UNCERTAINTIES OF TIMBER SUPPLY ESTIMATES USED FOR ALLOWABLE ANNUAL CUT DETERMINATIONS

A Professional Report
Prepared for
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By

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INTRODUCTION

The chief forester is an independent statutory decision maker, who must make the allowable annual cut (AAC) determinations for Crown forest land in British Columbia based on[1,2]:

- A wide range of environmental, social, and economic factors as specified in Section 8 of the *Forest Act*;
- The mandate of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) as set out in Section 4 of the Ministry of Forests and Range Act; and,
- Responsibilities under the *Forest Act*, *Forest and Range Practices Act* (FRPA), and *Foresters Act.*

Ultimately, the chief forester makes what is defined as an "independent professional judgment" for the AAC determination.

To add consistency to the approach of addressing relevant factors associated with AAC determinations, the chief forester has adopted a body of three guiding principles:

1. Consideration of information related to integrated decision making, cumulative effects and climate change.
2. Response to uncertainties.
3. Incorporation of information related to First Nations' rights, titles, and interests.

This report will not deal with First Nations' rights, titles, and interests, but with respect to the other two guiding principles, we assert that the chief forester:

- Is restricted by existing legislation and a lack of statutory authority to effectively implement integrated decision making that includes cumulative effects.
- Uses the concept of uncertainty to exclude factors that would lower the AAC, such as climate change, while at the same time ignoring the uncertainty associated with factors that enable an increase or simply increase the AAC, such as natural and managed stand growth estimates, genetic gain estimates for select seed and the increased productivity assigned to managed stands.
- Introduces avoidable uncertainty into the AAC determination through inadequate forest inventory and monitoring sampling, ineffective data management and invalid statistical analyses of inventory and monitoring data.

[1] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/sustainable-forest-management-practices

[2] Lakes Timber Supply Area – Rationale for Allowable Annual Cut (AAC) Determination – 2019

The net result is an AAC that is set too high and is unsustainable, particularly in the mid-term.

INTEGRATED DECISION MAKING, CUMULATIVE EFFECTS AND CLIMATE CHANGE

Integrated decision making is planning the use of forest and range resources such that the various natural resource values are coordinated and integrated.

Resource value objectives are defined by government under three tiers[3]:

- Tier 1 land use objectives (higher-order plan objectives) are defined by land use plan objectives that have been made legal, such as old growth management areas.
- Tier 2 resource value objectives are defined under FRPA in the Forest Planning and Practices Regulation (FPPR) for timber; visual quality; cultural heritage; soils; wildlife habitat; landscape and stand level biodiversity; water, fish, wildlife and biodiversity within riparian areas; fish habitat in fisheries sensitive watersheds; and water in community watersheds.
- Tier 3 resource value objectives are defined under FRPA using the Government Actions Regulation (GAR). These objectives are for site specific areas, such as ungulate winter range.

In the event of conflict, tier 1 objectives override tier 2 and 3 objectives; tier 2 objectives override tier 3 objectives. Tier 3 objectives must be consistent with tier 1 and 2 objectives. **Tier 2 and 3 resource value objectives are subject to a 6% timber supply constraint**.

Most land use plans in British Columbia (B.C.) date back to the late 1990s or early 2000s. Although land use plans tend to contain extensive land use objectives, only a limited number are made legal, if any. Tier 1 objectives are out-of-date as they precede the mountain pine beetle epidemic and recent large wildfires and did not consider cumulative effects or climate change. While the government has committed to the modernization of land use plans, little has been accomplished[4].

The resource value objectives in the FPPR favour the timber resource value over all other resource values. Resource value objectives cannot "unduly reduce the supply of timber", which is defined above as 6%.

[3] Summary of resource value objectives.docx
[4] https://www2.gov.bc.ca/gov/content/industry/crown-land-water/land-use-planning/modernizing-land-use-planning

Sections 64 and 65 of the FPPR specify maximum cutblock sizes and adjacency requirements (stocking and height) that an existing cutblock must meet before a new cutblock adjacent to it is established. Both requirements can be ignored for the recovery of timber (salvage) damaged by fire, insect infestation, disease, wind or other similar events, or for sanitation treatments.

