BEFORE THE UNITED STATES FOREST SERVICE
DATA QUALITY OFFICIAL

BLACK HILLS FOREST RESOURCE ASSOCIATION Petitioner	**Data Quality Act Challenge to U.S. Forest Service** **Correction of Information Presented in General Technical Report dated March 23, 2021**
v.	
U.S. FOREST SERVICE Agency.	November 19, 2021

REQUEST FOR CORRECTION OF INFORMATION

USDA Forest Service
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I. Requestor/Petitioner

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Organizational affiliation of person requesting correction: The BHFRA is a non-profit trade association of forest products manufacturers, forestry and timber harvest professionals, and concerned citizens in the Black Hills of South Dakota and Wyoming. Its mission is to advocate for responsible forest management that assures healthy forests and healthy communities for current and future generations.

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Furthermore, the following entities and organizations are in support of this Request for Correction of Information:

State of South Dakota
State of Wyoming
Lawrence County, South Dakota
Pennington County, South Dakota
Weston County, Wyoming
Crook County, Wyoming
South Dakota Stockgrowers Association
Black Hills Regional Multiple Use Coalition
South Dakota Cattlemen
South Dakota Trucking Association
Black Hills Women in Timber
Black Hills Log Haulers Association

II. Basis for Request for Correction of Information

This Request for Correction of Information ("Request") is submitted pursuant to Section 515 of the Treasury and General Government Appropriations Act of FY 2001 (Public Law 106-554) ("Data Quality Act," or "DQA"), and the "Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information disseminated by Federal Agencies" (67 Fed. Reg. 8452 (Feb. 22, 2002)) ("OMB DQA Guidelines") and "Final Information Quality Bulletin for Peer Review (70 Fed. Reg. 2664 (Jan. 14, 2005)) ("OMB Peer-Review Guidelines") issued by the Office of Management and Budget ("OMB"), as well as USDA Peer Review Implementation Guidelines (2005),[1] and "Improving Implementation of the Information Quality

[1] https://www.ocio.usda.gov/document/usdas-peer-review-guidelines

Act" of the U.S. Department of Agriculture[2] ("USDA Guidelines"), which is also applicable to the U.S. Forest Service ("USFS").[3]

III. Introduction

BHFRA hereby submits this Request related to the USFS final general technical report "A Scenario-Based Assessment to Inform Sustainable Ponderosa Pine Timber Harvest on the Black Hills National Forest General Technical Report" dated February 2021 and published March 23, 2021 (GTR-422)[4] ("GTR"). The GTR is said to "provide[ ] the context, rationale, and evaluation of harvest level scenarios across a range of mortality and growth rates in the Black Hills….[and] provide[ ] scientific information that can inform discussions concerning future harvest levels on the Black Hills National Forest."[5]

The GTR was commissioned by the BHNF with set objectives, sideboards, and direction to the researchers (formally and informally) of what relevant information to consider and which information to exclude. As a result, and as discussed herein, the GTR is a deeply flawed document. The GTR authors rely on simple arithmetic to calculate a sustainable harvest level: *sustainable harvest = growth – mortality*. But an equation is only as good as its inputs. And the inputs used in the GTR are deeply flawed. By excluding commercial tree species, relying on a fraction of the acres available for estimating timber resources, utilizing a significantly lower growth rate than the previous 19 years of actual USFS data , and exaggerated mortality rates, the GTR misrepresents actual conditions of timber resources on the Black Hills National Forest ("BHNF") and provides flawed information to decision makers. Publication of the GTR has

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[2] https://www.ocio.usda.gov/policy-directives-records-forms/information-quality-activities
[3] https://www.fs.fed.us/qoi/
[4] Graham, Russell T.; Battaglia, Mike A.; Jain, Theresa B. 2021. A scenario-based assessment to inform sustainable ponderosa pine timber harvest on the Black Hills National Forest. Gen. Tech. Rep. RMRS-GTR-422. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 61 p. https://doi.org/10.2737/RMRS-GTR-422
[5] https://www.fs.usda.gov/rmrs/sites/default/files/documents/GTR-422%20one-pager.pdf

resulted in dramatic declines in timber harvest levels on the BHNF. This decline is counterintuitive to the library of science that supports active management as the path to, healthy and diverse forests. Instead, the declining timber sales exacerbate risk of pine beetle ("PB") infestation and wildfire hazards amongst the worst wildfire seasons in the United States in recorded history. In addition, they harm BHFRA, its members, and the communities that depend upon active forest management. The Rushmore Forest Products mill in Hill City, South Dakota has already closed due to declining timber sales from the BHNF. That facility employed approximately 150 people in a community of 1,000 with a substantial minority population. To add insult to injury, this closure came amidst historic high prices for lumber. ***At least*** one additional mill is also likely to close in the first half of 2022 if the USFS does not retract the GTR and follow recommendations from formal collaborative groups and states, and the agency's own data, on the BHNF.

BHFRA respectfully requests the USFS retract the GTR. If the agency decides to later correct and re-release it, that release must be consistent with the tenets of quality, objectivity, utility, and transparency in the DQA.

A. Background

The BHNF is managed pursuant to the BHNF Land and Resource Management Plan 1997 Revision Phase II Amendment dated March 2006 ("RMPA").[6] The RMPA aims to offer the allowable sale quantity ("ASQ") of 181,000 ccf [1 ccf = 100 cubic feet.] of sawtimber from suitable lands per decade. RMPA at I-14. Importantly, many areas exist outside the suitable base, within the BHNF, that are not withdrawn from harvest activities and could contribute to accomplishments from the timber sale program. The RMPA was prepared in accordance with

[6] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf.

the National Forest Management Plan ("NFMA") and the National Environmental Policy Act ("NEPA"). As the RMPA states:

> NFMA requires that resource plans and permits, contracts, and other instruments issued for the use and occupancy of National Forest System lands be consistent with the Forest Plan. Site-specific project decisions must also be consistent with the Forest Plan, unless the Forest Plan is modified by amendment.

Between 2017 and 2019, the Forest Inventory and Analysis ("FIA") branch of the USFS collected data for the BHNF.[7] The FIA data was released to the public January 27, 2020.[8] During the collection of data by FIA, and after an initial internal report from Rocky Mountain Research Station ("RMRS") to the BHNF, "The Black Hills National Forest leadership asked the [RMRS] to assess trends in standing volume, growth, mortality, and the implications of various harvest levels to better understand sustainable harvest options."[9] In April 2020, the RMRS produced a draft general technical report ("Draft GTR") entitled "Timber Growth and Yield in the Black Hills National Forest: A Changing Forest." As stated above, the final GTR was published March 23, 2021. Both drafts of the GTR were prepared by Russell T. Graham, Mike A. Battaglia, and Theresa B. Jain, Research Foresters (Silviculturists) with the RMRS, USFS.

B. GTR is Based on Incorrect Assumptions and Inappropriate Use of Data, Which Produces Inaccurate Scientific Information

Although General Technical Reports are intended to be centered in science and the scientific process, the GTR contains numerous errors grounded in faulty data, analysis, and assumptions. Many of these errors were identified in comments to the authors but were not addressed in the final report. Some of these errors include:

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[7] FIA collects and houses the USFS data used in the GTR and the BHFRA report referenced herein.
[8] https://usfs-public.box.com/v/BlackHillsFIAData.
[9] https://www.fs.usda.gov/rmrs/science-spotlights/sustainable-timber-harvest-black-hills-national-forest

1. The authors of the GTR fail to analyze the overall subject they were tasked with addressing. This is true across multiple issues including: A) By excluding available timber resources and B) through a series of faulty assumptions and arbitrary exclusion of available timbered acres.

Within the GTR and the authors' "reconciliation of comments" ("Reconciliation"),[10] they regularly cite their task of establishing a sustainable harvest program for the BHNF. That task from the BHNF to the authors, as provided in the GTR, is:

> a) What impact does the current 2019 forest condition (i.e., standing volume, mortality, and growth) have on the out-year timber program of harvesting at current levels compared to other harvest level scenarios using probable growth and mortality estimates?
>
> b) What is a sustainable timber harvest estimate for the BHNF using the 2019 NRS-FIA data assuming rational tree mortality and growth rates informed by those of the past?
>
> c) What would be the standing inventory volume necessary using reasonable growth and mortality estimates to sustain a sawtimber allowable sale quantity (ASQ) of 181,000 CCF?

However, as pointed out in comments submitted by BHFRA and others, the authors failed to incorporate any spruce trees into their estimates. This is evidenced by the authors in their reconciliation document, when responding to the comment of suggesting inclusion of spruce, with their response of "Ponderosa pine was the species that was of most concern given the most recent MPB and wildfires. For RMRS-GTR-422, we were asked by the BHNF to just focus on this species."

[10] USFS Reconciliation of Comments for RMRS-GTR-422: A Scenario-Based Assessment to Inform Sustainable Ponderosa Pine Timber Harvest on the Black Hills National Forest (June 24, 2021), available at: https://www.fs.usda.gov/rmrs/sites/default/files/documents/Reconciliation_comments_FINAL_210707.pdf.

The task, as written, makes no mention of excluding spruce trees from their estimates. Spruce contributes to the ASQ in the current RMPA and is expected to continue contributing to the harvest program into the future. As the authors regularly frame the issue as what timber inventories and growth are necessary to meet the ASQ, exclusion of spruce resources becomes a critical oversight.

Further, the authors felt spruce was important enough to include from previous inventories in table 1 which were used to compare to current numbers showing only ponderosa pine. In its comments, BHFRA highlighted the inconsistency and recommended excluding spruce from previous inventories or including it in present inventories. In response, the authors stated "RMRS-GTR-422 was intended to address the sustainability of ponderosa pine sawtimber. However, we recognize that white spruce could contribute to ASQ and the timber sale program. In table 4, we highlight which years included white spruce and ponderosa pine in the volume estimates versus those that only report ponderosa pine."[11] Again, the authors acknowledged that spruce contributes to the ASQ and the timber sale program in their response to comments, but they continued to exclude it from any analysis of potential harvest in the GTR. Exclusion of spruce trees from the analysis in the GTR is contrary to the standards of the DQA and would be firmly grounded as arbitrary and capricious in a NEPA document used for these discussions and decisions.

[11] *See* Reconciliation at 84.

Additional exclusions of available resources, within the GTR, can be found in the decision to utilize only a subset of the suitable base and exclude additional areas available for management and harvest. First, the GTR assumes the suitable base will never change over the 80 years of estimates in the GTR despite the current RMPA undergoing a formal revision process to account for such changes, amongst other things. Additionally, this effectively excludes extensive amounts of timber that are not withdrawn statutorily or by the current RMPA and are available for harvest. Although the acres available outside the suitable base would not contribute to the ASQ, they do contribute to a sustainable program. Importantly, the task from the BHNF to the authors specifically asks: "What is a sustainable harvest for the BHNF…". Further, exclusion of areas outside the suited base disregard insect and disease risks and wildfire hazards along with timber that could support a sustainable program. This is especially true given the overstocked nature of many of these acres, as the BHNF has acknowledged and was recently highlighted in a joint letter to the BHNF from the State Foresters of Wyoming and South Dakota. *See* attached **Exhibit A** (State Foresters' Letter to BHNF) attached hereto and incorporated by this reference. In fact, the BHNF is already harvesting, to some degree, outside the suitable base. This issue was raised by BHFRA and others in comments. The authors' responses to those comments indicated they were directed to look exclusively at the subset of the suitable base they used. We find no language in the task from the BHNF to the authors that would direct or indicate the authors should exclude other areas of available timber that are available to contribute to the timber sale program on the BHNF.

2. The GTR, at its core, is projecting sawtimber (trees 9 inches and greater diameter at breast height ("DBH")) resources on the BHNF using three variables, including growth.[12] However, the GTR does not use sawtimber growth rates to project sawtimber growth. Instead, it relies on much smaller, often suppressed trees down to 5 inches diameter. On page 28 of the GTR it states, "The growth rates were the average annual gross growth as a percentage of the standing live volume for merchantable ponderosa pine trees > 5 inches d.b.h. (table 4). Growth rates for the > 9 inches d.b.h. were not used due to the lack of historical data." These smaller trees are often suppressed under the canopy of the sawtimber trees and, as a result, do not accurately reflect true sawtimber growth rates. In fact, the actual sawtimber growth rates directly from FIA data from 2000-2019 are significantly higher than the growth rates described in the GTR.

   Importantly, FIA has been tracking annual sawtimber growth rates on the BHNF since 2000. These actual sawtimber growth rates were presented to the GTR authors in comments from BHFRA that were affirmed by FIA staff with a written review. In that review, the FIA affirmed that: "[I]t is possible to reproduce the [growth] estimates" and that those estimates "yield an unbiased estimate [of sawtimber growth]". At the same time GTR authors claimed there was a lack of reliable historical (pre-2000) data regarding sawtimber growth

[12] All three variables are: starting timber inventory, gross growth rates as a percent of inventory, and mortality rates as a percent of inventory.

rates, they ignored the previous 19 years of available sawtimber growth rates on the BHNF which were provided in comments submitted by BHFRA and subsequently affirmed by FIA. Alison Hill, USFS Research Program Manager for the RMRS stated via email that, "I know our authors have seen the report." Despite having seen the report and acknowledging the need for better information, the authors of the GTR did not use or otherwise disclose the existence of the sawtimber growth rates from 2000-2019 and, instead, relied on historic growth rates for trees down to 5 inches in diameter that included areas outside the Black Hills such as the "short pines" region in northwest SD.

3. The authors of the GTR do not adequately disclose or discuss uncertainties with or implications from their chosen methods or data relied upon for their results. Scientific documents typically include a methods section which should include, among other things, a description of the methods for data collection, data analysis, errors associated with means, and other information that aids in establishing relevance of the science or any concerns that should be considered in application. This section is noticeably absent from the GTR. As a result, the GTR fails to indicate that only 253 trees were used when calculating growth for the BHNF in 2019,[13] fails to disclose any methods or rationale for excluding other trees which had repeated measurements for establishing growth or why/how those 253 trees were chosen from an FIA database with 2,400 FIA tree records of live growing stock trees and associated growth measurements. Without this critical information, the results

[13] *See* April 30, 2021 USFS Timber Stakeholders Chat Transcript at page 4, available at https://usfs-public.app.box.com/s/soqb4u5tlv6djnvsw10q0m7lxdaxznh1/file/648972344880.

in the GTR are potentially flawed and biased and are subject to misuse and misinterpretation.

4. The GTR draws from partial datasets, mixing and matching in a manner that is not supported in science or logic. On page 18 of the GTR, when discussing the historic (pre-2000) data, the authors make the statement, "This doesn't negate the data from [historic] periodic inventories, since it is the best available information from that time, *but it does suggest that users of this older data need to be careful in its interpretation and not use it to quantify trends.*" (emphasis added.) However, the GTR authors rely almost entirely on that historic data to not only identify trends in tree growth but to then project those trends into the future—all the while ignoring more recent and accurate information on sawtimber growth rates on the BHNF. In other portions of the GTR, the authors assert that historic data is not appropriate for use and make assumptions regarding, among others, future mortality rates based on data from other regions of the United States.

5. As part of the background and rationale supporting the flawed conclusions in the GTR, the authors cite a near 50 percent decrease in timber resources on the BHNF; from the all-time high for timber resources in 1999 to the estimate for 2019 (GTR figure 11). This comparison is substantially flawed because the GTR only reviewed timber resources on approximately 60 percent of the acres used for the 1999 estimate.

   These differences in area are listed in footnotes within the GTR. Although the GTR provides footnotes detailing the differences in acres for each comparison in reference to table 4, the GTR does not include the same footnotes for figure 11 which graphs the information in table 4. Additionally, the GTR does not include any substantive in-text discussion of the differences in land area or what impact that may have on proper interpretation or application of the information in the figure. Further, the authors failed to provide any further means of interpreting the differences in standing timber between different acres of measure, despite recommendations from BHFRA and others to make any comparisons "apples-to-apples". BHFRA recommended a simple solution that would have inserted one additional column in the table within the GTR that would have displayed timber volume per acre. As an example of the impact this has, when comparing timber volume per acre, the results indicate a reduction of available timber resources less than half of that indicated by the authors of the GTR. By not differentiating these acreages, the GTR is, at best, confusing to any reader and, at worst, misrepresenting important data to decision makers.

Adding to the uncertainty and confusion surrounding of the intentions of the authors in their use of figure 11, the authors continue to make statements to media[14] that timber resources have been reduced by 50 percent despite the footnotes in the GTR recognizing the tremendous difference in acres used for comparison.

[14] *See, e.g.,* https://apnews.com/article/fires-climate-environment-and-nature-forests-business-0cc8e3391c93a3ad8e77346f0610c4f0.

> *The problem is that the forest changed but logging rates have not, said Mike Battaglia, one of the lead authors.*
>
> *“In the late 90's, you had twice as much volume” of trees in the forest, he said. “To take out the same amount now, you’re taking too much.”*

Not only does the lead author (since the listed lead author passed away six months before publication) grossly misrepresent the factual difference in timber resources but continues by disregarding scientific standards.

6. The authors of the GTR settle on “reasonable” estimate of a mortality rate, representing current rates and into the future, that mirrors the rate in the 2011 report of FIA data by Walters et al. (2013). However, that report represents the impacts of the Jasper, Ricco, Roger Shack, Battle Mountain, and other fires in combination with the PB epidemic which had been running since 2000. Basing immediate and long-term mortality trends on a report that contains mortality from the largest wildfire in recorded history in the Black Hills, three other large fires, and 11 years of pine beetle mortality is illogical when looking at the long-term trends outlined in table 1. There has not been a large fire on the Black Hills National Forest in nearly a decade, and it has been more than 15 years since a large fire burned any significant portion of the suited base. The pine beetle epidemic was declared "over" 4 years ago with only 20 acres of pine beetle damage recorded during the last aerial survey." Despite the most recent mountain pine beetle epidemic being

declared "over" 5 years ago on the BHNF, the authors use a mortality rate that makes the assumption the BHNF is currently plagued by a mountain pine beetle epidemic. Recent and relevant data was presented in comments from numerous parties, including State forestry agencies, highlighting this flaw. Contrary to the GTR, there are currently exceptionally low mortality rates on the BHNF. Further, for a continuous period of more than 40 years, before the mountain pine beetle epidemic, the mortality rate on the BHNF was reported as ranging between 0.16 and 0.26 percent. These rates of .16 and .26 percent accurately reflect current conditions. In 2018, 230 acres were affected by bark beetles and was mostly scattered individual trees.[15] In 2019, 29 acres of forest land in the Black Hills was affected by mountain pine beetle caused tree mortality.[16] This same information was presented by State Forester Greg Josten to the Forest Service during an April 3, 2020 recorded meeting to discuss the GTR. Despite the information of the currently low rates of mortality plus the previously documented low rates of mortality, the authors labeled those rates "unreasonable", thus eliminating flexibility for agencies to apply any adjustments to reflect current conditions.

7. By relying on a fraction of the acres available for estimating timber resources, utilizing a significantly lower growth rate and exaggerated mortality rates, the GTR misrepresents actual conditions of timber resources on the BHNF and provides flawed information to decision makers with the potential for serious,

[15] *See* Allen, Kurt, Kendra Schotzko, and Alan Dymerski. 2019. Bark Beetle Activity on the Black Hills National Forest. RCSC-19-03.

[16] The 2019 Aerial Detection Survey Summary for the Rocky Mountain Region (R2) of the US Forest Service.

negative impacts to forest health on the BHNF and the companies and communities that depend upon it.

C. The GTR is functioning as a decision document.

While the March 23, 2021 USFS press release states that the "GTR is a scientific document, not a policy or decision document,"[17] the draft and final GTRs have served as the basis for substantive decision-making on the part of the USFS. It follows that "an agency may violate NEPA, and consequently the APA, when it predetermines the result of its environmental analysis." *Forest Guardians v. U.S. Fish & Wildlife Serv.*, 611 F.3d 692, 714 (10th Cir. 2010); 40 C.F.R. § 1502.2. BHNF, then, may not rationalize or justify decisions it has already made. As a result of the GTRs, timber harvest and sales have been drastically—and contrary to requirements imposed by NEPA and NFMA—reduced in the BHNF. The GTR cannot function as a decision document, in any capacity, without NEPA compliance.

The Final GTR is premised on the faulty assumption that "[t]he current harvest level in the BHNF Forest Plan of 181,000 CCF/yr is not a sustainable option." Final GTR at ii, 1. As a result, the Final GTR erroneously concludes that "because of declining standing live tree volume, we assumed that harvest levels would not be able to increase but rather there may be a need to decrease harvest levels to identify a reasonable sustainable harvest of sawtimber for the short- and long-term." *Id*. at 29.

The USFS has indicated its decision to decrease timber harvest and sales in stakeholder meetings, verbal communication, and correspondence with BHFRA. Furthermore, the sole document provided for consideration during the stakeholder meetings and correspondence was

[17] https://www.fs.usda.gov/rmrs/science-spotlights/sustainable-timber-harvest-black-hills-national-forest

the draft GTR. The BHNF held stakeholder and local government official meetings on the GTR on April 3, April 10, May 1, and May 15, 2020.[18]

As an example, the Draft GTR was the only document provided for discussion during the April 3, 2020 meeting. During the April 3, 2020 meeting, Jennifer Eberlien, Acting Regional Forester, made the following statement:

> We're collecting the data and presenting it that we all agreed would be collected. We're sharing that data with all the stakeholders to get that additional input. The data that will be presented, that you've already seen, will be presented and discussed today represents scientifically and statistically supportable information that we're gonna use…. [discussion on research station data collection/sharing]. So we agreed that the data and the subsequent analysis would inform our decision-making today and that, today, starts, marks the start of this process."

April 3, 2020 meeting between 9:30 and 12:30 minute marks.[19]

There are numerous other examples in those stakeholder meetings of USFS officials making similar statements about the FS making "decisions" based on the GTR. The April 10, May 1, and May 15 meetings contained similar discussion of using the data (from the GTR) to inform the decision-making process going forward and numerous instances in which USFS officials made similar statements regarding the USFS making "decisions" based on the Draft GTR. We understand no other information was provided during the stakeholder meetings to "help inform a decision" other than the Draft GTR.

On April 15, 2020, the Black Hills National Forest Advisory Board ("NFAB") was tasked to develop a recommendation for a maximum sustainable harvest level, based solely on the recommendations in the draft GTR.[20] The recommendation was to be based on the FIA data

[18] https://www.fs.usda.gov/detail/blackhills/landmanagement/resourcemanagement/?cid=fseprd731012
[19] https://usfs.adobeconnect.com/pf84e9rqbh6f/?launcher=false&fcsContent=true&pbMode=normal
[20] It was also tasked to provide a recommendation as to the need for, and timing of, a forest plan amendment.

set released in January 2020 and the conclusions in the GTR based upon it in addition to other considerations and assumptions.[21]

On September 16 and on October 21, 2020, the NFAB provided two recommendations. The first advised that "given the scope of changes that have affected the BHNF, and the requirement that Forest Plans should be revised every fifteen years…the BHNF [should] begin the Forest Plan revision process as soon as possible."[22] The second recommendation was that the BHNF not reduce the sawtimber sale program below the ASQ of 181 million cubic feet (181,000 ccf) of sawtimber for USFS fiscal years 2022-2027.[23]

i. Timber Harvest and Sales have Decreased

A graph generated from USFS cut and sold reports depicts dramatic declines in timber sales subsequent to the release of the GTR. See attached **Exhibit B** (Line Graph re Sold vs. ASQ Timber) attached hereto and incorporated by this reference. Exhibit B shows the total timber sale volume sold versus the ASQ since the current RMPA was adopted (annual targets are not shown on this graph). Timber sales starkly decreased subsequent to the preliminary draft GTR delivered to the BHNF and further after publication of the Draft GTR in April 2020.

Since the release of the GTR, the BHNF has consistently failed to meet timber harvest targets in the forest plan. Only purposeful reliance on the GTR can account for these failures. Other National Forests that failed to meet their targets had breaking wildfires or circumstances related to COVID-19, e.g., where the USFS offered timber for sale but it was not bid on. No such issues faced the BHNF. **Exhibit C** (Chart re Sales for Multiple Forests), attached hereto and incorporated by this reference is a chart showing Fiscal Year 2020 timber sales compared to timber targets from several National Forests including the BHNF. As Exhibit C depicts, timber

[21] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd738034.pdf.
[22] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd760068.pdf.
[23] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd884475.pdf.

sales from certain National Forests exceeded targets, despite wildfires or decreased bids (e.g., Bighorn National and Medicine Bow-Routt National Forests). Decreased sales in the BHNF were the result of the GTR—not wildfires, budget or the results of COVID-19. Instead, the USFS held multiple meetings aimed at discussing reductions to the timber sale program in the BHNF. The decrease was almost exclusive to the BHNF, despite COVID-19 impacts being greater in other National Forest areas.

Upon information and belief, the USFS has recently outlined harvest targets of 91,000 ccf in FY23 and 88,600 in FY24, indicating reliance on the GTR.

D. National Forest Advisory Board Recommendation

In a similar manner as when the BHNF commissioned the GTR from the RMRS, the BHNF also tasked the NFAB to provide the Forest a recommendation on a sustainable timber sale program, as discussed previously herein. The working group leading the data analysis and drafting of the recommendation included members from South Dakota and Wyoming forestry agencies including State Forester Greg Josten who chaired the working group, a Certified Forester, Certified Arborist and state legislator, and two individuals representing environmental group interests on the NFAB. After nearly seven months of thorough data analysis, including current and historic FIA data, the NFAB formally approved a recommendation to the BHNF that a sustainable sawtimber sale program should be 181,000 ccf annually (the current ASQ) and identified timber resources that could be used to increase the program. The NFAB recommendation was approved four to five months before the GTR was finalized but was not utilized by the authors of the GTR or mentioned.

Importantly, the NFAB implemented the same sustainability equation used by the authors of the GTR. However, the NFAB recognized some of the same shortcomings in historic FIA data and, instead, relied on the sawtimber growth rates of more than 3 percent as validated by FIA and more reasonable mortality rates based on recent surveys and data. Although the NFAB presentation highlights the mortality rate used in their recommendation was increased from their previously approved rate as a compromise to gain support from various interests, but the increase was not based on science.

At the least, authors of scientific reports such as GTRs should acknowledge and describe other works in the same subject area. Scientific publications should not have the luxury of ignoring and not acknowledging opinions that are counter to the authors own. By not acknowledging the existence of the NFAB recommendation, the authors do not provide the reader adequate context and information to make informed decisions.

E. BHFRA Report

Consultants Steve Scharosch (Abacus Enterprises), Dr. Mike Huebschmann (Huebschmann & Associates), and Tom Montzka (Straight Arrow Consulting) prepared a report dated July 15, 2020, which was entitled "Review of Black Hills National Forest 2017-2019 Augmented FIA Inventory Results" for the BHFRA ("BHFRA Report" or the "Report"), attached hereto and incorporated by this reference as **Exhibit D**. This report has been independently produced and reviewed by all three of the well-qualified consultants (all hold M.S. or PhD degrees and whose clients have included the US Forest Service). The results are supported by hard copies of EVALIDator runs and other available information. On August 3, 2020, Ben Wudtke, Executive Director of BHFRA, provided the BHFRA Report to Alison Hill, USFS Research Program Manager for the Rocky Mountain Research Station via email and asked that this new information be included as an addition to BHFRA's comments on the Draft GTR. On August 3, 2020, Ms. Hill stated: "I know our authors have seen the report. ¶ I understand you want us to accept this new comment under our public/stakeholder comment period; but as you know the comment period is closed." *See* **Exhibit E** (Email Correspondence re BHFRA Report), attached hereto and incorporated by this reference. Ms. Hill continued in her email, "Can you tell me if the report underwent a rigorous review and what that review entailed?" Ms. Hill's question regarding review indicates that the FS may be inclined to accept certain types of information or information from certain individuals/groups after the comment deadline.

V. Findings of the BHFRA Report

As stated previously herein, the BHFRA Report reviewed the same FIA data used in the GTR. The Report noted, however, that "[n]umerous issues, concerns, and uncertainties were uncovered" which "cast doubt on the accuracy of the reported inventory results." Report at 4. The BHFRA Report and NFAB recommendation accurately reflect conditions in the BHNF and should be relied upon as the best available science.

As an example of issues found in the GTR, using FIA data, the BHFRA Report determined that, since 2000, the sawtimber trees in the area analyzed in the GTR have been growing at a rate of greater than 3%.[24] This result was later supported in writing by FIA in its September 2, 2020 "FIA Responses to 'Review of the Black Hills National Forest 2017-2019 Augmented FIA Inventory Results' Report," attached and incorporated by this reference as **Exhibit F** (FIA Response to BHFRA Consultants' Report). *See* Concerns 12-13. Growth rates have a profound effect on the results of sustainable timber harvests. However, when presenting the Final GTR, the USFS stated (notwithstanding ample evidence) that 3% growth had never been reported on the BHNF and that that percentage was not used in any of their scenarios. Instead, the agency opted for the erroneously lower growth rate from the GTR.

Other significant issues with the GTR described in the Report include:

[24] BHFRA compiled this information and more in a report it provided to the USFS as discussed more fully below.

- Acreage estimates in prior FIA inventories remained fairly constant but began dropping after the BHNF initiated the augmented FIA inventory in 2017 – even though to the best of our knowledge there have been no sizable land sales or exchanges during this period that would have changed acreages as depicted in this more recent FIA-based data.

  [Table re: "Annual % Difference in Reported Acres Compared to Average 2010-2016 Reported Acres, by Inventory Year" omitted herein.]

- There is a large degree of uncertainty in the estimated volume inventory and growth estimates. For example, looking at the estimated growth of sawlog volume on sawtimber trees; even though the total net growth estimate is a negative value (-28,000 CCF) the 95% confidence limit indicates the actual growth could be anywhere from negative 107,000 to positive 51,000. When making decisions based on such an estimate, it is imperative to recognize the large degree of uncertainty associated with the estimate. FIA staff, in their written review of the BHFRA report, agreed with the importance of disclosing these levels of uncertainty (see review item number 12).

- A gross annual growth rate of greater than 3% is much more defensible as a long-term growth estimate than the 2.5% that was computed using the 2019 augmented data set. The 3% growth rate is grounded on multiple recent observations and mitigates the effects of incorrect acreage estimation in the 2019 augmented data. In addition, gross annual growth estimates derived from 2019 on-line FIA data, using ratio estimates based on an acreage that aligns with the NEPA-approved suitable base acres, is 3.04%. These estimates of 3% and 3.04% annual growth are for South Dakota acres only; also, the augmented data set, even with its deficiencies, indicates gross annual growth is higher on Wyoming suitable base acres than on South Dakota acres, which means a 3% growth rate is likely conservative.

- Forest growth simulations conducted using the USFS Forest Vegetation Simulator (FVS) showed annual mortality rates for suitable base timberlands of 0.23%; less than a quarter of the value used in the draft and final GTR.

- The FIA database flag that indicates whether an FIA plot is contained within the BHNF suitable base acres is being incorrectly applied to the entire cluster of four subplots that comprise an FIA sample point, rather than to each individual subplot. This is at odds with how the timberland flag, accessibility flag, reserved status flag, and growth potential flag are applied – all of which are assigned at the subplot level. Classifying all subplots as a group to either the suitable or non-suitable category could cause significant inaccuracies in acreage and volume estimation. There is no USFS documentation available that details how a cluster of four plots is assigned its suitability flag (by the center of the four-plot cluster?, by the majority of the sub-plot locations?, by some other means?), nor is there any justification for why this flag should be assigned differently than the timberlands flag, at the subplot level. This context is missing from discussion in the GTR.

- Analyzing the sawlog percent volume defect by tree DBH class in the 2017-2019 BHNF augmented FIA database showed that the 29+" DBH class for ponderosa pine, and **every**

DBH class for white spruce had the identical defect percentage value of 11.78%. We can find no USFS documentation explaining why this fixed defect value is being applied, or how it was derived. This context is missing from discussion in the GTR.

- By accelerating permanent plot remeasurements in 2017-2019, the growth period has been halved, resulting in the need to accurately measure diameter growth of 0.25 inch or less. In such circumstances, the relative impact of measurement error increases greatly, and the slightest inaccuracies in field measurement (e.g., the diameter tape placed too high/low, at an angle, over a loose piece of bark, etc.) have the potential to substantially affect growth estimates. This context is missing from discussion in the GTR.

VI. Information to be Corrected

A. Description of Information to Correct

i. The report to be corrected is: Graham, Russell T.; Battaglia, Mike A.; Jain, Theresa B. 2021. A scenario-based assessment to inform sustainable ponderosa pine timber harvest on the Black Hills National Forest. Gen. Tech. Rep. RMRS-GTR-422. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 61 p. https://doi.org/10.2737/RMRS-GTR-422.

ii. The specific information for which a correction is sought is identified in the BHFRA Report and NFAB recommendation and is summarized as follows:

   a. Arbitrary exclusions of available timber for harvest on the BHNF from spruce and timberlands outside the suitable base in the current RMPA.

   b. Incorrect sawtimber growth estimates

   c. Incorrect application of high mortality rates and labeling of “rational” mortality rates.

   d. Incorrect exclusion of plausible scenarios with observed lower mortality and/or higher growth rates as “unsustainable”.

   e. Incorrect/inconsistent suitable base flag

f. Thorough explanation of methods, including the use of a fraction of trees with available growth information, among others.

B. Explanation of Noncompliance with OMB and/or USDA Information Quality Guidelines

The OMB's April 24, 2019 memorandum "Improving Implementation of the Information Quality Act"[25] states that: "OMB policy emphasizes that, when data are made available to the public, potential users must be provided with sufficient information to understand which agency is responsible for the quality of the data being disseminated, *as well as the data's strengths, weaknesses, analytical limitations*, security requirements, and processing options. (emphasis added). Further, the memo included updated guidance that "Scientific Integrity, agencies should ensure that influential information is communicated transparently by "including a clear explication of underlying assumptions, accurate contextualization of uncertainties, and a description of the probabilities associated with both optimistic and pessimistic projections, including best-case and worst-case scenarios."

The USDA information quality guidelines apply to "all types of information disseminated by USDA agencies and offices."[26] The USDA Guidelines require that USDA agencies and offices:[27]

i. [S]trive to ensure and maximize the quality, objectivity, utility, and integrity of the information that its agencies and offices disseminate to the public.

[25] https://www.whitehouse.gov/wp-content/uploads/2019/04/M-19-15.pdf.
[26] https://www.ocio.usda.gov/policy-directives-records-forms/information-quality-activities.
[27] https://www.ocio.usda.gov/policy-directives-records-forms/information-quality-activities; *see also* https://www.fs.fed.us/qoi/.

ii. [A]dopt a basic standard of quality (including objectivity, utility, and integrity) and take appropriate steps to incorporate information quality criteria into their information dissemination practices.

iii. [R]eview the quality (including objectivity, utility, and integrity) of information before it is disseminated to ensure that it complies with the standards set forth in these Guidelines.

iv. [T]reat information quality as integral to every step in their development of information, including creation, collection, maintenance, and dissemination. [and]

v. In accordance with OMB guidance, when collecting information that requires OMB clearance under the Paperwork Reduction Act, USDA agencies and offices will demonstrate in the clearance package submitted to OMB that the information collection would result in information that will comply with OMB and USDA information quality guidelines.

The quality standards which USDA agencies must follow "in developing and reviewing information and disseminating it to the public" consist of:[28]

i. Objectivity

- USDA agencies and offices will strive to ensure that the information they disseminate is substantively accurate, reliable, and unbiased and presented in an accurate, clear, complete, and unbiased manner.
- To the extent possible, consistent with confidentiality protections, USDA agencies and offices will identify the source of the information so that the public can assess whether the information is objective.

[28] *Id.*

ii. Utility

- USDA agencies and offices will assess the usefulness of the information they disseminate to its intended users, including the public.
- When transparency of information is relevant for assessing the information's usefulness from the public's perspective, USDA agencies and offices will ensure that transparency is addressed in their review of the information prior to its dissemination.
- USDA agencies and offices will ensure that disseminated information is accessible to all persons pursuant to the requirements of Section 508 of the Rehabilitation Act.

iii. Integrity

- USDA agencies and offices will protect information they maintain from unauthorized access or revision to ensure that disseminated information is not compromised through corruption or falsification.
- USDA agencies and offices will secure their information resources by implementing the programs and policies required by the Government Information Security Reform Act.
- USDA agencies and offices will maintain the integrity of confidential information and comply with the statutory requirements to protect the information it gathers and disseminates. These include: The Privacy Act of 1974, as amended; The Paperwork Reduction Act of 1995; The Computer Security Act of 1987; The Freedom of Information Act; and OMB Circulars A-123, A-127, and A-130.

The GTR fails to comply with these standards—particularly the standard of objectivity. As the BHFRA Report has found, the information in the GTR is inaccurate, unreliable, and biased. As a result, the GTR vastly understates timber growth on the BHNF.

In addition, the GTR does not meet DQA standards for the best available data. Agencies are directed[29] to adopt congressional standards of scientific integrity stemming from the Safe Drinking Water Act ("SDWA"). For agency action based on science, the SDWA standards entail utilizing:

> (i) the best available, peer-reviewed science and supporting studies conducted in accordance with sound and objective scientific practices; and (ii) data collected by accepted methods or best available methods (if the reliability of the method and the nature of the decision justifies use of the data).
>
> 42 U.S.C. § 300g-1(b)(3)(A)(i) - (ii).[30]

Furthermore, "each agency [must]...subject 'influential' scientific information to peer review prior to dissemination," and "agencies should strive to ensure that their peer review practices are characterized by both scientific integrity and process integrity."[31] The GTR is clearly influential information as the USFS has been relying upon it to drastically reduce timber harvest levels on the forest. Although there was a comment and peer review process, simply completing the process without proper consideration of the comments does not completely "check the box".

'Scientific integrity,' in the context of peer review, refers to such issues as 'expertise and balance of the panel members; the identification of the scientific issues and clarity of the charge to the panel; the quality, focus and depth of the discussion of the issues by the panel; the rationale and supportability of the panel's findings; and the accuracy and clarity of the panel report.' 'Process integrity' includes such issues as 'transparency and openness, avoidance of real

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[29] OMB DQA Guidelines V3.b.ii.B.ii.C.
[30] *See also* 67 FR 8451, 8457 (Feb. 22, 2002).
[31] Available at: http://www.whitehouse.gov/omb/fedreg_reproducible.

or perceived conflicts of interest, a workable process for public comment and involvement,' and adherence to defined procedures. (*Citing* ILSI Risk Sciences Institute, ''Policies and Procedures: Model Peer Review Center of Excellence,'' 2002: 4.)[32] OMB Peer-Review Guidelines at 2668-9.

Lastly, the OMB Guidelines require a high degree of transparency for influential information such as the GTR. Transparency equates to disclosure of the "data and methods of analysis" such that replication of results could be achieved.[33] Peer-review of original and supporting data and results "does not necessarily imply that the results are transparent and replicable."[34]

The GTR fails to meet quality, objectivity, utility and integrity standards of the DQA, the Guidelines and the additional authorities cited herein. Accordingly, BHFRA asks USFS to correct, retract or supplement information referenced in the GTR as discussed in the BHFRA Report and to ensure that all information disseminated by USFS meets the requirements of the DQA and the USDA Guidelines.

C. Explanation of the Effect of the Alleged Error

As discussed herein, USFS is using the GTR as the basis for forest management decisions in the BHNF—primarily forest management decisions decreasing timber harvest and sales.

According to the USFS, "[e]ach year, an average of more than 73,000 wildfires burn about 7 million acres of federal, tribal, state, and private land and more than 2,600 structures."[35] The USFS acknowledges the increasing severity of wildfires, stating that "over the last few decades, the wildland fire management environment has profoundly changed. Longer fire seasons; bigger fires and more acres burned on average each year; [and] more extreme fire

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32 http://rsi.ilsi.org/file/Policies&Procedures.pdf
33 OMB DQA Guidelines V(3)(b)(ii).
34 OMB, Guidelines *for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies*, http://www.whitehouse.gov/omb/fedreg_reproducible.
35 https://www.fs.usda.gov/managing-land/fire

behavior….”[36] A Congressional Research Service paper “Wildfire Statistics,”[37] which was updated on July 15, 2021 as of the date of this Request, also discusses the increasing incidence and scale of wildfires. Mitigation against catastrophic wildfires should be among the highest priorities of the BHNF and the USFS as a whole. Active timber management is the best way to mitigate against such fires. As fires burn, carbon stored in trees and other vegetation combusts, releasing carbon dioxide and other potent greenhouse gases into the atmosphere. This means that as fires increase, so do emissions. For example, in California, the worst days of wildfires in 2020 have generated emissions that are roughly 4 to 8 times higher than the average daily emissions from all economic activity across the state.[38]

On August 7, Denver, Colorado was said to have the worst air quality in the world as a result from smoke from forest fires across the West. In large part, these fires were fueled by unmanaged forests as the result of high levels of management restrictions. In addition to destroying wildlife and wildlife habitat, these wildfires degrade water quality, transportation and even take human lives. Mudslides and flooding in their wake have caused repeated and numerous road and highway closures and have even cost human lives.

In addition, in the arid West, our precious water resources largely originate on USFS lands. When wildfires occur, soil in burned areas erodes into rivers, streams and reservoirs, impacting not only people, but wildlife and ecosystems according to a June 18, 2021 article by The Nature Conservancy. Wildfires also affect watersheds that are essential for irrigating crops and hurt the agriculture industry. Water supplies may take decades and untold millions of dollars to recover.

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[36] *Id.*
[37] https://fas.org/sgp/crs/misc/IF10244.pdf
[38] https://www.wri.org/insights/6-graphics-explain-climate-feedback-loop-fueling-us-fires

These devastating events take their toll not only on the national forests, but also on fire-fighting personnel, the timber industry, infrastructure, private property, and the public. It is well-documented that timber harvest (i.e., fuels management) is necessary to mitigate the spread and destructive impact of wildfires and PB epidemics. As testament to that fact, this year the USDA released a report titled, "Climate-Smart Agriculture and Forestry Strategy: 90 Day Report", calling for a 2-4 times increase in the number of acres treated annually on FS lands. The USFS' intention to reduce timber harvest and sales will inevitably serve only to fuel the disappearance of healthy and beautiful national forests, compounding atmospheric carbon and reducing other public land opportunities as a result.

D. Recommendation and Justification for How the Information Should be Corrected

BHFRA urges the USFS to withdraw the GTR in order to revise it in accordance with the specific recommendations identified in the BHFRA Report and NFAB recommendation. As the GTR is serving as the basis for significant USFS forest management decisions contrary to NEPA, it is vital that the GTR be wholly characterized by "quality, objectivity, utility, and integrity," and utilize the most accurate science possible.

VII. Conclusion

The GTR is a highly influential document, as the USFS is using it and citing it for substantial land use decisions in the BHNF. As such, USFS must adhere to the standards of quality, integrity, objectivity and utility under the DQA as well as administration standards of scientific integrity and transparency.

The GTR violates the DQA, USDA Guidelines, and OMB guidance cited herein as the information it conveys is inaccurate. Nonetheless, the GTR is serving as the basis for USFS decision-making regarding management of the BHNF. Reliance on this biased and faulty information has and will continue to harm the BHNF. In addition to the damage to BHFRA, the forests, the timber industry, the public, and the economy will be negatively impacted.

BHFRA respectfully requests the USFS retract the GTR and correct it consistent with the tenets of quality, objectivity, utility and transparency in the DQA.

Respectfully submitted this 19th day of November, 2021.

HOLSINGER LAW, LLC

Kent Holsinger

On behalf of:
Black Hills Forest Resource Association, Petitioner

EXHIBIT A

August 12,, 2021

Jeff Tomac
Forest Supervisor
Black Hills National Forest
1019 N. 5th Street
Custer, SD 57730

Mr. Tomac:

This letter is to express our concern regarding dense forest conditions on portions of the Black Hills National Forest (BHNF). As the Black Hills experiences a hot and dry year, and wildfires consume hundreds of thousands of acres of neighboring forests, the need to address forest health conditions that contribute to forest mortality events is clear. Allowing dense stands of coniferous forest to persist across the landscape creates the potential for detrimental impacts to public and private forests, and Black Hills communities.

Data provided by the BHNF indicates the northern portion of the BHNF has a substantial amount of dense, large diameter forest structure. On the Bearlodge Ranger District, 90 percent of the management areas (MAs) that form the suitable base are classified as stands of large diameter trees, with more than 60 percent of those stands considered high density. Similar conditions exist on the Northern Hills Ranger District where 75 percent of the same MAs are large diameter stands with nearly half of those stands considered high density. Few stands in these MAs are classified as young, or smaller diameter. Additional dense stands are likely to exist on areas outside the suitable base, but not withdrawn from forest management activities and certainly not immune to wildfires or insect infestation.

Research conducted on the BHNF has consistently shown that dense stands of large diameter trees are at an elevated risk of insect infestation and high severity wildfires, and that thinning those stands reduces the associated risks and hazards.

We strongly recommend taking action to develop and implement projects, using a variety of planning tools and engaging cooperating agencies, to thin these dense stands of trees. We also believe implementing new thinning projects to address these conditions would contribute to the BHNF meeting numerous goals in the Forest Plan, including goals 3, 7, 10, and 11.

Additionally, each of our agencies have staff dedicated to aiding the BHNF in implementation of additional management activities, but our staff are currently underutilized by the BHNF and represent additional opportunities for improving forest health.

EXHIBIT A

We look forward to working with the BHNF to develop and implement projects that would address these concerning forest health conditions.

Thank you,

Greg Josten
South Dakota State Forester
Department of Agriculture and Natural Resources
3305 W. South Street
Rapid City, SD 57702

Bill Crapser
Wyoming State Forester
Wyoming State Forestry Division
5500 Bishop Blvd
Cheyenne, WY 82002

EXHIBIT B

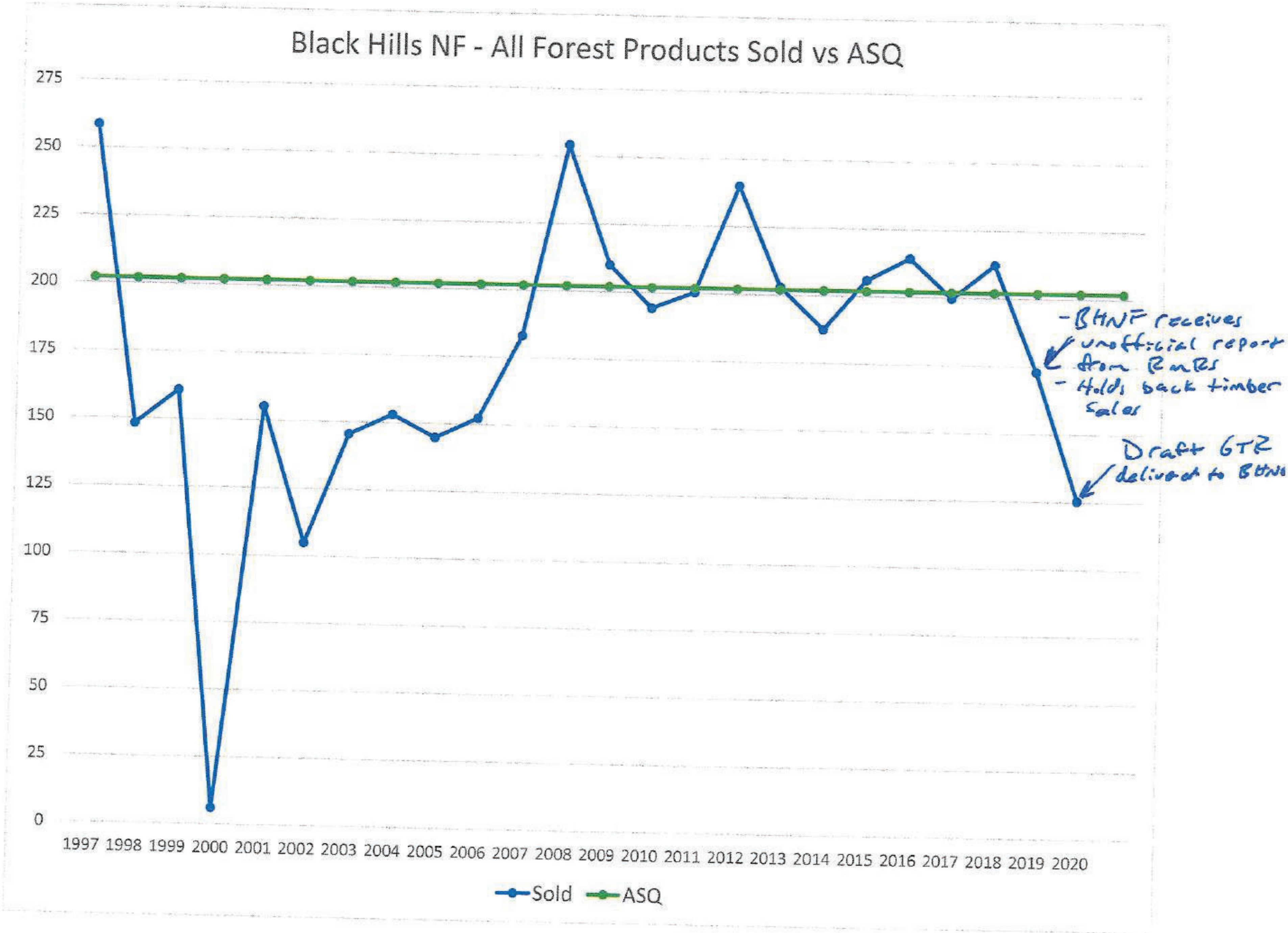
Black Hills NF - All Forest Products Sold vs ASQ
275
250
225
200
175
150
125
100
75
50
25
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Sold
ASQ
- BHNF receives unofficial report from RMRS
- Holds back timber sales
Draft GTR delivered to BHNF

EXHIBIT C

Had 2 - Sawtimber sales held back from '19 that were ...

