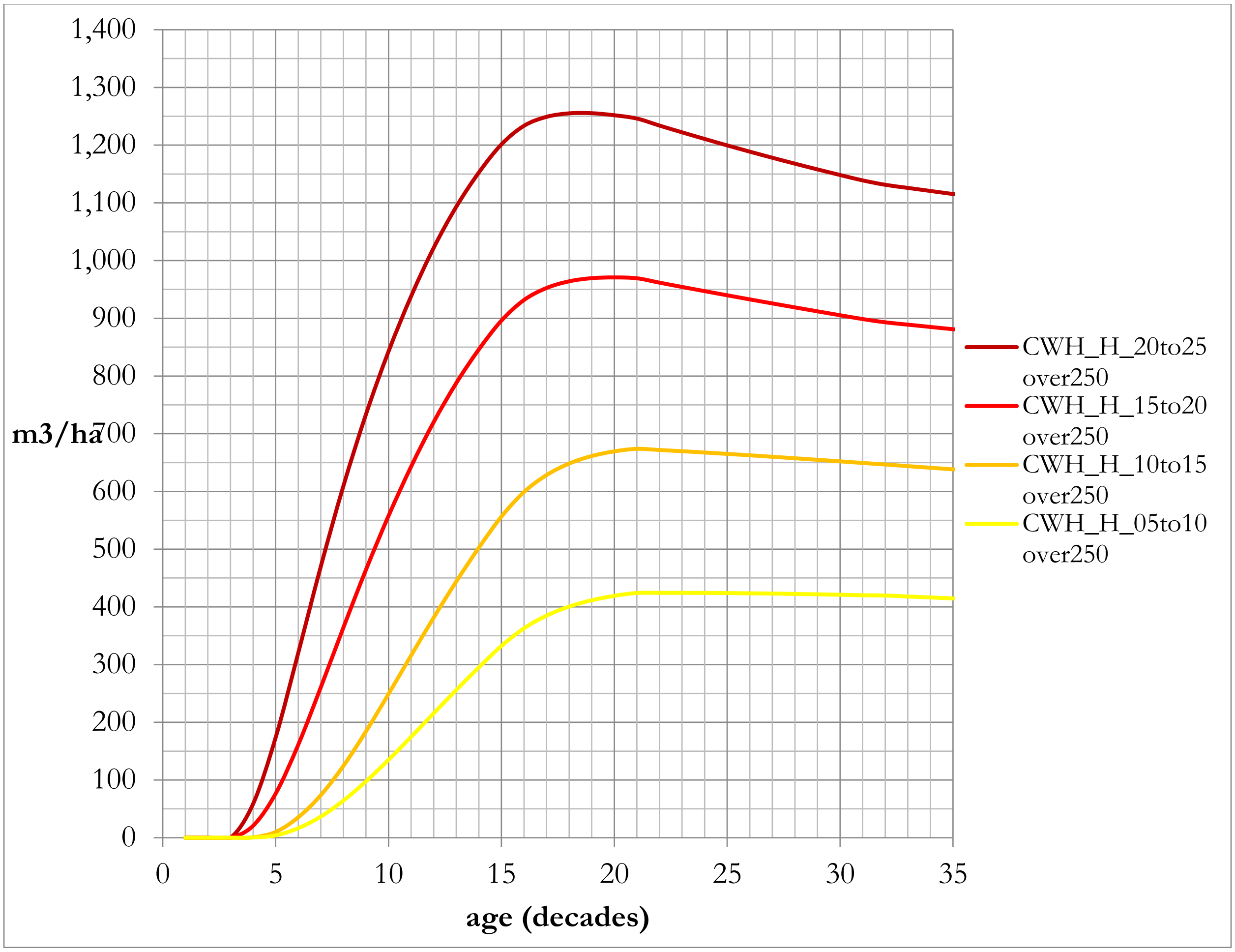


Figure 5.8.8.5 Western hemlock leading natural stand analysis units by BEC zone and site index class (natural stands over 250 years).

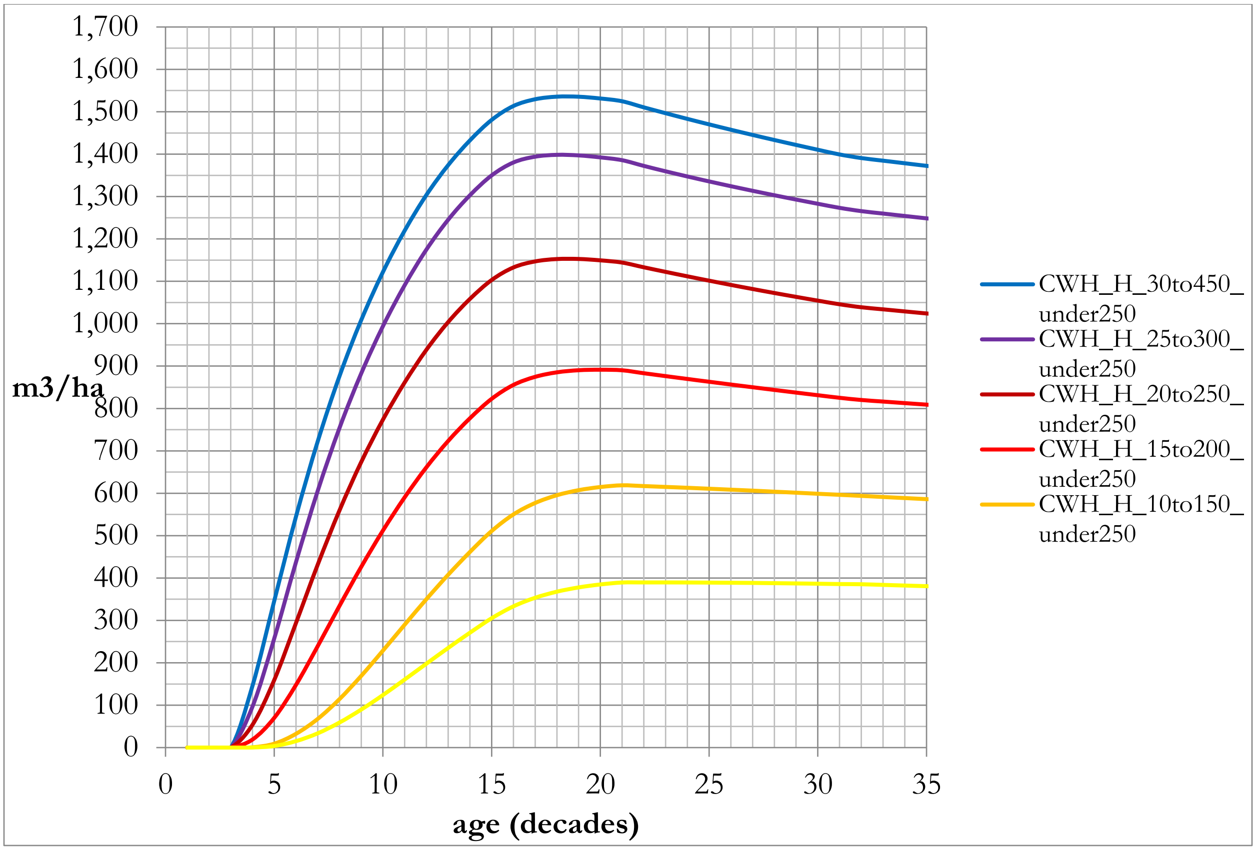


Figure 5.8.8.6 Western hemlock leading natural stand analysis units by BEC zone and site index class (natural stands under 250 years).

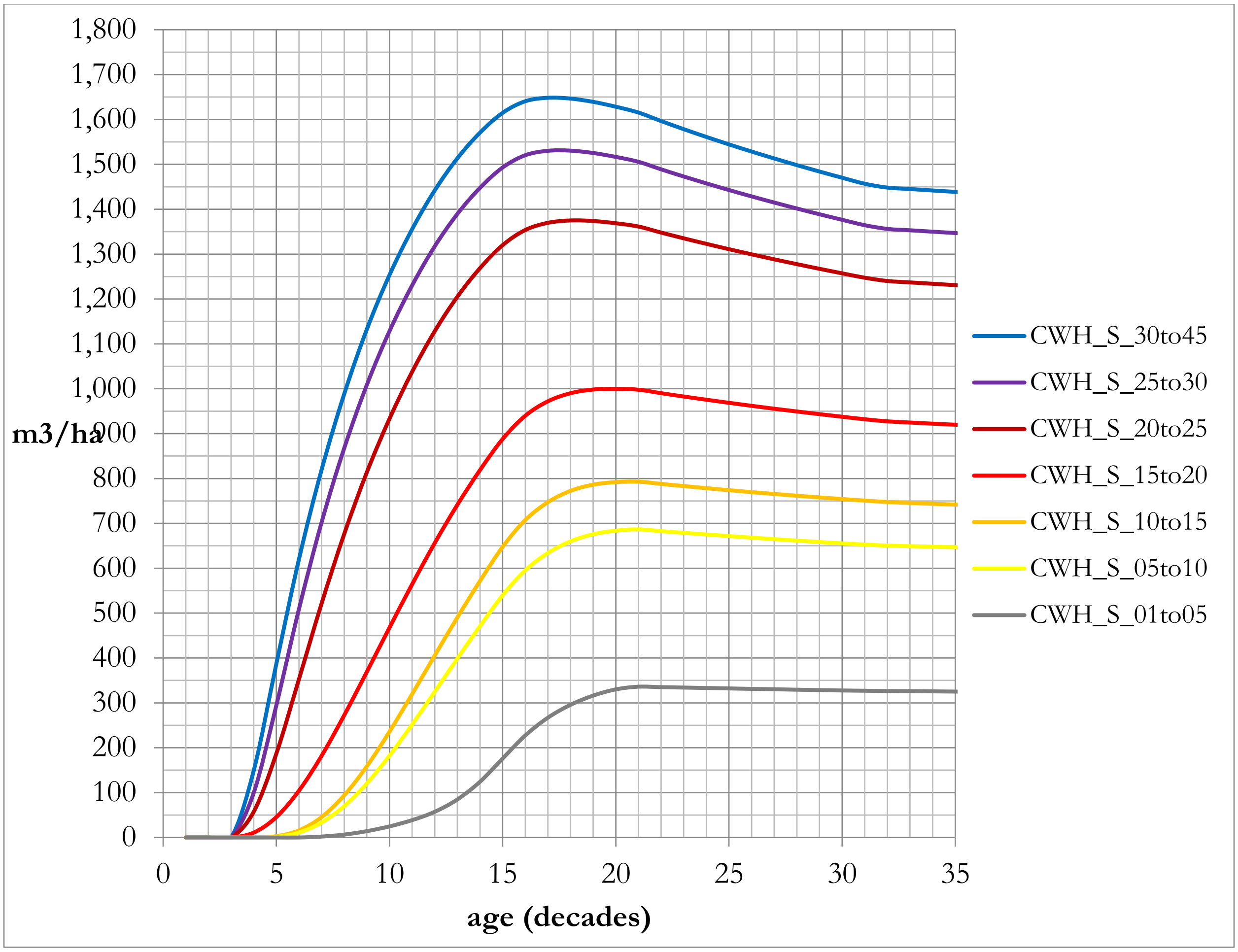


Figure 5.8.8.7 Sitka spruce leading natural stand analysis units by BEC zone and site index class.

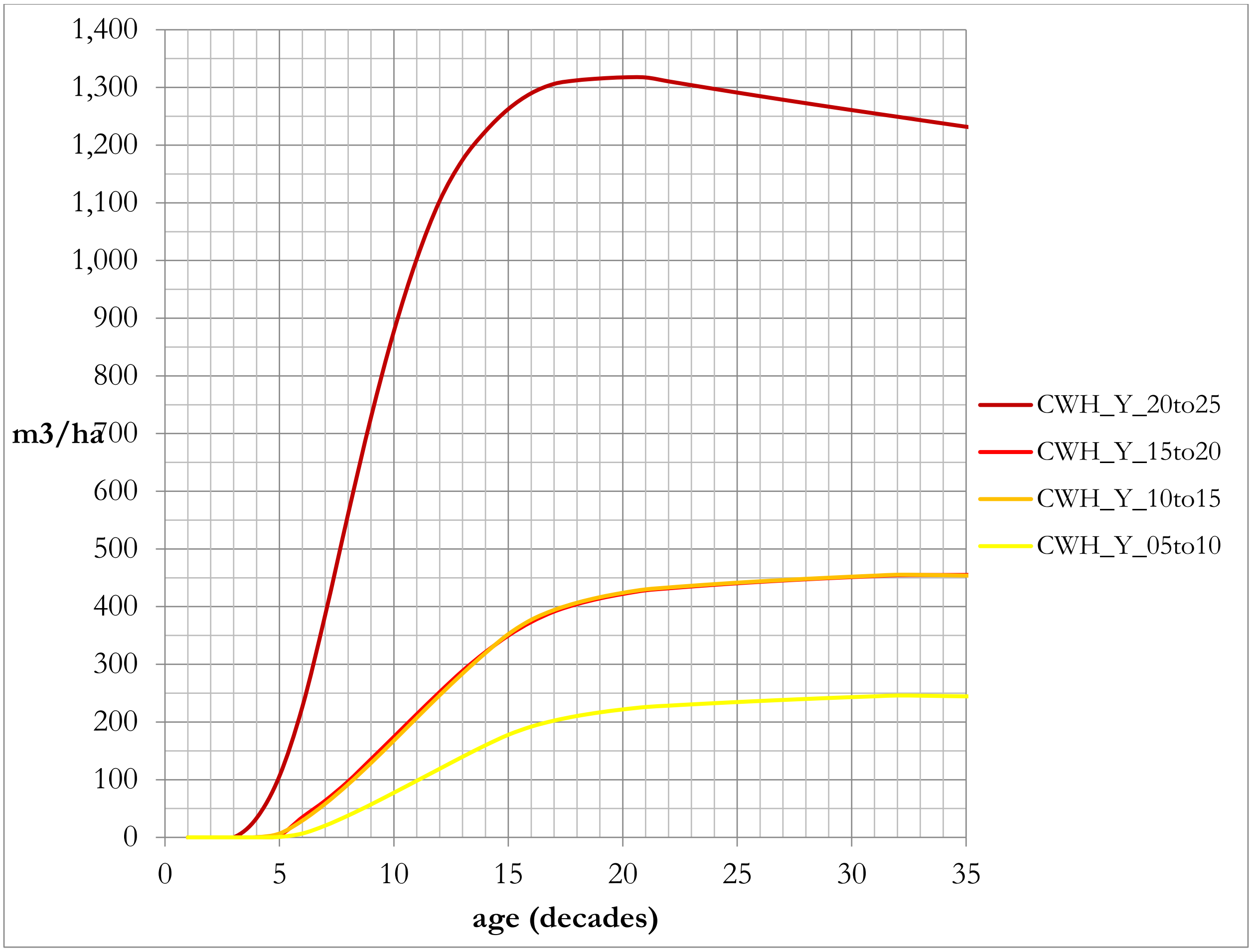


Figure 5.8.8.8 Yellow cedar leading natural stand analysis units by BEC zone and site index class.

Note that while the growth and yield estimates for the high site index yellow cedar sites (SI 20-25) are significantly higher than other sites, these sites do not occur within the THLB (see figure 5.8.7.7).

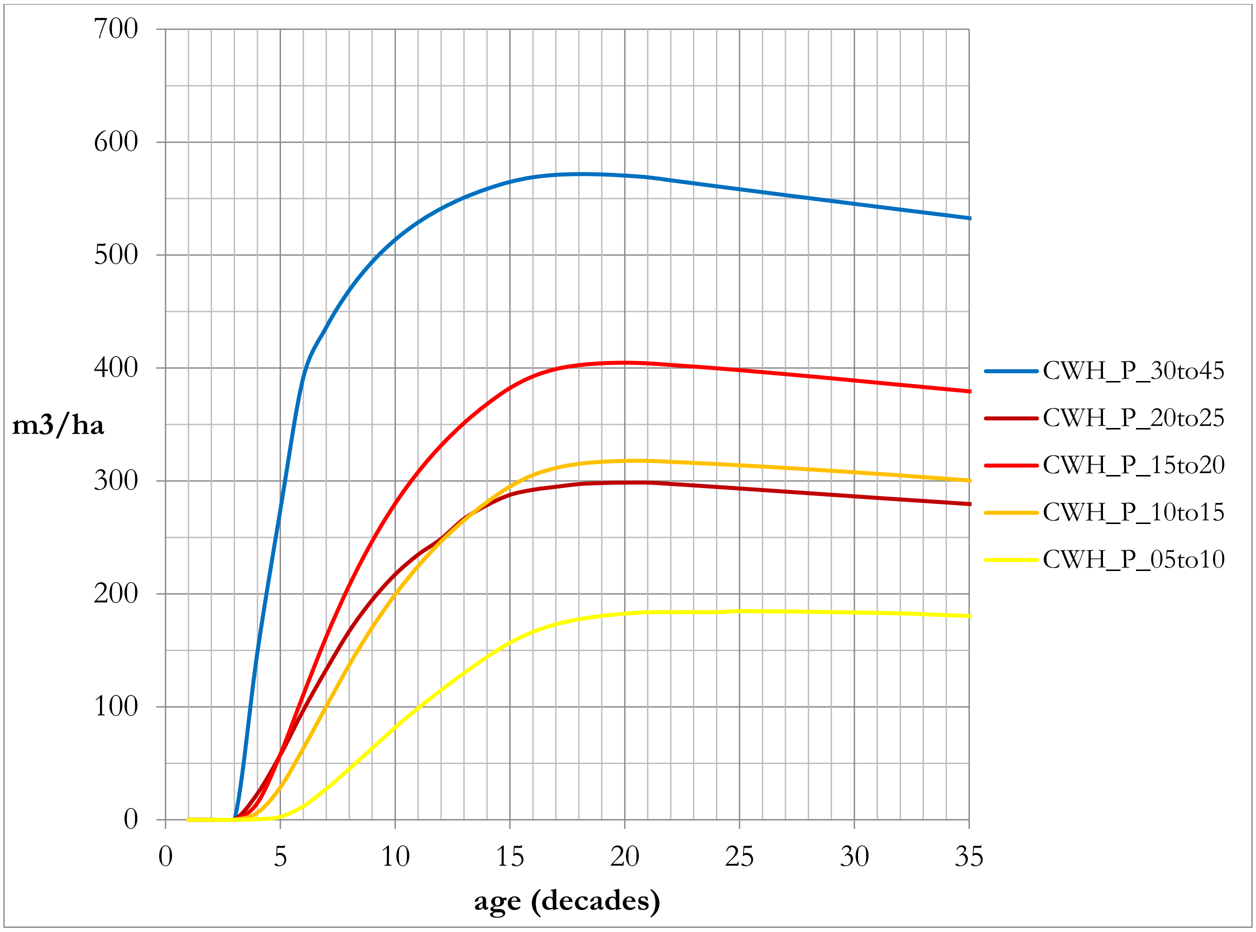


Figure 5.8.8.9 Lodgepole pine leading natural stand analysis units by BEC zone and site index class.

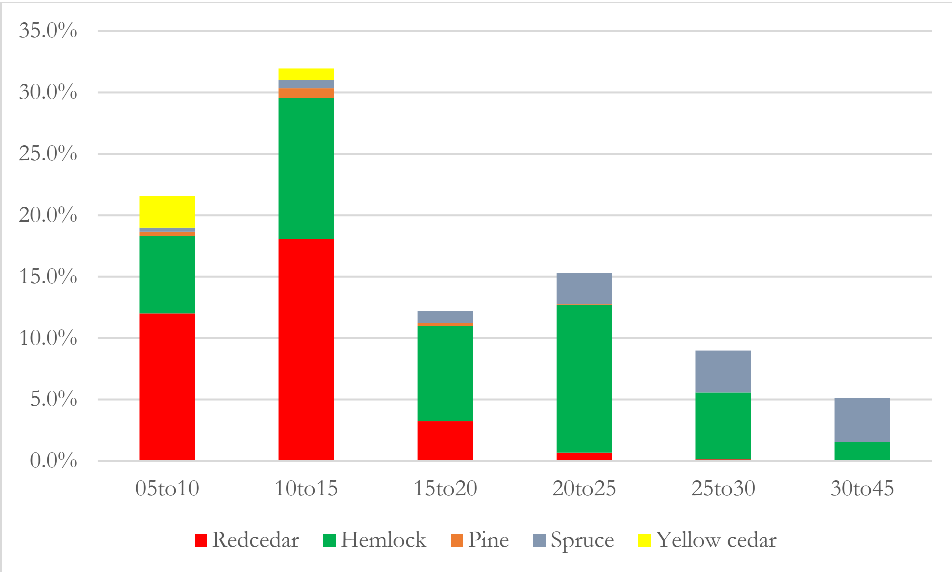


Figure 5.8.8.10. Distribution of species by site index classes for natural stands as a percent of the THLB[29].

[29] Note this graph only includes species and site index groupings within the CWH BEC zone. These units represent 95% of THLB.

Chapter 6- Resource Management

6.1 Visual Quality Management

Managing for visual quality is an important value on Haida Gwaii and is guided by several Provincial policies. Achieving Visual Quality Objectives (VQOs) in British Columbia involves setting thresholds for visually altered forests on landforms that are between 1 to 8 kilometres from a significant public viewpoint (e.g., how much logging is visible from significant public viewpoints). The *Forest and Range Practices Act* explicitly identifies the need to manage for scenic values. Section 1.1 of the *Forest Planning and Practices Regulation* sets out categories for visually altered forest landscapes. On Haida Gwaii, a Visual Landscape Inventory (VLI) was completed in the early 2000s identifying viewscapes based on known public vantage points, creating 1,014 polygons, each with its own VQO. The VLI includes spatial/mapped information on important viewscapes for communities, travel corridors and public recreation sites.

In 2005, the VLI was brought into force through the *Visual Quality Objective Order*, made under Section 7(2) of the Government Actions Regulations (*B.C. Reg. 582/2004*) (Munt, 2005). After the 2005 GAR Order, all forest companies needed to manage VQOs on a VLI polygon basis. The Visual Impact Assessment Guidebook (MoF, 2001) provided numerical ranges for measuring altered forest landscapes by Visual Quality Classes, and in 2013 the Haida Gwaii Natural Resource District established a new policy that set expectations around those numerical ranges (Munt, 2013), as outlined in table 6.1.

Table 6.1. Haida Gwaii Natural Resource District's Stewardship Policy for Managing Visual Resources on Haida Gwaii (2013)

VQO Class	**Scale** (MoF, 1998)	**Percent Alteration**	**Midpoint**
Preservation	No visible activities	0%	0
Retention	Activities are not visually evident	0% - 1.5%	0.75%
Partial Retention	Activities are visible, but remain subordinate	1.6% - 7%	4.3%
Modification	Activities are visually dominant but appear natural	7.1% - 18%	12.6%
Maximum Modification	Activities are dominant and out of scale	18.1% – 30%	24%

Percent alterations are implemented by ensuring that recent disturbance does not exceed the listed percentages for a given landform (VLI polygons), averaged across several established viewpoints. Many factors may contribute to meeting VQOs, such as block shape, distance from a known viewpoint, the shape or absorption capacity of a landform, or the size of an opening.

6.1.1 VQO's in Timber Supply

Applying VQOs to timber supply analyses requires constraining the amount of recently disturbed (not visually greened-up area) in VLI polygons to ensure that percent alterations are not exceeded. Three variables are commonly used to help calibrate VQO requirements within a spatial modelling environment: 'Visually Effective Green-up' (VEG); Visual Absorption Capacity (VAC); and Plan to Perspective ratio (P2P).

Visually Effective Green-up (VEG) is a term commonly used to describe forest regeneration that has reached a state that is no longer considered 'altered' or visibly disturbed. A greened-up state will vary based on biophysical conditions but is typically considered to be achieved if an area is well-stocked and trees are between 3 to 8 metres in height. Generally, a steeper slope requires taller trees to mask visibly disturbed ground.

Visual absorption capacity (VAC) refers to a landform's visual sensitivity to harvest openings; for example, a clearcut may be more visible on a steep straight slope as opposed to on an undulating slope or flat ground. Slope (%) is used as a surrogate for VAC in spatial modelling.

Estimates of tree heights required to meet VEG relative to hillslope gradients were published by the Province in 1998 (MoF) and have been considered standard practice to guide spatial modelling for timber supply analyses (table 6.1.1).

Table 6.1.1 Tree height required to meet Visually Effective Green-up relative to slope (MOF 1998)

	Slope range (%)											
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-45	46-50	51-55	56-60	60+
Height (m)	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5

Each VLI polygon was assigned a slope class (derived from 20-m Digital Elevation Model and gradient functions in ArcGIS) and then an area-weighted average tree height (VEG) was calculated for each VLI polygon. The mean VEG height for a polygon is therefore calculated by: $\frac{(x_1 * y_1)+(x_2 * y_2)+\cdots}{Total\ Area}$ whereas *x*= area and *y*= VEG tree height.

For example, a 100-hectare VLI polygon with 5 different slope classes (each 20 hectares in size) with 5 separate VEG height requirements of 4m, 5m, 6m, 7m, 8m, and would have a mean VEG height of 6m.

The perspective view is the point of view of someone on the ground looking horizontally across to a landform. VLI polygons and their subsequent VQOs were all developed in a perspective view, and operational approvals also vet alteration amounts based on the perspective view. Spatial timber supply models use the VLI spatial linework, but apply it from a plan view (e.g., as one looks at a map- from above). A plan to perspective (P2P) ratio converts the perspective percent alteration for each VQO using slope-specific ratios, thereby more accurately representing reality in a modelling environment. Slope-specific ratios have been developed from research undertaken within the MFLNRORD (MoF, 2003), and are presented in table 6.1.2.

Multiplying the P2P ratio with the alteration limit provides the plan-view alteration limit.

For example, if a VLI polygon has a *Partial Retention* VQO class (alteration limit of 1.6-7%, or mid-point of 4.3%), and a slope of 35%, then we would multiply the alteration mid-point of 4.3% by the P2P ratio of 2.45, which amounts to a planimetric view alteration limit of 10.5%. The P2P ratio suggests that the steeper the slope, the closer the alteration limit is to a perspective view.

Table 6.1.2 Plan to perspective ratios by slope class.

Slope range (%)	0-10	11-20	21-30	31-40	41-50	51-60	60-70	70+
P2P	4.68	3.77	3.04	2.45	1.98	1.60	1.29	1.04

For this timber supply analysis, each polygon within the Haida Gwaii VLI was assigned the plan-view alteration limit for its VQO class. The plan-view alteration limit is also an area-weighted calculation (e.g., a P2P ratio is proportionally determined by the area of slope classes within each VLI polygon).

All of Haida Gwaii's 1,014 VLI polygons were assigned mean VEG heights in addition to the alteration limits before being converted to a 1-hectare raster or *cell* for the spatial timber supply model (STSM).

A forest cover constraint was applied to each VLI cell within the STSM model based on the alteration limit and mean VEG height. While for timber supply analysis a minimum green-up height is assigned for each VLI polygon, table 6.1.3 provides the average minimum heights by VQO class.

Table6.1.3. Distribution of Visual Quality Objectives and average minimum VEG heights

VQO	Area (ha)	Area-weighted average minimum height (m)
Modification	53,244	5.4
Partial retention	148,532	6.4
Retention	52,297	5.6

6.2 Wildlife Habitat Areas

Wildlife Habitat Areas (WHA) are reserves designed to protect the habitat of Species at Risk or regionally important wildlife. The *Wildlife Act* mandates the Province to protect these two categories of identified wildlife, which subsequently provides formal management directions under the *Identified Wildlife Management Strategy (IWMS).* WHAs are one management strategy to protect or restore habitat for species' current or historic ranges. Originally WHAs were established under the *Operational Planning Regulation* through the *Forest Practices Code.* Currently, the authority to establish WHAs is enabled through sections 9 and 10 of the *Government Actions Regulation*.

WHAs on Haida Gwaii came into effect long before the Haida Gwaii Land Use Objectives Order (2010), which also provides measures to protect focal wildlife species. Currently four WHAs remain on Haida Gwaii, two areas for Northern Goshawk (*Accipiter gentilis laingi)* established in 2001 and 2003 amounting to a total of 4,905 hectares within the Datlamen and Bonanza Creek watersheds (orders 6-001 and 6-002). In addition, two areas for Marbled Murrelets (*Brachyramphus marmoratus*) were established in 2003 (orders 6-041, 6-046), amounting to a total of 380 hectares, within the Naden and Davidson watersheds.

Both Northern Goshawk WHAs are divided into *Post-Fledging Areas* (PFA) and *Foraging* areas. Post-fledging areas are smaller reserves nested within the broader WHA generally centered around known nest sites and do not allow any forest harvesting (Thompson & Pederson, 2001) (Macatee, 2003a). In other words, for timber supply analyses, the PFAs are 100% net-downs from the THLB. The two Marbled Murrelet orders also do not allow any forest harvesting (Macatee, 2003b) (Macatee, 2003c).

For the two Northern Goshawk WHAs, foraging areas have activity restrictions to maintain forest ages or succession classes (e.g., old, mature, young forest) as specified within each WHA (see table 6.2). For example, the WHA 6-001 must always be comprised of 384 hectares of old forest. In addition, the WHA requirements specify timing windows and other harvest/planning considerations.

Table 6.2. Foraging habitat forest succession class requirements for Northern Goshawk WHAs.

WHA_No	Old	Mature	Young	Very young
	>250 yrs	81-250 yrs	40-80 yrs	<40 yrs
6-001	384 ha	864 ha	432 ha	480 ha
6-002	240 ha	960 ha	960 ha	480 ha

Table 6.2 lists forest succession class requirements for each of the two Northern Goshawk WHAs. Ages have been referenced from the 1995 Biodiversity Guidebook (MoF)[30].

The timber supply analysis accounted for the WHAs by 100% netdowns or exclusion from the THLB for the two Marbled Murrelet WHAs and the two post fledgling areas of the two Northern Goshawk WHAs. Forest cover constraints were modelled based on the forest succession class restrictions (table 6.2) within the forage areas of the two Northern Goshawk WHAs.

6.3 Karst Management

Karst is a soluble carbonate bedrock (limestone) associated with subterranean cave systems and unique ecosystems. Karst is a resource feature often related to paleontological or archaeological resources as well, given the high potential habitation qualities of karst caves. Karst landforms are characterized by grooved rock surfaces, sinkholes, canyons,natural arches and caves and are divided into surface (epikarst) and subsurface (endokarst) features.

Geological mapping of karst began in the 1960s on Haida Gwaii (Brown, 1968), with most of the karst on Haida Gwaii occurring on the Sadler geological formation (Griffiths & Ramsey, 2009), which originated in the Triassic geologic period (227-208.5 million years ago). This relatively pure formation underlies approximately 60km^2 of the Islands, with about 1/3rd of the formation within Gwaii Haanas National Park Reserve and Haida Heritage Site. The Sadler limestone formation and other karst formations were mapped by Sutherland Brown in 1968, and again in the 1980s by the Geologic Survey of Canada (Desrochers & Orchard, 1991) (Woodsworth, 1991).

In 2006, the Haida Gwaii Natural Resource District established a Section 5 *GAR Order* under the *Forest and Range Practices Act* (FRPA) that identifies surface or subsurface elements of a karst system as a resource feature (Munt, 2006). These include significant surface karst features, high or very highly vulnerable karst terrain, and karst caves. Special management may include full protection from primary forest activities.

Schedule 2 of the HGLUOO (2010)lists karst as a Class 2 Haida Traditional Heritage Feature. Karst is protectedunder section 5(4) of that Order, when associated with high potential habitation sites, utilized on a temporary or permanent basis for shelter or other significant cultural or ceremonial activity.

The Sadler formation has the highest correlation with being karstic (pers. com. Paul Griffiths, 2019); with up to 50% being karst. Conversely, other formations such as the Peril formation may only include carbonates as a component, but karst still does occur in other geological formations; however there is incomplete inventory on the exact locations.

While there are uncertainties around the prescriptions for protecting karst (e.g. low samples of karst affecting forest management, therefore no clear patterns of buffering etc.), this uncertainty is more of a stand-level management uncertainty rather than a timber supply uncertainty.

For this timber supply analysis, 100% of the Sadler Formation was excluded from the THLB, which amounted to 12,356 hectares (gross) and 2,485 hectares (net after accounting for overlaps with other features). While this may over-represent karst in this specific geological formation, this is balanced by under-representing karst in the other limestone-based geologic formations.

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https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FPC%20archive/old%20web%20site%20contents/fpc/fpcguide/BIODIV/tab2.htm

6.4 Community Watersheds
Community watersheds are legally designated watersheds under the *Forest Planning and Practices Regulation* (Sec. 8.2). Currently only those watersheds that feed domestic water use for Skidegate and Queen Charlotte are formally listed under the regulation. These watersheds include the Honna, Jervis, Slarkedus and Tarundl watersheds. The regulation sets out objectives to ensure that the cumulative hydrological effects from primary forest activities do not materially adversely impact the quantity of water, timing of water flow or human health. Hydrological recovery of community watersheds is often gauged by calculating an Equivalent Clearcut Area (ECA).

A recent hydrologic assessment completed for the most developed of these watersheds (Honna) estimated the ECA in 2018 to be between 10-11.6% of the watershed area. This along with relatively low densities of road (0.89km/km^2) has led to low levels of hydrologic hazards for the area (Brayshaw, 2016). The current prescribed rate of development to maintain these low levels of hydrologic hazards is 1% of the watershed per year, which given the time taken to reach hydrological green-up, amounts approximately to a 20% ECA (Church & Eaton, 2001).

Hydrologic recovery is defined in the HGLUOO as *the point at which regenerated forest stands have hydrologic properties similar to the pre-harvest hydrologic properties of the stands, with hydrologic responses within the range of natural variability.* For timber supply analyses and modelling purposes, hydrologic recovery was calculated using a logarithmic recovery curve developed by Floyd (2012), whereby each polygon's forest height over time contributes as an area-weighted average towards the hydrologic recovery of a watershed. For the base case, a forest cover constraint was applied, whereby 80% of the entire area of the watershed (forested and non-forested) needed to be hydrologically recovered. See section 6.11.6 for a more detailed description of hydrologic recovery in timber supply analysis.

6.5 Wildlife Tree Retention Areas
Section 66 of the *Forest Planning and Practices Regulation* requires that areas with wildlife trees must be retained to provide wildlife habitat and assist in the conservation of stand-level biodiversity. The regulation stipulates that an annual average of 7% across all cutblock areas in a 12 month period must be retained as Wildlife Tree Retention Areas (WTRAs).

Data on WTRAs for the years 2012-2016 were collated from all licensees to determine the net downs on the THLB.

Data were submitted by licensees in standardized geo-database formats either at the end of the calendar year, or on an application-by-application basis (for Road Permit, Cut Permit or Timber Sale Licence information sharing) to the Solutions Table.

The TWG undertook a spatial analysis to determine the gross and net effect of WTRAs on the THLB by licencee and by Management Unit. Determining the net effect meant examining the extent of overlap between WTRAs and other retention designated under the LUOO. In addition, Ministry guidance is for licensees to locate WTRAs optimally to incorporate multiple values or purposes (Forest Practices Branch, 2006). In total, licensees retained 2,980 hectares, or almost 21%, within Development Areas to meet LUOO and WTRA objectives. Of this amount, 1,835 hectares were retained to meet LUOO objectives and as WTRAs. The area retained solely for WTRAs was 1,145 hectares. A total of 2,345 hectares, or nearly 17% of Development Areas, were labelled WTRA, meaning that 1,200 hectares (2,345 – 1,145) were subject to co-location of WTRAs and retention for LUOO values (see table 6.5.1).

Table 6.5.1. Total area, average size per development area and distribution of exclusive WTRA polygons by licensee. (includes walkaway areas.)