The Minister of Forests Lands, Natural Resource Operation and Rural Development (the Minister) also provides in a letter to the chief forester guidance regarding the objectives of the B.C. government to be considered when determining an AAC[5]. For land use planning, cumulative effects and climate change, the letter states:

> *"In order to ensure that AAC determinations align with government objectives to modernize land-use planning and sustainably manage B.C.'s ecosystems, rivers, lakes, watersheds, forests and old growth forests, the Timber Supply Review process should incorporate the best available information on climate change and the cumulative effects of multiple activities on the land base. Management options that align with established climate change strategies, adaptation and mitigation practices should be explored. Where the cumulative effects of timber harvesting and other land based activities indicate a risk to natural resource values, the process should identify those risks for consideration in land-use planning."*

The letter is a bit ambiguous as it indicates the best available information on climate change and cumulative effects should be used in the AAC determination, but then states when cumulative effects indicate a risk to natural resource values, they should be identified for consideration in land use planning.

The chief forester's interpretation is to simply pass any problems associated with cumulative effects to those responsible for land use planning[6] -- ironically staff in the same ministry:

> *"With respect to cumulative effects, I must interpret related information according to my statutory authority. As emphasized above, the chief forester is authorized only to make decisions on allowable harvest levels, not to change or institute new management regimes for which other statutory decision makers have specific authority. However, cumulative effects information can highlight important issues and uncertainties in need of resolution through land use planning, which I can note and pass to those responsible for such planning."*

[5] 230810 2017 Letter of Expectation from Minister Donaldson to CF Diane Nicholls.pdf
[6] Lakes Timber Supply Area – Rationale for Allowable Annual Cut (AAC) Determination – 2019

The chief forester states that climate change is too uncertain to be incorporated into current AAC determinations, but will incorporate it when research provides more definitive information:

> *"Nevertheless, the potential rate and specific characteristics of climate change in different parts of the Province are uncertain. This uncertainty means that it is not possible to confidently predict the specific, quantitative impacts on timber supply."*
>
> *"As research provides more definitive information on climate change and its effects, I will incorporate the new information in future AAC determinations."*

The AAC determination process clearly favours timber harvesting over integrated decision making, leading to an AAC that is too high and unsustainable, given that:

- **Land use planning is out-of-date;**
- **Cumulative effects and climate change are mentioned but not part of the AAC determination process; and,**
- **Government objectives for timber, and the resulting forestry legislation, override all other natural resource objectives, particularly when salvage logging is involved.**

RESPONDING TO UNCERTAINTY

The chief forester deals with uncertainty in the AAC determination process by[7]:

- Managing risks by evaluating the significance of specific uncertainties associated with the current information and assessing the potential current and future social, economic, and environmental risks associated with a range of possible AACs (sensitivity analyses)[8].
- Re-determining AACs regularly to ensure they incorporate current information and knowledge, and greater frequency in cases where projections of short-term timber supply are not stable and/or substantial changes in information and management are occurring.

Additionally, the chief forester often uses the term "*best available information*" to justify a decision or modelling assumption.

[7] Lakes Timber Supply Area – Rationale for Allowable Annual Cut (AAC) Determination – 2019

[8] We note that the chief forester's use of risk and uncertainty is confusing. Risk is present when future events occur with measurable probability, whereas uncertainty is present when the likelihood of future events is unknown or incalculable. We will simply use the term uncertainty to be consistent with the chief forester.

The chief forester states that "*no responsible AAC determination can be made solely on the basis of a precautionary response to uncertainty with respect to a single value*" but provides no justification for this statement.

The chief forester's statement on a precautionary response to uncertainty is in stark contrast to the federal government's guidelines on taking a precautionary approach in the absence of full scientific uncertainty[9]:

> *"The application of precaution is distinctive within science-based risk management and is characterized by three basic tenets: the need for a decision, a risk of serious or irreversible harm and a lack of full scientific certainty"*

AAC determinations require a decision; carry a risk of serious or irreversible harm to local economies and to ecosystems; and most certainly lack full scientific certainty.

The chief forester's statement on a precautionary response to uncertainty is also in stark contrast to the legislation governing forest carbon offsets projects in B.C., which use the same models and information as the AAC determination does. Under the *Greenhouse Gas Industrial Reporting and Control Act*, the Greenhouse Gas Emission Control Regulation requires forest carbon offsets to be validated and verified to ISO 14064 standards by independent, third-party auditors. These international standards specifically require a conservative approach (application of precaution) to be taken when dealing with uncertainty.

