A SUBMISSION TO THE

FOREST INVENTORY PROGRAM REVIEW PANEL

Respectfully submitted

by

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and

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ABOUT THE AUTHORS

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Specifically, Martin has 40 years of international and domestic forestry experience, specializing in:

- Growth and yield modeling
- Quantification, validation and verification of forest carbon offsets projects
- Statistical analysis of data
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- Timber supply analysis

After completing a M.Sc. Forestry in 1986, Martin spent 7 years as a growth and yield specialist and biometrician on Canadian International Development Agency projects in Southeast Asia and China.

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Since 1993, Martin has owned and operated a forestry consulting business located in Victoria, B.C.

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Anthony had a 40-year career with the B.C. Forest Service during which he held senior professional positions in inventory, silviculture and forest health. He has extensive expertise in forest inventory and in forest health as it relates to timber supply analysis, to lumber recovery and to climate change.

Anthony supervised large field crews to obtain lumber recovery factors for small wood in the Interior and for hemlock on the Coast. This work provided Anthony with expertise in relating incidence of forest health indicators in the field to impact on lumber recovery in the mill.

At Inventory Branch, Anthony reported to the director for many years before becoming the reports officer. In this latter capacity Anthony won the largest employee suggestion award ever granted for saving the ministry millions of dollars a year by moving inventory reporting from the IBM mainframe to PCs using reporting systems that he had designed. He was also responsible for the quality control of inventory data used to inform timber supply analysis for AAC determinations.

After the core review, Anthony moved to Forest Practices Branch where he kept the wheels turning on the silviculture progam. He was then asked to lead and re-build the forest health program. Anthony capped his career working on climate change and forest carbon files. He wrote the Premier's briefing for the 2009 United Nations Climate Change Conference (COP15) held in Copenhagen.

Anthony has a Bachelor of Science in Forestry degree from the University of New Brunswick and a Masters of Public Administration degree from the University of Victoria.

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SCOPE

The forest inventory program comprises three chief activities: the collection of data, the management of data and the use (modeling, reports and analysis) of data. In this submission we will not be directly commenting on field inventory or on budgets and funding for the forest inventory program.

Our submission focuses on:

- G&Y models. We consider VDYP7, TASS/TIPSY, Prognosis^{BC}, SIBEC, PSPL and individual tree volume estimation all to be models that contribute to the estimation of timber volume,
- The ITB and VTB equations used to assign biomass to the inventory and,
- The use of ground samples used to validate or adjust G&Y model estimates in the inventory.

Our submission will also focus on MFLNRO&RD's use of the inventory, monitoring data and G&Y models in the TSR and AAC determination processes, particularly with respect to how the uncertainty with G&Y model estimates is addressed compared to how it is addressed in forest carbon offsets projects that use the same G&Y models. By doing this, we outline some of the serious consequences associated with the problems we identify with the forest inventory and G&Y models.

INTRODUCTION

Our submission is based on a number of questions originally submitted by the opposition forest critic to the forest minister during the 2014 and 2016 Estimates Debates and on the ministerial responses to those questions prepared by MFLNRO&RD for the forest minister.

While FAIB managers seem to consider the 2014 and 2016 Estimates Debate questions to be some sort of personal condemnation of staff work, the questions are simply a reflection of real issues encountered in the course of completing contracts for clients and issues that FAIB managers chose to ignore, such as:

- MFLNRO&RD data management problems were identified when validating MFLNRO&RD data under contract for FAIB for use in parameterizing[1] VDYP7 and problems identified when preparing data for Prognosis^{BC} calibration under a contract for RPB,
- SIBEC problems were identified while under contract to RPB to assess the use of SIBEC data for planning and investing in silviculture activities under the LBIS and,
- SIBEC, TASS/TIPSY, biomass conversion and access to data problems were identified during the quantification, validation and verification of forest carbon offsets projects to ISO standards, which require uncertainty to be documented and, if possible, quantified in order to account for it.

In this submission, we go through the questions on the DVD (provided separately) in reference to the forest minister's responses, while adding any relevant updates. We also incorporate these subject areas:

- Individual tree volume,
- Additional ground sample programs and the analyses associated with them,
- The culling of the PSPs,
- The debate between the YSM and SDM programs and,
- The TSR and AAC determination processes with respect to VRI attribute adjustment, VRI statistical analysis, G&Y model assumptions and the use of monitoring data.

We submit that any review of forest inventory and G&Y models cannot be done in isolation from their main function, which is the AAC determination. Therefore, we illustrate identified problems with the forest inventory and G&Y models using examples drawn from TSRs and AAC determinations for a number of management units.

[1] Parameterization is the process in which parameters in an equation are fitted to a dataset, whereas calibration is the process in which model predictions are compared to an independent dataset and afterwards one or more parameters in the model are changed to produce predictions that match the observations. Calibration encompasses validation (http://bvcentre.ca/sortie-nd/devt-testing-validation)

Given the increased uncertainty in G&Y model predictions due to climate change, field monitoring of managed stands has become more crucial than ever to determine if they are meeting the expectations placed upon them at the time of free-growing surveys. These expectations are laid out in silvicultural prescriptions captured in the RESULTS database.

Over a number of decades we have planted over 7 billion trees at a direct and indirect cost to the public of an estimated $7 billion. It seems remarkable to us that during all that time we have had absolutely no assessment of how those managed stands are performing after they were declared free growing either at the polygon resolution at which they were planted or at the management unit resolution at which timber harvesting is planned.

With increased uncertainty in growth and yield models and the predicted increase in catastrophic weather events due to climate change, the assumed timber growth of managed stands used in TSRs is the Achilles heel of future timber supply.

We provide some background information on items that are not associated with any particular Estimates Debate question, but drive, or contribute to, the problems identified:

- Forest inventory legislation,
- Uncertainty and best available information,
- Statistical misconceptions within MFLNRO&RD,
- Climate change and growth projections, and,
- Professional reliance and the use of G&Y models.

We have already provided panel members Bill Bourgeois and Valerie Lemay with a DVD of the 2016 Estimates Debate questions and have included with this submission files containing the forest minister's response:

1. ***1298667.pdf*** contains the forest minister's responses to questions on the Boundary TSA inventory and biomass conversion,
2. ***faib_response_boundarytsa_2016jul19.pdf*** is a correction submitted by FAIB after we questioned the compilation used in ***1298667.pdf***,
3. ***225774 – response.pdf*** contains the forest minister's responses to questions on site index, PSP data, VDYP7, TASS/TIPSY and data access and,
4. ***data_2014_2017.xlsx*** is the ***data_2014_2015.xlsx*** file submitted with the 2016 Estimates to show problems with FAIB PSP data compilation problems updated to include the latest (2017) compilation. In this file:
    a. PHF_PM is the main plot per hectare factor,
    b. FHF_PS is the subplot per hectare factor,

c. DBHLIMIT_COMPILE is the DBH limit FAIB claims to be compiling the data to,
d. DBHLIMIT_ACTUAL is the DBH limit FAIB is actually compiling the data to and,
e. STEMSHA_LI is the stems per hectare of live original and ingrowth trees (veteran trees are not included).

Our submission references a number of documents located on the following MFLNRO&RD websites:

- Current TSR and AAC determination documents: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/timber-supply-review-and-allowable-annual-cut/allowable-annual-cut-timber-supply-areas
- Archived TSR and AAC documents: http://data.nrs.gov.bc.ca/TSR_Historical/TSA/
- YSM reports: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/inventory-analysis-reports/provincial-monitoring-reports
- VRI audits: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/inventory-analysis-reports/vegetation-resource-inventory-audits
- SDM summary reports: https://www.for.gov.bc.ca/ftp/hfp/external/!publish/2013%20SDM%20TSA%20Summaries/SDM%20-%20TSA%20Summaries/

For the reader unfamiliar with the jargon of forest inventory and timber supply, we provide a glossary of acronyms at the end of the submission but before the appendices.

For the convenience of panel members, we have identified recommendations and problem statements with bold red italics within each section. Given the length of this submission, we first summarize in the next section these recommendations and problem statements referenced by the section within the body of the report. The Panel members can quickly review this summary found in the next section and decide which items are of interest.

SUMMARY OF RECOMMENDATIONS AND PROBLEM STATEMENTS

FOREST INVENTORY LEGISLATION

1. Given that a reliable inventory is required to make land-use decisions and AAC determinations, we recommend that the legislative mandate for the province to develop and maintain a forest inventory be re-instated in the *Forest Act*. Without a legislative mandate, any recommendations that the panel might make concerning the forest inventory will have limited or no impact.

UNCERTAINTY AND BEST AVAILABLE INFORMATION

2. The net effect is that uncertainty is inadequately managed in the TSR and AAC processes**.** As suggested improvements, in addition to taking a conservative approach and having the TSR and AAC determination processes audited by an independent third-party, we recommend:

    a. Values used for the sensitivity analysis of G&Y model predictions be derived from comparisons to ground samples using sound statistical procedures and/or methodologies and established statistical practices.

    b. The periodic AAC re-determination policy be replaced with a recalculation policy based on a “significance threshold”, as is done with GHG emissions accounting. A significance threshold is a qualitative or quantitative criterion used to define any significant change to the data or calculation methodology that would trigger an immediate recalculation. This would require a streamlining of the TSR process. Therefore, we also recommend that the TSR process be shortened from two years to two months and cataloguing and maintenance of TSR data files be improved.

    c. Guidelines be established around the use of the phrase “best available information”. As a consequence of lawsuits in the United States over the words “best” and “available”, the NOAA developed guidelines around the use of the phrase. These guidelines are based in part on Canadian federal guidelines for the effective use of science and advice in government decision-making and for the application of precaution in science-based decision-making about risk. The use of the phrase “best available information” in inventory work and in AAC determinations falls short of these guidelines.

STATISTICAL MISCONCEPTIONS

3. Most of the statistical misconceptions listed above have previously been pointed out to MFLNRO&RD in a 1999 review of the application of inventory audit data, but the misconceptions seem to persist. We recommend that the ABCFP develop competency requirements for those conducting statistical analysis of G&Y and inventory data. This is consistent with the competency recommendations (3 and 4) of the recently released Summary of Recommendations from the Independent Report on Professional Reliance

CLIMATE CHANGE AND GROWTH PROJECTIONS

4. Given the increased uncertainty in G&Y model predictions due to climate change, monitoring has become more crucial than ever. We recommend that the forest inventory be strengthened with sufficient periodic monitoring to identify deviations from trends predicted by the G&Y models used in the TSR and AAC processes.

PROFESSIONAL RELIANCE AND THE USE OF GROWTH AND YIELD MODELS

5. We recommend that the ABCFP develop competency requirements for those that use G&Y models to estimate timber yields, the flow of timber for AAC determination, and forest carbon sequestration. This is consistent with the competency recommendations (3 and 4) of the recently released Summary of Recommendations from the Independent Report on Professional Reliance.

6. Also, we recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to oversee the development and use of G&Y models, to oversee the establishment and analysis of ground samples for model adjustment, model validation and monitoring, and to ensure all G&Y model users have access to the same and consistent model documentation. This is consistent with accessibility of professional documents recommendations (16 and 17) of the ABCFP Stakeholder Submission to the B.C. Government's Professional Reliance Review.

INDIVIDUAL TREE VOLUME

7. We recommend that MFLNRO&RD adopt a common method for the calculation of individual tree volume to be used among all branches within the ministry.

8. We recommend that MFLNRO&RD review the policy of subdividing species data by BEC zone for fitting taper functions and instead, look at groupings suggested and supported by the data.

9. We recommend that MFLNRO&RD make date-stamped databases of GVAF and NVAF factors available on their website with a rationale provided for the groupings. We also recommend that MFLNRO&RD ensure that the GVAFs and NVAFs are compatible between live and dead trees and, if not, provide guidance as to how they are to be applied.

10. We further recommend that MFLNRO&RD define a "change threshold" that triggers a recalculation of past analyses to account for changing NVAFs and GVAFs. If the response is that the GVAFs and NVAFs do not change enough over time to warrant such a threshold, the question as to why the GVAF and NVAF data are still being collected should be addressed.

11. We recommend that MFLNRO&RD develop NVAFs to be used in the compilation of PSP data (and of Timber Pricing Branch interior appraisal cruise data if the branch is not going to adopt net factoring and NVAF adjustment).

12. We recommend that the difference in TASS-generated individual tree volume and FAIB-compiled tree volume be taken into account when comparing stand volume derived from FAIB-compiled ground sample data to stand volume estimated by TASS/TIPSY.

GROUND SAMPLES

Phase II Vegetation Resources Inventory

13. We recommend that the use of VRI volume adjustments in the TSR and AAC determination processes be reviewed, particularly given the small sample sizes and large variability in strata estimates, as was done in 1999. We further recommend that MFLNRO&RD immediately revisit AAC determinations in which questionable adjustments were used.

National Forest Inventory and Change Management Inventory

14. We recommend that NFI and CMI plots not be used for VDYP7 attribute adjustments so that they can be used to assess the accuracy of the adjusted VDYP7 volumes.

Permanent Sample Plot

15. We recommend an independent third-party review the complete history of the replacement of the VAX-based PSP data storage, validation and compilation systems, along with an accounting of the public funds used and misused, and report to the legislature.

16. We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, review FAIB's rationale for, and the changes made to, the PSP data during the data validation project, whether the changes should be validated in the field, and provide a recommendation as to whether the data and records from the data validation project be destroyed.

17. We recommend that MFLNRO&RD review their website to ensure incorrect information is not being provided to users and the general public.

Stand Development Monitoring and Analysis

18. We recommend that the SDM data be summarized correctly, using the estimators documented in 2017, and that the SDM summaries be used in the AAC determinations as the "best available information" to reduce projected managed stand yields until such time as other MFLNRO&RD sampling programs can provide better estimates, that are supported with re-measured data over decades, of impact due to forest health agent incidence.

Young Stand Monitoring and Analysis

19. We recommend that a qualified, independent, third-party biometrician review the YSM program sampling method with respect to whether it results in a random sample of the intended target population and whether it can affordably maintain a sample that is representative (typical) of the target population in the event of catastrophic events that are predicted to increase with climate change.

20. We recommend that a qualified, independent, third-party biometrician review the YSM sample sizes with respect to whether the objectives can be met with the current sample sizes.

21. Given that there appears to be no oversight or quality control of YSM analysis within MFLNRO&RD, we further recommend that an independent third party audit all YSM analysis reports for errors, omissions and misrepresentations.

22. We recommend that specifications equivalent to those for Phase I VRI samples be used to assess the leading species match between the inventory file and the YSM ground plots. A failure would indicate increased uncertainty in projected managed stand yields that are based on the inventory file leading species.

23. We recommend that a qualified independent third party review the statistical analysis of the YSM data.

24. We recommend that YSM analysis use ratios of ground sample volume to model estimated volume, analysis of equivalence and changing the effect size until one can show equivalence to obtain the ± percent that should be used for sensitivity analysis in the TSR and AAC determination processes. This will not necessarily represent the accuracy of the model, but will represent that model accuracy that can be claimed, given the sample size.

25. In YSM analysis, we recommend:
    a. Ratios of ground sample volume to model estimated volume be used; and
    b. Analysis of equivalence and the changing of the effect size until one can show equivalence to obtain the ± percent that should be used for sensitivity analysis in the TSR and AAC determination processes be undertaken.

    This will not necessarily represent the accuracy of the model, but will represent the model accuracy that can be claimed, given the sample size.

Culling of the Permanent Sample Plots

26. We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to review the MFLNRO&RD 10-year strategic plan for PSPs, particularly with respect to the comments sent in by users of the PSP data.

DATA ACCESS

27. We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to review FAIB's data access policy with respect to the barrier it poses to the development of models in the private sector.

BIOMASS

28. We recommend that MFLNRO&RD, ME&CCS and the CFS coordinate their efforts, resolve the issues around ITBs and VTBs and put forth a final and consistent statement on the status of biomass conversion equations in B.C.

29. We recommend that the biomass estimation in TIPSY be reviewed and corrected.

SITE INDEX

30. We recommend that differences in site index due to the methodology of estimation within species-BEC SIBEC cells be further investigated and the uncertainty associated with SIBEC estimates of site index be adequately and properly accounted for in the TSR and AAC determination processes.

31. Given the small sample sizes in a species-BEC cell in the SIBEC database, we recommend that the lower limit of a confidence interval, possibly at the 90% significance level, be used as the SIBEC value.

32. We recommend MFLNRO&RD ecologists investigate combining species-BEC with similar site index estimates in the SIBEC database, thereby reducing the amount of first approximation estimates and, most likely, reducing the confidence interval associated with a SIBEC estimate.

33. Given that site indices based on the PSPL are used in the TSR and AAC determination processes, and not site indices based on SIBEC and BEC from silviculture surveys, the "best available information" is not being used. We recommend that PSPL site indices only be used for managed stand polygons that do not have BEC from a silviculture survey.

34. We recommend that the predicted BEC from the PSPL be tested against the BEC determined in silviculture surveys. Any differences identified should be accounted for in PSPL-based estimates of site index in the TSR and AAC determination processes.

PROGNOSIS[BC]

35. We recommend that MFLNRO&RD provide an explanation as to why it uses VDYP7 in the TSR and AAC processes for stand conditions for which it was not parameterized, instead of models that have been specifically parameterized for these stand conditions.

VDYP7

Parameterization Data

36. FAIB's claims on MFLNRO&RD's VDYP7 website about the data used to parameterize and the data used to validate VDYP7 are misrepresentations and the "best available information" was not used in the parameterization of VDYP7.

Model Validation – Current Inventory

37. FAIB's claim on the MFLNRO&RD's VDYP7 website about VDYP7 model validation using the 2,700 inventory audit samples is a misrepresentation, which we recommend be corrected.

38. We recommend that the use of VRI volume adjustments in the TSR and AAC determination processes be reviewed, particularly given the small sample sizes and large variability in strata estimates, as was done in 1999. We further recommend that AAC determinations for which questionable adjustments were used be immediately revisited.

Model Validation – Projected Inventory

39. Contrary to claims by the MFLNRO&RD, VDYP7 inventory projections have not been validated and, as such, the associated uncertainty has not been accounted for in the TSR and AAC determination processes.

Limitations of VDYP7

40. We recommend that MFLNRO&RD investigate the use of LiDAR to estimate polygon stems and basal area per hectare for VDYP7 input. Also, we recommend that MFLNRO&RD investigate the use of LiDAR to estimate current polygon volume instead of using VDYP7.

41. We recommend that MFLNRO&RD assess the impact of the decision to force VDYP7 yield predictions at older ages to approach limits similar to those in VDYP6 and whether the decision is responsible for underestimating volume in older stands, such as those outside of the THLB.

42. We recommend that MFLNRO&RD compare the timber volumes estimated for MPB-affected stands modeled with VDYP7 and the adjustment process with those volumes estimated using the June, 2018 version of VDYP7 that was specifically parameterized for the modeling of MPB-affected stands. If the outcome of the comparison indicates an over-prediction for stands modeled with VDYP7 and the adjustment process, then we recommend that the AAC determinations that used the VDYP7 adjustment process be immediately reassessed.

43. We recommend that MFLNRO&RD provide documentation on the parameterization of empirical functions within VDYP7. Also, given the misinformation provided by MFLNRO&RD on the parameterization and validation of VDYP7, we recommend an independent third party conduct a review and report to the legislature.

44. We recommend that an independent third party review current (and future) VDYP7 documentation for errors, omissions and misrepresentations.

45. We recommend that MFLNRO&RD articulate and explain the rationale for using VDYP7 instead of TIPSY within the VRIMS for the updating of polygons that are modeled with TIPSY in the TSR and AAC determination.

TASS/TIPSY

46. Given that TASS III and TIPSY v4.4 yields have been approved and the differences from TIPSY v4.4 exceed any managed stand sensitivity analyses in the TSR, we recommend that the AAC and Type 4 Silviculture Strategies for all interior TSAs with substantial amounts of Pl and Sw be revisited and the uncertainty with TASS/TIPSY yields be properly accounted for.

Genetic Gain

47. We recommend that the TSR and AAC determination processes use genetic gain for sensitivity analysis and not the base case until the current MFLNRO&RD review of genetic worth and realized gain in TASS/TIPSY has been completed. If the chief forester wishes to

increase the AAC determination as a result of genetic gain, then we recommend that the increase be accompanied with a rationale supported by realized gain trial results.

Operational Adjustment Factors

48. We recommend that MFLNRO&RD release a definitive statement of what OAF 1 and OAF 2 represent; whether they can be adjusted with sample plot data and, if so, how; and how to factor in the predicted increased losses for forest health due to climate change.

YSM AND SDM DEBATE

49. We recommend that the ABCFP develop competency requirements for those involved in the statistical analysis of data. This is consistent with the competency recommendations (3 and 4) of the recently released Summary of Recommendations from the Independent Report on Professional Reliance.

50. While probably too late, we recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to provide an unbiased review of the YSM and SDM program debate.

51. We recommend that for the Provincial Timber Management Goals, Objectives and Targets, MFLNRO&RD develop meaningful performance benchmarks for mid-rotation yields for comparison to the results of the ground sample monitoring programs.

ALLOWABLE ANNUAL CUT DETERMINATIONS

52. We recommend that the *Forest Act* include the same type of protection against material errors, omissions or misrepresentations in AAC determinations as the Greenhouse Gas Emission Control Regulation and that an independent, third-party auditor review all current rationales for AAC determinations for material errors, omissions and misrepresentations related to the forest inventory and to the use of forest G&Y models.

Boundary TSA AAC (October 2016)

53. FAIB has provided no evidence to support its rejection of the 2009 MFLNRO&RD report that indicated VDYP7 estimates of current timber volume used in the Boundary TSA AAC determination (October 11, 2016) were overestimated by 20%. We recommend that the TSR and AAC determination for the Boundary TSA be reviewed.

Arrow TSA AAC (November 2017)

54. We recommend that the TSR and AAC determination for the Arrow TSA be reviewed to reflect the spirit and intent of Minister Donaldson's letter of guidance dated October 30, 2017.

Bulkley TSA AAC (January 2014)

55. We recommend that the AAC determination be redone using the PEM/SIBEC managed stand site indices in a sensitivity analysis and not the base case scenario, as specified by MFLNRO&RD guidelines for PEM that do not meet the minimum accuracy statistics.

56. We recommend that the Bulkley TSA VRI be redone and a new AAC determination be based on the new VRI. Meanwhile, the chief forester should significantly reduce the current AAC based on precautionary principles until an AAC can be re-determined using a valid inventory.

57. We recommend that MFLNRO&RD develop VRI adjustment standards that are statistically sound and can be applied consistently among TSAs, with particular reference to the practice of applying some adjustments and not others.

Prince George TSA AAC (October 2017)

58. We recommend that MFLNRO&RD provide an explanation as to how the YSM, SDM and forest health strategy data were used to determine an additional 1.1% OAF 1 reduction, beyond the standard 15% reduction. This represents an omission.

59. We recommend that MFLNRO&RD provide an explanation for the discrepancy of the VDYP7 attribute adjustment ratios between what is stated in the 2017 technical summary report and the 2015 VRI statistical analysis report. This represents an error.

Invermere TSA AAC (June 2017)

60. Clearly, the "best available information" was not used in the Invermere TSA AAC determination. The omission of any mention of the existing forest inventory is of concern, as is the misrepresentation of audit results. The question also remains as to what happened

to the VRI ground sample data and NVAF data collected in 2007 and 2008. Did MFLNRO&RD not receive a copy of the data prior to TECO (formerly Timberline) going out of business? If so, are there more cases of missing government data?

Miscellaneous TSA AACs

61. We recommend the chief forester provide a forest inventory assessment for TSAs that are missing the assessment in the rationale for AAC determination document.

62. We recommend that an independent third party review the Phase II VRI in TSAs where the data collected was deemed too unreliable to use.

63. We recommend that an independent third party review how RESULTS data are used in managed stand yield projections in the TSR and AAC processes.

64. We recommend that MFLNRO&RD assess the impact of the decision to force VDYP7 yield predictions at older ages to approach limits similar to those in VDYP6 and whether the decision is responsible for underestimating volume in older stands, such as those outside of the THLB.

65. We recommend that an independent third party review how forest health data is accounted for and applied in the TSR and AAC determination processes.

BACKGROUND INFORMATION

FOREST INVENTORY LEGISLATION

Prior to 2002, Section 2 of the *Forest Act*[2] stated that "the chief forester must develop and maintain an inventory of the land and forests in British Columbia".

2 — Inventory of land and forests

2 The chief forester must develop and maintain an inventory of the land and forests in British Columbia.

3 — Assessment of potential

3 The chief forester must assess the land in British Columbia for its potential for

(a) growing trees continuously,

(b) providing forest or wilderness oriented recreation,

(c) producing forage for livestock and wildlife,

(d) conservation of wilderness, and

(e) accommodating other forest uses.

4 — Forest land

4 The chief forester must classify land as forest land if he or she considers that it will provide the greatest contribution to the social and economic welfare of British Columbia if predominantly maintained in successive crops of trees or forage, or both, or maintained as wilderness.

When the responsibility for forest inventory was moved from MFLNRO&RD to MSRM, Sections 2 to 4 of the *Forest Act*[3] were repealed.

Repealed

2-4 [Repealed 2002-45-2.]

When the provincial government returned responsibility for forest inventory to MFLNRO&RD, it did not put back the repealed Sections 2 to 4 in the *Forest Act*. As a result, the province has no legislative mandate to develop and maintain a forest inventory.

While the ABCFP dances around the issue, they do state that no single, land-use decision can be made without resource information and that some data must be present for the chief forester

[2] http://www.bclaws.ca/civix/document/id/consol2/consol2/96157_02
[3] http://www.bclaws.ca/civix/document/id/lc/statreg/96157_02#part2

to consider all the factors listed in Section 8 of the *Forest Act* when making an AAC determination. In its *Forest Legislation and Policy Reference Guide (2015)*, the ABCFP writes:

> *"There are several indirect references to the requirement to collect inventory information in the Forest Act, in the Forest Practices Code Act and in the Forest Range and Practices Act. These references are so obtuse that it may lead one to believe that there is no legal requirement to collect resources inventory data in British Columbia. On close look, however, one will realize that no single land-use decision can be made without resource information".*
>
> *"It is quite clear from what is stated in section 8 that some data must be present for the chief forester to consider all the factors listed in section 8".*

Given that a reliable inventory is required to make land-use decisions and to determine AACs, we recommend that the legislative mandate for the province to develop and maintain a forest inventory be re-instated in the Forest Act. Without a legislative mandate, any recommendations concerning the forest inventory will likely have limited or no impact.

UNCERTAINTY AND BEST AVAILABLE INFORMATION

In addition to there being no legislative mandate for the province to develop and maintain a forest inventory, there is also no legislative mandate or guidance for the chief forester to consider the uncertainty associated with a forest inventory, although Section 8.8e of the *Forest Act* does state that the chief forester must consider *"abnormal infestations in and devastations of, and major salvage programs planned for, timber on the area"* when determining an AAC.

This is in stark contrast to the legislation governing forest carbon offsets projects in B.C. Under the *Greenhouse Gas Industrial Reporting and Control Act*[4], the *Greenhouse Gas Emission Control Regulation*[5] requires forest carbon offsets to be validated and verified to ISO 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 all documents for TSRs and AAC determinations, MFLNRO&RD makes no mention of taking a conservative approach when dealing with uncertainty. Instead, MFLNRO&RD purports to manage uncertainty in three ways: by assessing risk associated with specific uncertainties

[4] http://www.bclaws.ca/civix/document/id/lc/statreg/14029_01
[5] http://www.bclaws.ca/civix/document/id/lc/statreg/250_2015#section15

through sensitivity analyses; by periodic re-determination of the AAC; and thirdly, by using what is described as the "best available information".

Problems associated with these three methods of handling uncertainty are:

- The sensitivity analyses for G&Y model predictions are based on values, such as ±5% or ±10%. The values do not appear to be based on any type of analysis, but appear to be simply "plucked out of the air".

- Previously, the *Forest Act* required the chief forester to re-determine the AAC for a management unit at least once every five years but this has been changed to at least once every 10 years and can be postponed for up to 15 years. The main problem with such a lengthy re-determination period is that an AAC determination can "fall out of sync" with changes to models, with assumptions used in the TSR process, or with an increase in catastrophic events, such as fire and forest health losses, particularly in an era of increasing climate variability and change.

- The term "best available information" is a nebulous phrase that the chief forester and FAIB staff frequently apply to forest inventory data. The phrase 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.

Uncertainty is inadequately managed in the TSR and AAC processes. As suggested improvements, in addition to taking a conservative approach and having the TSR and AAC determination processes audited by an independent third-party, we recommend:

- ***Values used for the sensitivity analysis of G&Y model predictions be derived from comparisons to ground samples using sound statistical procedures and/or methodologies and established statistical practices.***
- ***The periodic AAC re-determination policy be replaced with a recalculation policy based on a "significance threshold", as is done with GHG emissions accounting. A significance threshold is a qualitative or quantitative criterion used to define any significant change to the data or calculation methodology that would trigger an immediate recalculation. This would require a streamlining of the TSR process. Therefore, we also recommend that the TSR process be shortened from two years to two months and the cataloguing and maintenance of TSR data files be improved.***

- ***Guidelines be established around the use of the phrase "best available information". As a consequence of lawsuits[6] in the United States over the words "best" and "available", the NOAA developed guidelines[7] around the use of the phrase. These guidelines are based in part on Canadian federal guidelines for the effective use of science and advice in government decision-making[8] and for the application of precaution in science-based decision-making about risk[9]. The use of the phrase "best available information" in inventory work and in AAC determinations falls short of these guidelines.***

STATISTICAL MISCONCEPTIONS

Although MFLNRO&RD has highly competent statisticians on staff, it appears these staff have not been consulted for many projects. As such, a number of statistical misconceptions, errors and inappropriate statistical analyses are identified in MFLNRO&RD's work on forest inventory and timber supply analyses.