	Total Development Area (ha)	Total–LUOO retention[1] (ha)	Total LUOO retention	WTRA – net of LUOO retention (ha)	WTRA-net of LUOO	Average size of WTRA per Development Area (ha)
BCTS	3896	201	5.2%	257	6.6%	3.2
Husby	4648	962	20.7%	353	7.6%	3.5
TSA 25 (BCTS & Husby[2]	8544	1162	13.6%	611	7.1%	3.4
TFL 60 (Taan)	4422	623	14.1%	502	11.3%	6.3
TFL 58 (Teal Jones)	1286	49	3.8%	33	2.6%	0.9
Total	14252	1835	12.9%	1145	8.0%	3.5

Notes:

(1) LUOO&WTRA denotes areas labelled as being retained for both LUOO objectives and as WTRAs; that is, LUOO retention excludes area retained solely for the purpose of WTRAs

(2) TSA 25 areas are an area-weighted average based on submissions from BCTS and Husby

For the base case it was assumed that WTRAs will overlap with LUOO retention objectives. LUOO in-block retention netdowns were stratified by old forest (≥250 years) and young forest (<250) to reflect the observed distribution of LUOO features (see section 6.11.16-6.11.21 or appendix 6). These LUOO retention netdowns amounted to 10.94% and 5.89% in old forest and younger forest respectively, in the Development Areas.

Given the expectation that WTRAs will be located within areas that are already being retained for other reasons, the retention for the LUOO already exceeds the needs for WTRAs for old forest, but falls short of the 7% FPPR minimum for younger forests. Therefore, for the base case there is no specific THLB exclusion for WTRAs in old forest, and a total 7% (or 1.11% above and beyond LUOO retention) exclusion in younger forest.

See section 8.2.8.2 for details on a sensitivity analysis that explores current practice WTRA retention levels.

6.6 Permanent Sample Plots

Permanent sample plots (PSP) are field measurement plots used to collect and maintain long-term re-measurement data on forests. Data are important components of developing and testing growth-and-yield models used to project future stand conditions in the province. Throughout BC approximately 7,800 plots have been established (FAIB, 2018). On Haida Gwaii, there are a total of 419 active PSPs, with some re-measured as many as four times dating back to their establishment in the 1960s.

While PSPs are not afforded formal legislated protection from forest harvesting, the Chief Forester formally requests licensees and natural resource decision makers to protect these assets from harvesting by maintaining a windfirm buffer in addition to the plot radius itself (Nicholls, 2018). A 100-m buffer is requested of licensees on Haida Gwaii, in addition to the plot size, which is typically 400m^2 (pers. communication, A.Reid, Inventory Forester, FAIB).

For the timber supply analysis, 100-m buffers were placed on all active PSPs on Haida Gwaii, with a 100% exclusion from the THLB. This is not a legal requirement and protection measures are not always applied and therefore the netdown may overstate the actual impact on the THLB.

6.7 Recreation Sites and Trails

Recreation sites

Recreation sites are found throughout Haida Gwaii, with some sites receiving formal designations as a recreation site or interpretive forest for protection under section 56 of the *Forest and Range Practices Act,* and others formally designated as *Land Act* reserves, typically for an 'environment, conservation and recreation' purpose and what used to be known as Use, Recreation and Enjoyment of the Public (UREP) sites. The majority of recreation sites on file overlap with and are protected by protected areas under the *Protected Areas of British Columbia Act.* The following is a list of recreation sites that do not overlap with established protected areas. Bolded sites are those that have legal designation and were excluded from the THLB. The others are not be legally designated but have recreational use and may be considered/managed at an operational level:

Mosquito Lake	Lawn Hill
Moresby	Marie Lake
Clapp basin	Ship Kleta Island
Rennell Sound	Hangover Creek
Small Lake	Stanley Lake
Spirit Lake	Copper Bay
Kagan Bay	Shields Island
Tarundl Creek	Roderick Island

Trails

A number of known recreation trails also overlap with protected areas. The CHN's Heritage and Natural Resource Department completed a trails inventory using high resolution differential GPS for trails that are widely used, as well as existing inventories of trails maintained by community organizations (e.g., Anvil trail). The Haida Gwaii Strategic Land Use Agreement identified protection of UREP sites, as well as protection of 40 trails listed as important for the future development of a tourism strategy (PMT, 2006) as key objectives While some ended up in protected areas/conservancies, many of these were not legally designated or protected. As a result, there is uncertainty around how these trails may be managed during forestry operations. A total of 23 trails were excluded from the THLB. Bolded names indicate *section* 57 designations under FRPA:

3-mile	Old Massett trails
Anvil Trail (in Tlall protected area)	**Onward Point**
Crabapple Creek	Pallant Falls
Drizzle Lake	Gore Brook
Evan's Farm	Riley Creek (in Duu Guusd protected area)
Gore Brook	Sandy Bottom Lake
Jags Lookout	Skonun Lake
Kumdis	**Slatechuck Mountain**
Kumdis Bay	**Sleeping Beauty**
Moresby Mountain	Spirit Lake
Mosquito Mountain	Tarundl Loop
Old Growth Alley	**5 Mile Beach**

For the purposes of timber supply analyses, the recreation sites listed above were 100% excluded from the THLB andwere given 100-mbuffers.. Despite the uncertainty regarding how these trails will affect forestry operations over the effective period of the upcoming AAC determinations, the effect of netting them out of the THLB is <0.1% of the FMLB.

6.8 Terrain Stability

Unstable terrain, subject to mass wasting disturbances such as landslides or debris torrents are typically not suitable for timber harvesting. Section 35 of the *Forest Planning and Practices Regulation* sets soil disturbance limits, which requires mapping of sensitive soils. Unstable terrain is divided into two main types: Class IV and, Class V terrain as defined by Chatwin (Chatwin, Howes, Schwab, & Swanston, 1994) and the Forest Practices Code Guidebook (MoF, 1999). Class4 and Class 5 terrain contains areas with a moderate likelihood and high likelihood (respectively) of landslide initiation following timber harvesting or road construction. Section 7.4 of this data package.4 details netdowns for natural disturbance resulting from past landslides and the projected occurrence for future landslides.

A variety of terrain mapping projects have been compiled into a consistent dataset to map Class 4 and Class 5 terrain on Haida Gwaii[31]. One project commissioned by the HGMC was to complete Terrain Stability Mapping for the Bonanza watershed using LiDAR digital terrain models and high resolution digital aerial photogrammetry (1:10,000 scale softcopy mapping) (Weiland, 2018).

For the timber supply analysis, an empirical approach was used in defining the amount of unstable terrain that is unlikely to contribute to the THLB. The proportion of timber harvests within the unstable terrain was calculated based on current practice: cutblock openings from the last 10-year market cycle (18,723 hectares), with data sourced from RESULTS and the HGLUOO annual digital spatial submissions. The objective was to determine the preference to avoid unstable terrain.

If the proportional contribution of a terrain class to the total harvest equals or exceeds its contribution to the THLB, then no netdown is warranted; in other words, if a class of unstable terrain contributes to harvesting in proportion to its contribution to the THLB (prior to exclusion of any unstable terrain), this would suggest that there is no tendency to avoid such areas. A preference ratio was calculated using the percent contribution of harvest within each terrain class and the percent contribution of the terrain class to a preliminary THLB. Therefore, the percent of terrain stability exclusion can be calculated as:

$$1 - \frac{\sum B \div \sum D}{\sum A \div \sum C}$$

Wherein *A* represents all the hectares in Class 4 or 5 terrain, *B* represents the hectares logged within Class 4 or 5 terrain over the last 10 years, *C* amounts to the hectares of preliminary THLB (prior to unstable terrain being removed), and *D* represents all hectares logged over the last 10 years.

Given that the amount of unstable terrain varies considerably among the three management units, and that licencees log these areas at different rates, it was considered important to calculate this ratio by management unit (TFL 60, TSA, TFL 58).

Table 6.8.1. Inputs into the terrain stability exclusion calculation or preference ratio for TFL 60

	Total area (ha)	Proportion of THLB	Area logged in previous10 years (ha)	% that was logged	THLB inclusion factor
Class 4 terrain	6,003	9%	170	4%	0.48
Class 5 terrain	6,363	10%	124	3%	0.33
THLB (preliminary[32])	65,648		3,879		

[31] Terrain stability mapping projects included *MoE 1978 (Digital Terrain Map Library); Western Forest Products, TSM Level D (D.Maynard); Queen Charlotte TSA, TSM Level E; Rennel Sound 1996 (J.R. Fulton, Geologic Survey of Canada); Gwaii Haanas TSM Level D (D.Maynard); Bonanza TSM, 2018 (Irena Weiland).*

[32] Preliminary THLB is an initial estimate of THLB that includes unstable terrain. Based upon a provisional THLB.

Table 6.8.2. Inputs into the terrain stability exclusion calculation or preference ratio for TSA

	Total area (ha)	Proportion of THLB	Area logged in previous10 years (ha)	% that was logged	THLB inclusion factor
Class 4 terrain	13,711	11%	657	5%	0.46
Class 5 terrain	15,867	13%	200	2%	0.12
THLB (preliminary[33])	123,258		12,965		

Table 6.8.3. Inputs into the terrain stability exclusion calculation or preference ratio for TFL 58

	Total area (ha)	Proportion of THLB	Area logged in previous10 years (ha)	% that was logged	THLB inclusion factor
Class 4 terrain	1,631	11%	152	9%	0.77
Class 5 terrain	1,297	9%	66	4%	0.42
THLB (preliminary[34])	14,251		1,735		

The THLB inclusion factor is the inverse of the exclusion calculation above. For example, for TFL 60, the preference ratio (exclusion factor) for Class 4 terrain is 52%, therefore 48% of this terrain class is included in the THLB.

Using the numbers in table 6.8.1 to 6.8.3 amounts to a total gross netdown of 16,816 hectares from Class 4 terrain and 30,987 hectares from Class 5 terrain from the THLB. Areas harvested since 1996 within Class 4 and Class 5 terrain were kept in the THLB (no netdown inclusion factor applied).

Logging in class 4 or 5 terrain may increase the risk of mass wasting and therefore may not be good stewardship. Given that the preference ratio is dependent on the number of hectares logged in Class 4 or 5 terrain, an analysis was completed to determine the number of landslides within areas logged in Class 4 or 5 terrain over the last 10 years. Landslide mapping (including initiation points) were overlapped with cutblocks within Class 4 and 5 terrain. The total slide area overlapping cutblocks was 11 hectares, and the total slide area with the slide initiation inside the blocks is 6.4 hectares. Therefore, the area of slides relative to the total area logged within Class 4 and 5 terrain is small (<1%), suggesting that no further reduction beyond the preference-related exclusions discussed above are warranted.

See section 8.2.14 for details on a sensitivity analysis whereby a broader range of cutblocks were sampled (extending back to 1996).

6.9 Roads, Trails and Landings

Roads, trails and landings represent a loss of productive forest area. Existing roads were mapped using a variety of sources, including TRIM, historic licensee road data (TFL 39), road segments from the RESULTS dataset[35], as well as roads from a mapping gap analysis conducted by the CHN's Heritage and Natural

[33] Preliminary THLB is an initial estimate of THLB that includes unstable terrain. Based upon a provisional THLB.
[34] Preliminary THLB is an initial estimate of THLB that includes unstable terrain. Based upon a provisional THLB.
[35] WHSE_FOREST_TENURE.FTEN_ROAD_SECTION_LINES_SVW

Resource Department using high resolution imagery. Existing roads were classified as 'permanent', 'mainlines' and 'branches'. The following summarizes the lengths of road used within the timber supply analyses.

Road type	Length (km)
Permanent	322
Mainline	1,412
Branch	5,754
Total	7,488

An analysis of average non-vegetated road widths was completed to determine a net down to existing productive forests, leading to a 10m and 20m (total) buffer width on branches and permanent/mainlines respectively. 100% of these areas were excluded from the THLB.

A review of primary forest activities in second growth stands was conducted to determine what proportion of old road prisms and ditchlines were contributing to harvested volumes. Cruise and scale from a number of blocks within the Datlaman/Juskatla Inlet and Cumshewa (Aero camp) areas (Taan Forest Products) were reviewed and confirmed that right of way volumes from old branches/mainlines have not contributed to merchantable volumes. As more second growth is developed over the next timber supply period (10 years), further data can be gathered on historic right-of-way contributions to timber supply.

Exclusion of future roads from currently undeveloped areas of the THLB was calculated by determining the proportion of roaded to un-roaded area relative to 725 cutblock openings over the last 10 years (referred to as *market cycle blocks*). Using the road classifications and buffer widths above, 6.4% of openings were made up of roads.

Forest industry licensees commented that many roads become re-forested and therefore, excluding the full 6.4% figure from the future THLB would overstate the impact of roads. The TWG consulted with researchers with experience on the topic of road rehabilitation. Those experts indicated that while systematic research has not been done on Haida Gwaii, anecdotal observations are that where old road beds become re-forested, alder makes up on average approximately over 80% of the volume, and that the productivity on old roads is lower than the surrounding area. Alder is a minor commercial species on Haida Gwaii, contributing about 0.3% of the volume billed on Haida Gwaii in the 2013-27 period.

Therefore, for the base case, the assumption was that the full 6.4% would not contribute to future timber supply after the first harvest. However, since a concern was expressed, a sensitivity analysis was performed in which allowed for the regeneration of future roads to provide an indication of the potential impact of re-forested roads. See section 8.2.12 for more details on this sensitivity analysis.

6.10 Haida Gwaii Land Use Objectives Order

6.10.1 Data source overview

The Haida Gwaii Land Use Objectives Order (HGLUOO) came into effect in June of 2011 as a major milestone in the implementation of the Haida Gwaii Strategic Land Use Agreement (2007). The HGLUOO sets a total of 23 objectives under the *Land Use Objectives Regulation* of the *Land Act* for the management of cultural, aquatic, biodiversity and wildlife values.

A requirement repeated throughout the HGLUOO is for licensees to submit annual reporting data to the CHN and the Province of BC. This spatial data was used both to identify known reserve zones, management zones, retention areas and features (e.g., streams, monumental cedar, etc.), as well as to help predict the occurrence of currently unknown features.

Appendix 6 includes further descriptions of the HGLUOO annual submission spatial dataset.

6.10.2 Known and predicted exclusions from the THLB

Some objectives have landscape-level spatial inventories associated with them, and others do not. For example, Type I and Type II fish habitat can be mapped and modelled to represent all the estimated fish habitat across the Islands (e.g., HGLUOO Schedule 4) and therefore excluded from the THLB across the entire analysis horizon (400 years). However, most stand-level values (e.g., CMTs or monumental cedar) do not have l spatial inventories that cover all of Haida Gwaii, but their current known spatial occurrences are both excluded from the THLB and are used to predict the frequency of their distribution across the entire landscape. This frequency of distribution, expressed as a percent per hectare, is used to exclude predicted occurrences from the THLB.

Determining the amount of exclusion from the THLB by given objective is broadly defined by three applications:

- **Spatial net downs:** where the value has been mapped, either fully (all occurrences are known across the landscape), or in part (only some occurrences are known)
- **Predicted exclusions:** Where there is an incomplete inventory of a value then a frequency distribution analysis using known occurrences is used to predict unknown occurrences. For example, not all Haida Traditional Forest Features are inventoried across the landscape, however we have a robust dataset to predict their distribution. In certain cases, statistical analysis was used to assess whether values were most closely associated with specific site conditions (e.g., tree ages and/or species).[36].
- **Forest cover constraints:** Where targets have been set to conserve a value (e.g., a specified percentage of an ecosystem type must be covered by mature forest), static retention areas are not established. This allows for a dynamic constraint, whereby strata retention targets are met, but areas retained can move over the timber supply analysis horizon.

The following table classifies how HGLUOO objectives were applied in the TSR, with further details provided throughout this section:

[36] Statistical tests included classification and regression trees and chi-squared goodness-of-fit tests (where expected frequencies are tested against observed frequencies).

Table 6.10.2 HGLUOO data sources and their application to the TSR.

HGLUOO type	Data source[37]	Scale of application	Timber supply model application
Cedar Stewardship Area	HGLUOO Schedule 3	Landscape	Spatial netdown
Forest Reserves	HGLUOO Schedule 8	Landscape	Spatial netdown
Northern Goshawk Nesting Reserves	HGLUOO Schedule 12 and predictive territory model	Landscape	Spatial netdown and predicted exclusion
Marbled Murrelet Nesting Habitat	HGLUOO Schedule 11	Landscape	Forest cover constraint
Saw Whet Owl Nesting Reserves	HGLUOO Schedule 12	Landscape	Spatial netdown
Type I Fish Habitat	HGLUOO Schedule 4 and predictive habitat model	Landscape	Spatial netdown and predicted exclusion
Type II Fish Habitat	HGLUOO Schedule 4 and predictive habitat model	Landscape	Spatial netdown and predicted exclusion
Active Fluvial Units	Various terrain mapping products	Landscape	Spatial netdown
Forested Swamps	Various ecosystem mapping products	Landscape	Spatial netdown
Ecological Representation	Various ecosystem mapping products	Landscape	Spatial netdown
Red/Blue Listed Communities	Various ecosystem mapping products	Landscape	Spatial netdown
Sensitive Watershds	HGLUOO Schedule 7	Landscape	Forest cover constraint
Upland Stream Areas	HGLUOO Schedule 6	Landscape	Forest cover constraint
Northern Goshawk Nesting	HGLUOO Schedule 12	Landscape	Spatial netdown
Saw Whet Owl Nesting	HGLUOO Schedule 12	Landscape	Spatial netdown
Haida Traditional Heritage Features	Registered Archaeological Sites; CHN Heritage Feature database	Landscape & stand level	Spatial netdown
CMTs	Registered Archaeological Sites; CHN Heritage Feature database; HGLUOO licensee spatial submission	Stand level	Spatial netdown Frequency distribution analysis for predicted occurrence
Monumental cedar	HGLUOO licensee spatial submission	Stand level	Spatial netdown Frequency distribution analysis for predicted occurrence
Haida Traditional Forest Features	HGLUOO licensee spatial submission	Stand level	Spatial netdown Frequency distribution analysis for predicted occurrence
Cedar Retention	HGLUOO licensee spatial submission	Stand level	Spatial netdown
Western Yew Retention	HGLUOO licensee spatial submission	Stand level	Spatial netdown Frequency distribution analysis for predicted occurrence
Black Bear Dens	HGLUOO licensee spatial submission	Stand level	Spatial netdown Frequency distribution analysis for predicted occurrence

Final netdown values for HGLUOO objectives with explicit 'spatial netdowns' are listed in THLB netdown tables (section 3.2.1 of this data package). The netdown for those objectives with a frequency distribution analysis are summarized as LUOO in-block retention in section 3.2.1.The results of a frequency distribution analysis are expressed as a percentage of each hectare of THLB both in old forest and younger forest strata (see sections below for more details on analysis approaches).

[37] Details listed in subsequent sections.

6.10.3 Tree lengths

Many objectives within the HGLUOO require a buffer determined by an in-situ tree length, or a tree length based on Schedule 5 of the HGLUOO. Several HGLUOO objectives have landscape-level spatial inventories associated with them that could be used for TSR. Of those, Type I and II Fish Habitat, Active Fluvial Units, and Forested Swamps required tree length buffers to be modelled. Where management/reserve zones for Monumental cedar and CMTs aren't already spatially delineated, those values also require tree length buffers to be modelled. Management buffers were modelled by assigning a Schedule 5 tree length based on the site series that intersects the feature and multiplying that tree length by the HGLUOO requirements (e.g., 1.5 tree lengths).

Site series were determined using the primary decile of the ecosystem mapping layer. Schedule 5 assigns different heights for old and mature stands. For this TSR, old stands were existing unmanaged stands >250 years, and all other stands were assigned heights for mature stands.

Schedule 5 of the HGLUOO lists tree heights used to calculate buffers can be found at http://www.haidagwaiimanagementcouncil.ca/wp-content/uploads/2017/11/HGLUOOSched05_TreeHgt_20170713.pdf

Note that for analytical simplicity spatial boundaries between reserves and management zones were blended using a weighted-area average THLB inclusion factor.

Landscape level Objectives

6.10.4 Active Fluvial Units

Active Fluvial Units (AFU) are active floodplains including low and medium benches and zones of active fans and are reserved from harvest as per section 12 of the HGLUOO. AFUs vary significantly in size. The objective is to protect AFUs where harvesting could cause increased channel erosion and the consequent impacts to fish habitat.

Data source

A variety of data sources were used for delineating these features. Best available datasets were included in the following order of priority:

- LiDAR derived strategic floodplains and fans. This includes mapping from two projects by Horel (Horel, 2017): one for Taan Forest Products Ltd., and one for the Haida Gwaii Management Council covering areas where LiDAR was available. Both projects delineated floodplains and active fans using LiDAR-based digital elevation model, 1-m contours and high resolution (25cm) colour ortho-photography. Operational scale mapping for the Bonanza Creek watershed was included in this dataset.
- Watershed assessment mapping (operational scale) of active floodplains and fans for the Awun (Milne M. , 2002), Datlaman (Milne M. , 2004), Haans Creek (Milne M. , 2003), upper Deena (Milne, M.J., 2007) and Lower Yakoun watersheds.
- Terrain classification mapping (survey intensity level c) was completed by Terry Lewis for Skidegate lake and Mosquito lake for the delineation of floodplains and fans in 2009.
- Riparian Fish Forest floodplain mapping (Broadhead, 2008). For this layer, site series and other Terrestrial Ecosystem Mapping attributes were used to theme major riparian floodplain features.

Some overlaps between these projects exist, mostly between Lewis and Horel and Riparian Fish Forest mapping projects on North Moresby and RFF and Horel in TFL 60. All overlaps were removed, and the AFU layer for the analysis created according to survey or mapping intensity, with the following priority from highest to lowest: Horel, Lewis, CWAP, RFF model.

Net down assumptions
The HGLUOO stipulates a 1.5 tree length management zone from the edge of the active fluvial unit, along with a 10% allowable variance. Tree lengths from LUOO Schedule 5 were used, based on ecosystem mapping updated to mid-2019. As such 100% of the AFUs were excluded from the THLB, and 90% of the buffered management zones were excluded from the THLB.

6.10.5 Type I and Type II Fish Habitat.
The HGLUOO classifies retention for low gradient (<5%) S1, S2 and S3 streams (along with adjacent lakes, wetlands and marine interface zones) as Type 1 fish habitat and higher gradient (>5%) streams (including S4 streams) as Type 2 fish habitat. For the purposes of modelling timber supply, the provisions for riparian management for Type 1 fish habitat, described in section 10 of the HGLUOO, have greater retention objectives and therefore supersede the provisions under the *Forest and Range Practices Acts Forest Planning and Practices Regulation.*

Data source
HGLUOO Schedule 4 (Type I and II Fish Habitat)
2012-2016 HGLUOO annual submission data
Modelled Type I and II Fish Habitat

Net down assumptions
Type I and II fish habitat was spatially represented through a modified Schedule 4 fish habitat model, TRIM lakes and wetlands, and marine interface zone mapping, as described below. For Type 1 habitat, reserve buffers 2-tree lengths wide were created, with 95% of the buffers excluded from the THLB. Buffer width for Type 2 habitat was 1.5 tree lengths, and the exclusion was 80%.

Creating a Modified Schedule 4 Fish Habitat Model
Schedule 4 fish habitat mapping represents a strategic-level product that combines empirical fish absence/presence data (Broadhead, 2008), TRIM streams and modelled gradient breaks (JTT, 2011). The spatial linework of the Schedule 4 fish habitat mapping is TRIM streams, and as such is known to underestimate the number of smaller order streams and potentially overestimate the number of higher order streams. Underestimating smaller order streams could lead to an underestimation of netdowns from LUOO buffers, and as such overestimate available timber supply. Therefore a key objective was to:

- quantify the discrepancy between Schedule 4 fish habitat mapping and actual classified streams in the field, and then;
- spatially model what is believed to be a more accurate representation of fish habitat distribution on Haida Gwaii.

The following summarizes and borrows the results of that analysis and describes the subsequent landscape modelling conducted by Fall (2017). For more details see the Fall (2017) report.

Quantifying discrepancies between Schedule 4 fish habitat and field-classified fish habitat
Field mapped stream data were collected and analysed for 14,092 hectares of development areas between 2012 and 2016.

While field mapped stream data is not representative of the distribution of these streams over all of Haida Gwaii, the data is useful to characterize the distribution of fish habitat, as seen in table 6.10.5.1. Ecosections are physiographic groupings with distinct topographies that can be used to stratify the land base (Holland, 1976), helping refine our understanding of what habitat types we expect to find in different regions. For example, the QC Lowlands are made of low gradient landforms where we may expect a higher proportion of larger low gradient streams as compared to the QC Ranges ecosection (west coast) where we may expect more smaller high gradient streams. Table 6.10.5.1 summarizes the field mapped streams by ecosection and fish habitat class.

Table 6.10.5.1 Field map streams by ecosection and fish habitat class (sourced from table 2 Fall (2017)

Ecosection	Type I		Type II		Ratio of Type I to II	Type I + II metres per ha
	length (km)	metres per ha	length (km)	metres per ha		
QC Lowlands	114.6	12.7	78.2	8.6	1.47	21.3
Skidegate Plateau	55.3	11.8	55.6	11.8	1.00	23.6
QC Ranges	10.7	10.2	12.0	11.5	0.89	21.7
Total	180.5	12.2	145.7	9.9	1.24	22.1

The adequacy of using Schedule 4 fish habitat mapping for timber supply was evaluated by calculating whether the frequency and distribution of Schedule 4 fish habitat was similar to what was found in the field (see table 6.10.5.2). This confirmed the expectation that Schedule 4 fish habitat mapping overestimates higher order streams (large low gradient type I streams) and underestimates lower order streams (smaller higher gradient type II streams).

Table 6.10.5.2 Comparison between Schedule 4 fish habitat and fish habitat found in the field (sourced from table 3, Fall (2017))

Ecosection	Type I			Type II			Type I + II relative to field
	length (km)	metres per ha	Relative to field	length (km)	metres per ha	Relative to field	
QC Lowlands	158.6	17.5	**138%**	8.9	1.0	**11%**	**87%**
Skidegate Plateau	61.3	13.0	**111%**	39.8	8.4	**72%**	**91%**
QC Ranges	13.0	12.5	**122%**	12.1	11.6	**101%**	**111%**
Total	232.9	15.7	129%	60.8	4.1	42%	**90%**

A Chi-square test for equality of proportions was completed and demonstrated that the frequency/distribution of fish habitat *versus* non-fish habitat was statistically significantly different between these two data sets. These findings supported the development of a landscape-scale model to more accurately represent the distribution and types of fish habitat across Haida Gwaii.

Landscape level habitat modelling to improve estimations of fish habitat distribution
The proportions and amount of fish habitat found in the field needed to be scaled up to the entire land base while avoiding two types of error: (i) under or over-representing fish habitat in general; and (ii) misclassifying Type I habitat as Type II, or the converse. A scaling analysis compared Schedule 4 fish habitat to the expected proportion and amount of habitat found in the field. The results of a scaling analysis found that overall fish habitat is underrepresented in Schedule 4 across the land base by 7%, as seen in table 6.10.5.3.

Table 6.10.5.3. Schedule 4 fish habitat scaled based on field data. The % of S4 column is the relative percent of the scale values to the Schedule 4 values (sourced from table 5, Fall(2017)).

	Schedule 4			Scaled (expected)					
	Type I	Type II	Type I + II	Type I		Type II		Type I + II	
Ecosection	length (km)	length (km)	Scale factor	length (km)	% of S4	length (km)	% of S4	length (km)	% of S4
QC Lowlands	4,806	534	**115%**	2,615	54%	3,530	661%	6,145	**115%**
Skidegate Plateau	1,692	2,097	**110%**	1,423	84%	2,730	130%	4,153	**110%**
QC Ranges	1,500	2,055	**90%**	1,206	80%	2,005	98%	3,211	**90%**
Total	7,998	4,685	111%	5,245	66%	8,265	176%	13,509	107%

This scaling analysis provided targets for modifying the Schedule 4 fish habitat data in order to reflect stream lengths and distribution of habitat classes found in the field.

A stream model was built using SELES. The scaled Schedule 4 targets were used to re-classify Type I and II fish habitat and to extend or retract streams to match the scaled targets. Extensions of streams were initiated in the lowest gradient stream 'cells' and diffused upslope with preferences for low class streams (high contributing areas) and with a diffusion rate also linked to slope (faster diffusion in lower gradient streams). Final models were cross-validated using the field-based stream data using a Jaccard coefficient statistical test confirming aspatial correlation between the modified Schedule 4 and field data[38]..

Another Chi-squared analysis was done with the scaled or modified Schedule 4 data and resulted in the probability that the two datasets (field based vs. *modified* Schedule 4) were similar (not statistically different).

For timber supply analysis, the raster-based modified Schedule 4 model was converted to polylines and buffered.

Marine interface zones
Marine interface zones into which Type I or II fish habitat streams flow are protected under the HGLUOO. They are high-value marine habitats made up of kelp beds, herring spawn areas, shallow intertidal areas, nearshore habitats used by marine invertebrates for reproduction and rearing) (CIT, 2004) (JTT, 2011). Estuaries, herring spawn areas, eelgrass/kelp bed mapping and clam beds were used to intersect the modified Type I fish habitat. Estuary data was sourced from the Pacific Estuary Conservation Program (Remington, 1993) that mapped significant estuaries across the north coast. Shoreline herring spawn data is sourced from the Ecologically and Biologically Significant Areas (EBSA) project for the Pacific North Coast Integrated Management Area (PNCIMA) (Clark & Jamieson, 2006). Eelgrass, kelp and clam bed mapping from BC's *Coastal Resource Information Management System* (CRIMS) was also used. Data were cross-referenced with data from the *Haida Marine Traditional Knowledge Study* (Windbourne, 2011).

For the timber supply analysis, marine interface zones were assigned the Schedule 5 tree heights of the adjacent site series (buffered intersection)

[38] See table 8 in Fall (2017).

6.10.6 Upland Stream Areas and Sensitive Watersheds

Schedule 7 of the HGLUOO includes all the sensitive watersheds that must be managed under section 14 of the HGLUOO. These watersheds are listed as sensitive due to historic logging, fisheries or water quality importance, higher risk due to topography or stream morphologies or a combination of the above (JTT, 2009). Section 14 of the HGLUOO stipulates that 80% of each watershed must be hydrologically recovered. Hydrologically recovered is defined as *"the point at which regenerated forest stands have hydrologic properties similar to the pre-harvest hydrologic properties of the stands, with hydrologic responses within the range of natural variability"* (HGLUOO 2017).

Upland stream areas are those portions of the watershed sub-units identified in Schedule 6 of the HGLUOO (outside of the reserve and management zones of Type I and Type II fish habitat) wherein 70% of the forests must be hydrologically recovered. This objective is meant to maintain the integrity of non-fish bearing streams, typical of headwaters.

See appendix 7 for a discussion on concepts of hydrologic recovery relative to timber supply and recovery curves.

Data sources

- Schedule 7 of the HGLUOO (sensitive watershed boundaries)
- Schedule 6 of the HGLUOO (upland stream area watershed sub-units)
- Hydrologic recovery curves for rain on snow precipitation regimes[39]:

Modelling assumptions

The following recovery curve equation was used:

$$HR = 100(1-e^{-0.205(H-4.5)})^{1.05}$$

Where HR = hydrological recovery and H = average height of the stand. It is assumed stands have 75 to 90% plus crown closure. HR was cut off at 97.5% in the analysis (see table 7.11.16). See also appendix 7 (recovery curve tables).

[39] Sourced from W.Floyd, regional hydrologist, Ministry of Forests, Lands, Natural Resource Operations and Rural Development

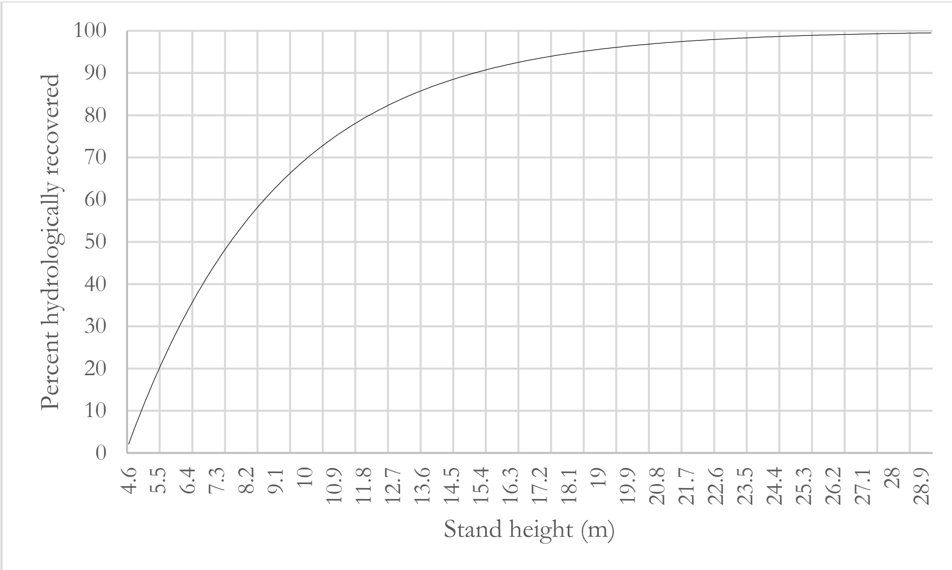

Figure 6.10.6.1 Hydrologic recovery curve used to inform a forest cover constraint for timber supply

For this timber supply analysis, hydrologic recovery curves were used to apply a *forest cover constraint* within the STSM model. Rate of recovery is linked to stand height, and an area-weighted calculation aggregated all the stands within a watershed or watershed sub-unit.

For sensitive watersheds, the entire watershed (forested and non-forested) was used as the denominator since the entire drainage basin forms the hydrological response to water inputs (Church & Eaton, 2001). The model then constrains forest harvesting to ensure that each watershed unit's summed hydrologic recovery does not go below the 80% target for sensitive watersheds.

For upland stream areas, the entire watershed (including non-forest) minus the reserve and management areas for type I and II fish habitat were used as the denominator. This matches the HGLUOO definition of upland stream areas, which are areas that exclude fish habitat (e.g. an objective to manage non-fish bearing streams). The model constrains forest harvesting to ensure each upland stream area's summed hydrologic recovery does not go below 70% target for upland streams areas.

For both sensitive watershed and upland stream areas wetland bogs are considered to be hydrologically recovered. See appendix 7 for more details on hydrologic recovery curves or section 8 that describes a sensitivity analysis that excludes bog wetlands from being considered hydrologically recovered.

6.10.7 Forested Swamps

Relatively rare ecological units classified as Cedar-Spruce-Skunk Cabbage (site series CWHwh1 12, CWHvh2 13[40]), are protected under section 15 of the HGLUOO.

Data source

Ecosystem maps for Haida Gwaii. Spatial layers described in Tripp and Temmel (2017) and section 4.4 of this data package. Primary site series were used to identify forested swamp site series outlined in Schedule 10 of the Haida Gwaii Land Use Objectives Order.

[40] Site series listed above correspond to the HGLUOO listings, however the biogeoclimatic classification system updated in 2014 lists them as site series CWHwh1 118 and CWHvh3 117 (Banner, W. MacKenzie, MacKinnon, Saunders, & H.Klassen, 2014).

Net down assumptions
The HGLUOO stipulates a 1.5 tree length management zone from the forested swamp, along with a 30% allowable variance. Therefore, 100% of the forested swamp units were excluded from the THLB, and 70% of the 1.5 tree length management zone was excluded from the THLB.

6.10.8 Blue/Red listed ecosystems
Site series listed in Schedule 13 are excluded from the THLB to reflect protection measures outlined in section 17 of the HGLUOO (see table 6.11.8.1). Note that all red listed forested ecosystems on Haida Gwaii are floodplain forest sites and therefore tend to overlap with fish habitat or active fluvial unit features.

Data source
Ecosystem maps for Haida Gwaii. Spatial layers described in Tripp and Temmel (2017) and section 4.4 of this data package. Primary site series were used to identify polygons with either red or blue listed ecosystems.