In 2015, the Forest Analysis and Inventory Branch (FAIB) under the chief forester released a draft report on building a framework to support working with uncertainty in natural resource management[10]. The report lists the five most common responses to uncertainty, along with the most likely outcome for each, all of which are useful in assessing the chief forester's approach to uncertainty:

1. **Proceed as though there is no uncertainty**. This will result in an incomplete understanding of the problem being faced and poor decisions when the anticipated future circumstances and management outcomes turn out to be incorrect.
2. **Await more certainty before acting**. This will result in continuing to act in accordance to past conditions and plans when circumstances have changed and missing opportunities to reduce risks or capitalize on potential benefits.

[9] A Framework for the Application of Precaution in Science-based Decision Making about Risk
[10] uncertainty_and_natural_resource_management_apr132015.pdf

3. **Frame the problem as being a lack of information**. This approach leads to collecting more information but can result in analysis paralysis and failure to think about how to make a good decision given the uncertainty.
4. **Focus on better understood problems or parts of the problem**. This can lead to a false sense of accomplishment, encourage actions that are not appropriate for the actual circumstances and divert focus from the important aspects of the problem.
5. **Understand and work with uncertainty**. Incorporating uncertainty into decisions and strategies increases the chance of achieving the desired outcomes and enhances the capacity for flexible thinking, which can be helpful when facing future uncertainty and complexity.

In terms of the 2015 FAIB report on uncertainty, the chief forester's approach to cumulative effects and climate change in the AAC determination is to proceed as though there is no uncertainty (#1), frame the problem as being a lack of information (#3) and focus on better understood aspects of the AAC determination process (#4), all which will lead to an ineffective decision.

While there are many sources, other than climate change and cumulative effects, of uncertainty in the information used for AAC determinations, we will concentrate of how the avoidable uncertainties are not properly accounted for and how existing data should be used to properly account for the uncertainty associated with four components of the Vegetation Resources Inventory (VRI) and timber supply review (TSR) process that affect the mid-term AAC:

1. Existing (natural) stand yield predictions
2. Managed (plantation) stand yield predictions
3. Managed stand site productivity
4. Genetic gain of select seed

We will review these four components of the VRI and TSR process in terms of the chief forester's approaches to dealing with uncertainty:

- Best available information
- Sensitivity analysis
- Periodic re-determination of AACs

BEST AVAILABLE INFORMATION

The chief forester often uses the term "*best available information*" to justify a decision or modelling assumption. The term is a nebulous phrase that does not embody an assessment of

the quality of the data being used or of the adequacy of the data for use in the determination of a trustworthy AAC.

As an example of inadequate data that is presented as the "best available information", the chief forester describes the VRI used for the 2014 Bulkley TSA AAC determination as:[11]

> *"I have reviewed the inventory information used in the timber supply analysis with staff and conclude that although there appear to be discrepancies in the VRI, the **best available information** was used in the base case."*

This is in spite of an independent audit of the Bulkley TSA Phase I VRI that concluded:[12]

- Page 2: *"The VRI polygon delineation of the Bulkley TSA does not meet Ministry requirements."*
- Page 4: *"The VRI polygon delineation of the Bulkley TSA does not meet Ministry standards."*
- Page 7*: "The polygon attribute estimation of the Critical Attributes of Species Composition and Leading Age do not meet Ministry standards"*
- Page 7: *"The polygon attribute estimation of the Standard Attributes do not meet Ministry Standards"*
- Page 10: *"The VRI polygon delineation and VRI polygon attribute estimations of the Bulkley TSA do not meet Ministry standards."*
- Page 10: *"The Ministry should either correct the existing VRI polygon delineation and polygon attribute estimation data sets or conduct a complete re-inventory of the Bulkley TSA"*

The statement is also in spite of the chief forester's Forest Analysis and Inventory Branch (FAIB) review of the Bulkley TSA Phase II VRI that concluded:[13]

> *"The review identified errors in specific phase I stand attributes in all stands, but particularly in the immature and mature stands in the ESSF biogeoclimatic zone. FAIB staff advised me that application of phase II adjustments is usually appropriate because the phase II ground samples are considered to be reliable. However, due to the large uncertainty associated with the adjustments for the ESSF immature and mature stands, they recommended not applying these particular adjustments. Application of the phase II*

[11] Bulkley_TSA_AAC_2014.pdf
[12] Bulkley_VRI_Review_Final_QA_Report.pdf
[13] Bulkley_TSA_AAC_2014.pdf

adjustments to all stands, except the ESSF immature and mature stands, resulted in existing stand volumes that are 12 percent higher than the inventory volume."