- 200k acre fire

Sheet of Numbers Updated 11/25/20

	BIGH-02	BLKH-03	GMUG-04	MBR-06	NEB-07	RG-09	AR-10	PSI-12	SJ-13	SHOS-14	WHR-15	RO-	REGION
FY 2020 Funding Allocations													
NFTM	$446.7	$6,761.4	$2,547.1	$4,259.0	$150.4	$1,661.7	$3,322.2	$948.3	$3,532.9	$796.5	$1,162.7	$1,376.2	$26,965.1
SSSS	$3.5	$37.8	$352.9	$136.5	$0.0	$185.7	$60.8	$0.0	$0.0	$72.8	$122.9		$972.9
Other Active Management Funds (UPN)	$0.0	$1,501.0	$965.0	$1,225.0	$0.0	$0.0	$0.0	$865.0	$30.0	$594.0	$500.0		$5,680.0
Total	$450.2	$8,300.2	$3,865.0	$5,620.5	$150.4	$1,847.4	$3,383.0	$1,813.3	$3,562.9	$1,463.3	$1,785.6		$32,241.8
FY 2020 Final Accomplishment													
Timber Target (ccf)	17,000	197,000	75,000	100,000	1,000	27,000	21,000	17,000	85,000	22,800	30,000	37,200	630,000
Volume Accomplished (ccf)	18,067	125,418	76,336	55,297	98	20,190	21,589	29,742	83,152	7,994	11,010		448,893
Accomplished % of Target	106%	64%	102%	55%	10%	75%	103%	175%	98%	35%	37%		71%
$/CCF Target	$26.48	$42.13	$51.53	$56.21	NA	$68.42	$161.10	$106.66	$41.92	$64.18	$59.52		$42.80
$/CCF Accomplished	$24.92	$66.18	$50.63	$101.64	NA	$91.50	$156.70	$60.97	$42.85	$183.05	$162.18		$71.83
No Bid Sales													
# No Bid Sales	2	0	1	3	0	5	0	1	0	3	3		18
Volume No Bid Sales (ccf)	164	0	2,783	26,861	0	32,922	0	1,930	0	6,307	20,253		91,220
Volume Reoffered and Sold in FY20 (ccf)	0	0	0	19,031	0	0	0	0	0	1,052	0		20,083
Stewardship Contracts													
Number of New SC Awarded	1	1	2	0	0	0	4	5	4	0	0		17
Number of Long Term SC Task Orders	0	0	0	0	0	0	0	0	0	0	1		1
Volume Accomplished (ccf)	9,601	199	21,215	0	0	0	9,667	14,730	28,215	0	8,460		92,087
Product Mix Percentage													
% Sawtimber	69%	94%	80%	92%	0%	88%	83%	63%	82%	32%	18%		82%
% Fuelwood	14%	5%	7%	2%	100%	8%	4%	26%	4%	47%	16%		8%
% Biomass	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%		0%
% Other Convertible	17%	1%	13%	6%	0%	4%	13%	11%	14%	21%	59%		10%
FY 2021 Initial Allocation													
NFTM Preliminary Allocation	$52.1	$911.2	$312.4	$494.7	$26.0	$78.1	$26.0	$26.0	$364.5	$104.1	$208.3	$1,500.0	$4,103.4
SSSS Request	$40	$0	$200	$200	$0	$150	$0	$30	$50	$100	$181		$951.0
Total Funding	$92.1	$911.2	$512.4	$694.7	$26.0	$228.1	$26.0	$56.0	$414.5	$204.1	$389.3	$1,500.0	$5,054.4
FY 2021 Targets													
Timber Target (ccf)	17,000	175,000	65,000	130,000	1,000	21,000	21,000	20,000	80,000	35,000	45,000		610,000

EXHIBIT D

Review of Black Hills National Forest 2017-2019 Augmented FIA Inventory Results

15/JUL/2020

Prepared for:

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abacus

EXHIBIT D

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1.0 Executive summary

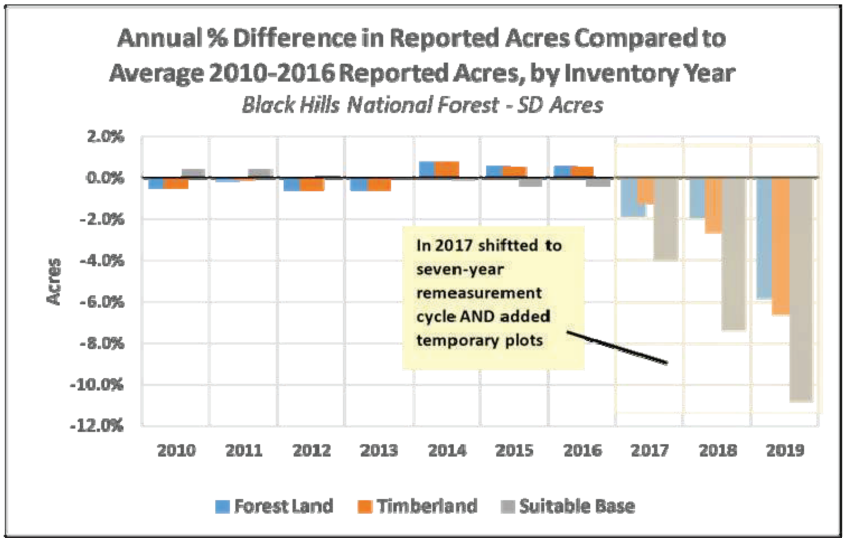
This report documents a technical review of the 2017-2019 Black Hills National Forest (BHNF) augmented Forest Inventory and Analysis (FIA) inventory database released to the public by the BHNF in January 2020.

Numerous issues, concerns and uncertainties were uncovered during the course of the analysis which, taken together, cast doubt on the accuracy of the reported inventory results. The following points summarize the major study findings, which are discussed in detail within the body of this report.

- The 2017-2019 BHNF augmented FIA inventory (incorporating the additional temporary plots installed during sample years 2017-2019) is less accurate (but more precise) than the 2016 FIA inventory utilizing only the permanent plots.
- The presence of both permanent plots (with growth information) and temporary plots (which lack growth information) in the 2019 BHNF augmented dataset complicate the derivation of appropriate expansion factors for estimating inventory (using all plots), and growth (using only permanent plots). Anomalies in inventory calculations coincide with the introduction of temporary plots in 2017, causing concern that the plot expansion factors have been incorrectly defined for both inventory and growth estimates.
- The 2017-2019 BHNF augmented inventory results in an estimated 765,733 acres of suitable timberland; that is 71,267 acres less than the **known** suitable timberland acreage of 837,000 acres (based on a 2019 USFS GIS shapefile which has not been provided by the USFS despite being requested), and 100,157 acres less than the 865,890 suitable timberland acres identified in the BHNF Forest Plan Phase II Amendment,[1] the result from the formalized National Forest Planning process.[2]
- Acreage estimates in prior FIA inventories remained fairly constant, but began dropping after the BHNF initiated the augmented FIA inventory in 2017 – even though to the best of our knowledge there have been no sizable land sales or exchanges during this period

[1] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf
[2] https://www.federalregister.gov/documents/2001/11/28/01-29548/phase-ii-amendment-of-black-hills-national-forest-land-and-resource-management-plan

that would have changed acreages as depicted in this more recent FIA-based data.



- The reported known, or actual, BHNF suitable timberland acres (as opposed to estimated acres derived from the FIA inventory) have been decreasing over time:
  865,890 acres in the BHNF Forest Plan Phase II Amendment[3]
  846,042 acres in a 2017 USFS GIS shapefile
  "about 837,000 acres" in a 2019 USFS GIS shapefile[4]
  "about 836,000 acres" in a 2019 USFS GIS shapefile[5]
  The reason for this decrease in reported suitable timberland acres has not been adequately explained. In terms of process this apparently monotonic change seems problematic as our understanding is the original 865,890 acres in the BHNF Forest Plan Phase II Amendment was determined as part of a formalized forest planning process whereas these subsequent changes have not been.

- There is only a one ten-thousandth of a percent probability (i.e., one-in-a-million chance) that the FIA estimate of 765,733 acres of suitable timberland acres, and the known suitable timberland acreage of 837,000 represent the same population.

- If the 2017-2019 BHNF augmented FIA data does not accurately estimate acres, there can be no confidence that the associated inventory or growth estimates are valid. A 10% difference in acreage estimates could potentially translate into an even greater error for inventory estimates.

- Using the BHNF forest plan suitable base acreage of 865,890 in place of the 765,733 estimate derived from the 2017-2019 BHNF augmented database results in a 13% increase in the estimated forest inventory on the suitable base acreage; expanding the

[3] https://www.fs.usda.gov/Internet/Fse_Documents/fseprd592921.pdf, Appendix G.
[4] March 11, 2020 email correspondence from Chuck Barnett, USFS FIA program, Durham, NH (see Appendix B).
[5] April 9, 2020 email correspondence from Chuck Barnett, USFS FIA program, Durham NH (see Appendix D).

inventory calculations to the total BHNF timberland[6] acreage of 1,062,776 results in a 41% increase in the estimated forest inventory on all timberlands in the BHNF.

- USFS FIA staff have claimed the inaccurate estimate of suitable base acres is "due to terminology" (see Appendix D), and that not all BHNF suitable base acres are timberlands by the FIA definition. This in no way explains why the suitable base acreage estimate has dropped precipitously since the augmented sampling began in 2017, while the actual suitable base acres have remained essentially static. This claim goes against the discussion of suitable base acreage derivation provided in Appendix G of the BHNF Forest Plan. Furthermore, if there is indeed a substantial proportion of the BHNF suitable base acres that are not timberlands (by the FIA definition), then it must follow that none of the inventory statistics provided to the public via the January 27, 2020 email from Andrew Johnson, acting BHNF forest supervisor, accurately represent the suitable base described in the BHNF Forest Plan, and upon which the ASQ is based.

- By accelerating permanent plot remeasurements in 2019, the growth period has been halved, resulting in the need to accurately measure diameter growth of 0.25 inch or less. In such circumstances, the relative impact of measurement error increases greatly, and the slightest inaccuracies in field measurement (e.g., the diameter tape placed too high/low, at an angle, over a loose piece of bark, etc.) have the potential to substantially affect growth estimates.

- We have been unable to obtain from the USFS a detailed description of the methodology used to distribute the supplemental temporary inventory plots across the landscape, and are therefore unable to evaluate if they were allocated in an unbiased, representative manner.

- Acreage inaccuracies in the sample results aside, there is a large degree of uncertainty in the estimated volume inventory and growth estimates. For example, looking at the estimated growth of sawlog volume on sawtimber trees; even though the total net growth estimate is a negative value (-28,000 CCF) the 95% confidence limit indicates the actual growth could be anywhere from negative 107,000 to positive 51,000. When making decisions based on such an estimate, it is imperative to recognize the large degree of uncertainty associated with the estimate.

- Forest growth estimates derived from on-line records of FIA inventories for South Dakota (excluding Wyoming BHNF acres due to growth data availability) are 3.21%, 3.31%, 3.16%, and 2.89% for 2019, 2018, 2017, and 2016 inventory years, respectively. This results in an average 3.14% annual growth rate; substantially above the 2.43% reported for South Dakota from the 2019 BHNF augmented data set, and the 2.5% being

[6] Timberland as used here follows the FIA definition of timberland: Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.) See: https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary/default.asp

used in the in-progress Graham (2020) study. If the growth estimate is pro-rated for growth observed on BHNF Wyoming lands, it increases to 3.24%.

- A gross annual growth rate of 3% is much more defensible as a long-term growth estimate than the 2.5% that was computed using the 2019 augmented data set. The 3% growth rate is grounded on multiple recent observations and mitigates the effects of incorrect acreage estimation in the 2019 augmented data. In addition, gross annual growth estimates derived from 2019 on-line FIA data, using ratio estimates based on an acreage that aligns with the NEPA-approved suitable base acres, is 3.04%. These estimates of 3% and 3.04% annual growth are for South Dakota acres only; also, the augmented data set, even with its deficiencies, indicates gross annual growth is higher on Wyoming suitable base acres than on South Dakota acres, which means a 3% growth rate is likely conservative.
- Although the FIA-reported timber inventory and total gross growth may change to some extent from mountain pine beetle mortality and other disturbances, the long-term gross growth, as a percent of standing inventory, is unlikely to waver substantially compared to FIA records from the previous 10 years. On average, the annual gross growth for the previous 10 years was 2.98%.
- Forest growth simulations conducted using the USFS Forest Vegetation Simulator (FVS) showed annual mortality rates for suitable base timberlands of 0.23%; less than a quarter of the value used by Graham et al. (2020).
- The FIA database flag that indicates whether an FIA plot is contained within the BHNF suitable base acres is being incorrectly applied to the entire cluster of four subplots that comprise an FIA sample point, rather than to each individual subplot. This is at odds with how the timberland flag, accessibility flag, reserved status flag, and growth potential flag are applied – all of which are assigned at the subplot level. Classifying all subplots as a group to either the suitable or non-suitable category could cause significant inaccuracies in acreage and volume estimation. There is no USFS documentation available that details how a cluster of four plots is assigned its suitability flag (by the center of the four-plot cluster?, by the majority of the sub-plot locations?, by some other means?), nor is there any justification for why this flag should be assigned differently than the timberlands flag, at the subplot level.
- Analyzing the sawlog percent volume defect by tree DBH class in the 2017-2019 BHNF augmented FIA database showed that the 29+” DBH class for ponderosa pine, and **<u>every</u>** DBH class for white spruce had the identical defect percentage value of 11.78%. We can find no USFS documentation explaining why this fixed defect value is being applied, or how it was derived.

In summary, as outlined above, there are numerous unresolved concerns on the accuracy of the 2017-2019 BHNF augmented FIA inventory.

Resolving these issues will require the constructive engagement of USFS at both the BHNF and FIA levels. That is something which (with certain notable exceptions) has not been forthcoming to date.

2.0 Introduction/Background

The Black Hills National Forest (BHNF) experienced a mountain pine beetle epidemic that began building in the early 2000s, peaked around 2014, and has been declining since – dropping to normal endemic population levels in 2016 (Meneguzzo and Paulson 2019, BHFRA[7]).

Impacts from the epidemic will influence forest conditions for many years to come. Periodic forest inventories can help quantify changing forest conditions following the epidemic.

The US Forest Service (USFS) maintains a system of permanent forest inventory plots across the US, under the Forest Inventory and Analysis (FIA) program. This system "collects, analyzes, and reports information on the status, trends, and condition of America's forests" at a strategic or landscape level.

On January 27, 2020 the BHNF released a custom database of FIA forest inventory sample data, along with summary tables and statistics for the 2017-2019 inventory cycle.[8] This custom database (the "augmented dataset") included plot measurement data from traditional FIA permanent inventory plots, and a system of temporary inventory plots installed during the 2017-2019 period intended to better assess forest conditions following the mountain pine beetle epidemic.

This report documents the results of a study undertaken to review the reported inventory statistics for the 2017-2019 BHNF augmented FIA inventory dataset, and compare those results with estimates from prior BHNF FIA inventories. In addition, growth rates computed from the various BHNF inventories were compared with growth rates derived from independent forest growth simulations, and with growth rates utilized in an in-progress USFS report on BHNF timber growth and yield (Graham et al., 2020).

[7] Black Hills Forest Resource Association, personal communications
[8] The FIA data was supplied by the BHNF, from the following site, as detailed in a January 27, 2020 email from Andrew Johnson, acting BHNF forest supervisor: https://usfs-public.box.com/v/BlackHillsFIAData

3.0 Methods/Results

3.1 Study area and associated inventory data

The Black Hills National Forest of western South Dakota and northeastern Wyoming encompasses roughly 1.2 million acres[9] of predominantly ponderosa pine forest types.

Forest conditions on the BHNF are monitored, in part, by the USFS Forest Inventory and Analysis (FIA) program, which provides forest inventory information at the strategic or landscape level.

The sampling intensity for FIA's base inventory estimation is roughly one field sample site for every 6,000 acres. Plots are initially allocated across the landscape using a systematic base grid (Bechtold and Patterson, 2005). Inventory data collection and processing have been administered by two FIA units: the portion of the BHNF in South Dakota by the Northern Regional Office and the portion of the BHNF in Wyoming by the Interior West Regional Office.

Until 2014 plots were remeasured every five years on the South Dakota portion of BHNF, and every 10 years on the Wyoming portion. The decision was made by the Northern office to transition toward a seven year remeasurement cycle, with 2014 to 2016 being measured on a six-year cycle *en route* to implementation of the seven-year cycle by 2017 (see Figure 4).

Each plot is typically remeasured once per cycle, with approximately equal proportion of the total plots being remeasured in any given year, and in a random fashion. Thus, each "panel" of plots remeasured in a single year is ostensibly a random sample that should accurately reflect forest conditions. However, because each panel is only a portion of the total number of samples required to attain desired levels of precision, the estimate of a single panel is imprecise, that is to say the confidence intervals around the estimates are large.

Because of the shorter remeasurement cycle length the Northern Region has been publishing gross annual growth, annual mortality, and net annual growth estimates for the time period 2006 to the present. The Interior West Region, because it had not yet completed a 10-year cycle had not yet published gross annual growth, annual mortality, and net annual growth on the Wyoming portion of BHNF.

In an attempt to better estimate impacts of the mountain pine beetle epidemic on forest resources, the BHNF implemented an intensified sampling process between 2017 and 2019, incorporating two modifications to the base FIA sampling:

1. Augment the 226 existing FIA permanent sample plots with an additional 213 temporary plots.
2. Speed up the remeasurement of existing permanent sample plots by reducing the plot remeasurement period to three years (2017-2019).

[9] 1,242,713 acres as reported in the BHNF Land and Resource Management Plan Phase II Amendment.

Figure 1 shows the distribution of the 158 permanent FIA sample plots that fall on suitable timberlands[10] within the BHNF. The plot distribution exhibits the expected grid-like appearance, as per the base sample design guidelines outlined by Bechtold and Patterson (2005).

Figure 2 shows the distribution of the 136 temporary plots on the suitable base acres that were installed during the period 2017-2019 on the BHNF. The distribution of sample plots across the landscape lacks the grid-based appearance of the plots in Figure 1. We have been unable to verify with the USFS what methodology was used to allocate the temporary plots, and therefore are unable to evaluate any potential bias in plot allocation.

In addition to the 2017-2019 BHNF augmented FIA inventory dataset, we also made substantial use of past state-level FIA inventory data available on the FIA website. This data provided some analysis options unavailable in the augmented database, and also allowed comparison of current inventory results with prior inventories.

[10] Suitable timberlands combines the terms "suitable base" and "timberlands" where timberlands are forested acres which are biologically capable of producing industrial wood, are accessible and economically harvestable, and which have not been excluded from timber production due to other management objectives; and suitable base is a geographic area defined in the BHNF Forest Plan to identify lands suited for timber production, based on several criteria including economics. As per Appendix G (Timber Suitability) of the BHNF Black Hills National Forest Land and Resource Management Plan, Phase II Amendment, "The suitability determination is used in developing the allowable sale quantity. It does not imply that timber harvest will be limited to these lands" (emphasis added).

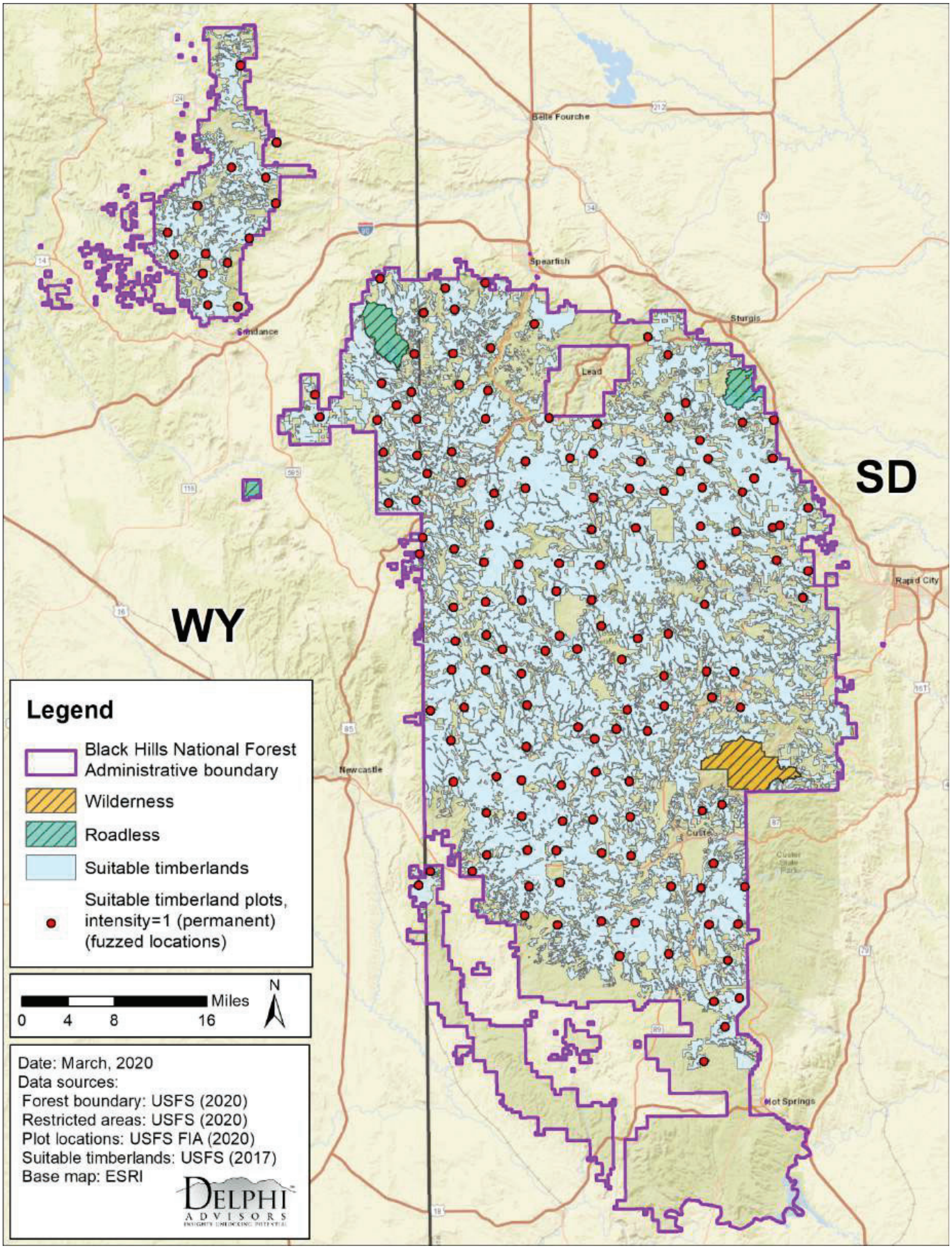


Figure 1. Map of FIA plot locations for permanent (intensity=1) sample plots, on suitable timberland acres, Black Hills National Forest.

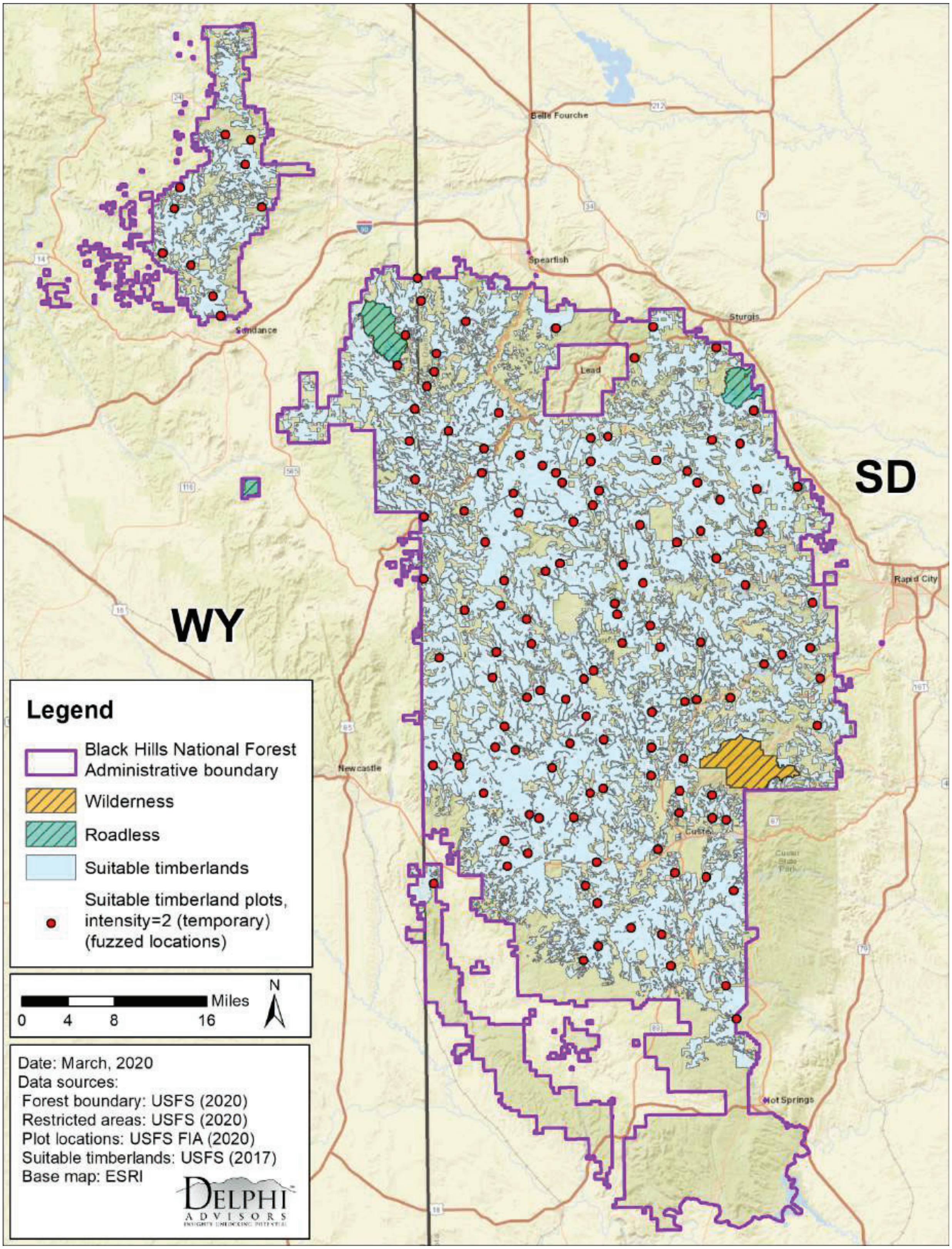


Figure 2. Map of FIA plot locations for temporary (intensity=2) sample plots, on suitable timberland acres, Black Hills National Forest.

3.2 Review of the BHNF augmented FIA inventory dataset

3.2.1 Accuracy and precision

It is important to note that within the following discussions, we use the terms "accuracy" and "precision" in their strict statistical meaning. Those meanings, along with the related statistical term "confidence interval," are defined as follows:

- Accuracy: the degree to which the sample data correctly reflects the phenomenon or population (BHNF timber inventory in the current application) it was designed to measure; or the closeness of the sample result to the "true" value.
- Precision: a measure of statistical variability or the degree to which repeated measurements show the same results.
- Confidence interval: a confidence interval is used to describe the amount of uncertainty associated with a given sample estimate. It defines a range of values we have the specified degree of confidence that the true value lies in. For example, if we estimated the acreage of a certain forest type as being 1,000 acres, a 95% confidence interval could be 950 – 1,050 (indicating a relatively high level of certainty in the estimate), or it could be 500 – 1,500 (indicating a relatively low level of certainty in the sample estimate). The confidence interval is computed from the sample statistics, based on the desired level of confidence (99%, 95%, 68%, etc.).

Using the above definitions, it is the goal of every statistical survey to generate results that are both accurate and precise. But it is possible to have a statistical survey that can be said to be either accurate, or precise, or both, or neither, as shown in Figure 3. A larger sample size does not guarantee increased sample accuracy, although it will typically increase sample precision.

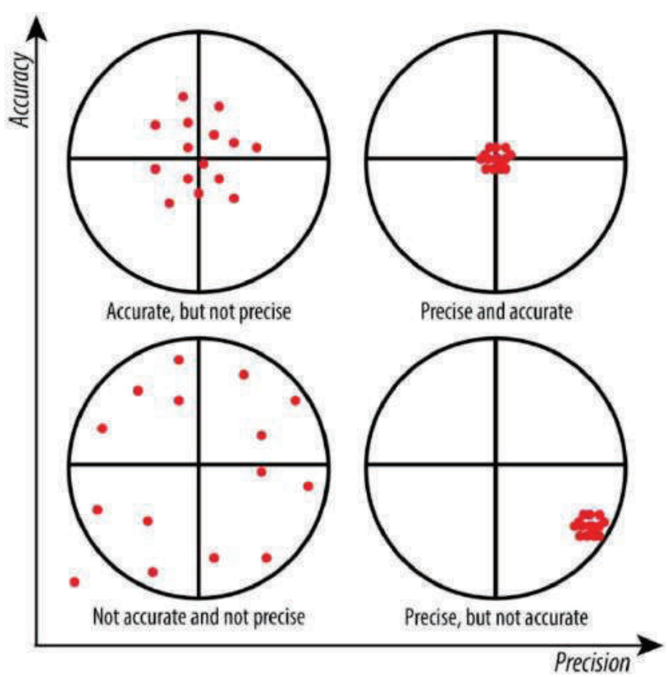


Figure 3. Statistical accuracy and precision.

In the following discussions, we have attempted to evaluate both the accuracy and the precision of the BHNF FIA inventory data, as well as the trends in sample accuracy/precision over time. To do so, we have reviewed both the data provided in the BHNF augmented FIA dataset, and historical FIA data available through the USFS web-based Evalidator program.

3.2.2 FIA inventory cycles

When looking at FIA inventory trends over time, one needs to be aware that the way in which the BHNF FIA sample plots are measured and combined into an inventory estimate has changed several times over the last 10 years. As discussed previously, the FIA plot measurement schedule that has been used most frequently in South Dakota is based on a five-year measurement cycle, in which one-fifth of the total inventory plots are measured within any given year. The inventory estimate for any given year is then derived by combining plots from each of these individual measurement years ("panels") into a composite estimate.

As previously noted for the BHNF, the FIA plot remeasurement cycle for South Dakota acreage has changed over the past 10 years, starting with a five-year cycle in years 2010-2013; changing to a six-year cycle in years 2014-2016; a seven-year cycle in years 2017-2018; and effectively a three-year cycle in year 2019 for the augmented inventory.[11]

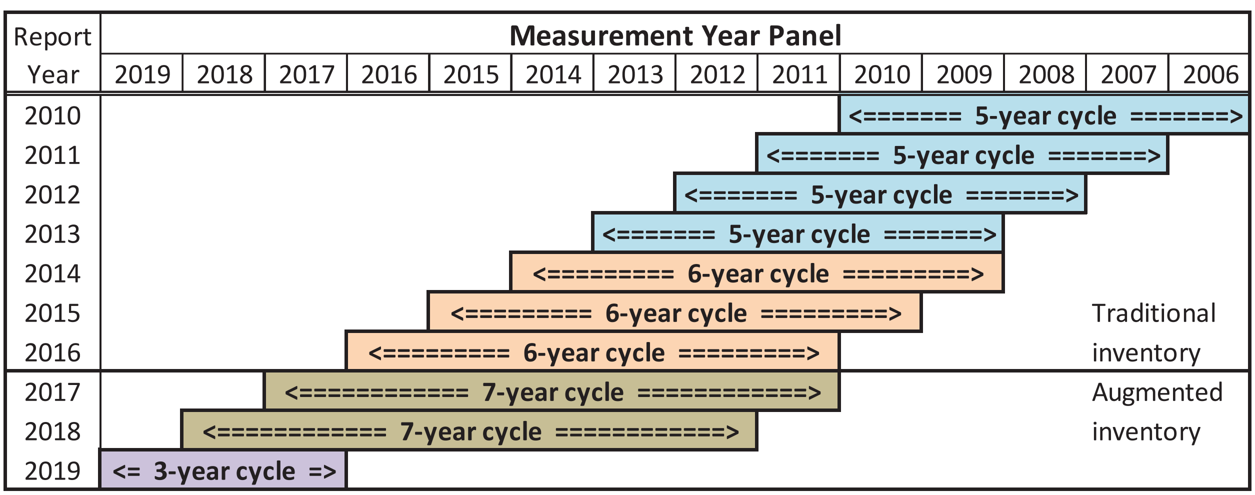


Figure 4. Plot remeasurement cycle by FIA inventory reporting year (BHNF South Dakota plots).

[11] Based on the recent FIA data by state, FIA loaded South Dakota's 2019 data for the entire state on 3/30/2020. The online South Dakota data for 2019 remains on a seven-year remeasurement cycle. It appears the permanent plots remeasured on BHNF as part of this effort included in the online data set are ONLY those permanent plots that originally were scheduled to be remeasured under the seven-year remeasurement cycle. Online (vs. Augmented data set) FIA Evalidator (see footnote 12) queries for the BHNF only still include inventory data from past data collection efforts consistent with a seven-year remeasurement cycle.

3.2.3 *Plot counts and descriptive statistics for the BHNF augmented inventory dataset*

As discussed in section 3.1, additional temporary plots were added to the existing BHNF FIA permanent plot system during the 2017-2019 period in an attempt to improve the resolution of forest inventory estimates.

While the added plots were located in both South Dakota and Wyoming portions of the BHNF, the installation schedule varied between the two regional FIA offices. The Northern Unit (responsible for South Dakota plots) remeasured permanent plots previously scheduled to be remeasured in 2017-2019 under the revised seven-year remeasurement cycle schedule. In addition, all temporary plots were installed in 2017 and 2018. All permanent plots that were not scheduled to be remeasured in 2019 and had not been remeasured in 2017 or 2018 under the new seven-year-cycle plan were also remeasured in 2019. Thus, all permanent plots within the BHNF in South Dakota were remeasured during the period 2017-2019, in addition to installing all temporary plots in 2017 and 2018.

Evalidator[12] queries report 181 non-zero permanent plots and 167 non-zero temporary plots for a total of 348 plots measured on BHNF's South Dakota forest land from 2017 to 2019. In the case of the suitable base acres there are 131 non-zero permanent plots and 110 non-zero temporary plots reported in Evalidator queries. Plot allocations by forest land, timberland, and suitable base acres are detailed in Tables 1 (for 2017-2020 inventory panel years) and 2 (for 2011-2016 inventory panel years).

In the case of Wyoming, as in South Dakota, all permanent plots were remeasured during the 2017-2019[13] field seasons. In contrast to South Dakota, no temporary plots were measured during the 2017 field season (in South Dakota no temporary plots were measured during the 2019 field season).

Evalidator queries report 33 non-zero permanent plots remeasured and 11 non-zero temporary plots measured on BHNF's Wyoming forest land during the 2017-2019 field seasons. In addition, the Evalidator queries report a total of 15 temporary[14] plots assigned to inventory panels 2011 to 2016 on BHNF's Wyoming forest land; why temporary plots are reported for inventory panels 2011 to 2016 is unclear, as one would have expected these plots to be the standard FIA permanent plots. In sum, there is a total of 59 plots on Wyoming forest land in the augmented data set. In the case of suitable base acres, there are 25 permanent non-zero plots and 15 temporary non-zero plots, five of which are reported on 2017-2020 inventory panels and 10

[12] Evalidator is the name of FIA's database query software, which allows the user to query an FIA database for a wide range of inventory statistics. The Evalidator program can be run against the BHNF augmented dataset, as well as against prior state-level inventory databases, which are maintained on the FIA website.
[13] As can be seen in Table 1, there are some plots for Wyoming that are reported as being on the 2020 data panel. These data were reported in early 2020 so it is doubtful they were collected and processed in 2020, and most likely represent 2019 data.
[14] The data field PLOT.INTENSITY = 2 for these particular plots in the dataset.

reported on 2011-2016 inventory panels. Plot allocations by forest land, timberland, and suitable base acres are detailed in Tables 1 and 2.

The 110 temporary non-zero suitable base plots in South Dakota and the 25 temporary non-zero suitable base plots in Wyoming, totaling 135 plots, reconcile to the 136 temporary plots noted above and in Figure 2, indicating there was a single “zero” plot among the 136 temporary plots installed. Similarly, Table 1 reports a total of 156 non-zero permanent plots on suitable base acres in the 2019 augmented dataset, indicating there were two “zero” plots among the 158 plots referenced above and depicted in Figure 1.

The 2017-2019 BHNF augmented FIA inventory includes a number of unique factors that add complexity to its collection and computation. These complexities include:

- The South Dakota inventory process was already undergoing a transition from a five-year to a seven-year cycle which was then re-adjusted yet again to remeasure all permanent plots in three years;
- The Wyoming inventory data had not been used to compute growth or mortality statistics due to the Interior West region operating on a 10-year remeasurement cycle;
- Administration and implementation of the accelerated and augmented data collection by two regional offices to forge a single inventory for BHNF;
- Because of accelerated permanent plot remeasurement there are necessarily varying growth periods by plot. This carries implications for field data (single-year weather anomalies such as very dry or very wet growing seasons can affect growth and/or mortality more than remeasurements averaged over longer growing periods), field measurement accuracy (small measurement errors are amplified across more years), as well as calculations if varying growth periods by plot are not handled appropriately.

In our expert experience, added complexity provides fertile ground for inadvertent missteps to occur.

Table 1. Distribution of acres and plots in 2019 BHNF augmented FIA dataset for forest land, timberland, and suitable base acres on BHNF's South Dakota and Wyoming landbase, by 2017 to 2020 inventory panel year.

Distribution of Acres and Non-Zero Plots by Plot Type and Inventory Panel for Augmented 2019 Inventory

Inventory Panel Unless Otherwise Specified	Metric	Plot Type	Forest Land			Timberland			Suitable Base		
			Total	South Dakota	Wyoming	Total	South Dakota	Wyoming	Total	South Dakota	Wyoming
2019 - Inventory Year (Sum of All Inventory Panels)	Acres	Total	1,106,558	943,314	163,244	1,062,775	905,284	157,491	765,732	653,753	111,979
		Permanent [1]	575,848	482,390	93,458	557,632	466,914	90,718	421,367	350,467	70,900
		Temporary [2]	530,710	460,924	69,786	505,143	438,370	66,773	344,365	303,286	41,079
	Non-Zero Plots	Total	407	348	59	391	334	57	281	241	40
		Permanent [1]	214	181	33	207	175	32	156	131	25
		Temporary [2]	193	167	26	184	159	25	125	110	15
2017 to 2020 are Years when Intensified/Accelerated Plot Collection											
2020	Acres	Total	20,749	-	20,749	20,749	-	20,749	14,724	-	14,724
		Permanent [1]	12,256	-	12,256	12,256	-	12,256	9,244	-	9,244
		Temporary [2]	8,493	-	8,493	8,493	-	8,493	5,480	-	5,480
	Non-Zero Plots	Total	7	-	7	7	-	7	5	-	5
		Permanent [1]	4	-	4	4	-	4	3	-	3
		Temporary [2]	3	-	3	3	-	3	2	-	2
2019	Acres	Total	434,592	370,164	64,428	419,388	357,700	61,688	313,665	268,006	45,659
		Permanent [1]	429,857	370,164	59,693	414,653	357,700	56,953	311,165	268,006	43,159
		Temporary [2]	4,735	-	4,735	4,735	-	4,735	2,500	-	2,500
	Non-Zero Plots	Total	160	137	23	154	132	22	115	99	16
		Permanent [1]	158	137	21	152	132	20	114	99	15
		Temporary [2]	2	-	2	2	-	2	1	-	1
2018	Acres	Total	323,440	307,504	15,936	301,046	285,110	15,936	206,440	192,739	13,701
		Permanent [1]	64,243	56,022	8,221	61,231	53,010	8,221	44,934	36,713	8,221
		Temporary [2]	259,197	251,482	7,715	239,815	232,100	7,715	161,506	156,026	5,480
	Non-Zero Plots	Total	120	114	6	112	106	6	76	71	5
		Permanent [1]	26	23	3	25	22	3	18	15	3
		Temporary [2]	94	91	3	87	84	3	58	56	2
2017	Acres	Total	285,247	265,646	19,601	281,322	262,474	18,848	203,284	193,008	10,276
		Permanent [1]	69,492	56,204	13,288	69,492	56,204	13,288	56,024	45,748	10,276
		Temporary [2]	215,755	209,442	6,313	211,830	206,270	5,560	147,260	147,260	-
	Non-Zero Plots	Total	105	97	8	103	96	7	75	71	4
		Permanent [1]	26	21	5	26	21	5	21	17	4
		Temporary [2]	79	76	3	77	75	2	54	54	-

Table continued on next page

[1]Data field PLOT.INTENSITY = 1

[2]Data field PLOT.INTENSITY = 2

Table 2. Distribution of acres and plots in 2019 BHNF augmented FIA dataset for forest land, timberland, and suitable base acres on BHNF's South Dakota and Wyoming landbase, by 2011 to 2016 inventory panel year.

Distribution of Acres and Non-Zero Plots by Plot Type and Inventory Panel for Augmented 2019 Inventory

Table continued from prior page

Inventory Panel Unless Otherwise Specified	Metric	Plot Type	Forest Land			Timberland			Suitable Base		
			Total	South Dakota	Wyoming	Total	South Dakota	Wyoming	Total	South Dakota	Wyoming
2011 to 2016 Data still included in the 2019 Augmented Inventory											
2016	Acres	Total	6,776	-	6,776	4,516	-	4,516	3,763	-	3,763
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	6,776		6,776	4,516	-	4,516	3,763		3,763
	Non-Zero Plots	Total	2	-	2	2	-	2	1	-	1
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	2	-	2	2	-	2	1		1
2015	Acres	Total	8,739	-	8,739	8,739	-	8,739	6,504	-	6,504
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	8,739	-	8,739	8,739	-	8,739	6,504		6,504
	Non-Zero Plots	Total	3	-	3	3	-	3	2	-	2
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	3	-	3	3	-	3	2	-	2
2014	Acres	Total	6,037	-	6,037	6,037	-	6,037	2,712	-	2,712
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	6,037	-	6,037	6,037	-	6,037	2,712	-	2,712
	Non-Zero Plots	Total	2	-	2	2	-	2	1	-	1
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	2	-	2	2	-	2	1	-	1
2013	Acres	Total	7,378	-	7,378	7,378	-	7,378	4,365	-	4,365
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	7,378	-	7,378	7,378	-	7,378	4,365	-	4,365
	Non-Zero Plots	Total	3	-	3	3	-	3	2	-	2
		Permanent	-	-	-	-	-	-	-	-	-
		Temporary	3	-	3	3	-	3	2	-	2
2012	Acres	Total	8,120	-	8,120	8,120	-	8,120	4,795	-	4,795
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	8,120	-	8,120	8,120	-	8,120	4,795	-	4,795
	Non-Zero Plots	Total	3	-	3	3	-	3	2	-	2
		Permanent	-	-	-	-	-	-	-	-	-
		Temporary	3	-	3	3	-	3	2	-	2
2011	Acres	Total	5,480	-	5,480	5,480	-	5,480	5,480	-	5,480
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	5,480	-	5,480	5,480	-	5,480	5,480	-	5,480
	Non-Zero Plots	Total	2	-	2	2	-	2	2	-	2
		Permanent [1]	-	-	-	-	-	-	-	-	-
		Temporary [2]	2	-	2	2	-	2	2	-	2

[1]Data field PLOT.INTENSITY = 1

[2]Data field PLOT.INTENSITY = 2

3.2.4 Acreage trends, concerns, and FIA responses

When comparing results from the historical FIA inventory results with the 2017-2019 augmented inventory, there was a distinct downtrend in forest inventory that coincided with the introduction of the temporary inventory plots in 2017. This downward inventory trend is most clearly examined with reference to the sample estimate for suitable timberland acres, because we know **with certainty** what the suitable timberland acres are, and therefore have a known basis for evaluating the accuracy of the associated FIA inventory estimate.

Figure 5 shows the decrease in estimated BHNF suitable timberland acres, for the FIA inventory years 2016-2019. During that period, the estimate of suitable timberland acres decreased from 858,420 in 2016, to 765,733 in 2019; a reduction of 92,687 acres (10.8%). The 765,733 acre estimate compares with **known** values of 837,000 acres in a 2019 USFS GIS shapefile,[15] and 865,890 acres in the BHNF Forest Plan Phase II Amendment.

Moreover, the 2017-2019 augmented inventory statistics imply there is high certainty in the suitable timberland acreage estimate; with the 95% confidence interval being 752,639 - 778,827 acres, even though that estimate **does not** include the known suitable timberlands acres value of 837,000. In fact, there is only a one ten-thousandth of a percent probability (i.e., one-in-a-million chance) that the FIA estimate of 765,733 acres of suitable timberland acres and the known suitable timberland acreage of 837,000 represent the same population, as shown in Table 3. Stated another way, were the 2017-2019 sampling repeated one million times, there would likely be only a single inventory resulting in the current estimate of 765,733 acres, or less, of suitable timberlands.

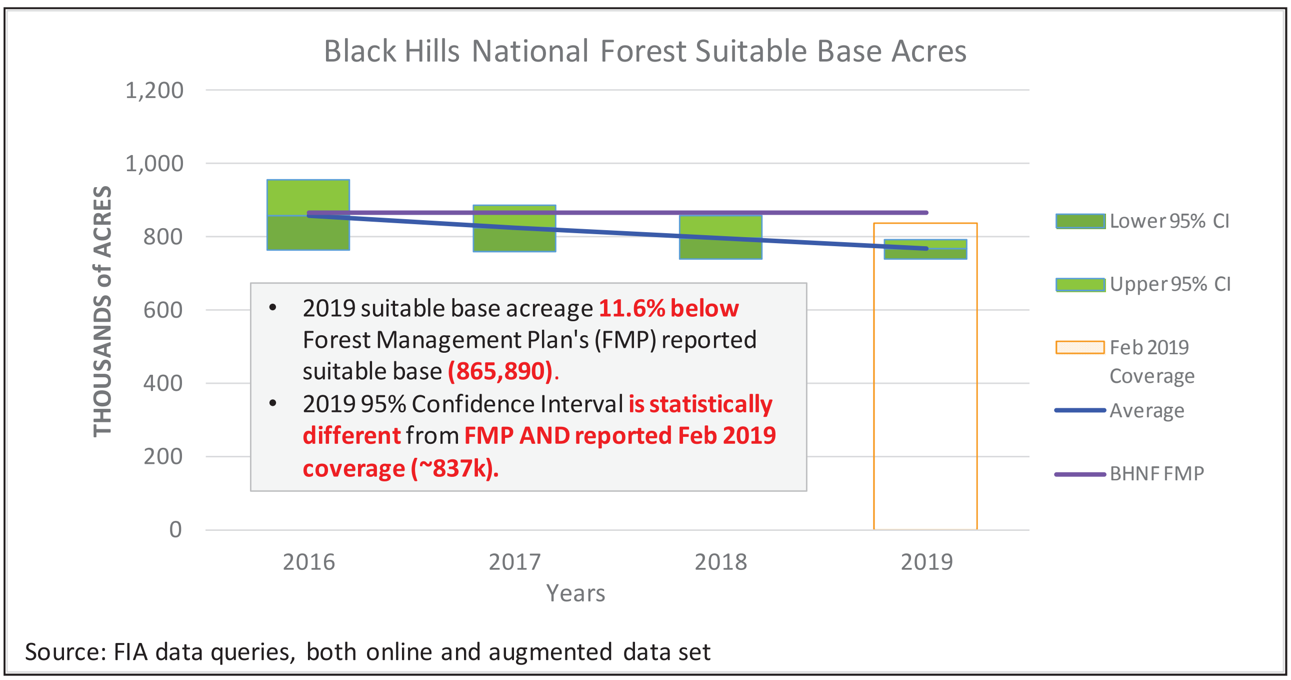


Figure 5. Reduction in estimated suitable timberland acres, inventory years 2016-2019.