MFLNRO&RD often uses the term "representative sample" to exclude data from analysis or to dismiss analyses based on data deemed "not representative". But MFLNRO&RD never defines what it means by "representative". In an overview[10] of what the term "representative" means in statistical literature, nine different interpretations were identified and it is recommended that instead of using the term "representative", one should specify exactly what one means.

MFLNRO&RD assumes that a random sample results in the previously undefined "representative sample". If "representative sample" is defined as selected by some process which gives all samples an equal chance of appearing to represent the population, thereby eliminating bias, this would be true. If "representative sample" is defined as typical of the target population in respect to certain characteristics, this would not necessarily be true[11].

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[6] Merrill, J.W. (2011). Trawling for meaning: a new standard for "best scientific information available" in the Magnuson-Stevens Fisheries Conservation Act, 60 Cath. U. L. Rev. 475. (http://scholarship.law.edu/lawreview/vol60/iss2/7)

[7] National Standard 2: Guidance on scientific information for fishery management (https://www.st.nmfs.noaa.gov/science-quality-assurance/national-standards/ns2_revisions)

[8] A Framework for Science and Technology Advice: Principles and Guidelines for the Effective Use of Science and Advice in Government Decision Making

[9] A Framework for the Application of Precaution in Science-Based Decision Making About Risk

[10] Kruskal, W. and Mosteller, F. (1979). Representative sampling, III: the current statistical literature. International Statistical Review, 47, 245–265.

[11] https://www.ma.utexas.edu/users/mks/statmistakes/RandomSampleImportance.html

The YSM study design[12] document contains a number of statistical misconceptions and errors:

- MFLNRO&RD incorrectly states that the CLT justifies a minimum sample size of 30. The CLT makes no recommendations of sample size for any given survey. This misconception often leads to MFLNRO&RD determining or reducing sample sizes due to budget constraints, with 50 seeming to be the most common sample size. More often than not, the result is an analysis with a sample size that is too small on which to make any definitive conclusions.

- MFLNRO&RD incorrectly describes domain analysis as post-stratification and provides incorrect formulae for determining the standard error of a domain. In domain analysis, the data within the domain are used to calculate the mean, but all of the data, including those not in the domain, are used to calculate the standard error. Data not in the domain are given a predicted value of zero for the standard error calculation to account for the random sample size.

  In sample survey terminology, the term post-stratification is used for sample weights that are used after sampling to make the sample typical of the target population in respect to selected characteristics. These weights are generally used to permit accurate estimation of population parameters when small groups within a population are purposefully over-sampled in order to gain precision sufficient for estimations within the groups[13].

- MFLNRO&RD recommends a value of 0.60 for the (1-β) term in the power calculation used to determine sample size, where β is the probability of not rejecting the null hypothesis when it is false. Most biometricians/statisticians would consider a value of 0.90 to be a more appropriate value, with 0.80 being the lowest that should be used.

- MFLNRO&RD recommends conducting a *post hoc* power analysis. This type of analysis, also known as a retrospective power analysis, provides no additional information beyond what the p-value has already shown, as the observed power can be derived from the observed p-value[14].

MFLNRO&RD incorrectly assumes that a non-significant result for a null hypothesis significance test infers equality. While equality can never be proven with statistics, equivalence can be

[12] A framework for implementing young stand monitoring in British Columbia – a discussion paper
[13] https://en.wikipedia.org/wiki/Sampling_bias
[14] Hoenig. J.M. and D.M Heisey. (2001). The Abuse of Power, The American Statistician, 55:1, 19-24

inferred using an analysis of equivalence test. Equivalence is based on an equivalence margin, defined as a range where the predicted and observed results are close enough to be considered similar. In practical terms, the equivalence margin is the maximum operational difference that one is willing to accept.

MFLNRO&RD has a tendency to focus on point estimates, which do not consider uncertainty, when they should be focusing on interval estimates, which do consider uncertainty. The inventory is full of what MFLNRO&RD refers to as "statistical adjustments", such as DVAF, GVAF, NVAF and VDYP7 attribute adjustments. What is missing in MFLNRO&RD analyses is whether the unadjusted (original) value is within the confidence interval of the data used to determine the adjusted value or, in other words, whether the unadjusted and adjusted values are equally likely given the uncertainty involved. The smaller the sample size used for adjustments, the more likely the unadjusted value will be in the confidence interval of the data used to determine the adjusted value.

Most of the statistical misconceptions and errors listed above have previously been pointed out to MFLNRO&RD in a 1999 review[15] of the application of inventory audit data, but the misconceptions and errors persist. We recommend that the ABCFP develop competency requirements for those conducting statistical analysis of G&Y and inventory data. This is consistent with the competency recommendations (3 and 4) of the recently released "Summary of Recommendations from the Independent Report on Professional Reliance"[16].

CLIMATE CHANGE AND GROWTH PROJECTIONS

Climate change has drastically increased the uncertainty in growth predictions made with current models – VDYP7 for existing (natural) stands and TASS/TIPSY for future (managed) stands.

VDYP7 is an empirical model parameterized using statistical relationships based on past forest growth to make future projections. As such, VDYP7 estimations are dependent on future conditions being similar to past conditions. This is no longer true with climate change.

TASS/TIPSY predictions are driven by height growth, crown expansion and bole increment, making TASS somewhat of a hybrid model. While the height-growth component of TASS is empirical, the crown expansion and its effect on bole increment and mortality are more of a

[15] Review of the Application of Forest Inventory Audit Information in Timber Supply Review Timber Supply Analyses, B.C. Forest Service, Research Branch
[16] https://engage.gov.bc.ca/professionalreliance/

process (mechanistic) model. The TASS modelers feel that the internal structure of TASS is sufficiently flexible to accommodate many of the predicted changes in tree growth and mortality under different climate change models because the fundamental biological relationships underlying tree growth and stand development are "assumed" to remain stable under climate change[17].

To date, nothing appears to have been done to account for climate change in VDYP7 or in TASS/TIPSY. In the forest minister's response to the Estimates Debate questions on TASS/TIPSY, dated December 12, 2016, the minister states:

> *"Another goal is to incorporate climate sensitivity into TASS. A range of possible approaches were identified in a recent FAIB problem analysis, including adjustments to site index equations and the use of seed population response functions. FAIB will be working closely with ministry and university site productivity and genetics specialists to evaluate which approach will be best".*

Actually, the only work that has been done is to link a transfer function to a lodgepole pine height-growth model[18]. The transfer function predicts relative height (site height of a population divided by the site height of the local population) as a function of mean annual temperature transfer distance and mean annual temperature of the provenance. Linking the transfer function to the height-growth model allows the evaluation of climate change on height growth, but only in terms of temperature and not precipitation.

Given the minimal efforts to date, it is unlikely the MFLNRO&RD will be able effectively to incorporate climate change into VDYP7 or TASS/TIPSY predictions in the near future. Although a recent ITT (1070-30/OT19FHQ113) for TASS Strategic Model Development contains a lengthy list of services to be provided, there is no mention of climate change. Similarly, a 2017 NOI specified a number of corrections and enhancements for VDYP7, but none deals with climate change.

Realistically, a process model that at a minimum links length of growing season, temperature and precipitation to tree growth is required to account for climate change. Problems associated with this are:

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[17] B.C. Ministry of Forests and Range. 2010. TASS: predicting British Columbia's future forests. For. Sci. Prog., Victoria, B.C. (www.for.gov.bc.ca/hfd/pubs/Docs/Bro/Bro90.htm)

[18] Gord Nigh; Mitigating the effects of climate change on lodgepole pine site height in British Columbia, Canada, with a transfer function, Forestry: An International Journal of Forest Research, Volume 87, Issue 3, 1 July 2014, Pages 377–387, (https://doi.org/10.1093/forestry/cpu009)

- Given MFLNRO&RD's commitment to VDYP7 and TASS, it is unlikely it will fund the development of such a model,
- Data to parameterize such a model is probably limited due to gaps in climate measurements and,
- Such models are difficult and time consuming to parameterize and validate.

One option may be to explore the use of existing models that have the ability to account for climate change, such as the FORECAST Climate[19] model. FORECAST is a proprietary UBC model that has been used to examine impacts of alternative, stand-level, management strategies in B.C.[20]

Given the increased uncertainty in G&Y model predictions due to climate change, monitoring has become more crucial than ever. We recommend that the forest inventory be strengthened with sufficient periodic monitoring to identify deviations from trends predicted by the G&Y models used in the TSR and AAC processes.

PROFESSIONAL RELIANCE AND THE USE OF GROWTH AND YIELD MODELS

The ABCFP defines professional reliance as "*the practice of accepting and relying upon the decisions and advice of forest professionals (Registered Professional Foresters and Registered Forest Technologists) who accept responsibility and can be held accountable for the decisions they make and the advice that they give"*[21]. They also go on to state professionals are accountable to the public through the ABCFP.

The ABCFP does not consider the development of G&Y models to fall under the practice of professional forestry, but they do consider the use of G&Y models to estimate yields and the flow of timber for an AAC determination to fall under the practice of professional forestry. This leaves a big hole in the professional reliance model when it comes to G&Y models and leads to the awkward situation where model users, not model developers, are professionally responsible for the model estimations and their inherent uncertainty.

This leads to two types of G&Y model users:

[19] http://web.forestry.ubc.ca/ecomodels/moddev/forecast%20climate/forecast%20climate.htm
[20] http://web.forestry.ubc.ca/ecomodels/projects/arrowifpa/ifpa_summary.htm
[21] https://abcfp.ca/web/ABCFP/About_Us/Governance/Professional-Reliance/ABCFP/Governance/Professional-Reliance.aspx?hkey=1f1c4d40-c9f7-483a-ba1a-5ca6f0362455#review

1. Those that have limited G&Y experience and simply run the models and accept the output under the guise of professional reliance, even though the ABCFP states that professional reliance "*is definitely not an avenue to divest responsibility or avoid accountability, nor an excuse for blind deference by either*[22]" and,

2. Those that have G&Y experience and attempt to understand the G&Y models being used, validate the G&Y model estimations, and account for the uncertainty in G&Y model estimations.

The work of the second type of model user is made difficult owing to (many of which can be described in terms of errors, omissions or misrepresentations):

- Documentation on the parameterization of G&Y models and/or their components is virtually non-existent for VDYP7 and TASS/TIPSY,
- Current MFLNRO&RD staff were not involved in the development of VDYP7 and tend to have misconceptions about VDYP7 parameterization, calibration and validation,
- MFLNRO&RD has provided some users with information on TASS/TIPSY that conflicts with what has been made public,
- MFLNRO&RD has provided conflicting information on VDYP7 and TIPSY comparisons,
- MFLNRO&RD has provided conflicting definitions of model adjustments and data required to initialize G&Y models,
- MFLNRO&RD has inconsistent data access policies and,
- MFLNRO&RD controls access to information and data collected with public funds to control the message they provide to the public on the sustainability of current AACs associated with publicly owned forest resources.

More importantly, there is currently no professional oversight of the development of G&Y models in B.C.

We recommend that the ABCFP develop competency requirements for those that use G&Y models to estimate timber yields, the flow of timber for AAC determination, and forest carbon sequestration. This is consistent with the competency recommendations (3 and 4) of the recently released Summary of Recommendations from the Independent Report on Professional Reliance.

[22] Role of the ABCFP in Professional Reliance – Victoria Workshop – December 15, 2010

Also, we recommend that a committee, such as the G&Y Cooperative[23] that the ABCFP has advocated for, be established to oversee the development and use of G&Y models, to oversee the establishment and analysis of ground samples for model adjustment, model validation and monitoring, and to ensure all G&Y model users have access to the same and consistent model documentation. This is consistent with accessibility of professional documents recommendations (16 and 17) of the ABCFP Stakeholder Submission to the B.C. Government's Professional Reliance Review[24].

[23] https://abcfp.ca/web/ABCFP/About_Us/Stewardship%20Advocacy/Advocacy-Activities/ABCFP/About_Us/Advocacy-Activities.aspx?hkey=ae5bc5a1-d9ab-47a4-abfe-61541a1ebbd4
[24] https://abcfp.ca/web/ABCFP/About_Us/Governance/Professional-Reliance/ABCFP/Governance/Professional-Reliance.aspx?hkey=1f1c4d40-c9f7-483a-ba1a-5ca6f0362455#review

ESTIMATES DEBATE QUESTIONS

INDIVIDUAL TREE VOLUME

There is no consistency in how MFLNRO&RD calculates individual tree volume in B.C.:

- Timber Pricing Branch ground samples use the 1988 Kozak FIZ-based taper function, net factoring and FIZ-based NVAFs derived from out-of-date NVAF data obtained from FAIB (NVAFs have not been updated since 2014) for the coast,
- Timber Pricing Branch ground samples use the 1988 Kozak FIZ-based taper function and 1976 FIZ-based DWB loss factors for the interior,
- FAIB PSP and TSP ground samples use the 2002 Kozak BEC-based taper function, 2000 BEC-based DWB loss factors v3.0 and BEC-based DVAFs and GVAFs,
- FAIB VRI, CMI and NFI ground samples use the 2002 Kozak BEC-based taper function, net factoring and BEC-based DVAFs, GVAFs and NVAFs,
- VDYP7 uses stand level reductions for DWB using equations derived from ground sample data compiled using the 2000 BEC-based DWB loss factors v3.0 and,.
- TIPSY v4.4 uses an OAF 2 to account for DWB,

With respect to terminology, there is no distinction between the different methodologies and all of the calculated volumes are referred to using the same terminology: total volume[25], GMV and NMV. This can cause confusion and errors when comparing model predictions to each other, model predictions to ground samples or ground samples from different MFLNRO&RD sampling programs. In fact, this type of confusion between the NMV used in VDYP7 and the NMV used in the compilation of PSP and TSP ground samples is what led to the CFS' stand-level volume-to-biomass conversion equations (VTBs) being declared problematic in 2009 and eventually replaced.

We recommend that MFLNRO&RD adopt a common method for the calculation of individual tree volume to be used among all branches within the ministry.

We recommend that MFLNRO&RD review the policy of subdividing species data by BEC zone for fitting taper functions and instead, look at groupings suggested and supported by the data.

The FAIB NVAFs are constantly in a state of change. Originally, NVAFs were supposed to be exclusively for the same management unit as the VRI with which the NVAFs were collected.

[25] Volume of the total stem

Given that the taper function is BEC-based and a management unit can contain many BEC zones, it is assumed that the NVAFs by management unit had too much variation and FAIB recalculated the NVAFs by BEC. As such, each time a management unit has new VRI and NVAF sampling, the BEC-based NVAFs require updating. As an example, in 2015 the GVAF for mature Douglas-fir in the ICH (all except ICHwk) was 0.96423 and in 2018 it is 0.98155.

Currently FAIB groups data for GVAF or NVAF by numerous combinations of live/dead, species/species group, and BEC-site series/BEC-site series group. This can lead to instances where the adjustment factors make no sense. As an example based on adjustment factors obtained from FAIB in 2015, the GVAF for dead Douglas-fir anywhere in the interior is 1.18419 and the GVAF for live mature Douglas-fir in the ESSF is 0.93693. When a tree dies, its volume will increase by over 25% if the GVAFs are blindly applied!

We recommend that MFLNRO&RD make date-stamped databases of GVAF and NVAF factors available on their website with a rationale provided for the groupings. We also recommend that MFLNRO&RD ensure that the GVAFs and NVAFs are compatible between live and dead trees and, if not, provide guidance as to how they are to be applied.

We further recommend that MFLNRO&RD define a "change threshold" that triggers a recalculation of past analyses to account for changing NVAFs and GVAFs. If the response is that the GVAFs and NVAFs do not change enough over time to warrant such a threshold, the question as to why the GVAF and NVAF data are still being collected should be addressed.

With respect to the last recommendation, the current status of NVAF sampling is not clear. Recent ITTs[26] for LiDAR CMI sample establishment specifies that call grading, net factoring, damage agent, loss factor, small tree and stump data are not to be collected.

The pathological indicators used to determine decay for the 2000 BEC-based DWB loss factors v3.0 are recorded as part of the NVAF data collection. As such, it would be possible to develop NVAFs that could be applied to the compilation of PSP data and other sample data without net factoring. If the same NVAF data and groupings used for the VRI, NFI and CMI data are used, the individual tree volumes for the PSP data would be more in line with the other sample types.

We recommend that MFLNRO&RD develop NVAFs to be used in the compilation of PSP data (and of Timber Pricing Branch interior appraisal cruise data if the branch is not going to adopt net factoring and NVAF adjustment).

[26] 1070-30/OT19FHQ185 and 1070-30/OT19FHQ186

TASS/TIPSY add another dimension to individual tree volumes. BEC has no influence on TASS individual tree volumes. Within TASS, volume for each individual tree is determined by an annual layer of bole increment that varies by crown size and stand density. As such, two trees of the same species, DBH and height in the same stand can have different volumes and trees of the same size in stands with different densities can have quite different volumes. This is not a problem until one compiles ground sample data with the FAIB methodology and one compares the resultant stand volume per hectare to a stand volume per hectare estimated with TASS/TIPSY, as is done in YSM analysis.

We recommend that the difference in TASS-generated individual tree volume and FAIB-compiled tree volume be taken into account when comparing stand volume derived from FAIB-compiled ground sample data to stand volume estimated by TASS/TIPSY.

TIPSY v4.4 does not have reductions for DWB. Previous versions of TIPSY had what was supposed to be the same stand level DWB as in VDYP7. As it turned out, FAIB had provided the wrong DWB functions. The stand-level DWB functions provided by FAIB were based on tree-level decay reductions developed by Lemay and Gulyas[27]. These were never implemented in VDYP7 by FAIB as they were replaced by stand-level DWB functions based on tree-level decay functions developed by Flewelling[28,29].

GROUND SAMPLES

Phase II Vegetation Resources Inventory

VRI ground sample data are collected by management unit and used to adjust volumes estimated with VDYP7, as outlined in the section on VDYP7 Validation – Current Inventory. Once VRI plots are used to adjust inventory volumes, another set of independent ground samples is required to assess the accuracy of the adjusted volumes.

We have identified three issues with using VRI data for volume adjustment – namely sample size, sample stratification, and sample location.

[27] LeMay, V. M. and G. Gulyas. (1995). Equations to estimate percent decay and waste by species, BEC zone, and risk group. A report prepared for the BC Ministry of Forests.

[28] IPSJF131A. (2000). Unpublished VDYP7 document prepared for FAIB by Jim Flewelling.

[29] IPSJF802. (2000). Unpublished VDYP7 document prepared for FAIB by Jim Flewelling

1. Compared to past inventories, the number of ground samples in a management unit is quite small. Stratification for volume adjustment is usually done by species and many of the adjustments are based on a very small sample size.

2. VDYP7 is parameterized by species and BEC zone (or combined BEC zone). Volume adjustments by species only will combine VDYP7 estimations for the various species-BEC estimations, thereby increasing the variation. This is the same problem that led to the NVAFs from all management units being combined and grouped by BEC classes.

3. VRI sampling covers the vegetated treed polygons in a management unit and not just within the THLB. In a number of the TSAs, the non-THLB portion contains a greater proportion of over-mature vegetated treed polygons, as compared to the THLB. For these types of management units, the VRI attribute adjustment and VRI statistical analysis documents indicate that this can lead to increased variation within a strata being adjusted within the THLB or to inappropriate adjustment ratios. In some cases, the non-THLB data are excluded, further shrinking the already small sample size.

We recommend that the use of VRI volume adjustments in the TSR and AAC determination processes be reviewed, particularly given the small sample sizes and large variability in strata estimates, as was done in 1999. We further recommend that MFLNRO&RD immediately revisit AAC determinations in which questionable adjustments were used.

National Forest Inventory and Change Monitoring Inventory

The NFI ground samples are a partnership between the CFS and MFLNRO&RD for monitoring change. The NFI sampling design divides the province into a 20x20 kilometre grid. At each grid intersection, a 2x2 kilometre photo plot is established. There are 2,414 photo plots in B.C., covering approximately 1% of the province. NFI ground samples are established in 268 of the photo plots.

The CMI ground samples are administered by MFLNRO&RD and are being located in all of the photo plots without an NFI plot. CMI ground plots have the same tree measurements as the NFI plots, but do not include soil sampling and other detailed non-timber measurements[30].

[30] Status of British Columbia's Provincial Forest Inventory – June, 2015.

Given that once VRI ground samples are used to adjust the VDYP7 estimates of volume and another set of independent samples is required to assess the accuracy of the adjusted volumes, the NFI and CMI are the only ground samples MFLNRO&RD has for this purpose.

In many cases, the NFI and CMI ground samples have been combined with the VRI ground samples for the VDYP7 volume adjustment, leaving no way to assess the accuracy of the adjusted volumes.

We recommend that NFI and CMI plots not be used for VDYP7 attribute adjustments so that they can be used to assess the accuracy of the adjusted VDYP7 volumes.

Permanent Sample Plot

The 2016 Estimates Debate questions identified the following issues with MFLNRO&RD's management of the PSP data:

1. The FAIB SAS PSP compiler does not compile data correctly, particularly since the Forest Productivity Council redefined how species composition, top height and site index are to be calculated in the mid to late 1990s.
2. The FAIB Oracle PSP database is incapable of proper data validation.
3. FAIB has no record of the changes made to the PSP data during the 1997-2002 data validation project, including:
    a. Changes that were supposed to be verified in the field;
    b. Changes that were made to bypass problems with the FAIB Oracle PSP database validation so that the data could be loaded into the database;
    c. Changes that affect FAIB's assessment of what PSP data to continue measuring and which PSP data to archive; and,
    d. Changes that should have been made to data management programs, but were made to the PSP data due to FAIB not having funding to correct the programs.
4. Although the species composition, stand age, top height and site index were calculated to Forest Productivity Council standards during the data validation project and embedded in the Standard Edit Data files returned to FAIB in 2002, FAIB immediately replaced these values with incorrectly compiled values from the FAIB SAS PSP compiler.

The net result is that FAIB has provided corrupt and incorrectly compiled PSP data to modelers and other data users for decades. To support these claims:

1. We documented the ongoing problems with biomass conversion equations, mainly due to corrupt and incorrectly compiled PSP data, from 2003 until 2014;

2. We documented compilation errors and their consequences in the FAIB report[31] entitled "Potential Applications of Growth Natural PSPs for MPB-Impact Analyses";
3. We documented the corrupt, out-of-date and incorrectly compiled PSP data used to parameterize VDYP7;
4. We provided examples of incorrectly compiled data provided to modelers and users that were reported to FAIB in 2003, 2011, 2013, 2014 and 2015;
5. We documented that FAIB direct awarded a contract in 2005 to load the PSP data into the FAIB PSP Oracle database without validation, primarily due to problems with the database's validation procedures that would not allow the data to load; and,
6. We documented that the PSP data had only partially been transferred for the "data warehouse" to the FAIB Oracle PSP database as of 2008, contrary to past claims by FAIB.

In the 2016 forest minister's response to questions put to him by the opposition forestry critic:

1. MFLNRO&RD claims that FAIB has a viable compilation system in place for all data when in fact, the first time FAIB compiled the data correctly was in an October, 2017 release and that was only due to the compilation errors repeatedly being pointed out to FAIB staff over many years. This correct compilation, we should add, happened more than 25 years after the initiation of the project to develop the FAIB SAS PSP compiler.

   The file ***data_2014_2017.xlsx*** that accompanies this submission is the ***data_2014_2015.xlsx*** file submitted with the 2016 Estimates Debate questions with the values from the 2017 FAIB compilation added. The FAIB 2017 compilation values support the criticism in the 2016 Estimates Debate concerning the compilation errors in the FAIB report entitled "Potential Applications of Growth Natural PSPs for MPB-Impact Analyses".

   The problem is not just with the above mentioned report, but with any analysis that relied on FAIB PSP data compilation.

2. MFLNRO&RD claims it cannot provide the amount of public funds spent to replace old PSP storage, validation and compilation systems as they were developed over many years, completed decades ago, predate current staff, and were part of a larger project. The only truth in this statement is that the work predates current staff. The systems were never completed decades ago. Instead, what should have been completed within a

[31] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/permanent-sample-plot/planning-reports

couple of years has been going on for decades with no accountability for the extensive amount of public funds used.

3. MFLNRO&RD strongly disagrees with the assertion that the PSP data are mismanaged, yet provides nothing to support this statement or to counter the examples of data mismanagement provided in the 2016 Estimates Debate question.

   Although the 2017 compilation finally appears to be correct, there are still problems with data management that affect the compilation. In the ***data_2014_2017.xlsx*** file, the 2017 values are still slightly different from the last compilation made for the data validation project in 2002. The reason for the difference is that FAIB is corrupting the per-hectare factors, as can be seen with the changing values in the 2014, 2015 and 2017 FAIB compilations. The per-hectare factors in the 2002 compilation are what was in the data returned to FAIB.

4. MFLNRO&RD claims to be committed to continuous improvement and communicating changes made to products and services. It is hard to envision how this is accomplished when MFLNRO&RD does not acknowledge problems with its products and services provided by FAIB. In spite of the overwhelming evidence of PSP data mismanagement presented in the Estimates Debate questions, MFLNRO&RD insists there is not, or ever has been, a problem.

We recommend an independent third-party review the complete history of the replacement of the VAX-based PSP data storage, validation and compilation systems, along with an accounting of the public funds used and misused, and report to the legislature.

We also documented that since FAIB has no record of the changes made to the PSP data during the data validation project, the opportunity to validate the changes in the field was missed during FAIB's 2012 to 2015 reconnaissance to determine the status of PSPs.

Instead, in spite of numerous attempts to make FAIB staff aware of the problem, FAIB has continued since 2003 to insist it does not require a record of the changes. The opposition forest critic asked the forest minister for authorization to destroy the data and records from the data validation project. The forest minister would not provide such authorization.

We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, review FAIB's rationale for, and the changes made to, the PSP data during the data validation project, whether the changes should be validated in the field, and provide a

recommendation as to whether the data and records from the data validation project be destroyed.

We do note that the main MFLNRO&RD website[32] provides the incorrect 2011 compilation of PSP data for users and the general public to download. The 2017 compilation, the first correct compilation ever provided by the FAIB SAS PSP compiler, is hidden on the MFLNRO&RD FTP site[33]. We have informed MFLNRO&RD of this problem numerous times since 2013.

We recommend that MFLNRO&RD review their website to ensure incorrect information is not being provided to users and the general public.

Stand Development Monitoring and Analysis

The SDM program was developed under FREP to assess whether or not managed stands were continuing to meet the expectations placed upon them at the time of free-growing surveys. The SDM protocol pays particular attention to forest health agents and how they affect mid-rotation stand productivity. The SDM protocol was designed to provide a mid-rotation check of stand conditions that could be used to update inventory labels to reflect current stand conditions.

In most MFLNRO&RD forest sampling programs, **every** incidence of a forest health issue is recorded for a tree. For this type of forest health monitoring, incidence does not necessarily translate into an impact, such as mortality, reduced growth, or reduced merchantability. Decades of successive measurements are required to gather enough information to model the impact based on **any** incidence.

While the collection of forest health incidence is a component of most MFLNRO&RD forest sampling programs, it has not been a priority. As a result, the forest health information collected in the past is very difficult to interpret, challenging to analyze and, for the most part, cannot be used to determine impact from incidence.

Because the intention is not to re-measure SDM samples, ministry forest health staff developed a specialized methodology for recording forest health issues:

- Record only forest health issues that the field crew felt would affect the survival or the merchantability of the tree at rotation;

[32] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/permanent-sample-plot/standards
[33] ftp://ftp.for.gov.bc.ca/HTS/external/!publish/faib_ground_samples

- Record only one, the most relevant, forest health issue for a tree; and
- Record the diameter of all affected trees, including those that were dead.

The objective of the SDM methodology is to provide forest health assessments that can be immediately applied to planning and management decisions without having to wait for decades. It is based on accepting the assessment of trained forestry professionals, otherwise known as professional reliance.

The original target population[34] for the SDM program was all polygons in the RESULTS database that were even-aged, between the ages of 15 and 40 and had been surveyed for free-growing.

The sampling frame for SDM is based on polygons within the target population. Polygons are randomly selected from the target population (not proportional to size) and 10 plots are randomly located in each selected polygon. The multi-plot design is intended to provide information that is representative, defined as typical of the polygon sampled, allowing meaningful comparisons to the polygon history records in the RESULTS database. The multi-plot design can also be used to assess within polygon variability.

The stand conditions at free-growing, obtained for the RESULTS database, were to be used as a comparison point and, as such, SDM measurements included those used in silviculture surveys, such as the number of well-spaced and free-growing trees, as well as the total number of trees.

The definition of the original target population was stable until 2013. Most SDM samples were established before 2013. After 2013, the definition went through a number of changes, such as a minimum polygon size, exclusion of polygons that had been silviculturally treated (thinned, pruned or fertilized, etc.) in the last 8 years, exclusion of polygons less than 10 years since the free-growing survey and a few others[35]. These changes led to the problem of what population do the SDM samples actually represent. Also, they seriously affected the comparison, interpretation and application of results using samples established after 2013.

Another issue with the SDM data was that tree heights were only measured on a maximum of four trees per plot. There is a great deal of variation in heights among trees in young stands. Consequently, height-diameter equations, derived from the heights that were measured, are usually inadequate for the estimation of all tree heights. Tree volume estimates using the

[34] Protocol for Stand Development Monitoring – June, 2010 (https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/indicators/)
[35] Protocol for Stand Development Monitoring – March, 2014 (https://www.for.gov.bc.ca/ftp/hfp/external/!publish/FREP/indicators/)

MFLNRO&RD taper functions that require species, DBH and height as input can be a problem in the SDM data. As such, basal area is more reliable than volume when making comparisons with SDM data.