"Based on my review of the VRI phase I and phase II adjustments and the advice of ministry experts, I conclude that the existing natural stand yields used in the original base case should have incorporated the phase II adjustments for all stands except the ESSF immature and mature."

"In order to reduce the level of uncertainty associated with the original base case (due to the factors discussed above), I requested that a revised base case be prepared in which: VRI phase II adjustments are applied to all existing natural stands with the exception of the ESSF immature and mature stands"

While the chief forester refers to the VRI as the "best available information", which it may have been at the time, the VRI data used were clearly inadequate for use in the determination of a trustworthy AAC.

A major source of uncertainty, and one that could easily be avoided, is ineffective data management. The chief forester's FAIB is responsible for the collection, validation, storage, and compilation of inventory, monitoring and growth-and-yield sample plot data. Throughout the 1990s, FAIB unsuccessfully attempted to develop an Oracle-based storage and validation system and a SAS-based compiler for their sample plot data. At the same time, FAIB was also acquiring a significant amount of sample plot data from the private sector.

Owing to a lack of effective data management, the sample plot data had become corrupted over time. From 1997 to 2002, FAIB contracted out the validation of the sample plot data at an expense of $700,000.00. Funding was not continued in 2002 and the data were returned to FAIB without any documentation of what had been completed and what remained to be completed. Since FAIB still did not have a functioning data management system, they immediately began corrupting the data, as evidenced by the incorrectly compiled data provided to the Canadian Forest Service (CFS) to develop stand-level volume-to-biomass conversion equations for use in forest carbon modelling in 2003.

Although errors in data management and compilation were pointed out to FAIB since 2003, they were unable:

- To calculate site index to standards set by the Forest Productivity Council (FPC) in the late 1990s until 2011.

- To correctly calculate correctly sample plot volume, basal area, and stems per hectare until 2017.

Due to staff turnover and a lack of corporate knowledge of their sample plot data, avoidable errors that had been previously identified and corrected, such as the correct classification of residual trees, began appearing in the newly established Change Monitoring Inventory (CMI) and Young Stand Monitoring (YSM) programs.

The net result is that any studies or models using FAIB sample plot data prior to 2017 are suspect.

SENSITIVITY ANALYSIS

The chief forester manages risks by evaluating the significance of specific uncertainties with the information used in an AAC determination using a range of possible AACs. The TSR process defines a base case scenario which assumes no uncertainty with the information used. It then applies various sensitivity analyses, based on uncertainty identified with the information used, to the base case.

The following sensitivity analyses are common to many TSRs:

- Change existing (natural) stand yields by ±10%.
- Change managed (plantation) stand yields by ±10%.
- Change managed stand site productivity (site index) by ±3 metres
- Do not apply genetic gain of select seed to managed stand yields

There does not appear to be any rationale for the sensitivity analysis thresholds. The thresholds used in the TSR are so low that the sensitivity analysis usually results in a statement that there is no noticeable effect on the base case AAC and the yields used for the base case are accepted without change.

How the chief forester approaches the sensitivity analysis used in the TSR is in stark contrast to how uncertainty is addressed in forest carbon offset projects that use the same inventory data and growth models as the TSR process does. The Protocol for the Creation of Forest Carbon Offsets in B.C. (FCOP) allows for two types of quantification methodologies and both require a conservative (precautionary) approach to dealing with uncertainty:

1. If direct measurements are used for both the project and the baseline, the upper bound of a 90% confidence interval is used for the baseline and the lower bound of a 90%

confidence interval is used for the project. Since the carbon sequestered is project minus baseline, the methodology ensures a conservative estimate. As an incentive, the more sampling that is done, the smaller the confidence intervals will be, thereby reducing the discount applied to the project.