15 March 11, 2020 email correspondence from Chuck Barnett, Biological Scientist, USFS FIA program, Durham, NH

Table 3. Computed confidence limits, at various confidence levels, for the FIA suitable timberland acreage estimate.

Confidence level	Probability*	T- Statistic	Suitable acres estimate	Standard error percent	Confidence limits	
					Lower	Upper
68%	32%	1.00	765,733	1.71%	752,617	778,849
90%	10%	1.65	765,733	1.71%	744,124	787,342
95%	5%	1.97	765,733	1.71%	739,958	791,508
99%	1%	2.59	765,733	1.71%	731,774	799,692
99.9%	0.1%	3.33	765,733	1.71%	722,187	809,279
99.99%	0.01%	3.95	765,733	1.71%	714,046	817,420
99.999%	0.001%	4.50	765,733	1.71%	706,818	824,648
99.9999%	0.0001%	5.00	765,733	1.71%	700,228	831,238
99.99999%	0.00001%	5.47	765,733	1.71%	694,113	837,353
99.999999%	0.000001%	5.91	765,733	1.71%	688,367	843,099

*Probability that the FIA estimate of 765,733 acres of BHNF suitable timberlands, and the known acreage of 837,000 BHNF suitable timberlands are describing the same population.

Figure 6 provides an alternate view of the acreage decrease reported by the 2017-2019 BHNF augmented FIA inventory, a drop of over 10% in the estimated South Dakota suitable timberland acres, even though actual acres remained essentially constant during that period; i.e., we are unaware of any sizable land exchanges or sales that would have dramatically reduced the suitable base acreage. Further, the acreage loss is not limited to just the suitable base acreage, as Figure 6 shows; in fact, all three categories (forest land, timberland, and suitable base) report acreage losses beginning in 2017. This suggests to us there is something awry with plot expansion factors being employed since the introduction of temporary plot remeasurements. However, for South Dakota there were no additional temporary plots re-measured in 2019 yet the acreage continued to drop; so there may be another and/or other factors affecting these estimates as well.

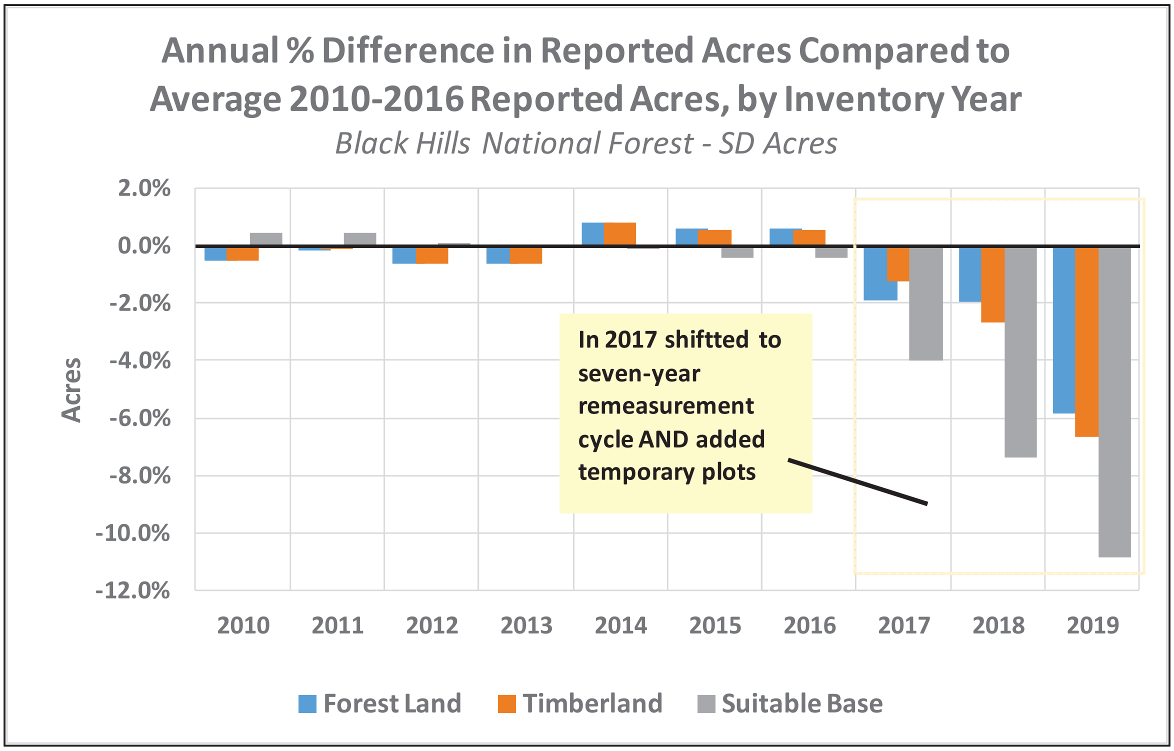


Figure 6. Percent difference in FIA estimated forest acres compared to average 2010-2016 reported South Dakota acres, by inventory year.

In comparison, the 2016 inventory (prior to the introduction of the temporary inventory plots and accelerated permanent plot remeasurement), produced an estimate for BHNF suitable timberland acres of 858,420 versus a value of 846,042 acres in a 2017 USFS GIS shapefile.

The decreasing acreage estimates in the 2017, 2018, and 2019 inventory results are particularly concerning because the FIA reported acres stayed constant in the seven years before 2017. Additionally, from the associated GIS-based map, we know with certainty the actual number of suitable timberland acres. Acreages are the easiest parameter to estimate (they do not grow, die, or reproduce like the tree-based volume estimates); so if the inventory cannot accurately estimate acres, we cannot have any confidence that the volume inventory or growth estimates are valid. A 10% difference in acreage estimates could easily translate into a much higher error for inventory estimates.

We have reached out to the USFS FIA support staff, sharing concerns about the observed downward trend in estimated acreage, as shown in Appendix A. USFS responses are shown in Appendix B. The USFS response ignored the concerns we raised; it instead questioned our comparison of on-line FIA data analysis against the augmented BHNF FIA dataset, and our use of specific plot numbers to limit analysis to the suitable timberland base. The following quote (extracted from the full response in Appendix B) is illustrative of the USFS response:

> "3. Trying to use the plot numbers from the BHNF study in the online version of EVALIDator could yield inaccurate results by using a subset of data that may not be representative of the data collected specifically for the BHNF."
>
> "4. I think it is unwise to try to compare estimates from the BHNF version of EVALIDator with estimates from the public data. While related, the BHNF dataset represents an augmented sample, with different adjustment factors and evaluations."

With regard to response 3, we have replaced the plot numbers used to identify suitable timberland plots with the Plot_CN identifiers, as suggested by FIA staff (to ensure there is no potential for duplicate plot numbers); the revised plot selection logic resulted in no material change to the analysis.[16]

Response 4 implies that even though the USFS assumedly stands by the accuracy of both their online FIA data and the BHNF augmented FIA dataset, we should not be comparing the results of the two inventory sources. On the contrary, we believe that comparing estimates from the two inventory sources provides valuable insights on inventory trends and accuracy that are unattainable by any other means. We feel ignoring such historical data would be unwise. As an aside, we note the draft GTR report[17] is also comparing augmented data findings to historical data.

A follow-up email was sent to the FIA staff (see Appendix C), resulting in a similar reply from the USFS (see Appendix D) with responses of limited value. For example, in response to a request for "specific information on how the temporary plots were allocated in the case of the BHNF plot intensification program," the USFS response provides no information on how the additional plot locations were specifically allocated to the ground. Instead, it provides vague overviews and statements such as "The process was a little different for WY since the plot-visit histories are different. However, the sample was verified." Responses such as these to valid scientific questions provide no useful information, and only serve to cast doubt on the objectivity and sincerity of USFS claimed interest to involve stakeholders in public resource decisions.

Also, in the second FIA response, the USFS has claimed the inaccurate estimate of suitable base acres is "due to terminology" (see Appendix D), and that not all BHNF suitable base acres are timberlands by the FIA definition. This in no way explains why the suitable base acreage estimate has dropped precipitously since the initiation of the augmented sampling in 2017 (see Figure 6), while the suitable base acres have remained essentially static. This claim goes against the discussion of suitable base acreage derivation provided in Appendix G of the BHNF Forest

[16] This suggestion came during a phone conversation with FIA staff. Suitable base plot numbers, and their corresponding Plot_CN identifiers were derived from the PlotGeom table (bhnf_suitable_land variable) in the BHNF augmented FIA data set. Using Plot_CN identifiers as a filter for Evalidator queries reliably reproduced results in the augmented dataset identical to using suitable base plot numbers retrieved from the PlotGeom table (for records with bhnf_suitable_land=Y). Results presented in this report from online FIA Evalidator queries on the suitable base timberland acres were all generated using the Plot_CN identifiers in combination with forest admin code for Black Hills National Forest (eliminating any extraneous non-USFS ownership acres) and on timberlands only (eliminated any low site productivity acres and/or any reserved acres).

[17] Timber Growth and Yield in the Black Hills National Forest: A Changing Forest. Draft 1, March 2020. Russell T. Graham, Mike A. Battaglia, Theresa B. Jain.

Plan. **Furthermore, if there is indeed a substantial proportion of the BHNF suitable base acres that are not timberlands (by the FIA definition), then it must follow that none of the inventory statistics provided to the public via the January 27, 2020 email from Andrew Johnson, acting BHNF forest supervisor, accurately represent the suitable base described in the BHNF Forest Plan, and upon which the ASQ is based.**

Two responses provided by FIA in the April 9, 2020 communication (Appendix D) are particularly noteworthy. Chuck Barnett, a member of the FIA staff, states (bold emphasis added and not in original):

> "Point 2: I disagree with the premise the estimates of area have declined over time without an explanation. Our estimates of forest land and timberland in both the public data and the special study **have remained consistent (within sampling error)**, given the changes in sampling intensity.
>
> "Point 3: When I stated **we were seeing consistent results from each of the datasets my contention was that we were seeing consistent results when looking at each of the datasets by themselves**. While the estimates pertain to the same area and each dataset has data in common, the plots are combined into evaluations independently. For the same plot, estimation unit assignments, expansion factors, and adjustment factors are different. If you compare the POP_STRATUM data applied to the same plot in the respective databases you will see these differences."

Taken together we infer from these responses the FIA deems successive inventories sampling the same population as being "consistent" if their confidence intervals overlap with one another (i.e., there is no statistical difference between them). This is a logical and evidence-based test and as can be seen in Figure 5, this is indeed the case for suitable base acres.

However, in this specific circumstance, as has been pointed out earlier, we **know** what the acreage base is based on GIS coverage. So, in this instance it would seem a more relevant test is not if successive confidence intervals overlap with one another but whether or not the confidence interval actually includes the known population metric. This is, after all, the purpose of a statistical confidence interval: to provide a quantitative statement regarding the probability of how near a sample estimate is to the true population metric. Since the sampled suitable base acres have monotonically declined since 2017, even though successive confidence intervals between samples overlap, the 2019 augmented dataset estimate of suitable base acres is statistically different from the known suitable base acreage for any practical level of statistical probability.

The concept of what comprises the BHNF "suitable base" of forest acres suitable for timber production is fundamental to all inventory, growth and yield calculations, and yet it appears the concept cannot be accurately defined by the USFS in the current application to FIA inventory data. Suitable base acres are set by the Forest Plan, form the basis for ASQ, and cannot be arbitrarily redefined. And yet we see the suitable base acreage value ranging from 865,890 in the Forest Plan, to 837,000 acres in a 2019 USFS GIS shapefile, to "about 836,000 acres" – while the acreage estimate of suitable timberlands, derived from the 2017-2019 BHNF augmented FIA database, and implied as the basis for setting BHNF ASQ, is 765,733.

In addition, there seems to be no consensus within the USFS as to who is responsible for the estimate of suitable base as estimated by FIA inventory data. While BHNF staff and the in-progress Graham et al publication rely on the FIA inventory data ("The intensified 2019 FIA sampling scheme for the BHNF provided robust and high quality data."), the FIA unit specifically distances itself from the estimation of suitable base acres, stating that:[18]

- "I cannot comment on the value of the area of suitable land on the Black Hills National Forest (BHNF)",
- "Note: suitability is not an attribute we use in the base FIA program.", and,
- With reference to changing suitable base acreages: "I believe the BHNF has addressed this issue with an area budget."

It is of concern to us that this fundamental parameter cannot be accurately defined or estimated, and is not integrated into the FIA system in a consistent or statistically valid manner when compared to timberland delineation (as discussed in section 3.4.3).

Taking a cursory review of the FIA acreage estimates by slope and distance to roads (as surrogate variables for commercial operability) indicates a substantial acreage of timberlands not currently classified as being within the suitable base, as shown in the green-highlighted cells of Table 4.[19] While it is possible these acres fall outside the suitable base because of other considerations (unstable soils, late successional status, etc.), it is also possible they are being incorrectly excluded from the suitable base because the current FIA analysis treats the suitable base flag in a statistically incorrect/inconsistent manner as being an attribute assigned to an entire plot cluster rather than to an individual plots (as discussed in section 3.4.3). Table 5 summarizes the acres identified as potentially being suitable base, from Table 4, and illustrates that even after removing acres associated with hardwood and juniper forest type, substantial acres remain as potential additions to the suitable base.

It is our hope that some kind of constructive dialog could be established with BHNF and FIA staff concerning the critical question of deriving defensible estimates of suitable base acres and inventory from the existing FIA inventory data.

[18] See Appendices B and D.
[19] In addition to possible misclassifications, recall that these acreages (which are not included in the suitable base but are classified as timberland by FIA) are the result of what we believe to be an incorrect plot expansion process. If true, it is probable these acreages are an underestimate of timberland by slope and distance form road that are not currently included in the suitable base acreage. Refer to Figure 6 showing acreage losses were not in suitable base alone but also in timberland and forest land.

Table 4. Distribution of timberland versus suitable base acres by slope and distance to road.

Distribution of BHNF Timberland and Suitable Base Acres by Distance from Road, Slope, and Forest Type

		PERCENT SLOPE CATEGORY					
		0-20 percent	21-40 percent	41-60 percent	61-80 percent	81-100 percent	TOTAL ACRES
		ACRES					
TIMBERLAND ACRES	**TOTAL by DISTANCE to ROAD**	579,894	320,498	121,886	40,406	93	1,062,776
	100 ft or less	45,800	13,833	1,737	-	-	61,370
	101-300 ft	65,004	21,665	2,348	9,089	-	98,105
	301-500 ft	70,181	34,767	8,080	-	-	113,028
	501-1000 ft	120,950	36,199	23,307	11,725	93	192,274
	1001 ft to 1/2 mile	140,935	101,499	40,791	7,634	-	290,859
	1/2 to 1 mile	62,278	50,628	23,975	6,710	-	143,591
	1 to 3 miles	66,173	56,394	21,648	5,247	-	149,463
	3 to 5 miles	6,337	5,512	-	-	-	11,850
	Greater than 5 miles	2,235	-	-	-	-	2,235
	TOTAL BY FOREST TYPE	579,894	320,498	121,886	40,406	93	1,062,776
	Ponderosa Pine Group	403,732	248,787	86,222	35,740	93	774,573
	Spruce/Fir Group	33,770	8,388	8,920	969	-	52,047
	Nonstocked Group	78,326	13,636	-	685	-	92,647
	Pinyon/Juniper Group	2,259	5,753	3,012	-	-	11,024
	All Hardwood Groups	61,805	43,936	23,731	3,012	-	132,484
SUITABLE BASE ACRES	**TOTAL by DISTANCE to ROAD**	477,268	210,220	62,662	15,583	-	765,733
	100 ft or less	34,313	11,092	-	-	-	45,404
	101-300 ft	57,004	18,340	685	4,795	-	80,824
	301-500 ft	62,072	26,972	2,055	-	-	91,099
	501-1000 ft	104,902	30,758	12,451	5,480	-	153,591
	1001 ft to 1/2 mile	115,644	61,529	19,883	4,622	-	201,678
	1/2 to 1 mile	51,784	20,756	14,977	685	-	88,201
	1 to 3 miles	51,551	38,273	12,611	-	-	102,436
	3 to 5 miles	-	2,500	-	-	-	2,500
	Greater than 5 miles	-	-	-	-	-	-
	TOTAL BY FOREST TYPE	477,268	210,220	62,662	15,583	-	765,733
	Ponderosa Pine Group	357,671	167,848	48,672	14,898	-	589,089
	Spruce/Fir Group	24,663	5,450	8,920	-	-	39,034
	Nonstocked Group	50,317	9,870	-	685	-	60,873
	Pinyon/Juniper Group	-	2,740	-	-	-	2,740
	All Hardwood Groups	44,616	24,311	5,070	-	-	73,998
TIMBERLAND ACRES NOT INCLUDED IN SUITABLE BASE ACREAGE	**TOTAL by DISTANCE to ROAD**	102,626	110,278	59,224	24,823	93	297,043
	100 ft or less	11,487	2,741	1,737	-	-	15,966
	101-300 ft	8,000	3,325	1,663	4,294	-	17,281
	301-500 ft	8,109	7,795	6,025	-	-	21,929
	501-1000 ft	16,048	5,441	10,856	6,245	93	38,683
	1001 ft to 1/2 mile	25,291	39,970	20,908	3,012	-	89,181
	1/2 to 1 mile	10,494	29,872	8,998	6,025	-	55,390
	1 to 3 miles	14,622	18,121	9,037	5,247	-	47,027
	3 to 5 miles	6,337	3,012	-	-	-	9,350
	Greater than 5 miles	2,235	-	-	-	-	2,235
	TOTAL BY FOREST TYPE	102,626	110,278	59,224	24,823	93	297,043
	Ponderosa Pine Group	46,061	80,939	37,550	20,842	93	185,484
	Spruce/Fir Group	9,107	2,938	-	969	-	13,013
	Nonstocked Group	28,009	3,766	-	-	-	31,774
	Pinyon/Juniper Group	2,259	3,013	3,012	-	-	8,284
	All Hardwood Groups	17,189	19,625	18,661	3,012	-	58,486

Table 5. Summary of potential additions to suitable base acreage.

	Possible Add'l Acres	TOTAL ACRES	Acres by Forest Type Pinyon-Jnpr	HDWD	Possible Add'l Acres Excluding PJ & HDWD	TOTAL ACRES
FIA Suitable Base	-	765,733	-	-		765,733
Potential ADD 1	33,662	799,395	-	8,342	25,320	791,053
Potential ADD 2	29,284	828,679	-	2,235	27,049	818,102
Potential ADD 3	65,261	893,940	-	11,616	53,645	871,747
Potential ADD 4	40,366	934,306	-	3,325	37,041	908,788
Forest Plan Amended in Phase II (USDA FS 2005, Appendix G-3)		865,890				865,890
Timberland Acres		1,062,776				1,062,776

3.2.5 Comparison of BHNF augmented inventory with prior inventory results

As stated in the previous section, we compared inventory estimates from the 2017-2019 BHNF augmented FIA dataset, with estimates generated from prior-year FIA datasets, available via the FIA website. These comparisons were made to gain insights on inventory trends and accuracy. We compared a range of inventory attributes between the various inventory years, for the BHNF suitable base timberlands:

- suitable base acres
- ponderosa pine sawlog volume
- ponderosa pine gross annual growth on sawlogs[20]
- ponderosa pine gross growth per acre on sawlogs
- ponderosa pine growth as a percentage of ponderosa pine inventory
- ponderosa pine sawlog inventory per acre[21]

Results of the above queries are presented separately for the South Dakota portion of BHNF, the Wyoming portion of BHNF, and for all of BHNF, in Tables 6, 7, and 8, respectively. Each table presents inventory estimates for the 2016, 2017, 2018, and 2019 inventory reporting years. For the 2019 inventory reporting year, two sets of results are presented; one generated from the augmented data set, the other from the 2019 online data set.[22] In addition, for the 2019 augmented data set, two sets of results are presented; one for queries made using the FIA-supplied suitable base plot numbers, and one for queries made using Plot_CN identifiers; to demonstrate the two approaches result in identical results, and thereby dispel any concern (as

[20] Estimated growth is dealt with in detail in section 3.3 of this report; some growth data is presented here for purposes of highlighting shifting acres/inventories over time.
[21] Wyoming does not report growth and mortality results except for those contained in the augmented data. Further, the augmented data set does not support ratio estimates that include growth as one of the queried metrics.
[22] The on-line 2019 inventory data differs from the 2019 BHNF augmented dataset by omitting temporary plot data. The temporary plots are deemed an extension of the base FIA inventory system applicable only to the 2017-2019 augmented inventory, and are therefore not included in the base on-line FIA datasets.

voiced by the USFS FIA staff) that using the suitable base plot numbers "could yield inaccurate results."

The 2019 BHNF augmented dataset reports 765,733 suitable base acres (653,753 in South Dakota and 111,980 in Wyoming). It reports ponderosa pine sawtimber inventory of 5,995,428 cunits and ponderosa pine gross annual growth of 150,694 cunits. Ratio estimates that incorporate growth are not supported by the augmented dataset, so the only ratio estimate that can be generated is sawlog volume per acre. For the augmented data set the numerator and denominator results for the ratio estimates are consistent with independent queries for the constituent metrics.

During the course of this project the 2019 FIA inventory data for both South Dakota and Wyoming was posted online. For comparison with the 2019 BHNF augmented dataset, the same queries were run against the recently updated and posted 2019 dataset using the Plot_CN identifiers to ensure the same suitable base acres as were evaluated as part of the augmented data set were being evaluated for this comparison.

For Wyoming, the acres and inventory are slightly different; there is no growth since the Interior West regional office, which administers Wyoming's data, does not report growth. We note the 2019 results from the online query for Wyoming are slightly higher than the augmented data, however: 115,193 acres (vs. 111,980 or 2.9% higher) and 1,405,814 cunits (vs. 1,405,475 or 0.02% higher). Because the acres difference is larger than the inventory difference, the volume per acre is lower in the 2019 online data: 12.204 cunits/acre (vs. 12.551 cunits/acre or 2.8% lower).

While the differences between the BHNF augmented inventory and the FIA 2019 online data for Wyoming are minimal, difference for the South Dakota online data are both more substantial and variable. For South Dakota there are two different sets of acres reported in the online queries, both higher than the corresponding acres reported from the augmented data set. The independently queried acres for the online data are 681,497 acres (vs. 653,753 for the augmented dataset, or 4.3% higher) and the acres from the growth per acre ratio estimate is 733,121 (12.1% higher).[23]

As can be seen in Table 6, the South Dakota-only table for suitable base acres on the BHNF, the acreage from the ratio query is significant in that it represents the mid-point inventory of the suitable base acres for the plots used to compute gross annual growth. Similar to the reported acreage, the reported inventory based on the growth ratio query is much higher as well: 5,220,532 cunits (vs. 4,589,954 cunits, or 13.7% higher). Finally, although the inventory is higher for this query (which might imply the growth rate percent would be lower), in fact the gross growth is higher as well: 158,449 cunits (vs. 111,578 cunits, or 42% higher). Because the growth increase is proportionately greater than the inventory increase, the growth rate, computed by dividing reported gross growth by reported gross inventory, is 3.04% (vs. 2.43%, reported for

[23] It is a result of the various calculation methodologies used in the FIA Evalidator program that different acres are reported depending on the specific metric being computed, even though we are ostensibly reporting on the same geographic base.

South Dakota only from the 2019 augmented dataset and also presented in Table 6). The growth rate is higher still if the reported gross growth for the period (158,449 cunits) is divided by the reported inventory at the end of the period (4,937.990 cunits), as is typically done, rather than the mid-point inventory. The computation when performed more conventionally results in a growth rate of 3.21%.

Taken collectively across all the BHNF, the 2019 online inventory is 6,343,804 cunits vs. 5,995,428 cunits, or 5.8% higher. That volume estimate is on 796,690 acres vs. 765,733 acres, or 4.0% higher. While these acres are closer to the NEPA-determined 865,890 acres, they are still 8% below that acreage level. We note that if the 2019 online Wyoming acres[24] are added to the 2019 "midpoint" acres for South Dakota the total suitable base acres are 848,813 acres. The confidence interval around that estimate includes the 865,890 acre Forest Plan value. Since there is no 2019 growth reported online for Wyoming, adding the augmented data set growth for Wyoming to the 2019 reported growth for South Dakota results in a growth estimate of 197,565 cunits vs. 150,694 cunits in the augmented data set (31% higher). Using the 2019 online inventories results in 6,343,804 cunits vs. 5,995,428 cunits in the augmented data set (5.8% higher). Dividing this revised growth estimate (197,565) by the revised inventory estimate for 2019 (6,343,804) yields an estimated growth percent per conventional methodology of 3.11% vs. 2.43%.

Recall, these values are still being computed on acreages that are 8% below the 865,890 suitable base acres as reported in the current Forest Plan. We submit that something seems amiss if presumably the same data for the same inventory year can yield such radically different outcomes.

[24] No growth reported for Wyoming online so a comparable estimate cannot be used in this case.

Table 6. Acres, inventory, and growth estimates for South Dakota BHNF suitable base, 2016 to 2019.

Comparison of Varying Query Results by Metric, 2016 to 2019		Suitable Base Acres *Acres*	Ponderosa Pine Swlog Inventory *CCF*	Gross Annual Growth Ponderosa Pine Sawlog *CCF*	Gross Annual Growth per Acre Ponderosa Pine Sawlogs *CCF/Acres*	Gross Annual Ponderosa Pine Sawlog Growth Percent *%*	Ponderosa Pine Sawlog Inventory per Acre *CCF/Acres*
Black Hills National Forest, South Dakota							
2019 Augmented Data ("Local")							
Independent Queries w/ plotgeom.bhnf_suitable_land table		653,753	4,589,954	111,578	0.171	2.43%	7.021
Independent Queries w/ Control Number list		653,753	4,589,954	111,578	0.171	2.43%	7.021
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	653,753	4,589,954	NA	NA	NA	7.021
2019 Online Evalidator Data							
Independent Queries w/ Control Number list		681,497	4,937,990	158,449	0.233	3.21%	7.246
Ratio Estimate	GAG/AC	733,121	NA	158,449	0.216	NA	NA
Queries w/ Control	GAG/INV	NA	5,220,532	158,449	NA	3.04%	NA
Number list	INV/AC	681,497	4,937,990	NA	NA	NA	7.246
2018 Online Evalidator Data							
Independent Query w/ Condition Number list		681,381	5,104,329	168,800	0.248	3.31%	7.491
Ratio Estimate	GAG/AC	725,728	NA	168,800	0.233	NA	NA
Queries w/	GAG/INV	NA	5,625,890	168,800	NA	3.00%	NA
Condition Number	INV/AC	681,381	5,104,329	NA	NA	NA	7.491
2017 Online Evalidator Data							
Independent Queries w/ Control Number list		707,584	5,508,452	174,224	0.246	3.16%	7.785
Ratio Estimate	GAG/AC	733,620	NA	174,224	0.237	NA	NA
Queries w/	GAG/INV	NA	5,840,254	174,224	NA	2.98%	NA
Condition Number	INV/AC	707,584	5,508,452	NA	NA	NA	7.785
2016 Online Evalidator Data							
Independent Query w/ Condition Number list		729,995	5,874,722	169,748	0.233	2.89%	8.048
Ratio Estimate	GAG/AC	731,499	NA	169,748	0.232	NA	NA
Queries w/ Control	GAG/INV	NA	5,883,109	169,748	NA	2.89%	NA
Number list	INV/AC	729,995	5,874,722	NA	NA	NA	8.048

Table 7. Acres, inventory, and growth estimates for BHNF suitable base, Wyoming only, 2016 to 2019.

Comparison of Varying Query Results by Metric, 2016 to 2019		Suitable Base Acres *Acres*	Ponderosa Pine Swlog Inventory *CCF*	Gross Annual Growth Ponderosa Pine Sawlog *CCF*	Gross Annual Growth per Acre Ponderosa Pine Sawlogs *CCF/Acres*	Gross Annual Ponderosa Pine Sawlog Growth Percent *%*	Ponderosa Pine Sawlog Inventory per Acre *CCF/Acres*
Black Hills National Forest, Wyoming							
2019 Augmented Data ("Local")							
Independent Query w/ plotgeom.bhnf_suitable_land table		111,980	1,405,475	39,116	0.349	2.78%	12.551
Independent Queries w/ Control Number list		111,980	1,405,475	39,116	0.349	2.78%	12.551
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	111,980	1,405,475	NA	NA	NA	12.551
2019 ("2020"-2019/2018) Online Evalidator Data							
Independent Queries w/ Control Number list		115,193	1,405,814	NA	NA	NA	12.204
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/	GAG/INV	NA	NA	NA	NA	NA	NA
Condition Number	INV/AC	115,193	1,405,814	NA	NA	NA	12.204
2018 ("2020"-2019/2018) Online Evalidator Data							
Independent Query w/ Condition Number list		115,193	1,405,814	NA	NA	NA	12.204
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	115,193	1,405,814	NA	NA	NA	12.204
2017 Online Evalidator Data							
Independent Queries w/ Control Number list		115,750	1,463,232	NA	NA	NA	12.641
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	115,750	1,463,232	NA	NA	NA	12.641
2016 Online Evalidator Data							
Independent Queries w/ Control Number list		128,425	1,483,479	NA	NA	NA	
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	128,425	1,483,479	NA	NA	NA	11.551

Table 8. Acres, inventory, and growth estimates for BHNF suitable base, 2016 to 2019 (SD & WY).

Comparison of Varying Query Results by Metric, 2016 to 2019		Suitable Base Acres (Acres)	Ponderosa Pine Swlog Inventory (CCF)	Gross Annual Growth Ponderosa Pine Sawlog (CCF)	Gross Annual Growth per Acre Ponderosa Pine Sawlogs (CCF/Acres)	Gross Annual Ponderosa Pine Sawlog Growth Percent (%)	Ponderosa Pine Sawlog Inventory per Acre (CCF/Acres)
Black Hills National Forest, South Dakota and Wyoming							
2019 Augmented Data ("Local")							
Independent Query w/ plotgeom.bhnf_suitable_land table		765,733	5,995,428	150,694	0.197	2.51%	7.830
Independent Queries w/ Control Number list		765,733	5,995,428	150,694	0.197	2.51%	7.830
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	NA	NA	NA	NA	NA	NA
2019 ("2020"-2019/2018 for WY) Online Evalidator Data							
Independent Queries w/ Control Number list		796,690	6,343,804	NA	NA	NA	7.963
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/	GAG/INV	NA	NA	NA	NA	NA	NA
Condition Number	INV/AC	796,690	6,343,804	NA	NA	NA	7.963
2018/2017 Online Evalidator Data							
Independent Query w/ Condition Number list		797,131	6,510,143	NA	NA	NA	8.167
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	796,574	6,510,143	NA	NA	NA	8.173
2017 Online Evalidator Data							
Independent Queries w/ Control Number list		823,334	6,971,683	NA	NA	NA	8.468
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/	GAG/INV	NA	NA	NA	NA	NA	NA
Condition Number	INV/AC	823,334	6,971,683	NA	NA	NA	8.468
2016 Online Evalidator Data							
Independent Queries w/ Control Number list		858,420	7,358,201	NA	NA	NA	8.572
Ratio Estimate	GAG/AC	NA	NA	NA	NA	NA	NA
Queries w/ Control	GAG/INV	NA	NA	NA	NA	NA	NA
Number list	INV/AC	858,420	7,358,201	NA	NA	NA	8.572

Tables 6, 7, and 8, along with Figure 6, all show a relatively stable estimate of suitable base acres, prior to the addition of supplemental plots in 2017. Given that the 2016 inventory data provides a closer estimation of actual suitable base acres (the one population estimate that we know with certainty), we must conclude that the 2016 inventory is more accurate than the 2017-2019 BHNF augmented inventory, even though it has fewer plots, and would therefore be expected to be less precise.

The historical FIA data (Table 8) do show a decline in inventory per acre over time, which is expected in light of the mountain pine beetle epidemic. Per-acre inventory declines from 8.6 CCF/acre in 2016, to 8.0 CCF/acre in the 2019 online FIA data – a 7% reduction in volume per acre. If the 2019 inventory/acre from the online FIA dataset is applied against the 2016 suitable base acreage estimate of 858,420[25] that would translate into an inventory of 6,835,598 CCF, 14% higher than the reported 2019 augmented inventory of 5,995,428 cunits. If the lower 2019 augmented dataset volume estimate of 7.8 CCF/acre is applied against the 2016 suitable base acreage, the inventory is still 12% higher than the 2019 augmented dataset inventory estimate.

Finally, the data would seem to indicate that a more reliable estimate of annual inventory growth is 3% rather than 2.5%. In this case, due to lack of WY growth data from online Evalidator, we have to rely on South Dakota data only. The reported growth on inventory for South Dakota from online Evalidator queries is 3.21%, 3.31%, 3.16%, and 2.89% for 2019, 2018, 2017, and 2016 inventory years, respectively. This results in an average of 3.14%, not the 2.43% reported for South Dakota in the 2019 augmented data set. If the ratio of 3.14%/2.43%=1.29 is applied to the 2019 augmented data set growth estimate of 2.51% (in the augmented data set, the Wyoming portion of the forest is growing at a faster rate than the South Dakota portion of the forest), a defensible estimate for BHNF growth in 2019 would be 2.51%x1.29=3.24%.

There is additional discussion regarding FIA growth rates in section 3.3.

In conclusion, there are several reasons (whether alone or in combination) why the 2017-2019 BHNF augmented inventory is less accurate, even though it has more plots, than the 2016 inventory. Among those reasons could be:

1. Potentially incorrect weighting of individual sample year data. As shown in Figure 4 for South Dakota FIA data, plot remeasurement cycles have changed repeatedly over the past 10 years. Each of these changes requires a recalculation of the weighting factors used to combine the individual annual plot measurement data (panels) into a composite inventory estimate. With the recalculation of the weighting factors comes the opportunity for error.
2. No growth was measured at any time in the complete set of temporary plots. Instead, growth was measured on the permanent plots, then adjusted and extrapolated to incorporate the temporary plots.
3. Potentially biased allocation of temporary sample plots. We have been unable to obtain a detailed description of the methodology used to distribute the supplemental temporary inventory plots across the landscape. There could conceivably be an inadvertent bias in how the temporary plots were allocated, resulting in too few plots falling within the suitable timberland base, and thereby decreasing the associated acreage and volume estimates. We do note however that plot distribution by live basal area categories is comparable between permanent and temporary plots (see Table 9) and there are only a few statistically significant differences between sawtimber volume per acre comparing permanent plots and temporary plots (see Table 10). So, while this is still a concern due to lack of transparency in how the temporary plot allocations were made, there is no direct evidence of bias (assuming the suitable base temporary plot count itself is not biased).

[25] 2016's acreage is essentially in agreement with the NEPA-approved 865,990 of the existing forest plan

4. There may be substantial measurement error associated with the accelerated remeasurement of permanent plots, due to the reduced remeasurement period. Diameter growth for trees in the BHNF is modest; an average of perhaps 0.1 to 0.2 inches per year for free-to-grow trees on moderate sites. Using the default FIA remeasurement period of five years, this means field crews would be measuring diameter changes of 0.5 to 1.0 inch between measurements. By accelerating permanent plot remeasurements in 2019, the growth period has been halved, resulting in the need to accurately measure diameter growths of a quarter inch or less. In such circumstances, the relative impact of measurement error increases greatly, and the slightest inaccuracies in field measurement (e.g., the diameter tape placed too high/low, at an angle, over a loose piece of bark, etc.) have the potential to substantially affect growth estimates.

5. The FIA database flag that indicates whether an FIA plot is contained within the BHNF suitable base acres is being incorrectly applied to the entire cluster of four subplots that comprise an FIA sample point, rather than to each individual subplot. Classifying all subplots as a group to either the suitable or non-suitable category could cause significant inaccuracies in acreage and volume estimation, and is at odds with how the timberland flag, accessibility flag, reserved status flag, and growth potential flag are applied – all of which are assigned at the subplot level. This topic is discussed in more detail in section 3.4.2.

Table 9. Comparison of suitable base timberland acres by live basal area class for permanent plots versus supplemental plots in 2019 augmented dataset.

SUITABLE BASE TIMBERLAND ACRES - "2019" Data		Permanment Plots (Intensity = 1)			Supplementary Plots (Intensity = 2)			ALL PLOTS			PERMA-NENT PLOTS	SUPPLE-MENTARY PLOTS	ALL PLOTS
		ESTIMATED ACRES	SE%	Non-Zero Plots	ESTIMATED ACRES	SE%	Non-Zero Plots	ESTIMATED ACRES	SE%	Non-Zero Plots			
SD	**ALL ACRES**	**350,467**	**6.81**	**131**	**303,286**	**7.49**	**110**	**653,753**	**3.05**	**241**	100%	100%	100%
	0-40 sqft/ac	133,674	12.52	57	106,550	14.36	46	240,224	8.41	103	38%	35%	37%
	41-80 sqft/ac	117,312	14.02	47	100,978	14.84	41	218,290	9.36	88	33%	33%	33%
	81-120 sqft/ac	60,716	20.09	24	64,887	18.88	23	125,603	13.11	47	17%	21%	19%
	120+ sqft/ac	38,764	24.76	14	30,871	27.14	16	69,636	17.50	30	11%	10%	11%
WY	**ALL ACRES**	**70,900**	**19.09**	**25**	**41,081**	**25.34**	**15**	**111,980**	**14.68**	**40**	100%	100%	100%
	0-40 sqft/ac	16,041	40.35	7	6,851	53.33	5	22,891	32.11	12	23%	17%	20%
	41-80 sqft/ac	16,153	39.52	7	17,006	39.15	6	33,159	27.54	13	23%	41%	30%
	81-120 sqft/ac	29,702	30.39	10	14,401	41.33	7	44,104	24.23	17	42%	35%	39%
	120+ sqft/ac	9,003	56.40	3	2,822	87.40	1	11,826	47.47	4	13%	7%	11%
ALL	**ALL ACRES**	**421,367**	**5.77**	**156**	**344,367**	**6.71**	**125**	**765,733**	**1.71**	**281**	100%	100%	100%
	0-40 sqft/ac	149,715	11.68	64	113,401	13.70	51	263,116	7.77	115	36%	33%	34%
	41-80 sqft/ac	133,465	12.89	54	117,984	13.56	47	251,449	8.44	101	32%	34%	33%
	81-120 sqft/ac	90,419	16.29	34	79,288	16.96	30	169,707	10.92	64	21%	23%	22%
	120+ sqft/ac	47,768	22.24	17	33,694	25.79	17	81,461	15.96	34	11%	10%	11%
CONFIDENCE INTERVAL (68% CONFIDENCE LEVEL)								**765,733**	**+/- 13,094**				
PER Black Hills Management Plan, Appendix G, Suitable Base acres are								**865,890**					
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf					(PDF Page number 413)								

Table 10. Comparison of suitable base timberland volume per acre by live basal area class for permanent plots versus supplemental plots in 2019 augmented dataset.

SUITABLE BASE PP SAWTMBR per ACRE - "2019" Data		Permanment Plots (Intensity = 1)			Supplementary Plots (Intensity = 2)			ALL PLOTS			INTENSITY= 1, Relevant Limit	INTENSITY= 2, Relevant Limit	STATISTICAL DIFFERENCE
		ESTIMATED CF per ACRE	SE%	Non-Zero Plots*	ESTIMATED CF per ACRE	SE%	Non-Zero Plots*	ESTIMATED CF per ACRE	SE%	Non-Zero Plots*			
SD	**ALL ACRES**	**683**	**8.15**	**131**	**724**	**8.95**	**110**	**702**	**5.98**	**241**	**739**	**659**	NO DIFF
	0-40 sqft/ac	186	14.48	57	174	17.86	46	181	11.21	103	159	205	NO DIFF
	41-80 sqft/ac	763	7.73	47	697	8.28	41	733	5.69	88	704	755	NO DIFF
	81-120 sqft/ac	928	15.92	24	1,116	11.69	23	1,025	9.72	47	1,076	986	NO DIFF
	120+ sqft/ac	1,770	11.65	14	1,888	13.78	16	1,822	8.99	30	1,977	1,628	NO DIFF
WY	**ALL ACRES**	**1,159**	**13.32**	**25**	**1,420**	**16.19**	**15**	**1,255**	**10.36**	**40**	**1,314**	**1,190**	NO DIFF
	0-40 sqft/ac	304	21.15	7	501	31.22	5	363	21.25	12	368	345	NO DIFF
	41-80 sqft/ac	668	30.89	7	1,137	15.90	6	909	16.89	13	875	956	**DIFF**
	81-120 sqft/ac	1,721	12.23	10	1,737	12.37	7	1,726	9.15	17	1,931	1,522	NO DIFF
	120+ sqft/ac	1,714	5.85	3	3,739	-	1	2,197	17.86	4	1,814	3,739	**DIFF**
ALL	**ALL ACRES**	**763**	**7.10**	**156**	**807**	**8.27**	**125**	**783**	**5.34**	**281**	**817**	**740**	NO DIFF
	0-40 sqft/ac	199	12.79	64	194	17.42	51	196	10.36	115	173	227	NO DIFF
	41-80 sqft/ac	752	7.70	54	761	7.95	47	756	5.53	101	809	700	NO DIFF
	81-120 sqft/ac	1,188	11.58	34	1,229	9.58	30	1,207	7.63	64	1,326	1,111	NO DIFF
	120+ sqft/ac	1,760	9.58	17	2,043	13.25	17	1,877	8.10	34	1,928	1,772	NO DIFF

*Non-zero plots for denominator (acres)

Lastly, we have purposely limited our independent analysis of inventory and growth trends to-date, since the augmented dataset values are undoubtedly influenced by the noted inaccuracies. We would, however, point out that our initial review of the volume inventory and growth estimates show a very large degree of uncertainty in the estimates. As noted by the FIA program itself: “Users should avoid making any inference about an estimate without knowing its variability.”[26] The example chart in Figure 7 shows net growth of sawlog volume on sawtimber trees, from the augmented BHNF FIA inventory database. Note that even though the total net growth estimate is a negative value (-28,000) the 95% confidence limit ranges all the way from -107,000 to + 51,000. When making decisions based on such an estimate, it is imperative to recognize the large degree of uncertainty associated with the estimate.

[26] https://www.fia.fs.fed.us/library/sampling/docs/supplement7_121704.pdf

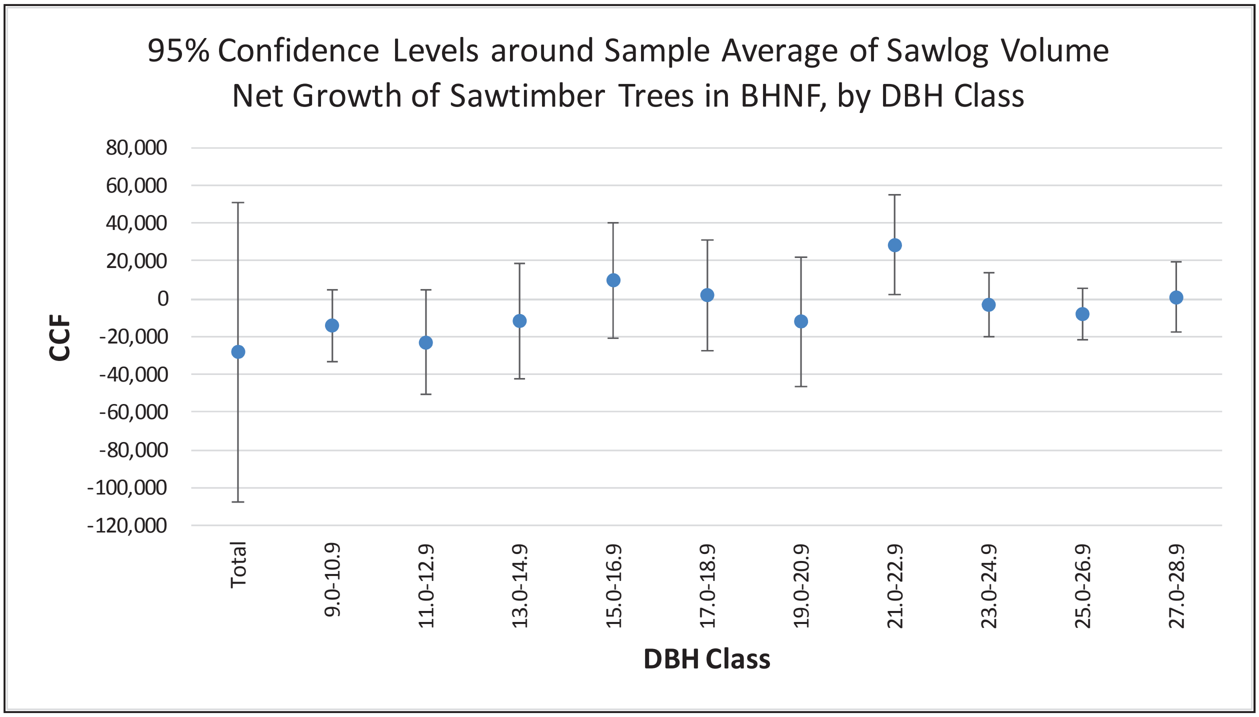


Figure 7. Confidence intervals for estimated net sawlog volume growth of sawtimber trees.[27]

3.3 Growth estimates derived from FIA data

Table 11 presents the 2019 augmented data set results for ponderosa pine sawtimber gross annual growth (GAG), mortality (MRT), net annual growth (NAG), and inventory on suitable base timberlands, along with the associated suitable base timberland acres, by South Dakota and Wyoming on permanent and temporary (supplemental) plots by inventory panel year. The data indicates that in 2019 the BHNF had negative NAG of 27,715 CCF, or -0.036 CCF per acre, with GAG of 0.197 CCF per acre.

Because the BHNF has recently experienced catastrophic mortality due to a mountain pine beetle infestation, focusing on net annual growth is ill-advised when looking at the revision of long-term forest management plans. While NAG (gross annual growth less annual mortality) is a simple concept to comprehend and explain, if used as the sole guide for setting harvest levels it can result in unintended consequences.

For example, in an old, overstocked forest, growth will be slow and mortality will be high, meaning NAG will be low. If harvesting is reduced in an attempt to make NAG positive (rather than harvesting old trees to replace them with more vigorous growth and/or reducing stocking to provide trees more space in which to grow), then the next time the forest is measured growth will

[27] The large variance displayed for the estimate of total sawlog volume growth was verified with various FIA Evalidator queries. While growth within a small diameter class has a relatively low variance (due to a rather fixed growth rate for trees within the class), variance on the total growth estimate is much larger.

have slowed even more, mortality will have increased even more, and thus NAG will be even lower – and if the objective is to keep harvest less than NAG, the situation will be even further exacerbated. Rather than addressing the underlying forest health issue (over-mature trees that are overstocked), repeatedly lowering harvest levels below NAG actually aggravates the problem. This creates something of a death spiral. Unfortunately, this scenario has been and is being played out over many publicly-managed forest lands across the U.S. West.

Table 11. Selected inventory statistics from the 2019 BHNF augmented data set.