Net down assumptions
While the LUOO requires that red-listed ecosystems be excluded from logging, since they overlap entirely with Type I and II fish habitat and/or Active Fluvial Units, their exclusion has no additional effect on the THLB beyond the impact of those other values.

All blue-listed ecosystems were also 100% excluded from the THLB as this represents the 'default' (low risk) requirements of the HGLUOO.

The table 6.11.8 lists red/blue-listed units.

Table 6.10.8 Applicable excerpts from the HGLUOO Schedule 10.

BEC	Site Series	Name	Status
CWHvh2	5	CwSs - Sword fern	BLUE
CWHvh2	7	CwSs - Devil's club	BLUE
CWHvh2	10	Dr - Lily-of-the-valley	BLUE
CWHvh2	16	Ss - Reedgrass	BLUE
CWHwh1	3	CwSs - Sword fern	BLUE
CWHwh1	6	CwSs - Conocephalum	BLUE
CWHwh1	14	Ss - Kindbergia	BLUE
CWHwh1	15	Ss - Reedgrass	BLUE
CWHwh2	4	CwSs - Conocephalum	BLUE
MHwh	3	SsHm - Reedgrass	BLUE
MHwh	5	YcHm - Twistedstalk	BLUE
CWHvh2	8	Ss - Lily-of-the-valley	RED
CWHvh2	9	Ss - Trisetum	RED
CWHwh1	7	Ss - Lily-of-the-valley	RED
CWHwh1	8	Ss - Trisetum	RED

Blue listed ecosystems make up 62,444 hectares of the forests of Haida Gwaii, however when overlapped with other areas excluded from the THLB only account for an additional 15,566 hectares of netdown from the THLB.

Section 17(3) and (4) of the HGLUOO allow for 30% of blue-listed ecosystems to be altered or harvested altered or harvested if required for road access or to address a safety concern, or for other reasons agreed to through an Intergovernmental Process (IGP). In theory this may represent an additional 4,606 hectares that could be considered THLB, however this allowance has not been put into practice and therefore it was not assessed in the base case, but it's timber supply implications are assessed in a sensitivity analysis detailed in section 8.

6.10.9 Landscape-Level Representation of Common and Rare ecosystems
Common and rare site series and their conservation targets listed in Schedule 10 of the HGLUOO are removed from the THLB to reflect measures outlined in section 16 of the HGLUOO.

Data source
Ecosystem mapping for Haida Gwaii. Spatial layers described in Tripp and Temmel (2017) and section 4.4 of this Data Package. Primary site series were used to identify site series outlined in Schedule 10 of the Haida Gwaii Land Use Objectives Order.

Schedule 10 can be downloaded at http://www.haidagwaiimanagementcouncil.ca/wp-content/uploads/2017/11/HGLUOOSched10_SSTargets_20170713.pdf

Net down assumptions
Landscape unit targets by site series are listed in Schedule 10. An analysis of each site series overlap with existing protection or exclusion from the THLB was completed to determine a landscape unit by site series deficit (area needed to be reserved to meet the Schedule 10 targets). A netdown to the THLB was used as opposed to forest cover constraints due to the complexity of modelling this objective.

In summary, landscape unit deficits were determined for each site series. Where there were deficits (e.g. the conservation targets weren't met in existing protected areas or outside of the THLB) then old forest was the preference to meet the targets, and if there wasn't enough old forest, then second growth/younger forest was identified to meet the targets.

The analysis stratified old forest (>=250 years) from younger forest (<250 years), as the HGLUOO mandates a preference for old forest retention.

Out of the 154 site series/landscape unit combinations, 105 had all Schedule 10 targets met outside of the THLB, therefore did not require any further exclusions. For the remaining 47 units, a deficit was calculated and used to exclude areas of those units from the THLB proportional to their landscape unit occurrence and conservation targets.

For example, to calculate the THLB exclusion for the CWHwh2 05 sites series in Honna Landscape Unit, the Schedule 10 target is to retain 586 hectares as old forest. Currently, approximately 316 hectares have a pre-existing exclusion from the THLB. Therefore, the Landscape Unit deficit is 270 hectares (586-316). The entire area of CWHwh2 05 in this Landscape Unit is 761 hectares, of which 324 hectares is old forest in the THLB. Therefore, a total 83% of this unit (270÷324) must be excluded from the THLB to meet the Schedule 10 target.

This target was subsequently applied to old forest, however, if there were not enough hectares of old forest, then the remaining proportional deficit was applied to younger forest in the THLB.

Note that for Skidegate Lake, Louise Island and Sewell, the TSR ecosystem mapping dataset has site units using both the old BEC classification and the new BEC classification. In these cases, the new BEC was cross-walked and the target/deficit/constraint calculations were aggregated/shared across the units to avoid double counting a constraint.

Table 6.10.9 lists the final retention targets to be excluded from the THLB by site series. Bold units represent hectares excluded from the THLB in order to meet targets, with the percentage in green to represent old forest exclusion, and orange to represent young forest exclusion[41] necessary to meet the targets. Units with a dash (-) represent areas where targets were met outside of the THLB. The following is a descriptive example of table 6.10.9.1

BEC Variant	Site Series	Exclusions for Honna LU	
CWHwh1	02	**15 ha**	area of this site series excluded from the THLB to meet Schedule 10 targets
		100%	excluded % of each old-growth polygon in this site series
		72%	excluded% of each second-growth polygon in this site series
CWHwh1	10	**218 ha**	
		100%	excluded% of each old-growth polygon in this site series was excluded
		100%	excluded% of each second-growth polygon in this site series
CWHwh2	05	**586 ha**	
		83%	excluded % of each old-growth polygon in this site series
		0%	excluded% of each second-growth polygon in this site series

[41] Site series/Landscape Units not listed means that targets have been met in protected areas, or the LU's do not overlap with the forest management land base.

Table 6.10.9 Ecosystem targets by landscape unit. Bold units represent hectares where area was excluded from the THLB in order to meet targets, with the percentage in green to represent old forest exclusion, and orange to represent young forest exclusion to meet those targets. All dashed (-) units mean that targets were met outside the THLB.

BEC Variant	Site Series	Eden Lake	Honna	Ian	Louise Island	Lower Yakoun	Masset Inlet	Naikoon	Otun	Rennell	Sewell	Skidegate Lake	Tasu	Tlell	Yakoun Lake
CWHvh2	2						-								
CWHvh2	6									-	-		-		
CWHvh2	14												-		
CWHwh1	1	-	-	-	-	-	-	-	-	-	-	3147 100% 68%		-	-
CWHwh1	2	-	**15** 100% 72%	**627** 100% 100%	**1030** 100% 100%	-%	**2181** 100% 100%		-		-	-		-	**382** 100% 97%
CWHwh1	4	-	-	-	-	-	-	-	-	-	-	-		-	-
CWHwh1	5	-	-	-	-	-	-	-	-		-	-		-	-
CWHwh1	9				-	-					-				-
CWHwh1	10	-	**218** 100% 100%	-	-	-	**272** 100% 1%	-	-		-	-		-	-
CWHwh1	11	**938** 100% 100%	-	**478** y 100%	**41** 100% 100%	-	**65** 100% **1%**	-	**5690** 100% 100%	-	**49** 0% 100%	-		-	**95** 100% 10%
CWHwh1	13										-	-			-
CWHwh1	16		-									-		-	
CWHwh2	1	-	-	-	-	-	-			-	-	-		-	-
CWHwh2	2	-	-	-	165 100% 5%	-	**1868** 13%			-	**81** 62%			-	-
CWHwh2	3	**2042** 100% 5%	-	**20** 100% 87%	**36** 100% 100%	-	**76** 100% 84%			-	-	**259** 50%			**148** 100% 100%
CWHwh2	5	**656** 27%	**586** 83%	**178** 100% 100%	62 100% 100%	**41** 100% 100%	**173** 100% 100%			**6** 62%	**315** 100% 100%	**76** 100% 100%		**210** 100% 100%	-
MHwh	1	-		**309** 100% 100%	-	-	**779** 100% 100%				**438** 0% 100%	**219** 100% 100%	-		**275** 100% 100%
MHwh	2		-	-	-	-	-			-		**184** 100% 100%	-		
MHwh	4	-	**158** 7%								-		**77** 100% 100%		
MHwh	6									-			-		
MHwh	8	-	-							**63** 100%			-		
MHwh	9									-					

6.10.10 Forest Reserves

These are areas reserved from harvesting as per section 23 of the HGLUOO to meet Marbled Murrelet and Ecosystem Representation targets. Section 23(2) allows for a 5% reduction of an individual forest reserve polygon (operational variance does not require an intergovernmental process).

Data source

HGLUOO Schedule 8.

Net down assumptions

95% exclusion from the THLB of each forest reserve polygon.

6.10.11 Marble Murrelet habitat

Areas retained to meet Marbled Murrelet nest habitat by landscape unit, as outlined in Objective 19, Schedule 9 (landscape unit targets) and Schedule 11 (mapped habitat) of the HGLUOO.

Data source

HGLUOO Schedule 9 (Landscape Unit targets), Schedule 11 (Marbled Murrelet habitat map), and Schedule 1 (Landscape Units).

Net down assumptions

An analysis was completed that calculated the amount of Schedule 11 Marbled Murrelet habitat outside of the THLB by landscape unit relative to Schedule 9 targets. The analysis found that all the targets (detailed in table 6.10.11) were met outside of the THLB and therefore no further forest cover constraints or netdowns were necessary.

Table 6.10.11 Applicable excerpt from HGLUOO Schedule 9- Marbled Murrelet conservation targets

Landscape Unit	TSR target for retention (ha)
Bigsby	397
Eden Lake	7687
Honna	3854
Ian	1253
Louise Island	4674
Lower Yakoun	1134
Masset Inlet	4881
Naikoon	1610
Otun	2243
Rennell	5280
Sewell	3488
Skidegate Lake	2210
Tasu	3941
Tlell	3315
Yakoun Lake	2340

6.10.12 Northern Goshawk

Northern Goshawk is a red-listed sub-species and the national bird of Haida Gwaii that is considered threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Its nesting areas are protected under the HGLUOO section 20 with approximately 200-hectare reserves of suitable habitat. As of September 2019, a total of 23 territories have been identified on Haida Gwaii.

Data source
HGLUOO Schedule 12
Predictive goshawk nesting territory model

Net down assumptions
All Schedule 12 Northern Goshawk nesting reserves, as well as additional nests discovered up to 2019 were excluded from the THLB. One breeding areas (Canoe creek) had a draft reserve design that was used for the THLB netdown, and another breeding area (Ian lake east) had a 800m buffer included around the nest area given that a reserve has yet to be designed.

Section 20 of the HGLUOO requires that when a new Northern Goshawk nest is discovered and is not within a Schedule 12 reserve, a restricted activity zone of at least 800-m radius and a 200-hectare reserve around the nest site be established. For the base case, discovery of new nests was not reflected. However, sensitivity analyses were performed to explore the implications of establishment of more nesting reserves in line with both provincial government implementation plans and the federal recovery plan. These are discussed in section 8.

6.10.13 Saw-whet Owl
Saw-whet Owls are a focal species listed within the HGLUOO that nest in mature/old forest snags. Nesting reserves are displayed in HGLUOO Schedule 12. Similarly, there is a requirement to retain *or recruit* 10 hectares of mature/old forest under 300m elevation in a grid approximately every 1400m as 'core nesting habitat'.

Data source
HGLUOO Schedule 12

Net down assumptions
All Schedule 12 Saw-whet Owl nesting reserves were 100% excluded from the THLB.

An analysis was conducted whereby hexagonal spatial units were placed on 1400m centres and a nearest-neighbour spatial function determined whether 10 hectares of contiguous old/mature forest was retained, or younger forest retained in the absence or deficit of old/mature forest within the hexagon. The results found that while some landscape units (notably Skidegate Lake and Lower Yakoun) have deficits of old/mature forest, all areas had contiguous forest retained to meet the core nesting habitat requirements. These findings coincide with recent findings from a Forest Practices Report that similarly evaluated Saw-whet Owl core nesting habitat requirements in the Skidegate Lake Landscape Unit (Forest Practices Board, 2019).

As a result of this analysis, no further netdowns were applied for core nesting habitat.

6.10.14 Blue Heron
Blue Herons are a focal species listed within the HGLUOO that nest in mature/old forests. The HGLUOO provides 45-hectare temporary (3-year) protection to active blue heron nests. Two Blue Heron nesting areas have been discovered between 2011-2018, amounting to approximately 90 hectares that are reserved from harvesting. Given the very small area affected, no area was excluded from the THLB for the analysis.

6.10.15 Cedar Stewardship Areas
CSAs are areas retained for long term access for Haida cultural use as per section 3 of the HGLUOO. The risk-managed provisions to harvest a total of 10% of the area for commercial purposes is covered in section 8 of the data package (sensitivity analyses). This risk-managed area (approximately 2500 hectares over 10 years)

amounts to approximately 1.6% of additional THLB that could be accessed through an Intergovernmental process. Note that <10 hectares have been accessed since the HGLUOO came into effect in 2011.
Data source
HGLUOO Schedule 3
Net down assumptions
Consistent with Schedule 3 of the LUOO, 100% of CSAs were excluded from the THLB.

6.10.16 Haida Traditional Heritage Features

Haida Traditional Heritage Features include those listed in Schedule 2 of the HGLUOO, with 500 metre buffers applied around class 1 features, and 100m buffers applied to class 2 features.

Table 6.10.16. Class 1 and 2 Haida Traditional Heritage Features (Schedule 2, HGLUOO).

Class 1:
Village/Seasonal Village
Inland Camp/Camp
Burial Site
Identified Oral History site
Identified Spiritual site

Class 2:	
Midden	Lookout site
Bear Trap	Fort
Fish Weir	Cache
Cave	Canoe run
Petroglyph	Shoreline habitation site
Lithic production site	Rock Shelter
Trail	Karst Feature

Data sourced from
These are the most sensitive but also most widely studied types of heritage features that also have protection under the *Heritage Conservation Act.* As a result, most timber harvesting avoids these sites, and identifies them as a result of Archaeological Impact Assessments and/or Cultural Feature Identification surveys (CHN, 2016). Data were sourced from the 2012-2016 HGLUOO annual submissions data from licensees, however this source was limited to only four records. Data were also sourced from the 2002 *Archaeological Overview Assessment Haida Gwaii, North of Gwaii Haanas* (Christensen & Stafford, 2002). Additional heritage data was sourced from the Council of the Haida Nation's *Placenames* database (village sites). Sites identified within the Remote Access to Archaeological Data (or *RAAD*) current to May, 2019, from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development were also excluded from the THLB.

Netdown assumptions
One hundred percent of the areas contained within the associated buffers were excluded from the THLB. 100m buffers were applied to class 2 features, 500m buffers applied to class 1 features.

6.10.17 Stand Level Objectives

A number of LUOO objectives are for features that don't have full inventories or are yet-to-be identified in the field. As discussed in section 6.10.2 and appendix 6, a sample of operational data was used to do a frequency distribution analysis to help predict these occurrences and then net them out of the THLB. The following table summarizes these net downs, with greater descriptions provided in the corresponding sections.

Table 6.10.17. Summary of netdowns for stand-level LUOO objectives.

Type	Total Netdown	Young forest	Old forest	Comment
Bear	0.1%	**0.1%**	**0.1%**	features found in young and old forest
HTHF	0.1%	**0.1%**	**0.1%**	features found in young and old forest
HTFF 2	2.5%	**0.15%**	**2.3%**	94% of the 2.5% netdown is found in old forest
HTFF 1	0.9%	**0.14%**	**0.74%**	84% of the 0.9% netdown is found in old forest
CMT	1.8%	**1.8%**	**1.8%**	features found in young and old forest
Yew	2.3%		**2.3%**	Features only found in old forest
Unspecified	3.6%	**3.6%**	**3.6%**	THLB retained with unspecified objectives
Total		**5.89%**	**10.94%**	

6.10.18 Culturally Modified Trees

Culturally Modified Trees (CMTs) are identified for protection under section 9 of the HGLUOO and include trees modified by Haida people for cultural use prior to 1920.

Data sourced from

The Council of the Haida Nation and the Province of BC have been systematically cataloguing Culturally Modified Tree data since the 1980s. A number of separate inventory initiatives have occurred over the decades, and for the purpose of timber supply analysis, these datasets have been collated in order to determine the current known extent of CMTs and the associated reserve network. Data sources include:

- The 2002 Archeological Overview Assessment (Christensen & Stafford, 2002), which is a collation of data from over 97 Archaeological Overview Assessment (AOA) reports; Archaeological Inventory Studies (AIS); excavation and Archaeological Impact Assessments (AIA). It also included data from over 300 reports produced by the CHN's CMT Inventory program;
- 2017 BC Heritage Branch's Registered Archaeological Sites - all CMT features from Haida Gwaii were parsed from the overall *Remote Access to Archaeological Data* (RAAD) data set, provided by Diana Cooper (Archaeological Site Information and Data Administrator - Ministry of Forests, Lands and Natural Resource Operations, and Rural Development).
- Archaeological inventory studies - a variety of data collated from licensee commissioned Archaeological studies (AOAs, AIAs etc.);
- Cultural Feature Identification survey data - CMT data sourced from the LUOO digital submission dataset from 2012-2016.
- Areas where some level of forest planning occurred but was not completed due to the number of values requiring retention making the area not viable for development. These areas were sourced from licensees. For CMTs these included blocks FLO004, CHI001 and DRL107.

Net down assumptions

The HGLUOO stipulates a 0.5 tree length reserve zone and a one tree length management zone around known CMTs, both of which are to be maintained (i.e., reserved from harvest). The data were used for two separate applications: (i) to exclude retention areas around known CMTs, and; (ii) to undertake an aspatial frequency distribution analysis for estimating an exclusion factor to account for yet to be identified CMTs.

For known CMTs, existing HGLUOO retention buffers were excluded from the THLB. For known CMTs without a designated retention area (e.g., CMTs not registered as an *Archaeological site* under the *Heritage Act*, or not included in Development Areas of the HGLUOO) 1.5 tree length buffers were assigned and excluded from the THLB, as described in section 6.10.3 of this data package.

For not yet identified CMTs, netdowns were predicted across the land base using operational adjustment factors outlined in appendix 6 using the 2012-2016 HGLUOO annual submission data. Similar to Haida Traditional Heritage Features, licensees tend to avoid areas with high numbers or high potential numbers of CMTs. Therefore, using the 5-year operating dataset (2012-2016) reflects a smaller netdown factor then when compared with past TSRs. For example, the netdown or exclusion factor for this base case is 1.8% of every hectare, compared to a 7.7% reduction (to old forest only) in 2011 (JTWG, 2012). The current base case exclusion factor applies to forests of all ages, as CMTs are found in all age classes. The exclusion factor was calculated based on information from the portion of the land base where harvesting has occurred, but also accounts for an additional 115 hectares where harvest planning was done, but was ultimately not harvested as a result of high densities of CMTs.

6.10.19 Monumental cedar

Monumental cedar are defined both within the Haida Gwaii Strategic Land Use Agreement (CHN & BC, 2007) and the HGLUOO as a "*visibly sound western redcedar or yellow-cedar tree that is greater than 100 centimeters in diameter at breast height and has a log length of 7 meters or longer above the flare with at least one face that is suitable for cultural use"*. Protection measures for monumental cedar detailed in section 9 of the HGLUOO provide long-term cultural access for the Haida Nation. Monumental cedar greater than 120cm diameter at breast height, or that occur within a 'cultural cedar stand' are, by default, protected from harvesting. Ten percent of smaller monumental cedar that are not within a 'cultural cedar stand' must be protected from harvesting.

Data sourced from
HGLUOO 2012-2016 annual submission data. This data included 1,085 monumental trees of which 763 or 70% of were protected and 30% were logged. Data to support the analysis was also sourced from the Harvest Billings System scaling data (2003-2010) and forest inventory (see descriptions below).

Timber Supply Considerations
For known occurrences of monumental cedar, the reserve and management zones within the HGLUOO annual submission data were entirely (100%) excluded from the THLB.
The following describes methods used to estimate netdowns to the THLB resulting from the current *Cultural Feature Identification Standards* (October, 2019, v.5).

This involved numerous steps using the following logical sequence:

1. What quality of cedar trees are included in monumental classifications? An analysis determined an equivalency to the Provincial scaling system.
2. How many of these trees are there? The frequency of occurrence of those log grades was based on an analysis of 7-years of log-scale data from Haida Gwaii. General volumes were converted to (average) individual tree volumes.
3. Where are these trees and how are they distributed? Assuming these trees are only found in old forest and not uniformly distributed, the forest inventory was used and higher cedar content meant a higher probability of a tree being there. Trees were randomly assigned across the old forest within management units..
4. How much area is in retention for these trees? A spatial model was used to identify buffers at 1m resolution to account for fine-scale overlap based on the spatial distribution of trees. This step produced an expected netdown for the randomly located trees that was used as an additional THLB netdown factor.

Determining tree quality

Correlating the approximate provincial log grades with the proposed monumental *Cultural Feature Identification* (CFI) standards changes allows for estimates in the frequency of occurrence of these log grades. A few key attributes were used for comparison.

Table 6.10.19.1 Log attributes comparison for 100-120cm monumentals and the BC Scaling Manual (MFLNRORD, 2011)

Attributes	Proposed CFI monumental allowances	BC Scaling manual maximum allowances		
		D	H	I
Knots	4 knots >8cm	Occasional knots in upper 1/3rd	Occasional up to 8cm on upper 50% of log,	Occasional up to10cm (log radius over 38cm)
Rot	<50%	<33% (50% merchantability of 66% gross scale)	<49% (65% merchantability of 75% gross scale)	<38% (50% merchantability of 75% gross scale)
Max twist	25%	6cm over 30cm= 20%	8cm over 30cm= 27%	30%

This comparison shows that the grade 'H' and better are the closest alignment between the new CFI monumental cedar identification and BC log grades. While the standard does allow for knots greater than 8cm diameter, and 'I' grade allows for knots up to 10cm, the maximum twist for 'I' grade exceeds the twist allowance for monumental identification.

Harvest Billings System and District scale data were used to quantify the frequency of occurrence of cedar log grades greater or equal to grade 'H', as well as the frequency of these logs being greater than or equal to 100cm[42] diameter (see table 6.10.19.2 and 6.10.19.3)

[42] Note that log length was not considered a variable as logs may have been cut to spec, but originally may have met the 7m minimum length criteria.

Table 6.10.19.2 Parameters used to determine the random distribution model.

Variables	Source	Value
Percent of Cw/Cy that are D, F and H grade over 100 cm diameter log(**b**illed data)	HG District scaling data (Scaled January 1, 2003 to March 30, 2010)	5%
Approximate m^3 per average monumental cedar based on average diameter (123cm) and average height monumental cedar (36.7m)	HGLUOO annual submission data; diameters used *n=722*; height used *n=645* samples. Volume based on QC2002 taper equations (net volume)	11.5m^3

Table 6.10.19.3. **Log grade distributions for cedar based on scale-data from 381,980 logs, sourced from the Haida Gwaii Natural Resource District from 2003-2010.**

		Cedar over 100 cm diameter	
Cedar grades	% of grade contributed to total cedar logged	% of grade made up of cedar ≥100cm diameter	% that grade (and diameter ≥ 100cm and 7m length) contributes of total cedar volume
D	1%	70%	0.3%
F	1%	62%	0.4%
H	25%	16%	3.3%
I	15%	10%	1.3%
J	26%	0%	0%
K	2%	62%	0.6%
L	6%	31%	1.4%
M	5%	11%	0.5%
U	14%	1%	0.1%
X	3%	3%	0.1%
Y	1%	4%	0%
Z	0%	33%	0%

Determining the number of trees

The next step was to estimate the number of these high quality trees per hectare.

High quality cedar is not uniformly distributed across the THLB, therefore two distribution parameters were used: a weighted correlation with cedar volume in the inventory, and; a random distribution. Sensitivity analyses (described in section 8.2.3.6) outline interpretations of the CFI standards that may include a broader range of grades, age classes and levels of retention.

Higher quality cedar is generally found in stands with higher volumes of cedar. Monumental cedar are also generally found in old forest (>250 years). This volume relationship was tested against several thousand monumental cedar data points from the CHN relative to cedar volume distribution in the inventory. The analysis, which compared the normalized weighted area of cedar sites to the number of high quality cedar in those sites confirmed this correlation (as seen in figure 6.10.19.2).

Determining the number of high quality trees (H grade and better) per hectare was calculated by:

1. Defining the applied landbase: forest within the management units (i.e. land in forestry tenures, as shown in Figure 3.1.4.5 above): about 492,000 ha;

2. Estimate old cedar volume (age >= 250 years) : %Cedar * initial Volume/ha in cells with initial age >= 250, summed across applied landbase: about 34,828,000 m3;

3. Multiply old cedar volume on applied landbase by % monumental (assumed to be 5% in base case, as per table 6.10.19.2 above): about 1,741,000 m3 of monumental cedar volume;

4. Divide estimated monumental cedar volume on applied landbase by average m^3 per monumental cedar (assumed to be 11.5 m3 in the base case, as per table 6.10.19.2 above): about 151,000 monumental trees;

The next step was to determine the proportion of these trees that might be logged (and made available to the Haida Nation), as per the HGLUOO. The HGLUOO allows for trees to be logged and made available to the Haida Nation if they are not in a cultural cedar stand, and if they are under 120 cm diameter (conditional to the greater of 10% of monumentals or 1 monumental being retained within the development area). However it is difficult to predict the distribution of tree sizes (over or under 120cm) and their spatial relationship (three or more trees within 50m of each other to be classified as a cultural cedar stand). The 2012-2016 HGLUOO annual submission data from licencees indicated that approximately 70% of all monumental cedar (regardless of size and spatial arrangement) were retained and 30% logged. Starting with the spatial distribution of monumentals (about 151,000), this was reduced by 30% by removing approximately 45,000 trees from the buffering step. About 43,000 are in cells with 3 or more (representing trees in cultural cedar stands). Of the approx. 106,000 in cells with 1 or 2, 45,000 were randomly removed.

Spatial distribution and netdown

The next step was to distribute the number of monumental cedar trees per hectare across the old forest within the management units based on this reference number (106,000 trees). Given lack of information regarding how monumental cedar trees are distributed in relation to each other (and to avoid making the assumption of a spatially uniform distribution), it was assumed that monumental cedar trees are distributed independently of each other. Each tree was located in an old forest grid cell with a relative probability based on its volume of cedar (i.e. spatially randomized but weighted by cedar volume).

Analytical steps included:

1. For a given number of monumental cedar trees, locate them in old stands that have at least 1% cedar, in the applied landbase, randomly but weighted by the amount old cedar volume (number of trees per 1 ha grid cell varied from 0 to 9 in the base case).

2. Create a layer that represents the % of each grid cell covered by a monumental cedar buffer.

   (a) Locate each monumental tree to a 1m x 1m site within each 1-ha grid cell.
   (b) Process each grid cell (focal cell) that includes or is adjacent to a cell with at least one monumental.
   (c) Place all the monumental cedar trees in the focal cell and adjacent cells on a 1m resolution buffer (300 cells by 300 cells).
   (d) Iteratively (10,000 times) compute 60m buffers on each tree to identify the average net buffer area within the focal cell (ranging from 0% to 100%).
   (e) Rescale buffers for each cell to the 1-ha resolution data set to produce a layer that represent the % of each cell the buffer of 1 or more monumental cedar trees (accounting for for buffer overlaps).

3. Use the % buffer grid as an incremental netdown on the base THLB (see Figure 6.10.19.1).

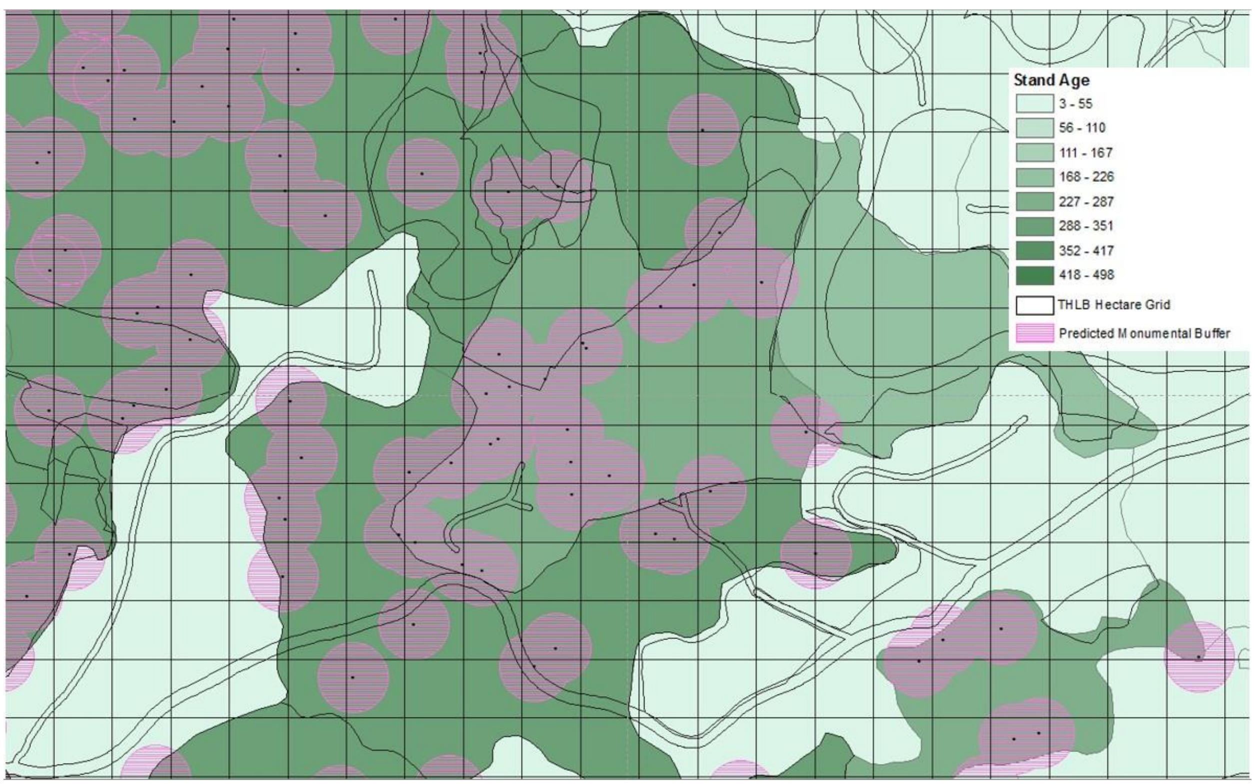

Figure 6.10.19.1 . Example of random spatial distribution of monumental cedar, correlated with stand volume, and their buffers relative to the THLB. This means that some cells will have more monumental cedar trees than others (even if they have the same cedar volume), but overall the reference (106,000 trees) number is

allocated across the land base. The range of the number of trees randomly allocated to a one-hectare cell was between 0 and 9 trees, with 60% of cells having 1 tree, 27% having 2 trees, 9% having 3 trees, 3% having 4 trees, and 1% having between 5-9 trees.

The final step was to assign buffers to the trees.

As there are many cases where buffers may extend beyond a one-hectare grid cell, a sub-model was designed to determine the expected spatial netdown from buffering trees. The sub-model randomly placed trees at 1m x 1m locations within each hectare in which they were located in the previous step. Each hectare and its immediately adjacent hectares were then iteratively processed (using a 1m resolution 300m x 300m grid). For each iteration, a 60m buffer was applied on each tree within the focal hectare and the adjacent hectares to determine the net buffer for the focal hectare, accounting for the buffers and overlaps of all trees that affect the focal hectare. For example, the average buffer on one-hectare (100m x 100x) areas with 3 trees was 94% (counting effects of trees in adjacent areas on the focal hectare, but not counting the area of buffer from the focal hectare that extended into adjacent hectares)

The buffers for each hectare were then rescaled to the one-hectare resolution of the main model to produce a gross netdown factor for monumental cedar and intersected with the THLB. The overall gross buffer netdown was significantly higher than the net effect due to prior THLB netdowns.

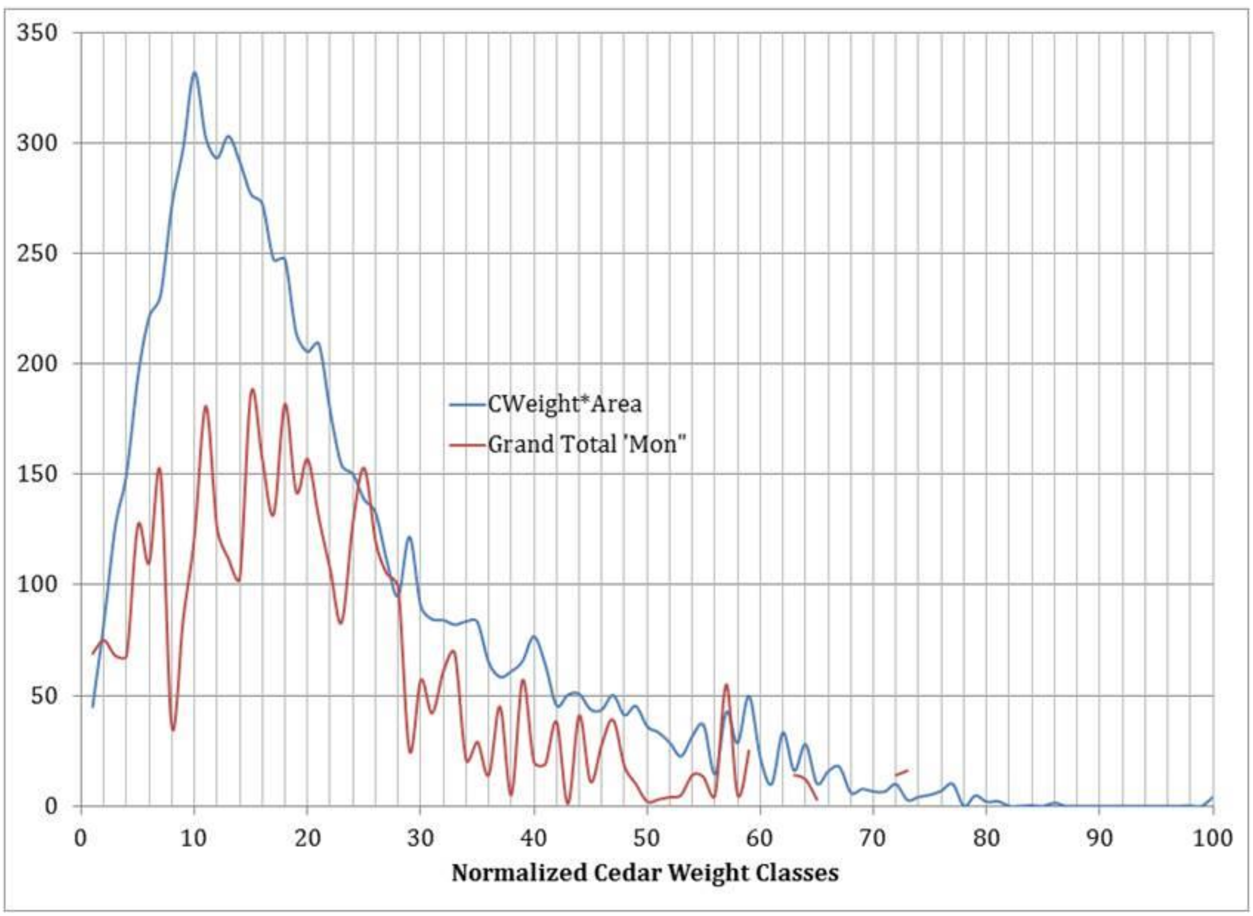

Figure 6.10.19.2 Relationship between cedar in the inventory and the occurrence of high quality cedar 'Mon'.

This resulted in a gross netdown of 77,737 hectares of forest and, after considering overlaps with other objectives, a net reduction of 44,584 hectares from the THLB.

6.10.20 Haida Traditional Forest Features
Haida Traditional Forest Features consist of 11 types of class 1 features and 10 class 2 features as per Schedule 2 of the HGLUOO. Class 1 features require a two tree-length buffer (sec 6 (2) and 6 (3)) whereas class 2 features require stand level retention to protect the integrity of the features (sec 6 (7)).