2. If models are used, sensitivity analyses must be conducted with field measurements used to determine sensitivity thresholds. Based on the sensitivity analyses, an approach to the management of uncertainty that ensures that changes in the reported carbon pools are conservative must be justified.

In the next sections we will discuss sources of uncertainty for components of the VRI and TSR process and how sensitivity analysis thresholds should be determined for each of the components from existing monitoring data.

Existing (Natural) Stand Yields

The Variable Density Yield Projection (VDYP7) model is used to assign timber volume to VRI polygons and to develop yield curves for existing stands[14]. Sources of uncertainty include:

1. The main purpose of the 1997-2002 contract to validate sample plot data was to correct the data and to incorporate a backlog of data which included new site productivity measurements for use in calibrating VDYP7. A data request in 2003 revealed that FAIB had used the corrupted data from 1997 and not the corrected data from 2002 to calibrate VDYP7. In addition, the data used for VDYP7 had errors in the plot volume calculations. FAIB indicated they had provided the wrong data and supplied another data set which had the same errors. A freedom of information (FOI) request in 2015 indicated that FAIB has no record of the actual data used to calibrate VDYP7[15].

2. When used with the new VRI inventory, VDYP7 requires basal area and stems per hectare as input. Estimation of these values from the VRI Phase I photo-interpretation are not accurate, leading to unreliable volume estimates. The future use of LiDAR in forest inventories has the potential to provide better estimates of these input values.

[14] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/variable-density-yield-projection-vdyp
[15] FOI Request FNR-2015-50010_2.pdf

3. No data were available to validate VDYP7 and an adjustment process is required using the VRI sample plot data[16]. In many cases, as indicated in the Bulkley TSA example above, the VRI sample plot data is inadequate to provide a reliable adjustment[17]:
    a. Sample sizes are usually adequate to obtain the target sampling error when all species are combined, but not when the data are compiled by species and age strata. Sampling error for species and/or age strata are usually greater than 20%.
    b. Sampling covers areas inside and outside the Timber Harvesting Land Base (THLB) and many TSAs have shown significant differences between the THLB and non-THLB sample plot volumes and accuracy of VDYP7 estimates.

4. Once VDYP7 estimates have been adjusted using VRI data, they should be validated against the CMI data to get an estimate of the accuracy of the adjusted volumes. This has never been done as FAIB combines the VRI and CMI data for the adjustment process.

5. Stand yield estimates for areas affected by mountain pine beetle (MPB) have an additional source of uncertainty. The B.C. Provincial Scale Mountain Pine Beetle Model (BCMPB) is used to construct a GIS layer for year-of-death due to MPB[18]. This layer is used to modify VDYP7 live volume estimates to account for mortality due to MPB.

6. VDYP7 was recently modified to estimate and project volumes for MPB affected stands[19], adding another component of uncertainty. Currently, there is little, if any, re-measured sample plot data with which to validate these estimates.

7. VDYP7 cannot account for climate change.

It is clear from the above that a ±10% sensitivity analysis for VDYP7 yield estimates is inadequate, particularly for future yields. It would be more appropriate to determine a sensitivity threshold using sample plot data, as is required by FCOP.

This can be accomplished using analysis of equivalence. While you can never prove equality with statistics, you can prove equivalence. Equivalence testing involves specifying a maximum operational difference (effect size) you are willing to accept.

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[16] biometrics_overview_of_vdyp7_compements.pdf
[17] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/inventory-analysis-reports/vegetation-resource-inventory-audits
[18] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/forest-pests/bark-beetles/mountain-pine-beetle/mpb-projections
[19] vdyp7_informationnote6.pdf

Once any adjustments have been done to VDYP7 volume estimates (VRI plots and BCMPB adjustments) and using the ratio of measured plot volume (CMI plots) to adjusted predicted volume, the effect size can be changed until equivalence is shown. The effect size at equivalence would then be used for the sensitivity analysis threshold.

This would not represent the actual accuracy of VDYP7 but would represent the accuracy that can be proven with the data collected. The more data that is collected, the lower the effect size will be.