2019 Augmented BHNF SUITABLE BASE PONDEROSA PINE RESOURCE CONDITIONS
Conditions Summarized by TYPE of FIELD PLOT (Pernanent of Supplement), STATE, and INVENTORY PANEL

PLOT TYPE	STATE	INVENTORY "PANEL" - Data Collection Field Season										
		TOTAL	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
Sawlog Gross Annual Growth ("GAG") - CCF - Ponderosal Pine												
PERMANENT	SD	111,578	0	73,372	14,154	24,052	0	0	0	0	0	0
PERMANENT	WY	39,116	7,220	22,560	3,023	6,312	0	0	0	0	0	0
PERMANENT	ALL	150,694	7,220	95,933	17,177	30,364	0	0	0	0	0	0
SUPPLEMENT	SD	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	WY	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	ALL	0	0	0	0	0	0	0	0	0	0	0
ALL	SD	111,578	0	73,372	14,154	24,052	0	0	0	0	0	0
ALL	WY	39,116	7,220	22,560	3,023	6,312	0	0	0	0	0	0
ALL	ALL	150,694	7,220	95,933	17,177	30,364	0	0	0	0	0	0
Sawlog ANNUAL MORTALITY ("MRT") - CCF - Ponderosa Pine												
PERMANENT	SD	154,587	0	115,263	20,790	18,534	0	0	0	0	0	0
PERMANENT	WY	23,822	15,088	8,215	519	0	0	0	0	0	0	0
PERMANENT	ALL	178,409	15,088	123,478	21,309	18,534	0	0	0	0	0	0
SUPPLEMENT	SD	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	WY	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	ALL	0	0	0	0	0	0	0	0	0	0	0
ALL	SD	154,587	0	115,263	20,790	18,534	0	0	0	0	0	0
ALL	WY	23,822	15,088	8,215	519	0	0	0	0	0	0	0
ALL	ALL	178,409	15,088	123,478	21,309	18,534	0	0	0	0	0	0
Sawlog NET ANNUAL GROWTH ("NAG") - CCF - Ponderosa Pine												
PERMANENT	SD	-43,008	0	-41,890	-6,636	5,518	0	0	0	0	0	0
PERMANENT	WY	15,293	-7,868	14,345	2,504	6,312	0	0	0	0	0	0
PERMANENT	ALL	-27,715	-7,868	-27,546	-4,132	11,830	0	0	0	0	0	0
SUPPLEMENT	SD	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	WY	0	0	0	0	0	0	0	0	0	0	0
SUPPLEMENT	ALL	0	0	0	0	0	0	0	0	0	0	0
ALL	SD	-43,008	0	-41,890	-6,636	5,518	0	0	0	0	0	0
ALL	WY	15,293	-7,868	14,345	2,504	6,312	0	0	0	0	0	0
ALL	ALL	-27,715	-7,868	-27,546	-4,132	11,830	0	0	0	0	0	0
Suitable Base Acres												
PERMANENT	SD	350,467	0	268,006	36,713	45,748	0	0	0	0	0	0
PERMANENT	WY	70,900	9,244	43,159	8,221	10,276	0	0	0	0	0	0
PERMANENT	ALL	421,367	9,244	311,166	44,933	56,024	0	0	0	0	0	0
SUPPLEMENT	SD	303,286	0	0	156,026	147,260	0	0	0	0	0	0
SUPPLEMENT	WY	41,079	5,480	2,500	5,480	0	3,763	6,504	2,712	4,365	4,795	5,480
SUPPLEMENT	ALL	344,365	5,480	2,500	161,506	147,260	3,763	6,504	2,712	4,365	4,795	5,480
ALL	SD	653,753	0	268,006	192,739	193,008	0	0	0	0	0	0
ALL	WY	111,979	14,724	45,659	13,701	10,276	3,763	6,504	2,712	4,365	4,795	5,480
ALL	ALL	765,732	14,724	313,665	206,440	203,284	3,763	6,504	2,712	4,365	4,795	5,480
Sawlog Inventory - CCFs - Ponderosa Pine												
PERMANENT	SD	2,393,516	0	1,735,658	237,928	419,930	0	0	0	0	0	0
PERMANENT	WY	822,063	104,064	527,687	69,546	120,766	0	0	0	0	0	0
PERMANENT	ALL	3,215,579	104,064	2,263,345	307,474	540,696	0	0	0	0	0	0
SUPPLEMENT	SD	2,196,437	0	0	1,146,426	1,050,011	0	0	0	0	0	0
SUPPLEMENT	WY	583,412	62,401	44,723	76,758	0	38,574	184,698	23,326	22,770	59,196	70,964
SUPPLEMENT	ALL	2,779,849	62,401	44,723	1,223,184	1,050,011	38,574	184,698	23,326	22,770	59,196	70,964
ALL	SD	4,589,954	0	1,735,658	1,384,354	1,469,942	0	0	0	0	0	0
ALL	WY	1,405,475	166,465	572,410	146,304	120,766	38,574	184,698	23,326	22,770	59,196	70,964
ALL	ALL	5,995,428	166,465	2,308,068	1,530,659	1,590,708	38,574	184,698	23,326	22,770	59,196	70,964

Just as is the case for inventory estimates, GAG (and MRT) estimates are expanded based on plot expansion factors representing the number of forest acres each plot is intended to represent in the forest sample. Thus, if plot expansions are incorrect for inventory they will be incorrect for GAG (and MRT) estimates as well.

The issue of plot expansions for GAG is further complicated for BHNF's augmented dataset because of the introduction of supplemental plots where no growth is computed. This means there is one set of expansion factors for inventory and acres (because all plots, whether permanent or supplemental are used to develop these estimates) and another set of expansion factors for GAG (because only permanent plots can be used to estimate growth, yet those plots have to be "expanded" in this instance as though there are no supplemental plots).

This aspect of FIA's inventory estimation procedures is depicted in Table 12. The most direct and accurate way to generate factors like GAG per acre ("GAG/Acre") or GAG as a percent of inventory ("GAG %INV") would be to generate a ratio estimate where GAG is in the numerator and either acres or inventory are in the denominator. Because the 2019 augmented dataset does not support ratio estimates for GAG we looked at the ratio estimates using the recently posted 2019 South Dakota[28] online data and compared the constituent numerator and denominator estimates from these ratio estimates to stand-alone queries for those same specific metrics. The results are shown by inventory panel in Table 12. These data are an in-depth examination of the underlying data presented in Table 6 for 2019.

Our first observation is that the 2019 online data set, while utilizing the supplemental plots taken in 2017 and 2018, is not utilizing all the permanent plots remeasured in 2019 but, instead, is continuing to report permanent plot remeasurements taken in 2013 to 2016 and include those in the online 2019 estimate. This certainly accounts for some of the differences seen in the augmented 2019 data set estimates of inventory and growth compared to the 2019 online estimates for BHNF.

However, the key issue to highlight regarding the 2019 online data is the differences between the stand-alone estimates and the estimates utilized in the ratio estimates. In all three cases the 2019 GAG estimates were identical whether generated as stand-alone or as part of the ratio estimates for GAG/Acre or GAG %INV. A total of 128 plots were used to compute GAG. However, the stand-alone inventory query for acres used 241 plots and the stand-alone query for ponderosa pine sawtimber inventory used 211 plots. In the ratio estimates there were 131 plots and 109 plots for GAG/Acre and GAG %INV, respectively.

But even more significant is the relative proportions of the estimate by panel year for each of these metrics. In the case of stand-alone acres, 58% of the acres in the stand-alone estimate are in the 2017-2018 panels while 27% of the GAG and 24% of the acres in the GAG/acre ratio. In the case of ponderosa pine sawtimber inventory, 59% of the inventory in the stand-alone estimate is in the 2017-2018 panels while 26% of the inventory in the GAG %INV is in the 2017-2018 inventory panel.

[28] Interior West does not post growth or mortality estimates for Wyoming so used only South Dakota for this illustration.

Table 12. Comparison of various FIA inventory estimates and their expansion factors.

BHNF's South Dakota 2019 Selected Inventory Statistics - Online and Augmented Data Sets	2019 Online INVENTORY	INVENTORY PANELS 2019	2018	2017	2016	2015	2014	2013
Ponderosa Pine Sawtimber GAG as reported from the following three queries:								
(1) Stand-Alone Query, (2) Ratio Query GAG / Inventory (i.e. growth percent), and (3) Ratio Query GAG / Acres								
GAG - CCF	158,449	23,829	16,076	26,760	13,910	23,576	24,815	29,483
Non-Zero Plots	113	22	13	15	16	16	13	18
Percent of Estimate by Panel Year	100%	15%	10%	17%	9%	15%	16%	19%
Difference from Stand-Alone Acres Plots	128	1	58	56	0	5	5	3
Difference from Stand-Alone Inventory Plots	98	-2	51	51	-1	0	0	-1
Suitable Base Timberland Acres								
Stand-Alone Query								
Acres	681,498	65,316	193,198	201,141	45,879	62,050	52,064	61,850
Non-Zero Plots	241	23	71	71	16	21	18	21
Percent of Estimate by Panel Year	100%	10%	28%	30%	7%	9%	8%	9%
GAG per Acre	0.233	0.365	0.083	0.133	0.303	0.380	0.477	0.477
GAG / Acre query								
Acres	733,122	125,697	77,653	95,632	90,900	120,561	102,205	120,474
Non-Zero Plots	131	23	15	17	16	21	18	21
Percent of Estimate by Panel Year	100%	17%	11%	13%	12%	16%	14%	16%
GAG per Acre	0.216	0.190	0.207	0.280	0.153	0.196	0.243	0.245
Ponderosa Pine Sawtimber Inventory								
Stand-Alone Query								
Inventory - CCF	4,937,990	495,511	1,345,779	1,565,146	272,983	466,374	388,460	403,736
Non-Zero Plots	211	20	64	66	15	16	13	17
Percent of Estimate by Panel Year	100%	10%	27%	32%	6%	9%	8%	8%
GAG % of Inventory	3.21%	4.81%	1.19%	1.71%	5.10%	5.06%	6.39%	7.30%
GAG/Inventory query								
Inventory - CCF	5,220,532	934,266	497,713	828,956	527,544	897,515	777,141	757,398
Non-Zero Plots	109	20	13	15	15	16	13	17
Percent of Estimate by Panel Year	100%	18%	10%	16%	10%	17%	15%	15%
GAG % of Inventory	3.04%	2.55%	3.23%	3.23%	2.64%	2.63%	3.19%	3.89%
2019 Augmented Data Base - Stand Alone Queries only as Ratio Estimates with Growth not Supported								
Ponderosa Pine Sawtimber Inventory GAG - CCF								
GAG - CCF	111,578	73,372	14,154	24,052				
Non-Zero Plots	113	85	13	15				
Percent of Estimate by Panel Year	100%	66%	13%	22%				
Difference from Stand-Alone Acres Plots	128	14	58	56				
Difference from Stand-Alone Inventory Plots								
Acres								
Acres	653,753	268,006	192,739	193,008				
Non-Zero Plots	241	99	71	71				
Percent of Estimate by Panel Year	100%	41%	29%	30%				
GAG per Acre	0.171	0.274	0.073	0.125				
Ponderosa Pine Sawtimber Inventory - CCF								
Inventory - CCF	4,589,954	1,735,658	1,384,354	1,469,942				
Non-Zero Plots	212	82	64	66				
Percent of Estimate by Panel Year	100%	38%	30%	32%				
GAG % of Inventory	2.43%	4.23%	1.02%	1.64%				

While it may be tempting to draw further inferences on trends and results by inventory panel comparing GAG/acre or GAG %INV, it is difficult to reach definitive conclusions without knowing more specifics regarding the mechanics of exactly how expansions are being done within the FIA algorithm. The complication arises because, although inventory is measured and acres reported for all sampled plots (whether permanent or temporary), growth and mortality are measured on only permanent plots. Typically only permanent plots are measured both for inventory and for growth, so growth is being reported for the exact same plots on which inventory was measured. However, without having growth from temporary plots, how is growth being reported for the entire inventory since the entire inventory is comprised of measurements from both permanent and temporary plots? The answer is that FIA is applying one set of expansion factors to plots (both permanent and temporary) to calculate inventory, and another set of expansion factors to only permanent plots to produce growth estimates for the entire inventory.[29]

Table 13 illustrates this issue by dissecting several of the estimates reported for the 2019 Online Inventory in Table 6 (**BOLD** font values in Table 13 are reported in Table 6). The estimates reported in Table 11 are all developed from "ratio query"[30] estimates and are for South Dakota only as online Evalidator does not yet report Wyoming growth data. The 2019 online data was used instead of the augmented 2019 data because the augmented data set does not support ratio queries including growth or mortality estimates.

Table 13 highlights the underlying calculation issues introduced when a mix of temporary and permanent plots are used. Look at 2018's panel data, a subcomponent of the 2019's online Evalidator inventory for BHNF's South Dakota suitable base acres, as an example (see in the top box of Table 13). The ratio estimate here is computing ponderosa sawlog inventory, expressed in cunits (CCF) per acre. As noted above, measurements from temporary and permanent plots can be combined for inventory, but only permanent plots can be used to estimate growth and mortality; further, 2018 was the last year on the South Dakota area of the BHNF during which both permanent and temporary plots were measured as part of the inventory intensification effort. For purposes of inventory, where both permanent and temporary plots were measured in 2018, the permanent plots measured for inventory purposes represent 39,298 acres of the 681,498 acre total reported in 2019; the temporary plots measured for inventory purposes represent 153,900

[29] In this discussion we are inferring the acres reported in the ratio estimate are aligned with the actual plot expansions used to compute growth estimates. It is clear that FIA expands growth from permanent plots across all acres inventoried so when temporary plots are introduced as part of the inventory the same plot expansions can't apply to inventory measured only on a permanent plot and growth measured on a permanent plot. Instead it expands inventory measured on both permanent and temporary plots but expands growth to represent that inventory from permanent plots only.

[30] One way to compute inventory metrics like trees per acre or volume per acre is to query the Evalidator database for number of trees, then to query for acres, and then to compute trees per acre in a side calculation. A "ratio query" is an FIA query where the program extracts both sets of data (trees and acres in this example) in a single query and performs the computation. An advantage of the ratio query is statistics will be computed on the ratio (trees divided by acres in this example), and the two components used to compute the ratio (trees and acres in this example). The disadvantage of the ratio query is to filter data you need to use SQL filtering statements against data dictionary items in the FIA evalidator database, so they can become more complex to execute. The additional advantage in this case is that when remeasured metrics (e.g., growth) are being queried, the Evalidator calculations incorporate additional information from its database that can improve the accuracy of the computed ratio statistics.

acres. Hence, all plots remeasured in 2018 that comprise part of the 2019 inventory estimate represent 193,198 (39,398 + 153,900) acres out of the total 681,498 acres reported for the 2019 online Evalidator inventory for South Dakota only.

Now look at the acreage representation for the same 2018 plots in the bottom box of Table 13 where ponderosa pine sawlog gross GAG/acre is being reported. There are acres reported for permanent plots but no acres reported for temporary plots; further, those same permanent plots, for purposes of GAG calculations, represent 77,653 acres out of the total number of inventory acres (reported as 733,122 – not 681,498; more on that below), not 39,298 as reported for the inventory as permanent plots only, and not 193,198 as reported as acres represented by all plots (both permanent and temporary) remeasured in 2018. These adjustments are necessary to account for the fact the temporary plots cannot contribute to estimates of growth but do contribute to estimates of inventory.

Table 13. In-depth comparison of BHNF's 2019 South Dakota ponderosa pine inventory, ponderosa pine gross annual growth ("GAG"), and suitable base acres reported as part of FIA Evalidator ratio queries for inventory per acre and GAG per acre.

METRIC DESCRIPTION	UNITS	REPORTED 2019	PLOT TYPE	INVENTORY PANEL 2019	2018	2017	2016	2015	2014	2013
Suitable Base	CCF/AC	7.25	TOTAL	7.59	6.97	7.78	5.95	7.52	7.46	6.53
Ponderosa Pine	CCF/AC	7.24	PERMANENT	7.59	6.56	8.77	5.95	7.52	7.46	6.53
Net Sawlog Inventory	CCF/AC	7.26	TEMPORARY	-	7.07	7.45	-	-	-	-
QUERY COMPONENTS supplied by FIA EVALIDATOR to COMPUTE RATIO ESTIMATE REPORTED ABOVE										
Suitable Base	CCF	4,937,990	TOTAL	495,511	1,345,779	1,565,146	272,983	466,374	388,460	403,736
Ponderosa Pine	CCF	2,726,848	PERMANENT	495,511	257,603	442,181	272,983	466,374	388,460	403,736
Net Sawlog Inventory	CCF	2,211,142	TEMPORARY	-	1,088,177	1,122,965	-	-	-	-
Suitable Base Area	ACRES	681,498	TOTAL	65,316	193,198	201,141	45,879	62,050	52,064	61,850
	ACRES	376,883	PERMANENT	65,316	39,298	50,426	45,879	62,050	52,064	61,850
	ACRES	304,615	TEMPORARY	-	153,900	150,715	-	-	-	-
Distribution of ACRES by PANEL		100%	TOTAL	10%	28%	30%	7%	9%	8%	9%

METRIC DESCRIPTION	UNITS	REPORTED 2019	PLOT TYPE	2019	2018	2017	2016	2015	2014	2013
Suitable Base	CCF/AC	0.216	TOTAL	0.190	0.207	0.280	0.153	0.196	0.243	0.245
Ponderosa Pine	CCF/AC	0.216	PERMANENT	0.190	0.207	0.280	0.153	0.196	0.243	0.245
Net Sawlog GAG	CCF/AC	-	TEMPORARY	-	-	-	-	-	-	-
QUERY COMPONENTS supplied by FIA EVALIDATOR to COMPUTE RATIO ESTIMATE REPORTED ABOVE										
Suitable Base	CCF	158,449	TOTAL	23,829	16,076	26,760	13,910	23,576	24,815	29,483
Ponderosa Pine	CCF	158449	PERMANENT	23,829	16,076	26,760	13,910	23,576	24,815	29,483
Net Sawlog GAG	CCF	-	TEMPORARY	-	-	-	-	-	-	-
NOTE from FIA Evalidator when computing RATIO metric *This ratio estimate is based on the plot area that was timberland at both the beginning and end of the remeasurement period. This provides a more realistic ratio estimate of the actual change component (growth, removals, mortality) that has occurred on lands that remain in the timberland base.*										
Suitable Base Area	ACRES	733,122	TOTAL	125,697	77,653	95,632	90,900	120,561	102,205	120,474
	ACRES	733122	PERMANENT	125,697	77,653	95,632	90,900	120,561	102,205	120,474
	ACRES	-	TEMPORARY	-	-	-	-	-	-	-
Distribution of ACRES by PANEL		100%		17%	11%	13%	12%	16%	14%	16%
2019 Acres Re-Distributed by Panel Year based on Mid-Point Year Distribution per Panel Year		681498	TOTAL	116,846	72,185	88,898	84,499	112,071	95,008	111,991
Permanent Plot Weight for GAG		1.81		1.79	1.84	1.76	1.84	1.81	1.82	1.81

DATA SOURCE: USFS FIA Evalidator data retrievals of 2019 online data

Before pressing further on the differing plot expansions between inventory and growth, it is worthwhile to ask why is the total acres reported for the FIA's 2019 online Evalidator ratio estimate of gross growth per acre based on a South Dakota's BHNF suitable base of 733,122 and not 681,498? As previously noted in Table 6, when FIA's Evalidator program computes a ratio estimate of ponderosa pine sawlog GAG per acre it reports the midpoint acres represented by the permanent growth plots. FIA's midpoint for South Dakota's suitable base acres totals 733,122 acres, 7.6% higher than the current number of acres being reported for suitable base acres in South Dakota. This clearly indicates that within the timeframe of computing gross growth estimates there has been a sizeable reduction in what FIA is computing/classifying as suitable base acres in South Dakota's portion of BHNF. While this is a substantial reduction in suitable base acres during the period 2019 net growth is being evaluated, as previously noted in Table 6, the reduction in the augmented 2019's data set (not the 2019 online version of the data set) is even more extreme with only 653,753 acres, 12.1% below the reported midpoint suitable base acres reported online for 2019.

Setting the issue of acreage losses aside for a moment and turning back to the issue of differing plot expansions between inventory and growth, another relevant question regarding the alternate plot expansions applied to permanent plots for growth estimation might be: how well does the growth measured on permanent plots represent the growth that occurred on parts of the forest represented by temporary plots?

While the inclusion of the midpoint acreage by inventory panel is insightful and is no doubt more accurate, it can obscure the essence of the calculations being carried out by FIA. Analysis of similar ratio estimates of 2017 and 2018 online Evalidator data indicates the adjustments being made by FIA to permanent plot expansions for purposes of growth when temporary plots are part of the inventory corresponds to the **<u>inventory acreage</u>** (represented by both permanent and temporary plots) for the entire inventory divided by the **<u>inventory acreage</u>** (represented by permanent plots only) for the entire inventory times the permanent plot inventory acreage for an individual inventory panel.[31] Thus, for the 2019 online inventory this is 681,498/376,883, or 1.81. The measured growth of each permanent plot is multiplied by 1.81 (with slight variation, accounting for the midpoint acreage fluctuations) to provide an expanded estimate across the entire property. This expansion is applied to an inventory panel's permanent plots to compensate for the lack of growth measurements made on temporary plots to compute a growth estimate for the entire inventory.

To better illustrate what is at work in these expansion in Table 13 the 2019 GAG/acre ratio midpoint acreage (733,132) was adjusted to correspond with the 2019 inventory acreage (681,498) by multiplying each of the ratio acreages by inventory panel by 0.9296

[31] It should be pointed out a similar methodology is used by FIA when computing a ratio query of gross annual growth and inventory, i.e. gross annual growth as a percentage of inventory. The ratio of the inventory from the permanent and temporary plots to the inventory from permanent plots alone is multiplied times the growth for each permanent plot. As with the ratio estimate for gross growth per acre FIA also reports the midpoint inventory after applying this adjustment. For an example see Table 6.

(681,498/733,132). These acreages are reported near the bottom of the bottom box of Table 13 and reflect both the distribution of acres by panel year reflected by the ratio estimate but agree with the 2019 online inventory acreage. What is clear to see in this presentation of the data is 2018 panel growth included in the 2019 online growth estimate is representative of growth on 72,185 acres.

While this is more than the acres represented by the 39,298 permanent plot acres measured in 2018 it is less than the 193,198 acres measured in 2018 by both permanent and temporary plots. This means that, while the growth on the temporary plots measured in 2018 is being represented in part by permanent plots remeasured in 2018, a portion of the growth reported on the 2018 inventory panel is based on remeasured growth on permanent plots taken in 2019, 2017, 2016, 2015, 2014, and 2013. This methodology is visually depicted in Figure 8.

In essence we are using the extrapolated growth from permanent plots representing 376,882 acres in the 2019 growth estimate to estimate growth on temporary plots representing 304,615 acres. Likewise, within the 2019 inventory, the 2019 inventory panel permanent plots measured (no temporary plots measured in South Dakota in 2019 inventory panel) represent 10% of the acres for purposes of inventory, but 17% of the acres for purposes of growth. This is probably not as fatal as it sounds since, in the main, FIA strives to maintain each panel as a simple random sample. Nevertheless, the methodology leaves open the question of the applicability of the extrapolated growth estimate to the unmeasured temporary plots and the possibility for inaccurate growth estimates.

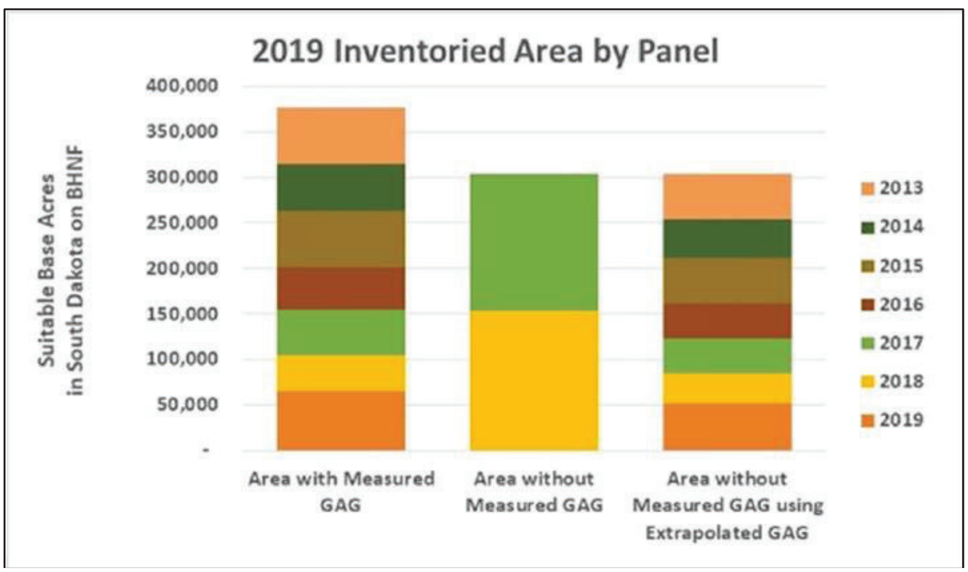


Figure 8. Visual depiction of 2019 online suitable base inventory in South Dakota's portion of BHNF, with direct measurements of gross annual growth and extrapolated measurements of gross annual growth and the source for those extrapolations.

While not definitive, one clue as to whether there could be extrapolation issues could be gained by comparing acres, volumes per acre, and distributions of acres between permanent and temporary plots in the 2019 online South Dakota BHNF inventory. This is done in Table 14.

Table 14. Comparison between permanent and temporary plot estimates in the 2019 online Evalidator inventory for South Dakota's portion of BHNF.

PLOTS by	Unit of	ALL PLOTS		Permanent Plots, 2013 to 2019				Temporary Plots, 2017-2018			
LIVE BA CLASS	Measure	Value	DIST	Value	DIST	CI - MIN	CI - MAX	Value	DIST	CI - MIN	CI - MAX
TOTAL	CCF/ACRE	7.25		7.24		6.63	7.84	7.26		6.60	7.92
0-40 sqft/ac	CCF/ACRE	1.83		1.86		1.56	2.16	1.79		1.48	2.10
41-80 sqft/ac	CCF/ACRE	7.66		8.02		7.42	8.62	7.21		6.55	7.87
81-120 sqft/ac	CCF/ACRE	10.45		9.61		8.19	11.03	11.48		10.11	12.84
120+ sqft/ac	CCF/ACRE	18.97		18.77		16.34	21.21	19.23		16.57	21.90
TOTAL	SE%	6.07		8.30				9.12			
0-40 sqft/ac	SE%	11.81		16.20				17.39			
41-80 sqft/ac	SE%	5.88		7.51				9.15			
81-120 sqft/ac	SE%	9.63		14.78				11.89			
120+ sqft/ac	SE%	9.46		12.99				13.86			
TOTAL	ACRES	681,497	100%	376,882	100%			304,615	100%		
0-40 sqft/ac	ACRES	249,929	37%	137,187	36%			112,742	37%		
41-80 sqft/ac	ACRES	229,170	34%	127,302	34%			101,868	33%		
81-120 sqft/ac	ACRES	130,737	19%	71,931	19%			58,806	19%		
120+ sqft/ac	ACRES	71,661	11%	40,463	11%			31,198	10%		

In general, there is no statistical difference at the 68% confidence level between permanent and temporary plots in terms of volume per acre and distribution of acres between live basal area classes with the single exception of volume per acre on the 81-120 sq ft basal area per acre plots. The fact there are not a significant number of differences between the permanent and temporary plots provides some hope the adjustments used to apply growth measurements from permanent plots to temporary plots have a degree of validity. However, there is evidence of a significant difference between permanent and temporary plots in the 81-120 sq ft class, and temporary plots in that class are carrying more volume per acre than the permanent plots. Presumably growth on these temporary plots would also be higher if it had been measured (more growing stock from which growth occurs) and so extrapolating the permanent plot estimates to that acreage, some 58,806 acres, could well result in an underestimate of forest growth.

That such adjustments are being made to the growth estimates by panel year is clear if reported gross growth by panel year is divided by panel year inventory acres (this includes both permanent and temporary acres for a panel year), which pushes growth per acre too high by panel year (see Figure 9; the data used to compute these per acre values is reported in Table 15) in a number years and too low in several others. When the adjustments indicated by the ratio-based estimate are applied the growth rate by panel is much more logical compared to past growth rate measurements.

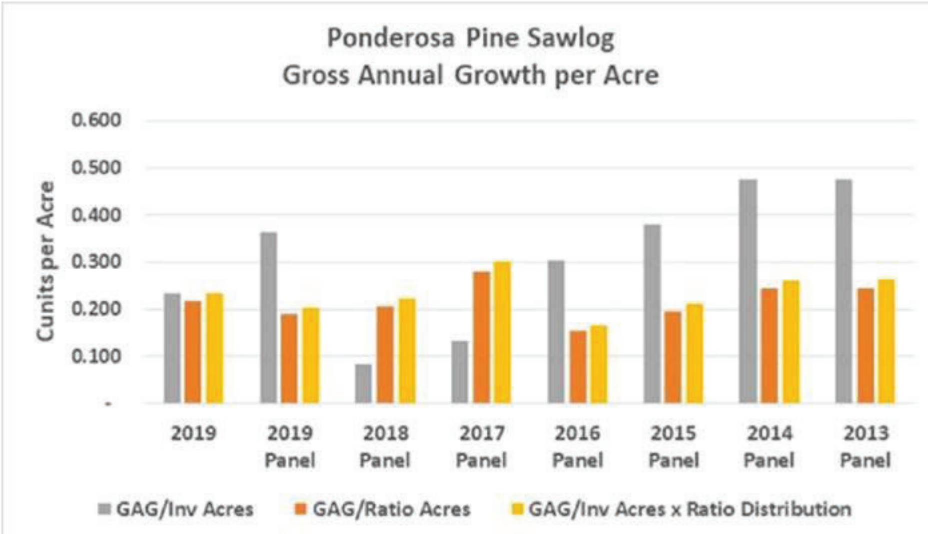


Figure 9. Comparison of gross growth per acre with and without FIA adjustments for no growth measured on temporary plots.

Table 15. BHNF's South Dakota 2019 online Evalidator estimates of gross annual growth on suitable base acres and suitable base acreage estimates.

	2019	2019 Panel	2018 Panel	2017 Panel	2016 Panel	2015 Panel	2014 Panel	2013 Panel
Reported GAG - Cunits	158,449	23,829	16,076	26,760	13,910	23,576	24,815	29,483
Various Suitable Base Acres used to Compute Gross Growth per Acre estimates								
Inventory Acres	681,498	65,316	193,198	201,141	45,879	62,050	52,064	61,850
Ratio* Acres	733,122	125,697	77,653	95,632	90,900	120,561	102,205	120,474
Inventory Acres x Ratio Distribution	681,498	116,846	72,185	88,898	84,499	112,071	95,008	111,991

*Acres reported by FIA Ratio Query for Gross Annual Growth (GAG) per acre. Those acres based on mid-point acreage for each growth plot processed between current and prior measurement.

When there are no temporary plots, no further adjustments are necessary; all inventory plots measured were also remeasured as growth plots. This is readily apparent when looking at Table 16 where 2016 information is summarized in a similar format to the data in 2019. There the ratio between the "growth" expansion acres and the "inventory" expansion acres is 1.00, not 1.81 as was seen for 2019's data.

Table 16. In-depth comparison of BHNF's 2016 South Dakota ponderosa pine gross annual growth ("GAG"), and suitable base acres reported as part of FIA Evalidator ratio queries and independently-queried suitable base acres (not part of ratio query).

METRIC DESCRIPTION	UNITS	REPORTED 2016	PLOT TYPE	INVENTORY PANEL 2016	2015	2014	2013	2012	2011
Suitable Base	CCF/AC	0.232	TOTAL	0.146	0.197	0.247	0.281	0.258	0.214
Ponderosa Pine	CCF/AC	0.232	PERMANENT	0.146	0.197	0.247	0.281	0.258	0.214
Net Sawlog GAG	CCF/AC	-	TEMPORARY	-	-	-	-	-	-
QUERY COMPONENTS supplied by FIA EVALIDATOR to COMPUTE RATIO ESTIMATE REPORTED ABOVE									
Suitable Base	CCF	169,748	TOTAL	13,243	23,060	25,385	50,657	34,983	22,419
Ponderosa Pine	CCF	169,748	PERMANENT	13,243	23,060	25,385	50,657	34,983	22,419
Net Sawlog GAG	CCF	-	TEMPORARY	-	-	-	-	-	-
NOTE from FIA Evalidator when computing RATIO metric									
This ratio estimate is based on the plot area that was timberland at both the beginning and end of the remeasurement period. This provides a more realistic ratio estimate of the actual change component (growth, removals, mortality) that has occurred on lands that remain in the timberland base.									
Suitable Base Area	ACRES	731,499	TOTAL	90,771	117,188	102,616	180,570	135,655	104,699
	ACRES	731,499	PERMANENT	90,771	117,188	102,616	180,570	135,655	104,699
	ACRES	-	TEMPORARY	-	-	-	-	-	-
Distribution of ACRES by PANEL		100%		12%	16%	14%	25%	19%	14%

METRIC DESCRIPTION	UNITS	REPORTED 2016	PLOT TYPE	2016	2015	2014	2013	2012	2011
Independently	ACRES	729,996	TOTAL	90,514	116,904	102,362	180,215	135,564	104,437
Queried*	ACRES	729,996	PERMANENT	90,514	116,904	102,362	180,215	135,564	104,437
Suitable Base Area	ACRES	-	TEMPORARY	-	-	-	-	-	-
Distribution of ACRES by PANEL		100%		12%	16%	14%	25%	19%	14%
2019 Acres Re-Distributed by Panel Year based on Mid-Point Year Distribution per Panel Year		729,996		90,584	116,947	102,405	180,199	135,376	104,484
Permanent Plot Weight for GAG		1.00		1.00	1.00	1.00	1.00	1.00	1.00

*Not part of a Ratio query

DATA SOURCE: USFS FIA Evalidator data retrievals of 2016 online data

The key takeaways from this discussion include the apparent issues with inventory plot expansions and the realization there is a different set of plot expansions for growth estimates when temporary plots are introduced; confidence in growth calculations must remain low until both sets of expansions are demonstrably corrected. A second takeaway is the importance of the permanent plot estimates of forest condition being an accurate representation of the temporary plot estimates of forest condition since permanent plot growth is extrapolated to temporary plots. To the degree that is not the case, forest-wide growth estimates will be inaccurate.

A possible rejoinder to all of this might be that the augmented data set eliminates these issues. We, on the other hand, believe the augmented data set could make the issues worse. While the augmented data set does not provide for ratio estimates using growth we can apply the general methodology described above and utilized by the FIA's ratio computations to the data provided in the augmented data set. We do not have access to the "midpoint" acreages but can compute the general ratio that would be applied – in this case 653,753 suitable base acres in the augmented data set for South Dakota[32] divided by the acreage represented by permanent plots for South Dakota, or 350,467, for a ratio of 1.865. This means for the 303,286 acres represented by temporary plots measured in 2017 and 2018, 76% of those acres have growth extrapolated from permanent plots measured in 2019, 10% of those acres have growth extrapolated from permanent plots measured in 2018, and 13% of those acres have growth extrapolated from permanent plots measured in 2017. A visual depiction of this is shown in Figure 10, adding the augmented data portrayal into the earlier portrayal seen in Figure 8 with online 2019 data only.

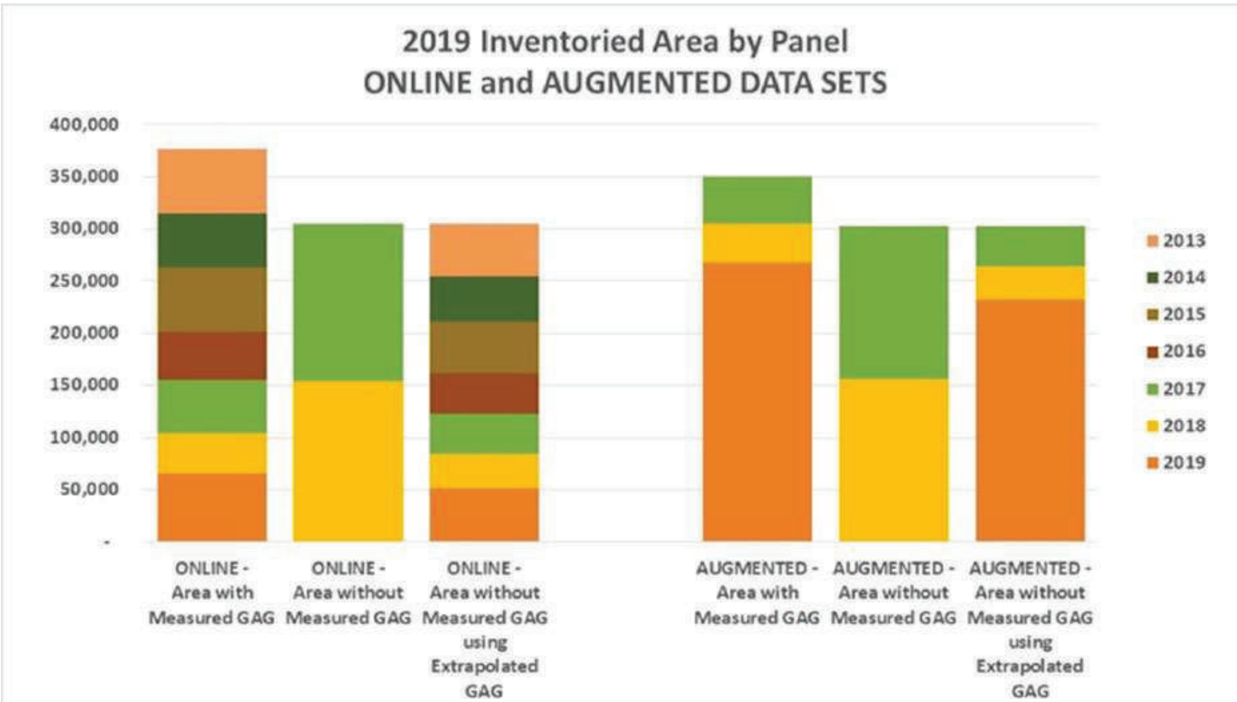


Figure 10. Visual depiction of 2019 online and augmented suitable base inventory in South Dakota's portion of BHNF with direct measurements of gross annual growth and extrapolated measurements of gross annual growth and the source for those extrapolations.

Table 17 compares permanent and temporary plots for the augmented South Dakota inventory. There are no statistically significant differences between permanent and temporary plot estimates of ponderosa pine sawlog volume per acre by basal area class. However, there are some close calls in terms of volume per acre across all classes and volume per acre in the 81-120 sq ft basal area class.

For the volume per acre in all classes the permanent plot average is 6.83 CCF per acre compared to 7.24 CCF per acre for temporary plots. For the 2019 data this result was 7.24 CCF per acre for permanent plots vs. 7.26 CCF per acre for temporary plots. However, for the augmented data set the confidence intervals do overlap at 68% confidence, so no significant statistical difference.

[32] We decided to not include the Wyoming portion of the acres here to both simplify the comparison between the online and local version and because in the Wyoming augmented data there are 15 temporary plots reported in years 2011-2016 (see Table 2). We are unsure of why that would be the case and to reduce complications decided to not include Wyoming acres in this part of the analysis.

For the volume per acre in the 81-1210 sq ft basal area class the permanent plot average is 9.28 CCF per acre compared to 11.16 CCF per acre for temporary plots. The confidence intervals overlap at 68% confidence in the augmented data set; in the online data set this class was statistically different at the 68% confidence level: 9.61 CCF per acre for permanent and 11.48 CCF per acre for temporary (see Table 14).

Also noteworthy, the percent distribution of acres for the 80-120 sq ft basal area class is lower in permanent plots compared to temporary plots, 16% vs 21%, respectively. Looking at standard errors around the total acres and 81-120 sq ft basal area acres classes indicates this difference is not statistically different either. However, what is worth noting is all the errors, although not statistically different, are all in one direction, and the largest error source affects one-fifth of the area and a much higher proportion of the inventory where growth would occur. This might indicate applying the growth from the permanent plots to the temporary plots in this case may not be applying a representative estimate of growth and the estimate of growth being applied is probably too low for the forest conditions represented by the temporary plots.

Also recall that, for the 2019 plot remeasurements the plots last measured in 2015 and 2016 would have shorter than the typical seven-year remeasurement cycle, and so any field measurement errors could be magnified because of the shorter remeasurement periods. The fact that growth from 2019 remeasured plots represents a sizeable portion of the growth being reported in the augmented inventory further amplifies that possible error.

Table 17. Comparison between permanent and temporary plot estimates in the 2019 augmented Evalidator inventory for South Dakota's portion of BHNF.

PLOTS by	Unit of	ALL PLOTS		Permanent Plots, 2013 to 2019				Temporary Plots, 2017-2018			
LIVE BA CLASS	Measure	Value	DIST	Value	DIST	CI - MIN	CI - MAX	Value	DIST	CI - MIN	CI - MAX
TOTAL	CCF/ACRE	7.02		6.83		6.27	7.39	7.24		6.59	7.89
0-40 sqft/ac	CCF/ACRE	1.81		1.86		1.59	2.13	1.74		1.43	2.05
41-80 sqft/ac	CCF/ACRE	7.33		7.63		7.04	8.22	6.97		6.40	7.55
81-120 sqft/ac	CCF/ACRE	10.25		9.28		7.80	10.76	11.16		9.86	12.47
120+ sqft/ac	CCF/ACRE	18.22		17.70		15.64	19.77	18.88		16.28	21.48
TOTAL	SE%	5.98		8.15				8.95			
0-40 sqft/ac	SE%	11.21		14.48				17.86			
41-80 sqft/ac	SE%	5.69		7.73				8.28			
81-120 sqft/ac	SE%	9.72		15.92				11.69			
120+ sqft/ac	SE%	8.99		11.65				13.78			
TOTAL	ACRES	653,753	96%	350,467	93%			303,286	100%		
0-40 sqft/ac	ACRES	240,224	35%	133,674	35%			106,550	35%		
41-80 sqft/ac	ACRES	218,290	32%	117,312	31%			100,978	33%		
81-120 sqft/ac	ACRES	125,603	18%	60,716	16%			64,887	21%		
120+ sqft/ac	ACRES	69,636	10%	38,764	10%			30,871	10%		

Finally, this table again reminds us there are some 80,000 acres unaccounted for in the augmented inventory on the suitable base acres for South Dakota (approximately 733,000 acres minus approximately 654,000 acres). Flawed expansion of the base inventory, application of a different set of expansions for growth from presumably the same flawed expansion methodology, and extrapolation of those results to temporary plots which may be reflecting dissimilar forest conditions from the forest conditions measured to produce the growth estimates do not confer confidence on the reliability of the growth estimate.

The next observation is that the 2019 online estimates for GAG/acre and GAG %INV, whether generated using ratio estimates or computed using stand-alone results, are substantially higher than the augmented 2019 inventory data estimates. Online GAG/Acre stand-alone and ratio estimates are 36% and 27% greater than augmented GAG/Acre estimate, respectively, with the average of the two online 2019 estimates being 0.224 CCF per acre compared to 0.171 CCF per acre for the augmented 2019 data set. Online GAG %INV stand-alone and ratio estimates are 32% and 25% greater than augmented GAG %INV estimate, respectively, with the average of the two online 2019 estimates being 3.12% compared to 2.43% for the augmented 2019 data set.

The argument in favor of the lower augmented data set GAG estimates being superior to the online 2019 data is that the augmented estimates are based on "more" and "better" data. As has already been pointed out (Section 3.2.5), while having more data may improve precision, higher precision does not necessarily translate into higher accuracy. We have highlighted what we contend are serious concerns regarding expansion factors that call into question the "better" argument.

FIA maintains that each "expanded" inventory panel represents a random sample but its precision is much lower than the entire estimate due to lower sampling intensity in the inventory panel than the multiple-year collection of data observations in the complete estimate. However, because an inventory panel does represent a random sample we could treat each inventory panel as an observation but in this case the observation is an average (a "mean"). Analyzing sample means as observations is a statistical methodology to gain insights from relatively few "observations" because the variance of sample means drawn from a common population are typically less variable than the variance in the population itself.

Table 18 provides an example of how such data might be generated and highlights several prior points we have made; it is a small selection of the full set of data presented in Tables 19, 20, and 21. Table 18 contrasts the full inventory for the consecutive inventory years 2014 to 2018 and the measurements for a single inventory panel utilized in those consecutive inventory years. As can be seen, the estimate of GAG remains relatively consistent over time the five-year time period 2014 to 2018.

The acres and inventory for the panel are also relatively stable 2014 to 2016 but then start to change dramatically in 2017 and 2018 when temporary plots are introduced. This underscores the fact that with the introduction of temporary plots, the expansion factors used for acres and inventory diverge from the expansion factors used for GAG. We would observe that the ratio estimates presented in Table 12 for GAG/Acre and GAG %INV for the 2014 panel year essentially agree with the 2014 panel year data in Table 18. This is why we previously stated the ratio estimates developed directly by the FIA Evalidator program provide more accurate estimates when a mix of permanent and temporary plots are being used rather than comparing stand-alone results.

While the results computing GAG %INV for a single panel year in a single inventory year cannot be interpreted in isolation, the single panel results can be interpreted as an unbiased observation for a panel year's data within the context of an entire inventory. Table 22 assembles these observations into averages and medians, both across inventory years and across all inventory panel observations. The average GAG %INV for roughly the past decade is 2.94% and a median of 2.94%; the SE% is 2.5% (i.e. +/- 0.07% at 68% confidence). The average of all inventory panels is 3.01% and a median of 3.47%; the SE% is 10.43% (i.e. +/- 0.31% at 68% confidence). Using both the inventories and inventory panels as observations yields an average of 2.98% and a median of 3.04%; the SE% is 5.72% (i.e. +/- 0.17% at 68% confidence).

The conclusion is a GAG rate of 3% is much more defensible as long-term estimate of GAG than the 2.5% that was computed using the 2019 augmented data set. As has been seen, the expansion factors for both inventory and GAG are suspect in that estimate. The 3% GAG %INV factor is grounded on multiple recent observations and mitigates the effects of what we suspect is an incorrect plot expansion calculation. In addition, the 2019 online ratio estimate of GAG, which is based on an acreage that aligns with the NEPA-approved suitable base acres, is 3.04%. Both of these estimates are for South Dakota acres only, and the augmented data set, even with its deficiencies, does indicate that GAG %INV on Wyoming suitable base acres is higher than the South Dakota GAG %INV – which means a 3% growth rate is likely conservative.

Table 18. BHNF South Dakota selected inventory data for 2014-2018 inventories and the 2014 panel year.

Inventory Year	Inventory					2014 Panel Year				
	Acres	GAG[2]	Inventory[2]	GAG[2]/Acre	GAG %INV	Acres	GAG[2]	Inventory[2]	GAG[2]/Acre	GAG %INV
2014	732,231	187,510	6,442,948	0.256	2.91%	102,082	25,285	826,211	0.248	3.06%
2015	729,996	179,086	5,958,785	0.245	3.01%	102,362	25,385	793,792	0.248	3.20%
2016	729,996	169,748	5,874,722	0.233	2.89%	102,362	25,385	793,792	0.248	3.20%
2017 [1]	707,583	174,224	5,508,452	0.246	3.16%	69,371	24,394	544,639	0.258	3.39%
2018 [1]	681,382	168,800	5,104,329	0.248	3.31%	51,646	25,627	400,417	0.268	3.57%

[1]includes both permanent and temporary (supplemental) plots
[2]CCF

Table 19. Comparison of various FIA inventory estimates and their expansion factors.