From 2009 until 2013, MFLNRO&RD established SDM samples in a number of TSAs across the province. The ministry produced a number of reports summarizing the data[36], but the compilations were erroneous because they did not account for the sample design and many had obvious errors. This is in part the result of the estimators required for analysis not being clarified prior to program implementation -- another issue with the SDM program.

In 2017 MFLNRO&RD Research staff in the North Area led an analysis to combine the SDM samples from the northern interior and to summarize the results[37]. MFLNRO&RD biometricians were consulted for guidance on how properly to compile the data, based on the sampling design. The estimators required for analysis were documented in a supplemental report. Results of the analysis indicate that losses due to forest health issues are not being adequately accounted for in yield estimations for managed stands.

SDM data were used as the rationale for increasing the minimum and target stocking values for the FSP regeneration and free-growing stocking standards in the Nadina District. This increase in stocking values is to offset a decrease in stocking that was observed in the SDM samples since the free-growing declaration[38].

Although the SDM program is referenced in some rationales for AAC determinations as an **unquantifiable** downward pressure on the AAC, SDM incidence summaries have not been used to reduce estimated future yields in managed stands.

In other words, while district and regional staff trust the forest health assessments of forest professionals, supported by the foundation of the SDM sampling protocol developed by professional forest health experts, the chief forester evidently does not. **Why?**

Recent changes to the SDM program are discussed under the **YSM and SDM Debate** section of this submission.

[36] https://www.for.gov.bc.ca/ftp/hfp/external/!publish/2013%20SDM%20TSA%20Summaries/SDM%20-%20TSA%20Summaries/

[37] Warning Signals of Adverse Interactions between Climate Change and Native Stressors in British Columbia (http://www.mdpi.com/1999-4907/8/8/280)

[38] Forest Health Strategy – Nadina District 2016-2017 (https://www.for.gov.bc.ca/HFP/health/TSA_strategies.htm)

We recommend that the SDM data be summarized correctly, using the estimators documented in 2017, and that the SDM summaries be used in the AAC determinations as the "best available information" to reduce projected managed stand yields until such time as other MFLNRO&RD sampling programs can provide better estimates, that are supported with re-measured data over decades, of impact due to forest health agent incidence.

Young Stand Monitoring and Analysis

The YSM program was implemented by FAIB in 2011 and the current objective[39] is:

> *To check the accuracy of the GY predictions (assumptions) of key timber attributes of young stands used in TSR in a management unit, based on an independent random sample of monitoring plots. The TSR assumptions include stand gross and net volume (gross volume less cruiser-called decay and waste), site index, total age, and species composition and succession.*

This is slightly different from the original objective[40] that listed pest and disease incidence and TASS/TIPSY OAFs under TSR assumptions.

The YSM target population is 15- to 50-year-old stands, based on the projected age in the VRI, on Crown land. As such, it can include both natural and managed stands within or outside of the THLB.

We should note that the YSM target population may lead to plot locations that are not in the RESULTS database and therefore have no record of the past history. As an example, only six of the 71 YSM samples are in a polygon that is also in the RESULTS database.

The YSM sampling design[41] is described as:

> *"The method for selecting monitoring plots is a systematic (grid) sampling design with a random start from within the NFI 20 km x 20 km grid. The grid will be such that the grid intersections uniformly cover the management unit. The grid size (spacing) will depend on the chosen sample size for a given monitoring unit. Each monitoring grid will be used for the initial plot establishment and for adding new (young) plots. The monitoring grid shall be nested within the NFI grid, and will not change over time."*

[39] A Framework for Implementing Young Stand Monitoring in British Columbia – November, 2013
[40] A Framework for Implementing Young Stand Monitoring in British Columbia – January, 2012
[41] A Framework for Implementing Young Stand Monitoring in British Columbia – November, 2013

The sampling frame for YSM is based on points within the target population. On the one hand, sampling points, as opposed to polygons, eliminates the problems associated with changing polygon boundaries over time. On the other hand, the Morice, Kootenay Lake and Quesnel YSM analyses point out that although YSM sample values are unbiased, they have low precision as they may not be representative of the polygon they are located in. This could cause problems when comparing results to past history, such as the data contained in the RESULTS database, if available.

We have encountered two different descriptions of how YSM samples are located:

1. The YSM sample selection for the Morice TSA required 50 samples with 100 alternates. A grid size of 2x2 km was selected as the grid nodes intersected 177 points that fit the YSM target population. The 177 was divided by 50 to obtain an interval (*n*) of 3.54 and every n^{th} sample was an initial sample.
2. For the Prince George TSA, the YSM sample size was determined by overlaying various grid sizes over the land base. A 10x10 km grid yielded 74 samples and this became the sample size with no alternates.

Neither description follows the documented methodology for selecting YSM sample locations. In the first description, there is no mention of a random start for the grid; samples are not established on each grid intersection; samples are established on a subset of the grid intersections, using a systematic sampling methodology, that suggests some sort of multistage sample design; and there is no random start to the selection of the subset of grid intersections. In the second description, there is no mention of a random start for the grid.

Our main concern is that in both descriptions, there is no mention of the term **"random"** and as such, no probability in the selection of sample locations.

The YSM sampling design states that the grid size will not change over time. A few scenarios are presented with anticipated changes in the target population over time and how the increase in samples eligible for inclusion (those that grow past age 15) and decrease in samples no longer eligible for inclusion (those that grow past age 50) can easily be managed. What is not considered is a large increase in the target population due to catastrophic changes, such as wildfire or mountain pine beetle.

This is exactly what happened in the Merritt TSA. Originally, a 2x2 km grid was used to establish 37 YSM samples in 2005-2007. By 2013, the target population had expanded from 16,596 hectares to 91,985 hectares owing to the mountain pine beetle, and the number of YSM sample locations on the 2x2 km grid rose to 200. The grid size was changed to a 4x4 km grid, which

yielded 57 YSM sample locations. Of the original 37 YSM samples, 22 were not on the 4x4 km grid and were dropped. Of the 15 remaining, one was older than 50 years and was dropped, leaving 14 of the original 37 YSM plots. Of the 57 YSM sample locations on the 4x4 km grid, 2 were older than 50 years and were dropped. The new YSM sample is 14 samples from the 2005-2007 establishment and 41 new YSM samples.

The net result is that MFLNRO&RD wasted public funds on the establishment of 22 samples that were dropped due to the change in grid size.

We recommend that a qualified, independent, third-party biometrician review the YSM program sampling method with respect to whether it results in a random sample of the intended target population and whether it can affordably maintain a sample that is representative (typical) of the target population in the event of catastrophic events that are predicted to increase with climate change.

The YSM sampling design indicates that power analysis **may** be used to determine sample size, but also leaves the door open to determining the sample size based on the available budget, with a minimum of 30 samples. The framework document devotes a lot of space to explaining power analysis and provides examples. Power analysis was never used to determine sample size for any of the TSAs sampled and it appears that the available budget was used for all TSAs.

The foolish researcher is one that sets sample size based on available budget[42]. Resource constraints are a fact of research life. If the goal is to conserve limited resources then the first question that should be asked is "does the study have the power to detect the phenomena one is seeking?" If not, one should consider whether the resources are best spent elsewhere.

We recommend that a qualified, independent, third-party biometrician review the YSM sample sizes with respect to whether the objectives can be met with the current sample sizes.

Although the YSM program clarified the estimators prior to program implementation, the concept of domain analysis (referred to as post-stratification by FAIB) was not properly accounted for in the calculation of standard errors. This has been corrected in a new sampling framework for YSM and CMI plots that was released in 2018[43]

[42] Ellis, P.D. (2010). The essential guide to effect sizes, statistical power, meta-analysis, and the interpretation of research results. Cambridge University Press.

[43] Provincial Change Monitoring Inventory (CMI) and Young Stand Monitoring (YSM) Sampling Framework – May, 2018 (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/provincial-monitoring)

While the 2018 CMI and YSM sampling framework provides point-in-time and change estimators for the population, it does not provide any statistical guidance for the comparison of ground plot data to photo-interpreted estimates and to TIPSY yield estimates in the YSM analyses.

Since 2013, we have made MFLNRO&RD aware of a number of errors in the YSM analyses. We discuss the errors under two listings: technical and statistical.

List of technical errors:

1. In the original Kootenay Lake YSM analysis (2013):
    a. Sample ages were different between the appendix and Table 16
    b. For site index, sample plots were different between Tables 12 and 18

    MFLNRO&RD replaced the analysis with a new one in 2014. In this new analysis many of the TIPSY values in Table 27 made no sense (volumes greater than 0, but stems and basal area per hectare were 0).

2. In the Quesnel YSM analysis there appears to be problems with how site index is calculated from the ground sample data. In Table 22, the species composition and the leading species used for site index do not match in a number of cases. For example, sample 39 is $Pl_{60}Act_{27}At_{13}$, but the site index species is Act.

3. In the original Prince George YSM analysis (2015), we pointed out that the stems and basal area per hectare do not agree with each other in Tables 21 and 25. For example, in Table 25, the "other" strata has 681 stems per hectare for the ground sample and 1,848 for TIPSY, but has a basal area of 11.2 m^2/ha for the ground sample and 4.0 m^2/ha for TIPSY.

    MFLNRO&RD replaced the analysis with a new one in 2016.

4. The CMI ground sampling procedures[44], also used by the YSM program, contains guidance for identifying residual trees in the field. YSM data analyses indicate that residual trees are not being consistently identified in the field and the CMI quality assurance procedures are not identifying or correcting the problem.

[44] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/provincial-monitoring/standards

The YSM data compilation and analysis procedure manual[45] specifies that the data have to be screened for residual (includes veteran) trees as they are not to be included in the analysis. **All** of the YSM analyses to date have identified additional residual or veteran trees in the data that were not identified in the field.

The Morice YSM analysis indicates that screening for residual trees in the office is subjective and suggests that guidelines should be established for the identification of residual/veteran trees and whether to include or exclude them from the ground sample compilations and TIPSY runs. MFLNRO&RD does not appear to have followed up on these recommendations.

One of the major components of the data validation project was to identify residual (mainly veteran) trees in the PSPs, reassess the stand structure classification and then recalculate age, site height and site index. At the time, MFLNRO&RD field procedures were based on mature stands and only obvious veteran trees were classified in the data. In the determination of age, site height and site index for the PSPs, MFLNRO&RD compilation programs were erroneously using trees that were not classified as veteran trees, but were residuals.

Although the PSP data were changed, MFLNRO&RD has no record of the methodologies or processes used or the changes made. This has resulted in these problems:

- The data changed during the data validation project was supposed to be checked in the field to identify problems with the methodologies developed, along with ways to refine or improve them and,
- It appears that MFLNRO&RD did not make any changes to their field procedures and the problem is now in the YSM data,
- The problem of misclassifying residual and veteran trees, as well as the stand structure, is now a problem in the YSM data that could have been avoided,
- YSM analyses are inconsistent in how they deal with the problem of residual trees.

In Appendix A, we use a sample from the Kootenay Lake YSM analysis that was not identified in the field or the YSM analysis as having residual trees. The methodologies developed during the data validation project identified residual trees and the sample was changed:

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

- From $Bl_{53}Se_{47}$ with breast height age 41, total age 53, site height 13.2 m and site index 20.0 m. The YSM report also has a total age of 45 for this sample, which is explained in Appendix A.
- A main layer of $Se_{56}Bl_{44}$ with breast height age 28 for Se and 25 for Bl, total age 41 for Se and 35 for Bl (based on SiteTools), site height 12.9 m for Se and 12.5 m for Bl and site index 23.0 m for Se and 21.6 m for Bl. A residual layer of Bl_{100} with breast height age 57, total age 71, site height 15.4 m and site index 14.4m.

In 2013, we notified MFLNRO&RD of the problem of residual trees in the YSM data for the Kootenay, along with the example in Appendix A. MFLNRO&RD re-did the Kootenay Lake YSM analysis in 2014.

The following summarizes the inconsistencies in residual tree identification and their use in the YSM analyses:

- The original Kootenay Lake analysis (2013) left the residual trees in the analysis.
- The replacement Kootenay Lake analysis (2014) removed two plots that were multi-layered and 10 trees identified as being residuals in 8 samples. No residual trees were identified in the field.
- The Morice analysis (2013) identified 8 trees that were residuals in 3 plots. Four residual trees were removed from 2 plots and the other 4 residual trees were left in the plot.
- The Williams Lake analysis (2014) identified numerous problems with residual tree, none of which had been identified in the field. Two of the trees identified as veterans were removed from the TIPSY comparison, but left in for other summaries.
- The Merritt YSM data had 11 out of 57 samples identified as being multi-cohort by FAIB staff. The data screening for the Merritt YSM analysis identified 3 more samples as being multi-cohort. Two analyses were done, one that included the multi-cohort samples and another that excluded the multi-cohort samples.
- The Prince George (2015 and 2016) and Haida Gwaii (2016) analyses had an unspecified number of trees identified as residual in the field and a number of additional trees identified during the analysis. Although not totally clear, it appears that the trees identified as residual in the field were removed from the TIPSY comparisons, but the trees identified during the analysis were not removed.
- The Quesnel analysis (2014) had an unspecified number of trees identified as residual in the field and a number of additional trees identified during the analysis. All residual trees were removed from the TIPSY comparisons.

- The Interior TSA analysis (2016) had 19% of the samples classified as multi-cohort. Two analyses were done, one that included the multi-cohort samples and another that excluded the multi-cohort samples.

The inconsistent manner in which residual trees identified in the field and in the data are handled in the YSM analysis will affect every aspect of the analysis, most importantly the comparison of TIPSY estimations to the actual ground plot data.

5. None of the YSM analyses, with the exception of Merritt and the Interior TSA analyses, specifies how NMV is accounted for in TIPSY.

   The Merritt and Interior TSA analyses specify that OAF 2 set to 0.95 is used to account for DWB:

   > *"Without the application of OAFs, TIPSY merchantable volume is equivalent to VRI gross merchantable. It is total standing volume less 30 cm stumps and 10 cm tops for trees above a specified dbh limit. TIPSY OAF 2 (or custom decay, waste and breakage factors) are applied to produce net merchantable volume".*

   There seems to be a typo in this description and it should probably be:

   > *"Without the application of **OAF 2**, TIPSY merchantable volume is equivalent to VRI gross merchantable. It is total standing volume less 30 cm stumps and 10 cm tops for trees above a specified dbh limit. TIPSY OAF 2 (or custom decay, waste and breakage factors) are applied to produce net merchantable volume".*

   Although the other YSM analyses specify that OAF 1 of 0.85 (sometimes 0.80) and OAF 2 of 0.95 are used, it is unclear as to whether the incorrect stand-level DWB reductions in previous versions of TIPSY are also being applied on top of this.

6. YSM samples do not provide any information on the species composition, stems per hectare or spatial distribution of the stems at time 0 with which to initialize TIPSY. The assumptions made for YSM analyses to date are:
   a. A planting density of 1,400 if VRI indicates a harvest history and the species are not Bl or deciduous and,
   b. A natural density of 5,000 if VRI does not indicate a harvest history or the species are Bl or deciduous.

   These are not the types of densities used for the most current TSR analyses, bringing the usefulness of the YSM TIPSY comparisons for assessing TSR assumptions into question.

The YSM samples will provide the information required to initialize TASS III to project yield from the first YSM sample measurement to subsequent YSM measurements to assess TASS III growth estimation.

7. The original objective of the YSM program included checking the accuracy of TASS/TIPSY OAFs. No attempt has been made in any of the YSM analyses to evaluate the OAF assumptions, as stated in the 2013 Morice YSM analysis.

   Without a measure of stand characteristics at establishment, it is impossible to evaluate OAF assumptions. This was probably realized during the 2013 (September) Morice YSM analysis, leading to the change in the objective in the 2013 (November) version of the YSM framework.

   Original YSM documents overstated the uses of YSM data, such as evaluation of OAF assumptions, evaluation of stocking standards, assurance of wise investments in incremental silviculture, confirmation that genetic gains are realized in the field, and assistance in adapting B.C.'s forest and range management framework to a changing climate.

Given that there appears to be no oversight or quality control of YSM analysis within MFLNRO&RD, we further recommend that an independent third party audit all YSM-analysis reports for errors, omissions and misrepresentations.

List of statistical errors:

1. In the Morice YSM analysis, a confusion matrix is created between the inventory file and ground sample leading species. The Kappa statistic is used as a measure of agreement. An unweighted Kappa only takes into account the disagreement, while a weighted Kappa implies different degrees of disagreement. Species in the confusion matrix are in alphabetical order (Ac/At, B, Pl and S) and a weighted Kappa statistic is used. This implies that misclassifying Ac/At as Pl is not as bad as misclassifying Ac/At as S. An unweighted Kappa test should have been used.

   It is unclear what was used for weights as the value provided in the analysis does not agree with an unweighted, linear weighted (Cicchetti-Allison) or quadratic weighted (Fleiss-Cohen) value. It could be that the confusion matrix (Table 12) is incorrect. The confusion matrix indicates 39 out of 49 samples (80%) had the same leading species.

The percent matched provided in the report is 78%. This would be correct if 39 out of 50 samples matched. Given that 50 samples were established, it appears the confusion matrix is missing an entry.

A statistically significant Kappa test indicates that the agreement between the inventory file leading species and the ground sample leading species is closer than what would be observed by chance. Both the Morice (78% matched) and the Kootenay Lake (60% matched) analyses had a statistically significant Kappa value. As a comparison, quality assurance standards for the Phase I VRI (photo-interpreted) classify leading species as a critical attribute that must achieve an overall minimum score of 85% per map[46]. While the leading species matching assessment in the YSM data does not match up with the Phase I VRI leading species standard, it is doubtful that either the Morice or Kootenay Lake YSM samples would meet the Phase I VRI standard. **In fact, it appears that no YSM analysis to date would meet the Phase I VRI standard.**

The Kappa test statistic was not used for any of the subsequent YSM analyses, including the replacement Kootenay Lake analysis in 2014. While the percent matched is provided in all YSM analyses, there is no interpretation of the practical significance of the percent matched value.

We recommend that specifications equivalent to those for Phase I VRI samples be used to assess the leading species match between the inventory file and the YSM ground plots. A failure would indicate increased uncertainty in projected managed stand yields that are based on the inventory file leading species.

2. The Morice (2013), Kootenay Lake (2013 and 2014) and Quesnel (2014) YSM analyses contain a *post hoc* power analysis. This type of analysis, also known as a retrospective power analysis, provides no additional information beyond what the p-value has already shown, as the observed power can be derived from the observed p-value.

   Not only does MFLNRO&RD conduct *post hoc* power analyses for the Morice, Kootenay Lake and Quesnel TSAs but the ministry also does it for significant and non-significant results. Even if a *post hoc* analysis did provide additional information, it could only do that for a non-significant outcome (no evidence to reject H_0). If a significant difference

[46] Vegetation Resources Inventory – Photo Interpretation Quality Assurance Procedures and Standards (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/forest-cover-inventories/photo-interpretation/standards)

were found (evidence to reject H_0), that already tells one that one's analysis had sufficient power.

We pointed this problem out to MFLNRO&RD in 2013. Since then MFLNRO&RD has discontinued the *post hoc* power analysis in the YSM analyses.

3. The YSM analysis uses a paired t-test to test for statistically significant differences between the ground sample data and the model estimates. As you increase sample size, the size of the statistically significant difference that can be detected becomes smaller. With sufficient samples, you can detect a significant difference between any ground sample data and model estimate. What is of interest is if the difference is operationally (scientifically) significant.

   A paired t-test is inappropriate for estimations that increase or decrease in magnitude over time, such as volume, basal area and stems per hectare because a meaningful operational (scientific) difference cannot be defined. For example a 10 m^3/ha difference in volume may exceed a meaningful operational difference at young ages where the estimated volume is 30 m^3/ha, but would not exceed a meaningful operational difference at older ages where the estimated volume is 400 m^3ha.

   The ratio of ground sample value to model estimate is what should be tested. One can then test for an operationally meaningful difference as a percent across all ages. For example, a difference of 0.1 would equate to 10%. This would mean a 3 m^3/ha difference at the young age with a volume of 30 m^3/ha and a 40 m^3ha difference at the older age with a volume of 400 m^3/ha.

   Site index would not have to use a ratio as it is assumed to remain constant over time.

4. The paired t-test is also the wrong test for what one is interested in. One is not interested if the model estimates are significantly different from the ground sample values, but one is interested in whether the model estimates are close enough to the ground sample values to be of no operational significance.

   One cannot infer equality from a non-significant t-test. In fact, statistics can never prove equality, but statistics can prove equivalence. For this, one would have to use analysis of equivalence instead of the paired t-test.

Using ratios of ground sample values to model estimates, an analysis of equivalence and changing the effect size until one can show equivalence will provide one with an effect size that can then be assessed for operational significance. For example, if on the one hand one can show equivalence with an effect size of 0.05, one would only have a 5% difference between model estimates and ground sample values. This would not be operationally significant and one can state that one has shown the model estimates have sufficient accuracy for their intended use. On the other hand, if one can only show equivalence with an effect size of 0.5, one would have a 50% difference between model estimates and ground sample values. This would be operationally significant and one would not be able to state that one has shown the model estimates have sufficient accuracy for their intended use.

It should be noted that the analysis of equivalence test is not a test of the accuracy of the model. It is a test of the accuracy of the model that one can show, given the sample data. Increasing sample size will allow one to show increased accuracy.

The practical application is that whatever percent difference one can show equivalence at with the sample data one has, is the percent one should use for sensitivity analysis in the TSR process.

5. The YSM sampling design does not include stratification. YSM analyses split the sample data into subgroups, such as species, BEC or age classes, for analysis. In complex survey terminology, this is referred to as domain analysis, whereas MFLNRO&RD refers to it as post-stratification.

   In a stratified sample design, no matter how many times one applies it with the same sample size to the target population; one will always have the same number of samples in each stratum.

   In the YSM systematic sample design (assuming a random start), each time it is applied to the target population and the samples are split into domains after the sampling has been completed, the same domain from different surveys can have a different number of samples. As such, the number of samples in each domain is considered to be random.

   The mean of a domain is based on all of the samples in the domain. The variance (and standard error) is based on all of the samples, with samples not in the domain being given a value of zero. The increase in variance accounts for the random sample size of the domain.

> In all YSM analyses the MFLNRO&RD has incorrectly calculated the variance of the domain, thereby invalidating all of the t-tests. Not only does the ministry use an inappropriate statistical test in the YSM analyses, but it also uses the wrong calculations for that test.

We recommend that a qualified independent third party review the statistical analysis of the YSM data.

In YSM analysis, we recommend:

- ***Ratios of ground sample volume to model estimated volume be used; and***
- ***Analysis of equivalence and the changing of the effect size until one can show equivalence to obtain the ± percent that should be used for sensitivity analysis in the TSR and AAC determination processes be undertaken.***

This will not necessarily represent the accuracy of the model, but will represent the model accuracy that can be claimed, given the sample size.

Culling of the Permanent Sample Plots

In an October 17, 2014 VRI newsletter, FAIB indicated it was only going to support the re-measurement of 1,500 PSPs out of approximately 5,500 active PSPs:

> *"Currently, we are developing a long-term strategy for PSPs that will maintain approximately 1,500 plots with high mensuration quality and long measurement history, selected to cover a wide range of conditions. Although emphasis in the inventory program is on the unbiased sampling programs, the legacy PSPs provide unique value in their multi-decadal growth series."*

This caused concern amongst users of the PSP data and FAIB organized a conference call on November 12, 2014 to discuss FAIB's plans and for users to provide comments on the plan.

On February 13, 2015, users of the PSP data received an email from a consultant who had been contracted by FAIB to develop a draft long-term (10-year) strategy for the FAIB's legacy Growth Natural PSP Program, for review and discussion by various stakeholders. Users of the PSP data were asked to provide comments that would be consolidated into a draft strategy for discussion.

On March 10, 2015, FAIB accidently forwarded an email to us, which contained their PSP re-measurement plan for 2015 and proposed re-measurements for the next four years. Based on the email trail, the plan had been in the making since November 20, 2014. There was no mention in the accompanying email of incorporating the comments from users that was requested February 13, 2015.

On March 13, 2015, FAIB requested that we not distribute the plan:

> *"This was intended for Pat Martin. There is nothing confidential about these plans, but as they are DRAFT, and as you can see, still under development, I would appreciate it if you did not distribute."*

The February 13, 2015 request for comments from users made no mention of this plan, which should have been circulated for discussion at that time.

On March 31, 2015, FAIB posted a discussion paper[47] on their website. The proposed plan was no different from the plan FAIB accidently forwarded to us on March 10, 2015. Users' comments were simply shoved into an appendix and were not considered in the plan that was put forward.

To the best of our knowledge, there was no more discussion with the users of the data.

In July, 2018, FAIB posted a strategic 10-year plan[48] for PSPs on their website that appears to be just an extension of the 2015 plan.

It should be noted that when the 2015 plan was designed:

- FAIB was incorrectly compiling their PSP data, a problem that was not corrected until 2017,
- FAIB has no records of data changes that required field verification, such as corrections for missed and dropped trees that affect the quality of the data and,
- It does not appear that FAIB has made any attempt to access the original electronic data collection files to recover data that was corrupted by FAIB programs to transferring data to their database, most notably forest health codes and BEC site series.

[47] A strategy for the Growth Natural Permanent Sample Plot Program: A Discussion Paper (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/permanent-sample-plot/planning-reports)

[48] Strategic 10-Year Plan for Permanent Sample Plots (PSPs) (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/permanent-sample-plot)

We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to review the MFLNRO&RD 10-year strategic plan for PSPs, particularly with respect to the comments sent in by users of the PSP data.

DATA ACCESS

In the 2016 Estimates Debate questions, the opposition forest critic raised some issues about access to FAIB data. The major problems identified were:

- Inconsistent access to data;
- Data made available to some users while being refused to others with no explanation provided; and,
- Condition 3 in the Conditions for Release of Sample Data that states *"Any models/analyses developed from the use of the data may be requested for review by the Branch and may be put into the public domain"*.

In a subsequent inquiry, FAIB indicated that under condition 3, FAIB could make any analysis or model developed using FAIB data public without any compensation for the work done. While there is no argument with FAIB's position on making analyses or models based on FAIB data public, there should be compensation for the time taken to complete the analysis or develop the model.

FAIB's interpretation of condition 3 acts as a significant barrier to model development in the private sector.

The forest minister's response did not provide any justification for FAIB's interpretation of condition 3.

We recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to review FAIB's data access policy with respect to the barrier it poses to the development of models in the private sector.

BIOMASS

The CFS 2007 VTBs were deemed to be problematic in 2009. The main issue was that the equations were fit to NMV, but FAIB had incorrectly compiled the data they provided for the CFS's intended use. There also seems to be a breakdown in communication between FAIB and

the CFS as VDYP7 provided the opportunity to fit the equations to GMV, a facility of which the CFS was not aware (VDYP6 did not output GMV).

FAIB had provided the data to fit the CFS 2007 VTBs in 2003. A check on the data indicated that FAIB had already managed to corrupt the PSP data that had been returned to them after the data validation project had been terminated in early 2003.

FAIB agreed to fit new VTBs that were completed in 2010, but the VTBs had problems:

- FAIB fit the VTBs to a model that was not compatible with the model used in the CBM-CFS3;
- FAIB used the wrong ITBs to compile the sample plot data used to fit the VTBs; and,
- During sample plot compilation, FAIB adjusted the individual tree stem wood biomass using oven-dried density values instead of basic relative (green) density values.

In 2012, FAIB used a contractor to fit new VTBs using the model used in the CBM-CFS3. These equations were never released.

In 2012, FAIB released a report that compared the 2012 FAIB VTBs to the 2010 FAIB VTBs. Although biomass predictions for some species-BEC combinations had differences of up to 40%, FAIB deemed both sets of equations to be valid as one set was to be used for forest carbon and the other for forest bio-energy. Although FAIB staff gave a number of irrelevant reasons for the differences, they left out the fact that they had used the wrong ITBs and oven-dried density to adjust stem wood biomass for the 2010 equations. When questioned about these omissions, FAIB indicated it was a moot point as there were many reasons for the differences and they all could not be listed.

The CFS took over the supervision of the VTB fitting, using the same contractor, and a new set of VTBs were released in 2014. The 2014 VTBs replaced the 2007 VTBs in the CBM-CFS3 in 2016.

MFLNRO&RD indicates that since the 2010 VTBs were not used in the CBM-CFS3, there were no negative financial consequences to the Crown because no forest carbon offsets projects used the 2010 VTBs. While this is true, it is also true that from 2007 to 2016 proponents of forest carbon offsets projects used the 2007 VTBs, which subsequently have been deemed invalid. At what cost to the provincial government?

The CFS had previously indicated they would provide a comparison between the 2007 and 2014 VTBs, but this has not been done. The CFS has indicated they do not have a dataset to do the

comparison. The dataset only needs GMV and NMV at 12.5^{+} and 17.5^{+} cm minimum DBH limits, both of which could easily be obtained from FAIB.

As an update to the 2016 Estimates Debate questions, the ME&CCS[49] submitted the FCOP to the Verified Carbon Standard, now known as Verra, for accreditation. It was approved in 2015 as VM0034[50]. Key differences between FCOP and VM0034 are:

- The pre-approval of the CBM-CFS3 and FORECAST models has been removed in VM0034,
- The basic relative (green) densities in the FCOP have been replaced with more realistic values in VM0034 and,
- **Most importantly, the individual tree biomass data[51] used to fit the ITBs for B.C. have been declared invalid in VM0034.**

Since the data used to fit the ITBs used in B.C. have been declared invalid, it follows that the ITBs are also being declared invalid as well as the 2014 VTBs that were derived with sample plot data compiled with the ITBs.