Managed (Plantation) Stand Yields

The Table Interpolation Program for Stand Yields (TIPSY) is used to develop yield tables for the TSR process. TIPSY is not a growth model but provides access to managed stand yield tables produced by the Tree and Stand Simulator (TASS). TASS is the model supported by FAIB to predict the growth and yield of managed stands and in the past was not publicly available[20].

The expectation of users, as promoted by FAIB, is that TIPSY provides the same yield estimates as TASS with some minor error due to interpolation between the TASS yields in the TIPSY database. In fact, there are many variants of TASS and some can produce yields that are significantly different than those produced by TIPSY, given the same input.

In 2019, FAIB released the first publicly available version of TASS (v4.0) along with a new version of TIPSY (v4.4). The main difference in TASS v4.0 is that it is supposed to be able to simulate competition between species and layers, whereas previous versions could not. TIPSY does not have the ability to simulate competition between species or layers. Since TASS v4.0 (also referred to as TASS III) currently only has two species – lodgepole pine and spruce -- it is expected that TIPSY will be used in the TSR for the foreseeable future.

Due to changes made to lodgepole pine (Pl) and spruce (Sw) in TASS, TIPSY v4.4 came with a confusing description of changes that were also in TIPSY[21]. The TIPSY help also indicated changes to interior Douglas-fir (Fdi):

> *"Slight changes in Fdi yields due to revised Site Height and Top Height linkages."*

[20] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling

[21] yield_comparisons_tipsy_44_tass_iii_40_vs_tipsy_43.pdf

Although changes to subalpine fir (Bl) and larch (Lw) were not indicated in the documentation, we expected changes in those as subalpine fir uses the same growth coefficients as spruce and larch (Lw) uses the same growth coefficients as interior Douglas-fir.

To get a better idea of the changes, we made some simple simulations using site index of 20.0 m, 1600 stems per hectare planted and TIPSY default operational adjustment factors (OAF 1 of 0.85 and OAF 2 of 0.95). The following table presents the results for total volume and merchantable volume greater than 12.5 cm DBH at age 100. **Clearly the uncertainty in yields is far greater than the ±10% used for sensitivity analysis in the TSR and far greater than what has been promoted by FAIB in the past.**

Species	Volume per Hectare (m^3/ha)						Difference (%)	
	TIPSY v4.3			TIPSY v4.4				
	TASS Version	Total	Merch. 12.5+	TASS Version	Total	Merch. 12.5+	Total	Merch 12.5+
Bl	2.05.24b	481	441	3.01.15W	417	376	-13.3	-14.7
Fd	2.05.24b	415	375	2.07.73WS	338	286	-18.6	-23.7
Lw	2.05.24b	409	368	2.07.73WS	334	282	-18.3	-23.4
Pl	2.05.24f	438	401	3.01.13W	529	485	20.8	20.9
Sw	2.05.24b	496	457	3.01.15W	439	399	-11.4	-12.7

The 20% differences in interior Douglas-fir yields are more than what was documented as being "slight". When asked if the previous version of TIPSY was incorrect, FAIB indicated that TIPSY v4.3 yields were inconsistent with TASS yields, but both are within the range of their data, basically confirming the uncertainty FAIB should be associating with TASS and TIPSY yields in TSRs[22].

Uncertainty in TIPSY managed stand yields comes from the following sources:

1. Models were calibrated with sample plot data that does not extend out to rotation age and as more data is collected over time, changes are inevitable. The differences between TIPSY v4.3 and v4.4 illustrate this.

2. TIPSY cannot simulate competition between different species and layers. TIPSY will simulate mixed species yields by generating separate yield tables for each species and

[22] TIPSY_Fd_differences.pdf

pro-rate them based on species composition. Species composition will not change over time and you cannot combine natural and planted species establishment.

This has led to the following methodologies of creating managed stand yield tables with ingress:

- Assume there is no ingress
- Increase the number of trees planted to account for ingress
- Simulate separate planted and natural yield tables and pro-rate them based on the percent of ingress expected. In some cases, the ages have been offset.

The various methods will produce different yields over time, with none of them being correct. It is more of a case of forcing a model to do something it is not designed for but trying to make it seem scientific.

Recently, FAIB has developed a standardized methodology to initialize TASS or TIPSY using data for the polygon from the RESULTS database. Originally the methodology was to be used in the TSR for the Lakes timber supply area (TSA) but will now be used in the TSR for the Kispiox TSA for the first time.