2012 - 2019's PONDEROSA PINE SAWLOG INVENTORY, GROSS ANNUAL GROWTH, and MORTALITY on BLACK HILLS NATIONAL FOREST's SUITABLE BASE in SOUTH DAKOTA

				INVENTORY "PANEL" - Data Collection Field Season														
YEAR	METRIC	UNITS	PLOT TYPE	TOTAL	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
2010	SBAC	ACRES	PERMANENT	736,363										156,862	147,439	177,460	140,003	114,599
	PP SWLG INV	CCF	PERMANENT	6,969,904										1,107,646	1,391,503	1,690,614	1,388,086	1,392,054
	PP SWLG GAG	CCF	PERMANENT	196,136										33,875	42,258	57,655	34,107	28,242
	PP SWLG MRT	CCF	PERMANENT	78,291										26,841	5,329	8,666	23,380	14,075
	PP GAG/AC	CCF/AC	PERMANENT	0.266										0.216	0.287	0.325	0.244	0.246
	PP GAG %	% of INV	PERMANENT	2.81%										3.06%	3.04%	3.41%	2.46%	2.03%
	PP MRT/AC	CCF/AC	PERMANENT	0.106										0.171	0.036	0.049	0.167	0.123
	PP MRT %	% of INV	PERMANENT	1.12%										2.42%	0.38%	0.51%	1.68%	1.01%
2011	SBAC	ACRES	PERMANENT	736,623									114,122	155,769	148,552	178,753	139,427	
	PP SWLG INV	CCF	PERMANENT	6,738,723									1,135,641	1,103,935	1,404,255	1,705,384	1,389,508	
	PP SWLG GAG	CCF	PERMANENT	195,075									26,526	33,821	42,699	57,889	34,140	
	PP SWLG MRT	CCF	PERMANENT	81,685									17,460	26,697	5,275	8,942	23,311	
	PP GAG/AC	CCF/AC	PERMANENT	0.265									0.232	0.217	0.287	0.324	0.245	
	PP GAG %	% of INV	PERMANENT	2.89%									2.34%	3.06%	3.04%	3.39%	2.46%	
	PP MRT/AC	CCF/AC	PERMANENT	0.111									0.153	0.171	0.036	0.050	0.167	
	PP MRT %	% of INV	PERMANENT	1.21%									1.54%	2.42%	0.38%	0.52%	1.68%	
2012	SBAC	ACRES	PERMANENT	733,782								138,864	113,782	155,823	147,721	177,592		
	PP SWLG INV	CCF	PERMANENT	6,294,472								1,025,363	1,124,394	1,091,814	1,383,514	1,669,386		
	PP SWLG GAG	CCF	PERMANENT	193,223								35,079	26,156	33,292	41,974	56,721		
	PP SWLG MRT	CCF	PERMANENT	97,680								39,832	17,436	26,537	5,275	8,600		
	PP GAG/AC	CCF/AC	PERMANENT	0.263								0.253	0.230	0.214	0.284	0.319		
	PP GAG %	% of INV	PERMANENT	3.07%								3.42%	2.33%	3.05%	3.03%	3.40%		
	PP MRT/AC	CCF/AC	PERMANENT	0.133								0.287	0.153	0.170	0.036	0.048		
	PP MRT %	% of INV	PERMANENT	1.55%								3.88%	1.55%	2.43%	0.38%	0.52%		
2013	SBAC	ACRES	PERMANENT	733,571							177,579	138,413	113,996	155,985	147,598			
	PP SWLG INV	CCF	PERMANENT	6,281,769							1,655,317	1,022,169	1,124,944	1,092,876	1,386,462			
	PP SWLG GAG	CCF	PERMANENT	186,077							49,435	34,971	26,296	33,315	42,059			
	PP SWLG MRT	CCF	PERMANENT	112,414							23,810	39,583	17,403	26,377	5,241			
	PP GAG/AC	CCF/AC	PERMANENT	0.254							0.278	0.253	0.231	0.214	0.285			
	PP GAG %	% of INV	PERMANENT	2.96%							2.99%	3.42%	2.34%	3.05%	3.03%			
	PP MRT/AC	CCF/AC	PERMANENT	0.153							0.134	0.286	0.153	0.169	0.036			
	PP MRT %	% of INV	PERMANENT	1.79%							1.44%	3.87%	1.55%	2.41%	0.38%			
2014	SBAC	ACRES	PERMANENT	732,231						102,082	179,949	136,556	114,181	153,471	45,992			
	PP SWLG INV	CCF	PERMANENT	6,442,948						826,211	1,740,522	1,045,993	1,189,314	1,078,937	561,972			
	PP SWLG GAG	CCF	PERMANENT	187,510						25,285	50,691	35,379	26,143	33,614	16,398			
	PP SWLG MRT	CCF	PERMANENT	153,346						43,563	26,026	39,209	16,875	25,767	1,905			
	PP GAG/AC	CCF/AC	PERMANENT	0.256						0.248	0.282	0.259	0.229	0.219	0.357			
	PP GAG %	% of INV	PERMANENT	2.91%						3.06%	2.91%	3.38%	2.20%	3.12%	2.92%			
	PP MRT/AC	CCF/AC	PERMANENT	0.209						0.427	0.145	0.287	0.148	0.168	0.041			
	PP MRT %	% of INV	PERMANENT	2.38%						5.27%	1.50%	3.75%	1.42%	2.39%	0.34%			

Table 20. Comparison of various FIA inventory estimates and their expansion factors.

2012 - 2019's PONDEROSA PINE SAWLOG INVENTORY, GROSS ANNUAL GROWTH, and MORTALITY on BLACK HILLS NATIONAL FOREST's SUITABLE BASE in SOUTH DAKOTA

				INVENTORY "PANEL" - Data Collection Field Season														
YEAR	METRIC	UNITS	PLOT TYPE	TOTAL	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
2015	SBAC	ACRES	PERMANENT	729,996					116,904	102,362	180,215	135,564	114,023	80,928				
	PP SWLG INV	CCF	PERMANENT	5,958,785					853,079	793,792	1,632,067	1,014,837	1,189,746	475,264				
	PP SWLG GAG	CCF	PERMANENT	179,086					23,060	25,385	50,657	34,983	26,007	18,994				
	PP SWLG MRT	CCF	PERMANENT	185,875					35,328	44,662	26,059	38,624	16,585	24,618				
	PP GAG/AC	CCF/AC	PERMANENT	0.245					0.197	0.248	0.281	0.258	0.228	0.235				
	PP GAG %	% of INV	PERMANENT	3.01%					2.70%	3.20%	3.10%	3.45%	2.19%	4.00%				
	PP MRT/AC	CCF/AC	PERMANENT	0.255					0.302	0.436	0.145	0.285	0.145	0.304				
	PP MRT %	% of INV	PERMANENT	3.12%					4.14%	5.63%	1.60%	3.81%	1.39%	5.18%				
2016	SBAC	ACRES	PERMANENT	729,996				90,514	116,904	102,362	180,215	135,564	104,437					
	PP SWLG INV	CCF	PERMANENT	5,874,722				510,659	853,079	793,792	1,632,067	1,014,837	1,070,288					
	PP SWLG GAG	CCF	PERMANENT	169,748				13,243	23,060	25,385	50,657	34,983	22,419					
	PP SWLG MRT	CCF	PERMANENT	185,332				24,743	35,328	44,662	26,059	38,624	15,917					
	PP GAG/AC	CCF/AC	PERMANENT	0.233				0.146	0.197	0.248	0.281	0.258	0.215					
	PP GAG %	% of INV	PERMANENT	2.89%				2.59%	2.70%	3.20%	3.10%	3.45%	2.09%					
	PP MRT/AC	CCF/AC	PERMANENT	0.254				0.273	0.302	0.436	0.145	0.285	0.152					
	PP MRT %	% of INV	PERMANENT	3.15%				4.85%	4.14%	5.63%	1.60%	3.81%	1.49%					
2017	SBAC	ACRES	PERMANENT	503,730			63,147	63,066	85,528	69,371	122,797	91,922	7,899					
			PERM + SUPP	707,583			267,000	63,066	85,528	69,371	122,797	91,922	7,899					
	PP SWLG INV	CCF	PERMANENT	4,043,218			577,627	361,185	691,047	544,639	1,098,793	681,240	88,686					
			PERM + SUPP	5,508,452			2,042,861	361,185	691,047	544,639	1,098,793	681,240	88,686					
	PP SWLG GAG	CCF	PERMANENT	174,224			25,490	14,396	24,394	25,153	50,279	35,232	-720					
			PERM + SUPP	174,224			25,490	14,396	24,394	25,153	50,279	35,232	-720					
	PP SWLG MRT	CCF	PERMANENT	175,490			17,525	22,574	35,227	32,226	25,618	39,298	3,023					
			PERM + SUPP	175,490			17,525	22,574	35,227	32,226	25,618	39,298	3,023					
	PP GAG/AC	CCF/AC	PERMANENT	0.346			0.404	0.228	0.285	0.363	0.409	0.383	-0.091					
			PERM + SUPP*	0.246			0.287	0.163	0.203	0.258	0.291	0.273	-0.065					
	PP GAG %	% of INV	PERMANENT	4.31%			4.41%	3.99%	3.53%	4.62%	4.58%	5.17%	-0.81%					
			PERM + SUPP*	3.16%			3.24%	2.93%	2.59%	3.39%	3.36%	3.80%	-0.60%					
	PP MRT/AC	CCF/AC	PERMANENT	0.348			0.278	0.358	0.412	0.465	0.209	0.428	0.383					
			PERM + SUPP*	0.248			0.198	0.255	0.293	0.331	0.149	0.304	0.272					
	PP MRT %	% of INV	PERMANENT	4.34%			3.03%	6.25%	5.10%	5.92%	2.33%	5.77%	3.41%					
			PERM + SUPP*	2.34%			0.63%	4.59%	3.74%	4.34%	1.71%	4.23%	2.50%					

The PERM+SUPP computations include adjustments consistent with FIA ratio estimators to account for no growth or mortality measurements on supplemental (temporary) plots.

Table 21. Comparison of various FIA inventory estimates and their expansion factors.

2012 - 2019's PONDEROSA PINE SAWLOG INVENTORY, GROSS ANNUAL GROWTH, and MORTALITY on BLACK HILLS NATIONAL FOREST's SUITABLE BASE in SOUTH DAKOTA

				INVENTORY "PANEL" - Data Collection Field Season														
YEAR	METRIC	UNITS	PLOT TYPE	TOTAL	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
2018	SBAC	ACRES	PERMANENT	368,602		38,487	47,382	45,779	59,543	51,646	91,127	34,638						
			PERM + SUPP	681,382		196,633	202,016	45,779	59,543	51,646	91,127	34,638						
	PP SWLG INV	CCF	PERMANENT	2,847,797		247,292	438,469	259,426	438,116	400,417	826,422	237,656						
			PERM + SUPP	5,104,329		1,391,017	1,551,277	259,426	438,116	400,417	826,422	237,656						
	PP SWLG GAG	CCF	PERMANENT	168,800		15,629	25,187	12,899	22,847	25,627	50,502	16,109						
			PERM + SUPP	168,800		15,629	25,187	12,899	22,847	25,627	50,502	16,109						
	PP SWLG MRT	CCF	PERMANENT	196,240		26,168	18,080	25,071	34,053	47,718	26,159	18,990						
			PERM + SUPP	196,240		26,168	18,080	25,071	34,053	47,718	26,159	18,990						
	PP GAG/AC	CCF/AC	PERMANENT	0.458		0.406	0.532	0.282	0.384	0.496	0.554	0.465						
			PERM + SUPP*	0.248		0.220	0.288	0.152	0.208	0.268	0.300	0.252						
	PP GAG %	% of INV	PERMANENT	5.93%		6.32%	5.74%	4.97%	5.21%	6.40%	6.11%	6.78%						
			PERM + SUPP*	3.31%		3.53%	3.20%	2.77%	2.91%	3.57%	3.41%	3.78%						
	PP MRT/AC	CCF/AC	PERMANENT	0.532		0.680	0.382	0.548	0.572	0.924	0.287	0.548						
			PERM + SUPP*	0.288		0.368	0.206	0.296	0.309	0.500	0.155	0.297						
	PP MRT %	% of INV	PERMANENT	6.89%		10.58%	4.12%	9.66%	7.77%	11.92%	3.17%	7.99%						
			PERM + SUPP*	2.14%		1.05%	0.65%	5.39%	4.34%	6.65%	1.77%	4.46%						
2019	SBAC	ACRES	PERMANENT	350,467	268,006	36,713	45,748											
			PERM + SUPP	653,753	268,006	192,739	193,008											
	PP SWLG INV	CCF	PERMANENT	2,393,516	1,735,658	237,928	419,930											
			PERM + SUPP	4,589,954	1,735,658	1,384,354	1,469,942											
	PP SWLG GAG	CCF	PERMANENT	111,578	73,372	14,154	24,052											
			PERM + SUPP	111,578	73,372	14,154	24,052											
	PP SWLG MRT	CCF	PERMANENT	154,587	115,263	20,790	18,534											
			PERM + SUPP	154,587	115,263	20,790	18,534											
	PP GAG/AC	CCF/AC	PERMANENT	0.318	0.274	0.386	0.526											
			PERM + SUPP*	0.171	0.147	0.207	0.282											
	PP GAG %	% of INV	PERMANENT	4.66%	4.23%	5.95%	5.73%											
			PERM + SUPP*	2.43%	2.20%	3.10%	2.99%											
	PP MRT/AC	CCF/AC	PERMANENT	0.441	0.430	0.566	0.405											
			PERM + SUPP*	0.236	0.231	0.304	0.217											
	PP MRT %	% of INV	PERMANENT	6.46%	6.64%	8.74%	4.41%											
			PERM + SUPP*	1.76%	3.46%	0.78%	0.66%											

The PERM+SUPP computations include adjustments consistent with FIA ratio estimators to account for no growth or mortality measurements on supplemental (temporary) plots.

Table 22. Comparison of various FIA inventory estimates and their expansion factors.

2012 - 2019's PONDEROSA PINE SAWLOG INVENTORY, GROSS ANNUAL GROWTH, and MORTALITY on BLACK HILLS NATIONAL FOREST's SUITABLE BASE in SOUTH DAKOTA

									INVENTORY "PANEL" - Data Collection Field Season									
YEAR	METRIC	UNITS	PLOT TYPE	TOTAL	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
AVERAGE by INVENTORY PANEL & YEAR																		
2006	PP GAG %	% of INV	ALL															2.03%
2007			ALL														2.46%	
2008			ALL													3.40%		
2009			ALL												3.01%			
2010			ALL	2.81%										3.22%				
2011			ALL	2.89%									1.84%					
2012			ALL	3.07%								3.53%						
2013			ALL	2.96%							3.15%							
2014			ALL	2.91%						3.28%								
2015			ALL	3.01%					2.73%									
2016			ALL	2.89%				2.76%										
2017			ALL	3.16%			3.14%											
2018			ALL	3.31%		3.31%												
2019			ALL	2.43%	2.20%													
INVENTORY YEAR STATISTICS				2.94%	= AVERAGE		2.94%	= MEDIAN		3.31%	= MAXIMUM		2.43%	= MINIMUM		2.50%	= SE %	
INVENTORY PANEL STATISTICS				2.86%	= AVERAGE		3.14%	= MEDIAN		3.53%	= MAXIMUM		1.84%	= MINIMUM		5.09%	= SE %	
INVENTORY YEAR and PANEL STATISTICS				2.90%	= AVERAGE		3.01%	= MEDIAN		3.53%	= MAXIMUM		1.84%	= MINIMUM		2.95%	= SE %	
2006	PP MRT %	% of INV	ALL															1.01%
2007			ALL														1.68%	
2008			ALL													0.52%		
2009			ALL												0.37%			
2010			ALL	1.12%										2.88%				
2011			ALL	1.21%									1.63%					
2012			ALL	1.55%								3.97%						
2013			ALL	1.79%							1.60%							
2014			ALL	2.38%						5.50%								
2015			ALL	3.12%					4.09%									
2016			ALL	3.15%				4.94%										
2017			ALL	2.34%			0.65%											
2018			ALL	2.14%		0.92%												
2019			ALL	1.76%	3.46%													
INVENTORY YEAR STATISTICS				2.06%	= AVERAGE		1.97%	= MEDIAN		3.15%	= MAXIMUM		1.12%	= MINIMUM		10.90%	= SE %	
INVENTORY PANEL STATISTICS				2.37%	= AVERAGE		2.25%	= MEDIAN		5.50%	= MAXIMUM		0.37%	= MINIMUM		22.22%	= SE %	
INVENTORY YEAR and PANEL STATISTICS				2.24%	= AVERAGE		1.97%	= MEDIAN		5.50%	= MAXIMUM		0.37%	= MINIMUM		12.78%	= SE %	

3.4 Growth estimates derived from FVS forest growth simulations

3.4.1 FVS growth and yield model, and FIA-based data inputs

Forest growth simulation provides an alternative approach, separate from the FIA growth estimates, to evaluating the long-term productivity of BHNF timberlands. The benefit of a forest simulation approach is that it provides an independent estimate of forest productivity, based on biological site potential, and observed long-term forest growth across a range of temporal conditions.

The USFS maintains a forest growth simulation model referred to as the Forest Vegetation Simulator (FVS) (Dixon, 2002), which has been continually refined and updated for over 40 years. The growth prediction algorithms within FVS are based on measured tree growth gathered over a wide range of site, stand, and temporal conditions, and as such provide a good basis for estimating long-term forest growth. FVS relies on measured tree and site data as inputs, and is widely used by forest managers throughout the US and Canada for simulating the future growth and management of forest stands.

The USFS also provides a utility program, called FIA2FVS, that translates FIA sample data into a format suitable for use in the FVS growth projection model.

A request was made to the USFS to provide FVS-ready input data, generated via the FIA2FVS utility, for the 2017-2019 BHNF augmented FIA inventory dataset. It was hoped that the FVS growth analysis could be completed prior to the 3/27/20 deadline for draft presentation submissions for the 4/3/20 BHNF stakeholder meeting, but that goal was unattainable. Creation of the FVS-ready dataset was delayed by four factors:

1. We postponed our request for the database until after receiving an initial response from the USFS FIA staff concerning acreage concerns on the augmented BHNF dataset.
2. The FIA2FVS program is in the final stages of a major revision.
3. The format of the augmented BHNF FIA dataset is incompatible with the standard input format for the FIA2FVS program.
4. COVID-19 impacts on normal USFS workflows.

John Shaw, with the USFS Interior West Forest Inventory and Analysis Unit (IW-FIA), in Ogden, Utah conducted some custom programming work to generate FVS-ready inputs from the atypical data format of the 2017-2019 BHNF augmented FIA inventory dataset. The FIA2FVS database was received on 3/25/2020.

3.4.2 Plot-level versus condition-level FIA data

The FIA2FVS database discussed in the previous section contains FVS inputs for conducting growth simulations at both the plot level, and the condition level. To understand the difference between plot-level and condition-level simulations, it is important to recognize that an FIA forest sample point is not a single plot, but rather is comprised of four separate subplots, arranged in a pre-defined orientation (subplot 1 is the center of the cluster with subplots 2, 3, and 4 located 120 feet away at azimuths of 360°, 120°, and 240°, respectively). Because the sample point has four separate subplots, it is possible for the subplots to span two or more conditions, defined by FIA as follows:

> Conditions are defined by changes in land use or changes in vegetation that occur along more-or-less distinct boundaries. Reserved status, owner group, forest type, stand-size class, regeneration status, and stand density are used to define forest conditions. For example, the subplots may cover forest and nonforest areas, or it may cover a single forested area that can be partitioned into two or more distinct stands. Although mapping is used to separate forest and nonforest conditions, different nonforest conditions occurring on a plot are not mapped during initial plot establishment. Each condition occurring on the plot is assigned a condition proportion, and all conditions on a plot add up to 1.0. For plot designs other than the mapped design, condition proportion is always equal to 1.0 in FIADB.

Figure 11 shows an example of a single FIA sample point spanning three separate forest conditions.

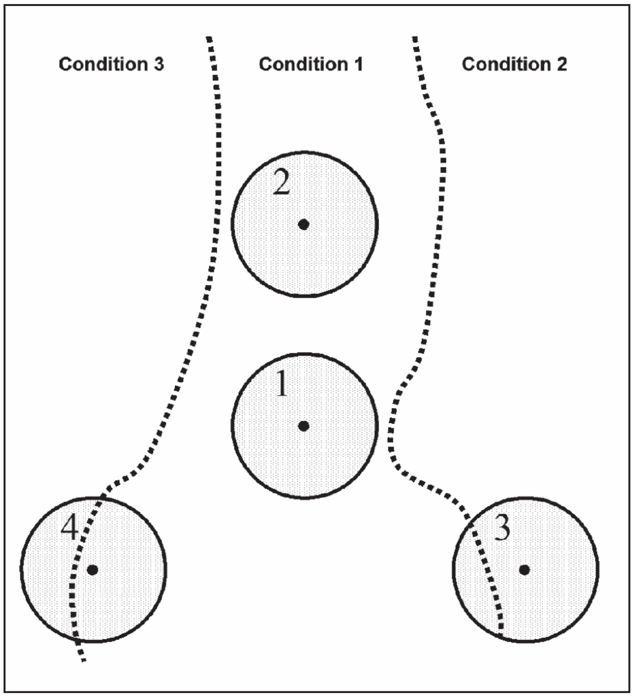


Figure 11. FIA sample plot schematic, showing three forest conditions occurring at a single sample point (from: Burrill et al. 2018).

When an FIA sample point spans two or more conditions, the results from the sample point are pro-rated according to the subplot conditions. Say, for example, that two subplots for an FIA sample point fell outside the BHNF boundary. In such a case, the volume that the sample point represents is apportioned between the USFS and non-USFS ownerships. Similarly, the USFS acreage that the sample point represents would be decreased by half.

3.4.3 Implications for the Suitable Base data field being incorrectly applied at the plot level

The concept of plot "conditions" discussed in the previous section becomes important because it impacts many of the FIA inventory and acreage calculations. When selecting (or "filtering") FIA data by certain land characteristics, the filtering is done at the subplot level. For example, when selecting FIA plots for the estimation of forest inventory on timberlands, the following filtering is applied:

1) Subplot condition status is accessible forest land (COND.COND_STATUS_CD=1), AND
2) Subplot condition is non-reserved land (COND.RESERVCD = 0), AND
3) Subplot timber growth potential is at least 20 CuFt/ac/yr (COND.SITECLCD <7)

Note that all three of the above attributes vary at the condition (subplot) level, as opposed to the plot level. It is possible for individual subplots to vary by timberland versus non-timberland status, and thereby by included/excluded from the timberland volume estimates.

While one might assume that it is rare for an FIA sample point to have subplots that fall within different conditions; it is not. Of the 423 plots in the BHNF augmented FIA dataset, with a measurement year of 2017-2019, 29% of the plots clusters spanned two or more conditions, as shown in Table 23.

Table 23. Distribution of 2017-2019 measurement plots, by number of conditions encountered on the plot.

Number of Conditions	Plot Count	Percent
1	300	71%
2	106	25%
3	17	4%
	423	100%

With the above background on the definition and occurrence of multiple conditions within an FIA sample plot cluster, it is important to point out that the current FIA inventory analysis for the BHNF augmented inventory treats the “Suitable Base” inventory filter as a plot-level, as opposed to condition-level attribute.[33] In other words, all four subplots at a sample point are either classified as being entirely within the suitable timberlands base, or entirely outside of it. This all-or-nothing treatment is inconsistent with how the “Timberlands” filter is applied, to each subplot or condition. If the FIA analysis protocol deems it necessary to have the timberlands inventory filter applied at the condition level, why would the same principle not be applied to filtering plots for the Suitable Base inventory?

As shown in Figures 1 and 2, the BHNF suitable base lands are represented by an intricate, highly convoluted shape. It would be expected that a significant number of FIA plot clusters could span the suitable base boundary; the same as is currently seen for the timberlands boundary. Why then, should the two filters be applied at different levels of spatial resolution?

When questions have come up about the suitable timberlands inventory estimates, the FIA unit has been quick to distance itself from the suitable timberlands inventory filter, responding to emailed questions (see Appendix B) that:

> "I cannot comment on the value of the area of suitable land on the Black Hills National Forest (BHNF). Based on a coverage from February 2019, our estimate of suitable land is about 837,000 acres." and,
>
> "Note: suitability is not an attribute we use in the base FIA program."

[33] Database field BHNF_SUITABLE_LAND in the PLOTGEOM table signifies whether a plot cluster is deemed to represent the suitable timberlands landbase. The field is recorded at the plot level (as opposed to the condition or subplot level), and therefore does not allow for the suitable timberlands classification to vary by subplot.

In essence, the FIA staff seems to imply that they have no ownership or responsibility for how the BHNF suitable land flag is applied to the base FIA data. And yet the resultant numbers are being used to make critical decisions on the future of the Blacks Hills National Forest.

There are numerous unknowns concerning how the USFS applies the definition of suitable timberlands to FIA-derived inventory estimates, including:

1. How does the USFS assign the BHNF_SUITABLE_LAND flag to the plot cluster as a whole? Do all four subplots have to fall within the suitable base GIS layer to quality the plot as a suitable base plot? Or three subplots? Or the center of the plot cluster? Or…?
2. Have the rules for assigning the suitable land flag (question 1) changed since 2016?
3. Who assigns the suitable land flag to the plot clusters; FIA staff or BHNF staff?
4. If BHNF staff assign the suitable land flag to FIA plot clusters, do they have access to actual FIA plot coordinates, rather than the approximate (i.e., nearest 1/2 to 1 mile) locations available to the general public?
5. How many FIA sample points actually have a mix of suitable versus non-suitable subplots?

Resolution of the above questions, as well as the overall question of how plot-level application of the suitable base inventory flag could be impacting inventory estimates requires a level of USFS cooperation which to this point has not been forthcoming. Since FIA plot locations, as released to the public, are purposely inaccurate,[34] it is not possible as part of this project to evaluate how many sample plots in the BHNF augmented FIA database span a suitable timberlands boundary. However, part of the USFS FIA unit's mission is to provide support/analysis for such circumstances. Forest Service Handbook Interim Directive number 4809.11-2003-1 provides that:

> Requests for Forest Inventory and Analysis (FIA) data that involves spatial specificity, such as Geographic Information System (GIS) applications that assign or compare FIA plot attributes to user-defined polygons or other mapped attributes, may be processed at:
>
> 1. A Regional FIA unit when the request involves an area solely within that unit's territory. The requester may conduct the data analysis himself/herself at the FIA unit or the Station Director may appoint an Authorized Agent, such as a State government entity or a university, to handle the request.
>
> 2. National FIA Spatial Data Services when the request involves an area that covers more than one FIA unit's territory. Regardless of the alternative used, only aggregate inventory and analysis results (derived layers, custom retrievals,

[34] FIA plot locations are "fuzzed" by randomly changing the plot coordinates by up to ½ mile from the actual location in any direction (generally within the county of origin). The primary purpose of fuzzing is to avoid unauthorized visits to plot locations, thus compromising the reliability of the data and credibility of the Forest Inventory and Analysis (FIA) program. Additional data masking is applied that swaps a small number of plot locations with other similar plots in the same county (or supercounty) to prevent users from discerning inventory values for private individual ownerships. (paraphrased from: FSH 4809.11 – Forest Survey Handbook Chapter 10 – Operational Procedures)

models, validation results, and so forth), not exact coordinates, may be taken from an FIA office or placed in a distribution tool. In addition, all released products shall be aggregated in such a way that landowner confidentiality is maintained.

We recommend that BHFRA officially request the USFS FIA staff to provide a report that details, for each sample point in the 2017-2019 BHNF augmented database, the status of each sample point sub-plot, as to whether it is located inside or outside of the current BHNF suitable timberlands landbase, as well as a copy of the GIS shapefile used to identify the suitable timberlands landbase.

Such a request may help explain why the 2019 BHNF augmented inventory reports an estimate of suitable base timberland acres of 765,733 versus a **known** GIS-based acreage of 837,000; a discrepancy that has less than a one-in-a-million chance of occurring if the sample is accurately representing the true population.

3.4.4 FVS inputs and model settings

To generate FVS growth projections that would be comparable to the FIA-based forest growth estimates, plots were selected from the FIA2FVS database that corresponded to the FIA plot selection criteria for 1) timberlands, and 2) suitable timberlands landbase. The plot filters used to select plots for the FVS growth projections are shown below in Table 24.

Table 24. FIA plot/condition selection criteria for conducting FVS growth simulations.

FIA Tablename.fieldname selection criteria	Meaning
Cond.Owngrpcd=10	USFS-managed lands
Cond.Cond_Status_Cd = 1*	Accessible forest land
Cond.Reservcd = 0*	Non-reserved lands
Cond.SiteClCd <7*	20+ cubic feet/acre/year growth potential
Plot.MeasYear >= 2017	Plot was measured in years 2017 – 2019
Optionally:	
PlotGeom.BHNF_suitable_land = 'Y'	Plot is in BHNF suitable timberlands base
Plot.Intensity = '1'	To select only permanent plots
Plot.Intensity = '2'	To select only temporary plots

* The combination of the Cond_Status, Reserved, and SiteClCd filters jointly define "Timberland"

Similarly, FVS volume merchandizing specifications were set to match those used in the FIA volume estimates:

Table 25. Volume merchandizing specifications used in FVS growth simulations.

Merchandizing limit	Softwoods	Hardwoods
Minimum DBH (inches)	9	11
Merchantable top (DOB in inches)	7	9
Stump height (feet)	1	1

Additional FVS model settings were as follows:

1. Simulation unit: FIA sub-plot condition
2. Results of individual FVS simulations at the sub-plot condition level were weighted by the associated acreage weighting factors (Cond.CondProp_Unadj field) to create forest-level inventory and growth estimates.
3. Fifty-year growth simulation period (five 10-year cycles)
4. No simulated management to keep stands at desired stocking levels or reduce insect/fire risk (this model assumption would be expected to reduce the simulated long-term growth rates).
5. No regeneration ingrowth simulated (this model assumption would be expected to reduce the simulated long-term growth rates).
6. Growth calibration turned on (for permanent plots with measured growth and sufficient sample trees).
7. Most recent Central Rockies (CR) variant of FVS used for simulations (version 2906 – Central Rockies, RV:20200101; executable file dated 12/31/19)
8. Individual tree defect was not included in the FIA2FVS database received from the USFS, even though field-estimated cull percentage was recorded in the Tree.Cull_Fld variable of the FIA database. To generate FVS-based volume estimates that would be comparable to FIA-reported volumes, we computed average defect values by species and DBH class from the FIA data, and then applied those values to the FVS volume computations (using the BFDEFECT and MCDEFECT keywords). Percent defect was estimated by computing the ratio of: (net sawlog volume of sawtimber trees) / (gross sawlog volume of sawtimber trees) on USFS timberlands, from the 2019 BHNF augmented FIA database. The results are shown below in Table 26.

Table 26. FIA ratio estimate of net board foot volume to gross board foot volume, by species and diameter class.

	Diameter class: 2 inch class to 29								
Species	Total	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-28.9	29.0+
ponderosa pine	0.8990	0.8921	0.8909	0.8961	0.8985	0.9065	0.9067	0.9030	0.8822
white spruce	0.8822	0.8822	0.8822	0.8822	0.8822	0.8822	0.8822	0.8822	-
paper birch	0.4600	-	0.4600	-	-	-	-	-	-
quaking aspen	0.8375	-	0.8375	-	-	-	-	-	-
bur oak	0.9012	-	0.9005	0.9020	-	-	-	-	-
Total	0.8982	0.8914	0.8898	0.8954	0.8978	0.9054	0.9062	0.9024	0.8822

Note in Table 26 that many of the soundness estimates for ponderosa pine and white spruce have identical values of 0.8822, across numerous diameter classes. It is extremely unlikely that such a coincidence would occur if the values were based on actual field-observed defect values. Further, the sampling errors reported by the FIA Evalidator program for all white spruce diameter classes, and the ponderosa pine 29+ diameter class are all zero. These results imply that the associated FIA sawtimber defect values are not derived from field observation, but rather are being assigned the constant value of 11.78% defect. A review of recent FIA publications on South Dakota forest resources (e.g., Forests of South Dakota, 2018. Resource Update FS-199) provide no discussion of applying fixed defect values to volume estimations. It is suggested that BHFRA pursue this topic with the appropriate FIA and/or BHNF staff to determine why these fixed defect values are being applied, and how they were derived.

3.4.5 FVS growth projection results

Results from the individual FVS growth simulations (by sub-plot condition) described in the previous section were combined to generate estimates of overall forest growth rates for the BHNF. Average annual growth rates were computed by treating the sub-plot simulations as a simple random sample (with appropriate weighting for multiple conditions per plot). This approach is consistent with the grid-based allocation of FIA sample plots, and with USFS statements that "[t]he estimators used by FIA are unbiased under the assumptions that the sample plots are a random sample of the total population and the observed value for any plot is the true value for that plot." (Gormanson et al, 2018).

Results of the FVS growth projections were analyzed for the following two plot groupings:

1) Suitable timberlands base: permanent plots that were measured in 2017-2019 (177 simulations)
2) Timberland base: permanent plots that were measured in 2017-2019 (235 simulations)

Only permanent plot data was used in the FVS growth projections because they contain information on past observed growth, whereas the temporary plots do not. This past observed growth is used by FVS to scale predicted stand growth up or down, as appropriate, to more closely match the past stand growth that has been observed on that particular site (see Dixon, 2002). Running the FVS growth simulations on only the permanent plot data also makes it more comparable with the FIA analysis, which contains growth estimates for only permanent plots.

Results of the FVS growth simulations are summarized in Table 27. Inventory values from Table 27 are shown graphically in Figure 12. Pertinent observations include the following:

1) The FVS initial inventory estimate for ponderosa pine sawlog volume (based on the incorrect suitable base acreage of 765,733 estimated by the 2019 BHNF augmented FIA inventory) is 6,115,124 CCF, versus 5,995,428 CCF from the FIA inventory analysis. The difference is less

than 2%, and well within the 5.49% sampling error reported for the FIA data. The close agreement of these two inventory values gives confidence that the FVS simulations data correctly represents the FIA plot data.

2) The first tier in Table 20 is based on the incorrect suitable base acreage (765,733 acres) estimated by the 2019 BHNF augmented FIA inventory. As discussed in section 3.2, this estimate is quite simply wrong. Forest Service FIA staff have claimed the suitable base acreage is "about 837,000 acres" (Appendix B), or "about 836,000 acres" (Appendix D). Both of these numbers are substantially below the suitable base acreage value of 865,890 acres reported in the Black Hills National Forest Land and Resource Management Plan Phase II Amendment (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf). We have requested from the Forest Service a copy of the GIS shapefile containing the 837,000 acre suitable base footprint, but it has not been provided. Therefore, we have used the forest plan value of 865,890 acres to expand the FVS inventory values to the forest level. The results of these calculations are shown in the second tier of Table 20 (labeled "Suitable base adj").

Using the Forest Plan suitable base acreage of 865,890 in place of the incorrect 765,733 FIA-based estimate results in a 13% increase in the estimated forest inventory (7,256,222 vs 6,416,899 CCF).

3) Due to the ambiguity of the USFS-supplied suitable base acreage, and the lack of supporting documentation from the USFS explaining the variance in suitable base acreage from the value reported in the Black Hills National Forest Land and Resource Management Plan Phase II Amendment, we included a third set of values in Table 27 based on FVS simulations for all FIA-defined timberland sample plots, expanded by the FIA-defined timberland acreage of 1,062,776 acres. These values, shown in the third tier of Table 27, result in a 41% increase in the estimated forest inventory (9,053,275 vs 6,416,899) compared to values computed using the incorrect suitable base acreage value of 765,733.

4) Gross annual growth rates were computed from the FVS growth projections using two different calculation methodologies:

- Prospectively, by dividing the projected 10-year growth by the initial inventory.
- Retrospectively, by dividing the projected 10-year growth by the ending inventory.

Using the prospective calculation method, annual growth rates range from 3.3% to 4.0%, depending on species and landbase. Using the retrospective calculation method, annual growth rates range from 2.5% to 2.9%, depending on species and landbase. For suitable base timberlands, the retrospective annual growth rate is 2.59; slightly higher than the value used by Graham et al. (2020), and lower than the average FIA growth rate derived from historical FIA data (see discussion in sections 3.2.5 and 3.3) . This growth rate should be considered conservative due to the fact that the FVS growth simulations did not include 1) any management activities such as stocking control that would be expected to be implemented in order to maintain stand vigor and reduce fire/insect/disease risks; and 2) no natural regeneration/ingrowth was simulated. Because of the simplifying assumptions involved in the FVS modeling, the reported annual gross growth values, as a percent of standing inventory, from FIA data prior to 2017 likely represent a more accurate scenario for current and future growth estimates.

4) Similar to the approach used for annual growth rates, annual mortality rates were calculated using both a prospective and retrospective approach, with the results presented in Table 20. Using the prospective calculation method, annual mortality rates range from 0.1% to 0.3%, depending on species and landbase. Using the retrospective calculation method, annual mortality rates range from 0.1% to 0.2%. For suitable base timberlands, the retrospective annual mortality rate is 0.23%; less than a quarter of the value used by Graham et al. 2020). We believe these FVS-derived mortality rates to be much more realistic for use in future growth estimates than either the FIA-generated mortality rates, or the rates used in the Graham publication. Having just experienced a bark beetle epidemic that inflicted heavy mortality, especially in dense, overstocked stands, the end result of the epidemic is a forest with reduced stocking levels and younger stands. These stands, because of their reduced competition, and free-to-grow status would be expected to have future mortality rates substantially lower than those of recent FIA inventories, and even long-term historical mortality rates; exactly as predicted by the FVS model.

Table 27. FVS inventory and 10-year projected growth of sawlog volume of sawtimber trees (using FIA merchandizing specifications), in CCF, based on growth plots from 2019 BHNF augmented FIA inventory.

	2019	Gross annual growth			Annual mortality			Net annual
	Inventory		Retrospect.	Prospect.		Retrospect.	Prospect.	growth
Landbase/Species	(CCF)	(CCF)	(%) (3)	(%) (4)	(CCF)	(%) (3)	(%) (4)	(CCF)
Suitable base (1)								
ponderosa pine	6,115,124	206,039	2.58%	3.37%	18,631	0.23%	0.30%	187,408
white spruce	301,775	12,143	2.89%	4.02%	306	0.07%	0.10%	11,837
Total	6,416,899	218,182	2.59%	3.40%	18,937	0.23%	0.30%	199,245
Suitable base adj (2)								
ponderosa pine	6,914,975	232,989	2.58%	3.37%	21,068	0.23%	0.30%	211,921
white spruce	341,247	13,731	2.89%	4.02%	346	0.07%	0.10%	13,385
Total	7,256,222	246,720	2.59%	3.40%	21,414	0.23%	0.30%	225,306
Timberlands								
ponderosa pine	8,523,099	277,903	2.51%	3.26%	23,689	0.21%	0.28%	254,214
white spruce	530,177	19,255	2.68%	3.63%	421	0.06%	0.08%	18,834
Total	9,053,275	297,157	2.52%	3.28%	24,110	0.20%	0.27%	273,048
FIA estimates (from 2019 BHNF augmented database) for suitable base								
ponderosa pine	5,995,428	150,694	2.51%		178,409	2.98%		-27,715
white spruce	244,917	7,453	3.04%		8,580	3.50%		-1,127
Total	6,240,346	158,147	2.53%		186,990	3.00%		-28,843

1. Inventory values computed based on incorrect suitable base acreage of 765,733 as estimated by 2019 BHNF augmented FIA inventory
2. Inventory values computed based on adjusted suitable base acreage of 865,890 acres
3. Percent growth rates computed retrospectively using the ending (10-yr growth period) inventory as the divisor, rather than initial inventory, to be consistent with the methodology used by Graham et al. (2020)
4. Percent growth rates computed prospectively using the beginning (10-yr growth period) inventory as the divisor

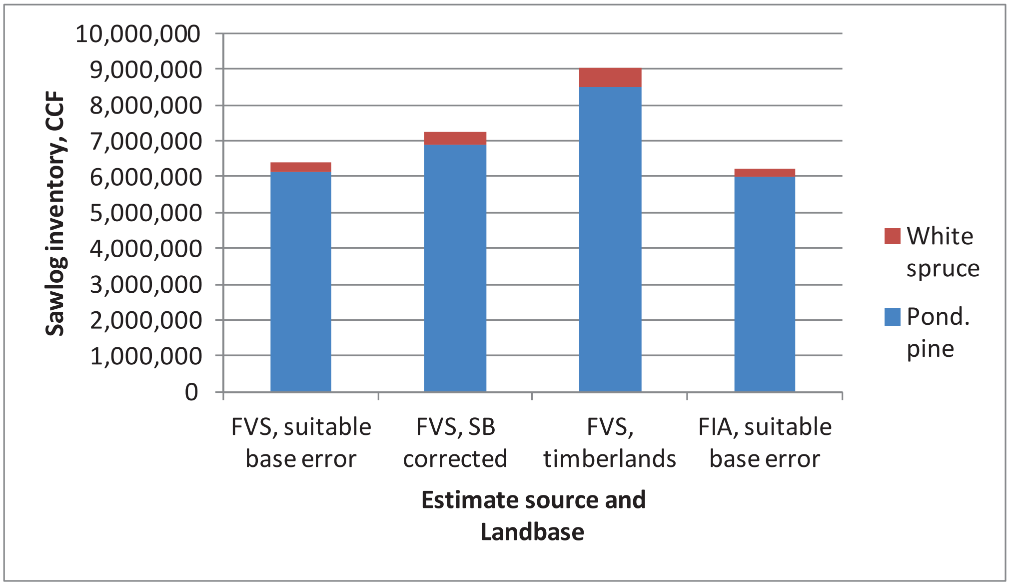


Figure 12. Current inventory estimates from FVS growth simulations, compared to FIA estimate, for suitable base, corrected suitable base, and timberland landbases.

3.5 Comparison of study findings with in-progress USFS GTR publication.

During the course of the current project, a draft copy of following publication became available: “Timber Growth and Yield in the Black Hills Nation[sic] Forest: A Changing Forest, Draft 1 March 2020.”

The document argues for very substantial reductions in BHNF harvest levels, based in large part on inventory, growth and mortality estimates derived from the current BHNF FIA sampling. Because of our ongoing work reviewing those BHNF inventory estimates, we were asked to undertake a cursory review of the growth and yield numbers used within the GTR draft document.

Following are our major observations resulting from a cursory review of the draft report:

1) Assumed accuracy of the 2019 BHNF augmented FIA inventory.

The draft GTR document states, in an opening list of Key Points, that "The intensified 2019 FIA sampling scheme for the BHNF provided robust and high quality data." As we have shown via previous analysis and discussions within this report, the statement is, at best, limited to selected population attributes, and open to serious debate. It is a common misconception that the larger sample size in the 2019 BHNF augmented FIA inventory dataset guarantees a more accurate estimate; it does not. As discussed in section 3.2.4 of this report, the accuracy of the 2019 augmented inventory, when evaluated against the known population value of suitable base acres, is less accurate than the 2016 FIA sample (prior to the initiation of intensified sampling). The highly inaccurate estimation of suitable base acres from the 2019 augmented FIA database, in particular, makes all analysis based on the associated inventory and growth highly suspect.

2) Assumes that the suitable timberland base acres estimated by the 2019 augmented FIA inventory is the appropriate landbase for computing ASQ.

Suitable base acres are set by the Forest Plan, and form the basis for computing ASQ. The suitable base acres presented in the BHNF Forest Plan are 865,890. The estimate of suitable base timberlands estimated by the 2019 BHNF augmented FIA database is 765,733 acres. USFS FIA staff have implied that the suitable timberlands base identified in the 2019 BHNF augmented inventory is not synonymous with the suitable base identified in the Forest Plan. Since the difference is substantial: over 100,000 acres, or 13%, any long-term estimates of ASQ based on the suitable timberlands base acres (and associated inventory, growth and yield) derived from the 2019 augmented FIA inventory must be assumed to underestimate forest inventory, growth and yield used to set ASQ.

3) Utilizes pessimistic growth and mortality rates.

The draft GTR document uses an assumed gross annual forest growth rate of 2.5%. As shown in section 3.2.5 of this report, forest growth estimates derived from on-line records of FIA inventories for South Dakota are 3.21%, 3.31%, 3.16%, and 2.89% for 2019, 2018, 2017, and 2016 inventory years, respectively. This results in an average 3.14% annual growth rate; substantially above the 2.5% rate being used in the GTR publication.

Similarly, the long-term mortality rates utilized in the GTR analysis would appear to be overly pessimistic. FIA-based data is of limited use in estimating long-term mortality rates, since much of the available data coincides with elevated mortality levels from the bark beetle epidemic. Certainly, mortality rates going forward should be greatly reduced due to reduced forest stocking and younger stands. As discussed in section 3.4.5, forest growth simulations conducted using the USFS Forest Vegetation Simulator (FVS) and current FIA inventory data showed annual mortality rates for suitable base timberlands of 0.23%; less than a quarter of the value used in the GTR analysis.

4) Assumes stocking levels existing prior to the beetle epidemic are a desired goal.

There seems to be an implicit assumption in the report that BHNF stocking levels should be returned to the conditions that existed prior to the recent bark beetle epidemic. Since those (overstocked) forest conditions helped precipitate the beetle epidemic, one must question whether that is a desirable goal.

The Phase II amendment of the 1997 BHNF Forest Plan specifically identified forest overstocking (and its associated insect and fire risks) as a management concern, with 13% of the forest being in a mature, dense condition (ripe for insect, disease and stand-replacing fire), versus a goal of 5%.[35] The BHNF supervisor at the time noted that the Forest Plan "… also provides for

[35] https://www.bhpioneer.com/black-hills-forest-issues-phase-ii-plan/article_a2a725e2-a70e-5ed9-ab2f-76380a0a58dc.html

the continuing viability of the existing forest products industry and infrastructure essential to cost effectively treat (thin) the forest."

5) Oversimplification.

The forest planning process is, by nature, an extremely complex process that must balance numerous (often competing) resource needs including timber, wildlife, recreation, water yields, local communities, carbon sequestration, and wildfire risk to name just a few. The existing BHNF Forest Plan was five years in the making and considered more than 5,000 public comments.[36] While it is tempting to think that we can come up with defensible long-term harvest levels in quick order, outside of the normal forest planning process, such an approach is fraught with risks and does not do justice to the public land management planning process.

[36] https://www.bhpioneer.com/black-hills-forest-issues-phase-ii-plan/article_a2a725e2-a70e-5ed9-ab2f-76380a0a58dc.html

4.0 Discussion/Conclusions

In reviewing the augmented BHNF 2017-2019 FIA inventory data, we identified a number of issues that cast serious doubt on the validity of the reported FIA inventory values:

1) As discussed in section 3.2, the FIA estimate of 765,733 suitable base acres significantly underestimates the **known** value of 837,000 acres; a difference of over 71,000 acres, or nearly 10%. There is only a one-in-a-million chance that the FIA estimate of 765,733 acres of suitable timberland acres, and the known suitable timberland acreage of 837,000 represent the same population.

Since all volume estimates are directly related to the associated suitable base acreage, the only logical conclusion can be that the volume estimates are highly suspect. To be blunt, if an inventory cannot accurately estimate a static, easily-measured population attribute such as acres, there can be little confidence placed in its ability to estimate dynamic, complex attributes such as inventory, growth, and mortality.

Despite documenting this sampling inaccuracy for the USFS, the FIA staff has been unwilling to engage in any meaningful dialog concerning this critical issue. Figure 6 shows that there has been an uncharacteristic decrease in the estimated suitable timberland base over the past three years of FIA inventory (the same three years during which the temporary plots were being installed, and the inventory cycle length changed from a six-year period to a seven-year period and then to a three-year period), even though the suitable base acreage has remained essentially constant during that period. The FIA staff has maintained that because the current suitable base acreage estimate is within the confidence limits of the previous year's estimate, that there is no problem with the estimate. This position is at odds with the concept of cumulative errors which is a standard focus for analyzing biological trends, and it ignores the obvious, atypical downward trend in suitable base acre estimates over the past three years.

Alternately, the USFS FIA staff have claimed that the inaccurate estimate of suitable base acres is "due to terminology" (see Appendix D), and that not all BHNF suitable base acres are timberlands by the FIA definition. This in no way explains why the suitable base acreage estimate has dropped precipitously since the initiation of the augmented sampling in 2017, while the suitable base acres have remained essentially static. This claim goes against the discussion of suitable base acreage derivation provided in Appendix G of the BHNF Forest Plan. Furthermore, if there is indeed a substantial proportion of the BHNF suitable base acres that are not timberlands (by the FIA definition), then it must follow that none of the inventory statistics provided to the public via the January 27, 2020 email from Andrew Johnson, acting BHNF forest supervisor, accurately represent the suitable base described in the BHNF Forest Plan, and upon which the ASQ is based.

Until the issue of inaccurate suitable base acreage estimation can be resolved, we must disagree with the USFS assertion that "[t]he intensified 2019 FIA sampling scheme for the BHNF provided robust and high quality data" (Graham et al, 2020), and suggest that little confidence be placed on the resultant inventory estimates.

2) As discussed in section 3.4.3, the suitable base flag is processed at the plot level rather than subplot. Treatment of the suitable base flag at the plot level is inconsistent with how the timberlands flag is recognized (at the sub-plot level), and is statistically incorrect.

We recommend that BHFRA officially request the USFS FIA staff to provide a report detailing, for each sample point in the 2017-2019 BHNF augmented database, the status of each sample point sub-plot, as to whether it is located inside or outside of the current BHNF suitable timberlands landbase, as well as a copy of the GIS shapefile used to identify the suitable timberlands landbase.

3) As discussed in section 3.4.4, fixed defect values were observed in the FIA data for all white spruce diameter classes, and the ponderosa pine 29+ diameter class. These results imply that the associated FIA sawtimber defect values are not derived from field observation, but rather are being assigned the constant value of 11.78% defect.

A review of recent FIA publications on South Dakota forest resources (e.g., Forests of South Dakota, 2018. Resource Update FS-199) provide no discussion of applying fixed defect values to volume estimations. It is suggested that BHFRA pursue this topic with the appropriate FIA and/or BHNF staff.

4) As discussed in sections 3.2.5 and 3.3, forest growth estimates derived from prior FIA inventories for South Dakota are 3.21%, 3.31%, 3.16%, and 2.89% for 2019, 2018, 2017, and 2016 inventory years, respectively. This results in an average 3.14% annual growth rate; substantially above the 2.43% reported for South Dakota in the 2019 BHNF augmented data set, and the 2.5% being used in the in-progress Graham (2020) study. If the growth estimate is pro-rated for growth observed on BHNF Wyoming lands, it increases to 3.24%.

5) As discussed in section 3.3, the presence of both permanent plots (with growth information) and temporary plots (which lack growth information) in the 2019 BHNF augmented dataset greatly complicate the derivation of appropriate expansion factors for estimating inventory (using all plots), and growth (using only temporary plots). Anomalies in inventory calculations coincide with the introduction of temporary plots in 2017. The derivation and application of appropriate plot expansion factors is a topic which deserves additional discussion with the USFS.

6) The plot expansion factors used in the 2019 BHNF augmented dataset are of particular importance because the limited number of inventory panels amplify the plot expansion factor impacts. The large proportion of temporary plots (unusable for growth estimation), the shortened measurement period (increased opportunity for measurement error), and the limited number of inventory panels provide a situation which is particularly sensitive to expansion factor accuracy.