The GHG Regulator has not responded to questions about this, but it is not something that can be ignored. One has to assume that validators and verifiers of forest carbon offsets are aware of VM0034.

We recommend that MFLNRO&RD, ME&CCS and the CFS coordinate their efforts, resolve the issues around ITBs and VTBs and put forth a final and consistent statement on the status of biomass conversion equations in B.C.

There are also problems with biomass estimation in TASS and TIPSY. TASS uses the ITBs developed by the CFS to assign biomass to TASS individual tree output[52].

Based on basic relative (green) density values in VM0034, the stem wood biomass in TIPSY is being grossly over-predicted for some species. As a couple of examples:

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[49] https://www.brinkmanearthsystems.ca/british-columbia-forest-carbon-offset-protocol

[50] British Columbia Forest Carbon Offset Methodology (http://verra.org/methodology/vm0034-british-columbia-forest-carbon-offset-methodology-v1-0/)

[51] Standish, J.T., G.H. Manning and J.P. Demaerschalk. (1985). Development of biomass equations for British Columbia tree species. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Information Report – BC-X-264 (https://cfs.nrcan.gc.ca/publications?id=2449)

[52] Ung, C.H, P. Bernier and X.J. Guo. (2008). Canadian national biomass equations: new parameter estimates that include British Columbia data. Can., J. For. Res. 38.

For Fdi, VM0034 has a basic relative density of 0.44 t/m^3.
If we plant 1600 stems per hectare, site index 20.0 and OAF 1 and 2 set to 1.0:

- At age 60, total volume is 210 m^3/ha and stem biomass is 111.0 ODT/ha which translates to a basic relative density of 0.53 t/m^3. *This is a 20% over-estimate*.
- At age 80, total volume is 318 m^3/ha and stem biomass is 171.8 ODT/ha which translates to a basic relative density of 0.54 t/m^3. *This is a 23% over-estimate*.
- At age 100, total volume is 420 m^3/ha and stem biomass is 229.1 ODT/ha which translates to a basic relative density of 0.55 t/m^3. *This is a 25% over-estimate*.

For Sw, VM0034 has a basic relative density of 0.36 t/m^3.
If we plant 1600 stems per hectare, site index 20.0 and OAF 1 and 2 set to 1.0:

- At age 60, total volume is 294 m^3/ha and stem biomass is 139.5 ODT/ha which translates to a basic relative density of 0.47 t/m^3. *This is a 31% over-estimate*.
- At age 80, total volume is 442 m^3/ha and stem biomass is 211.1 ODT/ha which translates to a basic relative density of 0.48 t/m^3. *This is a 33% over-estimate*.
- At age 100, total volume is 545 m^3/ha and stem biomass is 262.0 ODT/ha which translates to a basic relative density of 0.48 t/m^3. *This is a 33% over-estimate*.

We recommend that the biomass estimation in TIPSY be reviewed and corrected.

SITE INDEX

In 2012, a RPB report[53] comparing site index estimates within the SIBEC database indicates that overall, for a given species-BEC cell, growth intercept estimates of site index were greater than estimates of site index from stem analysis data and height-growth equations. The lower the stem analysis and height-growth equation estimates of site index were, the greater the differences between growth intercept estimates of site index.

Subsequent to the completion of the report, tree species were listed in order of the difference between the least squares means of site index estimates using height-growth equations and growth intercept in the SIBEC database. When shade tolerance is added, a clear pattern emerged showing that the more shade tolerant a tree species is, the larger the difference between height-growth equation and growth intercept estimates of site index.

[53] Watts, M. (2014). Comparison between SIBEC and RESULTS growth intercept estimates of site index and comparison between methods of site index estimation in the SIBEC database. Report for Resource Practices Branch.

The observed differences between site indices estimated with height-growth equations and site indices estimated with growth intercepts leads to three possible explanations:

- The growth intercept method is biased and overestimates site index. If this is the case, growth intercepts should not be used to estimate site index.
- The growth intercept method is not biased and managed stands are growing at a faster rate, possibly due to climate change, than the natural stands on which the height-growth equations are based. If this is so, estimates of site index for managed stands should be based on growth intercept estimates only. Mixing them with height equations and stem analysis estimates in the SIBEC database would result in underestimates of site index for managed stands and overestimates of site index for natural stands.
- Differences may be due to shade-tolerant tree species that have been established with no overstorey in managed stand conditions -- shade-tolerant tree species would normally establish under an overstorey in natural conditions. The difference in site index estimation may be due to a shift in the height-growth equations for managed stands due to the absence of competition, but not necessarily an increase in site index over the long term. This suggests that the shape of height-growth equations derived from natural stand data is different than that for managed stands. If this is so, current height-growth equations and their associated growth intercepts may not be applicable to managed stands.

In the forest minister's response, MFLNRO&RD referenced three growth intercept validation studies:

- The western hemlock validation study[54] is based on six stem analysis plots, with three trees sampled in each plot. The report is considered an interim validation as there were too few trees to assess precision, but no bias was observed.
- The white spruce validation study[55] is based on 20 stem analysis trees ranging in breast height age from 46 to 71. The study validated the existing growth intercept equations and the data was then used in the derivation of new growth intercept equations, strengthening the existing models. We do note that the BEC zone sampled was the BWBS and the site series classification for the BWBS has changed since the validation study. It is unclear if the sample trees would now be classified into different SIBEC cells. We also note in the validation study that in the BWBSmw 01, the SIBEC trees have a mean site index that is 2.5 metres greater than the stem analysis trees.

[54] Nigh, G.D. (1996). Interim validation of the western hemlock growth intercept model. B.C. Min. For., Res. Br., Victoria, B.C. Extension Note 04.
[55] Nigh, G.D. (2004). Growth intercept and site series–based estimates of site index for white spruce in the boreal white and black spruce biogeoclimatic zone. B.C. Min. For., Res. Br., Victoria, B.C. Tech. Rep. 013.

- The lodgepole pine validation study[56] is based on 45 stem analysis plots in the northern interior and 45 stem analysis plots in the southern interior. The study showed no difference between the northern and southern data, allowing the data to be combined, and no bias.

After the 2012 RPB report was released, there were a number of discussions between RPB and the SIBEC database administrators around the use of young trees in the SIBEC database. Overall, younger trees tended to have higher site indices within a SIBEC species-BEC cell. A SIBEC database administrator erroneously indicated that SIBEC sampling explicitly limits the proportion of trees less than 30 years old for a given SIBEC species-BEC cell and that only 3% of the species-BEC cells with second approximation estimates of site index have more than 60% of the trees less than 30 years old.

We found no evidence of restrictions on trees less than 30 years old in any given SIBEC species-BEC cell. In the SIBEC data provided, 8% of the species-BEC cells with second approximation estimates of site index had more than 60% of the trees less than 30 years old.
The SIBEC data provided for the 2012 RPB report has 9,111 observations:

- 1,759 (19.3%) are trees greater than 50 years old with site index estimated by stem analysis.
- 3,992 (43.8%) are trees greater than 50 years old with site index estimated using height growth equations,
- 1,495 (16.4%) are trees 30 to 50 years old with site index estimated using growth intercept equations and,
- 1,865 (20.5%) are trees less than 30 years old with site index estimated using growth intercept equations.

The SIBEC data used for the 2012 RPB report were provided in 2009, were in between SIBEC database releases, and do not quite match up with the 2008 or 2011 SIBEC databases. We do note some odd inconsistencies. For example, spruce in the SBS mc2 05 has a second approximation site index value of 21.3 from 35 observations in the 2008, 2011 and 2013 SIBEC database releases. The SIBEC data provided for spruce in the SBS mc2 05 had 78 observations:

- 13 with an age greater than 50 and an average site index of 18.6 (estimated with height growth equations),
- 4 with and age from 30 to 50 and an average site index of 21.2 (estimated with growth intercept equations) and,

[56] Nigh, G.D. (1997). Revised growth intercept models for lodgepole pine: comparing northern and southern models. B.C. Min. For., Res. Br., Victoria, B.C. Extension Note 11.

- 61 with and age less than 30 and an average site index of 23.1 (estimated with growth intercept equations).

If all of the 17 trees 30^+ years old were used, 18 of the 61 trees less than 30 years old would have been used, but which ones?

In a 2017 Invitation to Tender for SIBEC 2018 (1070-30/RE18FHQ297), schedule A indicates there are "additional standards not published", one of which indicates there is a maximum of two trees between 10 and 29 years old that can be used in SIBEC calculations (species-BEC cells).

It is unclear when FAIB implemented this unpublished SIBEC standard, but FAIB made no mention of it when the branch provided the SIBEC data in 2009. Additionally, another SIBEC database administrator asked for the SIBEC data provided in 2009 in order to duplicate the results of the RPB study. No mention was made of the unpublished SIBEC standard or differences between SIBEC data provided in 2009 and the data used in the SIBEC databases.

Implementation of the unpublished SIBEC standard would dramatically change the 2012 RPB study. Out of the 452 SIBEC species-BEC cells that had the minimum of seven observations required for a SIBEC species-BEC cell:

- 38 (8.4%) have more than 60% of the trees less than age 30,
- 169 (37.4%) have more than 2 trees less than age 30 and,
- 63 (13.9%) would no longer have the minimum of seven observations if only 2 trees between 10 and 29 years old are allowed.

It will be interesting to see the changes to the 2018 SIBEC database when it is released.

MFLNRO&RD did not respond to the opposition forest critic's question as to why BEC from the RESULTS database, which is determined on the ground, is not used in conjunction with the SIBEC database to assign site index to managed stands. FAIB extracts data such as stems per hectare from RESULTS to use with managed stands, but not BEC. **Why?**

Currently the PSPL, which utilizes PEM or TEM to assign BEC, is used in conjunction with the SIBEC database to assign site index to managed stands. PEM only has to achieve an accuracy of 65% to be used in the TSR process, with most PEM just achieving this standard. On average, based on YSM reports, the FAIB inventory files contain the correct leading species for a managed stand polygon less than 70% of the time. Based on a PEM with 70% accuracy in predicting BEC and an inventory with 70% accuracy for the leading species, there is less than a

50% chance that the correct BEC and leading species are currently being used to estimate site index for managed stands. Essentially, MFLNRO&RD relies on the hope that whatever site index comes out of the PSPL will be close to what would be obtained if the correct BEC and leading species had been used.

It should be noted that when justifying the use of the PSPL to estimate managed stand site indices, MFLNRO&RD often makes a comparison between the site index predicted by the PSPL and what MFLNRO&RD terms the "inventory site index", which is derived from the leading species top height and age in the inventory file. The problem with this comparison is that prior to the PSPL, the "inventory site index" was overridden by what was termed "special site". Special site was a categorical estimate (good, medium, poor and low) assigned to managed stand polygons during silviculture surveys. Each species site category was linked to a range of site indices by species and the midpoint was used in the TSR process. The SIBEC database was originally developed to replace the categorical special site with a numerical estimate. A more appropriate comparison would be to compare the PSPL estimate of site index with the site index estimate from the RESULTS database, which is based on SIBEC site index estimate based on the ground-determined BEC from the silviculture survey.

Although dated, the timber supply analysis report from the 2005 Arrow AAC determination provides a good description of how the increased site indices for managed stands affect the AAC (Figure 1).

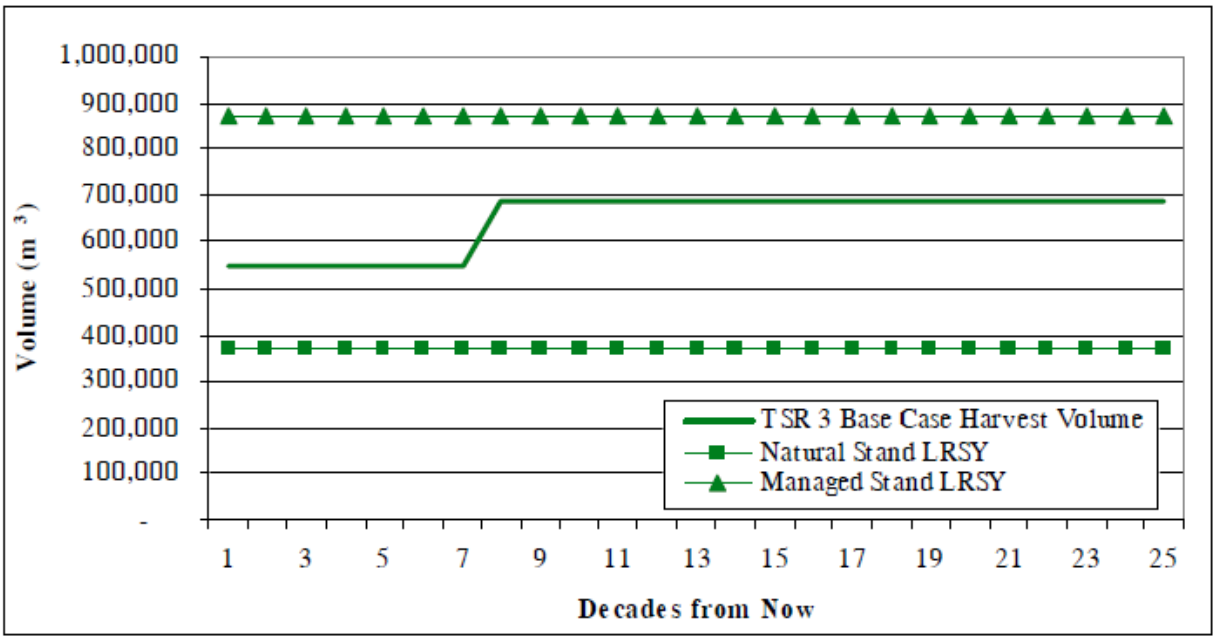

Figure 1. Base Case Harvest Flow and LRSY

The natural stand LRSY, based on inventory site index and VDYP6 yield estimates, is 350,000 m^3/year. The managed stand LRSY, based on SIBEC site index and TIPSY yield estimates, is 870,000 m^3/year. The short term base case harvest level is well above the productive capacity of the natural forests and is done in **anticipation** that the harvest level will be sustained by the higher yields of the future managed stands.

We recommend that differences in site index due to the methodology of estimation within species-BEC SIBEC cells be further investigated and the uncertainty associated with SIBEC estimates of site index be adequately and properly accounted for in the TSR and AAC determination processes.

Given the small sample sizes in a species-BEC cell in the SIBEC database, we recommend that the lower limit of a confidence interval, possibly at the 90% significance level, be used as the SIBEC value.

We recommend MFLNRO&RD ecologists investigate combining species-BEC with similar site index estimates in the SIBEC database, thereby reducing the amount of first approximation estimates and, most likely, reducing the confidence interval associated with a SIBEC estimate.

Given that site indices based on the PSPL are used in the TSR and AAC determination processes, and not site indices based on SIBEC and BEC from silviculture surveys, the "best available information" is not being used. We recommend that PSPL site indices only be used for managed stand polygons that do not have BEC from a silviculture survey.

We recommend that the predicted BEC from the PSPL be tested against the BEC determined in silviculture surveys. Any differences identified should be accounted for in PSPL-based estimates of site index in the TSR and AAC determination processes.

PROGNOSIS^{BC}

MFLNRO&RD has spent a significant amount of public funds on calibration, through the derivation of growth modifiers, and later on parameterization of Prognosis^{BC} for B.C. The main objective was to provide a model that could deal with complex stand structures resulting from partial harvests or natural disturbances, such as the MPB.

To date, the MFLNRO&RD has never used Prognosis[BC] in the TSR process. Instead, the ministry uses VDYP7, which until recently, was never parameterized for these types of stands. To use VDYP7, a number of untested assumptions had to be made[57].

An example of untested assumptions is found in the use of VDYP7 in the 2017 Prince George TSA AAC determination for polygons affected by the MPB[58]:

- The BCMPB v11 is used to determine when a stand reaches 50% mortality from MPB.
- A 10-year regeneration delay is initiated.
- VDYP7, with unadjusted attributes, is used to grow the understorey after the regeneration delay.
- It is unclear from the description provided by MFLNRO&RD whether a managed stand site index, obtained from the PSPL, or the existing stand site index, obtained from the inventory data, is used for the understorey.
- The understorey volume is reduced based on the proportion of remaining overstorey. As an example, if the overstorey volume has 60% mortality, the VDYP7 prediction of the understorey volume is multiplied by 0.6.
- The residual overstorey volume is added to the reduced value of the understorey volume.
- It is unclear from the description provided by MFLNRO&RD if the overstorey volume is also projected into the future with VDYP7.

We recommend that MFLNRO&RD provide an explanation as to why it uses VDYP7 in the TSR and AAC processes for stand conditions for which it was not parameterized, instead of models that have been specifically parameterized for these stand conditions.

VDYP7

Parameterization Data

We should like to clarify that in the 2016 Estimates Debate questions we are not questioning the qualifications of the VDYP7 modelers, as MFLNRO&RD implies in the forest minister's response. We are questioning the vintage and compilation of the data FAIB provided to the VDYP7 modelers and whether or not VDYP7 was validated using the inventory audit sample plot data (1998 vintage) as claimed by MFLNRO&RD on its VDYP7 website.

[57] Adjusting the Forest Cover to Reflect Mountain Pine Beetle Impacts, Fire and LiDAR Data Acquisition (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/data-management-and-access)

[58] Prince George TSA Timber Supply Analysis Technical Summary (2017).

Prior to the development of VDYP7, FAIB initiated a project to validate and correct, if possible, the FAIB PSP data that had been corrupted due to mismanagement, partly caused by an obsolete database and data management software developed in the late 1970s that was no longer functional. As documented in a 2006 report[59]:

> *"From 1996 to 2002, $700,000 was invested by MoFR in cleaning up Sample Plot data to support greater accuracy in estimation of the provincial Vegetation Inventory"*.

In 2003, the PSP data used to parameterize the basal area increment functions for VDYP7 was requested from FAIB. The data provided was not the data that had been validated and the data contained a major compilation error:

- In a May 27, 2005 meeting, FAIB conceded that it had not used the validated PSP data, but had used a version of the PSP data that pre-dated the data validation project.
- FAIB indicated that it had corrected the compilation error, but could provide no evidence to support this claim.

On the MFLNRO&RD's VDYP7 website[60], FAIB claims that 9,300 PSPs were used for VDYP7 model development. The VDYP7 modeler's 2007 report[61] indicates 6,860 growth periods were used. This is far short of the 17,000^{+} growth periods associated with the 9,300 PSPs. More importantly, most PSPs had data for one or two new measurements added during the data validation project. Additional sample plot measurements are far more valuable for modeling than are the number of plots. While some PSPs were rejected for valid reasons, such as the PSP having been thinned, many would have been rejected for errors that were corrected during the data validation project.

FAIB's claims on MFLNRO&RD's VDYP7 website about the data used to parameterize and the data used to validate VDYP7 are misrepresentations and the "best available information" was not used in the parameterization of VDYP7.

Model Validation – Current Inventory

Also on MFLNRO&RD's VDYP7 website, FAIB claims that 2,700 inventory audit plots were used to validate VDYP7. A FOI request revealed that FAIB has no record of a validation using

[59] Ministry of Forests and Range Data Quality Framework – A Guide for Business Data Quality
[60] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/variable-density-yield-projection-vdyp
[61] Biometrics Overview of VDYP7 Components

inventory audit plots. The following documents, provided with this submission, indicate the inventory audit data were used to develop prediction modifiers that were distributed with a 2003 beta version of VDYP7:

- The file ***IPSCB120.doc*** documents the derivation and application of basal area and quadratic mean diameter prediction modifiers,
- The file ***IPSCB123.doc*** documents the derivation and application of net volume prediction modifiers and,
- The file ***IPSCB121.doc*** documents the validation of starting net volumes and states "*For these reasons the results given in this memo should be viewed as a good indicator of net volume prediction trends; but not as an official set of validation statistics for the VDYP7 initiative*".

FAIB's claim on the MFLNRO&RD's VDYP7 website about VDYP7 model validation using the 2,700 inventory audit samples is a misrepresentation, which we recommend be corrected.

In the forest minister's response, MFLNRO&RD states

> "*VDYP7 developers have validated, tested and implemented the model, comparing model projections against ground sample data to improve model performance*". We assume MFLNRO&RD is referring to the VDYP7 statistical adjustment and the VDYP7 statistical analysis using ground sample (VRI, CMI and NFI) data. We will comment on how the ground samples have been used, but before that, a bit of history might prove useful.

In the early 1990s, RIB established the inventory audit samples with the objective of using them to identify management units that have inaccurate inventory data and require a re-inventory or update. By the late 1990s, the objective had changed from using the inventory audit data **to identify** inaccurate inventory data to using the inventory audit data **to adjust** inaccurate inventory data. The first adjustment was made for the 1999 AAC determination for the Fraser TSA using a methodology that became known as the "Fraser Protocol":

- Run VDYP6
- Derive adjustment factors for the leading species height and leading species age using the inventory audit data
- Input the adjusted height and age into VDYP6 and re-run the model
- Derive adjustment factors for the resultant VDYP6 volume using the inventory audit data

At the time, RIB and TSB were separate branches within the ministry. TSB objected to the adjustment process citing a number of statistical reasons[62]:

- Sample sizes are too small and have too much variability on which to base adjustments;
- A practical significant difference and not a statistically significant difference should be used to trigger the adjustment process;
- Adjustments should be made on the total unit, as opposed to adjustments on strata or sub-groupings of the data;
- Adjustments should only be made on the volume, as opposed to adjustments on individual attributes, such as age and height; and,
- Adjustments should only be used for sensitivity analysis and not for the "base case".

In 2004, RIB documented[63] the attribute adjustment process for VDYP6.

The VDYP7 modeler's 2007 report indicates that VRI ground samples are required to calibrate the yield functions for a particular management unit. Without the adjustments, VRISTART cannot be assumed to be correct.

In 2008, FAIB developed the VRI attribute adjustment methodology[64] for use with VDYP7, which was similar to the "Fraser Protocol":

- Run VDYP7.
- Derive adjustment factors for the leading species height, leading species age, stems per hectare and basal area per hectare (7.5^+ cm utilization) using the VRI ground sample data.
- Input the adjustment factors into VDYP7 and re-run the model.
- Derive adjustment factors for the resultant VDYP7 Lorey height and NMV. VDYP7 will run an internal module called VRIADJUST, which will produce adjusted volumes net, top, stump and DWB at 12.5^+ and 17.5^+ minimum DBH limits.

Problems associated with this methodology are:

- A review of VRI statistical adjustment reports indicates that while the overall population sample sizes and standard errors are often within a predetermined error tolerance, the strata sample sizes are small with standard errors exceeding the predetermined tolerance, making any strata-based adjustment questionable;

[62] Review of the Application of Forest Inventory Audit Information in Timber Supply Review Timber Supply Analyses, B.C. Forest Service, Research Branch

[63] Procedures and Standards for Data Analysis Attribute Adjustment and Implementation of Adjustment in a Corporate Database

[64] Interim Procedures and Standards for Statistical Adjustment of Baseline VRI Timber Attributes

- An independent set of data to determine the error/uncertainty of the adjusted inventory does not exist; and,
- The process requires tracking two inventory databases – the adjusted and unadjusted.

In 2011, FAIB abandoned the attribute adjustment process and adopted the VRI data analysis procedure[65], which involved using ground sample data and VDYP7 estimations to derive ratio of means for leading species height, leading species age, stems per hectare, basal area per hectare (7.5^{+} cm utilization), Lorey height and NMV. Additionally, a ratio-estimated overall total timber volume is calculated, along with the sampling error.

It is unclear why FAIB abandoned the VRI attribute adjustment process, as a 2014 report[66] announcing the discontinuation does not provide a rationale, but FAIB has come full circle in relation to the 1999 review of adjusting inventory data with inventory audit samples[67].

We recommend that the use of VRI volume adjustments in the TSR and AAC determination processes be reviewed, particularly given the small sample sizes and large variability in strata estimates, as was done in 1999. We further recommend that AAC determinations for which questionable adjustments were used be immediately revisited.

Model Validation – Projected Inventory

The final paragraph of the VDYP7 modeler's 2007 report states that B.C. does not have the data required to validate VDYP7 inventory projections:

> *"Growth predictions for individual stands contain error; this fact is known and accepted by everyone who uses growth models. However, there is sometimes a presumption that the growth models are correct on average. That assumption is not supported by data. Within the natural forests of British Columbia there has not been a comprehensive growth monitoring program; hence the average growth rates for any fixed population of stands is unknown. The growth model is put forward as being a reasonable way to project stands, subject to the limitations discussed here. Differences between the PSP characteristics and those of the overall inventory have been accounted for, but there has not and cannot be a true validation in the absence of growth data that is known to be representative".*

[65] VRI Sample Data Analysis Procedures and Standards
[66] Procedure for Adjusting VRI Attributes for VDYP7 Projection (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/variable-density-yield-projection-vdyp/publications-and-support)
[67] Review of the Application of Forest Inventory Audit Information in Timber Supply Review Timber Supply Analyses, B.C. Forest Service, Research Branch

Contrary to claims by the MFLNRO&RD, VDYP7 inventory projections have not been validated and, as such, the associated uncertainty has not been accounted for in the TSR and AAC determination processes.

Limitations of VDYP7

VDYP7 requires stems per hectare and basal area per hectare as input. Both are poorly estimated using photo-interpretation, leading to problems with VDYP7 volume estimation of standing timber. It should be noted that VDYP6 also had a variant[68] that used basal area instead of crown closure, but was most likely not implemented owing to a problem with the estimation of basal area per hectare. It is unclear why MFLNRO&RD developed a model requiring input variables that are so poorly estimated using photo-interpretation. Attempts[69] have been made at using tabular implementation to estimate polygon stems and basal area per hectare for VDYP7 input, but it does not appear that anything became of them.

We recommend that MFLNRO&RD investigate the use of LiDAR to estimate polygon stems and basal area per hectare for VDYP7 input. Also, we recommend that MFLNRO&RD investigate the use of LiDAR to estimate current polygon volume instead of using VDYP7.

The VDYP7 2007 modeler's report indicates MFLNRO&RD made a decision to force yield predictions at older ages to approach limits similar to those in VDYP6, thereby limiting the impact of some of the available growth data. VRI statistical analyses of the Morice and Mackenzie TSAs noted that VDYP7 underestimated volume in samples outside of the THLB and overestimated volume is samples inside the THLB. On average, forest stands outside of the THLB tend to be older than those inside the THLB. The question arises as to whether the decision to force yield predictions at older ages is responsible for the underestimation of volume in older stands outside of the THLB.

We recommend that MFLNRO&RD assess the impact of the decision to force VDYP7 yield predictions at older ages to approach limits similar to those in VDYP6 and whether the decision is responsible for underestimating volume in older stands, such as those outside of the THLB.

[68] Growth and yield prediction systems, BCMoF, Special Report Series 7, 1991.
[69] ITT 1070-30/OT15FHQ191 – Tree list development by tabular imputation

In June 2018, MFLNRO&RD released a new version of VDYP7 that has been calibrated for complex stand structures, such as those resulting from the MPB outbreak[70]. Prior to this new version, MPB-affected stands were modeled with VDYP7 using an adjustment process[71].

We recommend that MFLNRO&RD compare the timber volumes estimated for MPB-affected stands modeled with VDYP7 and the adjustment process with those volumes estimated using the June, 2018 version of VDYP7 that was specifically parameterized for the modeling of MPB-affected stands. If the outcome of the comparison indicates an over-prediction for stands modeled with VDYP7 and the adjustment process, then we recommend that the AAC determinations that used the VDYP7 adjustment process be immediately reassessed.

While there is considerable documentation explaining the function of VDYP7 core modules and how they relate to each other, there is no documentation on how the model was parameterized and no documentation on how well empirical functions within VDYP7 fit the data. By contrast, Alberta Agriculture and Forestry provides a detailed parameterization and validation summary for the GYPSY G&Y projection system on their website[72]. While FAIB staff and the chief forester blindly accept VDYP7 estimations in the TSR and AAC determination processes, validators and verifiers of forest carbon offsets projects require some sort of model validation on which to base assessments of uncertainty.

In the forest minister's response to the Estimates Debate questions, the MFLNRO&RD did not include a response to the statement that VDYP7 was parameterized with corrupt, out-of-date and incorrectly compiled PSP data and not the PSP data specified on the MFLNRO&RD VDYP7 website.

We recommend that MFLNRO&RD provide documentation on the parameterization of empirical functions within VDYP7. Also, given the misinformation provided by MFLNRO&RD on the parameterization and validation of VDYP7, we recommend an independent third party conduct a review and report to the legislature.

[70] VDYP7 Information Note #6

[71] Adjusting the Forest Cover to Reflect Mountain Pine Beetle Impacts, Fire and LiDAR Data Acquisition (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/data-management-and-access)

[72] Validation Summary of GYPSY SubModels (https://www.agric.gov.ab.ca/app21/forestrypage?cat1=Forest%20Management&cat2=Growth%20%26%20Yield&cat3=Growth%20%26%20Yield%20Projection%20System)

The VDYP7 frequently asked questions document[73], dated 2014, contains a misrepresentation. Question 29 asks how VDYP7 performs in relation to TIPSY. The response is that a comparison between VDYP7 and TIPSY has never been made, followed by a list of differences between the models in support of why a comparison should not be made. This statement is in contrast to the 2016 Kamloops TSA rationale for the AAC determination that lists a document[74] comparing VDYP7 and TIPSY in the Information Used in the AAC Determination section

We recommend that an independent third party review current (and future) VDYP7 documentation for errors, omissions and misrepresentations.