Data sourced from

- HGLUOO 2012-2016 annual submission data.
- 'Walk away' areas where some level of forest planning occurred but was not completed due to the number of values requiring retention, making the area not viable for development. 'Walk away' areas were sourced from licensees. For HTFFs these included blocks MOS500, NEC504, NEC503, NEC523, NEC524, NEC525, NEC505, NEC506, NEC508, NEC526, NEC527, NEC528.

Net down assumptions
A total of 8,626 features and their retention areas were excluded from the THLB and were used for a frequency distribution analysis for predicting netdowns from yet to be identified HTFF2s. 'Walk away' areas described above amounted to a total of 37 hectares (used for the frequency distribution analysis).

Existing HGLUOO retention areas were entirely (100%) excluded from the THLB. Note that class 1 buffers and the retention areas for class 2 features are built into the HGLUOO annual submission data. The HGLUOO class 2 HTFF retention areas do not always assign the specific HGLUOO value associated with the retention. See appendix 6 for a description on how HTFF values were assigned to retention areas to quantify and attribute specific HTFF netdowns.

For determining an exclusion factor for not-yet-identified HTFF2s, predictive indicators were analyzed to assess whether features were most closely associated with specific site conditions. The purpose is to apply an exclusion factor to sites with the highest likelihood of occurrence, and thereby more closely represent operational realities. Predictive indicators were reviewed using classification and regression tree statistical analysis and Chi-squared goodness of fit for BGC variants and stand age.

For Class 1 forest features, Devil's club constitutes 94% of all class 1 occurrences and for Class 2 forest features, Hellebore and Pacific crabapple constitute over 99% of all features.

BGC variants are a statistically significant predictor of presence, as per chi-squared goodness of fit tests. For example, Devil's club occur disproportionately in the CWHvh3 variant, hellebore occurs disproportionately in the CWHvh3 and CWHwh2 variants, and pacific crabapple only occurs in the CWHwh1 variant (within current samples). However, using BGC variants and HTFF species amounts to 27 different model assumptions for this one HGLUOO value.

Stand age was a simpler predictive variable for consistent application as 94% of all HTFF occurrences are in old forest. A chi-square goodness of fit[43] supported that HTFF presence was dependent on age (chi square 1481, critical value 3.81, $p<0.001$). As such, an exclusion factor proportional to HTFF occurrence by stand age of old forest >=250 years or younger forest <250 years was applied.
For HTFF class 2 features this amounted to a per hectare net exclusion factor of 2.3% and 0.1% for old and young forest respectively. For HTFF class 1 features this amounted to a 0.7% and 0.1% per hectare net exclusion factor for old and young forest respectively.

6.10.21 Yew trees

[43] Note that goodness-of-fit tests used the proportion of old forest vs. second growth forest logged to calculated expected frequencies.

The HGLUOO (sec 8(1)) provides stand-level protection to all yew tree patches. Similarly, individual yew trees are protected at the stand level where practicable (sec 8 (3)).

Data sourced from

- HGLUOO 2012-2016 annual submission data
- 'Walk away' areas are areas where some level of forest planning occurred but was not completed due to the number of values requiring retention making the area not viable for development. 'Walk away' areas were sourced from licensees. For Yew trees these included blocks NEC545 and NEC507.

Net down assumptions

A total of 16,226 features were used to exclude retention areas associated with known yew features, and to undertake a frequency distribution analysis for predicting netdowns from yet to be identified yew features. 'Walk away' areas described above amounted to a total of 9 hectares (used for the frequency distribution analysis).

For determining an exclusion factor for yet to be identified yews, predictive indicators were analyzed to assess whether features were most closely associated with specific site conditions. The purpose was to apply an exclusion factor to certain sites, and thereby more closely represent operational realities. Two predictive indicators were reviewed using classification and regression tree statistical analysis and chi-squared goodness-of-fit tests: BGC variants and stand age.

Of all yew features, 92% occurred within the CWHwh1 variant, as opposed to approximately 8% within the CWHvh3 and under 1% in the CWHwh2 variants. Stand age however was a stronger predictive variable, as a yew is a late-seral dependent species: 99% of occurrences were found in old forest (>=250 years)[44]. As such, age was used as a stratum to apply an exclusion factor to the THLB, which based on the HGLUOO annual submissions data, amounts to a net of 2.3% of old forest at the stand level.

6.10.22 Black Bear dens

Black bear dens are protected under section 18 of the HGLUOO. A total 20m wide reserve zone and 1 tree length wide management zone are established around each identified den.

Data sourced from

HGLUOO 2012-2016 annual submission data.

Net down assumptions

A total of 26 bear dens and their reserve and management zones were excluded from the THLB, and were used in an aspatial frequency distribution analysis for predicting netdowns for yet to be identified bear dens.

100% of the reserve and management zones within the HGLUOO annual submission data were excluded from the THLB. While bear dens are by definition found in old trees, there was no strong correlation between forest age and den occurrence based on the sample size. Therefore, based on a frequency distribution analysis, an exclusion factor of 0.1% of all forest was applied.

Note that CHN's protected area surveys proportionately found three times as many bear dens per hectares than in licensee HGLUOO annual submissions. As such, there is an uncertainty about the frequency of these features across the land base, which may amount to higher proportions of dens located in the future and a larger effect on the THLB.

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[44] Chi-squared value 4434, critical value 3.84, p=0.001

6.11 Archaeological Resources
The *Heritage Conservation Act* (HCA) provides protection to heritage sites within BC. A registry of heritage sites is maintained by the Ministry of Forests, Lands and Natural Resource Operations and Rural Development wherein spatial and reporting information on sites are catalogued and confidentially safeguarded. Heritage sites are protected under section 13 of the HCA. See sections 6.10.16-6.10.17 above.

Data sources

- 2017 BC Heritage Branch's Registered Archaeological Sites - all CMT features from Haida Gwaii were parsed from the overall *Remote Access to Archaeological Data* (RAAD) data set provided by Diana Cooper (Archaeological Site Information and Data Administrator- Ministry of Forests, Lands and Natural Resource Operations).

Netdown assumptions
A total of 2,132 archaeological sites were 100% excluded from the THLB. These sites are represented as polygonal features, and in many cases overlap with features protected under the HGLUOO. See section 6.10.17 for a description of how heritage sites and CMTs (under the HGLUOO) were netted down.

6.12 FPPR Requirements for Streams

The *Forest Planning and Practices Regulation* Division 3 sections 50, 51 and 52 outline restrictions on primary forest activities within riparian management areas. All fish-bearing stream classes and associated retention levels (S1-S4 classes) are in effect superseded by the HGLUOO sections 10 and 11, as FPPR requirements are less constraining. As such only S5 and S6 streams (non-fish bearing >3m and <3 m width respectively) were considered subject to the FPPR. Currently the FPPR only requires ≥10% of the basal area of trees within a 30m management zone of S5's to be retained if it is a minor tenure holder (generally <2,000m^3), or 'enough trees adjacent to the stream to maintain the stream bank or channel stability' if it is a direct tributary to a larger fish-bearing stream or a marine interface zone.

A variety of techniques have been used in previous TSRs to estimate the effect that non-fish bearings streams have on forest management:

- No buffers applied to S5 streams for TFL 47 Moresby Block (now TFL 58) (Angus, 2001);
- A 15% partial netdown of a 30m buffer (equivalent to 4.5m) was applied to modelled S5 streams for TFL 39, block 6 (now TFL 60) (Kofoed, 1999);
- No riparian area reductions for S5 streams for TFL 25 (now part of the Timber Supply Area) (Byng, 2003);
- Within the TSA, past timber supply analyses have modelled streams, assuming S5 streams were streams with >=20% gradient (Cortex Consultants and Gowland Technologies, 2004);

The approach used in this timber supply analysis follows that used in the 2012 TSR (JTWG, 2012). A previous analysis of detailed engineering stream class inventory from TFL 39 block 6 (now TFL 60) indicated that 9% of the total length of non-fish bearing streams were S5 streams. Assuming this frequency and applying FPPR sec 52 management areas would amount to an approximate 90-hectare reduction to the THLB. This is a relatively minor area and when considering the small retention requirements, therefore it was not modelled in this TSR.

Lakes and wetlands also require a riparian management zone. The following table describes specifications for these zones (RMZ retention under FPPR sec 52).

Table 6.12. FPPR derived buffers on non-fish bearing riparian management zones.

Riparian Class	Riparian Management Area (metres)	Riparian Reserve Zone (metres)	Riparian Management Zone (metres)	RMZ Retention (*sec 52)* ratio	***RMZ Buffer (m)***	***Total Buffer (m)***
W1	50	10	40	0.2	***8***	***18***
W2	30	10	20	0.2	***4***	***14***
W3	30	0	30	0.2	***6***	***6***
W4	30	0	30	0.1	***3***	***3***
W5	50	10	40	0.1	***4***	***14***
L1-B	10	10	0	0.2	***0***	***10***
L2	30	10	20	0.2	***4***	***14***
L3	30	0	30	0.2	***6***	***6***
L4	30	0	30	0.1	***3***	***3***

The total buffer widths outlined in table 6.12 were applied to lakes and wetlands mapped in the *Terrain Resource Information Management* (TRIM) dataset (GeoBC).

6.13 Cedar Partition

The HGMC's 2012 AAC determination recognized that there was a mid-term fall down of commercial cedar on Haida Gwaii, and that a strategy was needed to mitigate its economic effects. The HGMC recommended to the Chief Forester the use of partitions for a "*sustainable harvest of cedar-leading stands, in proportion to their contribution to the inventory, to ensure their continuing contribution to the harvest through the transition period to dependence on second growth"* (HGMC, Rationale for Allowable Annual Cut (AAC) Determination fo Haida Gwaii, 2012).

As a result of this, and further timber supply analyses, the Chief Forester established non-legally binding expectations that the harvest of cedar not exceed specific limits for TSA25, TFL58 and TFL60 (Sutherland, 2012). These limits have been referred to as 'soft-partitions'. Furthermore, in 2017, the Chief Forester added a partition under section 8(5) of the *Forest Act* to the TSA AAC since cedar harvest in the TSA had exceeded the direction in the 2012 determination. In 2018 the Minister signed an Order that brought that partition into effect for replaceable licences on the TSA (Order 75.02 (2)- 01/TSA25). For the purposes of this analysis, both the 'soft' partitions and the Order are referred to as the partition.

The following table describes these limits and have been applied in the timber supply model's base case or reference scenario.

Management unit	Partition class	Annual cedar (combined red and yellow) limit
TFL 60	'Soft-partition'	133,000m^3
TFL 58	'Soft-partition'	32,000m^3
TSA	Legal partition for licences A16869 and A16870; 'soft-partition' for other licences[45] within the TSA.	195,000m^3

[45] A16869 and A16870 have annual limits, cumulative over a 5 year period, of 73,142m^3 and 5,192m^3 which represents these licences proportions to the 195,000m^3 soft partition.

Within the Spatial Timber Supply Model, the proportional contribution of cedar to harvest for all stands was tracked (i.e.., all species composition deciles contributed or were aggregated and counted towards the harvest. A harvest constraint was applied such that when the management unit maximum was met no further harvest was permitted in stands with >10% cedar for the remainder of the 10-year period. Note that approximately 96.5% of the cedar within the THLB exists in stands with 10% or greater cedar composition. Therefore, this formulation for the harvest constraint provides some level of model flexibility to continue harvesting in stands with minor amounts of cedar, while ensuring substantial adherence to the partitions. There is some minor degree of flexibility through cut control allowances to exceed the partition, therefore restricting the model to reserve stands with >0% cedar would create undue restrictions. It is also important to note that running the base case at a 10% versus 0% threshold made no difference to timber supply.

Chapter 7 Timber Harvesting Model Parameters

7.1 Minimum harvestable criteria

Minimum harvestable criteria are parameters set within the timber supply model to limit when the model can harvest timber. These parameters are set to reflect current management or follow principles of sustainable forest management. Two such variables are minimum harvestable age (MHA) and minimum harvestable volume (MHV).

7.1.1 Minimum harvestable age

Minimum harvestable age (MHA) approximates how long it takes for a stand to achieve merchantable condition, or rather, the youngest age a timber supply model is allowed to harvest a stand. MHA has a direct relationship with inventory growing stock, as it defines how long the existing merchantable growing stock must be metred out while waiting for regenerated stands to achieve merchantability.

While there is uncertainty regarding when stands will actually be harvested in the future, the criteria is typically related to volume (over a certain operational minimum viability) and value (general increase in log grades over time). Three general scenarios have been considered during this timber supply review: (i) culmination mean annual increment; (ii) economic rotations, and; (iii) extended rotations. Economic rotations and extended rotations are described in detail in section 8.2.8 of this report.

Culmination Mean Annual Increment

Mean annual increment is a measure of the volume grown annually on a hectare, expressed either at the tree or stand level (yield divided by age). Culmination annual increment is the age on a yield curve where the slope is at its maximum, which occurs when the average annual growth reaches its maximum. Even-aged stand yield curves have a sigmoidal shape, and the inflection point on the curve is the maximum or culmination mean annual increment (Watts & Tolland, 2005). This inflection point is a result of canopy gaps in a mature stand achieve a balance between tree mortality and growth. Therefore, while volumes on individual trees may continue to increase the overall stand volume growth will slow.

CMAI is also referred to as the optimal biological age that maximizes the long-term volume production of a stand (FAIB, 2007). For this reason, CMAI was a key factor in determining the MHA for the base case or reference scenario for this timber supply analysis.

Due to harvest flow requirements (e.g, a consistent flow of timber over time), setting a timber supply model MHA to CMAI tends to force a model to harvest a stand after CMAI. **Therefore, for this timber supply analysis, the MHA was set to the age at which 95% of CMAI is achieved.**

For timber supply modelling, each analysis unit was assigned an MHA (see section 5.6 and 5.8 for a description of analysis units). For consistency and for the purpose of reporting, MHAs are summarized here for managed stands. Note that MHAs do not materially influence harvest criteria for existing natural stands as these tend to be much older (past CMAI) and therefore their MHAs are not reported here.

Table 7.1.1 Minimum Harvest Age for Managed Stands by site index class and leading species

Site index class (m@50 yrs)	CW	DR	HM	HW	PLI	SS	YC
0 to 5	145			170			
5 to 10	136		190	147	145	140	142
10 to 15	112	60	144	117	112	126	112
15 to 20	97	42	110	93	81	95	91
20 to 25	96	50		92	70	86	70
25 to 30	74	37		75		79	
>30		30		61		72	

7.1.2 Minimum harvest volume and low-productivity stands

Minimum harvest volume

Section 3 of this data package describes non-forest exclusions from the THLB which include lakes and wetlands. However there are a wide variety of forested ecosystems on Haida Gwaii that are considered transition forests between wetlands (or alpine) and upland forest. Transitions tend to be made up of lower productivity sites, characterized by scrubby and open forests. These are often located on poorly drained alluvial deposits, blanket mire complexes on toe slopes, depressions or bog woodland patches interspaced within topogenous or open blanket bog ecosystems or swamps (Banner, W. MacKenzie, MacKinnon, Saunders, & H.Klassen, 2014). Many of these ecosystems are found throughout all the physiographic regions and biogeoclimatic variants of the lslands.

Given the mandate to establish a long-term sustainable harvest level for Haida Gwaii, only forests that contribute to continued harvesting were included within the THLB. In other words, forests that could only be harvested once, and would not be expected to meet minimum harvesting criteria in a reasonable time frame were removed from the THLB. This is the basis for which TIPSY does not accept species with a site index estimate less than 10[46].

Minimum harvest volume (MHV) defines a volume threshold for including stands in sustained yield projections. This is done by identifying stands that will not meet the minimum volume (either current inventory or at any point on a yield curve).This can be factored into the timber supply analysis in a couple of different ways, either (i) excluding these areas from the THLB, or; (ii) setting a constraint parameter in the model so the stands below the threshold don't contribute to the predicted sustained yields.

This factor is one way to define the merchantability of low volume stands, but more so quantifying low productivity stands. Economic operability has many factors (e.g., access, markets, volumes etc.) and this is more comprehensively accounted for in section 8 (minimum harvest volume sensitivity analyses).

Past AAC determinations on Haida Gwaii have led to analyses and partitions of low volume cedar stands within the TSA (B.C. Ministry of Forests, 2000), acknowledging that low volume stands may contribute to actual harvests, but their merchantability is very sensitive to markets and access and therefore their contribution to timber supply should be carefully qualified. Past TSRs have qualified these low productivity stands to be under 350m^3 per hectare (B.C. Ministry of Forests, 2000).

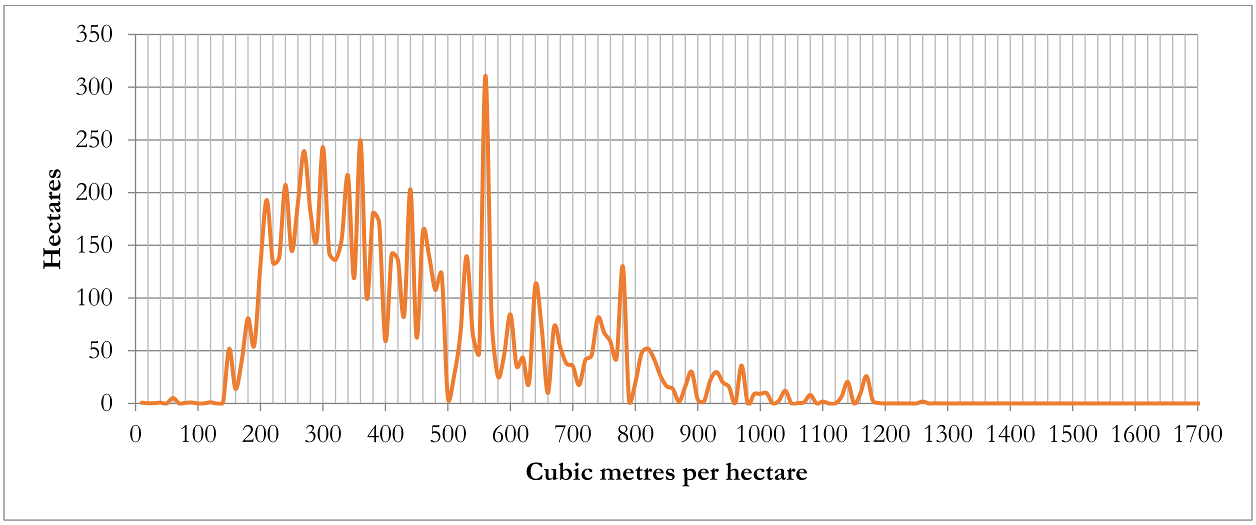
[46] With the exception of Lodgepole Pine (PLC), which excepts an SI as low as 5.

Evaluating MHVs with harvest history
Calibrating these minimum harvest volume thresholds with actual harvesting is considered an important step to validate the exclusion of stands.

Data from 2012-2016 was used to qualify the average cubic meter per hectare logged on Haida Gwaii. Net Area to be Reforested (NAR) data from the 2012-2016 LUOO annual submissions from licensees were used to determine opening size (ha). The timbermarks from these areas were linked to the Harvest Billing System (including avoidable, unavoidable waste). A total 102 timbermarks that had been logged by 2016 were included in the analysis[47]. The results show that 95% of the timbermarks logged had a volume greater than or equal to 257m^3/ha. The weighted area average was 595m^3 per hectare (range 214-2,043m^3/ha).

While this is a useful reference point, actual harvested volume data does not always correspond directly with inventory data. As a result, a second analysis was done that reported on the m^3/ha logged using recent spatial openings and forest inventory data for 7,295 hectares.

Table 7.1.2. Distribution of cubic metres per hectare (forest inventory volumes at 17.5cm utilization) within a sample of 7,295 hectares of recent openings.



The results found that overall approximately 95% of the volume from all openings were in a volume class over 230m^3/ha.
Interestingly, for openings that were second growth stands this threshold increased to 350m^3/ha.

As a result, a MHV was set as a parameter in the base case or reference scenario to 250m^3/ha. All natural and managed stands that are not projected to achieves at least 250 m3/ha within the analysis horizon (350 years) were removed from the THLB.
The following tables detail the site series on Haida Gwaii where the natural stand curves do not reach 250m^3/ha or conversely that have a site index under 10. Both of these categories of productivity contribute to the minimum harvest volume netdown.

[47] Logged by 2016 was qualified through satellite imagery references.

Table7.1.3.1. Site units with SIBEC site index under 10.

CWHvh2 02	MH wh 111 (previous 05, 06, 07, 09)
CWHwh2 111 (previous 05)	MH wh 02
CWHwh2 Wb51	MH wh 08
MH wh Wf	MH wh Wb53 (previous 08)

Table 7.1.3.2. Site units with Future Managed Stand volumes that do not reach 250m^3

CWHvh2 12	CWHwh2 11
CWHvh3 102	CWHwh2 09
CWHvh3 113	MHwh 11
CWHwh1 11	MHwh 13
CWHwh1 114	MHwh 102 (previous 02)

These non-productive area exclusions tend to have limited effect on timber supply as a result of the model not accessing these sites anyway due to their low volumes. Three sensitivity analyses were completed (see section 8) to explore outputs without any MHV, outputs with MHVs categorized by different volume classes, and MHV restrictions of 350m^3 for second growth stands.

7.1.3 Harvest preference relative to CMAI

While MHA represents a sort of binary criterion for when to log or not log a stand, the model is also able to prioritize stands based upon preference inputs once the model determines a stand is available to be harvested (e.g., meets the minimum harvestable criteria). Two harvest preferences were explored relative to CMAI.

7.1.3.1 Relative highest volume

After a stand meets the minimum harvest criteria outlined in section 7.1.1, a preference was explored to harvest the highest volume stand relative to the minimum harvest age. This was considered to be a less realistic preference since in reality both value and volume are key drivers for prioritizing stands (e.g., between two stands of equal volume, the higher value stand would be preferred). However this model preference was still explored in a sensitivity analysis, as described in section

7.1.3.2 Relative highest value

The relative highest value is a harvest preference that parameterizes the model to harvest the highest value stands relative to culmination age. The derivation of stand value is described in section 7.5. Relative highest value prioritization was used in the base case reference scenario.

7.2 Silvicultural systems

The RESULTS forest cover silviculture spatial database 'RSLT_FOREST_COVER_SILV_SVW) up to 2018 has 2,200 hectares of net logged area under a partial harvest silviculture system, or 4.5% of current areas under silviculture management (approximately 48,600 hectares). These blocks, primarily in the Rennell Sound and Eden Lake landscape units, represent the aerial harvest program that Husby Forest Products undertook in the early to mid 2000s, and given their vintage, these stands were therefore captured/attributed in the 2014 VRI re-inventory. Only ~25 hectares of partial harvest was completed during the last decade or market cycle (2008-2017). Therefore, for purposes of timber supply, only clearcut silviculture was modelled given that partial harvest is currently not practiced.

7.3 Maximum cutblock size and adjacency

Section 64(1) of the Forest Practices and Planning Regulation outlines that cutblocks cannot be larger than 40 hectares in the Coast Forest Region, specifically for clearcut silviculture.

Section 65(3) stipulates that cutblocks cannot be immediately adjacent to one another unless certain minimum green up requirements are met. In summary these requirements are:

- Minimum 75% of the block is re-stocked;
- Re-stocking meets the minimum requirement of 500 stems per hectare;
- Established trees are at least 1.3m in height with 10% of the stems being at least 3m in height.

In addition, section 65(3) does not apply to blocks that are under 40 hectares in size. In other words, the adjacency constraint only applies to blocks greater than 40 hectares in size.

Timber supply considerations
Two criteria needed to be defined for implementing the adjacency requirement: distance between blocks and time required to meet minimum green-up requirements.

With regards to distance between blocks, while the FPPR adjacency rule provides a minimum green up height it does not specify a distance between blocks to be buffered until the minimum green up height is met. The Spatial Timber Supply Model is based upon a 1-hectare grid cell, therefore the minimum between blocks could be set to 100m. However, when the minimum 100m buffer between blocks is applied the model returns to these sites after the adjacency requirement is met and harvests these 100m 'strips'. This in essence creates a harvest pattern where a large amount (e.g. nearly 25%) of all block sizes are under 5 hectares in size. This in turn did not seem to represent reality, where in fact the distribution is based on much larger cutblock sizes, as seen in figure 7.3.1.

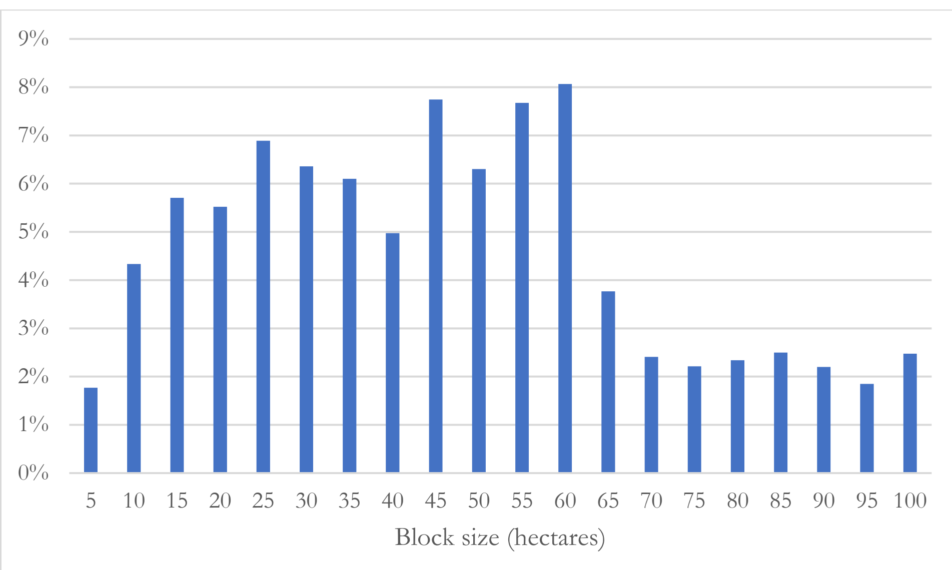


Figure 7.3.1. Block-size distribution from 2008-2017, converted to a 1-hectare raster within the STSM. Note that 'blocks' may be dispersed (not immediately adjacent) or have minor (e.g. 10m) buffer between openings that are lost at the 1 hectare resolution of the spatial timber supply model.

To minimize fragmentation that leads to small remnant patch sizes and subsequent small block sizes, the base case reference scenario applies a 400m buffer. 400m was applied as this reasonably represents the width of a typical block to fill the space between two blocks that had not met the adjacency requirement. This distance is also used by Taan Forest Products Ltd. to guide block placement for meeting adjacency requirements but does not preclude blocks being placed at a distance less than 400m (Taan Forest Ltd & Limited Partnership, 2018). For timber supply modeling, this 400m buffer was not a 'hard' or strict no-harvest buffer, but rather one where the harvest preference was to avoid this 400m area around new blocks.

This approach resulted in a more realistic size and distribution of blocks, as outlined in figure 7.3.2.

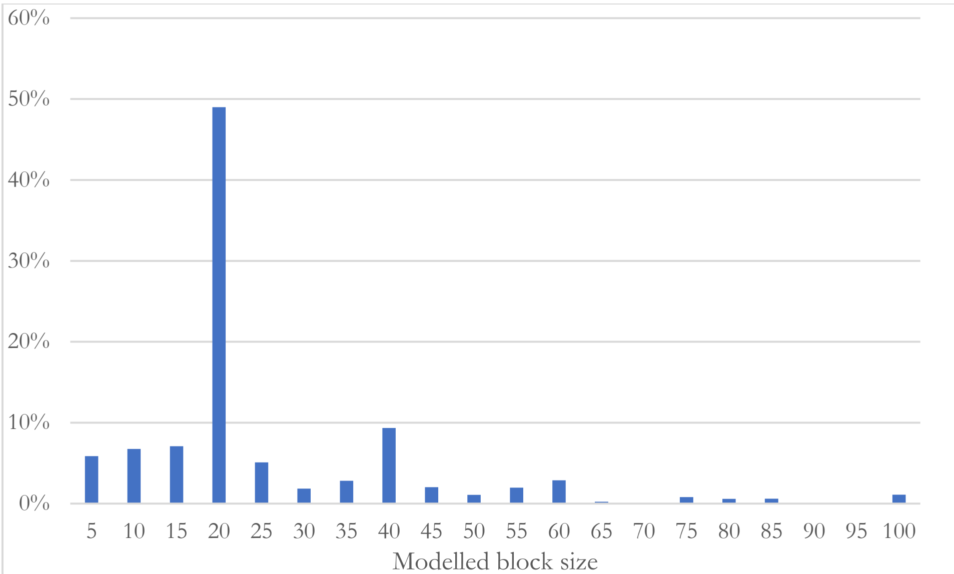


Figure 7.3.2 Modelled block size (first period or decade). The target was 20 hectare openings to reflect average operational openings on Haida Gwaii.

With regards to the time required to meet minimum green up requirements, managed stand yield curves were cross-referenced with the FPPR height requirements (between 1.3m-3m minimums). The weighted area average in the THLB for managed stands at year 10 is 1.03m, and at year 20 is 2.76m. This suggests that, in a modelling environment the green up requirements would be met, on average, between 10-20 years after harvest. The base case adjacency green up height is set to 3m.

7.4 Natural Disturbance

The effects of natural disturbance on timber supply are known as non-recoverable losses (NRL) in timber supply analyses. The intent is to quantify the effect of biotic (insect/disease) and abiotic (wind/slides/fire) stand-replacing events on the forest, and then estimate how much of the loss is likely to be salvaged. In coastal BC, stand replacing natural disturbances are considered rare, although over time the cumulative occurrences of these events can affect long-term forest management planning.

A number of tree-level health issues are not addressed at this scale. The most common influences on tree-level health (pathogens/insects) naturally occur in baseline levels as key parts of functioning ecosystems, particularly gap-phased forest types, where natural disturbance is mostly found at the tree level *versus* stand-replacing level (Lertzman, Sutherland, Inselberg, & Saunders, 1996). Some of these disturbance agents include disease or pathogens that are common in Haida Gwaii's forests, such as fungal root rots (ex. *Armillaria sp.*) and heart rots (ex. *Phellinus sp.*) (which more typically affect older stands), or the ubiquitous western hemlock dwarf mistletoe (*Arceuthobium tsugense)* or Keithia leaf blight (*Didymascella thujina*) which can affect young Western redcedar. These tree-level volume losses are dealt with in the decay reduction equations in the growth and yield models (see section 5).

Two key sources of information were used to evaluate natural disturbances: the Haida Gwaii Aerial Overview Survey data, and a change monitoring satellite image analysis.

The Aerial Overview Survey data (AOS) is a program administered by the MFLNRORD, with data spanning 2006-2017 for Haida Gwaii. Each year an overview flight in a fixed-winged aircraft occurs to map forest health factors across all of Haida Gwaii, following the AOS provincial standards (RISC, 2000)[48] at a 1:100,000 to 1:250,000 scale.

Forest health factors are mapped during the overview flight and each polygon is assigned the following severity classes:

Table 7.4.1. Aerial Overview Survey Forest Health classes

Intensity class	Description	Midpoint
Trace	<1% of the trees recently killed	0.05%
Light	1-10% of the trees recently killed	5%
Moderate	11-29% of the trees recently killed	20%
Severe	30-49% of the trees recently killed	40%
Very severe	50%+ of the trees recently killed	75%

Full annual spatial data for the provincial AOS program can be downloaded here: https://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/

For timber supply purposes, data from between 2006-2017 was collated to analyze trends applicable to strategic level timber supply analysis. Total polygon areas were multiplied by the assigned severity ratings (e.g.A total polygon of 10 ha *x* moderate severity of 20% amounts to an affected polygon size of 2 ha).

Two key variables are necessary to apply the findings to timber supply: a) how much forest (and what kind of forest) is affected, and b) over what time period is the effect measured? See figure 7.4.1 for the summary of the area of forest health occurrences over time.

Given the scale of the mapping from the AOS standard, broad scale (landscape, watershed or large stand level) disturbances are most accurate. Individual tree, or small stand replacing events are difficult to capture.

[48] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/aerial-overview-surveys/methods/standards-for-detailed-surveys

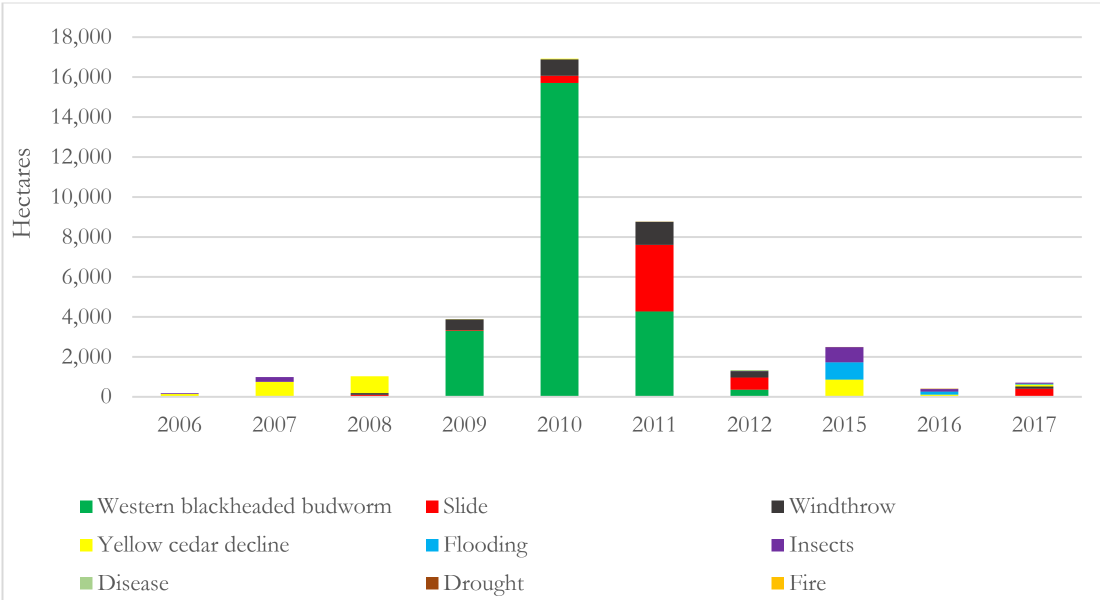


Figure 7.4.1. Haida Gwaii forest health occurrences over time. Source: Aerial Overview Surveys

7.4.1 Change detection analysis

The AOS is well suited for identifying large stand-level replacing events. Two of the most common disturbance events on Haida Gwaii are wind and landslides. Both events can range from very large (200 hectares) to very small (< 1ha) in size. It is the cumulative nature of these smaller events that the AOS data tends to not represent. As a result, a change detection analysis was completed mapping and comparing wind and landslide events from 2011 and from 2017 to determine the rate of change.

Figure 7.4.2. Light green areas represent the extent of satellite imagery cover used in change detection analysis.

Short wave near infrared 2.5m satellite imagery was used in 2011, and 5m near infrared satellite imagery was used in 2017 with a geographic extent that included the forestry operational land base of Haida Gwaii. Manual interpretation and polygon delineation[49] was done to 0.25 hectare resolution. Harvest history data was used to discern natural *versus* anthropogenic disturbance. For wind disturbance, severity rankings were assigned to polygons ranging from 100%, 50% or 25% disturbed. Adjacency to harvest openings was tracked to help distinguish catastrophic from endemic windthrow events. For landslides, point of initiation was tracked as being either within or outside of an existing harvest opening.

7.4.2 Disturbance type, distribution and severity

Not all disturbance types identified on Haida Gwaii are suitable for large scale (geographic and temporal) modelling. The following describes the natural disturbance agents, the source of the data, and their consideration in the timber supply review.

[49] Polygon delineation by Robert Kennedy and Sarah Good. Heritage and Natural Resource Department, Council of the Haida Nation.