References

Bechtold, William A.; Patterson, Paul L., Editors. 2005. The enhanced Forest Inventory and Analysis program—national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

Burrill, Elizabeth A.; Wilson, Andrea M.; Turner, Jeffery A.; Pugh, Scott A.; Menlove, James; Christiansen, Glenn; Conkling, Barbara L.; David, Winnie. 2018. The Forest Inventory and Analysis Database: database description and user guide version 8.0 for Phase 2. U.S. Department of Agriculture, Forest Service. 946 p.

Dixon, Gary E. comp. 2002 (Revised: June 13, 2017). Essential FVS: A user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 226 p.

Gormanson, Dale D.; Pugh, Scott A.; Barnett, Charles J.; Miles, Patrick D.; Morin, Randall S.; Sowers, Paul A.; Westfall, James A. 2018. Statistics and quality assurance for the Northern Research Station Forest Inventory and Analysis Program. Gen. Tech. Rep. NRS-178. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 25 p.

Graham, Russell T., Mike A. Battaglia, Theresa B. Jain. Timber Growth and Yield in the Black Hills Nation [*sic*] Forest: A Changing Forest, Draft 1 March 2020. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 37 p.

Keyser, Chad E.; Dixon, Gary E., comps. 2008 (revised October 2, 2019). Central Rockies (CR) Variant Overview – Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 76 p.

Meneguzzo, Dacia M; Paulson, Charles S. 2019. Forests of South Dakota, 2018. Resource Update FS-199. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 4 p. https://doi.org/10.2737/FS-RU-199.

Appendices

Appendix A. Questions submitted to USFS FIA, concerning BHNF FIA inventory, 2/25/20

First of two emails:

Subject: A mystery I hope you can help me with...
Date: 2020-02-25 12:25
From: tom@straight-arrow-consulting.com
To: charles.barnett@usda.gov
Cc: james.menlove@usda.gov

Hi Chuck -

As my message from a few weeks ago indicated, (when I inquired as to whether or not Evalidator was up and you responded quickly --- thanks), I and some colleagues are doing work for a client that straddles South Dakota and Wyoming. More specifically, we are using the FIA data that was collected on the Black Hills National Forest (BHNF). I'm going to lay-out the mystery I'm encountering, then provide some background, and then come back to a few details regarding the mystery. I'll follow this email with an email and supporting analysis documents and workbooks attached. I didn't want to send a first email loaded with attachments that could end up in a spam folder.

Our client has asked us to evaluate the impact of the mountain pine beetle on forest inventory and future forest growth. To form a perspective on that I've been focusing on making FIA runs on past inventories on the BHNF as well as the most current inventory. My mystery is it appears there is a loss of acres from what BHNF terms the "suitable base" in the 2017, 2018, and 2019 FIA data. The losses on BHNF (both SD and WY) appear to be 42,206 acres (4.9%), 67,185 (7.8%), and 95,915 acres (11.1%) for 2017 to 2019, respectively. Acreage changes of that magnitude coupled with increased mortality due to mountain pine beetle would obviously have a significant effect on inventory, growth, and mortality estimates.

Some background. The BHNF provided our client a more current FIA dataset on the BHNF than is available online via Evalidator. The current dataset (2019 data for SD; it appears the 2019 data for WY in the local dataset is actually in the online version of the Evalidator but I'm not 100% certain on that last point.) can be evaluated using a local version of Evalidator; the BHNF provided instructions on how that can be done and I've been doing that successfully. For all analysis on inventories prior to the current version provided by BHNF I'm using the online Evalidator version and datasets.

Most of my work to date has focused on the SD portion of BHNF. The reasons for this are:

the SD portion is the bulk of the area,

the SD FIA dataset provides a more consistent and longer data set that I can use for comparison to the most recent data set as well as to help interpret the impacts of the beetle since the inventory changes can be evaluated over time, and

I can compare current estimates of gross annual growth, mortality, net annual growth, and average annual harvest to prior measurements for SD; the Northern FIA station provides this analysis but the Interior West (i.e. WY) FIA station has not yet started doing that for their data. While most of the work to date has been on SD some of the issues I'm encountering also seem to be cropping up on the WY dataset and so I'm CCing Jim on this message as ultimately to fulfill client requirements I'll need to cover the entire BHNF, not just the SD area.

Enough on background. The focus of the analysis, per our client, is on what the BHNF refers to as it's suitable base for timberland production. The local dataset provided by BHNF has a SQL table that allows filtering the supplied data set to produce results on this "suitable base." I have successfully replicated the results they provided to us using this SQL table so it appears to be the same table as they used to generate their results.

I've generated a plot list out of the suitable base SQL table supplied with the most current local dataset and have used that plot list to filter the same "suitable base" plots when I make online Evalidator runs. For the SD acres the online suitable acres base has been consisting averaging around 733,000 acres in the 2010 to 2016 FIA inventories (SE% of +/-0.2%). I have reason to believe the plot list is an accurate gauge of what BHNF considered its suitable base. When I add the average 2010-2016 SD BHNF suitable base acres of 733,223 to the 2016 WY BHNF suitable base acres of 128,425 the total BHNF suitable base acres is 861,420 acres. This compares very favorably to the suitable base acreage reported in the Black Hills National Forest Land Resource Management Plan of 865,890 acres as reported in Appendix G (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf). The suitable base acres for the local data set (both SD and WY) supplied by BHNF do not approach this amount; it is 653,753 in SD and 111,980 in WY for a total of 765,733 acres.

An aside on using only WY 2016 acres when computing the suitable base acres out of Evalidator online data: The fact WY appears to still be moving toward gaining complete coverage for its annual inventory makes the situation murky re: suitable base acres on BHNF for WY. This can be readily seen in one of the schedules I'll include among the attachments on the next email. Based on what I saw in the FIA online data it appears there may be complete coverage in WY on BHNF in the 2016 inventory and so that is why I used that value. This concludes the "aside" on using WY 2016 suitable base acres on BHNF only.

As you know, the Northern Station has been transitioning from a five-year re measurement cycle to a seven-year re-measurement cycle. For the time period I've been analyzing, 2010 to 2013 was reported under the five-year cycle, 2014 to 2016 was reported under the six-year cycle as, I presume, a transition toward the seven-year cycle, and then beginning in 2017 FIA data is reported on a seven-year re-measurement cycle.

In addition to this ongoing transition there was an intensive effort by FIA to supplement the permanent FIA plots on the BHNF with temporary plots in 2017 and 2018. From best I can tell looking at plot counts all of those temporary plots were taken during those years (at least, that seems to be the case in SD). In addition, there appears to have been a concerted effort (this appears to be the case in SD; haven't located evidence of same in WY data) to re-measure all permanent plots within the three years 2017 to 2019 so that a better sense of mortality and growth effects can be acquired.

NOTE: At this point I'm shifting my discussion to SD only; The loss of acres noted earlier in this email are for both SD & WY. For SD only the losses are 29,531 (4.0%), 53,953 (7.4%), and 79,470 (10.8%). As can be seen, no surprise they follow a similar pattern to the total reported earlier; the WY percentage losses are slightly larger but owing to the smaller acreage that may simply be sampling noise. The key point is the pattern of loss of suitable base acres occurs consistently in both SD and WY.

As I noted at the outset, things were holding level on the SD side 2010 to 2016 for suitable base acres. I looked to see if there are similar losses in the forest land and timberland acreages for BHNF in SD in 2017 to 2019 compared to 2010 to 2016. There are but they are not as great either on an absolute basis or on a percentage basis as the the suitable base losses. When looking statewide at 2017 and 2018 data compared to 2010 to 2016 averages it's difficult to conclusively detect any losses at either a forest land or timberland acreage level.

This "introductory" email has gotten too long and for that I apologize. I'll follow-up with an email with supporting details and analysis. I believe it would be most efficient and effective if I talked you through on the phone what I've done in those workbooks so I can understand why these acres are declining in the BHNF suitable base and more importantly, what can be done to ensure I am looking at the data properly.

Many thanks,

Tom

Thomas B. Montzka
Straight Arrow Consulting Inc.
(208) 321-0136 (W) / (208) 867-3326 (C)
12435 W Bowmont Street
Boise, ID 83713

Second email:

Subject: FOLLOW-UP EMAIL w/ ATTACHMENTS to: A mystery I hope you can help me with...
Date: 2020-02-25 12:26
From: tom@straight-arrow-consulting.com
To: charles.barnett@usda.gov
Cc: james.menlove@usda.gov

Hi Chuck -

Per my earlier email, this email contains attachments of work I've done.

First is the workbook. Key tabs are the first two:

SUM.SD - ACRES for Forest land, timberland and suitable base acres for South Dakota, National Forests, and Black Hills National forest. Where available 2019, 2018, and 2017 acres are compared to averages for 2010-2013 (5-year re-measurement cycle inventories), 2014-2016 (6-year re-measurement cycle inventories), and 2010-2016.

FIA.DT.TBLs.SD - More detailed information on acreages used to develop SUM.SD schedule. This schedule also reports number of non-zero plots for relevant estimates by inventory year. The non-zero plot schedules highlight the sample intensification with temporary plots in 2017 to 2019. Note the 2018 and 2019 plots level out (rather than building) which leads me to conclude 2019's measurements consist of an accelerated re-measurement of permanent plots rather than adding more temporary plots. That observation is further substantiated by the supporting evalidator runs (more on that below). Finally, in rows 75 to 98 suitable acres are reported by SD and WY for BHNF. Note in row 81 the building acres of suitable base acres for WY in years 2012 to 2016. This pattern is what led me to believe the 2016 acres in WY is the best estimate for suitable base acres on BHNF in WY.

ALL OTHER TABS in the workbook are results of EVALIDATOR RUNS. The aforementioned schedules on the first two tabs of this workbook reference these data so one can track back to see where a particular piece of data was sourced. In all these tabs the column variable is reporting the data by INVENTORY panels that are included in a particular INVENTORY data run. Page variables vary from table to table so want to be alert to that; in most cased PAGE is NONE but for suitable acres I the page variable was STATE. Row variable is ownership. Filters can be seen on Evalidator results as well as the estimate being queried.

Specifically, there are 9 tabs for forest land acres in SD (yyyyFL), 9 tabs for timberland in SD (yyyyTL), 10 tabs for forest land on Black Hills National Forest (yyyyNFFL), 10 tabs for timberland on Black Hills National Forest (yyyyNFTL), and 10 tabs for suitable base acres on Black Hills National Forest (yyyyNFSB), for a total of 48 data tabs. The "yyyy" refers to the inventory year. The 2019 queries for the Black Hills National Forest forest land, timberland, and suitable base acres are all from the local data set. For BHNF forest land and timberland the queries are for SD only. For suitable acres the 2019 to 2012 queries include both SD and WY (page variable is state); there is no online WY data for 2010 and 2011.

Note that for local dataset runs and SOUTH DAKOTA the 2019 data drops to inventory panels for 2017 to 2019 (see 2019NFFL, 2019NFTL, 2019NFSB, all local dataset runs) from 2018 data for SD which includes inventory panels 2012 to 2018 (see 2018NFFL, 2018NFTL, 2018NFSB, all online dataset runs). That drop in inventory panels included between 2018 to 2019 fits with the non-zero plot count that all temporary plots were taken in 2017 and 2018 and then balance of permanent plots not yet re-measured were re-measured in 2019.

A second attachment, Data Access Tool.zip, is too large to attach to conventional email. This was the file provided to us by client. The client received it from BHNF and it is the data source and means by which 2019 results are generated. I'll send it to you and Jim via Hightail, which will create a secure link so you can download the file.

As I said earlier, I think most effective way is for us to discuss this on the phone. Please let me know when that might work for your schedule.

Again, many thanks for your help on this.

Tom

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Appendix B. Response from USFS FIA to questions submitted 2/25/20

From: Barnett, Charles -FS <charles.barnett@usda.gov>
Sent: Wednesday, March 11, 2020 12:29 PM
To: tom@straight-arrow-consulting.com
Cc: Menlove, James -FS <james.menlove@usda.gov>

Subject: RE: A mystery I hope you can help me with...

Good afternoon Mr. Montzka,

1. I cannot comment on the value of the area of suitable land on the Black Hills National Forest (BHNF). based on a coverage from February 2019, our estimate of suitable land is about 837,000 acres.

2. Within each of the datasets (the FIA Base Survey and the BHNF study) we are seeing consistent results. The augmented sample provides information with more precision so there might be differences in the estimates as the sample changes and more information is gathered.

3. Trying to use the plot numbers from the BHNF study in the online version of EVALIDator could yield inaccurate results by using a subset of data that may not be representative of the data collected specifically for the BHNF.

4. I think it is unwise to try to compare estimates from the BHNF version of EVALIDator with estimates from the public data. While related, the BHNF dataset represents an augmented sample, with different adjustment factors and evaluations.

5. Keep in mind the FIA program is a strategic-level survey, not a stand-based inventory. As you introduce more filters, from “all sampled land” through “forest land” and “timberland” down to “suitability”, the estimates will become less precise. Note: suitability is not an attribute we use in the base FIA program.

6. There is no need to distinguish estimates from the different surveys based on cycle lengths. Once a survey is fully annualized, each estimate includes data from a full sample of plots.

If you have any questions or concerns please let me know.

Make it a good day.

Chuck
USDA USFS
Charles J. Barnett
Biological Scientist
Forest Service

Northern Research Station, Forest Inventory and Analysis
271 Mast Rd.
Durham, NH 03824

Appendix C. Follow-up questions submitted to USFS FIA, concerning BHNF FIA inventory, 3/30/20

From: Tom@straight-arrow-consulting.com
Sent: Monday, March 30, 2020 3:32 PM
To: charles.barnett@usda.gov
Cc: james.menlove@usda.gov

Subject: FOLLOW-UP TO: RE: A mystery I hope you can help me with...

Hello Chuck,

Thank you for your email and the time you and your colleagues spent reviewing data re: our questions.

Since receipt of your response we've been busy following up on your statements. The following concerns remain, as well as questions regarding your response:

- Based on your suggestion during our phone conversation to use CN rather than plot numbers (see #3 below) we reworked our data for the suitable base acres. We found small differences in 2017 and 2018's data for SD (3,892 and 2,111 acres in 2017 and 2018, respectively). Acreages for 2012 to 2016 inventory results were the same whether using plot numbers or CNs. While the differences in 2017 and 2018 are important, they pale in comparison to the differences between the FIA suitable base acres versus the published suitable base acreage for the Black Hills National Forest (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd592921.pdf , Appendix G, PDF page number 413). As in your case in being unable to comment re: the 865,890 published acres (see #1 below), we can't comment on the roughly 837,000 acre Feb 2019 coverage (again, see #1 in note below; however, we'd be interested in acquiring a copy of that coverage as no one to date has mentioned any such coverage exists.). For the record, however, we note the SE% in the augmented base data for suitable base acres of 765,733 is 1.71%. As both the 865,990 published acres and the Feb 2019 about 837,000 acre coverage are GIS-based (thus, for practical purposes could be considered the population mean of suitable base acres), we find it troubling that neither value falls within a 99% confidence interval around the augmented data suitable base acres estimate of 765,733 acres. In our view this continues to be an important issue to resolve. As acres are based on plot expansion factors, how can other results be considered reliable if the acres are not correct? If the expansion factors are incorrect that suggests other results are incorrect as well.
- Regarding point 5, while we understand suitability is not a criterion used within the FIA program, selecting plot data (via CNs) that fall on acres classified as suitable forest is not a misuse of the FIA data provided we are aware reduction in sample size typically reduces precision of the estimate (assuming variances between the larger population and

the sub-population - in this case, the suitable base - are consistent). Further, acreage reductions on BHNF are seen in 2017 -2018 (online) and 2019 (augmented) data sets for forest land and timberland. The reductions are not proportional or constant in absolute terms with the reductions seen over the same time period for the suitable base acres. This suggests the “lost acres” issue is not simply because of filtering to the suitable base acres.

- We’re having difficulty reconciling statements made in statements 2 and 4. Perhaps you could explain more fully:
    - Statement 2: “Within each of the datasets (the FIA Base Survey and the BHNF study) we are seeing consistent results.” vs. Statement 4: “I think it is unwise to try to compare estimates from the BHNF version of EVALIDator with estimates from the public data." Statement 4 implies the augmented data can’t be reliably compared to the publicly available data while Statement 2 suggests FIA has internally made such comparisons in order to conclude FIA is, “seeing consistent results.” To us these two statements seem contradictory.
    - Statement 4 asserts the augmented data has different adjustment factors and evaluations. We’d appreciate more detail on these. Our analysis is actually focused on basic forestry metrics: acres, inventory, growth, mortality. We’d like to know more about what adjustments were made to the augmented data set that would cause its results re: these basic forestry metrics on the BHNF to be different than similar results for the same geography but taken at a different time from the publicly available date.
- All due respect to Statement 5, with the reduction in acres since 2016 we’ve been trying to understand how changes over time occur; that necessarily involves looking at panel-level data. The table below is a collection of data from our analysis looking at forest land acres (“FLAC”), timberland acres (“TLAC”), and suitable base acres (“SBAC”). For the suitable base these numbers have been corrected for CNs, not just plot numbers. They are for SD acres on BHNF only as the WY data is quite weak in terms of numbers of plots through much of this time period. We note that acres for a year’s panel change; however, the number of plots don’t, so clearly some type of re-stratifying is going on year-by-year. Our question is: Do you treat each plot as a simple random sample when rolling up for an inventory year, or do you roll up each panel year as a random sample and then weight results by panel year to compute the total inventory? The question arises because there seems to be a general trend in a plot’s “weight” (represented by the number of acres for a specific inventory panel in a particular inventory year) declining over time. We realize the combination of shifting re-measurement cycles and the addition of temporary plots in 2017 & 2018 (looks like 2019 was a re-measurement of permanent plots only in SD) complicate this.

BLACK HILLS NATIONAL FOREST, SOUTH DAKOTA ONLY

FROM: STATUS-202002xx-ACRES&VOLA.xlsx wor-bo3
TAB: TAB.25

CYCLE	SOURCE	RPTYR	METRIC	check	TOTAL	INVENTORY Panel 2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
5YR	ONLINE	2010	FLAC	1	996,982											207,945	209,110	237,494	195,036	152,938
5YR		2011	FLAC		1,000,381										154,274	207,032	210,672	234,247	193,756	
5YR		2012	FLAC	(1)	999,551									192,919	153,836	206,277	211,190	232,240		
5YR		2013	FLAC	-	993,409								252,930	191,701	134,320	206,327	230,709	-	-	-
6 YR		2014	FLAC	(1)	1,009,752							139,849	252,410	[illegible]	138,489	[illegible]	50,880	-	-	-
6YR		2015	FLAC	-	1,007,862						152,422	155,730	[illegible]	194,408	158,356	111,436	-	-	-	-
6YR		2016	FLAC	-	1,007,758					132,046	152,513	155,735	235,236	194,389	137,887	-	-	-	-	-
7YR+INT		2017	FLAC	-	982,797				366,541	90,395	111,889	106,477	161,244	132,696	14,875	-	-	-	-	-
7YR+INT		2018	FLAC	-	982,207			318,647	272,779	66,567	80,133	78,704	118,879	46,498	-	-	-	-	-	-
3YR?+INT	LOCAL	2019	FLAC		943,315		340,164	342,505	265,646											
5YR	ONLINE	2010	TLAC	(2)	965,015											207,955	194,774	220,435	182,871	152,938
5YR		2011	TLAC	2	968,613										154,274	207,033	196,699	222,190	182,419	-
5YR		2012	TLAC	(2)	963,989									186,865	153,836	206,278	196,436	220,592	-	-
5YR		2013	TLAC	-	961,824								230,429	186,439	154,520	206,327	196,109	-	-	-
6 YR		2014	TLAC	1	974,673							147,334	212,241	[illegible]	[illegible]	[illegible]	51,152			
6YR		2015	TLAC		975,413						147,457	147,377	221,089	[illegible]	150,549	111,326				
6YR		2016	TLAC	1	975,904					132,047	147,949	147,377	221,089	[illegible]	137,007	-	-	-	-	-
7YR+INT		2017	TLAC	(1)	937,948				[illegible]	90,59	108,466	100,932	132,108	121,768	14,676	-	-	-	-	-
7YR+INT		2018	TLAC	-	944,018			[illegible]	270,187	66,365	77,542	74,888	112,791	40,498	-	-	-	-	-	-
3YR?+INT	LOCAL	2019	TLAC	1	905,484		[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-
5YR	ONLINE	2010	SBAC		736,369											156,862	147,739	177,468	143,003	114,399
5YR		2011	SBAC		736,623										114,122	155,789	148,552	178,753	139,417	
5YR		2012	SBAC	-	733,782									138,864	113,782	155,823	147,721	177,992	-	-
5YR		2013	SBAC	(1)	733,577								177,579	133,413	113,996	152,965	147,298	-	-	-
6 YR		2014	SBAC	-	732,231							102,082	179,948	136,556	114,181	152,471	45,997	-	-	-
6YR		2015	SBAC	1	729,996						116,904	102,362	180,215	135,564	114,023	86,938	-	-	-	-
6YR		2016	SBAC	1	729,996					90,514	116,904	102,362	180,215	135,564	104,437	-	-	-	-	-
7YR+INT		2017	SBAC		707,983				[illegible]	61,786	85,428	69,317	[illegible]	91,917	7,899					
7YR+INT		2018	SBAC	1	681,382			198,611	252,016	43,776	59,543	51,640	91,127	34,608	-	-	-	-	-	-
3YR?+INT	LOCAL	2019	SBAC		651,753		208,006	192,729	191,008											

- We'd appreciate some specific information on how the temporary plots were allocated in the case of the BHNF plot intensification program. While the "National FIA Plot Intensification Procedure Report" (https://www.fs.fed.us/rm/pubs/rmrs_gtr329.pdf) provides some general information, it's not clear how the program was specifically implemented in the case of BHNF. We have statistically tested ponderosa pine sawtimber volumes per acre by basal area classes for plot intensities 1 (permanent) and 2 (temporary) for SD and WY acreages on BHNF. In the main the volumes per acre for the two samples are not statistically different from one another but we are still left with the question of how those per-acre results were expanded to the forest as a whole.

Thank you for your help on this.

Regards,

Tom Montzka

Straight Arrow Consulting Inc.
Thomas B. Montzka, President
12435 W. Bowmont Street
Boise, ID 83713
Tom@Straight-Arrow-Consulting.com
(208) 321-0136 Office (208) 867-3326 Cell

Appendix D. Response from USFS FIA to questions submitted 3/30/20

From: Barnett, Charles -FS <charles.barnett@usda.gov>
Sent: Thursday, April 9, 2020 6:51 AM
To: Tom@straight-arrow-consulting.com
Cc: Menlove, James -FS <james.menlove@usda.gov>

Subject: RE: FOLLOW-UP TO: RE: A mystery I hope you can help me with...

Good morning Mr. Montzka,

Point 1: The difference in the values you are referencing is due to terminology. Suitability as used by the Black Hills National Forest is defined as “lands suited or not suited for timber production” This is not the same as the FIA definition of timberland. The 1997 forest plan you reference does have a value of 865,890 acres of suitable land. This value has been updated to about 836,000 acres of suitable land. However, this does not mean all of that land is timberland or even forest land, as FIA defines it.

I believe the BHNF has addressed this issue with an area budget.

Point 2: I disagree with the premise the estimates of area have declined over time without an explanation. Our estimates of forest land and timberland in both the public data and the special study have remained consistent (within sampling error), given the changes in sampling intensity.

Point 3: When I stated we were seeing consistent results from each of the datasets my contention was that we were seeing consistent results when looking at each of the datasets by themselves. While the estimates pertain to the same area and each dataset has data in common, the plots are combined into evaluations independently. For the same plot, estimation unit assignments, expansion factors, and adjustment factors are different. If you compare the POP_STRATUM data applied to the same plot in the respective databases you will see these differences.

Point 4: Do we treat each plot as a simple random sample? We take a temporally indifferent approach, where all panels that represent a full survey are lumped together. Initially, all plots are treated with equal probability. We stratify the entire set of plots in the post-season and develop the expansion factors at that time. We re-stratify each year as the new data for a set of plots is added and the older corresponding set of plots drops out of the evaluation. This means the expansion factors for a plot or stratum will be slightly different from evaluation to evaluation, especially as the sample is intensified.

Point 5: Sample selection: The process for sample selection for SD for 2019 was:
1. Generate a list of the most recent visit to all plots in SD counties that contain NFS lands
2. Project the coordinates into Albers equal-area projection (USGS version)
3. Intersect plot with NFS administrative boundary layer
4. Upload the resulting intersection into ANL_FIA_BHNF_2019ANLYS.ZZ_2019_SD_PLOT_LIST
5. Select plots from the above list
    a. Only plots last visited between 2013 and 2016. This limits the re-measurement period to reasonable

amounts beyond simply measurement error.
b. Only plots within 10 meters of lands actually owned by NFS. Plots falling in inholdings were
excluded.

The process was a little different for WY since the plot-visit histories are different. However, the sample was verified.

The final plot counts for the 2019:

BHNF Row Labels	BASE ACCEL: N	ACCEL: Y	Total	INTENSIFIED ACCEL: N	ACCEL: Y	Total	Total
2017	29	0	29	27	74	101	130
2018	27	8	35	3	109	112	147
2019	30	131	161	0	0	0	161
Total	86	139	225	30	183	213	438

The accelerated plot visits generated for this 2019 special analysis are considered special study visits and not standard visits. As such, they are not tagged with the P2 study tag in NIMS. They are tagged with the RAPID_ASSESSMENT tag. This means they are not published to the national FS_FIADB as part of normal processing. These plot visits have been processed in their respective NIMS schemas according to regional standards. Upon completion of regional processing and review they were loaded into ANL_FIA_BHNF_2019ANLYS for custom processing. Upon completion of this custom processing and an internal review process they were sanitized for distribution. However, they are not available via the standard, national delivery methods (EVALIDator and DataMart). They have been provided in a separate and custom delivery mechanism, which you have.

Make it a good day.

Chuck

Charles J. Barnett
Biological Scientist
Forest Service
Northern Research Station, Forest Inventory and Analysis
271 Mast Rd.
Durham, NH 03824

Appendix E. Personal Resumes

The report authors have over a century of combined experience in forest inventory estimation, growth and yield projections, statistical analyses, and harvest scheduling; including extensive experience with the USFS FIA and FVS programs.

The following pages contain a short resume for each of the report authors, summarizing past work experience pertinent to the current analysis.

Steve N. Scharosch

P.O. Box 157
Alcova, WY 82620
307/235-1829

Education

- M.S. Forest Resources, University of Idaho, 1986. Specialized in quantitative ecosystem modeling/statistics/operations research for natural resource management.
- B.S. (summa cum laude) Forest Resources/Science option, University of Idaho, 1979.
- A.S. (summa cum laude) Biology, Casper College, 1977.

Professional Experience

APR/86--Present President, Abacus Enterprises Inc, Alcova, WY.

For over 30 years, owner/manager of a consulting firm specializing in forest resource planning and analysis. Services include design/application of forest simulation/planning software; data analysis; forest inventory; ecosystem modeling; operations research and harvest scheduling; financial analysis; GIS mapping and spatial analysis; and report preparation.

Specific areas of focus have included:

- Proprietary client extensions to the USFS FVS simulation model, including custom volume and stem merchandizing routines, thinning algorithms, habitat suitability predictions, user-defined Forplan yield table generation, and custom model variants for predicting short-rotation growth of US clonal cottonwood and Brazilian Eucalyptus plantations.
- Proprietary client extensions to the USFS Forplan/Spectrum forest planning model, including greatly expanded model size capability, development of post-solution silvicultural and financial reporting tools, and providing support to a consortium of industrial users.
- Development of integrated start-to-finish forest planning software systems to automate forest timbertyping; management prescription development and themeing; forest growth simulation; harvest scheduling; and financial and silvicultural reporting.
- Application of forest simulation and planning tools on both the strategic, landscape level, as well as the operational level for detailed analysis of smaller ownerships and acquisition/divestiture studies.
- Application of the FlamMap fire behavior model to evaluate fire risk at the landscape level, and the FVS Fire and Fuels Extension to assess the effectiveness of stand treatment options for reducing fire risk at the stand level.
- Geo-spatial analyses of mill and log transportation networks for fuel consumption predictions and log transportation economics.
- Analytical support for wood basin supply studies and validating economic viability of claimed fiber sourcing for Forest Stewardship Council certification.

Clients have included private forest products companies such as Boise Cascade and Mead Paper, timberland REITs, public agencies including the USFS, NPS, BIA, and state government agencies, tribes, and other natural resource consulting companies.

NOV/93--NOV/94 Forest Economist, Boise Cascade Corporation, Timberland Planning and Development, Boise, ID

Provide corporate-wide support for long-range forest management planning for roughly 3.5 million acres of company timberlands in the U.S. Responsibilities included development and support of software tools/procedures to facilitate long-range forest management planning efforts in nine timberland operating regions spread throughout the U.S.

MAR/84--APR/86 Forest Analyst, Boise Cascade Corporation, Midwest Woodlands, International Falls, MN

Provided technical support for improved timberlands management in computer applications, mathematical modeling, statistics, forestry research, and field measurements. System manager, security administrator and operator for Data General minicomputer system. Provided computer support for forestry staff of 15.

APR/82--MAR/84 Forest Statistician, Boise Cascade Corporation, Timberland Resources Planning, Boise, ID

Conducted long-range forest management planning for roughly 3.5 million acres of company timberlands in the U.S. Responsibilities included forest inventory sampling design and analysis, software specification and design for forest growth simulation models, design and implementation of linear-programming optimization models for forest harvest scheduling, written and oral presentations of planning results, provide nationwide support for forestry staff on computer use and statistical analysis.

JUN/81--APR/82 Graduate Assistant, University of Idaho, College of Forestry, Wildlife, and Range Sciences, Moscow, ID.

Conducted M.S. research on the development of mathematical computer models to predict forest understory vegetation response to overstory management.

SEP/79--MAY/81 Teaching Assistant, University of Idaho, College of Forestry, Wildlife, and Range Sciences, Moscow, ID.

Teaching assistant for upper-level quantitative forest management course. Responsibilities included preparation of lab sessions, instruction, preparing and grading homework problems and examinations, assisting students individually on projects and lecture material. Held full responsibility for class of 100 students, including teaching lecture sessions, for six weeks.

Summer, 1979 Remote Sensing Lab Technician, University of Idaho, College of Forestry, Wildlife, and Range Sciences, Moscow, ID.

Researched use of low-level aerial photography to risk-rate forest stands susceptible to Western Spruce Budworm defoliation. Responsibilities included field data collection, vegetation delineation on aerial photographs, mapping/digitizing, assist in navigation and aerial photography on reconnaissance flights. Also involved in field study to determine resolution of optical bar photogrametry from U-2 aircraft.

Summer, 1978 Forestry Aid, US Forest Service, Bighorn Natl. Forest, Worland, WY.

Timber sale preparation tasks including traverse and mapping of timber sales, tree marking, and timber cruising using the 3-P sampling system.

Professional Societies/Service

Society of American Foresters

Wyoming Project Learning Tree, Steering Committee Chair: 2008-13, Treasurer: 2013-18.

Wyoming Project WILD, initial incorporating member, Steering Committee Chair: 2014-18.

Michael Huebschmann
2328 W. Whitelaw Dr.
Meridian, ID 83646-9322
Phone: (208) 515-8425
Email: MikeH@Huebschmann-Associates.com

EDUCATION

Doctor of Philosophy – Agricultural Economics; July 2000. Oklahoma State University

Dissertation Title: Restoring the shortleaf pine-bluestem grass ecosystem in the Ouachita National Forest: An economic evaluation

Master of Science (non-thesis) – Forestry; May 1986. University of Wisconsin - Madison

Bachelor of Science – Natural Resources; August 1984. University of Wisconsin - Madison

PROFESSIONAL EXPERIENCE (1993 to Present)

February 2005 to present:

Principal | Huebschmann & Assoc., LLC | Meridian, ID

- Derived econometric framework to forecast behavior of the forest products sector (particularly stumpage prices) in selected geographies across the U.S. South. Co-authored monthly newsletter relating relevant global macroeconomic developments to the current and future performance of the forest products sector. Examples available at http://www.delphiadvisors.com/portfolio.html
- Conducted multiple wood basin and timber market studies in the U.S. South, Lake States and Pacific Northwest on behalf of forest products manufacturers, timber investment management organizations, and public agencies.
- Provided due diligence related to asset acquisitions and/or divestitures.
- Collected and summarized statistics for a "fact book" related to the Idaho forest products industry.
- Assisted with upgrades to a model that simulates all functions of a sawmill operation.

October 2000 to February 2005:

Natural Resource Economist | Boise Cascade Timberland Resources Div. | Boise, ID

- Developed linear programming models to evaluate optimal forest- and stand-management plans, assess potential acquisitions and divestitures, and assure compliance with Sustainable Forestry Initiative requirements.
- Designed and managed a stratum-based divestment inventory of 144,000 acres in southwest Oregon, and provided logistical and technical support to inventories covering an additional one million acres.
- Led the development of a methodology for quantifying the impacts of adopting alternative business structures on cash flows and wood costs for each of Boise's North American operating regions.
- Derived econometric models assessing the effects of structural changes in the Pacific Northwest fiber market upon short- and long-term hardwood fiber prices.
- Directed the collection and summarization of timberland management statistics required by the Securities and Exchange Commission, and for internal regional and corporate planning purposes.

September 1993 to September 2000:

Oklahoma State University
Senior Research Specialist | Department of Forestry | Stillwater, OK

Responsible for all aspects of research programs in the following areas:

Forest Economics and Management

- Obtained and managed an $18,000 grant from the USDA Forest Service. The project reviewed the validity of the Forest Service's environmental and regional economic assessments associated with its decision to restore red-cockaded woodpecker habitat on the Ouachita National Forest.

Forest Biometrics

- Developed growth and yield models for both even- and uneven-aged natural shortleaf pine stands in the Ouachita Highlands, and combined those models into a computer simulator for use by forest managers.
- Developed a model to predict needle litterfall in even-aged natural shortleaf pine stands as a preliminary step to promoting pine-straw harvesting as a business.
- Quantified the growth responses of natural, even-aged shortleaf pine from various thinning intensities as a demonstration project for industrial landowners.
- Created a computer program to monitor bias of per-tree estimates in a horizontal point sample.
- Estimated eastern redcedar biomass and oil content as part of a potential economic development opportunity for rural Oklahoma.

Silviculture

- Assisted with the development of a seed-crop forecasting model, enabling managers to better coordinate regeneration activities with above-average seed crops.
- Studied the effects of shading on pine regeneration in rips in an attempt to influence planting practices in the upper Gulf Coastal Plain.

PROFESSIONAL AFFILIATION AND SERVICE

- Society of American Foresters.

MOST-RECENT PEER-REVIEWED PUBLICATIONS

- Zhang, D., M.M. Huebschmann, T.B. Lynch and J.M. Guldin. 2010. Forest policy impact assessment in the Ouachita National Forest and the valuation of conserving red-cockaded woodpeckers. *American Journal of Applied Science* 7(10):1345-1352.
- Lynch, T.B., R.F. Wittwer, D.G. Stevenson and M.M. Huebschmann. 2007. A maximum size-density relationship between Lorey's mean height and trees per hectare. *Forest Science* 53(4):478-485.
- Huebschmann, M.M., T.B. Lynch, D.K. Lewis, D.S. Tilley and J.M. Guldin. 2004. A bid price equation for national forest timber sales in western Arkansas and southeastern Oklahoma. *Southern Journal of Applied Forestry* 28(2):100-108.
- Lynch, T.B., J. Nkouka, M.M. Huebschmann and J.M. Guldin. 2003. Maximum likelihood estimation for predicting the probability of obtaining variable shortleaf pine regeneration densities. *Forest Science* 49(4):577-584.

Thomas B. Montzka

12435 West Bowmont Street • Boise, ID 83713 • Phone: (208) 321-0136 • Tom@Straight-Arrow-Consulting.com

Professional Experience

Straight Arrow Consulting (LLC/Inc) **2005-Present**

Principal/President

Successfully started a consulting firm that serves the forest products sector. The firm's business model includes forming "virtual corporations" of independent consultants working collaboratively to meet an individual client's needs. Straight Arrow Consulting (www.Straight-Arrow-Consulting.com) delivers multi-faceted goods and services to a variety of clients in a range of diverse geographies.

Selected Project Experience

- Confidential timber, lumber, and fiber market forecasting in support of strategic acquisitions, divestitures, and capital re-configurations. Project sizes: $10 million to over $1 billion.
- Since 2006 have provided monthly macro-economic and stumpage price forecasting service to advance supply chain management for southern U.S. industry as part of a partnership (Delphi Advisors LLC.[i] Both the macro-economic and stumpage price forecast subscriptions[ii] are marketed through Forest2Market of Charlotte, NC.
- Participated/led development and review of strategic and tactical forest management plans[iii].
- Financial modeling and evaluation, including risk analysis[iv], to assess project feasibility for a variety forest product sector capital improvement projects. Projects sizes: $10 million to $350 million. Among financial modeling tools developed is an afforestation investment model for New Zealand's Maori tribe[v], financing models to identify feasible alternatives and support securing financing support for greenfield sawmills[vi] and sawmill re-starts[vii], and forest land valuation.
- Led and participated on project teams evaluating multi-state regional wood basin assessments[viii] for public and private corporations, investors, and organizations to support strategic capital deployment decision-making, prioritizing fiber procurement alternatives, and validating controlled-wood claims for FSC certification.[ix] More than four dozen studies covering all or parts of 16 different states in the West, South, and Upper Midwest since 2005

Boise Cascade LLC, Boise, Idaho **2004 – 2005**

Manager, Boise Timberlands Planning & Development and

Financial Manager, Boise Land and Timber Corporation

Managed staff and program for technical support activities required to sell approximately 2.2 million acres of timberlands. Coordinated financial reporting activities for Boise Land and Timber, an affiliate of Boise Cascade LLC, including SEC reporting. Annualized EBITDA from Boise Land and Timber was approximately $95 million. Notable accomplishment: The lands sold for $1.65 billion within 100 days.

Boise Cascade Corporation

Manager, Timberland Planning & Development (TPD) and

Financial Manager, Timberland Resources (TR), Boise, Idaho **1992-2004**

Managed staff averaging 8 persons. Annual budget averaged $2.5 million. Staff activities included harvest scheduling, inventory, silvicultural improvement, system development, wood basket analyses, acquisition and divestiture. Administered financial controls for the TR department (averaged 40 staff), including 18,000-acre irrigated cottonwood fiber farm. Annual TR budget $10-12 million. Selected notable accomplishments included:

- Managed marketing and sales support of single timberland transaction of approximately 2.2 million for $1.65 billion; during tenure involved in acquisition and divestiture activities totaling over 6 million acres in the Western Hemisphere;
- Led and facilitated efforts that ultimately instituted and maintained a company-wide forest stewardship environmental third-party certification program;

- Organized and led cross-functional teams for ecosystem management demonstrations, PNW watershed analysis program, and intensive fiber farming assessments;

Planning Associate and Senior Planning Associate
Corporate Planning, Boise, Idaho **1990–1992**
Worked on wide range of strategic corporate-level projects. Administered corporation's capital program (approximately $450 million per annum) and prepared communications for Board of Directors regarding major capital projects. Promoted to senior planning associate during 1991.

Inventory Forester, DeRidder, Louisiana **1988-1990**
Managed design, development, and maintenance of inventory systems and fieldwork for the Louisiana region's approximately 700,000 acres.

District Forester, Elizabeth, Louisiana **1986-1988**
Responsible for management and logging activities on approximately 70,000 acres of company timberland. Annually planned and harvested approximately 24 mmbf of pine logs (including 9 mmbf purchased stumpage) and 100 thousand cords of pine pulpwood delivered to 6-12 mills, including two company mills.

Forest Economist, DeRidder, Louisiana **1982-1986**
Provided technical support services and planning for regional operations on approximately 700,000 acres.

University of Minnesota – College of Forestry
Graduate & Undergraduate Research Assistant, St. Paul & Cloquet, Minnesota **1979–1982**
As graduate assistant developed new methodologies and prepared projections of regional timber supplies for northern Minnesota. As an undergraduate research assistant worked on white spruce biomass data collection for yield, site index curve, and soil-site modeling. Published graduate work as refereed article in Canadian Journal of Forest Research as co-author.[x]

Professional Affiliations

Forest Products Society Member □ Society of American Foresters Member
Project Management Institute Member

Education

University of Minnesota, Masters of Science – Forest Management and Economics, 1987*

- Program emphases in the following related fields: Industrial Engineering, Resource Economics, Applied Statistics, Remote Sensing
  *completed graduate thesis while working for Boise Cascade Corporation in Louisiana.

University of Minnesota, Bachelors of Science – Forestry, 1980

- Graduated with honors

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[i] http://www.delphiadvisors.com/
[ii] http://www.forest2market.com/products/forest2market/economic-outlook
[iii] One public example: http://www.delphiadvisors.com/IRMP/Critique.pdf
[iv] http://www.delphiadvisors.com/RiskTalk/Risk.pdf
[v] https://interpine.nz/toitu-te-waonui-a-maori-afforestation-initiative/
[vi] https://www.hcn.org/articles/can-a-ranch-sawmill-improve-forest-health-in-rural-colorado
[vii] http://www.tribaltribune.com/news/article_6aa8bf06-52ab-11e6-bdf6-87d87cb6f838.html; UPDATE: Tribal Council decided in June 2018 to NOT re-start the CIPP sawmill.
[viii] Most of wood basin assessments are highly confidential. This is a rare one that wasn't, done as part of a larger project for Grant county Oregon, : https://www.bluemountaineagle.com/news/private-forestlands-study-outlines-actions-for-grant-county/article_2a0cffb2-cec1-536d-a1fb-54d1f3f36ed4.html
[ix] Have performed FSC controlled-wood validation for clients since 2011. Presentation shows the correspondence between our FSC-controlled wood validation methodology and wood basin analysis. http://www.delphiadvisors.com/Certification/Cert_Fiber_Supp.pdf .
[x] http://www.nrcresearchpress.com/doi/abs/10.1139/x83-024#.W151H9JKjmY

EXHIBIT E

Sarah Ostby

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

From: Ben Wudtke <bwudtke@hills.net>
Sent: Monday, August 24, 2020 3:32 PM
To: 'Hill, Alison -FS' <alison.hill@usda.gov>
Subject: RE: Black Hills GTR Comment

Alison,
I may have missed it, but I don't believe you responded with a final determination of our request to include the team of consultants' report as a comment. I would appreciate you letting me know your decision.

EXHIBIT E

Thanks,
Ben

Ben Wudtke
Executive Director
Black Hills Forest Resource Association
605-341-0875

From: Ben Wudtke <bwudtke@hills.net>
Sent: Monday, August 03, 2020 4:45 PM
To: 'Hill, Alison -FS' <alison.hill@usda.gov>
Subject: RE: Black Hills GTR Comment

Alison,
This report is information that would have been incorporated into our comments if it were available at the time. Because it is new information, we had no way of providing it when the comment period closed. This report has been independently produced and reviewed by all three of the well-qualified consultants (all hold M.S. or PhD degrees and whose clients have included the US Forest Service). The results are supported by hard copies of EVALIDator runs and other available information.
Moreover, compliance with the Information Quality Act has been described throughout the stakeholder process. We believe this information should be included to meet the requirements outlined in the April 24, 2019 memo from OMB which included: "OMB policy emphasizes that, when data are made available to the public, potential users must be provided with sufficient information to understand which agency is responsible for the quality of the data being disseminated, *as well as the data's strengths, weaknesses, analytical limitations*, security requirements, and processing options. (emphasis added) Further, the memo included updated guidance that, "Scientific Integrity, agencies should ensure that influential information is communicated transparently by "including a clear explication of underlying assumptions, accurate contextualization of uncertainties, and a description of the probabilities associated with both optimistic and pessimistic projections, including best-case and worst-case scenarios."
We believe this report is critical to meeting those requirements – especially given the report is built on publicly available agency information.
Thank you,
Ben

Ben Wudtke
Executive Director
Black Hills Forest Resource Association
605-341-0875

From: Hill, Alison -FS <alison.hill@usda.gov>
Sent: Monday, August 03, 2020 3:41 PM
To: bwudtke@hills.net
Cc: bwudtke@hills.net
Subject: RE: Black Hills GTR Comment

Thank you for the report Bill. I know our authors have seen the report.

EXHIBIT E

I understand you want us to accept this new comment under our public/stakeholder comment period; but as you know the comment period is closed. Can you tell me if the report underwent a rigorous review and what that review entailed?

Alison Hill, PhD
Research Program Manager

Forest Service
Rocky Mountain Research Station

p: 928-556-2105
alison.hill@usda.gov

Southwest Forest Science Complex, 2500 S Pine Knoll Drive
Flagstaff, AZ 86001-6381
www.fs.fed.us

Caring for the land and serving people

From: Ben Wudtke [mailto:bwudtke@hills.net]
Sent: Monday, August 3, 2020 1:36 PM
To: Hill, Alison -FS <alison.hill@usda.gov>
Cc: bwudtke@hills.net
Subject: Black Hills GTR Comment

Alison,
We, the Black Hills Forest Resource Association, previously submitted comments on the draft Black Hills GTR and we appreciate the efforts from the researchers to incorporate the best available science from those comments. However, important information that wasn't available at the previous deadline for comments is now available. This information is in the form of analysis of FIA data completed by a team of well-qualified and reputable consultants. The report from that analysis is attached.
We believe this information is paramount as the researchers work towards a final draft and we hope you will accept this as a new comment and work to incorporate the findings from this analysis into the final GTR.
The file size is large so please let me know when you have received this email and feel free to contact me with any questions or discussion.
Thanks,
Ben

Ben Wudtke
Executive Director
Black Hills Forest Resource Association
605-341-0875

EXHIBIT F

FIA Responses to "Review of the Black Hills National Forest 2017-2019 Augmented FIA Inventory Results" Report

September 2, 2020

For further information, contact:
Hobie Perry
Program Manager
Northern Research Station Forest Inventory and Analysis
USDA Forest Service
charles.h.perry@usda.gov
651-649-5191

Overview

The Black Hills National Forest (BHNF[1]) established a collaborative working group in June 2016 – including members from BHNF, forest industry, and state forestry agencies – to define specific information needs about the standing forest inventory. These questions were forwarded to FIA with the understanding that its protocols for establishment and collection of forest survey data meet rigorous scientific and statistical standards so that the information derived can be used to make forest management decisions with confidence. Those questions included:

1. What is the standing live volume estimate for Black Hills NF?
2. What is the annual gross growth estimate for Black Hills NF?
3. What is the annual net growth estimate for Black Hills NF?
4. What is the net growth to removal ratio on Black Hills NF?

The questions were broken out by the defined suitable base for timber production as defined in the 1997 Forest and Land Management Plan as well as land defined as Timberlands. To assist with preparing the estimates, FIA was asked to use the suitable base geospatial polygon layer provided by the Forest to assign plot-level suitability tags for all plots in the analysis.

A team of three consultants prepared a report on behalf of the Black Hills Forest Resource Association detailing concerns with the resulting custom ("augmented") analysis provided to BHNF. This document provides FIA's response to these critiques as summarized in the report's Executive Summary. The concerns are addressed substantively in sequence as they were not numbered in the report.

The majority of the report's claims reflect misunderstandings about how FIA prepared, completed, processed, and reported the BHNF inventory. Only two of the concerns and/or observations expressed in the summary's 18 concerns stand-up to further scrutiny: 1) growth rates in the augmented data do rely upon shorter remeasurement periods relative to the rest of the observations, and 2) NRS FIA does apply a consistent defect value across ponderosa pine as a species.

This review offered an opportunity to scrutinize the underlying data, processing, and analyses again. None of the concerns expressed in the report have discernable impacts on the published estimates. To the contrary, this review fundamentally validates the substance and quality of the published inventory data and summaries.

Concern 1

The report asserts that the augmented inventory is "less accurate (but more precise)" than the 2016 inventory despite the fact that the new inventory includes a greater number of and more recent sampling points. This assertion implies

[1] NRS FIA uses this abbreviation to remain consistent with published database tables.

the true value of each population attribute is known. This is contrary to the entire premise underlying inventory statistics: sampling to estimate population attributes that, in fact, are not known.

The report's fundamental and recurring assertion of inaccuracy rests upon the claim that the augmented inventory does not reproduce the area of a polygon from a geospatial layer, namely the "suitable base" of timberland within the BHNF. There are two misunderstandings embedded in this claim: (1) while the area of the polygon is known, the actual acreage of suitable base within the polygon is not known, and of greater concern (2) the authors have conflated estimates of the suitable base polygon with a published estimate of suitable timberland. Suitable timberland is the subset of timberland (as determined by FIA definition) found on a subset of NFS ownership (the suitable base as determined by the forest plan and NFMA) within the proclaimed forest.