3. In TASS, tree volume is linked to crown growth. Based on crown growth, a layer of wood is deposited on the tree bole annually and used to determine stem volume. For trees in YSM plots, tree volume is estimated with the 2002 Kozak BEC-based taper function based on the tree's diameter at breast height (DBH) and height.

   A comparison of the taper function volume, using the DBH and height of trees from TASS v4.0 output, to the TASS volume for interior spruce showed that the TASS volume was 25% higher at age 30 and 15% higher at age 50[23].

   YSM comparisons of TIPSY volume-to-ground plot volume do not take this into account. The differences also raise concerns about the validity of TIPSY volumes for interior spruce. The taper function is based on data and the TASS volume is largely theoretical.

4. TASS and TIPSY cannot account for climate change.

[23] tass_iii_volume.xlsx

In the rationale for an AAC determination, the chief forester will often reference the YSM program and analysis. All the YSM analysis reports have used TIPSY v4.3 and, given the changes in TIPSY v4.4, the analyses cannot be considered relevant for any of the interior TSAs[24].

Even without the changes to TIPSY, the YSM analyses are problematic:

- Most YSM plots are not linked to the RESULTS database so TIPSY initialization was based on an estimate of 1500 stems-per-hectare planted. For aspen and subalpine fir, TIPSY was initialized with 5000 stems per hectare and a natural distribution.
- Sometimes an estimated genetic gain for select seed was used for plots less than 31 years old.
- The standard errors for the statistical tests were calculated incorrectly when data were split into subsets (domains) by species or by biogeoclimatic ecological classification (BEC) zone. Eventually, FAIB contracted a statistician to document the correct calculation methodology in 2018[25].
- The paired t-test used in the YSM analysis is inappropriate. Identifying whether a difference between the predicted and measured plot volume is statistically significant has no operational meaning.
- You cannot infer equality between predicted and measured plot volume with a non-significant t-test.
- As with VDYP7, the correct analysis is to use analysis of equivalence.

Managed Stand Site Productivity

Height growth is the main driver of TASS and TIPSY and the rate of height growth is defined by the site index.

Beyond a stand age of 120 years, site index equations tend to under-estimate site index. As such, the site index from a previous stand is inappropriate to use for the replacement managed stand.

Site Index by BEC Site Series (SIBEC) tables were developed to estimate site index for managed stands based on the BEC classification. While managed stands that have been surveyed have a ground-based BEC classification, future managed stands in the TSR process do not.

[24] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/inventory-analysis-reports/provincial-monitoring-reports
[25] provincial_cmi_and_ysm_sampling_framework_20180616.pdf

FAIB has developed the Provincial Site Productivity Layer (PSPL) to assign a site index to future managed stands. The PSPL combines predictive or terrestrial ecosystem mapping (PEM/TEM) with SIBEC.

Uncertainty associated with this process includes:

1. PEM/TEM only requires an accuracy of 65% to be accepted. YSM studies indicate the FAIB database only has the correct leading species about 70% of the time. This means that you can only expect to have the correct BEC and species less than half the time when assigning site index with the PSPL.

2. A 2012 report completed for the chief forester's Resource Practices Branch indicated that within a SIBEC species-BEC cell, young trees have higher site indices than older trees[26]. In a 2017 invitation to tender for SIBEC 2018 (1070-30/RE18FHQ297), schedule A mentioned an "undocumented" SIBEC rule that no more than two trees less than 30 years old are allowed in a SIBEC cell.

   Applying this rule would lower the SIBEC estimates for many cells. A new SIBEC database has yet to be released and the current database would be over-estimating site index for these SIBEC cells.

PSPL estimates are compared to site index estimates in the YSM data using an inappropriate t-test. As mentioned previously, an analysis of equivalence should be used to determine a sensitivity threshold for the sensitivity analysis in the TSR process.

Additionally, PSPL estimates of BEC should be compared to the BEC in RESULTS data to obtain a measure of accuracy.

Genetic Gain of Select Seed

In TASS/TIPSY, genetic gain is incorporated by increasing the site index to account for the expected increased height growth. Genetic worth and the selection age are required input, while the index age is fixed[27].