For whatever reasons, MFLNRO&RD updates stands modeled with TIPSY for the TSR process and AAC determination with VDYP7 in VRIMS[75]. This leads to problems, as documented in many of the YSM analysis reports, as VDYP7 will not update attributes for stands that are less than 7.0 m tall. From the Prince George YSM analysis report:

"For stands less than 7 m tall, VDYP7 will project the age and height until the height is 7 m and then generate the remaining attributes. Until the projected height is 7 m, the other attributes are not altered and the utilization limit is unchanged from the original data collection."

"As a consequence, for young stands, the Phase I inventory may not be a good source for basal area and trees/ha."

It appears that the TIPSY yield projections are discarded once they have been used in the TSR and AAC determination processes.

We recommend that MFLNRO&RD articulate and explain the rationale for using VDYP7 instead of TIPSY within the VRIMS for the updating of polygons that are modeled with TIPSY in the TSR and AAC determination.

[73] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/variable-density-yield-projection-vdyp/publications-and-support
[74] Ministry of Forests and Range. 2009. *TIPSY and VDYP7 volume comparison*. Draft. March 31, 2009, Forest Analysis and Inventory Branch, Victoria, BC
[75] Vegetation Resources Inventory Management System (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/forest-cover-inventories/forest-inventory-update)

TASS/TIPSY

In the forest minister's response to the 2016 Estimates Debates questions about TASS/TIPSY, he states,

> "*TASS II and TIPSY are the primary growth and yield modelling tools used to project managed stands in British Columbia, and are the result of almost 50 years of rigorous scientific research and development by highly qualified ministry scientists and collaborators*."

While we do not question the qualifications of ministry scientists and collaborators, we do note that the 50 years of rigorous scientific research and development has been accompanied by a lengthy list of errors, omissions and misrepresentations all of which influence one's assessment of the uncertainty associated with TASS/TIPSY estimations.

TASS is presented as a biologically based, spatially explicit, individual tree model[76]. TASS II is not publicly available, but TIPSY, which is publicly available, is described as a G&Y program that provides access to managed stand yield tables produced by TASS[77]. TIPSY retrieves and interpolates TASS yield tables from its database. As such yield tables should be the same as TASS II, with the exception of minor differences as a result of the interpolation.

Central to our claim of errors, omissions and misrepresentations is a 2001 report[78] provided to us in 2008, marked "draft and not for distribution", describing the top height and site productivity assumptions in TIPSY and TASS. The report was provided when we questioned why the TASS II volumes for Pl we received from the TASS modelers were 20% less than the TIPSY volumes for Pl, using the same input parameters (Table 1). It should be noted that we were asked not to distribute the report when the lead TASS modeler was informed that it had been provided to us.

As it turned out, there are two variants of TASS II. One version, **selection upgrade mode** (also referred to as unadjusted or vigour adjustment off) does not force the stand top height growth to follow the height growth defined by the site index (height growth) equation. Density affects

[76] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/tree-and-stand-simulator-tass
[77] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/table-interpolation-program-for-stand-yields-tipsy
[78] Mitchell, K.J. (2001). Top Height and Site Productivity Assumptions in TIPSY and TASS

stand height growth, with height growth increasing with stand density until density is so great that repression sets in. The other version, **selection suppressed mode** (also referred to as adjusted or vigour adjustment on) forces the stand top height to follow the height growth defined by the site index equation. Genetic gain and fertilization are modeled in TASS II through their effect on top height growth. As such, they should not be used with TASS II selection suppressed mode as their effect on top height growth will be confounded with forcing top height growth to follow the height growth defined by the site index equation. The existence of two modes of TASS II, along with their differences in managed stand yield estimation, is a major omission, possibly a misrepresentation given the fact we were asked not to distribute the report, in MFLNRO&RD's description of TASS.

TIPSY uses top height to interpolate between TASS yield tables in its database and as such, stand top-height growth follows the height growth defined by the site index equation. TIPSY managed stand volume estimations are more in agreement with TASS II selection suppressed mode.

The 2001 report indicates that by using TIPSY, the user makes two assumptions they are not aware of:

1. The relationship in TASS II between initial density and site height **does not** exist. While this assumption "*conforms to the expectation of most foresters*", it is not how TASS II is structured.
2. The relationship in TASS II between initial density and site height **does** exist, but stands will regenerate at the same density as those from which site index was determined. This assumption is violated when a natural stand is replaced by a lower density managed stand in the TSR and site index is based on the natural stand (measurement taken to estimate site index at rotation age) and/or trees collected from denser natural stands to derive the site index equations. The report indicates that the difference may not be large enough to be of concern to applications such as the TSR, but as Table 1 indicates, the difference is almost 20% for Pl.

These two assumptions greatly influence how a user would consider their use of, and the uncertainty associated with, TIPSY, but they are not mentioned in any publicly available MFLNRO&RD documentation of TASS or TIPSY, representing a major omission, possibly a misrepresentation.

In meetings with TASS modelers to discuss the 2001 report, TASS modelers indicated TASS III would be based on TASS II in selection upgrade mode. There will be no selection suppressed mode for TASS III.

Significant funding for TASS III began in 2005 with a scheduled release in 2008. Given that TASS III was supposed to be released in 2008, we assumed that the TASS II estimation from the selection upgrade mode would prevail and used those in our analysis.

In 2008, MFLNRO&RD released a version of TASS III to meet their obligation for funding. What was not stated in the release was that that the version of TASS III released was not operational, a clear misrepresentation.

Over the next decade, numerous TASS III release dates were announced, but never fulfilled -- a continuation of the original misrepresentation. During this time, 2015 was the last time we inquired, TASS modelers insisted that the 2001 report was valid and TASS III would be more similar to TASS II selection upgrade mode.

In late 2017, TASS III and TIPSY v4.4 were finally released[79], almost a decade after their original scheduled release date.

In Table 1 we update the examples of TASS and TIPSY yields for the Sw plantation and the Pl plantation presented in the 2016 Estimates Debate questions. With the exception of the 2018 TASS III v4.1.0.4 yields, all TASS simulations were provided by MFLNRO&RD.

Table 1 indicates that although TASS III may be structured the same as TASS II selection upgrade mode, the estimates for both Pl and Sw are not similar to TASS II in selection upgrade mode. This is a clear a misrepresentation in the information we were previously provided. In fact, TASS III estimates are not even similar to TASS II in selection suppressed mode.

Table 1 indicates the TASS modelers were aware of the differences, or at least potential differences, between TASS III and both versions of TASS II and TIPSY by 2012. These differences, otherwise known as uncertainty, are not accounted for in any TSR or AAC determination. To date, TIPSY v4.4 has not been used in any TSR or AAC determination. Not accounting for this uncertainty is an omission, possibly a misrepresentation.

[79] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/tree-and-stand-simulator-tass

Table 1. TASS and TIPSY Yields at Age 100 (m^3/ha)

Year	Model	Version	Lodgepole Pine	White Spruce
2009	TASS II	Selection Upgrade	461	604
	TASS II	Selection Suppressed	550	613
	TIPSY	v4.1	537	604
2012	TASS III	Preliminary	589	Not requested
2015	TASS III	Preliminary	727	506
	TIPSY	v4.3	539	604
2018	TIPSY	v4.4	617	528
	TASS III	4.1.0.4	631	519

Both species are 1,600 stems per hectare planted, site index 20.0 m and OAFs 1 and 2 set to 1.0

The MFLNRO&RD response indicates the disparities between TIPSY, TASS II and TASS III will be eliminated to the extent practicable and only a single mode of TASS II will accommodate both fertilization and genetic gain. Since the initial release of TASS III will only have two species, Pl and Sw, the new versions of TASS II and TIPSY will be used for the TSR in the near future.

The TASS III Use Policy and Installation Guide, available with the TASS III download, indicates that TIPSY v4.4 is based on TASS III yields. Based on Table 1, it appears that disparities between TASS III and TIPSY v4.4 have been eliminated. The document is vague on TASS II and it is unclear whether there are disparities between TASS II and TASS III or TIPSY v4.4, representing an omission.

The TASS III Use Policy and Installation Guide is confusing as on the one hand it states:

> *"TASS III is approved for use in all applications requiring managed stand yields of lodgepole pine and white spruce in British Columbia. It is appropriate for single species single cohort monocultures, mixed species stands and multi-cohort stands of pure or mixed species."*

On the other hand, it also states:

> *"The Ministry makes no warranties and is not liable for consequences resulting from its use."*

It is unclear how the MFLNRO&RD can approve a model for use but declare the ministry is not liable for its use.

In the forest minister's response to the 2016 Estimates Debate questions, the only explanation MFLNRO&RD was able to provide for the differences between the two modes of TASS III and TIPSY v4.3 was *"clients need to trust our judgment".*

Table 1 indicates significant differences between TIPSY v4.3 and TIPSY v4.4 for Pl yield (+14.5%) and Sw yield (-12.6%), both beyond the standard TSR sensitivity analysis of ±10% for managed stand yield.

The TASS III Use Policy and Installation Guide, dated September 2017, indicates, *"A technical report fully describing TASS III model development, testing and validation is currently in preparation"*. Yet in a June 2018 ITT (1070-30/OT19FHQ113) for TASS Strategic Model Development MFLNRO&RD lists this deliverable: *"Complete final draft of a manuscript on TASS III lodgepole pine and spruce modeling for publication as a Technical Report".*

Given the significant changes in TASS/TIPSY yields for Pl and Sw and that they have been approved, with MFLNRO&RD making no warranties and assuming no liability, the manuscript on TASS III modeling should have been released with the software. We are still just left with *"clients need to trust our judgment".* This represents a major omission associated with the release of TASS III and TIPSY v4.4.

In fact, given the differences between TIPSY v4.3 and TIPSY v4.4 with no explanation, the uncertainty associated with TIPSY yields has increased with the release of TIPSY v4.4.

Additionally, forest carbon offsets projects, which are audited by an independent third party, require model documentation. Although FCOP and VM0034 include TASS/TIPSY on their list of recommended models, the following applies to models not on the list:

- The model is scientifically sound, and has been peer reviewed in a process that: (i) primarily involved reviewers with the necessary technical expertise (eg., modeling specialists and relevant fields of biology, forestry, ecology, etc.), and (ii) was open and rigorous;
- The model is based on empirical evidence, and has been parameterized and validated for the general conditions of the project land area;
- Application of the model is limited to the scope for which the model was developed and evaluated;
- **The model's scope of application, assumptions, known equations, data sets, factors or parameters, etc., are clearly documented and;**

- The models must provide accurate modeling of time dependent parameters such as decay, below ground biomass and soil carbon changes, etc. The model must not assume that such changes take place instantaneously or within a short period of time.

Given the requirements for models not on the recommended list, it is puzzling how TASS/TIPSY qualified for the recommended list.

Given that TASS III and TIPSY v4.4 yields have been approved and the differences from TIPSY v4.4 exceed any managed stand sensitivity analyses in the TSR, we recommend that the AAC and Type 4 Silviculture Strategies for all interior TSAs with substantial amounts of Pl and Sw be revisited and the uncertainty with TASS/TIPSY yields be properly accounted for.

Disregarding the differences in TIPSY, TASS II and TASS III, there are two additional items associated with TASS/TIPSY that have a great deal of uncertainty and have not been resolved with the release of TASS III and TIPSY v4.4:

1. The increase in yields due to the genetic gain functions in TASS/TIPSY,
2. The determination of OAFs,

Genetic Gain

In B.C., the potential genetic gain through the use of orchard seed is expressed as genetic worth. Genetic worth is an index that has been developed in B.C. and is an estimate of a seedlot's average level of improvement for the commercial trait of interest at an index age[80]. Genetic worth is obtained by weighting the breeding value of each orchard parent by its proportional gamete contribution (male and female) to the seedlot.

Breeding values are determined from progeny tests where the effects of environmental variation are minimized and as such, represent a predicted increase. The actual increase is dependent on reintroducing the environmental variation through the establishment of realized gain trials. The true genetic gain will not be known until realized gain trials reach the index age.

The tree breeding and improvement program has adopted a number of conservative approaches when determining breeding value and genetic worth[81]:

[80] Stoehr, M., J. Webber and J. Woods. (2004). Protocol for rating seed orchard seedlots in British Columbia: quantifying genetic gain and diversity. Forestry, Vol. 77, No. 4.
[81] Xie, C.Y. and A.D. Yanchuk. (2000). Breeding values of parental trees, genetic worth of seed orchard seedlots and yields of improved stocks in British Columbia.

- A risk factor that reduces the genetic worth depending how far the selection age, at which breeding value is determined, is from the index age.
- Adjustments for pollen contamination;
- A conservative multiplier to convert breeding values of height to breeding values of stem volume; and,
- Switching from multi-tree plots, which tend to inflate family differences, to single-tree plots.

Breeding value is a joint property of the individual, of the population it was selected from and of the environment where the progeny grow. The seed zones in B.C. define the background population and the target environment. As such, climate change has the potential to significantly alter predicted genetic gain.

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.

While we can find numerous references of data collected for realized 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[82]. Both reports indicate that to date, coastal Douglas-fir is exceeding its expected genetic gain.

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 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.

Although there is a great deal of uncertainty associated with the predicted genetic gain at index ages, 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.

It should be noted that a recent ITT (1070-30/OT19FHQ113) for TASS Strategic Model Development contains the following deliverables in relation to genetic worth and realized gain:

- Investigate the nature and source of genetic gain in key conifer species within the Ministry Tree Improvement program;

[82] http://www.fgcouncil.bc.ca/doc-12-factsheets.html

- Evaluate and, if necessary, revise the implementation of genetic worth functionality in TASS.
- Investigate the evaluation of Site Index in stands established with genetically improved stock, and propose methods of avoiding overestimation of site productivity and potential height growth in growth and yield projection.

We recommend that the TSR and AAC determination processes use genetic gain for sensitivity analysis and not the base case until the current MFLNRO&RD review of genetic worth and realized gain in TASS/TIPSY has been completed. If the chief forester wishes to increase the AAC determination as a result of genetic gain, then we recommend that the increase be accompanied with a rationale supported by realized gain trial results.

Operational Adjustment Factors

In a 2014 email to FAIB, we summarized the constantly changing definitions for OAF 1 and 2 and requested clarification on the use of OAFs for a forest carbon offsets project. We present the email in Appendix B, but will just provide a summary of the main issues here.

A brief summary of OAF definitions:

1. Prior to TIPSY being released, TASS used a 15% reduction for unproductive areas and a 4% reduction for DWB which were combined into a single OAF of 0.816.

2. When TIPSY was introduced in 1991, the single OAF was split into:
    a. OAF 1 is a constant reduction in yields throughout the life of the stand and has a default of 0.85.
    b. OAF 2 is a reduction that increased linearly throughout the life of the stand and has a default of 0.95 at age 100. OAF 2 accounted for DWB.

3. In TIPSY v3.0, additional OAFs were introduced:
    a. OAF Armillaria is a reduction for armillaria root rot. It is only available for interior Douglas-fir in the ICH ecozone. Reductions are pre-defined, based on a low, medium and high setting. The reductions are based on a study by the CFS.
    b. OAF_Custom allows a custom OAF_1 or OAF_2 to be designed. It can be applied in terms of age or stand height and can either move trees to the mortality table or remove them from the stand.
    c. OAF_DWB is a reduction for decay, waste and breakage. Reductions are pre-defined, using inventory methods and data, and are based on species, ecozone,

stand age and stand height. Contrary to FAIB's comments in Appendix B, the DWB reductions in TIPSY are different from the ones used in VDYP7. This was confirmed with the TASS modelers.

4. At some point, OAF 1 was partitioned into OAF 1a and OAF 1b. In TIPSY v4.3, they are described as:
    a. OAF 1a is the portion that is not influenced by forest management. It reflects unproductive areas and does not change from rotation to rotation.
    b. OAF 1b is the portion that is influenced by forest management and can change from rotation to rotation.
    c. The overall OAF 1 reduction was 15%.

    The definition of OAF 2 was expanded to include reductions for agents, such as insect and disease, that increase over time.

5. In 1998, a new definition was released for use in the TSR process that partitioned OAF 1 into:
    a. OAF 1a is for non-productive areas (e.g. rock outcrops, swamps) not already addressed in the timber supply analysis process and accounts for a 4% reduction.
    b. OAF 1b is for management effects of espacement and non-commercial cover (stocking gaps and non-commercial species) and accounts for a 4% reduction.
    c. OAF 1c is for future losses due to endemic health (biotic) factors (diseases and pests) and accounts for a 4% reduction.
    d. OAF 1d is for future losses due to random risk (abiotic) factors (wind, snow etc.) and accounts for a 3% reduction.

    Most notable about the differences between the TSR OAF 1 definition and the OAF 1 definition supplied in TIPSY are:
    a. OAF 1a and OAF 1b have been reduced from a 15% reduction to an 8% reduction.
    b. OAF 1c and OAF 1d, which account for a 7% reduction, have been specifically added and represent future losses. In the TIPSY OAF 1 and OAF 2 definitions, future losses are just given a casual reference.

    OAF 2 is still defined in both the TSR and TIPSY definitions as being a 5% reduction to account for DWB, with the option of also using it to account for losses to other agents, such as diseases and insects.

In 1996, RPB initiated the OAF 1 project[83]. The project developed a survey methodology to measure stocking gaps and to assign an OAF 1 based on the survey results.

In subsequent years, a number of studies to quantify OAF 1 were initiated. Some used the methodology developed with the OAF 1 project and others used different methodologies, such as remote sensing methods. These studies consistently indicated that stocking gaps do not account for a 15% reduction in yields.

This led to the OAF 1 project releasing a lengthy list of factors that can cause yields to be less than those predicted by TASS/TIPSY, but did not define them as either OAF 1 or OAF 2 reductions.

In the 2001 Bulkley TSA AAC determination, OAF 1 was reduced for a number of analysis units based on a survey that utilized the OAF 1 project methodology. The chief forester rejected the OAF 1 reductions.

In the 2014 TFL 47 AAC determination, OAF 1 was reduced based on an analysis of gaps in plots established for a site index adjustment project. The chief forester rejected the reduced OAF 1 and indicated a preference for an overall monitoring approach to improve managed stand yield estimation, such as the YSM program, as opposed to focusing on individual factors such as OAFs.

As discussed in the previous section on YSM, the 2012 YSM framework included quantifying OAF 1 as an objective, but this was dropped in the 2013 YSM framework. The YSM data analysis has to assume initial managed stand conditions and as such, cannot make a definitive determination on OAFs.

Current recommendations, based on the majority of recent AAC determinations, appear to be OAF 1 set to a 15% reduction and OAF 2 set to a 5% reduction.

The 2017 Prince George AAC determination is a prime example of how attempts by MFLNRO&RD staff to project OAFs as a quantifiable attribute add to the confusion around OAFs. In the analysis, the OAF 1 reduction is split into 1.6% for empty plots and 13.4% for what is termed “remaining used”. There is no documentation on how the 1.6% for empty plots was determined. In the end, it is still an OAF 1 reduction of 15%.

[83] https://www.for.gov.bc.ca/hfp/meta/publications.htm#021

To add a bit more to the confusion, page 70 of the 2015 Prince George TSR data package indicates OAF 2 accounts for losses due to DWB, while page 119 indicates OAF 2 accounts for losses to damage agents other than MPB.

What we find most incredulous is that TIPSY has been in use since 1991 and nobody can actually provide a consistent definition of what OAFs represent, let alone develop any methodology to actually adjust OAFs with sample plot data.

While we can just accept the default OAF adjustments, it still leaves the problem of just what do they represent and what do we have to add to account for the predicted increase in forest health losses due to climate change.

We recommend that MFLNRO&RD release a definitive statement of what OAF 1 and OAF 2 represent; whether they can be adjusted with sample plot data and, if so, how; and how to factor in the predicted increased losses for forest health due to climate change.

YSM AND SDM DEBATE

The SDM program, initiated in 2009, and the YSM program, initiated in 2011, are the most recent attempts to collect data on managed stands. It should be noted that B.C. should have almost 40 years of data on managed stands, but owing to inadequate planning and mismanagement, past programs have been discontinued:

1. The Intensive Forestry program was initiated in 1979 to assess silviculture treatments, such as spacing, thinning and fertilization, in what were considered “operational treated areas”. Sample plots were purposively located in operationally treated and untreated (control) areas. The program was discontinued in 1995, primarily due to large differences in initial stand conditions between the control and treatment areas and the subjectively located samples cannot be used for monitoring purposes.

2. The Silviculturally Treated program was initiated in 1986 and targeted planted, spaced, thinned and fertilized managed stands. Plot location was purposive. The program was discontinued in 1998, primarily due to no control plots being established to assess the treatments against and the subjectively located samples cannot be used for monitoring purposes.

As a result, B.C. finds itself with limited data on managed stand growth beyond the point where industry has met its free-growing obligation and has transferred the responsibility for

management back to MFLNRO&RD. This lack of managed stand data hinders MFLNRO&RD's ability to assess whether silviculture investments and activities are consistent with long-term timber objectives.

In a 2012 audit report[84], the B.C. Auditor General concluded that not only did MFLNRO&RD not appropriately monitor and report its timber results against its objectives for timber; MFLNRO&RD had not clearly defined its objectives for timber.

As a response, MFLNRO&RD developed the "Provincial Timber Management Goals, Objectives and Targets"[85] with the vision of "*managing forests to meet present needs without compromising the ability of future generations to meet their needs*" and increased monitoring of managed stands through the SDM and YSM programs. Provincial objectives relevant to managed stands, and as such, the SDM and YSM programs, are:

1. *Timber flow over time objectives:*
    a. *Manage timber in an adaptive manner to address the dynamic nature of natural processes and the inherent uncertainty of managing over long timeframes,*
    b. *Achieve forecasted long-term harvest flows through the application of timber management activities, including harvest practices and silviculture investments and,*
    c. *Use available data to continuously improve timber flows, verify assumptions, and reduce uncertainty.*

    Timber flow over time targets are:
    a. *A mid-term timber supply of at least 57 million m^3/year and,*
    b. *A long-term timber supply of at least 65 million m^3/year.*

2. *Timber quality objectives:*
    a. *Proportions of high-value species within each management unit will be maintained at no less than pre-harvest levels based on the forest inventory,*
    b. *Restock new forests with trees that will produce high-quality fibre (including sawlogs) as the primary product objective and,*
    c. *Ensure a proportion of the growing stock will produce future logs of premium grade.*

[84] An Audit of the Ministry of Forests, Lands and Natural Resource Operations' Management of Timber (http://www.bcauditor.com/pubs/2012/report11/timber-management)
[85] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/timber-management-goals

The timber quality target is to produce a minimum of 10% premium grades annually.

3. *Stand productivity and growing stock objectives:*
    a. *Target full site occupancy of growing space after making effective allowances for other values and risks and,*
    b. *Risks to productivity and growing stock (including risks from insects, disease, fire and windthrow) will be reduced across the forest within the context of climate change and other long-term influences*.

Stand productivity and growing stock targets are:

a. *Free-growing stems per hectare exceed 75% of the target stocking 80% of the time,*
b. *Average planting delay is less than two years on harvested areas and,*
c. *By 2020, 75% of all trees planted will be grown from select seed with an average genetic gain of at least 20%.*

While these objectives are related to managed stands, only the timber quality target provides a performance benchmark to compare against monitoring data and report results. The timber flow target provides no performance benchmarks for managed stands to monitor and to report against. Also, the stand productivity and growing stock target provides no performance benchmarks for managed stands to monitor and report against beyond free-growing.

The targets in the "Provincial Timber Management Goals, Objectives and Targets" are too vague and do not appear to reflect the spirit and intent of the Auditor General's recommendations. In our view the MFLNRO&RD has failed to comply with the recommendations.

As an example using the SDM program, if MFLNRO&RD had targets of well-spaced trees at mid-rotation ages, such as they do at free-growing, the SDM data could use that as a performance benchmark.

The real problem we are faced with is that in the absence of performance benchmarks, MFLNRO&RD seems to be defaulting to comparing monitoring results to model results. Problems with this are:

- YSM analyses initializes TIPSY with assumed density values such as 5,000 stem per hectare for Bl or deciduous, otherwise 1,500 stems per hectare. These densities are different from what are used in the TSR and AAC determination processes.

- There is no accounting for the difference in individual tree volume determination between TASS/TIPSY and MFLNRO&RD individual tree volume calculation.
- The YSM analysis does not match ground samples and TIPSY predictions by age for comparison, but matches them by top height. While this favours TIPSY comparisons, it is not how MFLNRO&RD uses TIPSY in the TSR and AAC determination processes. Age is used and there is no indication of the age offset resulting from matching by top height. While this may seem trivial, a consultant to the TASS modelers did something similar by matching TASS top height to ground sample top height from an 80 year old stand for a forest carbon offsets project using the regeneration delay option. The resultant regeneration delay was 20 years.
- Given our experience with TIPSY providing Pl yields that range from 461 to 727 m^3/ha for the same stand and with the most recent changes to Pl and Sw yield estimation in TIPSY v4.4, using a model to set a target has its limitations.

Beginning in 2013, questions around duplication between the SDM and YSM programs began to emerge, touching off a debate as to whether both programs should be maintained. The entire debate seems to have been sparked by an analysis using SDM data that raised questions about how managed stands were being modeled with TASS/TIPSY, or more specifically, whether the mortality of top-height crop trees due to insects and disease causes problems with the principles on which TASS is based[86].

The debate is also fueled by FAIB's dismissal of silviculture survey and RESULTS data instead of trying to incorporate the information, along with the branch's misguided belief that all data has to be useful for modeling purposes.

In 2014, a consultant produced a report that concluded the SDM methodology lacks the required rigour to provide defensible information on managed stand development[87]. The report raised valid concerns about the changing definitions of target population, missing tree-height measurements/estimates, and incorrect compilation, but mainly focused on the problems with using well-spaced trees to assess change or to initialize TASS/TIPSY.

In 2015, the same consultant, under contract to FAIB, produced a report comparing the SDM and YSM programs[88]. Again, the main focus was on the problems with the definition of the SDM target population and with the use of well-spaced trees.

[86] Woods, A. and K.D. Coates. (2012). Are biotic disturbance agents challenging basic tenets of growth and yield and sustainable forest management?, Forestry, Vol. 86, Issue 543-554.
[87] McWilliams, E. (2014). Review of stand development monitoring (SDM): sampling and analysis procedures.
[88] McWilliams, E. (2015). Review of the young stand monitoring & stand development monitoring programs.

A few comments on the criticisms:

1. Many of the criticisms deal with incorrect compilation and what the TASS modelers consider to be an inappropriate use of their model. These can be corrected and should not be used as the basis to criticize a monitoring program.

2. While the use of well-spaced trees with which to initialize TIPSY is criticized, the confusion on the part of TIPSY users is understandable. In the 2015 Prince George TSA TSR, the data package states:

   > *"Where stands were established post-2002 and the regeneration survey summaries form the primary data, source stocking is based on the* ***area weighted uncapped well-spaced stems per hectare****, GW and the planted option in TIPSY is applied.* ***Use of this methodology was advised by FLNRs TASS/TIPSY growth and yield research group.*** *The well-spaced number implies a regular spatial configuration. Therefore the appropriate regeneration method to assume is 'planted' regardless of actual stand origin."*

   On the one hand, using well-spaced trees to initialize TIPSY is criticized, while on the other hand, the TASS modelers recommend it for the TSR and AAC determination processes.

3. Although species composition is estimated in the free-growing surveys, the total number of stems per hectare is provided. The well-spaced tree data could simply be ignored.

4. While it is true that the YSM program has a protocol for data analysis, it did not properly account for domain analysis. This was not corrected until 2018. While it is true the SDM program originally had no protocol for data analysis, MFLNRO&RD biometricians were consulted and compilation procedures have been documented[89].

In 2015, the chief forester, concerned about the overlap of the SDM and YSM programs, had staff look into whether either of the programs was redundant and whether they could be made more compatible.

[89] Supplemental material (http://www.mdpi.com/1999-4907/8/8/280)

The issue should not be that the YSM and SDM programs be more compatible; instead it should be how they can be used together to strengthen each other, which is an entirely different concept.

For example, PSPs are more efficient than TSPs if only change is of interest. The problem is whether a PSP established at time 1 still has the character of a statistical sample at time 2[90]. Sampling with partial replacement provides a solution to this. This method establishes TSPs at time 1. At time 2, some of the time 1 TSPs are re-measured and additional TSPs are established. Change is estimated from the matched TSPs and the new TSPs are used to test if the PSPs are still representative (typical) of the target population (Figure 2). This methodology was considered during the initial VRI planning, but since the methodology requires additional planning and computations are quite involved, it was not pursued.

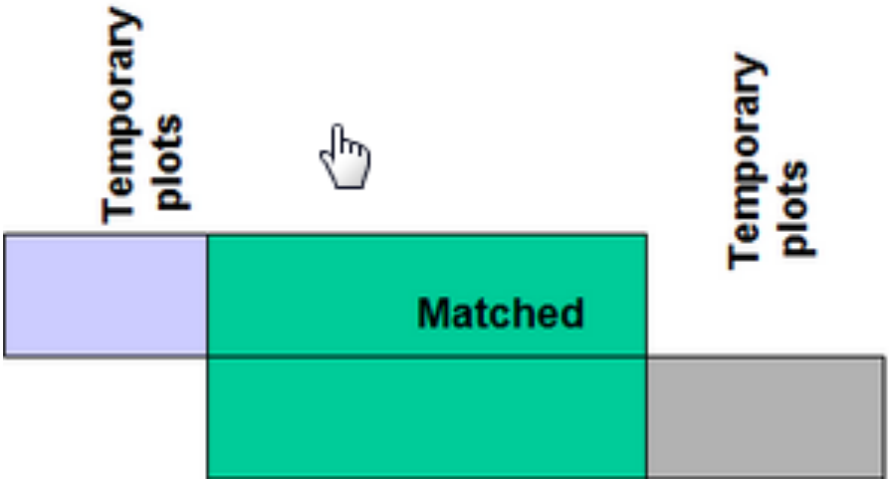

Figure 2: Sampling with Partial Replacement

Our understanding is that changes made to the SDM program include:

- Using the VRI database instead of the RESULTS database to select polygons to sample,
- Polygons will be selected proportional to size,
- Well-spaced trees will not be recorded, only total trees,
- The SDM forest health assessment will be replaced by the YSM forest health assessment,
- Plot size will be increased to a 5.64 m radius plot to be compatible with site tree selection,

[90] http://wiki.awf.forst.uni-goettingen.de/wiki/index.php/Estimation_on_changes

- Procedures for properly dealing with boundary plots and,
- Dead and down tees will not be assessed as to the cause.