It is important to reiterate the purpose of this inventory: to estimate forest attributes on lands within the BHNF. To that end, the target population is constrained to those lands actually owned by the National Forest System (NFS)[2]. Privately-held lands within the proclaimed boundary (inholdings) are excluded. Some of the area of the polygons identified as suitable base are not owned by BHNF and were therefore excluded from the evaluation. Consequently, the area of the estimation unit is less than the area of all the suitability polygons because they include both NFS and non-NFS lands. Furthermore, some suitable base polygon area is not timberland and not included in the suitable timberland estimate. This reinforces the point that the actual area of suitable base is not known with certainty. To understand the acreage assignments one must refer to Appendix A. – Acreage Comparisons and Appendix B. – Area Budget for FIA and FSVeg Suitable Base.

BHNF staff maintain a geospatial layer that depicts the Forest's suitable base. This geospatial layer (in ESRI shapefile or geodatabase format) shows many updates over time, and there have been numerous estimates of the total area of suitable base. FIA was provided an initial version of the layer from December of 2015 and a single updated version from February 2019.

FIA incorporated the layer into the analysis in two ways. First, the layer was used to assign plot-level suitability tags (as requested) for all plots in the analysis. Second, the layer was used to define the estimation units within the target population. Estimation units are mutually exclusive sub-populations within the target population that are individually stratified. This provides an ability to generate an area-controlled estimate of that sub-population if desired.

FIA uses the EXPALL evaluation to account for all acreage within an inventory. The expansion factors are computed based on the sample and stratification within each estimation unit.

The inventory meets the "accuracy" standard set by the report: FIA estimates the total area of suitable base as defined by the supplied suitable polygon layer (rasterized to 30 m pixels) and NFS ownership polygon layer (rasterized to 30 m pixels) (Table 1). The EU_AREA (based on rasterized version of the suitable base layer polygon and constrained to NFS-owned lands) and EST (acreage computed using the expansion factors) columns match. Appendix C. – SQL for Estimation Unit Area Calculations provides the Structured Query Language (SQL) used to calculate Table 1; Appendix D. – Calculating Expansion Factors covers the calculation of expansion factors.

[2] It is more appropriate to use the phrase "managed by the National Forest System" to make clear the fact that National Forest System lands are Federally owned and managed on behalf of the American public. However, we are using the term "ownership" to avoid confusion with Forest Service management delineations like "suitable base" on subsets of the Federal lands.

Table 1. EXPALL Estimation Unit Area Calculation

EVALID	ESTN_UNIT_DESCR	EU_AREA	EST	DIFF	PLT_CNT
561700	BHNF_NotSuitable	428,388	428,388	-	104
561700	BHNF_Suitable	817,388	817,388	-	222
561800	BHNF_NotSuitable	413,127	413,127	-	137
561800	BHNF_Suitable	836,982	836,982	-	297
561900	BHNF_NotSuitable	413,151	413,151	-	140
561900	BHNF_Suitable	836,959	836,959	-	298

Concern 2

The report claims that the presence of two groups of sampling points (PERMANENT and TEMPORARY) complicate the derivation of expansion factors for various estimates. This concern also includes the assertion that ‘anomalies’ exist in the data that coincide with the presence of these two groups.

Regarding the first point, the presence of groups of sampling points does not pose any challenge for FIA. FIA regularly constructs evaluations (see Appendix D. – Calculating Expansion Factors; EVALID identifies unique evaluations in Table 1) to bundle together all data required to generate unbiased estimates of specific population attributes. Each FIA evaluation is composed of two key components: a sample and a stratification of the target population.

When assembling the sample for an evaluation, each sampling point must meet certain prerequisites in order to be included. Most importantly, it must be possible to produce the desired estimate from a sampling point before it can be included in the sample. For example, one evaluation targets current estimates (the report refers to this as ‘inventory’), and each plot must meet the prerequisite of being able to produce estimates of domain areas (such as timberland) as well as tree inventory estimates (such as volume or biomass). Both the PERMANENT and TEMPORARY plots meet this prerequisite and are included in this evaluation. Another evaluation targets change estimation (such as tree growth), and only plots that have been successfully sampled at two consecutive visits may be included. Only the PERMANENT and some of the TEMPORARY plots (those that are base intensity but off-panel) are included.

Once the samples (current and change) are identified, calculations are performed that compute the expansion factors and adjustment factors (to compensate for non-response) at the stratum level. The results of these calculations are unique for each sample-stratification pairing. They can be checked for internal consistency by performing the calculation shown under the response to Concern 1.

Regarding the second point, the authors assert that ‘anomalies’ exist, coincident with the introduction of the TEMPORARY plots. These TEMPORARY plots include a full set of 2X (intensified) plot visits with accelerated implementation over the 2017 and 2018 field seasons, as well as off-panel (accelerated) visits to base plots that would not normally be sampled by the 2017-2019 field seasons. The 2X plot visits are initial establishment of new sampling points that have never been visited before and therefore have no remeasurement information. By contrast, the off-panel base plots are accelerated remeasurement (ahead of schedule) that do have remeasurement information. The inclusion of both of these sub-groups creates a new sample. Each unique sample of a target population will naturally yield different results. What the report highlights as ‘anomalies’ are simply the result of collecting a new sample. Appendix D. – Calculating Expansion Factors provides detailed examples for creating expansion factors for the change evaluation and the current inventory evaluation.

Concern 3

The report observes that FIA reports an estimate of suitable timberland on the BHNF that is below the area of a polygon in a geospatial layer. It is noteworthy that the report cites two different area estimates from two different versions of this layer which is regarded as **known** [emphasis in the original].

Several steps are taken to generate an estimate, and each “filter” subsets the area into smaller and smaller totals. First, FIA used the supplied suitable base polygons to define estimation units within the BHNF target population: one for suitable land and the other for non-suitable lands. For the purpose of this inventory, these areas are constrained to lands actually owned by BHNF and excludes inholdings of private ownership. Second, FIA computed an estimate of timberland area (importantly, by FIA's definition applied on the ground) for each of these estimation units. In addition, FIA was asked to 'tag' each plot visit with a BHNF suitability tag. This was done using the geospatial layers provided (in vector format). This plot-level tag was used to further filter the results. As a result, starting with all the plots within each estimation unit (which *does* match the area of the suitable base polygon supplied by BHNF), filtering for those plots that meet the FIA definition of timberland, and then filtering further for only those that are tagged as suitable **and** owned by the BHNF, the resulting value will be less than the area of the original polygon.

Additional detail: FIA used the vector format of the provided suitability geospatial layer to tag plot visits. This was done using the best available coordinate representing Plot Center (PC) on each plot as requested. That same vector layer must then be converted to a raster layer (30m resolution) as part of the FIA's stratification methodology. The process of 'rasterization' must resolve all the fine details of lines in the vector layer into 30 m pixels. This rasterization process can result in a pixel containing a plot where the classification changes from suitable (polygon overlay) to not suitable (pixel) and vice versa, particularly with plots on the edge of a polygon. There are 9 such cases in the 2019 sample. Appendix A. – Acreage Comparison and Table 2 show the acreage represented by these 9 plots and the relationship between the rasterized suitable estimation unit and the computed suitable land acreage. The total acreage of the BHNF Suitable estimation unit is 836,959 acres (Appendix A. – Acreage Comparison and Table 3), 41 acres less than the 837,000 acres that report cites as the **known** [emphasis in the original] suitable base acreage. The estimate of all suitable land (across all land and ownership types) is 828,925 acres, which is 8,034 acres less than the BHNF Suitable estimation unit acreage (836,959-828,925 = 8,034 ac.).

EXHIBIT F

Table 2. Suitable Land Discrepancies

EVALID	ESTN_UNIT _DESCR	EU_AREA	SRATUM_ DESCR	STAT ECD	INVY R	PLT_CN	INTENSITY	BHNF_SUITABLE _LAND	ACRES	DISCREPANCY_TYPE	REMARKS
561901	BHNF_NotSuitable	413,150.50	Canopy cover 51-65	46	2017	414838809489998	1	Y	3,325.03	RASTERIZATION	11 meters from non-suitable polygon.
561901	BHNF_NotSuitable	413,150.50	Canopy cover 6-50	46	2017	414839804489998	2	Y	3,012.36	RASTERIZATION	less than 1 meter from non-suitable polygon.
561901	BHNF_NotSuitable	413,150.50	Canopy cover 6-50	46	2018	461069453489998	1	Y	3,012.36	RASTERIZATION	9 meters from non-suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 66-100	46	2019	563086431126144	1	N	2,499.79	RASTERIZATION	8 meters from suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 6-50	46	2018	461070452489998	2	N	2,740.22	RASTERIZATION	8 meters from suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 51-65	46	2018	461070421489998	2	N	3,763.31	RASTERIZATION	8 meters from suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 51-65	56	2019	659449472126144	1	N	3,763.31	RASTERIZATION	12 meters from suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 0-5	46	2019	563086389126144	1	N	2,117.12	RASTERIZATION	7 meters from suitable polygon
561901	BHNF_Suitable	836,958.60	Canopy cover 66-100	46	2019	511296963126144	1	N	2,499.79	RASTERIZATION	18 meters from suitable polygon

Table 3. Area Estimates by Estimation Unit and BHNF Suitability Tag

EVALID	ESTN_UNIT_DESCR	EU_AREA	BHNF_SUITABLE_LAND	EST	PLT_CNT
561901	BHNF_NotSuitable	413,150.50	N	403,800.76	137
561901	BHNF_NotSuitable	413,150.50	Y	9,349.74	3
561901	BHNF_Suitable	836,958.60	N	17,383.54	6
561901	BHNF_Suitable	836,958.60	Y	819,575.06	292

Concern 4

The report observes that area estimates begin falling starting in the 2017 reporting year which corresponds to the first inclusion of the 2X sample. However, the addition of the 2X sample combined with the existing base sample constitutes an entirely new sample, bringing new information not present in the 2016 and prior samples. A change in the population-level estimates is expected as it would be with any new sample including new observations.

Concern 5

The report cites several areas for suitable timberland taken from multiple geospatial layers. FIA estimates of lands that are both classified as Suitable (via a plot tag) and also meet FIA's timberland definition have decreased in the period between 2017 and 2019.

As observed above, each of these reporting years (2017, 2018, 2019) represents a new and unique sample of the population. In this instance, the addition of more information yields lower estimates of the area of land classified as suitable timberland owned by the NFS. Rather than interpreting this as a loss of accuracy, FIA interprets this to suggest the base sample alone presents an overly optimistic estimate of these lands; more data resulted in lower area estimates and tighter confidence intervals.

As demonstrated in Concern 1, a sample-based estimate of the area of provided polygons is a straightforward calculation but not the fundamental objective of this inventory.

Concern 6

The report offers a t-test showing that it is highly unlikely that the FIA estimate of suitable timberlands comes from the same population as the area of the suitability polygon. As explained above, FIA was not trying to reproduce the area of that polygon in the "tested" estimate. On that basis alone, the test is uninformative. Additionally, a sample-based estimate of any polygon area can be produced provided that FIA uses that polygon as the basis for an estimation unit.

Concerns 7-8

The report continues its focus on the area of the suitable base polygon and attempts to "correct" FIA's estimate of suitable timberland compared to the suitable base acres from a geospatial layer. The report asserts that all subsequent estimates cannot be trusted. Even though the report demonstrates a misunderstanding of FIA's estimate of suitable NFS timberland, an exercise was performed to see the degree to which net growth is affected if all the suitable land (identified by the suitability vector layer) was designated as NFS timberland (Appendix E. – Example Adding Net Growth for Areas which are not National Forest System Timberland). The example focuses on adding an identified maximum net growth for conditions that are not NFS timberland to the total net growth estimate of ponderosa pine growing-stock trees on NFS timberland (-5,965,376 cu. ft./ac./year), BHNF 2019. After adding the identified maximum net growth, the adjusted total net growth estimate for ponderosa pine growing-stock trees is -3,595,353 cu. ft./year. Since most areas will not attain the identified maximum net growth, this is an overly optimistic estimate.

Concern 9

The report expresses dissatisfaction with FIA's previous explanations about the suitable timberland area discrepancy. The responses to concerns above address this. The report's claims that FIA's responses have not explained the decline in FIA's estimates of suitable timberland are also covered in a previous response. Simply put, new samples yield new estimates. In this case, the estimates fell when additional and more current data were used. An analysis of the ecological causes of these observed changes was outside the scope of the Forest's original request which focused upon the four estimates outlined above.

The report goes on to assert that the FIA estimates are not representative of the BHNF suitable base acres. This claim is based on the observation that a "substantial proportion" of lands classified as suitable via the polygon layer are not classified as timberland by FIA. FIA does not participate in the Forest's planning process, but the Forest's intent of defining suitable base appears to be the identification of lands capable of and authorized for producing timber products. FIA has developed its definition of timberland with the same goal, but rather than being determined solely through a map exercise, FIA implements this definition as a function of field-collected observations. As with the map products, there are various sources of error in this process, and FIA reports these uncertainties by publishing standard errors for each estimate.

It is possible for a particular piece of land to be classified via a GIS exercise as suitable base and for this land to not meet the FIA definition of timberland in the field. Discrepancies could be attributed to the definitions used in the two efforts as well as errors from either or both sources. For example, FIA's calculations may conclude the site to be unproductive and therefore not timberland. If such a determination was made from observations on the FIA plot footprint, then it is very likely well below the minimum mapping unit of the polygon layer. It is misleading to construe this as "unrepresentative." This is also addressed in the area budget prepared by BHNF staff and distributed in preparation for the April stakeholder meeting (Appendix B. – Area Budget for FIA and FSVeg Suitable Base).

Concern 10

The report expresses concern over shortened remeasurement periods for the 2019 off-panel (accelerated) base plots. This is a valid concern and one that was discussed at the time of the 2019 sample selection. The determination was that FIA field crews are capable of making accurate diameter measurements at remeasurement periods of 3 years or more.

Blind checks are one quality assessment tool used by FIA where a random sample of at least 4 percent of all plots are measured independently by a quality assurance (QA) crew. Blind check measurements are used to observe how often individual field crews are meeting a set of measurement quality objectives (MQOs) that are set for every data item collected and to assess the overall compliance among all crews.

FIA is meeting the measurement quality objective (MQO) tolerance (Table 4) for diameter-at-breast height (d.b.h.). Data in the two columns labeled "All NRS states" are derived from all measurements made by Northern Research Station-FIA crews within the entire 24-state region.

The mean change in d.b.h. at approximately 3 years is 0.27 inches (Figure 1) and increases with lengthening remeasurement intervals. These changes in d.b.h. are readily measurable given the compliance to MQO tolerances. Additionally, there is not a pronounced relationship between mean annual increment and remeasurement class (Figure 1).

Table 4. Compliance to measurement quality objectives (MQO) tolerances for d.b.h. on blind check plots, Northern Research Station, 2017

			All NRS states	
Variable	Tolerance	Objective	Data within tolerance	Number of observations
D.b.h.	±0.1 inch per 20 inches	95%	96%	48,623

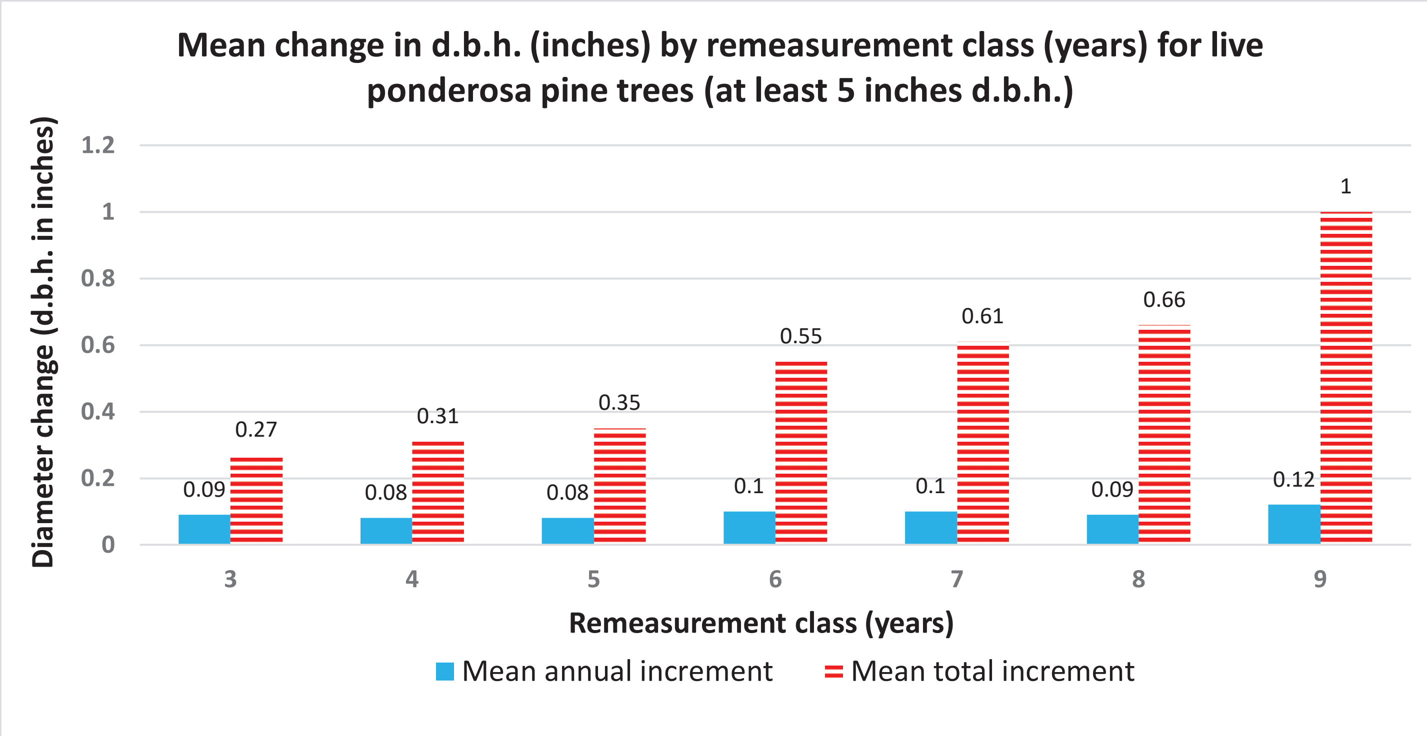

Figure 1. Mean annual and total change in d.b.h. (inches) by remeasurement class (years) for live ponderosa pine trees (at least 5 inches d.b.h.). Remeasurement class bins remeasurement period such that it is less than (down to the next class) or equal to the shown value; e.g., remeasurement periods less than or equal to three years are identified as remeasurement class 3. Remeasurement class 9 only includes two trees; whereas, the other classes have tree counts ranging from 169 to 698.

Concern 11

The report expresses concern over the implementation of the intensified sampling points. Specifically, the goal appears to be to determine if there is a bias in the establishment of these additional sampling points.

Blackard and Patterson (2014)[3] cover the topic in detail.

To summarize, the BHNF intensified sampling points were established using the following methods:

1) Create a bounding polygon around the target population (BHNF) with buffer to reduce any possible edge effects
2) Use the EPA GRID program to generate a finer point network than the base sampling frame
    a. This is the same method used to generate FIA's P2 (~6,000 acre hexagonal sampling frame) but generates a finer network
3) Convert this finer point network into a hexagonal tessellation of the landscape
4) Execute a script that implements the FIA national panels (5 values) and the 14 sub-panels.
    a. These are repeating spatial patterns orthogonal to each other
5) Break the tessellation hexagons created in step 3
    a. These finer hexagons are not constrained to the parent hexagon. They are broken at the boundary and combined such that there is the desired number of sub-polygons within the parent P2 hexagon and all these polygons are equal area.
    b. Note that some of the polygons are multi-part polygons but still have the same area as all the other sub-polygons

[3] Blackard, Jock A.; Patterson, Paul L. 2014. National FIA plot intensification procedure report. Gen. Tech. Rep. RMRS-GTR-329. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.

6) Update the panelization
    a. FIA never reassigns plots to panels. So the sub-polygon in which the base plot falls inherits that plot's panel information. If that conflicts with the assignment made by the script in step 4 then sub-polygons exchange panel assignments
    b. This is random relative to the underlying landscape
7) Assign spatial intensities randomly to all sub-polygons (excluding the base sub-polygon)
8) Randomly locate new sampling points within each of the new sub-polygons
    a. Each new sampling point inherits the characteristics of the sub-polygon: intensity and panel address

In this way, the intensified sample is distributed as a systematic sample with a random element; each plot location is a randomly located point within a network of equal-area polygons. This limits the degree of spatial clumping permitted. The panel assignments ensure that there is no clumping on the time axis of the sampling frame. Note: at no point are locations coerced to fall in any particular area. In fact, this sampling frame intensification work was done prior to selection of the 2017 field sample which occurred before FIA received any geospatial layers used during analysis.

Concern 12

The report highlights the large amount of uncertainty in some of inventory estimates. As analyses are conducted in finer domains within the population (for example, only sawtimber trees of a particular species on a particular land basis filtered for suitability), the uncertainty of that estimate will increase. This is referred to as the "curse of dimensionality": the more dimensions one adds to an analysis, the greater the volume of the resulting feature space, and consequently the lower the density of data available to estimate attributes within that volume of feature space.

The report also makes the point that one must always look at the uncertainty associated with any estimate. FIA completely agrees and would include areas of polygons intended to classify land characteristics under that rule.

Concern 13

The report computes growth rates (defined as gross growth divided by gross volume in CCF units) and compares the resulting growth rates of the 2019 "augmented" data set to the four most recent years available in the public FIADB. See Appendix F – SQL Estimating Growth Rate for the calculations. This analysis was constrained to only the SD side of the population (Table 5). It is possible to reproduce these estimates:

Table 5. Growth rates for BHNF, South Dakota only.

EVALID	GROSS_SL_VOL_CF	EVALID	PLT_CNT	TREE_CNT	ANN_GROSS_GROWTH	GROWTH_RATE
561901	4,589,953.80	561903	113	1019	111,578.30	2.43%
461901	4,937,990.00	461903	113	1115	158,449.30	3.21%
461801	5,104,329.20	461803	114	1152	168,800.50	3.31%
461701	5,508,451.60	461703	115	1203	174,224.20	3.16%
461601	5,874,722.00	461603	114	1194	169,747.60	2.89%

The concern is that the "augmented" 2019 gross growth estimate is lower than the corresponding estimates from the public database. There are some key differences contributing to these changes in estimated growth rates:

- The "augmented" data set uses a different sample than the 2019 public data set even though the plot counts match.
    - The "augmented" data set includes more recent observations than the public dataset. These are the off-panel (accelerated) visits to base plots.
    - Also note that there is a lower number of trees contributing to these estimates as well. This is because the more recent plot visits recorded fewer trees.
        - As an example, consider a plot that was last visited in 2013 in the public dataset but was visited in 2019 in the "augmented" data set. The 2013 visit would have observed change from the previous visit (2008), whereas the 2019 visit would have observed change from its last visit (2013).
- The "augmented" and public data sets both employ different stratifications
    - The "augmented" uses a stratification that ignores the WY/SD state line. The estimation units are defined by suitable and not-suitable areas and the BHNF boundary (actual ownership, not proclaimed). Then each estimation unit is stratified. Expansion and adjustment factors are computed for this specific sample/stratification pairing, yielding an unbiased estimate
    - The public data set uses a stratification with estimation units defined by FIA survey units and the BHNF boundary (actual ownership, not proclaimed). This stratification is geographically constrained to only SD. The expansion and adjustment factors were computed for this specific sample/stratification pairing, yielding an unbiased estimate
- The "augmented" and public 2019 estimates do represent the same reporting year but are based on different samples which observe different periods of change and employ different stratifications. As a result, the "augmented" data set shows a different, lower gross growth rate.

If the gross growth rate is computed from the "augmented" data set, without excluding WY, the rate is 2.51%.

There is no reason to suspect these lower growth rates are biased or otherwise underrepresenting the components of this attribute. As the previous concern suggests, the uncertainty of these values is an important consideration in interpreting these estimates.

Concern 14

The report builds on the previous concern, gross annual growth rate. The report states that the 3% rate is "more defensible" because it aligns more closely with the recent SD estimates from the on-line data and because it "mitigates the effects of incorrect acreage estimation…"

Regarding the first point, the 3% rate computed from the on-line data is based on older observations. It ignores the more recent observations included in the "augmented" data set (Figure 2).

EXHIBIT F

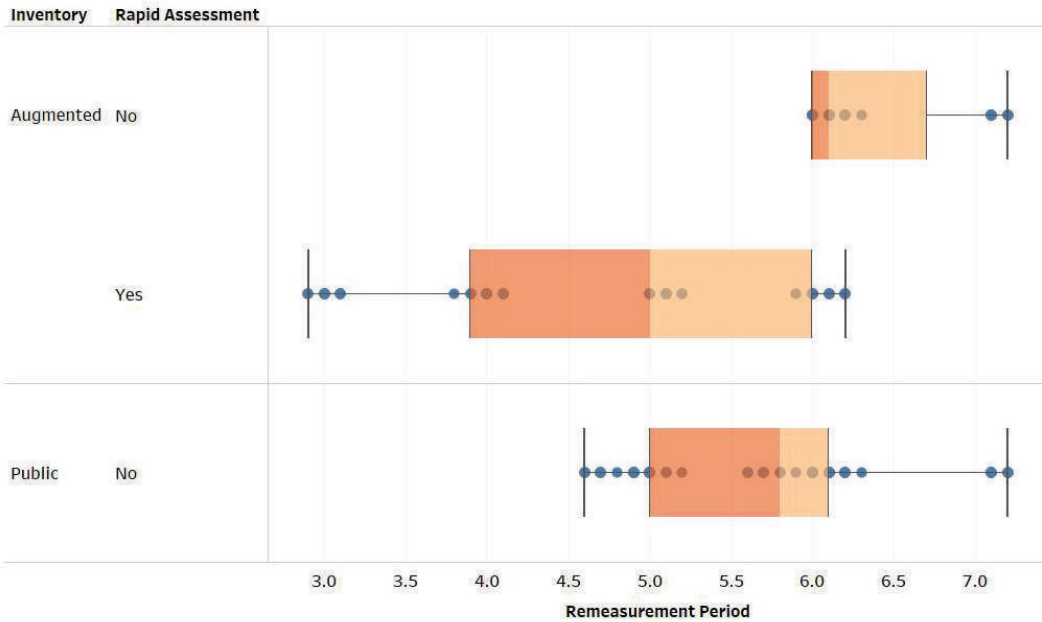

Figure 2. Distribution of plot remeasurement periods by 2019 inventories and rapid assessment status.

Regarding the second point, we have already addressed the report's concerns with acreage estimation.

Concern 15

The report acknowledges the recent mountain pine beetle outbreaks and other disturbances but state that the long-term gross growth rate is unlikely to waver from FIA estimates "from the previous 10 years." This assumes no other outbreaks or other stressors will impact growth rates in the future.

Concern 16

FIA does not attempt to model mortality; it relies on empirical observation of these events. From these observations, an annualized rate of mortality is calculated. As a result, the FIA estimates empirically show the ebb and flow of forest characteristics, particularly when looking at two decades of annualized inventory. These estimates help to quantify and contextualize the ranges of growth and mortality, and, as a result, the important variable of net growth.

The report's concerns about values used by Graham et al. (2020) are outside the scope of this response.

Additionally, discussion of the report's FVS modeling results, while noted by several reviewers, is not in NRS FIA's purview aside from the observation that the low simulated mortality rates produced by the generic FVS simulation are not supported by FIA data.

Concern 17

The report correctly observes that the BHNF suitability flag is assigned at the plot level and proceeds to assert that it would be more appropriate to have this flag assigned at the subplot level on the grounds that it is really functioning as a condition-level variable.

First, FIA completed what was requested: plot-level tagging.

Second, the report states that suitability should be assigned at the subplot level. The authors presumably mean condition level based on their reference to other condition-level variables for justification.

Third, this approach is reasonable if suitability does indeed vary more at a finer spatial resolution than at the plot level. This suggestion also appears to accept that the definition of suitable base through any GIS exercise will necessarily have "inclusions" that are contrary to each polygon's classification: GIS-suitable may be field-unsuitable and vice versa.

If this variable is indeed a condition-level attribute, then there are two methods to provide this, neither of which can be completed at this point in the analysis. The first would be to request the crews to collect this information on-plot. The second is to model it in the office based on field-collected measurements. Direct field measurements would need to be developed and deployed on some test plots to assure some reliability to the field measurement. The second method requires training a model where field measurements can be associated with the “correct” answer. FIA has no such model. Given the sensitivity of this variable for the analysis, such an addition should be developed and tested before including it in the final analysis.

Concern 18

The report observes a constant defect percentage was applied to sawtimber trees for two species of concern: ponderosa pine and white spruce. Early QA/QC results for defect found it to have low repeatability across the former North Central Research Station’s FIA unit. An average value is applied by TREECLCD as a way of limiting the effects of this noise at the population level. This value was applied in both the “augmented” and on-line dataset.

While there is no formal documentation for this value, the estimate applied by FIA (11.78%) is consistent with defect observed on recent BHNF ponderosa pine timber sales (11.8%, J. Krueger, pers. comm.).

EXHIBIT F

Appendices

Appendix A. – Acreage Comparisons

This appendix compares area estimates of the custom BHNF 2019 inventory (generated from FIA SQLite database and MyEVALIDator) to the spatial data sets used to create estimation units for the BHNF 2019 inventory.

Estimation Unit Acreage

NFS ownership GIS vector polygon layer (10/15/18) with 1,537,519.90 total acres from NFS Enterprise Data Warehouse

A. NFS at 1,250,851.2 acres (ac.)
B. NonNFS at 286,668.7 ac.

Suitability vector polygon layer (Feb. 2019) from NFS FSVeg intersected with NFS ownership vector layer resulting in 1,250,851 total ac. delineated as

	Suitability Vector			
BHNF Ownership Vector	No	Yes	(blank)	Grand Total
NON-FS	275,941	6,679	4,047	286,668
USDA FOREST SERVICE	413,082	836,713	1,057	1,250,851
(blank)	980	325		1,305
Grand Total	690,003	843,717	5,104	1,538,824

NFS ownership and suitability vector layers are rasterized (30m pixels) and intersected with other layers to form the NFS suitable/nonsuitable estimation units as follows

A. Total 1,250,110 ac., *only NFS owned*
   a) suitable estimation unit at 836,959 ac.
   b) unsuitable estimation unit at 413,151 ac.

NFS owned ownership vector layer acreage is more than NFS owned estimation unit acreage (1,250,851 - 1,250,110 = 741 ac.)

NFS owned suitable estimation unit acreage is more than NFS owned suitable acreage of the suitability vector layer (836,959 - 836,713 = 246 ac.)

MyEVALIDator BHNF 2011-2020 Acreage (ver. 1.8.0.01, rev. Dec. 16, 2019)

Plots are tagged as suitable/unsuitable using the suitable/nonsuitable vector layer.

A. Three plots are assigned suitable but fall within the rasterized not suitable estimation unit.
   a) Accounts for 9,349.7 ac.
B. Six plots are assigned not suitable but fall within the rasterized suitable estimation unit.
   a) Accounts for 17,383.54 ac.

C. Result is more acreage assigned to not suitable than the non suitable estimation unit represents.
   a) 17,383.54 - 9,349.7 = 8,033.8 ac.

D. Suitable estimation unit acreage minus MyEVALIDator total suitable land acreage matches the difference in C.
   a) 836,959 - 828,925 = 8,034 ac.

MyEVALIDator All land

	Ownership class			
BHNF Suitability	Total	National Forest	Private	Other
Total	1,250,109	1,110,383	21,253	118,473
Suitable	828,925	783,293	5,456	40,176
Not suitable	421,184	327,090	15,797	78,297

EXHIBIT F

MyEVALIDator BHNF 2011-2020 Acreage (ver. 1.8.0.01, rev. Dec. 16, 2019) continued

Nonforest, forest and timberland land use, along with ownership, are assigned to plots in the field according to FIA protocol.

The estimation units, which are delineated as NFS ownership, have inholdings of private land identified in the field. The suitable estimation unit has areas that do not meet the FIA definition of timberland.

A. MyEVALIDator estimate of all land owned by National Forest and tagged as suitable with vector layer is 783,293 ac.
B. MyEVALIDator estimate of timberland owned by National Forest and tagged as suitable with vector layer is 765,733 ac.

MyEVALIDator All Land (repeat from previous slide)

	Ownership class			
BHNF Suitability	**Total**	**National Forest**	**Private**	**Other**
Total	1,250,109	1,110,383	21,253	118,473
Suitable	828,925	783,293	5,456	40,176
Not suitable	421,184	327,090	15,797	78,297

MyEVALIDator National Forest Only

	Land use					
BHNF Suitability	**Total**	**Timberland**	**Other forestland**	**Reserved productive forestland**	**Reserved other forestland**	**Nonforest**
Total	1,110,383	1,062,776	27,556	13,214	3,012	3,825
Suitable	783,293	765,733	10,995	2,740	-	3,825
Not suitable	327,090	297,042	16,561	10,474	3,012	-

Rocky Mountain Research Station (RMRS-FIA) records ownership on nonforest land. The 3,825 acres is nonforest NFS land identified in Wyoming by RMRS-FIA. The remaining nonforest land was inventoried by NRS-FIA in South Dakota. NRS-FIA does not record ownership on nonforest land. A remaining 118,473 acres of nonforest with unknown ownership is labeled as “Other” in the MyEVALIDator All Land table.

EXHIBIT F

Appendix B. – Area Budget for FIA and FSVeg Suitable Base

COMPARISON OF FOREST INVENTORY ANALYSIS AND FSVEG AREA ESTIMATES
SUITABLE AND ACCESSIBLE TIMBERLAND

Black Hills National Forest & Northern Research Station, Forest Inventory & Analysis
March 25, 2020

Background

Since the release of the online FIA data several questions have come up regarding the acreages that were reported. A comparison between the Forest Inventory Analysis (FIA) 2017–2019 inventory on the Black Hills National Forest (BHNF) land class area estimates and the 2015 forest Field Sampled Vegetation (FSVeg) Spatial layer was conducted to ensure consistency between inventories with an emphasis on suitable and accessible timberlands.

FSVeg Spatial is a geodatabase platform that combines vegetation stand data with survey information from various sources including common stand exam surveys (CSE), photo interpretation, quick plot surveys, and post-harvest updates. CSE data is collected following rigorous national protocols. Data is used to develop site-specific resource estimates to assess vegetation and site attributes, determine stand treatment needs, and develop detailed silvicultural prescriptions. Since 2015 we have collected CSE data on 20,000 plots geographically dispersed across the forest. For more information regarding CSE go to https://www.fs.fed.us/nrm/fsveg/.

Forest Inventory Analysis data are collected by professional field crews implementing national protocols and subject to quality assurance/quality control procedures. Details on field data collection are available online. The peer-reviewed statistical foundations of the FIA sample ensure that reliable, unbiased estimates are generated along with associated values of uncertainty.

A comparison between these inventory datasets is imprecise due to the differences in how area is calculated, the timing of exams, sampling intensity, and classification protocols. CSE has been collected over a longer time period in comparison with the FIA inventory. These exams are designed to sample forest stands in comparison with the landscape scale sampling intensity of FIA inventories.

The 2015 FSVeg layer was selected for comparison since this layer was provided to FIA to determine the land class of plot locations during inventory design.

The 2015 FSVeg spatial layer was compared to the timber suitability calculations in Appendix G of the 2006 BHNF Land and Resource Management Plan Phase II Amendment to assess land class area changes during this time period.

We have concluded the following:

- The net suitable and accessible timberland total area estimates for each inventory are comparable (See Table B1). The FSVeg spatial total (731,283 acres) falls within the 95% confidence interval for the FIA estimate (704,860 ± 30,808 acres).
- Differences in FIA and forest land classification are apparent regarding classification of currently non-forest areas or regenerating areas with low stocking. FIA data indicates that 44,000 acres is non-forest, presumably through a type conversion from forest to grasslands. The majority of these acres are still designated as part of the suitable and accessible timber base by the BHNF as non-stocked or marginally stocked areas (84,244 acres).
- Differences in classification of non-forest or regenerating areas with low stocking will not affect volume estimates.
- The BHNF suitable timber base decreased 2006-2015 by approximately 42,000 acres from 865,890 to 824,240 acres (See Table B2). Major changes to area estimates occurred for uneconomical areas and reserved areas such as wilderness, research natural areas, late successional reserves, and backcountry recreation areas.

EXHIBIT F

Table B1. Comparison of FIA and FSVeg spatial inventory estimates of suitable and accessible timberland.

Land class or condition	FIA Inventory 2017 - 2019	FSVeg Spatial Dec 2015 Suitable Base	Comments
	acres		
Total Acres - BHNF Suitable Base	**828,925**	**824,240**	For FIA data, plot locations were derived from the forest suitable base layer
Private and other ownership	-5,456	-4,194	Includes state lands for FSVeg
Reserved productive	-2,740	0	Wilderness, already filtered from FSVeg spatial layer
Net USFS Acres	**820,729**	**820,046**	
Other forestland	-10,995	-2,471	Non-commercial stands
Non-forest	-44,000	-1,904	Other land use or vegetation type conversion
Not classified	0	-144	
Net USFS suitable timberlands	**765,734**	**815,527**	
Non-stocked	-60,873	-84,244	Canopy closure < 10% on site that is capable of growing commercial timber.
Net stocked, suitable timberland	**704,861**	**731,283**	

Table B2. Net major changes to suitable and accessible timberlands by land class category, BHNF, 2006 -2015.*

Description	Change (acres)
Increase in net NF acres	10,693
Increase in grasslands	-8,567
Expansion of wilderness	-3,490
Designation of RNAs	-1,780
Increase in inaccessible Area	-18,445
Increase in LSR	-3,876
Decrease in riparian reserved	4,134
Increase in developed recreation sites	-6,528
Decrease in backcountry recreation areas	3,129
Decrease in Spearfish Canyon acres	-3,497
Decrease in southern hills unsuitable	7,387
Increase in steep slope - uneconomical designation	-11,484
Increase in isolated patched - uneconomical designation	-6,774
Forest type conversion	-3,446
Net Change to suitable and accessible timberland (acres)	-42,543

*Comparison between land class area in 2006 BHNF Land and Resource Management Plan Phase II Amendment and the February 5, 2015 FSVeg Spatial layer. This table does not include all land class changes.

Appendix C. – SQL for Estimation Unit Area Calculations

SQL used to produce Table 1.

```
--tab=SuitableAreaEstimateAll
WITH dat AS
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.area_used AS eu_area,
         plt.statecd,
         plt.invyr,
         plt.cn AS plt_cn,
         plt.intensity,
         plt.bhnf_suitable_land,
         SUM(cnd.condprop_unadj * ps.expns * ps.adj_factor_subp) AS acres
    FROM pop_eval pe
    JOIN pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN pop_eval_grp peg
      ON peg.cn = pe.eval_grp_cn
    JOIN pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
    JOIN pop_plot_stratum_assgn ppsa
      ON ppsa.stratum_cn = ps.cn
    JOIN plot_vw plt
      ON ppsa.plt_cn = plt.cn
    LEFT JOIN plot pplt
      ON plt.prev_plt_cn = pplt.cn
    JOIN cond cnd
      ON cnd.plt_cn = plt.cn
   WHERE peg.eval_grp IN (562017, 562018, 562019)
     AND pet.eval_typ = 'EXPALL'
   GROUP BY pe.evalid,
            peu.estn_unit_descr,
            peu.area_used,
            plt.statecd,
            plt.invyr,
            plt.intensity,
            plt.cn,
            plt.bhnf_suitable_land)
----------------------------------------------
SELECT dat.evalid,
       dat.estn_unit_descr,
       dat.eu_area,
       round(SUM(dat.acres), 2) AS est,
       COUNT(DISTINCT dat.plt_cn) AS plt_cnt
  FROM dat
 GROUP BY dat.evalid, dat.estn_unit_descr, dat.eu_area
 ORDER BY evalid, estn_unit_descr;
```

Calculating Expansion Factors for the Black Hills National Forest 2019 Inventory
USDA Forest Service, Forest Inventory & Analysis Program (FIA)
7/9/2020

Executive summary

The Forest Inventory and Analysis (FIA) program is responsible for generating statistically valid estimates of a wide range of forest attributes. The program employs a stratified estimation methodology to accomplish this task while improving the precision of the estimates. This methodology is based upon peer-reviewed literature[4].

The process of generating an estimate of a population attribute (such as the total number of trees) involves two "expansions": (1) Trees Per Acre and (2) Expansion Factor. The Trees Per Acre (TPA) expansion is the number of trees per acre represented by a sampled tree. This value is determined by FIA's fixed-radius plot footprint as follows:

- Sampled trees (sampled on 24' subplots): 6.01846
- Sampled saplings (sampled on the 6.8' microplot): 74.965282

To understand the Expansion Factor (EXPNS) it is important to first understand what an 'evaluation' is. FIA has defined the term 'evaluation' to mean the unique combination of a sample (set of plot visits) combined with a stratification of the target population for the purpose of generating estimates of a specific set of population attributes. The sample used for any given evaluation is filtered such that only plot visits that are capable of producing the intended estimates are included. For example, if the intended estimate is tree growth, then only plots that have been re-measured are included in the sample. The Expansion Factor (EXPNS) is a value computed at the stratum level as the area of the stratum divided by the number of sampling points (n) and is expressed in units of Acres Per Plot. This value is multiplied by whatever attribute is being estimated to expand it to the population level. For example, if the desired population attribute was total number of trees then the basic calculation would to as follows:

- Multiply each sampled tree or sapling on a plot visit by its TPA
- Sum the above products
- Multiply the above Sum by the EXPNS

The result represents that plot visit's contribution to the population total of interest. In practice, most estimates are also subject to filters that tune the estimate to desired domain of the population (such as a particular species or forest type).

The details of this process are laid out below with sample code for the Black Hills National Forest (BHNF[5]).

INTRODUCTION

FIA has defined the term 'evaluation' as the unique combination of a stratification of the population and a sample for the purpose of generating a particular set of estimates. Evaluations are typically constructed for current estimates (which do not require remeasurement) or change estimates (which do require remeasurement). Each evaluation has an evaluation identifier (POP_ESTN_UNIT.EVALID) in the database.

[4] Bechtold, William A.; Patterson, Paul L.; [Editors] 2005. The enhanced forest inventory and analysis program - national sampling design and estimation procedures. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 85 p.

[5] The National Forest System uses the abbreviation BKNF for the Black Hills National Forest, and all of our tables use BHNF. That abbreviation is repeated here for internal consistency.

EXHIBIT F

This document presents the elements required to create plot expansion factors, in acres, and the associated Structured Query Language (SQL) used to derive the elements. SQL presented in this document attempts to meet the American National Standards Institute (ANSI) standard. Data from the current and change evaluations of the Black Hills National Forest (BHNF) 2019 inventory are covered.

Process

1. Identify estimation units

Estimation units are specific geographic areas of independent sub-populations within the total target population. Each estimation unit is stratified independently from other estimation units. Each strata within an estimation unit is a non-overlapping subdivision of the population. The strata are also independent. Strata are usually based on land use or cover and other criteria such as ownership.

GIS layers from the National Forest System (NFS) are used to create estimation units for the BHNF inventory. An ownership layer (S_USA.BasicOwnership; source: USDA Enterprise Data Warehouse, 7/3/2018) and a suitable/not suitable layer (source: BHNF) identify each of the two estimation units. Estimation unit 1 is area labeled as not suitable and owned by NFS. Estimation unit 2 is area labeled as suitable and owned by NFS. In the database, estimation unit 1 is identified by POP_ESTN_UNIT.ESTN_UNIT = 1 and described as POP_ESTN_UNIT.ESTN_UNIT_DESCR = BHNFS_NotSuitable. Likewise, estimation unit 2 is identified by POP_ESTN_UNIT.ESTN_UNIT = 2 and described as POP_ESTN_UNIT.ESTN_UNIT_DESCR = BHNFS_Suitable.

The change evaluation used for BHNF 2019 inventory is identified by POP_ESTN_UNIT.EVALID = 561903. The change evaluation can also be identified by POP_EVAL_GRP = 562019 and POP_EVAL_TYP = ‘EXPGROW’ for net growth, by POP_EVAL_GRP = 562019 and POP_EVAL_TYP = ‘EXPMORT’ for mortality, and by POP_EVAL_GRP = 562019 and POP_EVAL_TYP = ‘EXPREMV’ for removals. The same set of remeasured plots are used for net growth, mortality and removals. There is a separate EVAL_TYP in the database for each type of change just in case a different set of plots was used among the types. In this case, and in almost all change evaluations for FIA, the same set of remeasured plots are used for every change type. In this case, the remeasured plots are from the base (1x) sample. The intensified (2x) sample has been established but not remeasured; hence, change estimates are only available for the base sample.

The evaluation for current inventory estimates is identified by POP_ESTN_UNIT.EVALID = 561901 or by POP_EVAL_GRP = 562019 and POP_EVAL_TYP = ‘EXPVOL’ for current volume and number of trees or by POP_EVAL_GRP = 562019 and POP_EVAL_TYP = ‘EXPCURR’ for current area. The same set of currently measured plots are used for current number of trees, volume and area. The current inventory plots are from the 1x and 2x intensity samples collectively.

2. Obtain area, in acres, and number of pixels for each estimation unit

The GIS layers that comprise the estimation units are rasterized (converted from polygons to 30m square pixels) and the area of the pixels comprising each estimation unit is calculated and stored in POP_ESTN_UNIT.AREA_USED. The number of pixels comprising each estimation unit is stored in POP_ESTN_UNIT.P1PNTCNT_EU. These metrics are used with others from the strata layer to calculate the plot expansion factors. The strata layer, NLCD LANDSAT 2011 Tree Canopy Cover, is a 30m resolution raster data set. The GIS layers are rasterized to facilitate the geospatial processing that identifies the strata (canopy cover classes) within each estimation unit and identify the coincident plots.

SQL identifying area of each estimation unit is as follows (replace the variable &fiadb_schema with the literal database schema):

```
select evalid, estn_unit, estn_unit_descr, area_used, p1pntcnt_eu from
&fiadb_schema.pop_estn_unit where evalid in (561901,561903)
```

Table D6. Area by estimation unit on the Black Hills National Forest.

EVALID	ESTN_UNIT	ESTN_UNIT_DESCR	AREA_USED	P1PNTCNT_EU
561901	1	BHNFS_NotSuitable	413,151	1,857,733
561901	2	BHNFS_Suitable	836,959	3,763,390
561903	1	BHNFS_NotSuitable	413,151	1,857,733
561903	2	BHNFS_Suitable	836,959	3,763,390

3. Select strata layer boundaries within each estimation unit and identify the plots and pixels by strata or canopy cover class

Actual plot locations are intersected by estimation unit and stratum layer and then assigned to their overlapping estimation unit and stratum in the database. Strata are categorized by canopy cover class. Up to five canopy cover classes are employed. Count the number of plots (POP_STRATUM.P2POINTCNT) and the number of pixels (POP_STRATUM.P1POINTCNT) by estimation unit and strata or canopy cover class. These metrics are used with others to calculate the plot expansion factor.

SQL identifying the relationship among the estimation units, strata and plots for the change evaluation is as follows (EXPGROW is for net growth; substitute with EXPMORT for mortality, EXPREMV for removals, EXPVOL for volume or EXPCURR for area):

```
SELECT PEU.*, POP_STRATUM.*, PLOT.*
  FROM &FIADB_SCHEMA.POP_EVAL_GRP PEG
  JOIN &FIADB_SCHEMA.POP_EVAL_TYP PET
    ON (PET.EVAL_GRP_CN = PEG.CN)
  JOIN &FIADB_SCHEMA.POP_EVAL PEV
    ON (PEV.CN = PET.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_ESTN_UNIT PEU
    ON (PEV.CN = PEU.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_STRATUM POP_STRATUM
    ON (PEU.CN = POP_STRATUM.ESTN_UNIT_CN)
  JOIN &FIADB_SCHEMA.POP_PLOT_STRATUM_ASSGN
    ON (POP_PLOT_STRATUM_ASSGN.STRATUM_CN = POP_STRATUM.CN)
  JOIN &FIADB_SCHEMA.PLOT
    ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
 WHERE PET.EVAL_TYP = 'EXPGROW'
   AND PEG.EVAL_GRP = 562019
```

Identify sampled plots (entire or partial) and remove entirely non-sampled plots

Use values from PLOT.PLOT_STATUS_CD to identify sampled plots (includes partially sampled plots) and nonsampled plots. Plots with values of 1 (sampled – at least one accessible forest land condition present on plot) or 2 (sampled – no accessible forest land condition present on plot) will be part of the evaluation and those with a value of 3 (nonsampled) will not. Obtain a total count of the plots with values of 1 or 2 (not separate counts for each value). These counts are stored in POP_STRATUM.P2POINTCNT.