[26] Ralph_Winter_Report.docx
[27] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/tree-seed/forest-genetics/research-projects/breeding-values

Realized genetic gain trials are used to test whether the genetic gains observed in progeny tests hold up in an operational setting. While we can find numerous references of data collected for realized genetic gain trials, we can only find two reports that present the results. Both are for coastal Douglas-fir, one at age 12 and the other at age 20.

While the tree breeding and improvement program has adopted a number of conservative measures to avoid over-estimation, there is still a great deal of uncertainty because realized genetic gain trials are nowhere near index ages. Also, climate change has the potential to significantly alter the target environment on which breeding values are dependent.

The TSR and AAC determination processes use genetic gain in the base case scenario and make no mention of the uncertainty. The predicted genetic gain is taken as a given.

Genetic gain should not be used in the base case scenario. It could be incorporated into a sensitivity analysis. The chief forester would then have to supply a justification, based on realized genetic gain trials, to include genetic gain in the AAC determination.

PERIODIC RE-DETERMINATION OF AACs

The chief forester indicates that periodic re-determination of AACs is used to deal with uncertainty.

When sensitivity analyses indicate a component of the TSR process points to uncertainty the chief forester requests that additional data or information be collected on that component to be used in the next AAC determination. This appears under the “implementation” section.

According to the 2015 FAIB report on uncertainty, this is equivalent to framing the problem as being a lack of information that results in a failure to think about how to make a good decision given the uncertainty.

Using this approach, instead of dealing with uncertainty, the periodic re-determination of the AAC is a way of avoiding dealing with uncertainty.

IS THE AAC DETERMINATION A PROFESSIONAL JUDGEMENT?

While the chief forester’s AAC determination is defined as an “independent professional judgement”, we question the “independent”, “professional” and “judgement” aspects of this definition.

We question the independence given:

- The Minister's letter of guidance allows the chief forester to ignore the risk that the cumulative effects of timber harvesting and other land-based activities pose to natural resource values during the AAC determination and simply to identify the risks for land use planning.
- The FPPR favours timber harvesting over all other resource values by restricting the chief forester from "unduly reducing the supply of timber" to protect other resource values.
- The FPPR allows salvage logging to ignore restrictions on cutblock size and adjacency requirements, which can have severe hydrological consequences in watersheds.
- The Ministry has failed to modernize land use plans to include cumulative effects and climate change. As such, higher-order plan objectives are outdated.
- The ministry makes few land use plan objectives legal.

We question the professionalism given:

- The chief forester's methodologies for accounting for uncertainty do not require a conservative approach or the use of the precautionary principle, in contrast to federal guidelines and FCOP.
- The chief forester's methodologies for the accounting of uncertainty lead to poor decisions, as noted by the 2015 FAIB draft report on building a framework to support working with uncertainty in natural resource management.
- The chief forester's use of the term "best available information" ignores the adequacy of the information for AAC determinations.

We question the judgement given:

- In a July 2020 response to questions about impediments to making unfettered decisions that affect the AAC, the chief forester responded[28]:

> *"The provincial inventory program continues to establish and remeasure Change Monitoring Plots in mature timber and Young Stand Monitoring plots in immature stands. This ensures inventories accurately reflect current timber volumes and young stands are growing as projected in the TSR."*

  Given the problems identified with the existing stand yield estimation, managed stand yield estimation and YSM analyses, the chief forester's comment is unfounded. It

[28] FM_Diane_Nichols _Response.pdf

appears staff are providing bad advice or the chief forester is ignoring professional advice.

- The chief forester appears to reinforce the bias towards timber harvesting in the FRPR as evidenced by the chief forester's leadership team that is composed entirely of industrial chief foresters currently operating on B.C. crown land[29].

In order for the AAC determination to be considered a professional judgement all legislation favouring timber harvest over all other resource values must be removed; land use plans must be modernized to include cumulative effects and climate change with all objectives made legal; the management of uncertainty should follow more established guidelines and include the concept of conservatism and the precautionary principle; and the chief forester's leadership team should be disbanded or modified to include members that represents resource values other than timber harvesting.

As it stands right now, having the chief forester determine AACs with all the legal and political restrictions on making a true professional judgement just presents a façade of professionalism.

[29] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/sustainable-forest-management-practices