Most notable about the changes:

1. Selecting polygons from the VRI database does not ensure there will be accompanying data from the RESULTS database. There is no longer any direct link to silviculture practices and mid-rotation managed stand performance. One has to wonder if that is by design -- Does the ministry really want to know how managed stands are performing?
2. Replacing the SDM forest health assessment, designed for single measurement samples, with the FAIB forest health assessment, designed for re-measured samples, makes no sense as it makes the forest health assessment useless. It would make more sense to **add** the SDM forest health assessment to the YSM program to test in the future whether there is any correlation between the systems.
3. Without a link to the RESULTS database, one will never know in the future if one is dealing with trees with genetic gain, a major shortcoming of the YSM program.

We also note that no reference seems to have been made to analyses by a MFLNRO&RD biometrician in one of the few attempts that have been made to bridge the gap between FPB data and FAIB modelers[91] (the reference provided is only one of many).

The nature of the changes give the impression that the entire exercise was to neuter the SDM program, something that has been effectively done. From our perspective, there appears to be a significant amount of internal politics operating in the background to the debate. The entire process appears to be tainted.

The result seems to be something that has the elements of sampling with partial replacement, but without the statistical design of the methodology. We can only hope that we don't have another debacle in the making, such as the Silviculturally Treated and Intensive Forestry programs.

As a final thought, in the TFL 47 AAC determination, the chief forester rejected the OAF 1 adjustment and indicated a preference for an overall monitoring approach. Similarly, in the

[91] Looking ahead: will free-growing stands produce the volumes we expect? (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards/stocking-standards-density-espacement)

2014 McWilliams critique of the SDM program calls for a holistic approach to managed stand data collection, management and analysis protocols. Perhaps it is time to:

- Cut down on the number of openings subject to survival and free-growing assessments using a sampling scheme with a sufficient sample size that will not increase the risk to the Crown. The sampling can be augmented by different technologies, such as satellite imagery or photography using drones.
- Use the savings to fund a large expansion of mid-rotation sampling, using both TSPs and PSPs. PSPs could be established at an early enough age to capture variables such as genetic gain and the distribution of stems.
- Ensure data is collected to satisfy both the modelers and silviculturalists, even if they can't agree on what is valid and what is not.

We recommend that the ABCFP develop competency requirements for those involved in the statistical analysis of data. This is consistent with the competency recommendations (3 and 4) of the recently released Summary of Recommendations from the Independent Report on Professional Reliance.

While probably too late, we recommend that a committee, such as the G&Y Cooperative that the ABCFP has advocated for, be established to provide an unbiased review of the YSM and SDM program debate.

We recommend that for the Provincial Timber Management Goals, Objectives and Targets, MFLNRO&RD develop meaningful performance benchmarks for mid-rotation yields for comparison to the results of the ground sample monitoring programs.

ALLOWABLE ANNUAL CUT DETERMINATIONS

We have described the term "best available information" as a nebulous phrase as it makes no assessment of data quality or of whether the data are adequate for determining a trustworthy AAC. To illustrate this point, we have selected a few TSAs to assess the adequacy of forest inventory data used for the AAC determination. For all the selected TSAs, the rationale for the AAC determination stated the "best available information" was used.

The *Greenhouse Gas Emission Control Regulation* states that validation and verification bodies cannot issue a validation or verification statement if the forest carbon offsets project plan or report is subject to material errors, omissions or misrepresentations. The AAC determinations for the selected TSAs contain examples of material errors, omissions or misrepresentations in the respective TSR documents and in rationale documents for the AAC determination. Material

errors, omissions or misrepresentations are also present in the forest minister's responses to questions from the public about the AAC determination related to the forest inventory, to the use of monitoring analyses and to the use of forest G&Y models.

We recommend that the Forest Act include the same type of protection against material errors, omissions or misrepresentations in AAC determinations as the Greenhouse Gas Emission Control Regulation and that an independent, third-party auditor review all current rationales for AAC determinations for material errors, omissions and misrepresentations related to the forest inventory and to the use of forest G&Y models.

Boundary TSA AAC (October 2016)

For the Boundary TSA AAC, FAIB used a FIP based (old) inventory. The critique focused on a 2009 MFLNRO&RD report[92] comparing the VDYP7 VRISTART mode with the FIPSTART mode using the MFLNRO&RD TSP data that indicated the FIPSTART mode overestimated current volume by approximately 20% and that this overestimation was not accounted for in the AAC determination because FAIB staff did not inform the chief forester of the 2009 report.

In the forest minister's response, MFLNRO&RD staff indicated that they do not support their 2009 report as the TSPs do not represent the forest stands in the TSA and as such, could not be used to infer either an overestimation or underestimation.

MFLNRO&RD then cited two studies (a 1998 inventory audit report and a 1999 VRI Phase II adjustment project for dense pine in the Boundary TSA) claiming both studies showed no significant difference between the ground samples and the VDYP6 comparisons. Given that these studies used VDYP6, MFLNRO&RD also cited a 2006 report that showed only a 0.4% difference between VDYP6 and VDYP7 volumes in the Boundary TSA operable land base. The inference is that since two studies showed no significant difference between VDYP6 estimates and ground samples and another study showed very little difference between VDYP6 and VDYP7 estimates, VDYP7 estimates would also not be significantly different from ground samples in the 1998 and 1999 studies.

MFLNRO&RD also conducted what it purports to be a paired t-test between VDYP7 estimates and the 1998 inventory audit data that showed no significant difference. It was pointed out that the 1998 audit data were compiled with the 1988 Kozak FIZ-based taper function and FIZ-based

[92] TSP and VDYP7 Volume Comparison (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/growth-and-yield-modelling/variable-density-yield-projection-vdyp/publications-and-support)

DWB loss factors. FAIB recompiled the inventory audit data using the 1994 BEC-based taper function and the 2000 BEC-based DWB loss factors v3.0. Again, the branch conducted what it purports to be a paired t-test between the VDYP7 estimates and the ground samples that showed no significant difference.

The forest minister's response is flawed with error, omission and misrepresentation.

MFLNRO&RD provides no evidence to support its claim that the TSP data are not representative of the Boundary TSA or whether post-stratification sampling weights could have been used if the data were not representative, assuming representative means typical of the target population.

FAIB provides no evidence to support its claim that the 1998 inventory audit data are representative (typical of) of the Boundary TSA.

The 1999 VRI Phase II adjustment project actually showed a significant difference between the ground samples and the VDYP6 estimates for the TSA, not a non-significant result as MFLNRO&RD claims.

MFLNRO&RD refused to provide the 2006 report comparing VDYP6 and VDYP7 estimates.

Serious problems exist with MFLNRO&RD's paired t-test including error and misrepresentation:

- MFLNRO&RD refers to the inventory audit data as "statistically placed samples", whatever that means, indicating a lack of knowledge of the actual sampling design.
- While MFLNRO&RD claims to have performed a paired t-test, it provides no evidence to support this claim. The mean difference, confidence interval for the mean difference, t-value, degrees of freedom and significance level are not provided.
- The mean and 95% confidence intervals for the ground samples and VDYP7 predictions are provided, but these are only descriptions of the data.
- MFLNRO&RD incorrectly states that the data descriptions provided are proof of no significant difference, indicating MFLNRO&RD does not understand the statistical test it is trying to apply. What MFLNRO&RD should present is the mean difference with the 95% confidence interval.
- While, the data descriptions provided would be appropriate for an independent sample t-test, MFLNRO&RD implies significance can be determined by observing the overlap of confidence intervals. This is incorrect and further indicates MFLNRO&RD does not understand the statistical test they are trying to apply. If MFLNRO&RD had presented

the correct information (mean difference and 95% confidence interval), a non-significant result could be declared if the 95% confidence interval contained zero.

- Even if the paired t-test was conducted correctly and reported properly, it would not support MFLNRO&RD's conclusion. One cannot infer equivalence from a non-significant result for a paired t-test.
- A 1999[93] review of the application of inventory audit data pointed out a similar lack of understanding of basic statistical concepts: "*Statistical concepts (such as "statistical significance") relating to the interpretation of inventory audits are either poorly understood or misapplied by many users of the inventory data*".
- Standing timber volume is the variable being tested and since it increases over time, a meaningful effect size cannot be determined for the range of ages in the inventory audit data. MFLNRO&RD should be testing the ratio of values instead of the difference between values.
- MFLNRO&RD should be conducting an analysis of equivalence on the ratio of timber volumes, increasing the effect size (10%, 20% etc.) until equivalence is obtained and then using the resultant effect size to assess the uncertainty associated with the VDYP7 predictions. The resultant effect size would not be the true accuracy of the model, but would be the accuracy MFLNRO&RD can show, given the small sample size. Increasing sample size would most likely lower the resultant effect size.
- In addition to the problems with the statistical analysis, the inventory audit samples were not compiled to current standards (2002 Kozak BEC-based taper function and 2000 BEC-based DWB loss factors v3.0).

FAIB has provided no evidence to support its rejection of the 2009 MFLNRO&RD report that indicated VDYP7 estimates of current timber volume used in the Boundary TSA AAC determination (October 11, 2016) were overestimated by 20%. We recommend that the TSR and AAC determination for the Boundary TSA be reviewed.

Arrow TSA AAC (November 2017)

The 2017 rationale for the AAC determination has a major omission, as it does not contain any information on the inventory under "Existing Forest Information".

Under "Reasons for Decision" in the rationale for the Arrow TSA AAC determination the chief forester states that the base case AAC is 506,000 m^3/yr.

[93] Review of the Application of Forest Inventory Audit Information in Timber Supply Review Timber Supply Analyses, B.C. Forest Service, Research Branch

The chief forester goes on to state the base case AAC is over-estimated owing to:

- Losses due to Armillaria root disease not being properly accounted for, resulting in a 12.1% over-estimation of the long-term timber supply.
- The inclusion of inoperable areas, resulting in a 7% over-estimation of the short and long term timber supply.
- Overestimation of managed stand yields as indicated by preliminary data from the Young Stand Monitoring program, but for some unstated reason, the extent of the over-estimation is unknown.
- Future recruitment for OGMAs representing a marginal unquantified downward pressure on the short- and long-term timber supply.
- Future recruitment for wildlife habitat supply and actions for wildlife management representing an unquantified downward pressure on the short- and long-term timber supply.

Also under the "Reasons for Decision" section, the chief forester states the dead potential pine was not included, resulting in a 5.3% under-estimation of the short-term timber supply.

On the one hand, the short- and long-term timber supply was over-estimated by 19.1% plus additional over-estimations that could not be quantified. On the other hand, the short-term timber supply was under-estimated by 5.3%. Although the difference is an over-estimation in excess of 15%, the AAC was only reduced from 506,000 m^3/year to 500,000 m^3/year, just slightly more than a 1% reduction.

We note that although Minister Donaldson provided a new letter of guidance[94] to the chief forester on October 30, 2017, replacing guidance letters from former ministers Rich Coleman and Pat Bell, it was not referenced in this AAC determination (November 2017). Appendices 3 and 4 of the rationale for the AAC determination contain the letters from Coleman and Bell.

The main guidance provided by former ministers Rich Coleman and Pat Bell was to maintain or enhance the AAC, particularly in the mid-term, and to show leniency when dealing with timber supply reductions due to the mountain pine beetle infestation.

In contrast, the guidance provided by Minister Donaldson, while recognizing the economic importance of the forest sector to rural communities, emphasizes: consultation with First

[94] Can be found in appendix 3 of the rationale for the Fort St. John AAC determination.

Nations; sustainable resource management through the modernization of land-use plans; the expansion of investments in reforestation; collaboration in the development of management strategies for wildlife management and habitat; and consideration of the impact of forest health issues and wildfires in the AAC determination.

The "Reasons for Decision" in the rationale for AAC determination suggest most, if not all, of the guidance provided by Minister Donaldson was ignored.

We recommend that the TSR and AAC determination for the Arrow TSA be reviewed to reflect the spirit and intent of Minister Donaldson's letter of guidance dated October 30, 2017.

Bulkley TSA AAC (January 2014)

The Rationale for AAC Determination for the Bulkley TSA states that the "best available information" was used.

The Phase I inventory used in the TSR process failed the MFLNRO&RD's own quality assurance, with the recommendation that

> "*the ministry should either correct the vegetation resources inventory (VRI) polygon delineation and polygon attribute estimation data sets or conduct a complete re-inventory of the Bulkley TSA*[95]".

The PEM thematic accuracy was below the minimum threshold of 65% required for approval for use in ecosystem-based timber supply analysis[96]. The alternate ecosystem accuracy scores were 59.3% for dominant correct and 68% for percent overlap. The shortcoming in dominant correct was "overlooked" and the PEM was conditionally approved for use with SIBEC in the TSR process to assign site index to managed stands.

The PEM was used in conjunction with SIBEC for the base case scenario even though PEM guidelines[97] specify that if a PEM does not meet the minimum accuracy statistics, it can only be used in a sensitivity analysis.

The VRI statistical adjustment[98] increased stand timber volume by 29% overall, with timber volumes for the immature and mature strata in the ESSF zone increasing 50%. MFLNRO&RD

[95] Bulkley TSA VRI Review Project – Final Quality Assurance Report
[96] Bulkley TSA Predictive Ecosystem Mapping (PEM) Level 4 Accuracy Assessment - Second Assessment
[97] Meidinger, D. (2003). Ecosystem mapping accuracy and timber supply applications. Research Branch, BCFS

applied the increases to all but the ESSF zone, resulting in a 12% increase in timber volume. Issues with the VRI adjustment include:

- The Phase II VRI far exceeds the target sampling error of ±10%, but was still used in the TSR process.
- Some volume adjustments were implemented, while others were not. Either the sampling is valid and all adjustments should be implemented; or the sampling is invalid and no adjustments should be implemented. In this case, it appears that the sampling is not valid and should either be redone or none of the adjustments implemented.
- Based on a comparison to recent cruise volumes, a licensee (Pacific Inland Resources) indicated that the VRI-adjusted stand yields overestimate volume and could lead to an upward pressure on the AAC. MFLNRO&RD dismissed this concern stating the cruise data is not a random sample and cannot be used to identify a statistical bias in the inventory. The cruise data is best described as a convenience sample and while MFLNRO&RD is correct in stating it cannot be used to determine bias, convenience sampling is often used to provide a quick understanding of trends. In the case of cruise data, the trends would apply to the short-term AAC and, if the trend is a consistent overestimate, it is a red flag that should not be ignored.

Originally, an OAF 1 of 5% was used for the managed stand yield tables, based on a large study[99] of managed stand polygons using the OAF 1 definition put forward by Nussbaum[100]. This was later rejected by MFLNRO&RD and a 15% OAF 1 was applied, emphasizing the confusion around different OAF definitions and the uncertainty associated with defining OAFs.

Initial stems per hectare for managed stands were based on the target density of 1,200, but reduced by 100 to reflect lower than expected free-growing densities reported in results from the SDM program, and on some incorrect discussion about TIPSY volumes being primarily based on the top 100 stems per hectare. The SDM data actually shows that the acceptable stems per hectare are closer to 950. There seems to be some misunderstanding of what district staff was recommending.

We recommend that the AAC determination be redone using the PEM/SIBEC managed stand site indices in a sensitivity analysis and not the base case scenario, as specified by MFLNRO&RD guidelines for PEM that do not meet the minimum accuracy statistics.

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[98] The report does not appear to be publicly available, but a summary is provided in the Usage Notes section of the VRI-Analysis_Workbook-2010-11-04.xlsm file distributed by FAIB

[99] Operational Adjustment Factor 1 (OAF) Sampling in the Bulkley, Lakes and Morice Forest Districts (https://www.for.gov.bc.ca/hfd/library/fia/html/FIA2003MR188.htm)

[100] Default Operational Adjustment Factors used in Allowable Annual Cut Determinations in B.C.

We recommend that the Bulkley TSA VRI be redone and a new AAC determination be based on the new VRI. Meanwhile, the chief forester should significantly reduce the current AAC based on precautionary principles until an AAC can be re-determined using a valid inventory.

We recommend that MFLNRO&RD develop VRI adjustment standards that are statistically sound and can be applied consistently among TSAs, with particular reference to the practice of applying some adjustments and not others.

Prince George TSA AAC (October 2017)

Although the AAC determination for the Prince George TSA uses the term "best available information", this does not seem to be the case for forest health issues in managed stands. In the 2017 TSR technical report, MFLNRO&RD indicates it made the following reductions from managed stand yield tables to account for mortality above that accounted for by OAFs 1 and 2:

- 0.7% for DSG
- 0.3% for DSC and DSS
- 0.1% for IBM

MFLNRO&RD indicates that these values were derived from the YSM data for young managed stands in the Prince George TSA, but the YSM data indicate:

- For all species combined, 70% of the trees have some form of damage, with 18% of the trees being affected by disease, insect or abiotic damage.
- For lodgepole pine, 79% of the trees have some form of damage, with 28% of the trees being affected by disease, insect or abiotic damage.
- For spruce, 64% of the trees have some form of damage, with 16% of the trees being affected by disease, insect or abiotic damage.

Since FAIB does not provide any methodology, it is unclear how the mortality values for the managed stand yield tables were derived from these data, particularly given that YSM data requires repeat measurements to determine the impact associated with the incidence.

Existing forest health information that does not appear to have been used in the TSR process includes:

- SDM data indicates 25% of pine and 10% of spruce are affected in the northern TSAs and the damage is across all size classes. The SDM program only records forest health damage that is assumed will either kill the tree, reduce utilization by maiming the tree or reduce the growth of the tree by rotation age.

- The MRVA that is produced for the FREP indicates that 36% of the stands samples in the Prince George TSA had a high or medium impact on stocking due to forest health issues.

- In the previous (2011) TSR technical report, volume in pine stands less than 60 years old was reduced to account for the IBM attacks in 2005 to 2007.

  In the data package for the current TSR (2017), MFLNRO&RD mentions the IBM attacks, but indicates no additional attacks in young stands have occurred post 2008. In the current TSR technical report, MFLNRO&RD omits to mention the IBM attacks or yield table reductions for young pine. In the 2015 AAC determination, the IBM attacks in young pine stands are mentioned under the rehabilitation section, but it is unclear if the timber volumes were reduced for the AAC determination.

  A report by Maclauchlan[101] indicates that additional IBM attacks in young pine stands occurred from 2009 to 2012. These were definitely omitted from the TSR data package and not included in the 2017 AAC determination

  Given that the young pine stands influence the mid-term AAC, MFLNRO&RD needs to confirm that all IBM attacks in young pine stands were accounted for in the 2017 AAC determination.

- The 2017/2018 Forest Health Strategy[102] for the Omineca Region indicates that the IBM population has only been temporarily reduced. The IBM population will likely recur when the managed-stand lodgepole pine trees reach a size where the phloem and bark thickness are within the range required for successful IBM development. Enhanced silvicultural practices, such as thinning and fertilization, will reduce the time it takes the trees to reach a critical size.

- The 2017/2018 Forest Health Strategy for the Omineca Region includes rankings for forest health issues, by district, within the Prince George TSA:
  - In the Fort St. James District, IDB, IBB, IBD, DSS, DSC and DSG are ranked as high.
  - In the Prince George District, IBS and IBD are ranked very high and DSS, DSC and DSG are ranked high.

[101] Maclauchlan, L.E., J.E. Brooks, & K.J. White. 2015. Impacts and susceptibility of young pine stands to the mountain pine beetle, *Dendroctonus ponderosae*, in British Columbia. Journal of Ecosystems and Management 15(1):1–18.

[102] https://www.for.gov.bc.ca/hfp/health/TSA_strategies.htm

- In the Vanderhoof District, IBD is ranked very high and DSS, DSC and DSG are ranked high.

Based on a 2017 TSR technical report, it appears that the impact of forest health agents on managed stands modeled in the TSR process is only based on an undocumented interpretation of YSM data. Based on the data, analyses and recommendations listed above, the 1.1% reduction in managed stand timber volume for forest health issues not included in OAF 1 and OAF 2 and used in the TSR, appears to be a gross underestimation. This can have a significant effect on the mid-term AAC assumptions.

In the 2017 AAC determination, all three sensitivity analyses modeling the impact of spruce beetle (IBS) impact used the 2016 infestation area of 116,000 ha. The sensitivity analyses showed that the current infestation can be accommodated with stands under current attack harvested in the short term and an uplift in the AAC to accommodate salvage would not be required. It is mentioned that the infestation will be monitored and, if stewardship and sustainability issues materialize that affect timber supply, the AAC determination will be revisited sooner than 10 years at which time partitions may be considered.

The IBS infestation for the Omineca Region has increased from 150,000 ha in 2015 to 210,000 ha in 2016 and then to 340,000 ha in 2017. It can be assumed the current infestation in the Prince George TSA is now substantially greater than 116,000 ha.

It should be noted that the 2017/2018 Forest Health Strategy indicates 142, 827 ha were infested with IBS in 2016 and not the 116,000 ha modeled in the TSR process.

It is unclear how it will be determined that the AAC determination should be revisited as none of the sensitivity analyses explored the implications of the infestation increasing beyond the current level.

Given the discrepancy in how much area was infested and the fact that the infestation was projected to increase, it seems that the sensitivity analyses should have included increased infestation levels. By doing so, the chief forester would have some guidance as to whether or not the AAC determination should be revisited when new levels of infestation are reported.

The confusion around different OAF definitions and the uncertainty associated with OAFs can be shown with the 2015 TSR data package. On page 70 it states OAF 2 accounts for DWB and on page 119 it states OAF 2 accounts for damage agents other than IBM.

Attempts by MFLNRO&RD staff to project OAFs as a quantifiable attribute add to the confusion around OAFs. In the 2017 TSR technical report, the original OAF 1 is split into 1.6% for empty plots and 13.4% for the rest. It is not documented how the 1.6% was determined. Given that the total OAF 1 is still the default 15%, with 13.4% remaining undefined, the OAF 1 partitioning process is irrelevant. It also raises the question that if in another TSA the same process determines the empty plots is 7.4%, will the total OAF 1 be 7.4+13.4=20.8%?

The 2017 TSR technical report indicates site indices for managed stands were predicted using the PSPL. In the report, MFLNRO&RD also indicates that the PSPL site indices were compared to:

- YSM data
- SDM data
- Site index adjustment projects for TFLs 30 and 53

MFLNRO&RD presents only the results from the YSM comparison with no explanation as to why the results of the other comparisons are not presented.

MFLNRO&RD does not appear to have done any sensitivity analyses around the predicted yields for managed stands. Changes in TIPSY since the 2017 AAC determination show managed pine stands will have more volume and managed spruce stands will have less volume for the current planting densities. Sensitivity analyses would have been useful in assessing the impact of the changes to TIPSY on the mid- and long-term AAC.

The 2017 TSR technical report indicates that MFLNRO&RD adjusted yields for existing stands based on 186 VRI Phase II samples, 4 CMI samples and 2 NFI samples, but the table of adjustments factors indicates only 186 samples were used. The AAC rationale document states 100 VRI Phase II and 86 CMI samples were used.

There are a number of VRI statistical adjustment or analysis reports for the Prince George TSA located on the MFLNRO&RD website[103] (Table 2):

- Prior to 2008 and mentioned in the 2008 VRI adjustment reports, Timberline completed VRI statistical adjustment reports for the Prince George, Fort St. James and Vanderhoof Forest Districts using VDYP6.
- 2008 Prince George Forest District VRI statistical adjustment completed by Jahraus and Churlish using VDYP7

[103] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/inventory-analysis-reports/vegetation-resource-inventory-audits

- 2008 Vanderhoof Forest District VRI statistical adjustment completed by MFLNRO&RD using VDYP7
- 2008 Fort St. James Forest District VRI statistical adjustment completed by MFLNRO&RD using VDYP7
- 2010 Prince George Forest District VRI statistical analysis and adjustment completed by Timberline using VDYP7
- 2010 Fort St. James Forest District VRI statistical analysis and adjustment completed by Timberline using VDYP7
- 2015 Prince George TSA VRI inventory analysis completed by Penner using VDYP7

The 2015 VRI inventory analysis used new VRI data collected in 2014, excluding the northern portion of the Fort St. James Forest District. Two sets of adjustment factors, each based on a different variant of the BCMPB[104] model, were produced.

Table 2. Prince George TSA VRI Attribute Adjustment

Species	Analysis	Height	Age	Basal Area	Stems per Hectare	Volume net DWB
Balsam	TechRep	1.03	0.83	1.14	1.12	1.11
	Penner-1	1.03	0.81	1.11	1.07	1.25
	Penner-2	1.03	0.80	1.12	1.06	1.25
Spruce	TechRep	0.95	0.84	1.05	1.54	1.04
	Penner-1	0.94	0.82	0.97	1.55	0.95
	Penner-2	0.92	0.81	1.01	1.52	0.93
Pine	TechRep	0.87	0.91	**0.90**	**1.25**	**1.08**
	Penner-1	0.86	0.93	**0.51**	**1.84**	**0.84**
	Penner-2	0.85	0.92	**0.90**	**1.56**	**0.71**
Other	TechRep	1.01	0.90	0.97	1.16	1.16
	Penner-1	1.02	0.90	1.02	1.18	1.16
	Penner-2	1.03	0.84	1.03	1.13	1.15
All	TechRep	0.93	0.87	0.98	1.31	1.08
	Penner-1	0.94	0.86	0.94	1.46	1.01
	Penner-2	0.94	0.83	0.94	1.37	0.96

[104] B.C. Mountain Pine Beetle Model – used to estimate the progression of mountain pine beetle outbreak and the mortality of pine (https://www.for.gov.bc.ca/hre/bcmpb/)

Although the rationale for the Prince George AAC determination and the Prince George TSR technical report indicate the Penner analysis was used to adjust the VRI inventory, neither set of adjustment factors in the Penner report match what is used in the technical report.

Most notable are the differences in the pine adjustment ratios, but the balsam and spruce volume adjustment ratios also have significant differences.

The 2011 and 2017 TSR technical reports indicate that growth of existing lodgepole pine stands with more than 50% mortality are modeled as follows:

- Mortality is predicted with the BCMPB v11 model
- For stands with 50% or more mortality, the dead volume is subtracted from the live volume and the remaining overstorey live volume is grown at the same trajectory, but with less volume.
- After 10 years, the same yield curves for the existing stand are used to add ingrowth (understorey) in the same proportion as the mortality predicted for the existing stand.
- Overstorey and understorey volumes are combined for the AAC determination.

Although the technical reports state a great deal of uncertainty is associated with this method, no sensitivity analysis around the volumes seems to have been done. Uncertainty associated with this methodology includes:

- BCMPB v11 estimates of mortality and,
- Using VDYP7 for projections for which it was never parameterized, namely the projection of overstorey and understorey volumes of IBM damaged stands.

We recommend that MFLNRO&RD provide an explanation as to how the YSM, SDM and forest health strategy data were used to determine an additional 1.1% OAF 1 reduction, beyond the standard 15% reduction. This represents an omission.

We recommend that MFLNRO&RD provide an explanation for the discrepancy of the VDYP7 attribute adjustment ratios between what is stated in the 2017 technical summary report and the 2015 VRI statistical analysis report. This represents an error.

Invermere TSA AAC (June 2017)

The 2016 data package indicates that the inventory was completed in 1995, based on air-photo interpretation of 1988 photos. FIP lines and attributes were rolled over to VRI format in 2000. The inventory was updated to 2009 using RESULTS data and further updated to 2013 using

satellite imagery. There is no mention of VRI ground sampling, but there is mention of the 1996 audit indicating volumes in the TSA were overestimated by 5%, but it was not statistically significant. VDYP7 was used to assign volume to the inventory, but no use of NVAF for data compilation or of a VDYP7 statistical adjustment is mentioned.

The 2017 rationale for the AAC determination has a major omission, as it does not contain any information on the inventory under "Existing Forest Information".

This is in stark contrast to a 2009 VRI statistical adjustment for the Invermere TSA completed by Timberline. This document indicates 119 VRI ground samples were established in 2007 and 2008 and 120 trees (110 live and 10 dead) were destructively sampled for the NVAF program in 2008. The statistical adjustment, using VDYP7, indicated the inventory was underestimated by 12%.

It should be noted that the 1996 audit mentioned in the data package is irrelevant as it was done using VDYP6 and data were compiled with the 1988 Kozak FIZ-based taper function and FIZ-based DWB loss factors instead of to the current standard of the 2002 Kozak BEC-based taper function and 2000 BEC-based DWB loss factors v3.0.

The data package also indicates PEM and 2011 SIBEC values were used to estimate site index for managed stands. The PEM scored 63%, which is below the provincial standard of 65%, but was recommended by the regional ecologist for use in the base case.

Not only did MFLNRO&RD use failed PEM but also the ministry used out-of-date SIBEC data -- the SIBEC database had been updated in 2013 and 2014.

Additionally, the 2017 rationale for the AAC determination indicates that the increase in expected managed yields due to the use of SIBEC site indices was of concern to regional staff in the 2005 AAC determination. The chief forester at the time requested that licencees monitor the growth of managed stands to track against the increased expected managed stand yields due to the use of SIBEC site index estimates. This was not done.