Western black-headed budworm

The natural disturbance agent that affects the most hectares of forests on Haida Gwaii at one time is the western black headed budworm (*Acleris gloverana).* The last outbreak ranged from 2009-2011, and before that it occurred between 1996 and 2001. By 2010 the outbreak extended to cover 97,497 hectares on Moresby Island (Maclauchlan & Burleigh, 2011), however the net area affected (accounting for severity ratings using the AOS mapping) amounted a total of 23,716 hectares. The compiled AOS spatial data was used to calculate timber supply impacts.

Figure 7.4.2.1. Young western hemlock affected by blackheaded budworm on Moresby Island. Source (MFML, 2010)

The timing between outbreaks corresponds with the 12-16 year frequency coastal outbreak cycle, with defoliation in one stand lasting for 2 to 3 years (Shepard & Gray, 2001) . These outbreaks primarily affect second growth stands, in many cases affecting 100% of the stands resulting in a loss of growth, with recovery lags of over 5 years after the outbreak (NRCAN, 2005). While this defoliator can affect an entire stand, it only has an estimated mortality rate of 3.6% (Nealis & Turnquist, 2010).

A 20-year study on incremental silviculture (thinning treatments) on Graham Island collected data on the 1996-2001 outbreak. Stem-mapped trees were measured before, during and after the outbreak (5-year measurement cycles) with the conclusion that 2% of affected trees were killed by the infestation (Reynolds & de Montigny, 2015).

Utilizing the conservative mortality estimate of 3.6%, with a recurring cycle of 12 years would translate into an annual mortality rate of 59 ha per year within the THLB.

Windthrow

Windthrow is a natural disturbance that uproots trees (wind strength exceeds anchor strength) or causes stem breakage (wind exceeds stem strength) either in individual trees or at a scale that affects an entire stand (>1 ha). There are two classifications of windthrow in coastal BC: Endemic windthrow is caused by frequent (1-3 year) recurring peak winds affecting localized stand edges or exposed trees; or catastrophic winds which are infrequent (>20 year recurrence) affecting high proportion of trees in a stand as a result of a major wind event (Kielke, Bancroft, Byrne, & Mitchell, 2010). Windthrow, particularly endemic windthrow on Haida Gwaii, is highly correlated with topographic exposure (ex. ridges or shoulders are at higher risk), soil conditions (ex. shallow wet soils are at higher risk) and tree characteristics (ex. tall thin trees are at higher risk) (Rollerson, Peters, & Beese, 2009).

On Haida Gwaii the average winter winds range between 22-27 km/hr, where winds of 43-60 km/hr occur 20% of the time and winds 60-75 km/hr occur 3% of the time during winter (Kielke, Bancroft, Byrne, & Mitchell, 2010). The maximum recorded wind gust speed for Haida Gwaii was 164 km/h at the Sandspit Airport (Banner A. P., 2014).

Haida Gwaii is often divided into three physiographic regions or ecosections that exhibit distinct climactic, geologic, topographical and ecological characteristics (Banner A. P., 2014): Queen Charlotte Lowland (QCL) on the north and east; Skidegate Plateau (SKP- central latitudinal band) and the Queen Charlotte Ranges (QCR). The majority of the windthrow occurrences identified in the change detection mapping occurred in the SKP and QCR ecosections, as outlined in figure 7.4.2.2

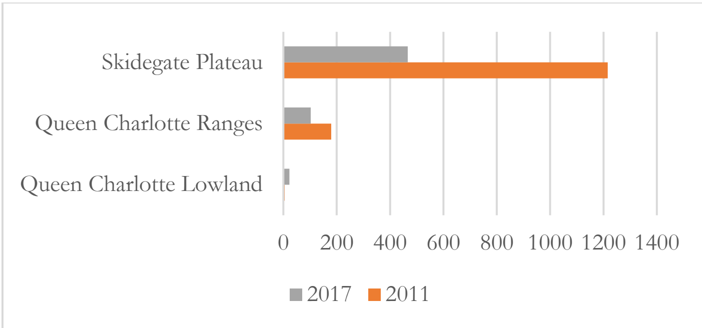


Figure 7.4.2.2 Windthrow occurrences (hectares) between 2011 and 2017 across three physiographic units.

Change detection analysis (described above) mapped all recent windthrow occurrences[50] down to 0.25 hectares in size. The results mapped a total of 1,992 hectares of windthrow, with 1400 hectares mapped from 2011 imagery, and an additional 592 hectares mapped in the 2017 imagery, amounting to an annual rate of change of 114 hectares per year. Applying this to the THLB amounted to an annual disturbance rate of 70 hectares per year.

Landslides

Figure 7.4.2.3. Major landslides in 2012 near Kin.gii Llnagaay (Wells cove) in Gwaii Haanas after the 2012 earthquake.

Landslides are a leading abiotic natural disturbance on Haida Gwaii caused by the downslope movement of overlying weathered material and rock initiated by high rainfall intensities, earthquakes or other mechanisms. A landslide is a general term that geologists may further classify into debris slides, debris flows, debris avalanches, rockslides or avalanche tracks. Landslide susceptibility is typically influenced by topography (ex. steeper slopes are higher risk), bedrock geology (ex. sedimentary bedrock is higher risk), surficial geology/soils (ex. folisols are higher risk), and climate (ex. higher precipitation regimes present higher risks) (Howes, 1987). Comprehensive landslide mapping has occurred on Haida Gwaii, with up to 0.84 landslides per km^2 for all of Haida Gwaii (Gimbarzevsky, 1988) which can increase to between 3.82 to 7.23 landslides per km^2 when only accounting for areas with 'active' geomorphology (steeper, unstable terrain) (Jagielko, 2012). Past logging practices, along with natural climate/geomorphology led to significant occurrences of mass wasting on Haida Gwaii through the 1960s-1990s. This led to numerous studies on the causation of landslides on Haida Gwaii (Rood, 1990) and their effects on streams and sedimentation (Hogan & Schwab, 1991), eventually leading to several land management guidance documents for BC on minimizing landslide risks from logging (Hogan, Tschaplinski, & Chatwin, 1998). Likely because of changing forest management practices, an analysis of landslides in the change detection mapping highlighted that only 6 hectares, or 0.5% of the last 10 years of cutblocks (26,483 hectares) overlapped with landslides.

[50] Areas with little or no vegetation response after an event or low normalized difference vegetation index (NDVI) values. Occurrences tend to by <10 years of age.

Note that analyzing the frequency, scale and distribution of landslides has been done to estimate and project the effect (netdown) on forests available for logging over time. Unstable terrain (not a natural disturbance, but often an operational limitation) has been removed from the THLB (see section 6.8).

Change detection mapping showed that, 787 hectares of landslides were mapped in 2011 and an additional 394 hectares were mapped in 2017 with 99% of the landslides occurring within the QCR and SKP ecosections. The annual natural rate of disturbance was 26 hectares within the THLB.

Yellow cedar decline
The decline of yellow cedar is primarily attributed to environmental stress caused by climate change (P. Hennon, 2016). The mechanism of decline has been extensively researched in southeast Alaska since the 1980s (P. Hennon, 2016). Ecodormancy (winter hibernation that conifers go into) is temperature regulated (versus regulated by photoperiod) and is believed to be triggered at the roots by warming soils. Lower snow pack lessens insulation, warms roots and leads to de-hardening (tree comes out of ecodormancy). The de-hardened trees are then susceptible to late spring freezing events, that lead to freezing injuries (lesions), that in turn lead to phloem necrosis and death. Decline because of freezing injury can be abrupt or last many decades (per tree). By 2014 the decline in southeast Alaska had affected 236,600 hectares (USDA, 2015) and up to 95,000 ha on BC's northcoast (Westfall, 2014).

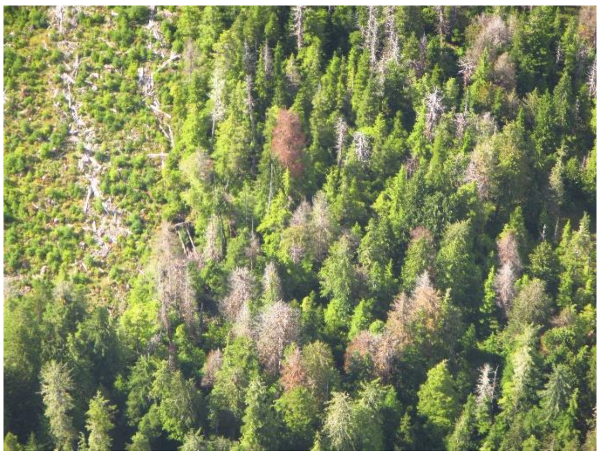


Figure 7.4.2.4. Yellow cedar decline in Florence creek

Climate model studies suggest the decline will expand for several decades, but ultimately not affect the entire population. There is some evidence that yellow cedar is expanding further north and into higher elevations, but at very slow rates (~5m over ~50 years) (Krapek, Buma, D'amore, & Hennon, 2017).

Aerial overview surveys and field surveys have identified yellow cedar decline across Haida Gwaii regardless of elevational gradients (e.g. ephemeral snow pack and temperate climate) (MFML, 2010) (Reynolds, 2016). Haida Gwaii climate patterns (warming winters, greater winter precipitation) are causing both divergent growth trends where asymptomatic trees show greater growth and symptomatic trees are less sensitive to climatic variation after the onset of decline (L. Daniels, 2016).

Observations on Haida Gwaii are currently restricted to old forests, however there are uncertainties regarding the impact on young forests on Haida Gwaii. In southeast Alaska, the decline seems to affect young stands as well, with about 18% of the yellow cedar in age classes between 40-60 years showing symptoms of decline (Graham, 2017).
Since 2006 approximately 2,720 hectares of yellow cedar decline have been mapped during Aerial Overview Surveys, amounting to an annual disturbance of 40 hectares within the THLB.

7.4.3 Other disturbance agents
The following disturbance agents have not been included in timber supply calculations for a variety of reasons described herein.

Lodgepole pine sawfly (*Neodiprion sp.*) is a defoliator that has affected over 700 hectares west of Burnaby Island in pine dominated forests in Gwaii Haanas. Mortality is uncommon (Burleigh, Ebata, White, Rusch, & Kope, 2014), but has happened concurrently with a localized outbreak of lodgepole pine beetle (*Dendroctonus* *murryanae*). These outbreaks have been documented since 2012 with no sign of occurrences spreading north of Island Bay (Reynolds, 2016).

Minor occurrences (6 ha) of spruce beetle (*Dendroctonis rufipennis)* have been identified throughout mature second growth stands on southern Graham and Moresby Islands. These are considered to be a natural baseline levels common with maturing successional forests and not affecting timber supply.

While nearly 400 hectares have been affected by the green spruce aphid (*Elatobium abietinum*) since 2006, losses attributed to green spruce aphid are assumed to result in a mortality rate of 10% (Koot, 1991). These low mortality numbers spread over a long period result in negligible effects on timber supply.

Over 1,000 hectares of forest have been affected by paludification or natural advancement of wetlands (mapped as flooding) on eastern Graham Island. These areas however have been localized within Naikoon Park (Cape ball area) and do not affect the THLB.

7.4.4 Natural disturbance calculations in timber supply

Natural disturbance happens regardless of administrative boundaries. As described above, the *distribution* of natural disturbance is rather associated with certain physiological/biological characteristics - which can be stratified for the purpose of quantifying their scale and frequency of occurrence. For example:

- Yellow cedar decline affects old yellow cedar stands;
- Black headed budworm primarily affects second growth hemlock leading stands (exists in old forest- but is spotty);
- Windthrow affects older/mature stands as windthrow dynamics are linked, in part, to stand characteristics;
- Landslides almost always occur in the SKP/WQC ecosections, and affect forests of all ages.

Determining the *frequency/distribution* can then be calculated as a disturbance ratio, calculated as

$$\frac{\text{area of disturbance}}{\text{stratified area of interest}}$$

Four factors help quantify this disturbance ratio to determine its impacts on timber supply:
a. **Disturbance strata defined:** What is the forest type affected by the disturbance type (disturbance strata)?
b. **Area of disturbance strata:** How much area does this disturbance strata represent within the area of study? The area of study would be the full geographic extent/area where baseline surveys were conducted (ex. AOS derived data is for all of Haida Gwaii, change detection derived data is for the area identified in figure 7.4.1).
c. **Total disturbance ratio:** What is the ratio of disturbance between the strata affected and the total strata within the area of study?
d. **Area of disturbance strata within the THLB:** total area of the disturbance strata found within the THLB.
e. **THLB annual disturbance:** the annual area of disturbance strata within the THLB.

The following table summarizes the four natural disturbance factors accounted for in this timber supply review:

Table 7.4.4 Annual reductions to timber supply resulting from natural disturbances.

Natural disturbance type	Disturbance strata	Area of disturbance strata (ha)	Annual disturbance (ha)	Disturbance ratio (*rounded*)	Area of disturbance strata in THLB (ha)	THLB annual disturbance (ha)
Wind	>Age class 4 trees in SKP/QCR ecosections	109,000	114	0.1%	66,900	70
Slides	Treed areas in SKP/QCR	323,100	77	0.02%	109,900	26
Black-headed budworm	<Age class 5 Hemlock leading	100,900	142	0.1%	42,100	59
Yellow cedar decline	Old YC leading stands	62,200	389	1.0%	6,400	40
Total annual disturbance on the THLB						195

7.4.5 Application in Spatial Timber Supply Model

The strata and disturbance targets above were applied as an expected rotation (the inverse of the disturbance ratio, or area potentially affected/annual area effected) as the main parameter in the natural disturbance model. The STSM model treats the natural disturbance strata as stochastic analysis units that do not contribute to the overall annual harvest (hence non-salvageable loss). This was because the disturbance targets listed above are typically catastrophic events or events not associated with salvage operations (e.g., slides, catastrophic windthrow or single tree volume losses due to pest or abiotic factors).

7.5 Climate Change

Climate change is widely affecting forests in Canada, ranging from changes in the frequency and intensity of natural disturbances (Abbott & Chapman, 2018), rates of carbon sequestration (R.Hember, K.Werner, & M.Girardin, 2019) shifts in species composition, as well as affecting silviculture such as adapting climate-based seed transfer protocols (Johnston, Webber, O'Neill, T.Williamson, & Hirsch., 2009).

Changes in global climate are expected to increase natural disasters, including drought, flooding, wildfire, rising sea levels and extreme storm events (International Panel on Climate Change, 2014).

On Haida Gwaii, climate trends have demonstrated a moderate increase in temperature (2.5%) and precipitation (2.25%) over the last 70 years. An Environment Canada climate station on Langara Island has continuous daily climatology data since July 1936. Average annual precipitation levels[51] and average daily maximum temperatures indicate a slow increase between 1937-2018[52] (see figure 7.5.1 and 7.5.2). This trend aligns with the CanESM2 model[53], with 2040-2069 precipitation predictions on Haida Gwaii to increase by a maximum of 2.75mm per day (November) and decrease by 1.18mm per day (July) when compared to a 1961-1990 baseline (see table 7.5.7climate data for wet and very wet hypermaritime variants).

Analysis of weather station data from Cape St.James, the southernmost weather station on Haida Gwaii, indicates there hasn't been an increase in average daily windspeeds on Haida Gwaii, and the frequency and intensity of storms (gale force, ≥62km/hr or above) has also remained stable or decreased since a 1980's baseline. This data doesn't suggest an increase in storm intensity and frequency, therefore it was decided to not complete a related sensitivity analysis on wind-related natural disturbance.

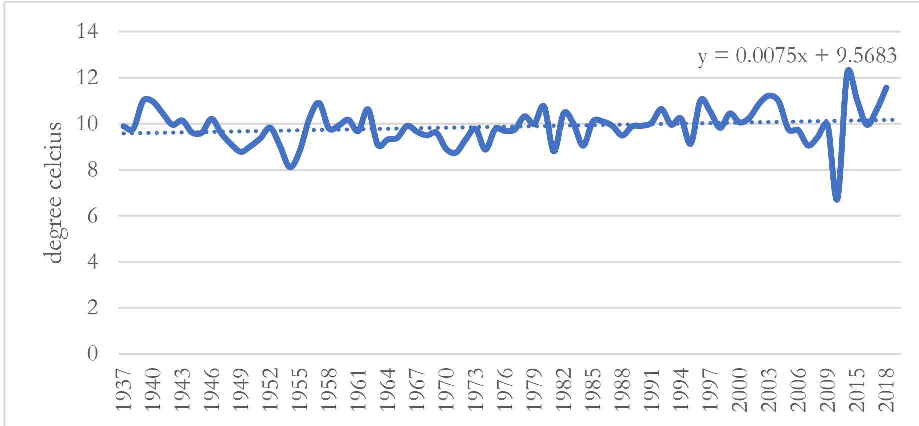


Figure 7.5.1. Average daily maximum temperature and linear trendline- Langara Island (Environment and Climate Change Canada).

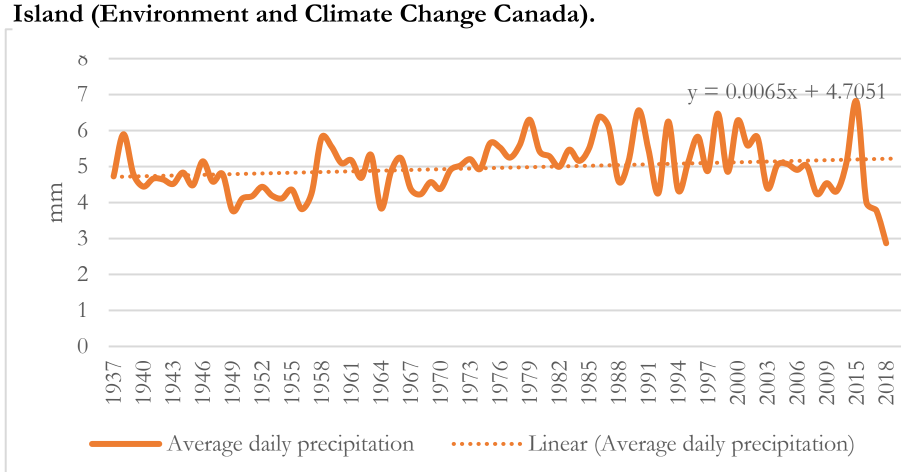


Figure 7.5.2. Average daily precipitation and linear trendline- Langara Island (Environment and Climate Change Canada)

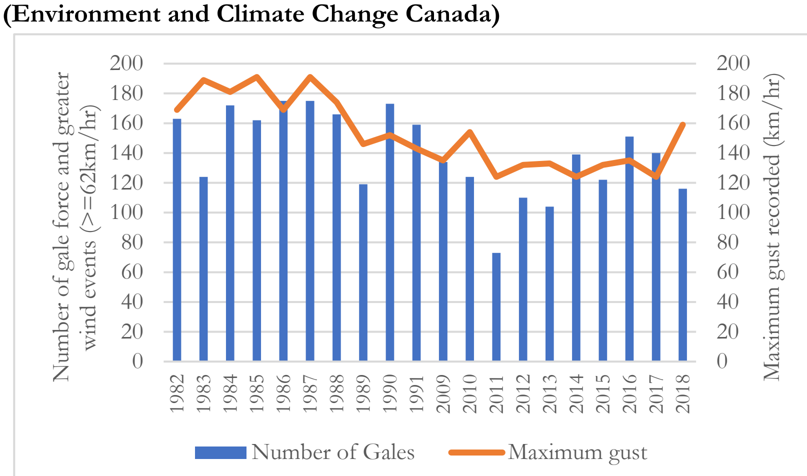


Figure 7.5.3. Decadal trends in gale force storm events and maximum wind gusts at Cape St.James between 1982-1991 and 2009-2018 (Environment and Climate Change Canada)

Effects on forests

Potential changes to natural disturbance types are uncertain, particularly the biotic effects from insects or pathogens. Abiotic natural disturbance factors may include increased peak flows and flooding, increased windthrow, landslides, drought, fire as well as continued or increased decline in yellow cedar forests on Haida Gwaii.

Some of these variables have been monitored and their timber supply impacts quantified in developing estimates of disturbance used in the analysis. Where evidence of natural disturbance is

[51] Average daily precipitation aggregated to month and then to year.
[52] Data retrieved through the Pacific Climate Impacts Consortium www.pacificclimate.org
[53] Canadian Centre for Climate Modelling and Analysis.

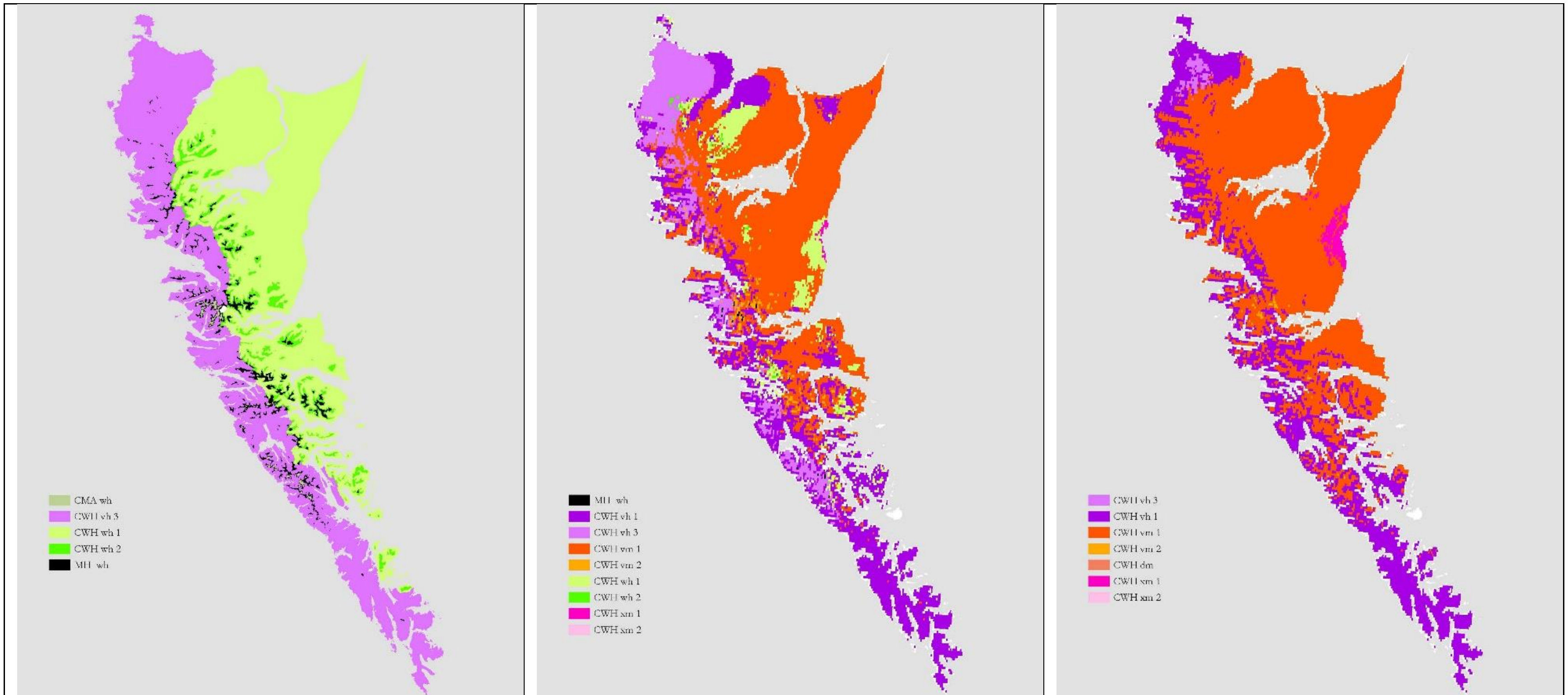
expected to have a material impact on forests, annual-change predictions are built into the timber supply model (see section 7.4). While these predicted effects are stochastically accounted for in the spatial timber supply (e.g natural disturbance targets are randomly applied across the land base) the annual targets do not vary (e.g. they do not increase or decrease in response to climate change).

Some elements of climate change may be significant, such as increased peak flows and flood events, but may have relatively inconsequential effects on timber supply (e.g. hydrogeomorphological features, such as floodplains, have been removed from the THLB).

Changes in temperature and precipitation redraw ecological boundaries and may affect species composition and site potential. ClimateBC project future seasonal and annual climate variables by using both global circulation models (PRISM, (Daly, Gibson, Taylor, Johnson, & Pasteris, 2002.)) and historical weather station data. The program uses historical data (1901-2013) (Mitchell & Jones, 2005) and forecasts future climate scenarios (2020s, 2050s, 2080s) generated by global models from IPCC Assessment Report 5 (International Panel on Climate Change, 2014). The program, described in Wang *et al* (2016), uses a combination of elevation adjustments and bilinear interpolation to deliver 23 annual and 168 monthly climate variables. Regional results for Haida Gwaii are illustrated in figures 7.5.4. While there is a predicted shift in biogeoclimatic (BGC) variants, Haida Gwaii's maritime environment is anticipated to moderate these changes when compared to the changes anticipated in bioclimates in BC's interior.

The long term BGC shift between 2019 and 2080 is expected to be from the CWH wh1 to the CWH vm1 and from CWHvh3 to CWH vh1, which represents a shift from wet to very wet and maritime to hypermaritime climates. The majority of the current THLB would shift to CWHvm1, which is a climate currently more characteristic of the west coast of Vancouver Island (Green & K.Klinka, 1994). Site components, expressing relative moisture and nutrient availability, are a function of physical properties such as soil, terrain, slope position and aspect. While these "enduring features" may not change (the relative edatopic relationships will be the same) the change in bioclimate may result in a change in site potential for tree growth, or productivity. Figure 7.5.5 and 7.5.6 illustrates a comparison of site index by species expressed on edotopic grids between the current and most common BGC unit in the THLB (CWHwh1) and the predicted BGC unit CWHvm1 by 2080. For both western hemlock and western red cedar there is a slight increase in site potential between these two variants.

Despite the minor predicted change in site potential, a sensitivity run with changes to growth and yield were not completed. The growth and yield implications are uncertain due to the interplay of underlying soil productivity with projected climate changes (i.e., moisture is not likely limiting on Haida Gwaii) and of stand productivity with stand-level disturbance agents. As more information become available on climate changes implications for productivity, it can be included in future TSRs.



CMA wh	0.3%	CWH vh 1	29%	CWH vh 1	31%
CWH vh 3	40%	CWH vh 2	13%	CWH vh 2	1%
CWH wh 1	49%	CWH vm 1	49%	CWH vm 1	66%
CWH wh 2	7%	CWH vm 2	1%	CWH vm 2	0.2%
MH wh	4%	CWH wh 1	7%	CWH xm 1	2%
		CWH wh 2	0.3%	CWH xm 2	0.1%
		CWH xm 1	0.2%		
		MH	0.1%		

Figure 7.5.4. Current proportions of BGC variants and predicted ClimateBC shifts in BGC Units for Haida Gwaii, present (left), 2050 (centre), 2080 (right)

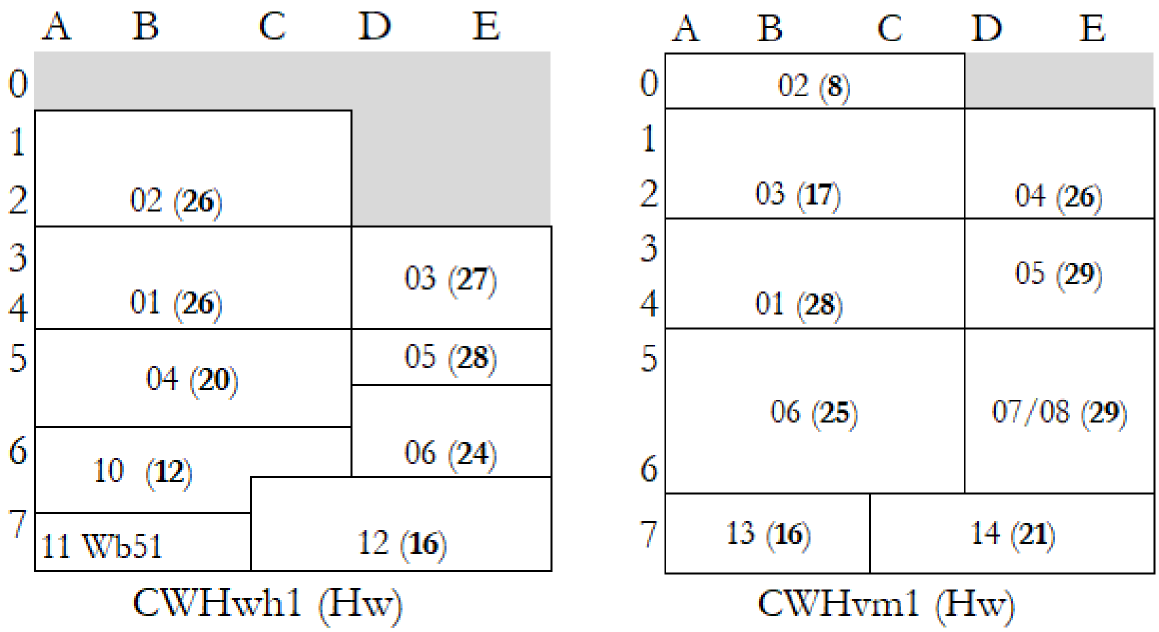


Figure 7.5.5. Ecological edotopic grid (rows increase with relative moisture, columns indicate relative nutrient) comparing SIBEC site index (bold in parentheses) between CWHwh1 (current) and CWHvm1 (predicted future) BGC site series units for western hemlock.

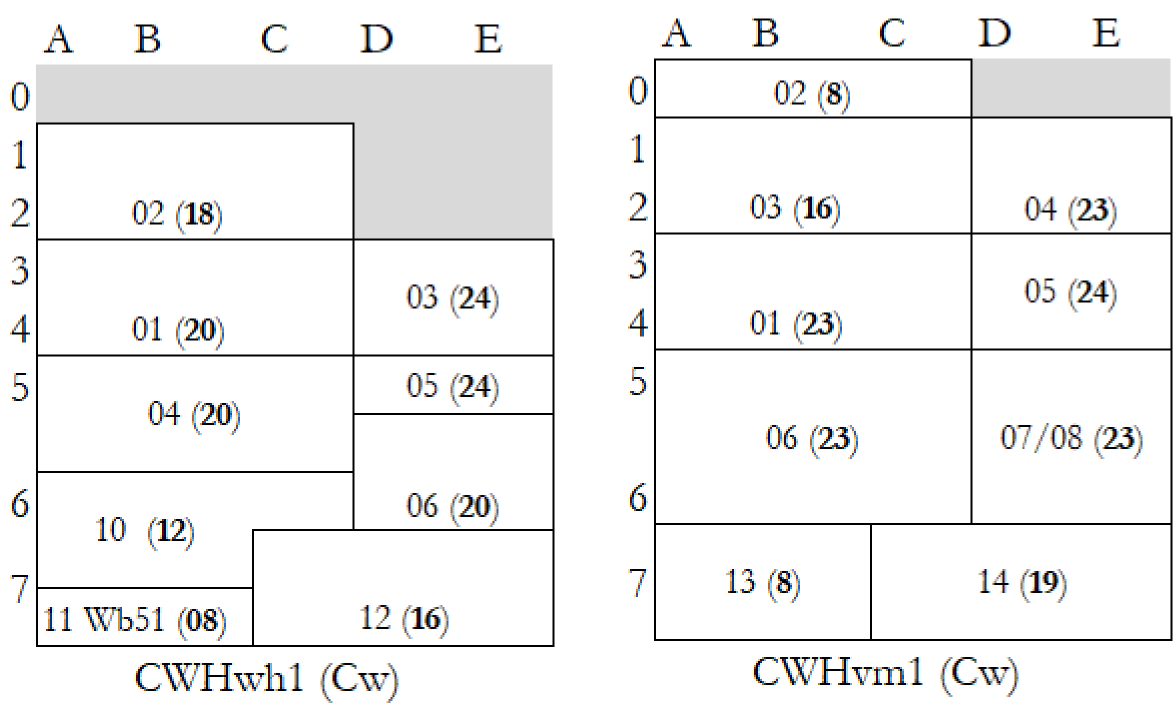


Figure 7.5.6. Ecological edotopic grid (rows increase with relative moisture, columns indicate relative nutrient) comparing SIBEC site index (bold in parentheses) between CWHwh1 (current) and CWHvm1 (predicted future) BGC site series units for western red cedar

Table 7.5.7. Climate data for wet and very wet hypermaritime variants (Green & K.Klinka, 1994).

	CWHwh1[54]	CWHvm1	
Mean annual precipication (mm)	1152 to 1535	1555 to 4387	
Mean annual temperature	7.1 to 7.9	7.0 to 10.1	
Growing degree-days >5 (C)	1206 to 1385	1313	2011

7.6 Economic operability assessment

Realized THLB

The timber supply model typically identifies a long run non-declining flow of timber based upon the THLB (availability), growing stock and key constraints that reflect current forest management strategies or policy. Accessibility, species distribution and markets however play a major part in the economic feasibility of sustainable forest management. Haida Gwaii has areas that significantly vary in age class distribution, access, productivity and species composition, all affecting economic feasibility. Therefore, an AAC that doesn't account for these discrepancies, for example including economically inaccessible areas into a broader cut, may lead to over-harvesting of accessible areas.

To account for this, this TSR incorporated an economic operability assessment through a relative cost and marginal value model. This model incorporates costing surrogates (roads) and value surrogates (dynamic stand values) that approximate operational limitations. The model addresses operability at multiple scales. For example, at the stand level there is often concern that small areas of practically inaccessible low value timber contribute to timber supply, whereas in reality they would not be harvested. At a broader scale this is applicable in woodsheds that may not come 'on-line' (e.g., actually contribute to timber supply) until the growing stock supports a stable harvest over a given time period. Both scenarios can be reflected in a THLB that is never 'realized'.

The following section is sourced directly from Fall (2018) and describes the road costing and stand value model.

The goal of the road cost aspect is to model relative differences in construction and maintenance costs based on geophysical attributes (e.g. slope, land cover). A road cost surface was developed, which was used to develop a full build-out potential road network that can provide access to the entire THLB via a relative lowest-cost layout. The underlying cost of each road segment is retained during timber supply analysis, where segment cost is the relative cost/km multiplied by road segment length.

The goal of the stand value aspect is to model relative differences in stand values per cubic metre of merchantable volume by species. Relative values were derived using log market prices. As these market prices vary by year, scenarios can apply average values, or higher/lower market values. Stand values can be computed dynamically as value/m^3 multiplied by merchantable stand volume, and can be summed at various scales, such as grid cell, block or woodshed.

Limits can be defined for the maximum average unit of road cost per unit of stand value (cost/km to value/m^3 ratio) that can be incurred during a period within each woodshed for road building and maintenance. These limits influence the order in which stands may be harvested (and hence the resulting timber supply). When limits are reached, further harvesting is constrained to the active road network at that point. For remote stands, the effect may be to cause rotations to be extended (e.g. to allow further stand growth that will lower the cost:value ratio to within acceptable limits), and in extreme cases may lead to a stand never being harvested (e.g. stand "isolation" may occur for a small stand of low volume/poor value that would require high road construction costs to access).

[54] Reference weather stations (*n*)=6 for CWHwh1; (*n*)=32

7.6.1 Road costs

The relative road cost layer ranges from 1 to 10, where a value of 1 represents the lowest cost condition (e.g. flat areas through forest). Higher values represent the relative increase in cost (e.g. a value of 10 represents a 10-fold increase in cost, or alternatively, a road segment of length 1 km across an area with cost 10 has the same cost as a segment of length 10 km through an area with cost 1). The same cost factors were applied as in the mainland coast analysis, where cost values were computed as (Fall A. , 2015)maximum cost (10) for glaciers, lakes, rivers, salt water, tide flats, rivers, mud and swamps.
Elsewhere: function of slope in percent: slope/10 (rounded up to next highest integer and bounded to range between 1 and 10).

Figure7.6.1.1 Relative road cost surface in Haida Gwaii: lighter shades indicate higher relative cost.

"Exit points" were identified from log handling site information (which are generally at existing road access points from water). Since log handling sites were polygons, an overlay was done with the existing road network, and a single grid cell was selected as the road network exit point.