Clearly, the "best available information" was not used in the Invermere TSA AAC determination. The omission of any mention of the existing forest inventory is of concern, as is the misrepresentation of audit results. The question also remains as to what happened to the VRI ground sample data and NVAF data collected in 2007 and 2008. Did MFLNRO&RD not receive a copy of the data prior to TECO (formerly Timberline) going out of business? If so, are there more cases of missing government data?

Miscellaneous TSA AACs

In the May 2016 rationale for the **Kamloops TSA** AAC determination, it states that the VRI audit indicated that the ratio between ground samples and photo-interpreted polygons for age, height, basal are, volume and site index were all within 10% of the target ratio of 1.0. Species were grouped as balsam, Douglas-fir, other species and spruce.

This is a misrepresentation because the 2015 Kamloops TSA VRI statistical analysis indicates that the following are **not** within 10% of the target ratio of 1.0:

- Other species and spruce for age,
- Douglas-fir, other species and spruce for leading species height,
- Balsam, other species and spruce for Lorey height,
- Balsam for basal area,
- Balsam and spruce for volume,
- Balsam for site index (ground versus inventory) and,
- Balsam, Douglas-fir, other species and spruce for site index (ground versus PSPL)

In the March 2016 rationale for the **Merritt TSA** AAC determination, there is a major omission as it does not contain any information on the existing inventory, with the exception that the inventory data accounted for the IBM epidemic through the provincial BCMPB model. There is also no mention of a VRI statistical analysis or NVAF.

The 2015 Merritt TSA VRI statistical analysis indicates that the majority of photo-interpretation was done prior to 1990. In 1999, 125 VRI ground samples were established. In 2000 and 2006 NVAF sampling was conducted on 25 of the VRI ground samples. In 2013, 50 VRI ground samples were re-measured and used along with 15 NFI plots for the 2015 VRI statistical analysis.

The 2016 Merritt TSA AAC determination states that managed-stand yields were underestimated by 6% due stems per hectare from free-growing surveys being used to initialize TIPSY instead of the planting density. The example provided was using a free-growing stems per hectare of 1,200 instead of the planting density of 1,500 stems per hectare. This underestimation was taken into account in the “Reasons for Decision”.

The Merritt YSM analysis was completed in 2015. It indicates that using a planting density of 1,400 stems per hectare to initialize TIPSY is too simplistic, as it does not account for the observed ingress of natural regeneration. Based on the YSM analysis, neither assumption of the stems per hectare to initialize TIPSY with in the AAC determination is valid.

In addition, the YSM analysis indicates 69% of the trees (76% of the basal area) had some type of damage, with the majority being damage from insects and disease. Potential managed-stand yield losses due to damage were not taken into consideration. Ignoring the YSM analysis is a major omission.

In the February 2015 rationale for the **Williams Lake TSA** AAC determination it states that SDM data indicates lodgepole pine managed stands may have less timber volume due to forest health issues relative to what was assumed in the base case, but classifies it as an "unquantifiable downward pressure on timber supply in the mid-term". The YSM plots are mentioned, but only to say that they have been established. In the "Reasons for Decision" section, it states that if significant new information is made available or changes to the management assumptions on which the AAC is based, the AAC determination can be revisited before the legislated 10-year period.

The 2014 YSM analysis for the Williams Lake TSA indicates that overall, managed stands have only 35% of the timber volume used in the TSR, with lodgepole pine having only 12% of the volume used in the TSR. Not incorporating this information in the AAC determination is a major omission, possibly a misrepresentation. Based on this "new" information, the Williams Lake TSA AAC should be immediately re-determined.

The 2011 VRI statistical analysis for the **Robson Valley TSA** indicates that inventory timber volumes are underestimated by 20%, based on 73 VRI ground samples established in 2008/2009. The March 2014 rationale for the Robson Valley TSA AAC determination states that district staff and licencees expressed concern over the magnitude of the suggested underestimation. MFLNRO&RD undertook a comparative analysis of 29 cutting permits representing 90 cutblocks and determined the current (unadjusted) inventory is reasonable and that adjusting it based on the VRI statistical analysis would unduly inflate the volume estimates for the existing stands. In addition, only 30% of the ground samples were within the THLB.

Interestingly, MFLNRO&RD rejects the adjustment suggested by the statistical analysis based on the results of the cruise data. This is in direct contrast to what happened with the Bulkley TSA where MFLNRO&RD refused to reject the adjustment suggested by the statistical analysis based on the results of cruise data, stating the data was not a random sample and could not be used to identify a statistical bias in the inventory. It was also suggested that the problem could be that the majority of the samples were outside of the THLB. On average, stands outside of the

THLB tend to be older and the problem may be due to a MFLNRO&RD decision to force yield predictions at older ages to approach limits similar to VDYP6[105].

In the August 2017 rationale for the **Cranbrook TSA** AAC determination, the chief forester does not provide any information on the existing inventory. This is a major omission.

The 2016 data package for the Cranbrook TSA AAC determination indicates that the inventory was completed in 1992, based on air-photo interpretation of 1988 photos. FIP lines and attributes were rolled over to VRI format in 2000. The inventory was updated to 2009 using RESULTS data and further updated to 2013 using satellite imagery. There is no mention of VRI ground sampling, but there is mention of the 1997 audit indicating volumes in the TSA were overestimated by 5%, but it was not statistically significant. VDYP7 was used to assign volume to the inventory, but no use of NVAF for data compilation or of a VDYP7 statistical adjustment is mentioned. No VRI statistical analysis exists on the MFLNRO&RD website.

No valid assessment of the uncertainty in the inventory is provided. Citing the 1997 audit in the data package is a misrepresentation as the 1997 audit was done using VDYP6 and data were compiled with the 1988 Kozak FIZ-based taper function and FIZ-based DWB loss factors instead of to the current standard of the 2002 Kozak BEC-based taper function and 2000 BEC-based DWB loss factors v3.0.

In the November 2014 rationale for the **Mackenzie TSA** AAC determination, the chief forester acknowledges uncertainty in the inventory, but then states that in the absence of reliable data demonstrating any systematic bias in the forest inventory information it is accepted that the "best available information" was used in the base case.

The 2012 VRI statistical analysis for the Mackenzie TSA indicates that although the 2005 VSIP recommends 140 VRI ground samples to be established, the 2011 VPIP recommended only 50 VRI ground samples be established.

The 2014 Mackenzie TSA VRI statistical analysis indicates that out of the 50 VRI ground samples established; only 14 are within the THLB. The analysis shows that non-THLB volumes are underestimated by 35% (60% if dead pine is included), while THLB volumes are overestimated by 50% (20% if dead pine is included).

[105] Biometrics Overview of VDYP7 Components

The statistical analysis demonstrates a great deal of uncertainty and if the data is to be declared unreliable, it is due to only one third of the recommended VRI ground samples being established, with the majority outside of the THLB. The problem may be due to a MFLNRO&RD decision to force yield predictions at older ages to approach limits similar to VDYP6[106].

A more appropriate decision would be for the chief forester to declare the Mackenzie TSA forest inventory too unreliable for use in the determination of an AAC.

The March 2013 **Morice TSA** VRI statistical analysis indicates that the inventory underestimated volume by 25%. The March 2015 rationale for the Morice TSA AAC determination indicates that only 30 out of the 50 VRI ground samples are within the THLB and most of the underestimation is associated with stands outside of the THLB. The VRI statistical analysis was redone using the 30 VRI ground samples in the THLB and the results indicated that the inventory was overestimated by an unspecified amount.

MFLNRO&RD decided the results of the statistical analysis were inconclusive and due to the uncertainty in the volume adjustments, the inventory volumes were not adjusted. The unadjusted inventory was declared the "best available information". Again, a more appropriate decision would be for the chief forester to declare the Morice TSA forest inventory too unreliable for use in the determination of an AAC.

TIPSY OAF 1 reduction was increased from 15% to 20% in pine-leading managed stands to account for rusts, particularly DSG, based on Nadina Natural Resource District health surveys, YSM and SDM data. Interestingly, SDM and YSM data for the Merritt TSA and SDM data for the Bulkley TSA show the same levels of rust in pine-leading managed stands, but no adjustment was made to OAF 1.

We recommend the chief forester provide a forest inventory assessment for TSAs that are missing the assessment in the rationale for AAC determination document.

We recommend that an independent third party review the Phase II VRI in TSAs where the data collected was deemed too unreliable to use.

We recommend that an independent third party review how RESULTS data are used in managed stand yield projections in the TSR and AAC processes.

[106] Biometrics Overview of VDYP7 Components

We recommend that MFLNRO&RD assess the impact of the decision to force VDYP7 yield predictions at older ages to approach limits similar to those in VDYP6 and whether the decision is responsible for underestimating volume in older stands, such as those outside of the THLB.

We recommend that an independent third party review how forest health data is accounted for and applied in the TSR and AAC determination processes.

CONCLUSION

We recognize that forest inventory data and growth models can never be perfect. That is why we need to use the data and models with precaution and to account properly for their inherent uncertainty.

Accordingly, it is important that our predictions of present and future timber supply are conservative and the associated risks fully accounted for:

> *The application of precaution is distinctive within science-based risk management and is characterized by three tenets: the need for a decision, a risk of serious or irreversible harm and a lack of full scientific certainty.*[107]

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

We conclude that the Ministry of Forests, Lands, Natural Resource Operations and Rural Development:

1. Fails to consider and properly account for uncertainty in its forest inventory data and in its growth models;
2. Pays too much heed to growth models in the TSR and AAC processes when, under conditions of climate change, the ministry should be placing far greater emphasis and reliance on field monitoring to define uncertainty;
3. Needs to improve its management of forest inventory data and growth models and to improve the competencies of its staff in their use; and,
4. Mismanages forest inventory data and growth models and misuses uses them in the timber supply review and annual allowable cut determination processes in ways

[107] Government of Canada. 2003. *A Framework for the Application of Precaution in Science-Based Decision Making About Risk.* Page 2. Ottawa: 13 pages.

(namely errors, omissions and misrepresentations) that are not in the public interest and are incompatible with principles for sustainable forest management.

GLOSSARY OF ACRONYMS

AAC. Allowable annual cut
ABCFP. Association of BC Forest Professionals
Ac. Poplar
Act. Black cottonwood
At. Trembling Aspen
BCMPB. B.C. Mountain Pine Beetle Model
BEC. Biogeoclimatic ecological classification
Bl. Subalpine fir
CBM-CFS3. Carbon budget model for the Canadian forest sector
CFS. Canadian Forest Service
CLT. Central limit theorem
CMI. Change monitoring inventory
DBH. Diameter at breast height
DSC. Commandra Blister Rust
DSG. Western Gall Rust
DSS. Stalactiform Blister Rust
DVAF. Dead volume adjustment factor
DWB. Decay, waste and breakage
ESSF. Engelmann Spruce-Subalpine Fir (BEC Zone)
FAIB. Forest Analysis and Inventory Branch (A branch of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development)
FCOP. Protocol for the creation of forest carbon offsets in British Columbia
Fdi. Interior Douglas-fir
FIP. Forest inventory planning
FIZ. Forest inventory zone
FOI. Freedom of information
FPB. Forest Practices Branch. Now Resource Practices Branch
FREP. Forest and Range Evaluation Program
FSP. Forest stewardship plan
FTP. File transfer protocol
GHG. Greenhouse gas
GMV. Gross merchantable volume (Total stem volume minus the volume above a 10.0 cm top and below a 0.3 m stump height)
GVAF. Gross volume adjustment factor
G&Y. Growth and yield
IBB. Western Balsam Bark Beetle

IBD. Douglas-fir Beetle
IBM. Mountain Pine Beetle
IBS. Spruce Beetle
IDB. Two-year Budworm
ISO. International Organization for Standardization
ITB. Individual tree biomass equations
ITT. Invitation to tender
LBIS. Land based investment strategy
LRSY. Long-run sustained yield
ME&CCS. Ministry of Environment and Climate Change Strategy
MFLNRO&RD. Ministry of Forests, Lands, Natural Resource Operations and Rural Development
MPB. Mountain pine beetle
MRVA. Multiple Resource Value Assessment
MSRM. Ministry of Sustainable Resource Management
NFI. National forest inventory
NMV. Net merchantable volume (GMV minus decay, waste and breakage)
NOAA. National Oceanic and Atmospheric Administration
NOI. Notice of intent (to direct award a contract)
NVAF. Net volume adjustment factor
OAF. Operational adjustment factor
PEM. Predictive ecosystem mapping
Pl. Lodgepole pine
Prognosis^{BC}. A growth-and-yield model for complex stands
PSP. Permanent sample plot
PSPL. Provincial site productivity layer (Used to estimate site index for future managed stands using SIBEC with a predicted BEC)
RESULTS. Reporting silviculture updates and land status tracking system
RIB. Resources Inventory Branch (Now Forest Analysis and Inventory Branch)
RPB. Resource Practices Branch (A branch of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development)
S. Spruce
SAS. Statistical analysis system
SDM. Stand development monitoring
Se. Engelmann spruce
SIBEC. Site index estimate by BEC site series (Used to estimate site index based on biogeoclimatic ecological classification)
Sw. White spruce
TASS. Tree and Stand Simulator (Used to model managed stand growth)

TEM. Terrestrial ecosystem mapping
TFL. Tree farm licence
THLB. Timber harvesting land base
TIPSY. Table Interpolation Program for Stand Yields
TSA. Timber supply area
TSB. Timber Supply Branch (Now Forest Analysis and Inventory Branch)
TSP. Temporary sample plot
TSR. Timber supply review
VDYP7. Variable density yield projection, version 7 (Used to model natural stand growth)
VM0034. British Columbia Forest Carbon Offset Methodology
VPIP. Vegetation Resources Inventory Project Implementation Plan
VRI. Vegetation resources inventory
VRISP. Vegetation Resources Inventory Strategic Plan
VRIMS. Vegetation resources inventory management system
VSIP. Vegetation Resources Inventory Strategic Plan
VTB. Stand level volume-to-biomass conversion equations
YSM. Young stand monitoring

APPENDIX A

RESIDUAL TREES

Both the Morice (2013) and Kootenay Lake (2013 version) YSM analyses show problems with residual and veteran trees in the sample plot data or sample plots in stands greater than the 15- to 50-year target-age range of the YSM program. The Morice analysis identifies plots 57, 91 and 97 and the Kootenay Lake identifies plots 61, 69, 87 and 96 as being problematic. In some cases, such as Morice plots 57 and 91, the residual/veteran trees were removed. In other cases, the solution seemed to be conducting an analysis with all plots and then conducting an additional analysis with the problematic plots removed. The Kootenay Lake report recommends removing the problematic trees prior to data compilation and the Morice report recommends the development of guidelines for screening data, of guidelines for excluding problematic trees within plots, and of guidelines for rejecting entire plots.

The problem of advanced regeneration and residual/veteran trees is more than what was reported in the analyses, as there are additional problem sample plots that were not identified. An example is sample plot 0131_088_CMI in the Kootenay Lake analysis. In the analysis, this sample plot was defined as:

- Bl as the leading species and Se as the second species (Appendix II – page 29).
- A top height of either 13.1 metres (m) (Appendix II – page 29) or 13.2 m (Table 16 – page 45).
- A site index of 20.0 m (Table 18 – page 48).
- A total age of either 45 years (Appendix II – page 29) or 53 years (Table 16 – page 45).

In an October, 2013 version of the FAIB data compilation, sample plot 0131_088_CMI is listed as $Bl_{53}Se_{47}$, breast height age of 41 years, total age of 53 years, top height 13.2 m and site index 20.0 m.

Table A-1 summarizes the site tree data. It should be noted that the FAIB compiler used Sw growth intercept equations for the Se site index and Sw height growth equations to derive years to breast height to obtain total age. In Table A-1, site index, years to breast height and total age are also estimated using the Se height growth equations (there are no growth intercept equations for Se).

Table A-1. Site Tree Data for Sample plot 0131_088_CMI

Species	Rank by DBH		DBH (cm)	Height (m)	BH Age (yrs)	Site Index (m)	Total Age (yrs)	Site Index (m)	Total Age (yrs)
	Plot	Species							
Bl	1	1	33.9	16.0	71	11.8	86.5	Using Sw growth intercepts for Se (as per FAIB compilation)	
Bl	2	2	28.9	14.7	42	17.0	54.5		
Bl	10	3	17.7	12.7	24	22.5	33.5		
Bl	13	6	16.7	12.1	26	20.7	35.5		
Se	3	1	24.8	12.8	33	19.0	46.5	18.8	43.5
Se	4	2	24.6	12.8	27	23.1	39.5	22.1	36.5
Se	5	3	23.4	12.6	27	22.8	40.5	21.8	36.5
Se	8	6	20.7	13.5	24	27.2	36.5	25.0	32.5

Using the data in Table A-1, it can be shown that:

- The total age of 45 in Appendix II is the average total age of all of the Bl and Se site trees, with Se using Sw growth intercept and height growth equations. (86.5 + 54.5 + 33.5 + 35.5 + 43.5 + 36.5 + 36.5 + 32.5 / 8 = 45 (rounded to nearest whole number).
- The total age of 53 in Table 16 is the average total age of all of the Bl site trees. (86.5 + 54.5 + 33.5 + 35.5) / 4 = 53 (rounded to nearest whole number).
- The site index of 20.0 in Table 18 is the average of the Bl site indices, excluding the largest Bl tree. (17.0 + 22.5 + 20.07) / 3 = 20.1 (some rounding error).
- The top height of 13.2 in Table 16 is the average height of the Bl heights, excluding the largest Bl tree. (14.7 + 12.7 + 12.1) / 3 = 13.2.

It is unclear why all of the Bl trees are used to determine age, but only three of the Bl trees are used to determine top height and site index. This leads to a breast height age – top height – site index description whose components are not compatible with each other. For example, the FAIB compilation of a breast height age of 41 and a top height of 13.2 m for Bl results in a site index of 15.6 m and not the 20.0 m site index used in the analysis.

Table A-1 suggests that the two largest Bl trees are either advanced regeneration or residual trees and not part of the main stand population. Reclassification of these trees and the plotting of species by DBH class (Figure A-1) confirm this. Using this classification, the species composition, based on basal area of trees 4.0^{+} centimetres (cm) DBH, becomes:

- Main stand Se has a basal area of 11.70 m^2/ha (47%)
- Main stand Bl has a basal area of 9.12 m^2/ha (37%)
- Residual/advanced regeneration Bl has a basal area of 3.90 m^2/ha (14%)

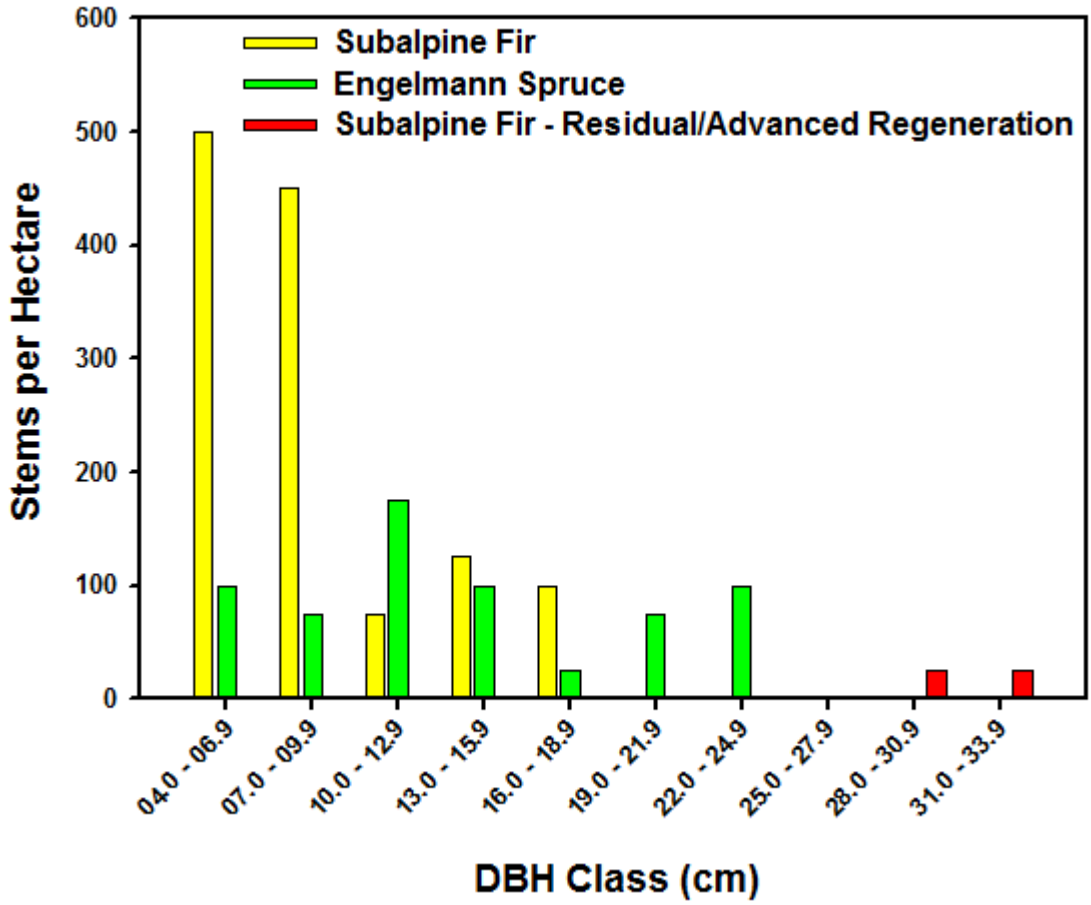

Figure A-1. Trees in Sample Plot 0131_088_CMI Summarized by Species and DBH Class

Other stand parameters, using the Se height growth equations for Se, become:

- Based on the four main stand Se site trees, Se has a breast height age of 28, a total age of 41, a top height of 12.9 m and a site index of 23.0 m.
- Based on the two main stand Bl site trees, Bl has a breast height age of 25, a total age of 35, a top height of 12.5 m and a site index of 21.6 m.
- The residual/advanced regeneration layer has a breast height age of 57, a total age of 71, a top height of 15.4 m and a site index of 14.4 m. The low site index is most likely due to previous suppression of the Bl trees, as indicated by the years to breast height of 14.

Instead of the a 53-year-old Bl stand with some 28-year-old Se (based on total age derived from Sw growth intercept and height growth equations) and a site index of 20.0 m, this stand becomes a 41 year old Se stand with Bl ingress and a 71-year-old Bl residual/advanced regeneration layer. The Se and Bl site indices for modeling are 23.0 and 21.6 m, respectively.

As suggested by the analysts, FAIB should develop guidelines for the proper classification and modeling of these types of stands. The current practice of omitting the "problem" trees without compensating for what would have occupied their growing space, or including the "problem" trees in the sample-plot classification and calculation of species composition, top height, age and site index, are not appropriate solutions.

The occurrence of advanced regeneration and residual/veteran trees in previously harvested areas (the target population of the YSM program) is not uncommon and will be significantly more prominent in future managed stands. As an example, a Forest Practices Branch analysis for coastal TSAs and TFLs indicates the area of residual tress left in openings after harvesting increased from 2.5 percent (%) for 1991-1995 to 11.7% for 1996-2000 to 23.3% for 2001-2005 and the area of openings that contain residual trees increased from 10.0% for 1991-1995 to 59.9% for 1996-2000 to 86.4% for 2001-2005[108]. Owing to the increased use of retention harvesting systems in coastal areas, these averages are probably higher than interior averages, but a review of interior harvested areas would probably find a similar trend (wildlife trees etc.).

During a data validation project (1997-2002) for the FAIB PSP data, these problems were encountered and guidelines were developed for the reclassification of PSP stand structure and the recalculation of ages, top height and site index. It appears that current FAIB data management has lost track of the guidelines developed and the changes implemented, thereby allowing all of the errors in stand classification, age estimation, top height estimation and site index estimation to creep back into the G&Y databases.

Based on experience gained during the data validation project, the biggest change FAIB could make is to add tree class codes to their data collection for advanced regeneration and for residual trees, along with guidelines around their use for species composition, age, top height and site index determination. Further guidelines would also have to be developed for how to correctly model these types of stands with TASS/TIPSY.

[108] Summary of Harvesting, Planting and Regeneration Trends for Western Redcedar in Coastal TFLs and TSAs 1991 – 2005 (https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture)

APPENDIX B

OPERATIONAL ADJUSTMENT FACTORS

From: Martin Watts [mailto:martin_watts@telus.net]
Sent: Monday, March 17, 2014 9:19 PM
To: Goudie, Jim W FLNR:EX; Prasad, Atmo P FLNR:EX; Martin, Pat J FLNR:EX; Nussbaum, Albert F FLNR:EX
Cc: Rehsler, Paul R FLNR:EX; Woods, Alex J FLNR:EX
Subject: Requesting clarification on OAF_1 and OAF_2 reductions

I would like to obtain some clarification on the use of operational adjustment factors (OAFs) used in TASS/TIPSY. I have noticed that FLNRO has been putting together some standard operating procedures which also include OAFs (http://www.for.gov.bc.ca/HFP/silstrat/index.htm), but the document on the website is just section headings with no content (***SOP_website_intro.docx***).

Over the years, the definitions of OAF_1 and OAF_2 have undergone a number of revisions. Currently, there appears to be differences in how they are defined in the TASS/TIPSY help files and how they are defined for use in the Timber Supply Review (TSR) process. Adding to the confusion are what appear to be contradictory recommendations for quantifying OAFs in the Allowable Annual Cut (AAC) determination process.

I am looking for a consistent definition for use in the quantification, validation and verification of forest carbon offset projects. Unlike the TSR process, where OAFs tend to only have an effect on the long term timber supply, they have an immediate effect on forest carbon offset projects involving afforestation and reforestation.

I have put together a brief summary of the changes in definitions over time (primarily for clients, validators and verifiers that are not foresters), including recent documents dealing with OAFs and forest health issues, and attached any documents that I have referenced (or links to ones that are too big to email). Also included are a few examples of inconsistent applications of OAFs, inconsistent acceptance or rejection of OAFs and an overall summary.

I then briefly describe one of the afforestation/reforestation projects I am working on, along with six different OAF options based on the various definitions for assigning OAFs.

I have also included a number of questions in **red**.

I am looking for answers to the questions, which of the six options, if any, for assigning OAFs would currently be considered the most appropriate and a rationale for why the option is the most appropriate. I should also add that under ISO14064 standards and guidelines (used to quantify, validate and verify forest carbon offset projects), a conservative approach is required if uncertainty is present.

TASS (PRE-TIPSY) OAF

TASS was developed from re-measured research plots located in fully stocked stands. Prior to using TASS yields for timber supply analysis, the yields had to be reduced to reflect conditions found in the operational environment. Of most concern were unproductive areas (rock, swamps, brush etc.). A reduction of 15% was used based on:

Inventory samples from unmanaged stands in BC produced 65-85% of the volume of research plots:

- The USFS reduced their model generated yields by 10%
- Finnish studies recommended a reduction of model generated yields of 12% for pine and 20% for spruce
- Swedish studies recommended a reduction of model generated yields of 12%

In addition, a 4% reduction for decay, waste and breakage (DWB) was added. This was based on inventory studies that indicated DWB reduced yield by 4% compared to cruise volumes.

TASS combined these into a single OAF of 0.816 (0.85 * 0.96).

VDYP7 OAF

VDYP7, the natural stand growth model released in 2007, also contains an OAF of 0.85.

For model calibration, TSP basal areas were adjusted by a factor of 1.0 / 0.85 to bring them in line with basal area growth from the PSPs (highlighted section in ***IPSJF176_highlighted.doc***). The adjustment is later reversed by applying a 0.85 stocking factor to VDYP7 projections. Although it appears that some sort of algorithm was developed to determine the OAF, the custodians of the model (FAIB) cannot define how

it was derived and oddly enough, may have a different interpretation of the stocking factor than the modeller (***RE: VDYP7 question for Sam (37 KB)***). It is unclear how the percent stockable attribute in VDYP7 is being used in the TSR and AAC determination processes, but using a reduction of less than 15% would over-estimate future yields and thereby, over-estimate the short-term AAC.

Can FAIB provide an explanation of how they use the percent stockable attribute when updating the inventory and generating yield tables for the TSR and AAC determination processes?

Sam:
VDYP7 uses an attribute labeled "Stockability" to moderate growth rates for stands under different conditions. It does not affect point-in-time volume estimation, however, for long-term projection, the "Stockablility" attributes will modify yield to reflect the amount of space available for trees to grow into. For instance if a polygon area is 20% rock, VDYP7 will take this into account and limit volume increase knowing that trees will not grow on the rocky surface. Other factors that may be taken into account in the computation of "Stockability" are small ponds in a polygon, and other vegetation cover, such as shrubs that may not be trees.

VDYP7 also applies an additional reduction for DWB, based on species, ecozone, stand age and stand height.

TIPSY OAF DEFINITIONS

DOS TIPSY was introduced in 1991. At this time, the original TASS OAF was partitioned into:

- OAF_1 is a constant percent reduction in yields throughout the life of the stand. It accounts for factors that constantly reduce the productive area.
- OAF_2 is a percent reduction that increases linearly over the life of the stand. It is indexed at age 100 and the OAF_2 reduction is defined by $\left(Age * \frac{(1.0 - Specified\ OAF_2\ Value)}{100{,}0}\right)$.