To generate a full build-out, a location requiring access is stochastically selected, with probability increasing with distance from network roads. The least cost path across the road cost surface is then found to join the site to the road network. Distance and cost to network information is updated and the process is repeated iteratively until all target areas are within 1 km of a road.

The reason for preferentially selecting sites further from roads is that this creates segments that follow the cost surface and avoid lots of short, angular segments (which look more like spurs than the longer segments, which have a pattern more comparable to mainline roads). Conversely, the reason for not simply selecting the furthest site from the road network is that this creates a road network that is more linear than the actual existing network.

The road network was then decomposed into segments, with segment breaks at forks, where roads change from existing to future, and at woodshed boundaries. The average length of segments in the base case scenario was about 300m.

Information for each road segment is stored in a table that includes the length and relative cost of each road segment, as well as information on connections with other segments in the network.

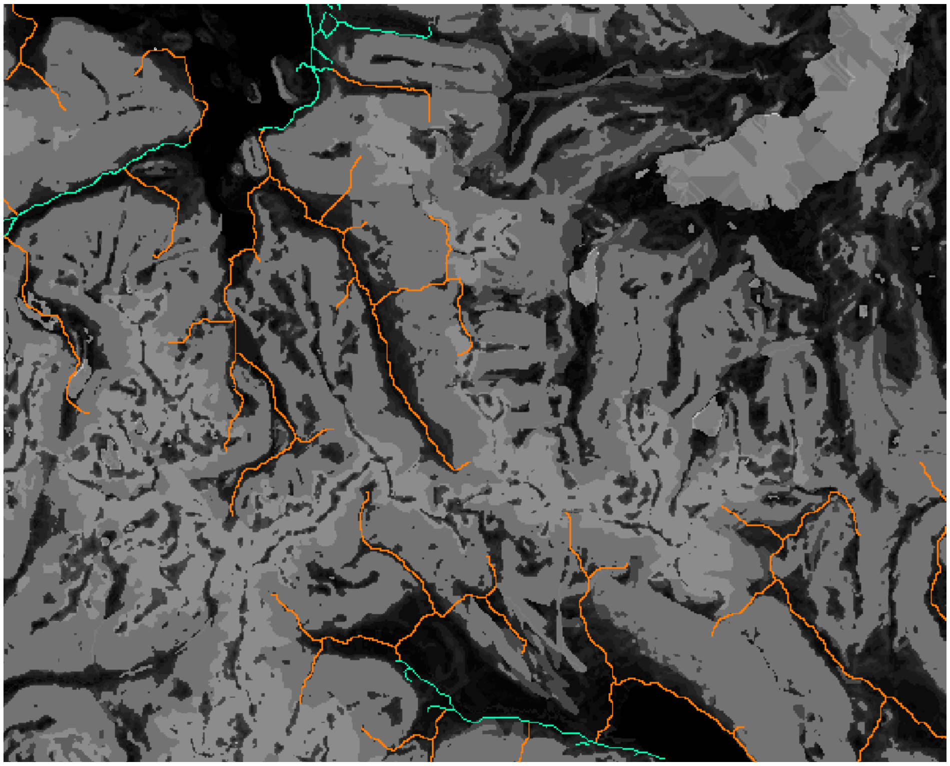


Figure7.6.1.2. Example of full build-out road network. Shades of grey represent relative road costs, where lighter shades represent higher cost. Cyan represents existing roads and orange represents potential future modelled roads.

7.6.2 Relative stand values

The goal was to quantitatively derive value factors per cubic metre for each major species. Two sources of information were explored for deriving relative stand values:
(a) Harvested stands in Haida Gwaii
(b) Log market prices

Information for harvesting in Haida Gwaii was available by timbermark, in which information was available on the percent by species of each harvested unit. Given an overall value for the harvested area, as well as the total volume harvested, factors for the value of each species could be derived via a least-cost-fit (i.e., minimizing the sum of the square of the differences between the actual values of the harvested units and the estimated values using the species factors, prorated by the percent of each species in the harvest unit). Direct information on harvest unit value was not available by timbermark, and so explorations were made on potential surrogates for value (in particular stumpage rate).

Developing stand value parameters based on log market prices
Log market prices provide information for various grades and types of timber based on species, product, etc. These vary by year.

Since log prices for spruce are not published, 2x4 commodity prices for were used for all species. The actual dollar values are not what is important for this application, but rather the relative differences between species and between years. It is, however, important that the prices used for each species are comparable.

An analysis of the rate of export was completed for Haida Gwaii in order to develop a domestic-export value composite for hemlock and spruce. It was important to account for the domestic-export volumes due to the value discrepancy, as seen in figure 7.6.2.1.

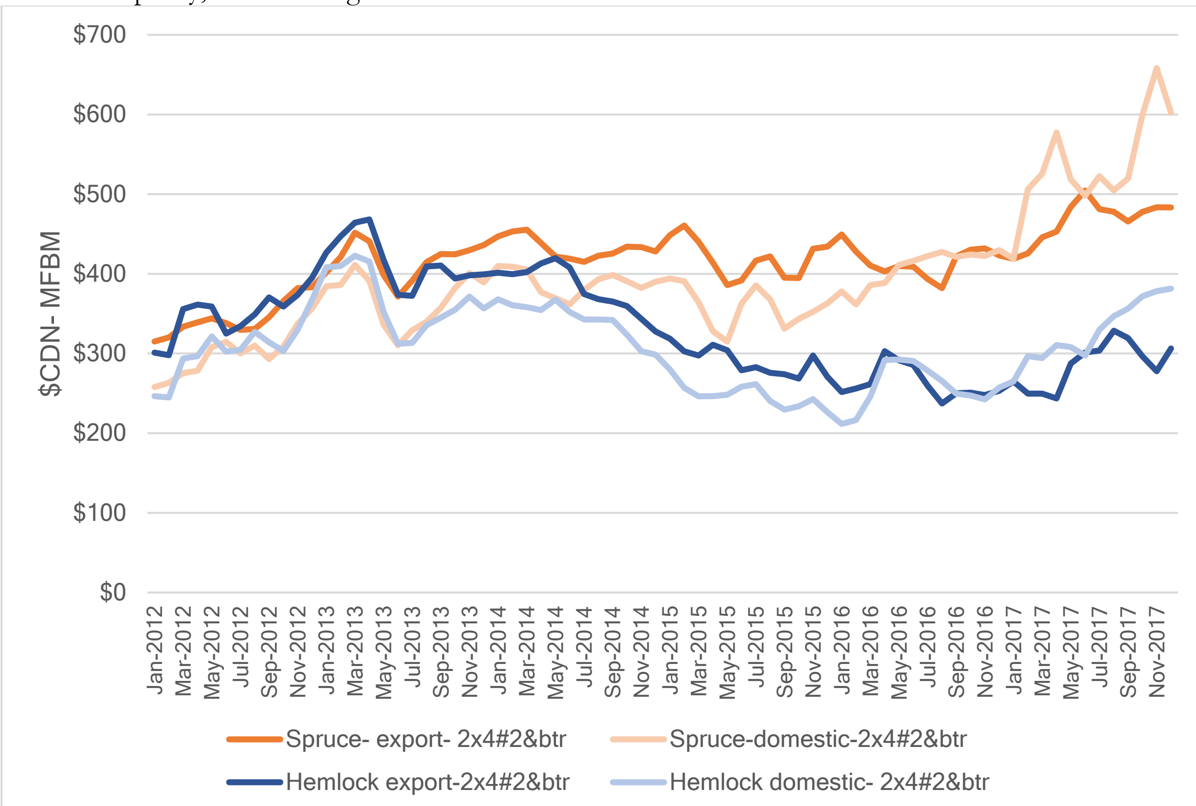


Figure 7.6.2.1. Domestic versus export commodity prices 2012-2017[55]

Export data for 2012-2017 were sourced from the tenure pricing branch[56].

[55] Values were sourced from Madison Lumber Reporting for domestic prices, and from Random Lengths Publications for export values.
[56] https://www2.gov.bc.ca/gov/content/industry/forestry/competitive-forest-industry/log-exports/bi-weekly-advertising-lists

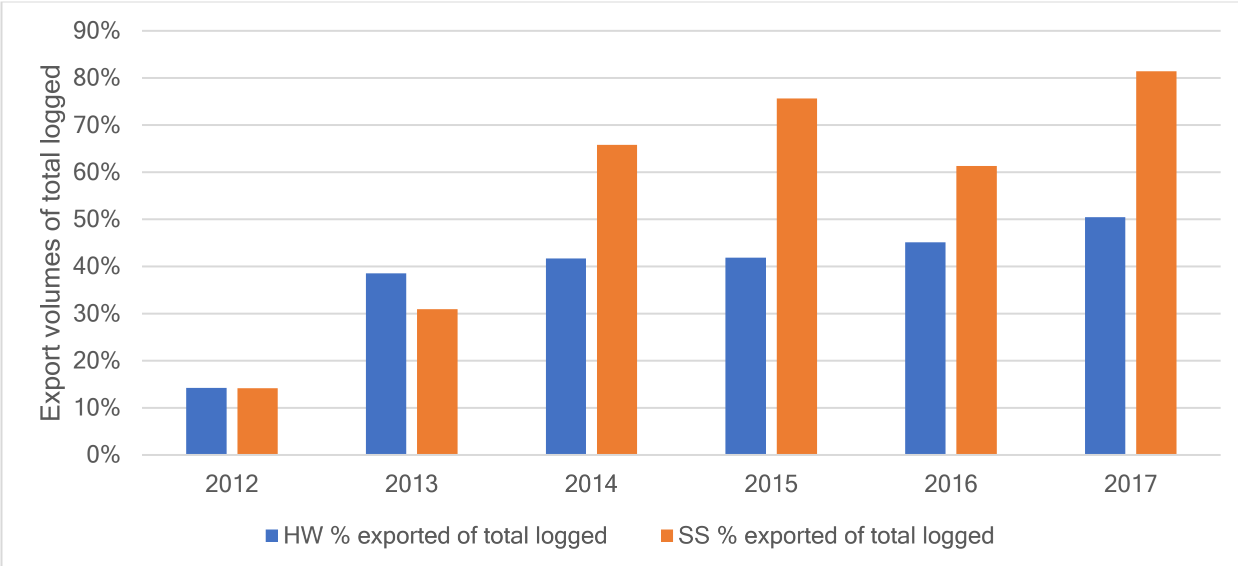


Figure 7.6.2.2. Hemlock and spruce exports from Haida Gwaii, 2012-2017

Hemlock and spruce prices were prorated according to the proportion of export from Haida Gwaii.

Table 7.6.2.2 shows summary information for each species group over the timeframe 2008 to 2017.

Table 7.6.2.2 Summary commodity prices for Cedar, HemBal and Spruce 2008-2017

Species type	Min $/m^3$	Max $/m^3$	Mean $/m^3$
Cedar (WRC 2x4 green)	547	1009	750
Hem/Fir KD Coast Std&Btr	162	385	278
Spruce (WSPF KD #2&Btr 2x4)	206	480	335
Overall	47.73	273.91	

For each species group, monthly prices were averaged across each year (2008-2017) representing a market cycle index.

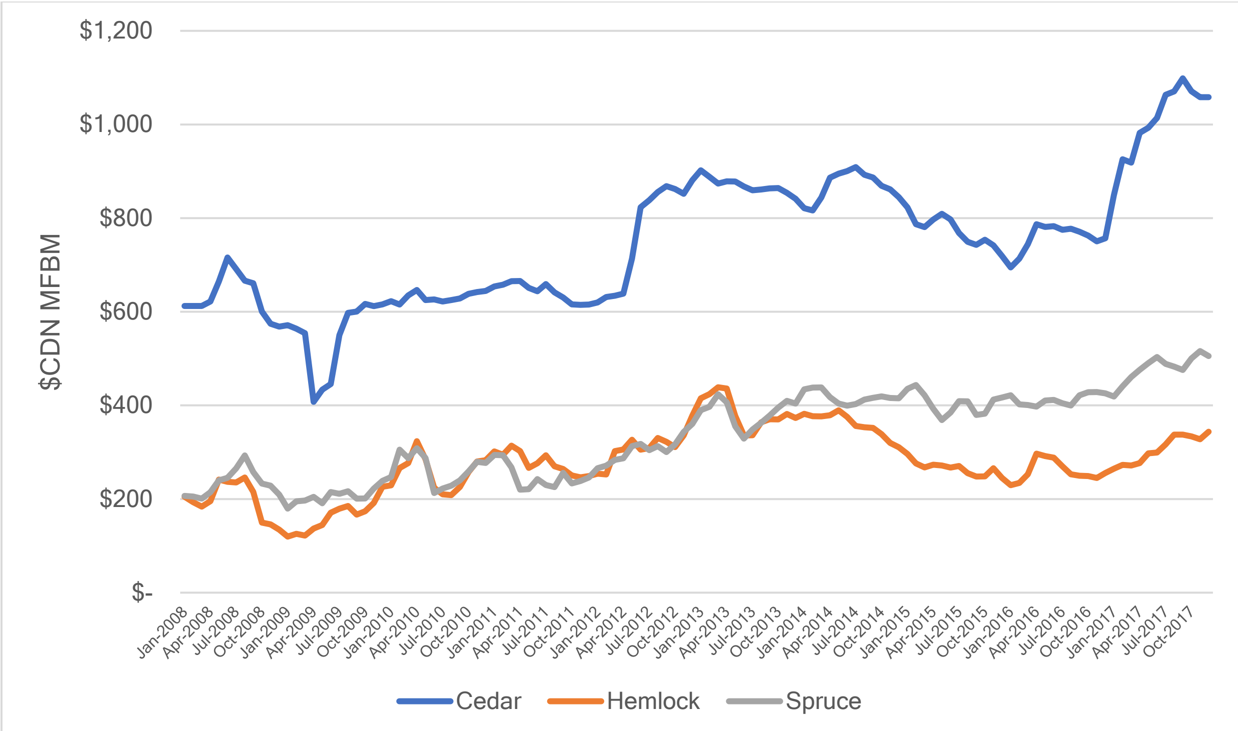


Figure 7.6.2.3. Market cycle index: species commodity values between 2008-2017

Average yearly price values were then divided by the minimum yearly price across all years and species, to put prices on a relative scale. (Table 7.6.2.3).

Table 7.6.2.3. Relative value/m3 by year for Cedar, HemBal and Spruce

Year	Cedar	HemBal	Spruce	All
2008	3.9	1.2	1.4	2.2
2009	3.4	1.0	1.3	1.9
2010	3.9	1.6	1.6	2.4
2011	4.0	1.7	1.5	2.4
2012	4.7	1.9	1.9	2.9
2013	5.4	2.4	2.4	3.4
2014	5.4	2.2	2.6	3.4
2015	4.8	1.6	2.5	3.0
2016	4.7	1.6	2.5	2.9
2017	6.2	1.9	3.0	3.7
Overall average	4.6	1.7	2.1	2.8

The relative values/m^3 by species group can be used to compute total relative stand values by multiplying these relative values by volume proportional to the percent of each species in the stand. The base scenario used the average for each species group across all years.

Sensitivity analyses (section 8 of this data package) explored high/low values by year and/or species. To facilitate this, years were classified into low, mid and high market years by species group and overall based on equal percentiles (table 7.6.2.4), and then the mid-point value/m^3 for each percentile class was calculated.

Table 7.6.2.4 Year value class for Cedar, HemBal and Spruce

Year	Cedar	HemBal	Spruce	All
2008	Low	Low	Low	Low
2009	Low	Low	Low	Low
2010	Low	Low	Mid	Low
2011	Mid	Mid	Low	Mid
2012	Mid	High	Mid	Mid
2013	High	High	Mid	High
2014	High	High	High	High
2015	Mid	Mid	Mid	Mid
2016	Mid	Mid	High	Mid
2017	High	Mid	High	High
Low percentile	**3.95**	**1.59**	**1.59**	**2.39**
Mid percentile	**4.93**	**1.90**	**2.51**	**3.07**

Table 7.6.2.4 Relative value/m3 for each value class for Cedar, HemBal and Spruce

Year	Cedar	HemBal	Spruce	All
Low	3.4	1.0	1.3	1.9
High	6.2	2.4	3.0	3.7
Average	4.6	1.7	2.1	2.8

7.6.3 Projecting stand values

The Spatial Timber Supply Model (STSM) projects stand ages, analysis units, road network and other attributes. A minor modification was made to the STSM to expand the timber analysis unit (AU) input table to include the percent of the three leading species expected in typical stands for the AU. The merchantable volume in a grid cell was then pro-rated by species using these percentages, and the relative value was computed as the sum across all species:

$Total\ Stand\ value = StandVolume * \sum_{i=1,n} SppPercent_i * SppValue_i$

where (i) *StandVolume* is the total merchantable volume in the stand;

(ii) There are *n* species types (in this case Cedar, HemBal and Spruce, so *n=3*);

(iii) Each species type has a relative value/m^3 *SppValue*; and

(iv) Each species has a percentage in the stand *SppPercent* (which sum to 100%).

Developing and applying cost:value ratios

The relative road costs and relative stand values are used to influence stand availability and preference, in combination with other factors in the timber supply model discussed in this data package.

Road construction and maintenance constraints are applied by "roadshed". Within each roadshed, limits are placed on the maximum cost that can be incurred within a period on road construction and maintenance relative to value harvested (i.e. road cost: stand value ratios).

Roadsheds
A roadshed is defined as a group of one or more adjacent exit points (log handling sites), and all the road segments that are connected to those sites. Analogous to a watershed, wood harvesting in a roadshed flows from further inland to these exit points.

Woodsheds were used as a basis for roadsheds. Fragmented portions of woodsheds were merged with adjacent roadsheds or placed in a separate roadshed, and each roadshed had at least one exit point. This resulted in 14 roadsheds figure 7.6.3.1).

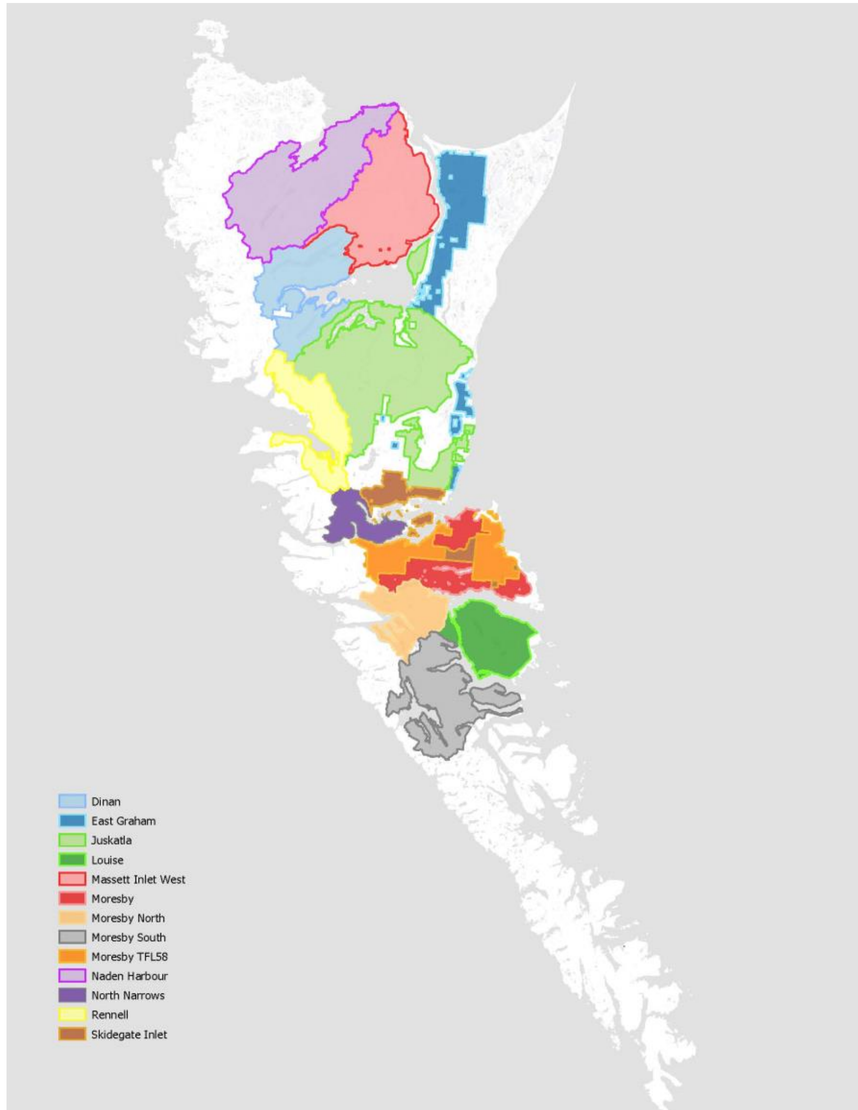


Figure 7.6.3.1. Roadsheds

Roadshed information tracked in timber supply analysis
The SELES Spatial Timber Supply Model tracks information for both individual road segments and entire roadsheds. The net relative cost of each road segment was computed using the road cost surface (represented as the sum of cost values across the length of each segment). During harvest, the volume and relative value of stands harvested, and the length and cost of road segments that are built by the model ("activated" from the road network) is tracked by roadshed. Also, the model tracks the length and cost of previously built segments that are maintained (accessed for the first time in the period). At present, roads are built once, and maintained up to once per period. In addition, hauling effort is tracked as sum of haul distance for each m^3 (volume-weighted haul distance).

Deriving base road cost: stand value ratio parameters
Separate cost:value ratios are derived for road construction and road maintenance. Both road building and road maintenance are relative and independent costs in this model (no scaling between building/maintenance is necessary). Baseline road building and maintenance costs were estimated by running the pre-LUOO scenario with no road cost constraints to produce output by period for each roadshed that included total volume and relative value harvested, and total km and cost of roads built and maintained. This was done using average stand values . Dividing total road building and maintenance costs by the total relative value harvested results in the mean cost per unit value of roads built and maintained.

Road building constraints were derived using the above outputs in each period and adding 10% to provide some within-period flexibility in stand harvest sequencing[57]. In general, road building declines over time (as

[57] The road cost constraints must be met at all times during a period. In some cases, higher cost/lower value stands must be harvested prior to reaching higher value stands. The additional 10% allows modest overrun of the cost:value during a

the road network reaches buildout), and hence maximum mean cost of roads built per unit value of wood harvested also declines (while maintenance costs do not change over time).

Evaluating road cost: stand value parameters
Past harvesting information from the timbermark data was used to assess, and calibrate, the road cost and stand value parameters (Market Cycle Blocks). Given the location, area and volume harvested, modelled relative road costs and stand values for the past harvest units were compared to the overall distribution of modelled road costs and stand values for available stands.

Three modelled harvest scenarios were developed to compare against historical harvesting in order to evaluate model performance:

- Operational Road Cost constraints: the base case TSR scenario (i.e. all constraints, criteria, etc.) with operational road costs.
- No Operational Road Cost constraints: The same as above, but without operational road costs.
- No Operational Road Costs Randomized: The same as the "No Operational Road Costs", but also applying a random harvest preference order for stand harvest selection (rather than based on relative to the age at the culmination of mean annual increment. This scenario was intended to represent as close to "random" as possible, but still respecting constraints, min. harvest criteria, etc.

For each of these scenarios, the Spatial Timber Supply Model (STSM) was run for 10 years, with output of grids for areas harvested and volume/ha prior to harvest.
To make comparisons relevant, the rate of harvest was based on the total volume harvested in the Market Cycle Block data. This is because, in general, road costs/unit value will decline with increasing harvest level (with lots of potential for variability), so it is important to compare scenarios at the same (or nearly the same) harvest level.
For each scenario, a number of metrics were calculated:

- The "value/ha" in harvested cells was calculated using the stand type value weights derived from log market data (by multiplying volume by relative stand value).
- The total road length and total road cost was summed for the road segments accessed for the harvest.
- The average cost/unit value for the roads accessed (separating permanent high-use roads from branch roads) was calculated by dividing total road cost by total value.

Average cost/unit values were then normalized by dividing values for each of the modelled scenarios by the historical harvesting scenario. The final evaluation found:

- Operational Road Costs: 107% for branch roads alone and 98% for all roads
- No Operational Road Costs: 129% for branch roads and 112% for all roads
- No Operational Road Costs Randomize: 161% for branch roads and 147% for all roads

These results show that the modelled operational road costs in the projected 1st decade result in road cost per unit value that are close to (~%7), but slightly higher than the Market Cycle Blocks. This is reasonable, since in the first pass, one would expect that road costs per unit value to increase over time

period. Post-hoc analysis can be done to assess average end-of-period cost:value ratios to ensure that they are not consistently exceeded.

as more remote and isolated stands are accessed, which may require more road or more costly road access, and possibly lower volumes per ha.
The results for scenarios without operational road costs show the magnitude of the improvement, which is reasonably significant given the other factors that constrain and direct harvesting.

Apply road cost constraints
A *road building constraint* is defined, for each roadshed and in each period, as an upper limit on the mean cost of roads built per unit value of wood harvested in the roadshed. A *road maintenance constraint* is defined as an upper limit on the mean cost of roads maintained per unit value of wood harvested in the roadshed during the period.

At the start of each period, information on the current harvest level, roads built and roads maintained by roadshed is cleared. The volume of "potentially available" timber (merchantable timber not reserved to meet a specific constraint) accessed from each road segment is computed (using a grid of nearest road segments).

During the period, "block initiation" cells are queued using the harvest order criteria (e.g., relative oldest-first with preference increasing with stand value, and declining with distance from road to a maximum distance of 1.5km from an existing road for road access and 1.5km from a future road or ocean access) (Ecora, 2015). Before harvest, road constraints are tested as follows.

If the nearest road is not yet built, a test is made as to whether building this segment would exceed the construction constraint limit for the roadshed. Specifically, the test is for whether the net cost (total cost of roads built so far during the period plus the cost for this segment) divided by the net value harvested (the relative value of volume harvested so far during the period plus the relative value of volume available for this road segment) is less than the constraint cost per unit value for road construction.

If the road has been previously built, but has not yet been accessed in this period, a test is made as to whether maintaining this segment would exceed the maintenance constraint limit for the roadshed. Specifically, the test is for whether the net cost (total cost of roads maintained so far during the period plus the cost for this segment) divided by the net value harvested (the relative value of volume harvested so far during the period plus the relative value of volume available for this road segment) is less than the constraint cost per unit value for road maintenance.

As logging progresses, distance to road information is updated. Further, at the end of each period, the total volume harvested with access from each road segment is "flowed" down the road network to the water access point to support computing the total hauling effort.

When applying road constraints, some areas may never be accessed if the cost per length of road is high relative to the available value (which depends on the area of THLB, productivity of stands and relative species value). Some areas will be accessed with delay (compared to not applying road constraints) if available volume must increase to satisfy the road cost requirements. Other areas will be unaffected (e.g. areas with dense, high productivity THLB, with existing road access close to water entry points).

7.6.4 Isolated planning units
Certain operating areas on Haida Gwaii are considered very remote and difficult to operate in as a result of terrain, needs for infrastructure investments and young stands due to past harvest histories. Three of these areas have been identified Sewell inlet (Moresby south) and Peel Inlet (Moresby north), both of which are in the TSA, and Louise Island, which is a part of TFL 60.

The inclusion of areas in the AAC that are practically not operable, or only operable under specific conditions, may lead to over-harvesting other areas in the THLB that are more easily accessible.

Licencees were surveyed to determine what operating criteria would lead to investment and harvesting in these areas (see figure 7.6.3.1 for a map of these areas).

Operational feedback indicates that the Sewell and Peel areas require at least 100,000 m3 for 3 consecutive years, and Louise requires 50,000 m3 for 2 consecutive years.

Scaled to a 10-year model step would mean 333,000 m3 for Tasu/Sewell and Peel, and 250,000 m3 for Louise. This constraint was applied in the base case reference scenario as a minimum harvest volume requirement for these areas.

7.6.5 Small Islands

Haida Gwaii is made up of over 3,670 islands, the majority of which are forested. While most of the islands are in protected areas, a number of islands are available for forest harvesting but are difficult to log. Historically many of these islands were logged using A-frame yarding techniques. Conventional logging has changed dramatically since the A-framing logging era, and islands require log handling, barge/machine loading areas as well as infrastructure such as roads. As a result small islands are typically not operationally feasible. An analysis of the last decade of logging showed that, other than private lands, islands under 150 hectares have not been accessed for commercial logging. As result these islands, amounting to a gross reduction of 3,123 hectares and a net reduction of 249 hectares were removed from the THLB.

Chapter 8 Sensitivity Analyses

8.1 Sensitivity analyses overview

Sensitivity analyses are meant to explore 'what if' scenarios that may have implications to timber supply. These analyses are used as comparisons against what is considered 'base-case' or those assumptions that most reflect current inventory, forest growth and forest management policy. Changing one element or assumption of the base case allows decision makers to explore the interaction of supply over time and place. Types of sensitivity analysis include:

- anticipated policy changes (either from legislation, regulation, resolutions or strategies employed by licensees),
- reasonably foreseen changes to markets or economic operability,
- potential changes in inventory (e.g. the type, frequency and distribution of natural disturbance over time);
- potential changes in forest growth over time, or;
- potential changes in forest management strategies (e.g. rotation lengths);
- alternative technical approaches to represent management assumptions (e.g., different ways of constraining visual quality, etc.).

The following sections describes the context for a sensitivity analysis, the considerations or rationale (e.g., policy driven, information driven, etc.) and the specific technical assumptions employed.

Table 8.1. Summary of sensitivity analysis scenarios.

Category	Description	Data package section
Cedar	Evenflow (long run sustained yield) cedar harvest on TFL 58, TFL 60 and TSA	8.2.1
	Evenflow (long run sustained yield) cedar harvest on TFL 58, FNWL, CFA, TSA	
	Evenflow (long run sustained yield-LRSRY) cedar harvest on TSA woodsheds	
	Evenflow LRSY + 10%(e.g. 110% of LRSY)	
	Evenflow LRSY – 10% (e.g. 90% of LRSY)	
Management Units	Base reference run on TFL 58, FNWL, TSA	8.2.2
	Base reference run on TFL 58, FNWL, CFA, TSA	
House of Assembly/ CHN	Mosquito lake protection	8.2.3
	Slatechuck creek protection- track flow/THLB contribution	
	100% Monumental cedar protection- factor consideration impact on old natural stands	
	Monumental cedar standard identification change (lower grades included) on TFL 58, TFL 60 and TSA- Uniform distribution	

Category	Description	Data package section
	Monumental cedar standard identification change (lower grades included) on TFL 58, TFL 60 and TSA- Random distribution	
Goshawk	Northern goshawk nesting reserves on 25 territories on TFL 58, TFL 60 and TSA	8.2.4
	Northern goshawk nesting reserves on 38 territories on TFL 58, TFL 60 and TSA	
	Northern goshawk nesting reserves on 67 territories on TFL 58, TFL 60 and TSA	
	Northern Goshawk foraging habitat constraint targeting 5,564 ha (65% territories) of suitable/capable habitat for 22 territories on TFL 58, TFL 60 and TSA	
	Northern Goshawk foraging habitat constraint targeting 5,564 ha of suitable/capable habitat for 38 territories on TFL 58, TFL 60 and TSA	
	Northern Goshawk foraging habitat constraint targeting 5,564 ha of suitable/capable habitat (or all suitable/capable habitat if a territory is below this target) for 67 territories on TFL 58, TFL 60 and TSA	
	Northern Goshawk foraging habitat constraint targeting 4,672 ha (55%) of suitable/capable habitat for 67 territories on TFL 58, TFL 60 and TSA	
	Northern Goshawk foraging habitat constraint targeting 3,823ha (45%) of suitable/capable habitat for 67 territories on TFL 58, TFL 60 and TSA	
Economic operability	No road operability constraints TFL 58, TFL 60 and TSA	8.2.5
	Maximum market (High market) scenario TFL 58, TFL 60 and TSA	
	Minimum market (Low market) scenario TFL 58, TFL 60 and TSA	
	No new roads permitted to be built	
	High cost access exclusion	
	Partition or exclude (and long run sustained yield or evenflow) of isolated planning units (Sewell, Peel, Louise Island)	
	No restriction to isolated roadsheds	
Minimum Harvest Criteria	Economic rotation (and MHV) on TFL 58, TFL 60 and TSA	8.2.6

Category	Description	Data package section
	Extended harvest rotation (and MHV) on TFL 58, TFL 60 and TSA	
	No minimum harvest volume constraint on TFL 58, TFL 60 and TSA	
	No minimum harvest age on TFL 58, TFL 60 and TSA	
	Minimum harvest volume constraint raised to 350m3 for managed stands, 250m3 for natural stands on TFL 58, TFL 60 and TSA	
	Maximum harvest age 250 years	
Harvest preference	Relative volume harvest preference (as opposed to relative value)	8.2.7
	Oldest first relative to CMAI TFL 58, TFL 60 and TSA	
	Randomized order of harvest	
Alternate THLB	LUOO risk managed targets	8.2.8
	Assume WTRA retention levels match current practice, is considered exclusive in-block retention 'above and beyond' LUOO retention (7.1% increase on the TSA, 11.6% increase in TFL60 and FLTC).	
	Assume increased access to unstable terrain, based on 20 year average of licencee behaviour	
	Assume branchline roads (basecase 10m exclusion) regenerate on Alder AU with site index 21 with natural densities (4444) and a 4 year delay	
Forest cover constraints	Wetlands not considered 'recovered' forests on TFL 58, TFL 60 and TSA	8.2.9
	Don't apply forest cover constraints	
Harvest flow	Short-term uplift (Allow short-term harvest level to increase such that steps to reach mid-term level cannot be more than 10% per decade.)	8.2.10

8.2 Sensitivity analysis scenarios

8.2.1 Ts'uu – Ts'uu sgiid, Sgaahlaan - Sgaahlaang (red cedar and yellow cedar)

Cedar is central to the Haida cultural and an economic mainstay on Haida Gwaii.
This sensitivity deals with the commercial availability of cedar and is one of the principle reasons for an early Timber Supply Review. Historical harvesting and deer browse has led to large age gaps in cedar, threatening a mid-term shortage, or fall down, in cedar supply.

These age gaps are due to the majority of cedar within the THLB being mature or old. The small amounts of mid seral forest creates a reliance in the near and short term for whatever mature and old cedar is left. This, along with cedars high value and historical harvest above the natural profile has in turn has led to considerable administrative and legal conflicts over the last several years.

Cedar, and the variable growing sites of cedar, are not equally distributed among the management units on Haida Gwaii, especially within the operating areas of the TSA. As a result, some operating units with intensive historical logging (such as Sewell, Tasu, north Moresby) have highly productive growing sites with little to no cedar regeneration or mature cedar, while other areas have moderate productivity and high concentrations of mature cedar (Collison point) or low productivity and high concentrations of mature cedar (north east Graham).
A concern was that, without a partition, the AAC contribution of volumes from less operable or marginal areas of the TSA (typically with low cedar content) were being applied to areas with high cedar composition, thereby undermining its long term sustainability.

Policy considerations
In 2012 the HGMC called on the Chief Forester to consider an orderly transition to harvesting in second growth stands to account for the shortening supply of mature cedar. The Chief Forester then set a soft or non-legal partition for cedar in 2012 with recommended annual limits within each management unit generally based on cedars proportionate contribution to the inventory.
In 2017, in response to the over harvesting of cedar relative to the soft partition in the Timber Supply Area (TSA), the Chief Forester set a legal partition within the TSA which was brought into effect with a Ministerial Order in August of 2018. This partition is currently considered to be part of the base case for this TSR (see section 6.13).

The 2018 partition used limits that were originally included as the 2012 'soft' partition on the three management units (TFL60, TFL 58, TSA). These numbers therefore use the previous TSR inventory and assumptions, but also represent harvest limits to cedar that are nested within the HGMC's 2012 AAC determination. In other words, while the current partition approximates the proportionate contribution of cedar to mature forest in the previous inventory, it also represents a limit that theoretically allows for the HGMC's 2012 AAC to be met (e.g., the partition does not constrain the overall AAC). As a result, while the partition mitigates the mid term fall down it does not resolve the mid-term shortage of commercially available cedar. Therefore, the sensitivity analyses described herein explore means to further mitigate this fall down.

For all scenarios, while an evenflow is sustained, there is a decline of natural stand growing stock over time as mature/old growth timber is replaced with second growth stock, as illustrated in figure 8.2.1.

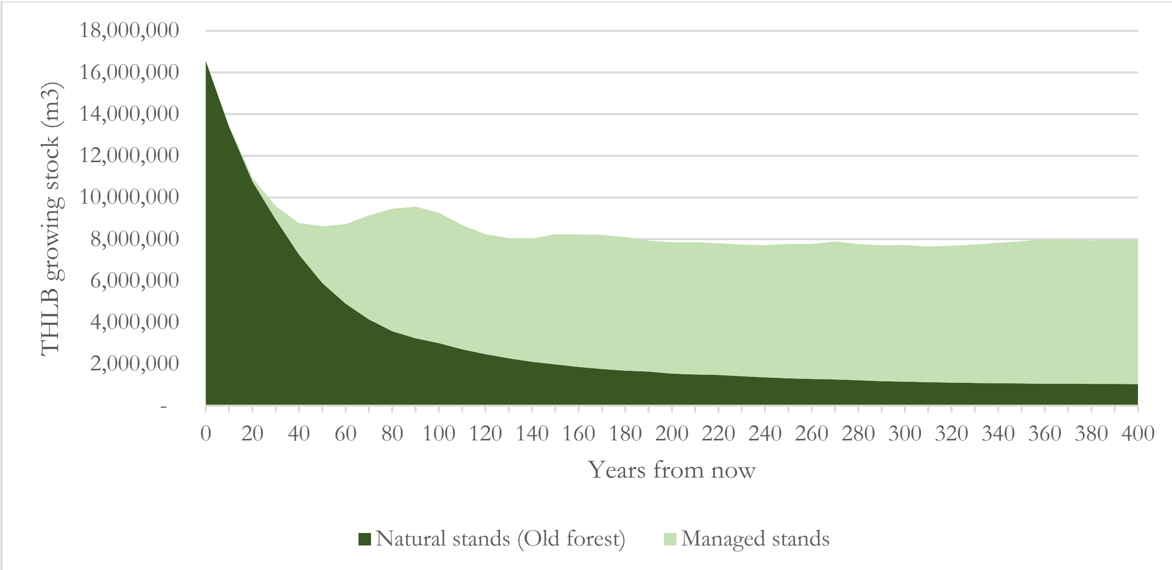


Figure 8.2.1 Base case natural vs. managed growing stock over time

Timber Supply Considerations

Four supply strategies were employed within this TSR:

(i) An analysis was done to assess limits to cedar harvest to accounts for the mature/old cedars contribution to the harvest over time. Contribution to the harvest is based on tracking all species components (leading, secondary, tertiary, etc.). An even or sustained flow of cedar within each management unit (TFL60, TFL58, TSA) was calculated based upon the long-run range average yield (LRAY) of cedar harvest.

This average amounted to approximately 146,371m^3 per year across all management units:

TSA	81,827 m^3
TFL 58	15,245 m^3
TFL 60	49,299 m^3
Total	146,371 m^3

Within the Spatial Timber Supply Model, harvests tracked the proportional contribution of cedar for all stands (e.g., all species composition deciles contributed or were aggregated towards a harvest target). When the target was met a constraint was applied for all stands that had >10% cedar until the end of the period (10 years) (see section 6.13 for a discussion on the 10% model threshold).

(ii) Considering the major discrepancy in the geographic distribution of cedar across the THLB, a second analysis employed the same evenflow as described in (a) but applied to distinct area-based operational units within the THLB (see map 8.2.1). Operational units represent approximate 'woodsheds' or boundaries of supply units with similar timber attributes or operating limitations. These operational units are not formal, or legally designated units or tenures, however, provide a way to measure where cedar contributions are coming from, and evaluate contributions over time.

(iii) The third sensitivity increases the partition constraint by +10% to the long range average yield targets outlined in (a) above.

(iv) The fourth sensitivity decreases the partition constraint by -10% from the long range average yield targets outlined in (b).

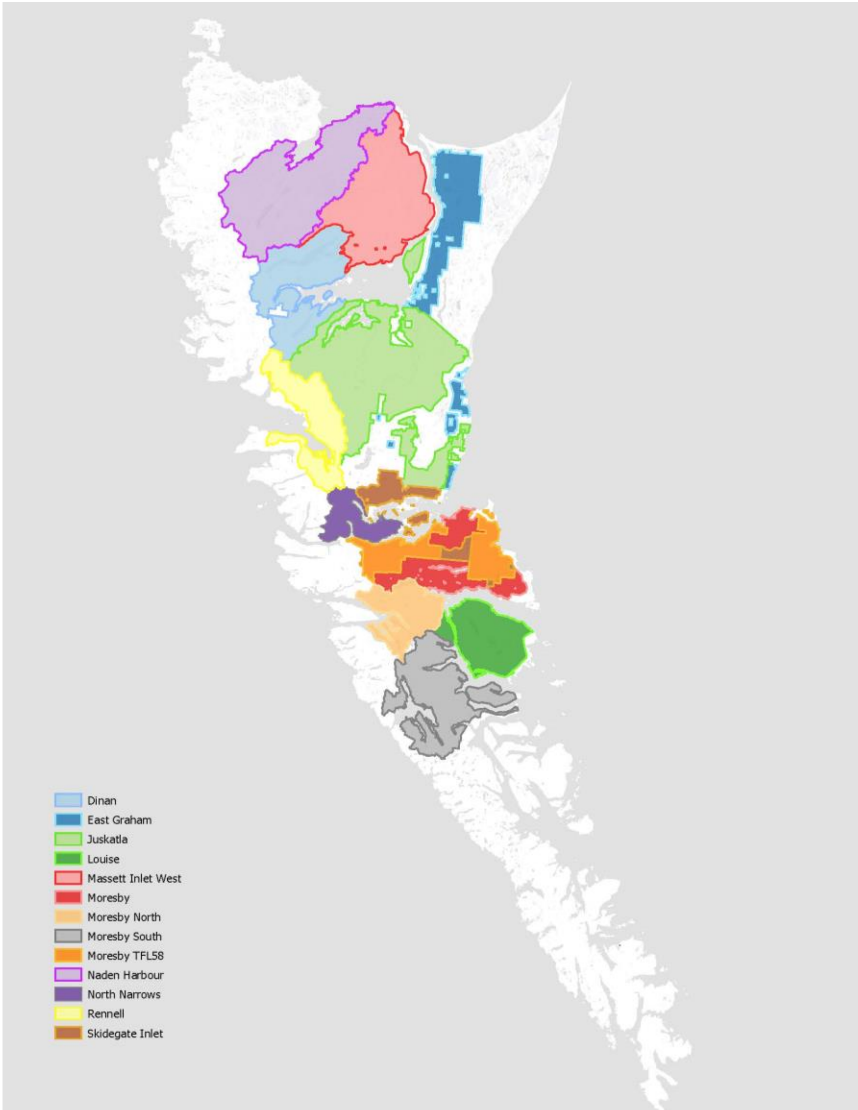


Figure 8.2.1. Timber supply units, or roadsheds within the THLB for purposes of a cedar sensitivity.

8.2.2 Management Units

8.2.2.1 Community Forest

The Province of BC has been working with the Communities of Haida Gwaii (as represented by the Misty Island Economic Development Society, or MIEDS[58]) towards the establishment of a Community Forest Agreement area to come out of the Timber Supply Area. The initial and formal community forest discussions date back to 1996, but in 2010 the Province offered a volume commitment of 80,000m^3 year in partnership with BC Timber Sales. In 2013, with the Ministerial AAC apportionments of volume in the TSA, the 80,000m^3 was tracked as part of the formal apportionment system. While there had been a level of partnership between BCTS and the communities an area had never been formally established or a Community Forest Agreement had not been signed. The Council of the Haida Nation continued to support the establishment of an area-based community forest.

[58] www.mieds.ca

Policy considerations
At the end of 2017 the Province made a formal offer of tenure *K5F* to MIEDS that included a *reduced volume condition* that outlined a formal and legal partnership with BCTS. While the offer has not been accepted, the area proposed within the formal 2017 offer is the area used within this sensitivity analysis, and comes entirely out of the Timber Supply Area, as shown on the following map:

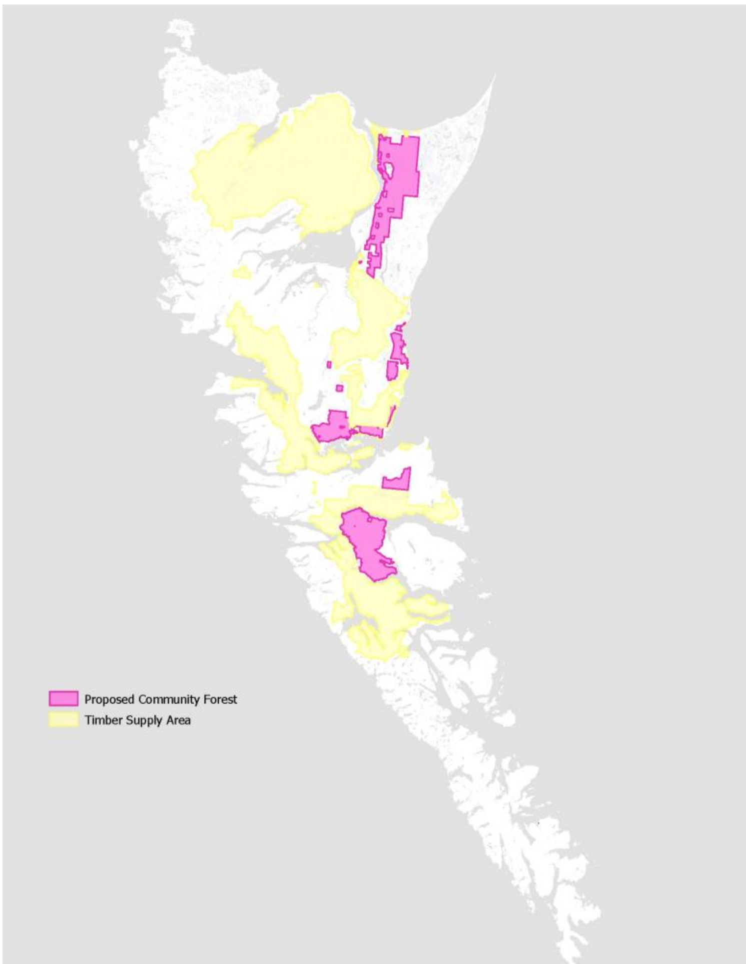


Figure 8.2.2.1 Proposed area of Community Forest Agreement and remaining Timber Supply Area

Timber Supply Considerations
All base case assumptions were applied to the proposed CFA management unit. Given the effect on the TSA (e.g., the CFA is removed from the broader TSA), the refined TSA unit was also modelled using base case assumptions.

8.2.2.2 First Nations Woodland Licence

In 2011, Taan Forest Ltd.became the forest manager of TFL 60, as well as a defined 'chart area' within the Timber Supply Area through an award of a Forest Licence To Cut (A87661). This FLTC was in turn the result of the Strategic Land Use Agreement and subsequent Kunst'aa Guu-Kunst'aayah Reconciliation Protocol which outlined the provision of a tenure to support 120,000m^3 per year for the Haida Nation.

Policy Considerations
The BC Timber Pricing branch (MFLNRORD), the Ministry of Indigenous Relations and Reconciliation (MIRR), the CHN and Taan Forest Products Ltd. have been negotiating the creation of a First Nations Woodland Licence that would effectively merge TFL60 and FLTC A87661 into one management unit. For all intents and purposes, Taan Forest Products Ltd. manages both tenures as though they were one already[59] (e.g., one FSP, integrated management planning and harvest scheduling, etc.).

Timber Supply Considerations
A sensitivity run was completed that merged the management unit boundaries of TFL 60 with FLTCA87661. All the base case assumptions were applied to these unit boundaries. Much like the CFA analysis, this required the complete removal of FLTCA87661 from the TSA, and as a result has implications to the long run sustained yield for the TSA and the proposed FNWL. The following map depicts the management units used in this sensitivity:

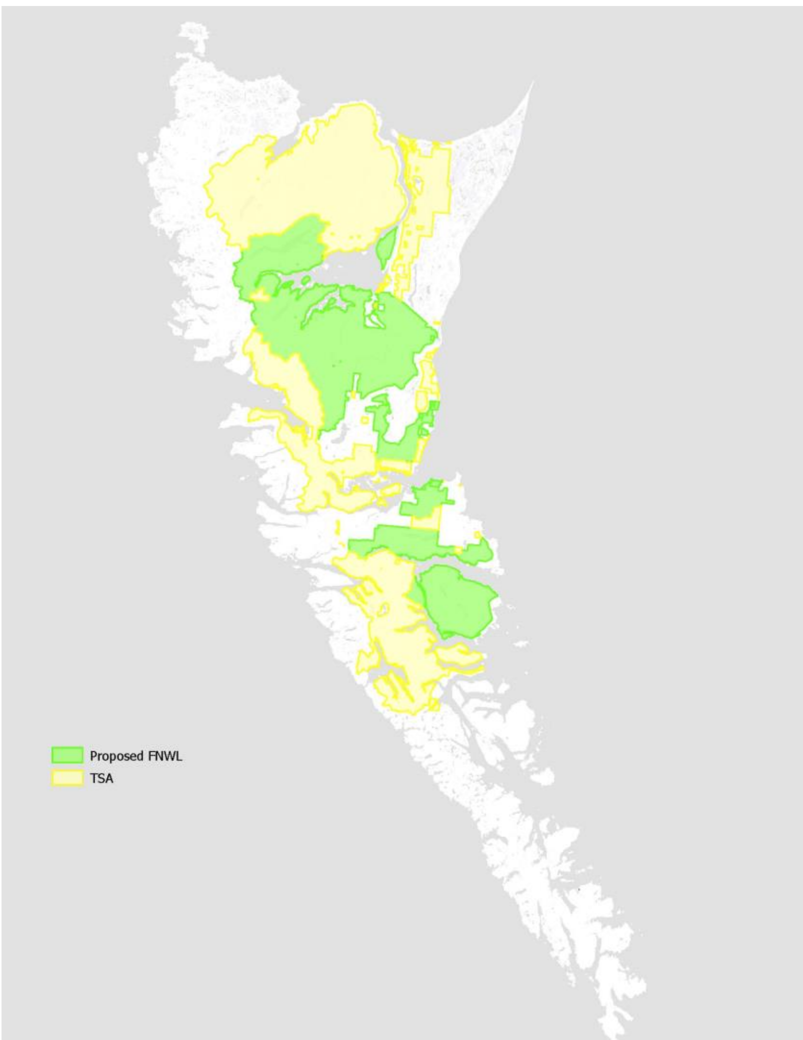


Figure 8.2.2.2. Area of proposed First Nations Woodland License

[59] With the exception of tracking cedar volumes harvested.

8.2.3 Council of the Haida Nation policies

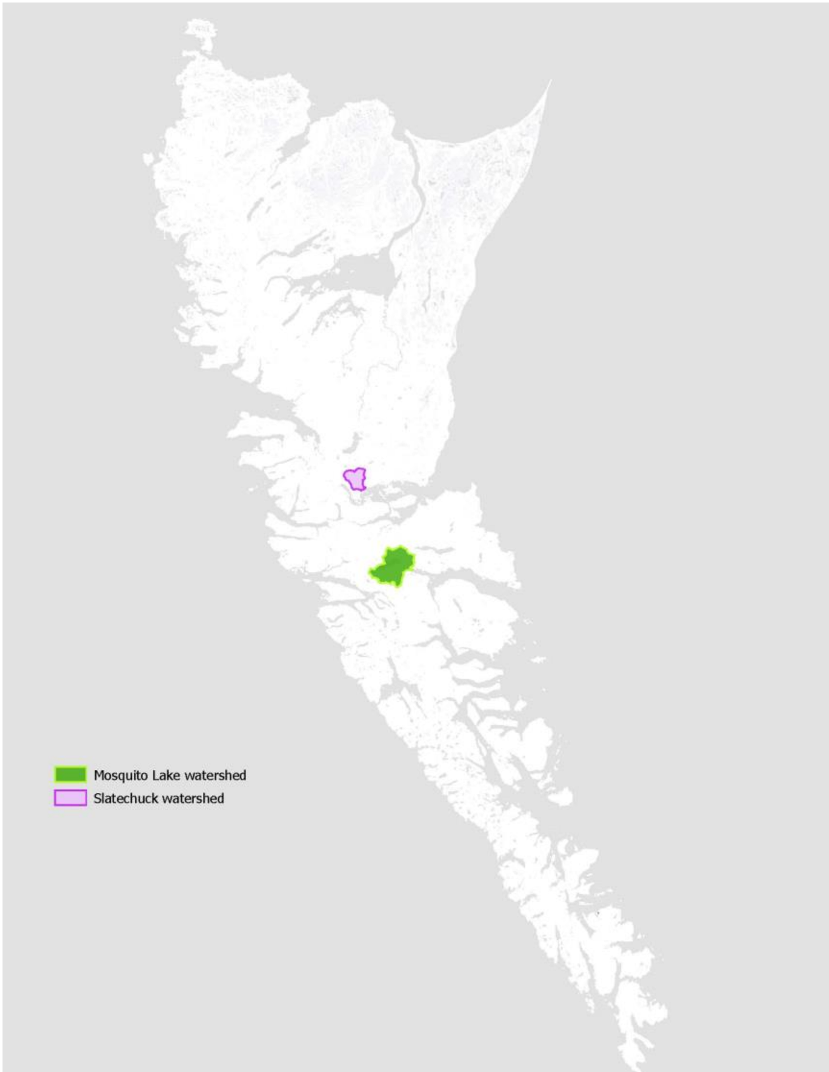
The Haida Nation's House of Assembly is an institution borne from the Haida Nation's constitution. Through resolutions democratically adopted by the citizens of the Haida Nation the Council of the Haida Nation is provided a mandate to implement policy. A number of these mandates include resource management directives. Some resolutions require significant interpretation, process and policy work to implement and/or require a wide variety of actors and legal instruments to bring into effect. Other resolutions are very straight forward and can be immediately incorporated into the doctrine of decision making by the Nation. Several sensitivity analyses were conducted concerning Mosquito lake, Slatechuck watershed, monumental cedar and the Northern Goshawk.

8.2.3.1 Mosquito lake Policy Considerations

In 2015 a House of Assembly resolution was passed (#2015-04) that designated the Mosquito Lake watershed as an area of importance to be placed under the protection of the CHN. Mosquito lake is currently within the Timber Supply Area on north Moresby Island, with the northern half of the watershed within FLTCA87661 (Taan Forest Products Ltd.) and the southern half within the general TSA . The CHN and Taan have confirmed that no harvesting will occur in those areas that drain into Mosquito lake. Planned harvests under Timberwests FLTC A90533 that overlapped the area of interest were rescinded (e.g., block MOSQ013) and currently no planned operations overlap within the watershed.

Timber Supply Considerations

The CHN Executive committee considers the full watershed area to include those hydrologic units that drain into and out of Mosquito lake. A sensitivity run was completed that removed 100% of the Mosquito lake watershed from the THLB (see Map 8.2.3.1).



Map 8.2.3.1 Mosquito lake and Slatechuck Creek watersheds

8.2.3.2 Slatechuck

Slatechuck or *Tllgaduu* is a watershed and mountain east of the Village of Queen Charlotte whose creek, *Tllgaduu Gandlaay*, empties into Skidegate inlet to the ancient village of *Tllgadaaw Llnagaay*. Part of the watershed is composed of the Skidegate Formation, made up of sedimentary deposits of thin bedded sandstone and siltsone (turbidites) along with lesser mudstone and shale. The rocks found here are principally argillite, greywacke and conglomerate turbidites from the cretaceous period (88.5-97 million years old). The argillite deposits are the focus of a sacred quarry that the Haida Nation has traditionally used to access high quality argillite for carving. Historically the Haida used the trail to the quarry and up the watershed for travel between Skidegate inlet and Masset Inlet (Dawson, 1878).

Policy Considerations

The Slatechuck quarry is protected by a small 18-hectare Federal crown reserve (tenure ID 015813495). The quarry is in active use by the Haida Nation, and while there is no formal policy designation for the area, recent proposals to log within the watershed have been met with opposition by the CHN.

Timber Supply Considerations
A sensitivity analysis was conducted to remove 100% of the Slatechuck watershed from the THLB. Watershed boundaries were defined by the aggregation of HGLUOO Schedule 6 upland stream area watersheds (map 8.2.3.1).

8.2.3.3 Monumental cedar
A House of Assembly resolution in 2018 mandated the CHN to conserve all monumental cedar. Currently 100% of large (>120cm DBH) monumental cedar are protected, but only 10% of monumental cedar between 100-120cm are protected, with the remainder being made available to the Haida Nation. Implementing this mandate would require a change by the HGMC of the HG Land Use Objectives Order, which has not occurred. Nonetheless, understanding the timber supply implications is important to informing potential regulatory changes.

Another change in managing for monumental cedar comes from changes in the Haida Nation's *Cultural Feature Identification* manual. Changes in these standards increase the acceptable defects in cedar (e.g., increased knot size and numbers, increased thresholds in rot, fewer indicator to rule out cedars being classified as monumental cedar).

8.2.3.4 Full monumental cedar protection (former monumental classification)
The objective of the monumental cedar sensitivity was to determine *how much area is net down if 100% of monumental cedar are protected.* This analysis used the former classification of monumental cedars (CFI manual version 4), which is congruent with spatial submission data from licencees, and as such is less relevant as it does not represent the current classification of monumental cedar. A spatial analysis of monumental cedar that were part of the 2012-2016 HGLUOO annual submissions data was completed. 1,085 monumental trees and their reserve and management zones formed the basis of the analysis. Where management/reserve zones weren't already spatially delineated (e.g., had been logged under LUOO provisions), tree length buffers were required to be modelled. Buffers were modelled by assigning a Schedule 5 tree length to the site series that intersected the feature and multiplying that tree length by the HGLUOO requirements (e.g., 1.5 tree lengths). A total of 322 or 30% of identified monumental cedar were logged between 2012-2016 and had this buffer applied.

Site series were determined using the primary decile of the ecosystem mapping layer described in section 3 of this data package. Schedule 5 assigns different heights for old and mature stands. For this TSR, old stands were existing unmanaged stands >250 years, and all other stands were assigned heights for mature stands.

Analysis methods included:

- Identifying those trees without reserve and management zones (e.g., within the Net Area to be Reforested), and not within road right of way. Past practice has shown that monumentals within road right-of-ways are in many cases removed and offered to the Haida Nation;
  Buffering those monumentals with the LUOO Schedule 5 (as described above). Buffers within road right of ways were excluded.

8.2.3.5 Netdowns from the former monumental identification standards

In October 2019 the CHN published an update to the CFI standards that included changes to the classification of monumental cedar. The previous classification system had been in place since the HGLUOO had been implemented in 2011, resulting in a significant sample of operational data available to determine how this objective affects timber supply. This scenario applies the learnings from that data to estimate what the predicted netdown would be for as yet to be identified monumentals based on the former CFI standards (v.4).

Net down assumptions
Data from a total of 1,085 monumental trees and their reserve and management zones were used in the analysis to exclude retention areas around known monumental trees and were used in a frequency distribution analysis for estimating an exclusion factor for yet to be identified monumental trees.

The frequency distribution analysis for extrapolating future exclusions from the THLB found that the net exclusion from monumental cedar was 1.9% of all Development Areas (all forest ages) between 2012-2016. Most of these features were found within old forest (92% of occurrences), therefore the exclusions were proportionately weighted by age strata (old forest/younger forest). Note that monumental cedar commonly overlap with other HGLUOO values, as illustrated in appendix 6. This exclusion factor is less than the 2011 prediction of 13.7% exclusion from all old forest (JTWG, 2012). Note however, that the 2011 estimates did not benefit from any operational data that represented the application of the HGLUOO.

Given the importance of Monumental cedar to the Haida Nation, and the policy uncertainties surrounding the future protection of monumentals, sensitivity analyses were undertaken to explore effects on timber supply from potential policy changes (see section 8).

8.2.3.6 Increased estimate of monumental cedar

A new version of the Cultural Feature Identification Standards Manual was released in late October 2019. The standards were designed to implement the LUOO requirements as currently written, not to revise the LUOO. A preliminary estimate of the frequency of monumental cedar was applied in the base case. However, some uncertainties remain, including: how many cedar trees with diameters over 100-cm meet monumental cedar criteria; and how monumental cedar will be managed and harvested. In response to these uncertainties, the HGMC through the Technical Working Group will be compiling additional information and undertaking analysis to explore: (1) the likelihood that a broader range of log grades than estimated for the base case will contribute monumentals; (2) indications that younger ages classes than assumed for the base case will contain monumental cedar; (3) timber supply implications of various levels of retention of monumental trees from harvesting. Given the recent release of the new standards, these analyses are ongoing. The results will be available for the HGMC for its determination of the Haida Gwaii AAC.

8.2.4 Stad's Kun (northern goshawk) foraging habitat

Stad's Kun or the northern goshawk (laingi subspecies) has been designated as the national bird of Haida Gwaii by the Haida Nation.

Stad's Kun or northern goshawk nesting habitat is protected under the HGLUOO (see section 6.10.12) and subsequently accounted for by the removal of areas from the THLB.

The Council of the Haida Nation, the Federal government and the Provincial governments have all adopted policies or the pursuit of policies that support the recovery of this species. The following briefly outlines these policies.

Policy Considerations
A 2017 House of Assembly resolution (2017-08) mandated the Council of the Haida Nation to develop an "Island-based recovery strategy that includes population monitoring, inventories of potential habitat, habitat recruitment and restoration, introduced species mitigation, and proper foraging habitat management."

The Provincial Government published a recovery strategy in 2008 (Ministry of Environment, 2008) with a strategic action goal of identifying critical habitat using habitat and territory models, although was lacking sufficient information at the time to define critical habitat. A Habitat Recovery Implementation Group (RIG) was established as an action of the recovery strategy to help map, model and define critical breeding and foraging habitat.

The Federal Government designated the species as Threatened under the Federal Species at Risk Act in 2013 and in December 2018 published a Recovery Strategy that incorporated the work from the Recovery Implementation Group (Parks Canada Agency, 2018). The federal recovery strategy provides targets for nesting and foraging habitat. Targets use habitat suitability indices for defining critical habitats (discussed in detail below). Critical breeding area list known breeding territories, but also proposes protection of additional breeding areas (e.g., known and currently unidentified territories) in response to the birds genetic isolation (Sonsthagen, et al., 2012), concluding that 38 breeding pairs are necessary to contribute to a minimum viable population to reduce the risk of extinction from the effects of inbreeding depression on demography (Parks Canada Agency, 2018).

In February 2018, the Provincial government published an *Implementation Plan for the Recovery of Northern Goshawk, laingi Subspecies (Accipiter gentilis laingi) in British Columbia* (MFLNRORD, 2018). The implementation plan sets clear targets for the protection of breeding habitat in Coastal British Columbia, including a target of 25 nesting areas protected on Haida Gwaii. While acknowledging the importance of foraging habitat the implementation plan does not provide immediate direction for foraging habitat management, citing the need for continued research.

A recent publication *Science-Based Guidelines for Management Northern Goshawk Breeding Areas* (McClaren, Mahon, F.Doyle, & W.Harrower, 2015) concluded that territories with 60% suitable foraging habitat have the lowest risk of abandonment based on analysis of territory abandonment from data on Haida Gwaii and Vancouver Island. This conclusion was supported by a territory analysis conducted in 2010 that looked at the correlation between active nests and the proportion of suitable habitat by known territories on Haida Gwaii and Vancouver Island (Daust, et al., 2010). Since then a new peer-reviewed article has been published that cites the Haida Gwaii Goshawk as a genetically distinct population apart from the coastal goshawk subspecies (*Accipiter gentilis laingi*) and one of the most endangered organisms on the planet (Geraldes, et al., 2019).

8.2.4.1 Nesting habitat

For the base case reference scenario, known nesting reserves were netdown from the THLB (as of 2019 currently there are 23 territories/breeding areas- but several of them are in protected areas).
To account for the recurring annual netdowns from newly discovered Goshawk nesting territories, predicted nest sites were based upon a predictive territory model. The predictive model started with a mean center statistical analysis to identify the centre of known nesting territories. From known centres, geometric expansion buffers were calculated using 5200m radius territory sizes (10,400m between territory centres, or 8,495 hectares per territory) based on the 2018 Federal Recovery Strategy (Government of Canada, 2017) to identify predicted territories. Predicted territories are all based on future capability (mature/old forest). The 2003 Land Use Plan analysis (Holt R. , 2003) spacings were used to further guide territory placement (see figure 8.2.6.1).

As a sensitivity analysis included nesting reserve netdowns from an additional 2 predicted territories (to match the provincial implementation target of 25), 15 territories (to match the Federal recovery strategy of 38) and a third sensitivity that includes all capable breeding areas/territories (e.g. up to 67 as per Provincial estimates when assuming territory occupancy rates are contingent on ≥40% of a territory made up of suitable foraging habitat). The predicted nesting reserves were based on the updated provincial nest habitat model applied to predicted territories. The centroid of these territory polygons represented a systematic random nest location which was used to identify 200 ha of the most suitable contiguous habitat using the updated Provincial nest habitat model data and a 'roving window' functionality in SELES.

The predicted territories included in the modelling (ex. additional 2 or 15 territories etc.) were chosen from a priority listing of the territories with the most amount suitable habitat first (assuming territories with more suitable habitat have an increased likelihood of occupancy). The updated provincial goshawk foraging (suitability) model (2017) was used to calculate the priority listing of territories with the most to least amounts of suitable habitat.

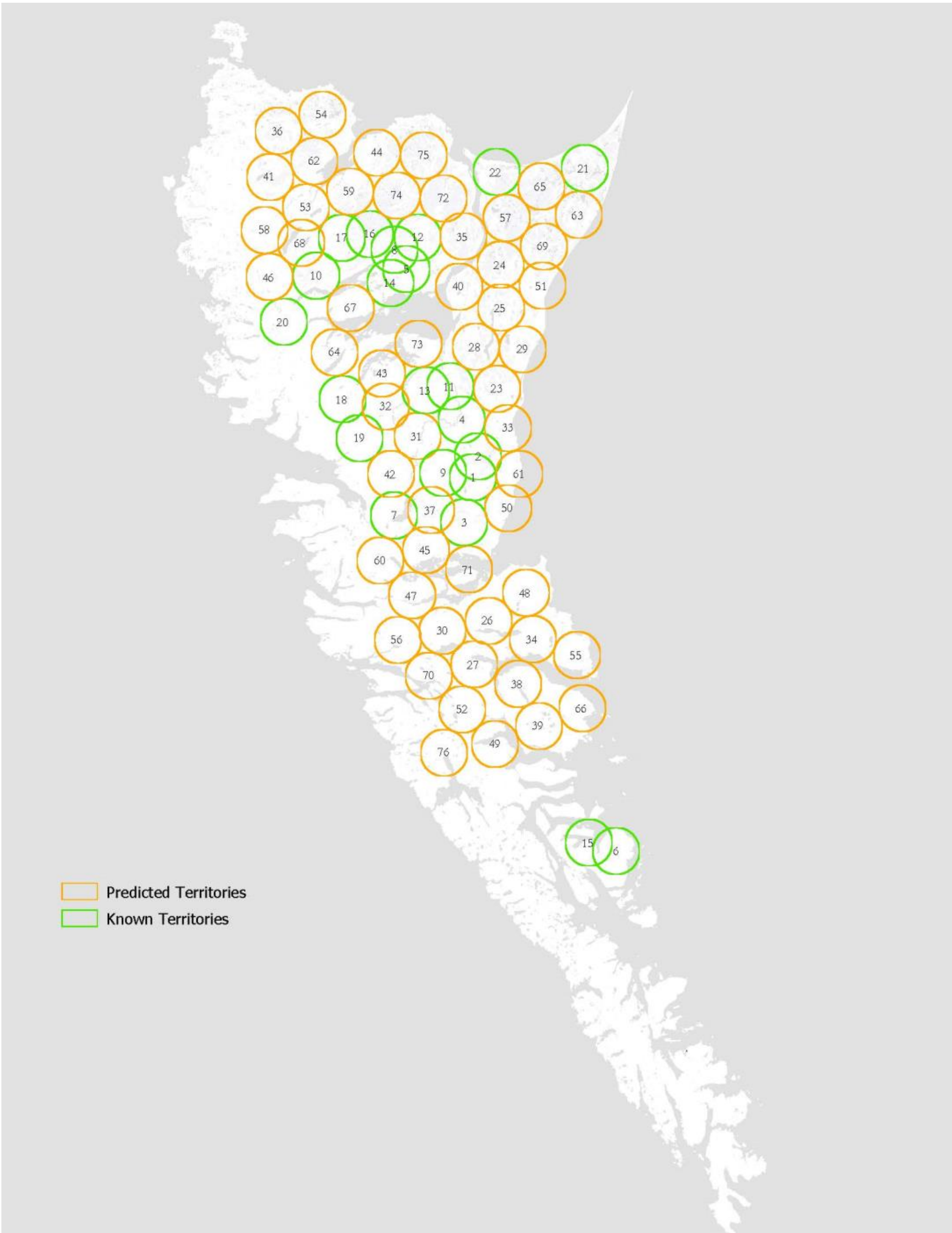


Figure 8.2.4.1 Known and predicted breeding areas/territories for Northern Goshawk, with territories ranked based on amount of suitable habitat in each territory.

8.2.4.2 Foraging habitat

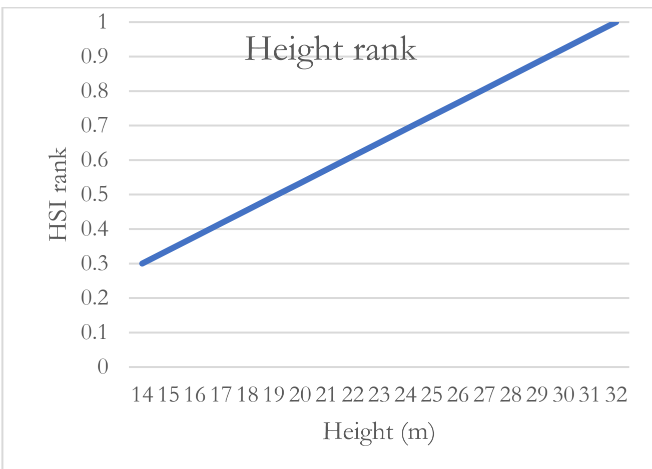
The objective of a goshawk foraging sensitivity analysis was to determine the effects on timber supply using a foraging capability model and current science-based habitat thresholds (McClaren, Mahon, F.Doyle, & W.Harrower, 2015; Daust, et al., 2010; Parks Canada Agency, 2018).

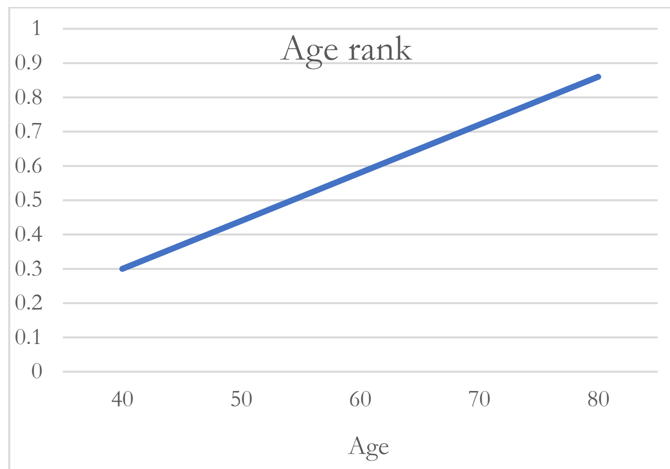
While the initial habitat threshold models used 'backcasting' to determine the territory capability, suitability habitat modelling is applied to a 'current state' to determine habitat availability. Suitability models are less useful for forecasting, as they underestimate future sites that are capable of supporting goshawk foraging (through regeneration etc.). Given the objective of TSR to forecast up to 400 years, a capability model was developed (parameters described below).