OAF_1 accounts for unproductive areas and is split into two components (current TIPSY v4.3 definition):

- OAF_1a is the portion of OAF_1 that is not influenced by forest management. OAF_1a represents non-productive areas in the land base and will not change from rotation to rotation. Its magnitude will be influenced by the level of information you have. A silviculture survey will map non-productive areas at a higher resolution than a TFL/TSA inventory, leading to a smaller reduction.
- OAF_1b is the portion of OAF_1 that is influenced by forest management and as such, can change from rotation to rotation. OAF_1b is influenced by:
    - Irregular spacing, such as gaps or a clumped distribution of stems, as compared to the distribution of stems assumed by TASS/TIPSY. If the irregular spacing increases the time to crown closure, OAF_1b should be increased.
    - Competition from non-commercial species.

The default OAF_1 value is 0.85 (15% reduction). This value is based on:

- The difference in volume production observed between unmanaged stands and the research plots used to calibrate TASS/TIPSY.
- Inventory level mapping of non-productive land (a minimum polygon size of two hectares).

OAF_2 was originally used to make reductions for decay, waste and breakage (DWB), but it could also be used to make reductions for agents, such as insects or diseases, that have an impact that increases over time. The default OAF_2 value is 0.95 (5% reduction) and is defined as representing losses due to DWB.

When TIPSY v3.0 was released in 2004, the following additional OAFs were added:

- OAF_DWB is a reduction for decay, waste and breakage. Reductions are pre-defined, using inventory methods and data, and are based on species, ecozone, stand age and stand height. It should be noted that the DWB reductions in TIPSY are different from the ones used in VDYP7. TIPSY uses functions fit by Lemay and Gulyas (1995) for FAIB, but were never implemented in VDYP7. VDYP7 uses functions fit by Flewelling (1998).

This statement is incorrect. The preliminary plot compilation was done by Lemay and Guylas (1995), but TIPSY implemented the same OAF_DWB functions as in VDYP, that is, those developed by Flewelling (1998) . TIPSY help states:

The volume losses due to DWB are calculated internally by TIPSY using the models derived by Jim Flewelling for the Ministry of Forests, Resource Inventory Branch.

These models were originally developed for the Variable Density Yield Prediction system version 7 (VDYP 7).

- OAF_Armillaria is a reduction for armillaria root rot. It is only available for interior Douglas-fir in the ICH ecozone. Reductions are pre-defined, based on a low, medium and high setting. The reductions are based on a study by the CFS.
- OAF_Custom allows a custom OAF_1 or OAF_2 to be designed. It can be applied in terms of age or stand height and can either move trees to the mortality table or remove them from the stand.

These additional OAFs should have made OAF_2 obsolete as OAF_DWB accounts for DWB and OAF_Custom can be used to make reductions for insects and diseases until more specific OAFs, such as OAF_Armillaria, can be developed. For some reason, the use of OAF_2 has persisted in the TSR and AAC determination processes.

Not necessarily. The OAF_DWB was added to TIPSY to provide an alternative option to either substitute or combine with the existing OAF_2, OAF_Armillaria or OAF_Custom. There was never an intention to use the OAF_DWB as standard default loss factor in TSR for managed stands. We always stated that the analysts should use their data, professional experience and best available local information to define alternative OAFs. Otherwise, they should rely on the recommended default values.

OAF_1 PROJECT

In 1996, Forest Practices Branch (now Resource Practices Branch) initiated the OAF_1 Project (http://www.for.gov.bc.ca/hfp/silviculture/OAF1/default.htm). At this time OAF_1 was defined as a 15% reduction for stocking gaps (***OAF_1_01.pdf***). The project developed a survey methodology to measure stocking gaps and to assign an OAF_1 based on the survey results (***OAF_1_02.pdf***). Stocking gaps are defined as plots that have no acceptable trees within a critical distance of a plot centre. Critical distance is defined as 2.7 metres for lodgepole pine and interior spruce and 3.6 metres for all other species.

In subsequent years, a number of studies to quantify OAF_1 were initiated. Some used the methodology developed with the OAF_1 Project and some used other methodologies, such as remote sensing methods (http://www.for.gov.bc.ca/hfp/silviculture/OAF1/publications.htm). These studies consistently indicated that stocking gaps do not account for a 15% reduction in yields.

As a result, the OAF_1 Project also produced a list of many factors that can cause yields to be less than those predicted by TASS/TIPSY, but did not define them as either OAF_1 or OAF_2 reductions. The list includes (http://www.for.gov.bc.ca/hfp/silviculture/OAF1/gallery/index.htm):

- Wood defect
- Poor stem form
- Root rot pockets
- Ponds and swamps
- Low density
- Disease
- Non-commercial cover
- Only data from uniformly stocked and disease free stands were used to calibrate TASS
- Non-productive area
- Rock outcrops
- Old roads
- Senescence, stand breakup and succession
- Espacement (different inter-tree distances than those modelled in TASS)
- Excessive slash impeding seedling growth
- Animal damage
- Logging waste

In 2010, Forsite Consultants Ltd. developed a methodology to combine the OAF_1 survey with the free-growing survey (***LBIP_9059008.pdf***).

TSR OAF DEFINITIONS

In 1998, a new TIPSY OAF_1 definition was released for use in the TSR process. It appears to be the result of the additional reduction factors identified in the OAF_1 Project. The new definition partitions OAF_1 into four components. It also quantifies the contribution of each component to the overall 15% reduction, but the quantification should be thought of as a guideline as there are no data to support it.

Correct, the- OAFs were recommended as guidelines to use in TSR because there is not enough empirical data to support these yield adjustments; however in TIPSY we documented the literature background and related studies that explained why it was

decided to use 15% for OAF_1 and 5% for OAF_2 as guidelines unless better local information is available. Here is the explanation on TIPSY help:

> *The USFS routinely reduced their yields to 90% of the yield generated by their models unless better local information was available (personal communication). A formal study in Finland reported operational volumes of 88 % and 80 % for pine and spruce stands, respectively, in the vicinity of research plots (Oikarinen 1978). A Swedish study recommended 85 % based on a study that reported 85 % standing volume, and 90 % for volume growth over 39 years (Eriksson 1967). Inventory samples from unmanaged stands in BC produced about 65 to 85 % of the volume found in research plots. This information led to the decision to adopt 85 % for operational yields in managed forests in BC. It was based on inventory level mapping of non-productive land with a minimum polygon size of approximately 2ha.*
>
> *Inventory studies determined that DWB reduced the yield of second-growth stands to 96 % of the cruise volume. Consequently, a standard OAF 2 of 0.816 (i.e. 0.85 x 0.96) was applied to all volume estimates generated by TASS (Mitchell and Cameron 1985b). More precise local information was rarely available or applied at that time. Little effort was made to identify the agents that contributed to the reduction, or the myriad of other factors that can affect yield in the operational environment, particularly as stands approach maturity. However, yield curves in TASS were "pulled down" a little beyond a height of 40 m to allow for the yield impact of these other factors. This "feature" became obsolete with the introduction of OAF 2, and concurrent recalibration of TASS in the early 90's.*

OAF_1 is defined as (http://www.for.gov.bc.ca/hfd/library/FIA/HTML/FIA2010MR084.htm):

e. OAF_1a is for non-productive areas (e.g. rock outcrops, swamps) not already addressed in the timber supply analysis process and accounts for a 4% reduction.
f. OAF_1b is for management effects of espacement and non-commercial cover (stocking gaps and non-commercial species) and accounts for a 4% reduction.
g. OAF_1c is for future losses due to endemic health (biotic) factors (diseases and pests) and accounts for a 4% reduction.

h. OAF_1d is for future losses due to random risk (abiotic) factors (wind, snow etc.) and accounts for a 3% reduction.

Most notable about the differences between the TSR OAF_1 definition and the OAF_1 definition supplied in TIPSY are:

- OAF_1a and OAF_1b have been reduced from a 15% reduction to an 8% reduction.
- OAF_1c and OAF_1d, which account for a 7% reduction, have been specifically added and represent future losses. In the TIPSY OAF_1 and OAF_2 definitions, future losses are just given a casual reference.

OAF_2 is still defined in both the TSR and TIPSY definitions as being a 5% reduction to account for DWB, with the option of also using it to account for losses to other agents, such as diseases and insects.

INCONSISTENT APPLICATIONS OF OAFS AND THEIR ACCEPTANCE/REJECTION

The following are a few examples that highlight the confusion over the application of OAFs and the acceptance/rejection of various applications of OAFs:

- In a study for Forest Practices Branch (FPB) to assess the relationship between silvicultural management and carbon sequestration (***ESSA_Interim_Report_April2009.doc***), fertilization treatments had fertilizer applied in TIPSY, but also had the OAF_1 and OAF_2 reduced to zero to account for better growth (highlighted on pages 6 and 10). This is then compared to other silviculture management regimes that had default OAFs applied. I am assuming default OAFs means an OAF_1 reductions of 15% and an OAF_2 reduction of 5%. FPB would not supply the Excel file of TIPSY inputs that is referred to on page 28.

  It is unclear how fertilization decreases OAFs, regardless of which OAF definition is applied. Can someone elaborate on this?

  The interaction between fertilization and OAFs has not been addressed yet. This report compared untreated regimes with OAFs and treated regimes without OAFs. This is an incorrect application of OAFs in TIPSY and the statement in Page 10 refers to the validity and applicability of these results. The untreated and fertilized runs

can only be compared if both scenarios are using the same OAFs, or alternatively not using them at all.

Page 10

Note that these results are dependent on the growth curve that was used. The base growth curve, and its fertilization impacts, was produced in Tipsy with using the operational adjustment factors to help account for all the miscellaneous sources of mortality or sub-optimal growth of a stand. The increased growth curve did not use these factors and thus the stand was able to grow better and respond better to fertilization. As a consequence, stands that were grown with this growth curve also contained higher levels of C. These optimal stands are not prevalent, so results from this growth curve may not be widely applicable.

- Many of the TSR analyses still use an OAF_2 to account for decay, waste and breakage, even though an OAF_DWB has been available since 2004. For some species, this may be acceptable, but for others it does not seem to be. As examples:
    - For a Pli plantation in the ICH (1400 sph, SI 20, OAF_1 of 0.85 and OAF_2 of 1.00), the reduction for DWB at age 100 is 5.0% using OAF_DWB. The Kootenay Lake TSA TSR uses OAF_2 reduction of 5% (***Kootenay_Lake_TSR.pdf*** – pages 110-111).
    - For a Bl plantation in the ICH (1400 sph, SI 20, OAF_1 of 0.85 and OAF_2 of 1.00), the reduction for DWB at age 100 is 13.3% using OAF_DWB. The Kootenay Lake TSA TSR uses OAF_2 reduction of 5% (***Kootenay_Lake_TSR.pdf*** – pages 110-111).
    - For a Cwi plantation in the ICH (1400 sph, SI 25, OAF_1 of 0.85 and OAF_2 of 1.00), the reduction for DWB at age 100 is 33.0% using OAF_DWB. The Kootenay Lake TSA TSR uses OAF_2 reduction of 5% (***Kootenay_Lake_TSR.pdf*** – pages 110-111).
    - For a Cwc plantation in the CWH (1600 sph, SI 30, OAF_1 of 0.85 and OAF_2 of 1.00), the reduction for DWB at age 100 is 19.9% using OAF_DWB. The Arrowsmith TSA TSR uses OAF_2 reduction of 5% (***Arrowsmith_TSR.pdf*** – page 35 of the data package – page 113 of the pdf).
    - For a Hwc plantation in the CWH (1600 sph, SI 30, OAF_1 of 0.85 and OAF_2 of 1.00), the reduction for DWB at age 100 is 9.8% using OAF_DWB. The Arrowsmith TSA TSR uses OAF_2 reduction of 5%

(***Arrowsmith_TSR.pdf*** – page 35 of the data package – page 113 of the pdf).

Is the OAF_DWB only meant to be applied to stands of natural origin?

Yes, these adjustments are most applicable to natural origin stands, although it was never stated as such in TIPSY. These factors were designed using data from natural unmanaged stands and therefore they may not be applicable to the managed stand types simulated with TISPY. We have already initiated a review to investigate whether or not the OAF_DWB should be used in TIPSY at all.

If the OAF_DWB is meant to be applied to plantations, why isn't this done in the TSR analyses?

TIPSY does not specifically recommended the use OAF_DWB for plantations. In addition, there is not a standard policy for the use of OAF_DWB in TSR. Some Ministry analysts considered them only applicable to mature old-growth stands and therefore not suitable to second-growth projections. A few external analysts have used them in some interior analysis units in combination with inventory ground sampling adjustments. The examples above demonstrated that these factors are species specific and that in certain cases their impact can be significantly higher than the recommended 5 % OAF_2.

There were two main reasons for the inclusion of OAF_DWB as an alternative loss factor in TIPSY. First, we considered them as best available information and were already used in VDYP to account for the losses in mature unmanaged natural stands. Second, they provided the option to localize their impact on specific stands because they used species, age, DBH, height and the ecozone (BEC) inventory data to predict the loss adjustments.

We initiated a review of the background of these factors and consulted with Will Smith (Volume and Decay Sampling Officer) about the applicability of their application to account for losses in second-growth stands and here are some of his recommendations:

1) *They would apply to natural unmanaged stands and not managed stands.*
2) *It is completely unknown what loss conditions will exist in older managed stands since we have not collected data from these stands and to a great extent, these stands do not yet exist.*
3) *Some conclusion to draw is that stem volume loss in older managed stands is likely to be far lower than unmanaged stands.*

4) *To account for this loss in the absence of any data, a kludge based on the NVAF data and pathologist's opinion about levels of stem decay by species and BEC zonation could be developed.*

As a consequence, we proposed to management a project to further investigate the BEC loss factors that may be bias and generally overestimate decay and waste on managed stands, and to improve the models for OAF_DWB accounting in TIPSY. In the short term, we do not recommend the use of OAF_DWB in TIPSY for TSR or silviculture applications until the investigation is completed and peer reviewed.

- For the Bulkley TSA, an OAF_1 adjustment survey, using the methodology developed by the OAF_1 Project, recommended an OAF_1 reduction of 5% for certain species/BEC combinations (***Bulkley_OAF_1.PDF***). This was originally accepted for the Bulkley TSA TSR analysis (***Bulkley_TSR.pdf*** – pages 34 and 35). The OAF_1 reduction of 5% was subsequently rejected in the Bulkley AAC determination (***Bulkley_AAC_determination.pdf*** – page 10) as it did not consider non-commercial competition, endemic forest health losses and random risk factors. The analysis was rerun with an OAF_1 reduction of 15%. No credit was given for the OAF_1 adjustment survey, even for the OAF_1a partition.

Is the methodology developed by the OAF_1 Project now considered invalid or is it now only applicable to the OAF_1a of 4% of the TSR OAF definition?

- In the TFL 30 AAC determination (***TFL_30_AAC_determination.pdf*** – page 12), a base OAF_1 reduction of 7.5% was used. This was increased to account for non-productive areas, resulting in a range of OAF_1 reductions from 7.5 to 76.7%, with an area weighted average of 11%. Although no justification was given for the base OAF_1 reduction of 7.5%, it was accepted given that other factors in the TSR analyses suggested the timber supply may be underestimated.

Can managed stand OAF_1 estimates be balanced with other TSR inputs, even though the other TSR inputs, such as initial inventory, may not be linked in any way to managed stand yields?

- In the TFL 47 AAC determination (***TFL_47_AAC_determination.pdf*** – page 22), it indicates an OAF_1 survey indicated that the OAF_1a should be a reduction of 1.8% and that the OAF_1 should be a reduction of 13%. The TSR analysis only

used the OAF_1 reduction of 13% for a sensitivity analysis, but it was considered in the "Reasons for Decision" section (page 43).

- In the TFL 30 AAC determination (page 12), it is stated that the licensee should work with the FLNR staff to develop a better estimate of OAF_1 for future TSR analysis. In the TFL 47 AAC determination (page 22), it is stated that overall stand monitoring be used as opposed to focusing on one component, such as OAFs.

  Can someone reconcile the differences in these recommendations?

- The TFL 47 AAC determination (page 22) states that it is preferred that young stand monitoring be used to assess predicted yields and not to focus on individual factors, such as OAFs.

  The development of managed stand yield curves uses a number of estimated values that can affect future yield predictions, such as site index, OAFs and genetic worth. The genetic worth response is modelled by increasing the height growth, which is essentially an adjustment of the estimated site index. If managed stand yields measured during a monitoring program are different from the predicted yields, how will it be determined that the problem is due to incorrect site index estimation, incorrect genetic worth response or incorrect OAFs given that:

  - **Site index and genetic worth response are confounded as they both influence height growth and you will not be able to determine which, if either, is in error or how much each contributes to any observed error.**
  - **Without being able to quantify errors in site index estimation or genetic worth response, any errors in OAF estimation cannot be determined or quantified.**
  - **Without being able to separate or quantify the contribution of estimated site index, estimated genetic worth response or estimated OAF to differences between predicted and observed yields, how will it be determined that TASS/TIPSY are not in error.**

  It should also be noted that the recent young stand monitoring analyses of the Kootenay Lake and Morice TSAs (reports available here: http://www.for.gov.bc.ca/hts/vri/monitoring/monitoring.html) did not

include any type of assessment of OAFs when comparing the ground measured data to TIPSY predictions/assumptions.

Young Stand Monitoring Program Design

When we designed the young stand monitoring framework, we had a team of 14 inventory, timber supply and biometrics specialists thoroughly review the objectives. We also had a peer review from members of the industry and consulting communities. It was decided that checking OAFs was outside of the scope of the young stand monitoring (YSM) program. It was determined that the sample design, attributes collected, and the sample size would not permit such checking.

Kootenay Lake and Morice Young Stand Monitoring Analyses

TIPSY MSYTs are generated for each YSM ground sample location, by applying similar regeneration assumptions used in the most recent TSR. These include OAF1/OAF2 estimates of 15/5% for all of Kootenay Lake, and for non-pine leading stands in Morice. Pine leading stands in Morice are assigned 20/5%, consistent with TSR.

In the near future the YSM program will provide data to replace or enhance the TIPSY default adjustment factors and the collection of forest health agents will provide data to develop models (eg. western gall rust) to predict the potential volume loss impact.

OAF SUMMARY

It appears that both the TASS and VDYP7 modellers, based on observed differences in volume between research plots and forests in an operational setting, agree that for yields predicted by growth models developed from research plot data, there should be a 15% reduction of the yield predictions when they are applied in an operational setting.

It also appears that the differences can be attributed to a number of factors, as identified in the OAF_1 Project, that could affect yields in any operational setting. The degree to which each factor has an effect is different for individual operational areas and forest types. As such, any attempts to quantify the reduction by particular factors

(or groups of factors) is highly subjective, particularly when there is no empirical data to support the quantification by factor.

It also appears that the attempted quantification of factors has led to a great deal of wasted time and money in developing methodologies/surveys to reduce OAF_1 for managed stands. Each time OAF_1 is reduced by applying an approved methodology or survey, either the quantification of the OAF_1 factors is changed so that OAF_1 returns to a 15% reduction or a subjective decision is made to reject the new OAF_1 reduction. This can be seen in:

- The progression of TASS OAF to TASS/TIPSY OAF_1a, OAF_1b and OAF_2 to the TSR definition of OAF_1a, OAF_1b, OAF_1c, OAF_1d and OAF_2.
- Decisions made about OAF_1 reductions in the AAC determinations.

The confusion around OAFs has also led to some questionable applications, such as the carbon sequestration example (item 1) provided above.

OAFS FOR AFFORESTATION/REFORESTATION FOREST CARBON PROJECTS

As mentioned above, I am looking for clarification in the use of OAFs for forest carbon offset projects and will use a project I am working on as an example.

The Ministry does not have a standard policy procedure to describe the use of OAFs for forest carbon offset projects.

The project is planting trees on marginal agricultural land, located throughout interior BC, but primarily around Prince George. Properties fall within the Prince George TSA, Willliams Lake TSA, Quesnel TSA and Fort St. John / Dawson Creek TSAs. Areas for planting are classified as:

- Afforestation of cultivated areas. These sites were previously planted to hay or grain and have little or no ingress after planting.
- Afforestation of rough pasture areas. These sites were previously used for grazing (cleared and stumped) and have a moderate amount of ingress after planting.
- Afforestation of reclaimed areas. These site were previously used for home sites, farmyards and corrals. They have compacted soils with a lot of gravel (probably from fill), high establishment mortality and little ingress after planting.
- Reforestation of recently harvested areas. These areas have been cleared, but not stumped. They have a significant amount of ingress after planting.

The sites are further stratified by BGC/SS and species planted. Species planted are mixtures of lodgepole pine, white spruce and interior Douglas-fir. A Donaren mounder was used for the majority of site preparation, with some areas using an excavator. In the first year, trees were planted at 1400 sph (2.67 metre inter-tree distance) , but subsequent planting years used 1600 sph (2.5 metre inter-tree distance). Establishment mortality has primarily been from vole damage, drought and desiccation due to a lack of snow cover. Sites are examined annually and fill planted if necessary. Ingress, if present, is primarily aspen and lodgepole pine. The main biotic damage agents that have potential to cause future losses are spruce weevil, western gall rust, blister rusts (the previously cultivated areas do not contain alternate hosts for blister rusts) and mountain pine beetle. The main abiotic damage agents that have potential to cause future losses are drought and windthrow around the edges (many of the plantations are exposed as they are surrounded by cultivated areas).

Any non-productive areas (old roads, streams etc.) have been netted out of the land base and as mentioned above, the less productive reclaimed areas have been given their own stratum. As a result, afforestation areas are 100% plantable and reforestation areas are slightly less due to stumps and rocks that have not been removed.

The plantations are monitored annually, until they are declared free-growing, and fill planted if necessary. After the plantations have been declared free-growing, monitoring will consist of:

- Annual walk throughs.
- Periodic (5 or 10 year) surveys, based on a modified version of the FREP Stand Development Monitoring Protocol. The focus will be on monitoring plantation health, site index estimation and obtaining strata densities and volumes to be compared to TASS predicted volumes.
- There is an option to continue measuring approximately 100 permanent sample plots that were established prior to planting, using the NFI plot design, to measure onsite carbon (soils, forest floor, woody debris, residual trees and advanced regeneration).

Under any offset purchase agreement, there are requirements for monitoring and legal provisions for replacing carbon credits with ones of equal or greater value if the carbon credits predicted for the project are used in an ex-ante (created in the future, but claimed in the present) fashion, but are not realized in the future.

OAF_2 and OAF_DWB

Since the plantations are not going to be harvested, reductions for decay, waste and breakage can be defined as:

- There are no reductions for breakage, which is defined as any piece broken at both ends and shorter than three metres which results from normal falling or yarding/forwarding operations.
- There are no reductions for waste, which is defined as the firmwood volume associated with five metre logs in a tree which contain less than 50% of their gross scale in firmwood volume.
- There is a deduction for decay, which is defined as the decomposition of wood substance caused by the action of wood-destroying fungi, resulting in a loss of mass.

The deduction for decay should be based on the loss of mass (carbon). This is best determined for a standing tree by the difference between decay class 1 and 3. For example, using a Sw plantation (1600 sph, SI20, genetic worth of 28, OAF_1 of 0.85 and OAF_2 of 1.00) in the Prince George TSA (BEC zone SBS):

- The total volume (0.0+ cm) at age 100 is 571 m^3/ha
- The total volume (0.0+ cm) net decay at age 100 is 554 m^3/ha, using the decay only option of OAF_DWB
- The percent decay is 3.00%
- Using the CFS decay classes, decay class 1 is 356 kg/m^3 and decay class 3 is 218 kg/m^3
- The loss in density is 38.76%
- The loss of carbon due to decay at age 100 is 1.16% and can be modelled with an OAF_2 of 0.99 (1% reduction)

Would this be a correct interpretation for a reduction due to decay, waste and breakage within the TASS/TIPSY modeling environment?

As stated above, we do not recommend the decay option in TIPSY until further review is done. A decay factor for carbon loss has not been included in TIPSY yet; however Karen Dymond recommended the use of 2% decay as an average based on a previous literature review investigations. I can't comment on the application of the CFS decay classes because of the lack of familiarity.

OAF_1

Based on the OAF_1 definitions and AAC determinations above, there appear to be a number of options for determining OAF_1.

For these examples, I will use the afforestation of cultivated land stratum described above, planted at 1600 sph, which has the following characteristics:

- The net area is 100% plantable.
- The average inter-tree distance is 2.5 metres.
- Any mortality has been fill planted.
- Given the above, any point selected as a plot centre would have at least one tree within the 2.67 metre critical distance defined by the OAF_1 Project. As such, there would be no empty plots.

Of the six options listed below for assigning OAFs, which would be considered the most appropriate and why?

There is no standard policy on assessing OAFs to provide any advice on afforestation of cultivated land at the present time. Therefore, the default OAFs are still recommended and Option 4 is the most appropriated for now.

Option 1

Using the tables provided by the OAF_1 Project (***OAF_1_02.pdf***), this would result in a z-value of 0 (Table 1, Section C, Page 14) and an OAF_1 reduction of 0% (Table 2, Page 18). OAF_1 would be 1.00.

Future losses due to endemic health and random risk are not accounted for, but will be picked up during the monitoring phase (included in the difference between predicted and observed volume).

Option 2

Using the TASS/TIPSY help OAF_1 definition:

- The reduction for OAF_1a would be 0% as there are no non-productive areas.
- The reduction for OAF_1b would be 0% as there is no irregular spacing and for a forest carbon sequestration project, non-commercial trees are acceptable.
- The total OAF_1 reduction would be 0% (OAF_1 of 1.00).

Future losses due to endemic health and random risk are not accounted for, but will be picked up during the monitoring phase (included in the difference between predicted and observed volume).

Option 3

Using the TSR OAF_1 definition:

- The reduction for OAF_1a would be 0% as there are no non-productive areas.
- The reduction for OAF_1b would be 0% as there is no irregular spacing and for a forest carbon sequestration project, non-commercial trees are acceptable.
- The reduction for OAF_1c would be 4%.
- The reduction for OAF_1d would be 3%.
- The total OAF_1 reduction would be 7% (OAF_1 of 0.93).

Future losses due to endemic health and random risk are accounted for, but with values that have absolutely no basis. In fact, I believe that entomologists and pathologists are predicting much higher losses to insects and diseases in the future, partly due to climate change. The actual reductions will be picked up during the monitoring phase (included in the difference between predicted and observed volume).

Option 4

Using the TASS (pre-TIPSY) OAF_1 definition, the reduction for OAF_1 should be 15% (OAF_1 of 0.85). This is the only value that seems to be supported by data and it appears to be independently determined by the TASS and VDYP7 modellers. It is probably an average value that takes into account all of the factors listed by the OAF_1 Project (and probably a few others), which can occur in various combinations and intensities for any given area of forested land. Any changes to the OAF_1 reduction should only be allowed if there are supporting data, which would probably only be obtainable when managed stands approach rotation age.

Option 5

Using the TASS (pre-TIPSY) OAF_1 definition, the reduction for OAF_1 should be 15% (OAF_1 of 0.85), but should be applied at an age similar to the ages of the data used by the TASS and VDYP7 modellers that indicate an OAF_1 reduction of 15% is appropriate. For lack of a better term, I will label this the OAF_1 reference age. Using TASS individual tree output, trees at the OAF_1 reference age could be randomly (or some sort of

algorithm) deleted until a 15% reduction in volume or basal area has been achieved. The same trees would then be deleted for all other ages in the TASS simulation. Summary statistics could then be re-calculated based on the new tree list, although I don't know how this would work out for managed stands with treatments, such as a thinning.

This method has the advantage of maintaining a consistency between OAF_1 and living trees between yield table ages. For ages other than the OAF_1 reference age:

- The OAF_1 would probably behave differently between species, based on the species' mortality pattern.
- The OAF_1 would probably behave differently within species at different densities.

Option 6

This option looks at increasing the OAF_1c or OAF_2 reductions due to potential increased losses due to biotic damage agents. It is widely expected that climate change will most likely increase future losses to biotic damage agents.

Recent studies in stands averaging 26-27 years of age in the Nadina Forest District (***2013_DND_Timber_Summary_Sheet_long_July2013.pdf***) and the Okanagan TSA (***Woods and Coates, 2013 –*** available from http://www.for.gov.bc.ca/ftp/DND/external/!publish/Forest_Health/), indicate the presence of biotic damage agents and the potential for future losses are significantly higher than the 4% reduction assigned to OAF_1c in the TSR OAF definition. After taking forest health into consideration, the basal area of many stands fall below the basal area predicted by TIPSY and the well-spaced stems per hectare have fallen below densities that would be consistent with TSR assumptions. While some argue that natural ingress should fill any gaps created by increased mortality of planted trees (***Ralph Winter – pers. comm.),*** the studies found that this was not the case and instead, a clumped distribution with gaps was forming.

As noted above, the project plantations on previously cultivated land have little or no ingress and as such, losses of plantation trees to biotic damage agents would significantly reduce future yields.

OAFs are sometimes increased in the TSR analyses to account for known biotic damage agents. For example, the Kootenay Lake TSR increases the OAF_2 to account for the presence of root disease in Douglas-fir managed stands (page 35).

Are there localized adjustments to OAF_1 or OAF_2 to account for future losses due to known biotic damage agents and if so, where can they be obtained?

If not, is it better to:

- **Apply the default OAF reductions and alter them in the future, if such adjustments are indicated by a monitoring program?**
- **Use any available Young Stand Monitoring or Stand Development Monitoring data to estimate new OAFs. If so, have procedures been developed to do this? The recent Young Stand Monitoring reports for the Morice and Kootenay Lake TSAs did not address OAF validation/verification.**
- **Just guess at increased OAF values for now?**

There are not available localized adjustments of OAF_1 and OAF_2 to account for future losses due to know biotic agents at the moment.

It is recommended to use the OAFs defaults until the stand monitoring programs provide enough information to develop adjustment factors for the predicted yields achieved in the operational forest. These factors can then be used to adjust yield predictions for similar stands where actual yields differ from predicted yields.