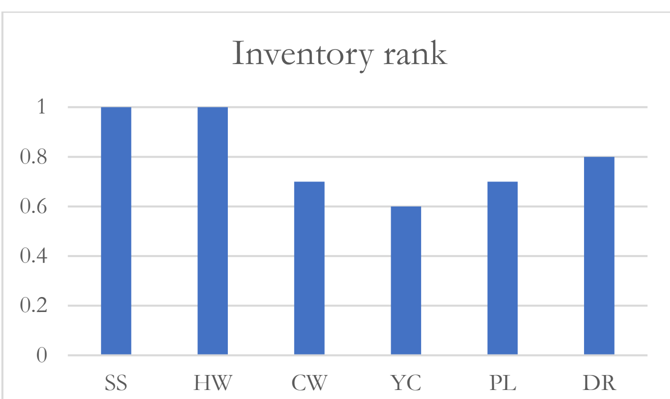
Habitat suitability index (HSI) criteria and rankings were used based upon the *Nesting and Foraging Habitat Suitability Models and Territory Analysis Model* (Mahon, McClaren, & Doyle, 2015). The HSI uses non-compensatory parameters to determine suitability on a polygon level. Each parameter was given a value or rank and the results were binned into a four-class rating scheme of nil, low, moderate and high suitability. Only polygons with an HSI of >=0.5 (moderate to high) were counted towards habitat thresholds (as per (Mahon, McClaren, & Doyle, 2015; Parks Canada Agency, 2018)).

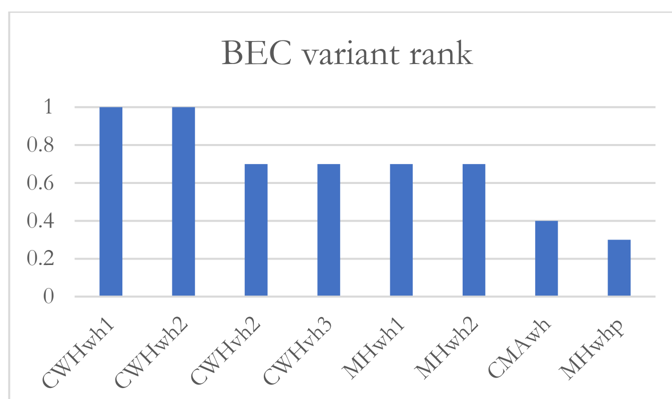
The equation used to calculate suitability ratings was:
HSI_f= mean(Age, Height) * Inventory Type Group * BEC variant **or** non-forest rating (whichever is greater).

The following graphs summarize the parameter rankings for each input:









All roads (20m buffer on mainlines/highway, 10m buffer otherwise) and lakes were given a non-productive value of 0 and wetlands were given a non-productive value of 0.3.

Methods and data inputs:

- Previous territory boundary estimates (primarily from the mid 2000s for Land Use Planning) did not account for updated known territories or minor changes in estimates of nest spacing. Therefore, for capability modelling, the boundaries of territories were determined using a 10.4 km territory radius (Mahon, McClaren, & Doyle, 2015). Radii were applied to all known goshawk territories (22 at the time of analysis[60], see figure 8.2.6.1).
- Inventory inputs (to determine height, age and leading species for the HSI) were based upon the current TSR datasets:
  - VRI for all stands >120 years (mature stands with no history of commercial logging);
  - For stands <120 years, silviculture survey RESULTS-based existing managed stand curves were used to backcast stands values at curve age 350 (e.g., stand height, age and species attributes for existing managed stands were used);
  - For stands <120 years where no silviculture survey is not available, future managed stand curves were used to backcast stands values at curve age 350 (e.g., stand height, age and species attributes for future managed stands were used);

The resulting spatial output represents a pre-industrial condition capability model of moderate to highly suitable habitat by territory. For the purpose reserving habitat, suitable habitat was binarily re-classified (e.g., suitability equals yes or no, as opposed to highly suitable, moderately suitable and not suitable).

The spatial timber supply model was constrained to maintain 65.5%, or 5,564 ha, of each territory as suitable habitat to maintain the lowest risk of territorial abandonment (Mahon, McClaren, & Doyle, 2015) and reflect the current Federal Recovery Strategy.

For territories where there was not enough suitable habitat to meet the 5,564 ha habitat target, the Spatial Timber Supply Model applied the constraints using a recruitment technique. The age at which each analysis unit (natural and managed) met the HSI requirement of >=0.5 was calculated and output as an index layer. This layer represents, for each cell, the youngest age that the cell is suitable (meets the 0.5 HSI requirement). Analysis units were therefore prioritized by units that met the minimum HSI requirements soonest and those were reserved to contribute to meeting the 5,564 ha area targets per territory. This way harvesting could happen in a territory if the appropriate amount of habitat had been reserved by the model and represents meeting a threshold while accounting for spatial variability of sites. Otherwise, if <5,564 ha of habitat was available then the recruitment strategy reserved those areas that meet the minimum HSI requirements soonest (generally oldest first).

Similar to the nesting reserve analysis, the foraging model analysis was completed on existing territories (22), and on 25, 38 and ~67 territories to provide bookend results. The sensitivity analysis that assumes 67 territories assumes territory occupancy rates are contingent on ≥40% of a territory made up of suitable foraging habitat.

8.2.5 Economic operability

Six sensitivity analyses were completed in relation to economic operability:
(i) removing road operability constraints; (ii) assuming a low/weak market values, and; (iii) assuming high market values, (iv) constraining new roads from being built; v) partitioning or excluding isolated planning units; (vi) not restricting isolated planning units.

8.2.5.1 Removing road operability constraints

This scenario does not use the economic operability model, and associated constraints, that were described in section 7.6. Therefore this run is more in line with a biophysical estimate of what the long run sustained yield

[60] Note that one subsequent territory was found after this analysis in 2019 in Gwaii Haanas.

could be based on growing stock, without any limitations on relative costs or relative values in the forest. This scenario was completed to explore how sensitive the model was to the economic operability constraints applied in the base case.

8.2.5.2 Dynamic stand values ('Low' and 'High' market scenarios)

The economic operability sensitivity analyses used the relative net value model described in section 7.6.2. The base case used the average relative value for each species across a 10-year time horizon. The relative values/m^3 by species group were used to compute total relative stand values by multiplying these relative values by volume proportional to the percent of each species in the stand.

The 10-year sample (2008-2017) spanned some of the lowest and highest historical market prices for the industry, therefore helping to justify an assumed average market for the base case. Two sensitivity analyses explored assigning stands with the (i) lowest market value, and (ii) the highest market value. While neither scenario is realistic, it provides insight into how well the model is performing relative to macroeconomic principles (e.g., market demand implications to net marginal values), but also provides bookends for anticipated timber supply implications from weak or strong markets.

The relative values used in the 'low market' and 'high market' scenarios are listed in table 8.2.5, and derived from market commodity indices for all species, accounting for domestic and export values from Haida Gwaii between 2008-2017. Details on how the numbers are derived are described in section 7.5.2.

Table 8.2.5. Relative value/unit for each value class for Cedar, Hemlock and Spruce Year

	Cedar	Hemlock	Spruce	All
Low	3.5	1.2	1.2	2.0
High	6.3	2.1	2.0	3.5
Average (base case)	4.7	1.7	1.6	2.7

8.2.5.3 No new roads permitted to be built

This scenario is primarily devised to test the effects of future road building and the development of previously unlogged areas on timber supply. The model parameters only allow access to harvesting from the current road network.

8.2.5.4 Exclusion of isolated planning unit

Section 7.5.4 details how isolated planning units (Sewell-Moresby south, Peel- Moresby north, and Louise Islands) have minimum volume requirements before the timber supply model can access/harvest these areas in order to reflect operational viability. Once these criteria are met (e.g. 333,000m^3 of available volume over a 10-year period for Sewell/Peel, and 250,000m^3 over the same period for Louise Island) then these areas contribute to the overall volumes of their respective management units.

This sensitivity analysis partitions, or excludes the volumes from these isolated planning units, effectively taking them out of the THLB in order to determine what their contribution is to the broader planning unit.

8.2.5.5 No restriction on isolated planning unit

This sensitivity removes all constraints or model restrictions imposed upon the isolated planning units (Sewell-Moresby south, Peel- Moresby north, and Louise Islands) in order to explore a hypothetical situation that these planning units had an unbiased contribution to their respective management unit.

8.2.5.6 High Cost Access Exclusion

The base case reference scenario uses the road cost model outlined in section 7.6, whereby a relative cost surface model, accounting for physiographic factors like slope, wetlands and distance to sorts, directs a least-cost decision sequence for the building of future roads. Most of the THLB (95.8%) has an access cost of <=10% of the maximum access cost in the THLB. In other words, 4.2% of the THLB has an access cost between 10% and 100% of the maximum cost for the THLB. These areas, characterized by steep slopes or isolated timber, typically have never had road or development access, and may represent a continual future challenge to access (see figure 8.2.5.6).

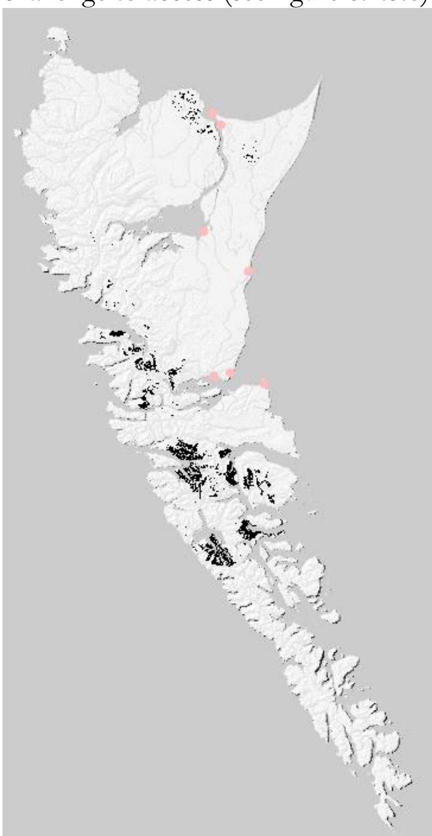


Figure8.2.5.6. Modelled high access cost areas

A sensitivity analysis was completed where these areas were removed from the THLB.

8.2.6 Minimum Harvest Criteria

Stand age is typically used to determine minimum harvest criteria for timber supply analyses (see section 7.1) however in reality other factors contribute towards harvest entry decisions.

While the timber supply base case has age preferences set to meet culmination mean annual increment, often times stands are harvested more on an *economic rotation* age (typically much younger than CMAI). Similarly, there has been interest in evaluating an *extended rotation* scenario, whereby wood quality is a condition for logging as opposed to volume.

For the base case or reference scenario, the minimum harvest age was set to 95% of Culmination Mean Annual Increment (CMAI). The weighted area CMAI age within the THLB for future managed stands is 98 years. For existing managed stands, the weighted area CMAI age within the THLB is approximately 101 years.

8.2.6.1 Economic rotation age

Stands are often logged based upon economic opportunism, rather than a biological optimum criterion. Species composition, timber accessibility, mean log diameter and stand volume are common variables that forest managers use to determine whether to log a second growth stand. Many of these variables are already accounted for in the timber supply model: the model already factors in access into the harvest queue (regardless of stand age), and; minimum harvest volume is also an existing parameter in the model (see section 7).

Over the last 10 years, the average age of 2nd growth stand harvested on Haida Gwaii has been approximately 60 years old. However a single age model parameter is not ideal as every stand and site type reaches a volume or log diameter at different ages. In addition, higher productivity sites (valley bottoms) were commonly logged first, and these higher productivity sites (leading to harvest criteria being met earlier) may not be representative of all second growth sites on Haida Gwaii.

Timber supply considerations

Existing and future managed stand curves were analyzed to determine the age where minimum log diameter of 30cm was reached.

Not all analysis units reach this diameter threshold before Culmination Mean Annual Increment (CMAI), which presupposes that not all stands are capable of being targeted for an economic rotation. Generally this diameter threshold is only met before CMAI for richer sites therefore a standard decrease in minimum harvest age does not make sense.

Table 8.2.6.1 Age where minimum log diameter targets are met (TIPSY) for forested site series on Haida Gwaii. Grey rows indicate ages below CMAI.

Site Series	Age 30cm dia is met	CMAI age	% Difference
CWHwh1 01	80	80	0%
CWHwh1 02	80	90	11%
CWHwh1 03	70	70	0%
CWHwh1 04	110	100	-10%
CWHwh1 05	50	70	29%
CWHwh1 06	60	90	33%
CWHwh1 10	n/a (does not reach 30cm)	130	n/a
CWHwh2 01	90	110	18%
CWHwh2 02	150	120	-25%
CWHwh2 03	90	100	10%
CWHwh2 04	110	120	8%
CWHwh2 05	260	180	-44%
CWHwh2 06	230	140	-64%
CWHvh2 01	100	110	9%
CWHvh2 03	140	130	-8%
CWHvh2 04	70	70	0%
CWHvh2 05	50	80	38%
CWHvh2 06	50	80	38%
CWHvh2 07	50	90	44%
CWHvh2 11	190	160	-19%
MHwh 01	140	180	22%
MHwh 02	170	170	0%
MHwh 03	230	170	-35%
MHwh 04	160	170	6%
MHwh 05	260	170	-53%
MHwh 06	220	170	-29%
MHwh 07	260	170	-53%
MHwh 09	220	170	-29%

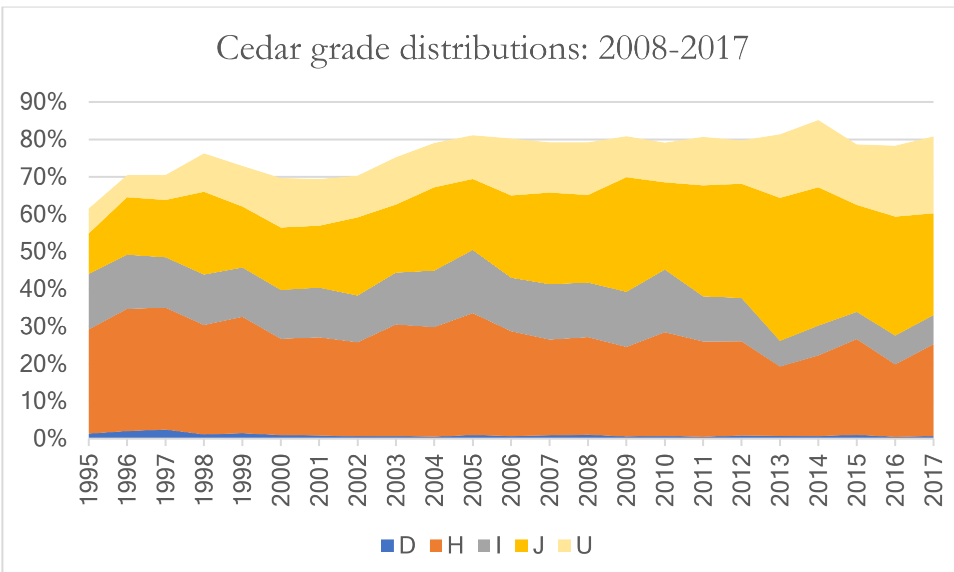
For a timber supply sensitivity analysis within the existing managed and future managed stands, the minimum harvest age was lowered for each analysis unit that met the minimum diameter target before CMAI, otherwise the MHA was kept at CMAI (as per base case).
For this sensitivity analysis, the weighted average minimum harvest age of future managed stands within the THLB was 94 years, and for existing managed stands within the THLB was 77 years. The likely reason for this difference in ages is that existing managed stands include a higher proportion of richer sites (e.g. biased or preferred harvest sites) which therefore reach the minimum diameter at a younger age.

8.2.6.2 Extended rotation age

An extended rotation age can better represent the natural forest age distribution on Haida Gwaii, but also may be a management consideration to increase log qualities, increase carbon sequestration and improve the availability of habitat for late seral dependent wildlife.

Historic harvests provide an empirical basis to define merchantability, and the 2012 Timber Supply Review introduced a product-based assessment approach that references actual grades harvested over the last timber supply period (decade), using this grade distribution to review predictions from TIPSY model outputs. This approach allows for the comparison between the assumed minimum harvest age (e.g., 95% culmination mean annual increment) to the age reached when the target grade distribution is met.

While historic grade distributions do largely represent products from old forest, it provides an empirical benchmark for the marketability of timber. Therefore establishing a grade distribution target that is largely based on old forest provides a reasonable benchmark for setting an extended rotation age target. Log grade distributions from Harvest Billings System were used to generate the following charts.

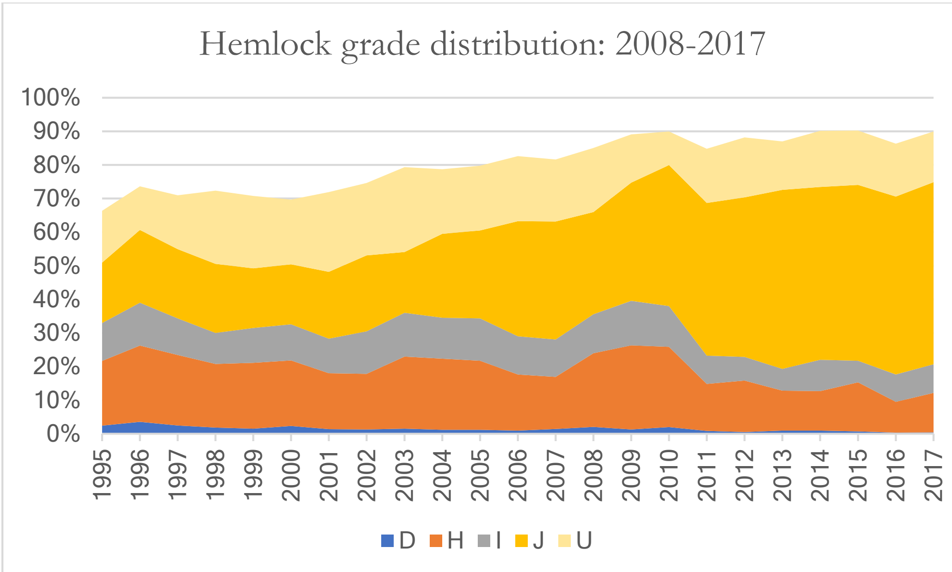


Average decadal distributions

	2008-2017	1998-2007
D	1%	1%
H	24%	28%
I	11%	14%
J	30%	20%
U	15%	12%

Figure 8.2.6.2.1 Cedar log grade distributions 2008-2017

Source: Harvest Billing System
D: High grade/custom cut/peeler; H: Merch/custom cut; I: Merch/standard; J: Shingle/gang/sawlog U: Utility sawlog

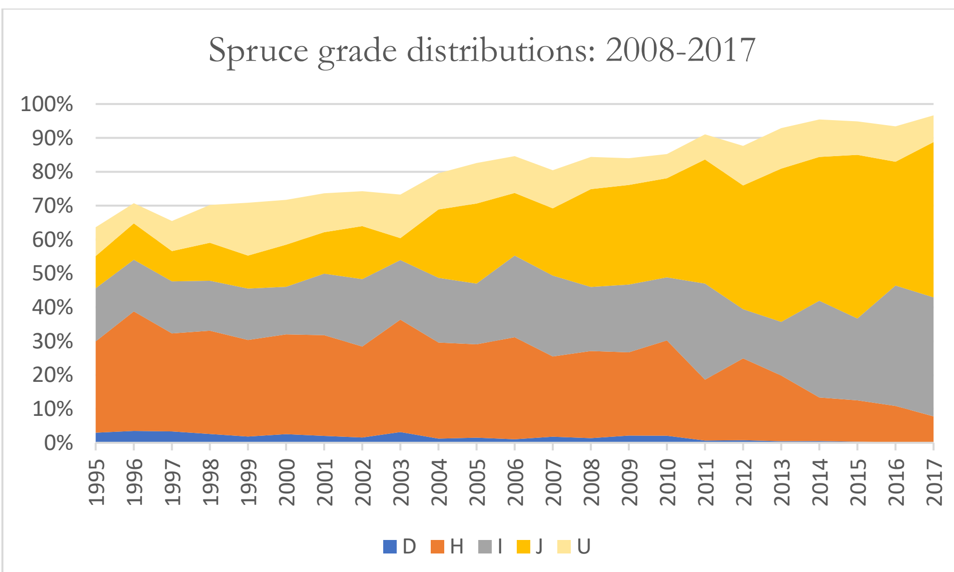


Average decadal distributions

	2008-2017	1998-2007
D	1%	1%
H	16%	19%
I	9%	11%
J	46%	24%
U	16%	21%

Figure 8.2.6.2.2 Hemlock log grade distributions 2008-2017

Source: Harvest Billing System
D: High grade/custom cut/peeler; H: Merch/custom cut; I: Merch/standard; J: Shingle/gang/sawlog U: Utility sawlog



Average decadal distributions

	2008 -2017	1999 - 2007
D	1%	2%
H	18%	29%
I	24%	18%
J	38%	15%
U	9%	12%

Figure 8.2.6.2.3. Spruce log grade distributions 2008-2017

Linking these broad aggregations of log grade distributions to actual inventory stands is not feasible, given the high variability in site types, species composition and block blending by timbermark (the common variable within HBS). Timber supply is not meant to estimate the actual harvest age of each inventory stand, but to explore the implications of minimum harvest criteria applied to average stand conditions. In addition, not all individual stands can produce the aggregate grade distribution target (e.g., poor stands will never yield a significant proportion of high grade logs). Therefore, in order to approximate actual grade distributions with TIPSY, analysis units were grouped into leading species strata.

While 'J' grade is the most common quality log harvested, it may be a poor extended rotation indicator as stands can produce this lower log grade at younger ages. 'H' grade, the highest grade predicted as an output of TIPSY, takes the longest for a stand to achieve and therefore is a limiting factor worth using as a target indicator for exploring extended rotation ages.
The objective of the analysis was to determine *what age are future inventory stands predicted to have a log grade distribution that approximates the actual Haida Gwaii log grade distribution?*
The follow steps were completed:

- The grade distribution target from 2008-2017 was calculated for each species strata, and also aggregated (all species, as reported above).

Table 8.2.6.2.4 Actual log grade distribution on Haida Gwaii from 2008-2017. Source: Harvest Billings System

Grade	**Hemlock**	**Cedar**	**Spruce**	**Pine**	**Combined**
D	1%	1%	1%	0%	1%
H	16%	24%	18%	10%	19%
I	9%	11%	24%	2%	13%
J	46%	30%	38%	1%	38%
U	16%	15%	9%	78%	14%

- The TIPSY predicted log grade distribution (for grades 'H', 'I', 'J') was referenced for each analysis unit/site unit curve at a specific age (year 120, 150, 200, 300);

- The percent contribution of each analysis unit to the THLB was spatially calculated;

- For each analysis unit, the area-weighted average of the grade distribution was calculated for both leading species strata and combined (all species).

This provides the TIPSY-predicted ages when strata approximate target grade distributions within the THLB at select ages for both different strata (Cw, Hw, Ss leading units) and combined analysis units (all species blended) (see figure 8.2.6.2.4).

Extended rotation analysis results

The results show that the grade distribution targets for cedar strata cannot be met at any harvest age. This is likely because second growth cedar leading strata tend to be poor growing sites. In reality, higher quality cedar will come from those analysis units (such as zonal or richer) that are represented by the second growth spruce or hemlock leading strata. As a result, trying to achieve empirical log grade distribution by second growth leading species strata would not be possible. Therefore, using a combined (aggregation of all species) grade distribution target, meant that overall predicted log grades approximate the empirical log grade distribution by age 150.

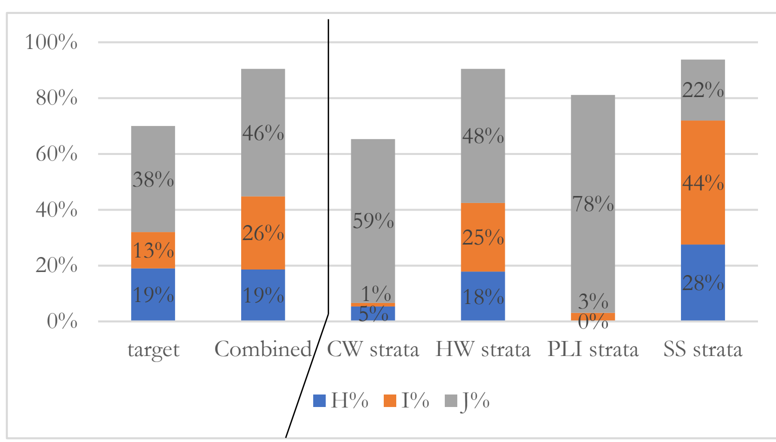


Figure 8.2.6.2.4 Distribution of predicted (TIPSY) log grades and target (HBS 2008-2018 average) log grades, by strata and combined (all species) at curve age 150.

Using this combined grade distribution target may initially underestimate a target for higher grade cedar (currently 'H' grade makes up 24% of the log profiles), however there is a clear decline in higher quality grades over time (see figure 8.2.8.2.1). When averaged across all species, the 150 year target would achieve a TIPSY future managed stand predicted distribution of 19% of 'H' grade logs and 26% distribution of 'I' grade logs for existing managed stands.

Timber supply considerations
All existing and future managed stand had a minimum harvest age constraint set to 150 years or maintained the CMAI age if it was over 150. While some units have a minimum harvest age above 150, the weighted average MHA for the THLB was 150.4.

8.2.6.3 No minimum harvest volumes
As described in section 7.1.2, the base case reference scenario removes all areas that do not have, or will not have, a minimum volume of 250m^3 per hectare (areas removed from the THLB). A sensitivity scenario was applied where the minimum harvest volume constraint was removed, allowing the model to harvest low productive forest (e.g.<250m^3/ha).

8.2.6.4 No minimum harvest age constraint
As referenced in section 7.1.1, the base case sets a minimum harvest age as the age where 95% of the Culmination Mean Annual Increment volume is achieved. This scenario explores an option where there are no constraints related to minimum harvest age but maintains the base case minimum harvest volume constraints of 250m^3 per hectare.

8.2.6.5 Minimum harvest volume increase
As discussed in section 7.1.2, past timber supply reviews have defined low volume stands as 350m^3 per hectare. This volume threshold also aligned with an analysis of volumes harvested over a recent 10-year period where 95% of the inventory volume from all second growth openings amounted to 350m^3 per hectare. Therefore, this scenario applies a minimum harvest volume of 350 m3/ha for existing managed and future stands while maintaining a minimum harvest age (95% of culmination age).

8.2.6.6 No old growth logging
At different times throughout BC there has been public discourse on the benefits and shortcomings of logging old growth forest. While no specific policy from the CHN or the Province has mandated this dialogue for Haida Gwaii, the HGMC was interested in a scenario that restricts the model from harvesting stands over 250 years old (old growth) forest to better understand the contribution old growth forest to timber supply.

8.2.7 Harvest preference
As detailed in section 7.1.3, harvest preferences are model parameters that help the model decide on the chronological sequence of harvest over time. The base case reference scenario is guided by logging the highest value relative to CMAI. Three sensitivity scenarios were explored:

(i) Preference to log stands with the highest volume relative to CMAI;
(ii) Preference to log stands that are oldest first relative to CMAI;
(iii) Randomized order: no age, volume or value preference (as long as other minimum harvest criteria are met)

8.2.8 Alternate Timber Harvesting Land Base scenarios

8.2.8.1 Risk-managed Land Use Objectives

The Haida Gwaii Land Use Objectives Order and the Haida Gwaii Strategic Land Use Agreement established 'default' and 'risk-managed' provisions for managing different values (HGMC, 2019). The majority of objectives have risk-managed provisions that allow for alternative management practices to be employed, generally offering greater operational flexibility while meeting key criteria for safeguarding or mitigating impacts on a particular value. All risk-managed applications are submitted to and tracked at the Solutions Table ahead of decisions from the CHN and Province of BC.

Data from 6 years of Solutions Table submissions was compiled and reviewed in order to determine the level of risk-managed applications and the associated implication (assumed upward pressure) on Timber Supply. Table 8.2.8.1 summarizes the objectives where risk-managed strategies were applied:

Table 8.2.8.1 HGLUOO risk managed applications submitted to the Solutions Table and implemented (2013-2018)

Objective	Description
Removal of monumental cedar >120cm (HGLUOO section 9.4)	8 monumental removed (reserve and management zones) 4 management zones reduced
Reduction of cultural cedar stand management zones (HGLUOO section 9.7/ 9.8)	2 cultural cedar stand management areas reduced
Haida Traditional Forest Feature reserve reduction (HGLUOO section 6.5)	3 management areas of class 1 Haida Traditional Forest Features were reduced
Haida Traditional Heritage Feature reserve reduction (HGLUOO section 5.6)	4 management areas were reduced
Forest reserve reduction or amended (HGLUOO section 23.2/23.3)	39 hectares of forest reserve were amended (moved to other areas- no increase in THLB)
Cedar Stewardship Areas (HGLUOO section 3.2)	3 hectares of CSA were harvested. 1 area reduced to accommodate road building.

Timber Supply implications
Table 8.2.8.1 represents risk-managed applications that were implemented between 2013-2018, however do not represent the suite of risk-managed opportunities afforded under the HGLUOO. However, in line with timber supply representing current management practices, the results of 6 years of operations amount to approximately 20 hectares of additional THLB available through the risk managed provisions (~3 hectares per year). Given that this is such a small annual increase in THLB (+0.002%) this provision was not modelled, but results reported to the HGMC as a factor consideration in their AAC determination.

8.2.8.2 Wildlife Tree Retention Areas (WTRA)

Some licensees have been retaining area in excess of FPPR requirements in the TSA and TFL 60 (see section 6.5.1 above). A sensitivity analysis was performed in which additional THLB exclusions are applied to account for the current practice for WTRA designs: 7.1% in the TSA and 11.3% in TFL 60.

Table 8.2.8.2. In-block retention netdowns by management unit.

		Base case		Sensitivity	
		LUOO retention	in-block THLB inclusion factor	additional WTRA retention	in-block THLB inclusion factor
TFL 60/FLTC	Old growth	10.89%	0.8911	11.6%	0.7751
	2nd growth	6.1%	0.93	11.6%	0.823
TSA	Old growth	10.89%	0.8911	7.1%	0.8201
	2nd growth	6.1%	0.93	7.1%	0.868
TFL 58	Old growth	10.89%	0.8911	-	-
	2nd growth	6.1%	0.93	-	-

8.2.8.3 Roads

The base case reference scenario excludes all permanent, mainline and branch roads from the THLB. Concern was expressed from a licensees that abandoned branch roads do support trees and forest cover. While this contested by data from several second growth developments (that did not support merchantable trees), a sensitivity analysis explored how timber supply is affected by regenerating roads. Note that while roads are de-commissioned on Haida Gwaii, they are not re-habilitated (e.g. not re-contoured).

Input was sought from provincial soil scientists[61] regarding natural ingress and stocking on roads. Opinions aligned with the experience from the HG Natural Resource District and CHN Foresters that:

- Red alder is typical ingress species for abandoned secondary roads (branches);
- Road prisms tend to have less productive soil versus adjacent forest stands;
- Regeneration is delayed compared to adjacent openings;

Therefore, an analysis unit was designed in TIPSY with the following criteria for branch roads:

- 100% red alder composition;
- Natural regeneration @ 4,444 stems per hectare (TASS default for natural regeneration, amounting to 1.5m spacing)
- 4 year regeneration delay
- Site index of 21 (20% less productivity then the TIPSY average site index for alder sites on Haida Gwaii).

This results in a Culmination Mean Annual Increment for this analysis unit of 6.7m^3 at year 30.

8.2.8.4 Terrain stability

Section 6.8 details the methods for excluding areas of unstable terrain from the THLB. This was done using a preference ratio that determines the frequency of development on unstable terrain based on a sample of blocks from the last 10 years. A sensitivity analysis was proposed to determine the frequency of development on unstable terrain based on a sample of blocks since 1996 (after the Forest Practices Code took effect).

[61] M.Kranabetter, R.Kabzems (Ministry of Forests, Lands, Natural Resource Operations and Rural Development).

While the base case reference scenario calculated the ratio of unstable terrain within the THLB (which is relatively unchanged in the last 10 years), the current THLB cannot be used when extending the logged area sample back to 1996. In this case the Forest Managed Land Base (FMLB), or simply the forested area within the jurisdiction of the management units, was used in the preference ratio calculation.

The following tables document the area logged by management unit since 1996. The THLB inclusion factor used for this sensitivity represents more frequent access to unstable terrain as these areas were historically harvested more frequently than current practice.

Table 8.2.8.4.1. Inputs into the terrain stability exclusion calculation or preference ratio for TFL 60

	Total area (ha)	Proportion of FMLB	Area logged in since 1996 (ha)	% that was logged	THLB inclusion factor
Class 4 terrain in FMLB	9,565	8%	618	6%	0.74
Class 5 terrain in FMLB	10,928	9%	415	4%	0.443
FMLB	127, 484		11,082		

Table 8.2.8.4.2 Inputs into the terrain stability exclusion calculation or preference ratio for TSA

	Total area (ha)	Proportion of FMLB	Area logged in since 1996 (ha)	% that was logged	THLB inclusion factor
Class 4 terrain in FMLB	22,847	8%	1,257	6%	0.76
Class 5 terrain in FMLB	26,225	9%	434	2%	0.23
FMLB	291,559		21,029		

Table 8.2.8.4.3. Inputs into the terrain stability exclusion calculation or preference ratio for TFL 58

	Total area (ha)	Proportion of FMLB	Area logged in since 1996 (ha)	% that was logged	THLB inclusion factor
Class 4 terrain in FMLB	2,543	11%	201	8%	0.76
Class 5 terrain in FMLB	2,307	10%	119	5%	0.50
FMLB	23,397		2,433		

8.2.9 Forest cover constraints
Forest cover constraints are conditions within a specific area associated with a management objective that must be met prior to the model harvesting in that area.

8.2.9.1 No constraints applied
A sensitivity scenario was explored the overall timber supply implications of forest cover constraints. This scenario is primarily to test to see how the model interacts with these constraints in part to verify that the model is performing as intended. In this case the forest cover cosntraints for watersheds (Community Watersheds, Sensitive Watersheds and Upland Stream Areas), Wildlife Habitat Areas, Marbled Murrelet habitat targets and visuals quality objectives were disabled.

8.2.9.2 Wetlands not considered "recovered forests"

Section 6.10.6 above describes the constraints applied to meet the Upland Stream Area objectives of the HG LUOO. For this objective, which requires 70% of the forests in upland stream areas to be hydrologically recovered, the model used the entire watershed (forested and non-forested) as the denominator since the entire drainage basin forms the hydrological response to water inputs (Church & Eaton, 2001). Concern has been raised that the intent of this objective was to exclude non-forest (e.g. wetlands) from this calculation. This may affect timber supply in those low-relief areas within the TSA that are made up of bogs and mature cedar-leading stands. The effect of non-forest (alpine, parkland, wetlands) is being studied on the central coast's Kwakshua Channel watersheds on Calvert Island (https://www.viu-hydromet-wx.ca/watershed-monitoring/kwakshua-watersheds-program/), and is expected to contribute to our understanding of the role of coastal wetland bogs on regulating peak flows.

To help scope the affect that this uncertainty may have in timber supply a sensitivity scenario was designed where the denominator excludes wetlands in upland stream areas. This therefore set a constraint to ensure 70% of forested areas outside of Type I and Type II Fish Habitat buffers were hydrologically recovered within each of the Schedule 6 Upland Stream Area sub-basins.

8.2.10 Harvest flow

The base case reference scenario follows a non-declining flow, or even flow, principle (the long run sustained yield average of all species combined). This sensitivity allows short-term harvest level to increase such that steps to reach mid-term level cannot be more than 10% per decade.

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