SQL counting the number of sampled plots for the change evaluation (POP_EVAL_TYP = 'EXPGROW'; results are the same for mortality and removals) as follows:

```
SELECT Sum(CASE PLOT.PLOT_STATUS_CD
  when 3 then 0
  else 1
  end) P2POINTCNT
  FROM &FIADB_SCHEMA.POP_EVAL_GRP PEG
  JOIN &FIADB_SCHEMA.POP_EVAL_TYP PET
    ON (PET.EVAL_GRP_CN = PEG.CN)
```

```
  JOIN &FIADB_SCHEMA.POP_EVAL PEV
    ON (PEV.CN = PET.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_ESTN_UNIT PEU
    ON (PEV.CN = PEU.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_STRATUM POP_STRATUM
    ON (PEU.CN = POP_STRATUM.ESTN_UNIT_CN)
  JOIN &FIADB_SCHEMA.POP_PLOT_STRATUM_ASSGN
    ON (POP_PLOT_STRATUM_ASSGN.STRATUM_CN = POP_STRATUM.CN)
  JOIN &FIADB_SCHEMA.PLOT
    ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
 WHERE PET.EVAL_TYP = 'EXPGROW'
   AND PEG.EVAL_GRP = 562019
```

Output

P2POINTCNT for all sampled remeasured plots

225

SQL counting the number of sampled plots for the current evaluation (POP_EVAL_TYP = 'EXPVOL') as follows:

```
SELECT Sum(CASE PLOT.PLOT_STATUS_CD
  when 3 then 0
  else 1
  end) P2POINTCNT
  FROM &FIADB_SCHEMA.POP_EVAL_GRP PEG
  JOIN &FIADB_SCHEMA.POP_EVAL_TYP PET
    ON (PET.EVAL_GRP_CN = PEG.CN)
  JOIN &FIADB_SCHEMA.POP_EVAL PEV
    ON (PEV.CN = PET.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_ESTN_UNIT PEU
    ON (PEV.CN = PEU.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_STRATUM POP_STRATUM
    ON (PEU.CN = POP_STRATUM.ESTN_UNIT_CN)
  JOIN &FIADB_SCHEMA.POP_PLOT_STRATUM_ASSGN
    ON (POP_PLOT_STRATUM_ASSGN.STRATUM_CN = POP_STRATUM.CN)
  JOIN &FIADB_SCHEMA.PLOT
    ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
 WHERE PET.EVAL_TYP = 'EXPVOL'
   AND PEG.EVAL_GRP = 562019
```

Output

P2POINTCNT for all sampled current inventory plots

438

SQL identifying the number of pixels by estimation unit and canopy cover class as follows:

```
select evalid, estn_unit, stratumcd, stratum_descr, p1pointcnt from
&fiadb_schema.pop_stratum where evalid in (561901, 561903) order by evalid, estn_unit,
stratumcd
```

Table D7. Number of pixels by estimation unit and canopy cover class.

EVALID	ESTN_UNIT	STRATUMCD	STRATUM_DESCR	P1POINTCNT
561901	1	1	Canopy cover 0 - 5	256,738
561901	1	2	Canopy cover 6 - 50	1,056,128
561901	1	3	Canopy cover 51 - 65	343,873
561901	1	45	Canopy cover 66 - 100	200,994
561901	2	1	Canopy cover 0 - 5	209,432
561901	2	2	Canopy cover 6 - 50	2,297,813
561901	2	3	Canopy cover 51 - 65	786,861

561901	2	45	Canopy cover 66 - 100	469,284
561903	1	12	Canopy cover 0 - 50	1,312,866
561903	1	345	Canopy cover 51 - 100	544,867
561903	2	1	Canopy cover 0 - 5	209,432
561903	2	2	Canopy cover 6 - 50	2,297,813
561903	2	3	Canopy cover 51 - 65	786,861
561903	2	45	Canopy cover 66 - 100	469,284

4. Calculate expansion factor for each plot by stratum

The expansion factor for each plot by stratum is the area of the estimation unit multiplied by the stratum weight divided by the number of sampled plots in the stratum. Expansion factors, in acres, are stored in POP_STRATUM.EXPNS. Stratum weights are not stored directly, but calculated in each query by dividing POP_STRATUM.P1POINTCNT by POP_ESTN_UNIT.P1PNTCNT_EU.

SQL expression calculating expansion factor for each plot by stratum as follows:

```
Sum (POP_ESTN_UNIT.AREA_USED * POP_STRATUM.P1POINTCNT / POP_ESTN_UNIT.P1PNTCNT_EU /
POP_STRATUM.P2POINTCNT)
```

Full SQL statement calculating expansion factors for each plot by stratum of the change evaluation (POP_EVAL_TYP = 'EXPGROW'; results are the same for mortality and removals):

```
SELECT POP_STRATUM.EVALID,
       POP_STRATUM.ESTN_UNIT,
       POP_STRATUM.STRATUMCD,
       POP_STRATUM.STRATUM_DESCR,
       POP_STRATUM.P2POINTCNT,
       POP_STRATUM.P1POINTCNT,
       PEU.P1PNTCNT_EU,
       Sum (PEU.AREA_USED * POP_STRATUM.P1POINTCNT / PEU.P1PNTCNT_EU /
POP_STRATUM.P2POINTCNT) EXPNS
   FROM &FIADB_SCHEMA.POP_EVAL_GRP PEG
  JOIN &FIADB_SCHEMA.POP_EVAL_TYP PET
    ON (PET.EVAL_GRP_CN = PEG.CN)
  JOIN &FIADB_SCHEMA.POP_EVAL PEV
    ON (PEV.CN = PET.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_ESTN_UNIT PEU
    ON (PEV.CN = PEU.EVAL_CN)
  JOIN &FIADB_SCHEMA.POP_STRATUM POP_STRATUM
    ON (PEU.CN = POP_STRATUM.ESTN_UNIT_CN)
 WHERE PET.EVAL_TYP = 'EXPGROW'
   AND PEG.EVAL_GRP = 562019
group by POP_STRATUM.EVALID,
          POP_STRATUM.ESTN_UNIT,
          POP_STRATUM.STRATUMCD,
          POP_STRATUM.STRATUM_DESCR,
          POP_STRATUM.P2POINTCNT,
          POP_STRATUM.P1POINTCNT,
          PEU.P1PNTCNT_EU
order by estn_unit, stratumcd
```

Table D8. Expansion factors for change evaluation (EVAL_TYP = 'EXPGROW')

EVALID	ESTN_UNIT	STRATUMCD	STRATUM_DESCR	P2POINTCNT	P1POINTCNT	P1PNTCNT_EU	EXPNS
561903	1	12	Canopy cover 0 - 50	45	1,312,866	1,857,733	6,488
561903	1	345	Canopy cover 51 - 100	19	544,867	1,857,733	6,378
561903	2	1	Canopy cover 0 - 5	14	209,432	3,763,390	3,327

561903	2	2	Canopy cover 6 - 50	100	2,297,813	3,763,390	5,110
561903	2	3	Canopy cover 51 - 65	20	786,861	3,763,390	8,750
561903	2	45	Canopy cover 66 - 100	27	469,284	3,763,390	3,865

Table D9. Expansion factors for current inventory evaluation. (Users may substitute 'EXPGROW' with 'EXPVOL' in SQL; results are the same for current area using 'EXPCURR'.)

EVALID	ESTN_UNIT	STRATUMCD	STRATUM_DESCR	P2POINTCNT	P1POINTCNT	P1PNTCNT_EU	EXPNS
561901	1	1	Canopy cover 0 - 5	18	256,738	1,857,733	3,172
561901	1	2	Canopy cover 6 - 50	79	1,056,128	1,857,733	2,973
561901	1	3	Canopy cover 51 - 65	23	343,873	1,857,733	3,325
561901	1	45	Canopy cover 66 - 100	20	200,994	1,857,733	2,235
561901	2	1	Canopy cover 0 - 5	22	209,432	3,763,390	2,117
561901	2	2	Canopy cover 6 - 50	187	2,297,813	3,763,390	2,733
561901	2	3	Canopy cover 51 - 65	47	786,861	3,763,390	3,723
561901	2	45	Canopy cover 66 - 100	42	469,284	3,763,390	2,485

SQL verifying estimates from expansion factor calculation match those stored in POP_STRATUM.EXPNS as follows:

```
select evalid, estn_unit, stratumcd, stratum_descr, expns from &fiadb_schema.pop_stratum
where evalid in (561901, 561903) order by evalid, estn_unit, stratumcd
```

Output

EVALID	ESTN_UNIT	STRATUMCD	STRATUM_DESCR	EXPNS
561901	1	1	Canopy cover 0 - 5	3,172
561901	1	2	Canopy cover 6 - 50	2,973
561901	1	3	Canopy cover 51 - 65	3,325
561901	1	45	Canopy cover 66 - 100	2,235
561901	2	1	Canopy cover 0 - 5	2,117
561901	2	2	Canopy cover 6 - 50	2,733
561901	2	3	Canopy cover 51 - 65	3,723
561901	2	45	Canopy cover 66 - 100	2,485
561903	1	12	Canopy cover 0 - 50	6,488
561903	1	345	Canopy cover 51 - 100	6,378
561903	2	1	Canopy cover 0 - 5	3,327
561903	2	2	Canopy cover 6 - 50	5,110
561903	2	3	Canopy cover 51 - 65	8,750
561903	2	45	Canopy cover 66 - 100	3,865

EXHIBIT F

Appendix E. – Example Adding Net Growth for Areas which are not National Forest System Timberland

What if all sampled conditions, on plots identified as suitable with suitability vector layer, are identified as NFS-owned timberland and an identified maximum net growth is assigned to those conditions which need to be changed, for the sake of the example, to NFS-owned timberland?

This example shows the addition of net growth (for areas that are not NFS timberland) to the existing total net growth estimate of ponderosa pine growing-stock trees on suitable (@ suitability layer) timberland for NFS ownership (-5,965,376 cu. ft./ac./year), BHNF 2019.

The total estimate which will be adjusted is -5,965,376 cu. ft./ac./year and is described in detail as attribute number 208 or average annual net growth of merchantable bole volume of growing-stock trees (at least 5 inches d.b.h.), in cubic feet, on timberland. Filter applied is "and cond.owngrpcd=10 and plotgeom.bhnf_suitable_land = 'Y' and tree.spcd = 122" limiting domain of interest to ponderosa pine (tree.spcd = 122), NFS owned (cond.owngrpcd = 10) and plots identified as suitable with the suitability GIS vector layer (plotgeom.bhnf_suitable_land = 'Y').

The example adds net growth for sampled conditions that are not timberland and or not owned by NFS but are on plots identified as suitable with the suitability vector layer. By definition outside of this example, this domain of sampled conditions contributes no net growth to the total estimate of NFS timberland.

1) The area of this domain is calculated using the remeasurement sample expansion and adjustment factors identified by EVALID = 561903. 2) Next, the maximum net growth per acre of ponderosa pine (for BHNF 2019 inventory) is identified for timberland owned by NFS on plots identified as suitable with the suitability layer (domain used for the total estimate of -5,965,376 cu.ft./year). 3) Then, this maximum net growth per acre is assigned to the previously calculated acreage. 4) Finally, the existing total of -5,965,376 cu. ft./year is adjusted by adding the maximum net growth.

The results show 35,268 acres (using the remeasurement sample) that does not contribute net growth by definition. A maximum net growth of 67.2 cu. ft./ac./year was identified. Assigning the maximum identified net growth to the acreage results in 2,370,023 cu. ft./year. Adding the existing total net growth of -5,965,376 cu. ft./year with the previous result, yields -3,595,353 cu. ft./year. One would need to attribute the identified maximum net growth to approximately 88,771 acres to reach a total net growth of 0 (67.2 cu. ft./ac./year * 88,771.48 = 5,965,376 cu. ft./year).

1)

```
-- Calculate area not timberland and or not owned by NFS but identified at the plot level
as suitable with the suitability GIS vector layer, BHNF 2019
SELECT SUM((COND.CONDPROP_UNADJ * CASE COND.PROP_BASIS
             WHEN 'MACR' THEN
              POP_STRATUM.ADJ_FACTOR_MACR
             ELSE
              POP_STRATUM.ADJ_FACTOR_SUBP
           END) * POP_STRATUM.EXPNS) AS Acreage
  FROM POP_STRATUM POP_STRATUM
  JOIN POP_PLOT_STRATUM_ASSGN
    ON (POP_PLOT_STRATUM_ASSGN.STRATUM_CN = POP_STRATUM.CN)
  JOIN PLOT
    ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
  JOIN PLOTGEOM
    ON (PLOT.CN = PLOTGEOM.CN)
  JOIN COND
    ON (COND.PLT_CN = PLOT.CN)
 WHERE COND.CONDPROP_UNADJ IS NOT NULL
   AND COND.COND_STATUS_CD < 5
   AND ((pop_stratum.rscd = 23 and pop_stratum.evalid = 561903))
   and (cond.owngrpcd <> 10 or cond.cond_status_cd <> 1 or
       cond.siteclcd = 7 or cond.reservcd = 1)
```

```
   and plotgeom.bhnf_suitable_land = 'Y'
   and 1 = 1
```

Result for acreage: 35,268.19 acres

2)

```
-- Identify maximum net growth per acre/year of ponderosa pine for timberland owned by NFS on
-- plots identified as suitable with the suitability GIS vector layer, BHNF 2019
select max(netgrowth_per_acre) max_netgrowth_per_acre_and_year
  from (SELECT cn plot_cn,
               Case
                 when sum(denom) <> 0 then
                  SUM(Numerator) / SUM(DENOM)
               end Netgrowth_Per_Acre,
               SUM(Numerator) numerator,
               SUM(DENOM) denominator
          FROM (SELECT plot.cn,
                       SUM((GRM.TPAGROW_UNADJ * (CASE
                             WHEN COALESCE(GRM.SUBPTYP_GRM, 0) = 0 THEN
                              0
                             WHEN GRM.SUBPTYP_GRM = 1 THEN
                              POP_STRATUM.ADJ_FACTOR_SUBP
                             WHEN GRM.SUBPTYP_GRM = 2 THEN
                              POP_STRATUM.ADJ_FACTOR_MICR
                             WHEN GRM.SUBPTYP_GRM = 3 THEN
                              POP_STRATUM.ADJ_FACTOR_MACR
                             ELSE
                              0
                           END) * (CASE
                             WHEN BE.ONEORTWO = 2 THEN
                              (CASE
                                WHEN (GRM.COMPONENT = 'SURVIVOR' OR
                                     GRM.COMPONENT = 'INGROWTH' OR
                                     GRM.COMPONENT LIKE 'REVERSION%') THEN
                                 (TREE.VOLCFNET / PLOT.REMPER)
                                WHEN (GRM.COMPONENT LIKE 'CUT%' OR
                                     GRM.COMPONENT LIKE 'DIVERSION%') THEN
                                 (TRE_MIDPT.VOLCFNET / PLOT.REMPER)
                                ELSE
                                 0
                              END)
                             ELSE
                              (CASE
                                WHEN (GRM.COMPONENT = 'SURVIVOR' OR
                                     GRM.COMPONENT = 'CUT1' OR
                                     GRM.COMPONENT = 'DIVERSION1' OR
                                     GRM.COMPONENT = 'MORTALITY1') THEN
                                 CASE
                                   WHEN TRE_BEGIN.TRE_CN IS NOT NULL THEN
                                    - (TRE_BEGIN.VOLCFNET / PLOT.REMPER)
                                   ELSE
                                    - (PTREE.VOLCFNET / PLOT.REMPER)
                                 END
                                ELSE
                                 0
                              END)
                           END)) * POP_STRATUM.EXPNS) AS Numerator,
                       0 as denom
                  FROM BEGINEND BE, POP_STRATUM POP_STRATUM
                  JOIN POP_PLOT_STRATUM_ASSGN POP_PLOT_STRATUM_ASSGN
                    ON (POP_STRATUM.CN = POP_PLOT_STRATUM_ASSGN.STRATUM_CN)
```

EXHIBIT F

```
    JOIN PLOT PLOT
      ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
    JOIN PLOTGEOM PLOTGEOM
      ON (PLOT.CN = PLOTGEOM.CN)
    JOIN PLOT PPLOT
      ON (PLOT.PREV_PLT_CN = PPLOT.CN)
    JOIN COND PCOND
      ON (PLOT.PREV_PLT_CN = PCOND.PLT_CN)
    JOIN COND COND
      ON (PLOT.CN = COND.PLT_CN)
    JOIN TREE TREE
      ON (TREE.CONDID = COND.CONDID AND TREE.PLT_CN = PLOT.CN AND
          TREE.PREVCOND = PCOND.CONDID)
    LEFT OUTER JOIN TREE PTREE
      ON (TREE.PREV_TRE_CN = PTREE.CN)
    LEFT OUTER JOIN TREE_GRM_BEGIN TRE_BEGIN
      ON (TREE.CN = TRE_BEGIN.TRE_CN)
    LEFT OUTER JOIN TREE_GRM_MIDPT TRE_MIDPT
      ON (TREE.CN = TRE_MIDPT.TRE_CN)
    LEFT OUTER JOIN (SELECT TRE_CN,
                            DIA_BEGIN,
                            DIA_MIDPT,
                            DIA_END,
                            SUBP_COMPONENT_GS_TIMBER     AS COMPONENT,
                            SUBP_SUBPTYP_GRM_GS_TIMBER   AS SUBPTYP_GRM,
                            SUBP_TPAGROW_UNADJ_GS_TIMBER AS TPAGROW_UNADJ
                       FROM TREE_GRM_COMPONENT) GRM
      ON (TREE.CN = GRM.TRE_CN)
   WHERE 1 = 1
     AND ((pop_stratum.rscd = 23 and
         pop_stratum.evalid = 561903))
     and cond.owngrpcd = 10
     and plotgeom.bhnf_suitable_land = 'Y'
     and tree.spcd = 122
     and cond.owngrpcd = 10
     and plotgeom.bhnf_suitable_land = 'Y'
     and 1 = 1
   GROUP BY plot.cn
  UNION
  SELECT plot.cn,
         SUM(0) AS ESTIMATED_VALUE,
         SUM(POP_STRATUM.EXPNS * COND.CONDPROP_UNADJ *
             CASE COND.PROP_BASIS
               WHEN 'MACR' THEN
                POP_STRATUM.ADJ_FACTOR_MACR
               ELSE
                POP_STRATUM.ADJ_FACTOR_SUBP
             END) AS DENOM
    FROM POP_STRATUM POP_STRATUM
    JOIN POP_PLOT_STRATUM_ASSGN
      ON (POP_PLOT_STRATUM_ASSGN.STRATUM_CN = POP_STRATUM.CN)
    JOIN PLOT
      ON (POP_PLOT_STRATUM_ASSGN.PLT_CN = PLOT.CN)
    JOIN PLOTGEOM
      ON (PLOT.CN = PLOTGEOM.CN)
    JOIN COND
      ON (COND.PLT_CN = PLOT.CN)
   WHERE COND.RESERVCD = 0
     AND COND.SITECLCD IN (1, 2, 3, 4, 5, 6)
     AND COND.COND_STATUS_CD = 1
     AND COND.CONDPROP_UNADJ IS NOT NULL
     AND ((pop_stratum.rscd = 23 and
         pop_stratum.evalid = 561903))
```

EXHIBIT F

```
                and cond.owngrpcd = 10
                and plotgeom.bhnf_suitable_land = 'Y'
                and 1 = 1
              GROUP BY plot.cn)
      GROUP BY cn
      ORDER BY Netgrowth_Per_Acre, cn)
```

Result for maximum net growth ac./year: 67.2 cu. ft./ac./year

3)

Assign maximum net growth per acre/year to the suitable acreage not contributing to net growth by definition.

35,268 acres x 67 cu. ft. /ac./year = 2,370,023 cu. ft./year

4)

Adjust total net growth of ponderosa pine growing stock on suitable (@ suitability layer) timberland for the BHNF using net growth derived from maximum net growth per acre/year and suitable acreage not contributing to net growth by definition.

-5,965,376 cu. ft./year + 2,370,023 cu. ft./year= -3,595,353 cu. ft./year

EXHIBIT F

Appendix F. – SQL Estimating Growth Rate

```
-- These first two scripts generate the components of "growth rate"
-- from the 2019 "augmented" dataset
----------------------------------------------------------------------------------------
--tab=TimberlandGrossGrowthSL
--  Script was taken from a TreeSketchWork script and modified
WITH std AS -- A list of plots assigned to the RAPID_ASSESSMENT study
 (SELECT m.nppt_cn
    FROM fs_nims_nrs.nims_prefield_study_mtx_vw m
    JOIN fs_nims_nrs.psd_study s
      ON m.psds_cn = s.cn
   WHERE s.study_name = 'RAPID_ASSESSMENT'),
agtcd AS -- Look-up values for agent codes (cause of death)
 (SELECT r.category,
         r.code,
         r.abbr,
         regexp_substr(r.meaning, '[A-z]*', 1, 1) AS meaning,
         r.manual_start,
         r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category = 'CAUSE_DEATH_CD'
     AND r.manual_end IS NULL),
distb AS -- Look-up codes for condition-level disturbance codes
 (SELECT r.category, r.code, r.abbr, r.meaning, r.manual_start, r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category = 'DISTURBANCE'
     AND r.manual_end IS NULL),
trt AS -- Look-up codes for condition-level treatment codes
 (SELECT r.category, r.code, r.abbr, r.meaning, r.manual_start, r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category LIKE '%STAND_TREATMENT%'
     AND r.manual_end IS NULL),
pop AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
         peu.p1pntcnt_eu,
         ps.p1pointcnt,
         ps.p2pointcnt,
         ps.expns,
         ps.adj_factor_subp,
         ps.adj_factor_micr
    FROM pop_eval pe
    JOIN pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
   WHERE pet.eval_typ = 'EXPGROW'
     AND pe.evalid IN ( /*561703, 561853,*/ 561903)),
cnddstblst AS -- Assemble the condition-level disturbance codes on each condition with
labels
 (SELECT cnd_cn,
         nvl("Weather damage", 0) AS "Weather damage",
         nvl("Vegetation", 0) as"Vegetation",
         nvl("Disease", 0) as"Disease",
         nvl("Insect", 0) as"Insect",
         nvl("Animal Damage", 0) as"Animal Damage",
         nvl("Fire", 0) as"Fire",
```

```
        nvl("Human", 0) as"Human"
    FROM (SELECT cnd_cn, distb.abbr, val
           FROM (SELECT cond.cn AS cnd_cn,
                        1 AS val,
                        trunc(cond.dstrbcd1 / 10) * 10 AS dstrbcd1,
                        trunc(cond.dstrbcd2 / 10) * 10 AS dstrbcd2,
                        trunc(cond.dstrbcd3 / 10) * 10 AS dstrbcd3
                   FROM cond) unpivot(dstrbcd FOR distb IN(dstrbcd1,
                                                            dstrbcd2,
                                                            dstrbcd3)) t
           JOIN distb
             ON t.dstrbcd = distb.code
          WHERE dstrbcd > 0)
  pivot(MAX(val)
     FOR abbr IN('Weather damage' AS "Weather damage",
                'Vegetation' AS "Vegetation",
                'Disease' AS "Disease",
                'Insect' AS "Insect",
                'Animal Damage' AS "Animal Damage",
                'Fire' AS "Fire",
                'Human' AS "Human"))),
cndtrtlst AS -- Assemble the condition-level treatment codes on each condition with
labels
 (SELECT cnd_cn,
        nvl("None", 0) AS "None",
        nvl("Cutting", 0) AS "Cutting",
        nvl("Site prep", 0) AS "Site prep",
        nvl("Art regen", 0) AS "Art regen",
        nvl("Nat regen", 0) AS "Nat regen",
        nvl("Other", 0) AS "Other"
    FROM (SELECT cnd_cn, trt.abbr, val
           FROM (SELECT cond.cn     AS cnd_cn,
                        1           AS val,
                        cond.trtcd1,
                        cond.trtcd2,
                        cond.trtcd3
                   FROM cond) unpivot(trtcd FOR trt IN(trtcd1,
                                                       trtcd2,
                                                       trtcd3)) t
           JOIN trt
             ON t.trtcd = trt.code
          WHERE trtcd > 0)
  pivot(MAX(val)
     FOR abbr IN('None' AS "None",
                'Cutting' AS "Cutting",
                'Site prep' AS "Site prep",
                'Art regen' AS "Art regen",
                'Nat regen' AS "Nat regen",
                'Other' AS "Other"))),
trees AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
        decode(std.nppt_cn, NULL, 'N', 'Y') AS rapid_assessment,
        plt.measyear,
        plt1.measyear AS measyear_t1,
        plt.remper,
        tre.condid,
        tre.cn AS tre_cn,
        tre.spcd,
        tre.statuscd,
        tre.agentcd,
        nvl(cnddstblst."Weather damage", 0) AS "Weather damage",
        nvl(cnddstblst."Vegetation", 0) AS "Vegetation",
        nvl(cnddstblst."Disease", 0) AS "Disease",
```

EXHIBIT F

```
          nvl(cnddstblst."Insect", 0) AS "Insect",
          nvl(cnddstblst."Animal Damage", 0) AS "Animal Damage",
          nvl(cnddstblst."Fire", 0) AS "Fire",
          nvl(cnddstblst."Human", 0) AS "Human",
          nvl(cndtrtlst."None", 0) AS "None",
          nvl(cndtrtlst."Cutting", 0) AS "Cutting",
          nvl(cndtrtlst."Site prep", 0) AS "Site prep",
          nvl(cndtrtlst."Art regen", 0) AS "Art regen",
          nvl(cndtrtlst."Nat regen", 0) AS "Nat regen",
          nvl(cndtrtlst."Other", 0) AS "Other",
          tre.dia,
          tre1.dia AS dia_t1,
          rs.common_name,
          rs.sftwd_hrdwd AS CLASS
     FROM plot_vw plt
     LEFT JOIN std
       ON plt.cn = std.nppt_cn
     JOIN tree tre
       ON plt.cn = tre.plt_cn
     JOIN cond cnd
       ON tre.plt_cn = cnd.plt_cn
      AND tre.condid = cnd.condid
     JOIN ref_species rs
       ON tre.spcd = rs.spcd
     LEFT JOIN tree tre1
       ON tre.prev_tre_cn = tre1.cn
     LEFT JOIN plot plt1
       ON plt.prev_plt_cn = plt1.cn
     LEFT JOIN cnddstblst
       ON cnddstblst.cnd_cn = cnd.cn
     LEFT JOIN cndtrtlst
       ON cndtrtlst.cnd_cn = cnd.cn
    WHERE tre.spcd = 122 -- only Ponderosa pine
      AND cnd.owngrpcd = 10 -- only forest service conditions
   /* AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7)*/ --
timberland only
   ),
grm AS -- Combine tree-condition data with change data and apply analysis parameters
 (SELECT grm.plt_cn,
         grm.tre_cn,
         trees.rapid_assessment,
         trees.measyear,
         trees.measyear_t1,
         trees.remper,
         trees.spcd,
         trees.statuscd,
         trees.agentcd,
         trees.dia,
         trees.dia_t1,
         trees."Weather damage",
         trees."Vegetation",
         trees."Disease",
         trees."Insect",
         trees."Animal Damage",
         trees."Fire",
         trees."Human",
         trees."None",
         trees."Cutting",
         trees."Site prep",
         trees."Art regen",
         trees."Nat regen",
         trees."Other",
         trees.common_name,
```

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```
          trees.class,
          grm.component,
          grm.subptyp_grm,
          grm.tpagrow_unadj,
          grm.tparemv_unadj,
          grm.tpamort_unadj,
          grm.ann_net_growth,
          grm.mortality,
          grm.removals,
          grm.est_begin,
          grm.est_midpt,
          grm.est_end,
          (grm.g_s + grm.i + grm.g_i + grm.g_m + grm.g_c + grm.r + grm.g_r +
          grm.g_d) / grm.remper AS gross_growth,
          grm.g_s,
          grm.i,
          grm.g_i,
          grm.m,
          grm.g_m,
          grm.c,
          grm.g_c,
          grm.r,
          grm.g_r,
          grm.d,
          grm.g_d,
          grm.cd,
          grm.g_cd,
          grm.ci,
          grm.g_ci
     FROM tree_grm_estn grm
     JOIN trees
       ON trees.tre_cn = grm.tre_cn
    WHERE grm.land_basis = 'TIMBERLAND'
      AND grm.estn_type = 'SL'
      AND grm.estn_units = 'CF'
      AND grm.estimate = 'VOLUME'
      AND grm.component != 'NOT USED')
-------------------------------------------------------------------------------------------
-- MAIN SQL LOGIC STARTS HERE
-------------------------------------------------------------------------------------------
SELECT pop.evalid,
       COUNT(DISTINCT grm.plt_cn) plt_cnt,
       COUNT(DISTINCT grm.tre_cn) tree_cnt,
       /*to_char(*/
       round(SUM(grm.gross_growth * grm.tpagrow_unadj *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,

'999,999,999.9')*/ AS ann_gross_growth,
       /*to_char(*/
       round(SUM(grm.ann_net_growth * grm.tpagrow_unadj *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,
```

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```
'999,999,999.9')*/ AS ann_net_growth,
       /*to_char(*/
       round(SUM((grm.ann_net_growth * grm.tpagrow_unadj -
                 grm.removals * grm.tparemv_unadj) *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,

'999,999,999.9')*/ AS ann_net_change
  FROM pop
  JOIN pop_plot_stratum_assgn ppsa
    ON ppsa.stratum_cn = pop.ps_cn
  JOIN plot_vw plt
    ON ppsa.plt_cn = plt.cn
  JOIN grm
    ON grm.plt_cn = plt.cn
  LEFT JOIN agtcd
    ON grm.agentcd = agtcd.code
 WHERE plt.bhnf_suitable_land = 'Y' -- filter for only suitable lands
   AND plt.statecd = 46
 GROUP BY pop.evalid
 ORDER BY pop.evalid;

--tab=TimberlandGrossInventorySL
WITH pop AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
         peu.p1pntcnt_eu,
         ps.p1pointcnt,
         ps.p2pointcnt,
         ps.expns,
         ps.adj_factor_subp,
         ps.adj_factor_micr
    FROM pop_eval pe
    JOIN pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
   WHERE pet.eval_typ = 'EXPCURR'
     AND pe.evalid IN ( /*561703, 561853,*/ 561901)),
trees AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
         plt.statecd,
         plt.measyear,
         plt1.measyear AS measyear_t1,
         plt.remper,
         tre.condid,
         tre.cn AS tre_cn,
         tre.spcd,
         tre.statuscd,
         tre.agentcd,
         tre.dia,
         tre1.dia AS dia_t1,
```

```
         rs.common_name,
         rs.sftwd_hrdwd AS CLASS,
         tre.volcsnet * tre.tpa_unadj AS volcsgrs_exp
    FROM plot_vw plt
    JOIN tree tre
      ON plt.cn = tre.plt_cn
    JOIN cond cnd
      ON tre.plt_cn = cnd.plt_cn
     AND tre.condid = cnd.condid
    JOIN ref_species rs
      ON tre.spcd = rs.spcd
    LEFT JOIN tree tre1
      ON tre.prev_tre_cn = tre1.cn
    LEFT JOIN plot plt1
      ON plt.prev_plt_cn = plt1.cn
   WHERE tre.spcd = 122 -- only Ponderosa pine
     AND tre.statuscd = 1 -- live trees only
     AND cnd.owngrpcd = 10 -- only forest service conditions
     AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7) -- timberland
only
     AND plt.bhnf_suitable_land = 'Y' -- retrict to only suitable lands
  )
------------------------------------------------------------------------------------------
-- MAIN SQL LOGIC STARTS HERE
------------------------------------------------------------------------------------------
SELECT trees.spcd,
       trees.statuscd,
       round(SUM(trees.volcsgrs_exp * pop.expns * pop.adj_factor_subp) / 100,
             1) AS gross_sl_vol_cf
  FROM trees
  JOIN pop_plot_stratum_assgn ppsa
    ON trees.plt_cn = ppsa.plt_cn
  JOIN pop
    ON ppsa.stratum_cn = pop.ps_cn
 WHERE trees.statecd = 46
 GROUP BY trees.spcd, trees.statuscd;

-----------------------------------------------------------------------------------------
-- These next two script generate the components from the on-line data.
--tab=TimberlandGrossGrowthSL
--  Script was taken from a TreeSketchWork script and modified
WITH std AS -- A list of plots assigned to the RAPID_ASSESSMENT study
 (SELECT m.nppt_cn
    FROM fs_nims_nrs.nims_prefield_study_mtx_vw m
    JOIN fs_nims_nrs.psd_study s
      ON m.psds_cn = s.cn
   WHERE s.study_name = 'RAPID_ASSESSMENT'),
agtcd AS -- Look-up values for agent codes (cause of death)
 (SELECT r.category,
         r.code,
         r.abbr,
         regexp_substr(r.meaning, '[A-z]*', 1, 1) AS meaning,
         r.manual_start,
         r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category = 'CAUSE_DEATH_CD'
     AND r.manual_end IS NULL),
distb AS -- Look-up codes for condition-level disturbance codes
 (SELECT r.category, r.code, r.abbr, r.meaning, r.manual_start, r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category = 'DISTURBANCE'
     AND r.manual_end IS NULL),
trt AS -- Look-up codes for condition-level treatment codes
```

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```
 (SELECT r.category, r.code, r.abbr, r.meaning, r.manual_start, r.manual_end
    FROM nims_ref_category_code r
   WHERE r.category LIKE '%STAND_TREATMENT%'
     AND r.manual_end IS NULL),
pop AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
         peu.p1pntcnt_eu,
         ps.p1pointcnt,
         ps.p2pointcnt,
         ps.expns,
         ps.adj_factor_subp,
         ps.adj_factor_micr
    FROM fs_fiadb.pop_eval pe
    JOIN fs_fiadb.pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN fs_fiadb.pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN fs_fiadb.pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
   WHERE pet.eval_typ = 'EXPGROW'
     AND pe.evalid IN (461603, 461703, 461803, 461903)),
cnddstblst AS -- Assemble the condition-level disturbance codes on each condition with
labels
 (SELECT cnd_cn,
         nvl("Weather damage", 0) AS "Weather damage",
         nvl("Vegetation", 0) as"Vegetation",
         nvl("Disease", 0) as"Disease",
         nvl("Insect", 0) as"Insect",
         nvl("Animal Damage", 0) as"Animal Damage",
         nvl("Fire", 0) as"Fire",
         nvl("Human", 0) as"Human"
    FROM (SELECT cnd_cn, distb.abbr, val
            FROM (SELECT cond.cn AS cnd_cn,
                         1 AS val,
                         trunc(cond.dstrbcd1 / 10) * 10 AS dstrbcd1,
                         trunc(cond.dstrbcd2 / 10) * 10 AS dstrbcd2,
                         trunc(cond.dstrbcd3 / 10) * 10 AS dstrbcd3
                    FROM fs_fiadb.cond) unpivot(dstrbcd FOR distb IN(dstrbcd1,
                                                                     dstrbcd2,
                                                                     dstrbcd3)) t
            JOIN distb
              ON t.dstrbcd = distb.code
           WHERE dstrbcd > 0)
  pivot(MAX(val)
     FOR abbr IN('Weather damage' AS "Weather damage",
                 'Vegetation' AS "Vegetation",
                 'Disease' AS "Disease",
                 'Insect' AS "Insect",
                 'Animal Damage' AS "Animal Damage",
                 'Fire' AS "Fire",
                 'Human' AS "Human"))),
cndtrtlst AS -- Assemble the condition-level treatment codes on each condition with
labels
 (SELECT cnd_cn,
         nvl("None", 0) AS "None",
         nvl("Cutting", 0) AS "Cutting",
         nvl("Site prep", 0) AS "Site prep",
         nvl("Art regen", 0) AS "Art regen",
         nvl("Nat regen", 0) AS "Nat regen",
```

EXHIBIT F

```
       nvl("Other", 0) AS "Other"
  FROM (SELECT cnd_cn, trt.abbr, val
          FROM (SELECT cond.cn     AS cnd_cn,
                       1           AS val,
                       cond.trtcd1,
                       cond.trtcd2,
                       cond.trtcd3
                  FROM fs_fiadb.cond) unpivot(trtcd FOR trt IN(trtcd1,
                                                                trtcd2,
                                                                trtcd3)) t
          JOIN trt
            ON t.trtcd = trt.code
         WHERE trtcd > 0)
pivot(MAX(val)
   FOR abbr IN('None' AS "None",
              'Cutting' AS "Cutting",
              'Site prep' AS "Site prep",
              'Art regen' AS "Art regen",
              'Nat regen' AS "Nat regen",
              'Other' AS "Other"))),
bhnf AS -- bring in suitability tags
 (SELECT cn, bhnf_suitable_land FROM plot_vw),
trees AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
         bhnf.bhnf_suitable_land,
         decode(std.nppt_cn, NULL, 'N', 'Y') AS rapid_assessment,
         plt.measyear,
         plt1.measyear AS measyear_t1,
         plt.remper,
         tre.condid,
         tre.cn AS tre_cn,
         tre.spcd,
         tre.statuscd,
         tre.agentcd,
         nvl(cnddstblst."Weather damage", 0) AS "Weather damage",
         nvl(cnddstblst."Vegetation", 0) AS "Vegetation",
         nvl(cnddstblst."Disease", 0) AS "Disease",
         nvl(cnddstblst."Insect", 0) AS "Insect",
         nvl(cnddstblst."Animal Damage", 0) AS "Animal Damage",
         nvl(cnddstblst."Fire", 0) AS "Fire",
         nvl(cnddstblst."Human", 0) AS "Human",
         nvl(cndtrtlst."None", 0) AS "None",
         nvl(cndtrtlst."Cutting", 0) AS "Cutting",
         nvl(cndtrtlst."Site prep", 0) AS "Site prep",
         nvl(cndtrtlst."Art regen", 0) AS "Art regen",
         nvl(cndtrtlst."Nat regen", 0) AS "Nat regen",
         nvl(cndtrtlst."Other", 0) AS "Other",
         tre.dia,
         tre1.dia AS dia_t1,
         rs.common_name,
         rs.sftwd_hrdwd AS CLASS
    FROM fs_fiadb.plot plt
    LEFT JOIN bhnf
      ON bhnf.cn = plt.cn
    LEFT JOIN std
      ON plt.cn = std.nppt_cn
    JOIN fs_fiadb.tree tre
      ON plt.cn = tre.plt_cn
    JOIN fs_fiadb.cond cnd
      ON tre.plt_cn = cnd.plt_cn
     AND tre.condid = cnd.condid
    JOIN fs_fiadb.ref_species rs
      ON tre.spcd = rs.spcd
```

EXHIBIT F

```
    LEFT JOIN fs_fiadb.tree tre1
      ON tre.prev_tre_cn = tre1.cn
    LEFT JOIN fs_fiadb.plot plt1
      ON plt.prev_plt_cn = plt1.cn
    LEFT JOIN cnddstblst
      ON cnddstblst.cnd_cn = cnd.cn
    LEFT JOIN cndtrtlst
      ON cndtrtlst.cnd_cn = cnd.cn
   WHERE tre.spcd = 122 -- only Ponderosa pine
     AND cnd.owngrpcd = 10 -- only forest service conditions
  /* AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7)*/ --
timberland only
  ),
grm AS -- Combine tree-condition data with change data and apply analysis parameters
 (SELECT grm.plt_cn,
         grm.tre_cn,
         trees.bhnf_suitable_land,
         trees.rapid_assessment,
         trees.measyear,
         trees.measyear_t1,
         trees.remper,
         trees.spcd,
         trees.statuscd,
         trees.agentcd,
         trees.dia,
         trees.dia_t1,
         trees."Weather damage",
         trees."Vegetation",
         trees."Disease",
         trees."Insect",
         trees."Animal Damage",
         trees."Fire",
         trees."Human",
         trees."None",
         trees."Cutting",
         trees."Site prep",
         trees."Art regen",
         trees."Nat regen",
         trees."Other",
         trees.common_name,
         trees.class,
         grm.component,
         grm.estn_units,
         grm.subptyp_grm,
         grm.tpagrow_unadj,
         grm.tparemv_unadj,
         grm.tpamort_unadj,
         grm.ann_net_growth,
         grm.mortality,
         grm.removals,
         grm.est_begin,
         grm.est_midpt,
         grm.est_end,
         (grm.g_s + grm.i + grm.g_i + grm.g_m + grm.g_c + grm.r + grm.g_r +
         grm.g_d) / trees.remper AS gross_growth,
         grm.g_s,
         grm.i,
         grm.g_i,
         grm.m,
         grm.g_m,
         grm.c,
         grm.g_c,
         grm.r,
```

EXHIBIT F

```
          grm.g_r,
          grm.d,
          grm.g_d,
          grm.cd,
          grm.g_cd,
          grm.ci,
          grm.g_ci
    FROM /*fs_fiadb.tree_grm_estn grm*/ fs_nims_nrs.nims_grm_estn_debug grm
    LEFT JOIN trees
      ON trees.tre_cn = grm.tre_cn
   WHERE grm.land_basis = 'TIMBERLAND'
     AND grm.estn_type = 'SL'
     AND grm.estn_units = 'CF'
     AND grm.estimate = 'VOLUME'
     AND grm.component != 'NOT USED')
------------------------------------------------------------------------------------------
-- MAIN SQL LOGIC STARTS HERE
------------------------------------------------------------------------------------------
SELECT pop.evalid,
       COUNT(DISTINCT grm.plt_cn) plt_cnt,
       COUNT(DISTINCT grm.tre_cn) tree_cnt,
       /*to_char(*/
       round(SUM(grm.gross_growth * grm.tpagrow_unadj *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,

'999,999,999.9')*/ AS ann_gross_growth,
       /*to_char(*/
       round(SUM(grm.ann_net_growth * grm.tpagrow_unadj *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,

'999,999,999.9')*/ AS ann_net_growth,
       /*to_char(*/
       round(SUM((grm.ann_net_growth * grm.tpagrow_unadj -
                 grm.removals * grm.tparemv_unadj) *
                 decode(grm.subptyp_grm,
                        1,
                        pop.adj_factor_subp,
                        2,
                        pop.adj_factor_micr,
                        0) * pop.expns) / 100,
             1) /*,

'999,999,999.9')*/ AS ann_net_change
  FROM pop
  JOIN fs_fiadb.pop_plot_stratum_assgn ppsa
    ON ppsa.stratum_cn = pop.ps_cn
  JOIN fs_fiadb.plot plt
    ON ppsa.plt_cn = plt.cn
  JOIN grm
    ON grm.plt_cn = plt.cn
  LEFT JOIN agtcd
```

EXHIBIT F

```
    ON grm.agentcd = agtcd.code
 WHERE grm.bhnf_suitable_land = 'Y' -- filter for only suitable lands
   AND plt.statecd = 46
 GROUP BY pop.evalid
 ORDER BY pop.evalid DESC;

--tab=TimberlandGrossInventorySL
WITH pop AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
         peu.p1pntcnt_eu,
         ps.p1pointcnt,
         ps.p2pointcnt,
         ps.expns,
         ps.adj_factor_subp,
         ps.adj_factor_micr
    FROM fs_fiadb.pop_eval pe
    JOIN fs_fiadb.pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN fs_fiadb.pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN fs_fiadb.pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
   WHERE pet.eval_typ = 'EXPCURR'
     AND pe.evalid IN (461601, 461701, 461801, 461901)),
bhnf AS -- bring in suitability tags
 (SELECT cn, bhnf_suitable_land FROM plot_vw),
trees AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
         plt.statecd,
         plt.measyear,
         plt1.measyear AS measyear_t1,
         plt.remper,
         tre.condid,
         tre.cn AS tre_cn,
         tre.spcd,
         tre.statuscd,
         tre.agentcd,
         tre.dia,
         tre1.dia AS dia_t1,
         rs.common_name,
         rs.sftwd_hrdwd AS CLASS,
         tre.volcsnet * tre.tpa_unadj AS volcsgrs_exp
    FROM fs_fiadb.plot plt
    LEFT JOIN bhnf
      ON plt.cn = bhnf.cn
    JOIN fs_fiadb.tree tre
      ON plt.cn = tre.plt_cn
    JOIN fs_fiadb.cond cnd
      ON tre.plt_cn = cnd.plt_cn
     AND tre.condid = cnd.condid
    JOIN fs_fiadb.ref_species rs
      ON tre.spcd = rs.spcd
    LEFT JOIN fs_fiadb.tree tre1
      ON tre.prev_tre_cn = tre1.cn
    LEFT JOIN fs_fiadb.plot plt1
      ON plt.prev_plt_cn = plt1.cn
   WHERE tre.spcd = 122 -- only Ponderosa pine
     AND tre.statuscd = 1 -- live trees only
     AND cnd.owngrpcd = 10 -- only forest service conditions
```

```
     AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7) -- timberland
only
     AND bhnf.bhnf_suitable_land = 'Y' -- retrict to only suitable lands
  )
------------------------------------------------------------------------------------------
-- MAIN SQL LOGIC STARTS HERE
------------------------------------------------------------------------------------------
SELECT ppsa.evalid,
       trees.spcd,
       trees.statuscd,
       round(SUM(trees.volcsgrs_exp * pop.expns * pop.adj_factor_subp) / 100,
             1) AS gross_sl_vol_cf
  FROM trees
  JOIN fs_fiadb.pop_plot_stratum_assgn ppsa
    ON trees.plt_cn = ppsa.plt_cn
  JOIN pop
    ON ppsa.stratum_cn = pop.ps_cn
 WHERE trees.statecd = 46
 GROUP BY ppsa.evalid, trees.spcd, trees.statuscd;

------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
-- The following script performs a tree-to-tree comparison on the 2019 data set to
-- explore the differences in estimates at the atomic level.
------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------

-- tab=CombinedSet
WITH -- The first set of objects pull data from the ANL
-- "Augmented" data set
std AS -- A list of plots assigned to the RAPID_ASSESSMENT study
 (SELECT m.nppt_cn
    FROM fs_nims_nrs.nims_prefield_study_mtx_vw m
    JOIN fs_nims_nrs.psd_study s
      ON m.psds_cn = s.cn
   WHERE s.study_name = 'RAPID_ASSESSMENT'),
pop AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
         peu.p1pntcnt_eu,
         ps.p1pointcnt,
         ps.p2pointcnt,
         ps.expns,
         ps.adj_factor_subp,
         ps.adj_factor_micr
    FROM pop_eval pe
    JOIN pop_eval_typ pet
      ON pet.eval_cn = pe.cn
    JOIN pop_estn_unit peu
      ON peu.eval_cn = pe.cn
    JOIN pop_stratum ps
      ON ps.estn_unit_cn = peu.cn
   WHERE pet.eval_typ = 'EXPGROW'
     AND pe.evalid IN ( /*561703, 561853,*/ 561903)),
trees AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
         decode(std.nppt_cn, NULL, 'N', 'Y') AS rapid_assessment,
         plt.statecd,
         nbp.countycd,
         nbp.plot_fiadb AS plot,
```

EXHIBIT F

```
          plt.measyear,
          plt1.measyear AS measyear_t1,
          plt.remper,
          tre.condid,
          tre.cn AS tre_cn,
          tre.subp,
          tre.tree,
          tre.spcd,
          tre.statuscd,
          tre.agentcd,
          tre.dia,
          tre1.dia AS dia_t1,
          nvl(tre.actualht, tre.ht) AS ht,
          nvl(tre1.actualht, tre1.ht) AS ht_t1,
          rs.common_name,
          rs.sftwd_hrdwd AS CLASS
     FROM plot_vw plt
     JOIN nims_plot_tbl nplt
       ON plt.cn = nplt.cn
     LEFT JOIN std
       ON std.nppt_cn = plt.cn
     JOIN fs_nims_nrs.nims_base_plot nbp
       ON nplt.nbp_cn = nbp.cn
     JOIN tree tre
       ON plt.cn = tre.plt_cn
     JOIN cond cnd
       ON tre.plt_cn = cnd.plt_cn
      AND tre.condid = cnd.condid
     JOIN ref_species rs
       ON tre.spcd = rs.spcd
     LEFT JOIN tree tre1
       ON tre.prev_tre_cn = tre1.cn
     LEFT JOIN plot plt1
       ON plt.prev_plt_cn = plt1.cn
    WHERE tre.spcd = 122 -- only Ponderosa pine
      AND cnd.owngrpcd = 10 -- only forest service conditions
  /* AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7)*/ --
timberland only
  ),
grm AS -- Combine tree-condition data with change data and apply analysis parameters
 (SELECT grm.plt_cn,
          grm.tre_cn,
          trees.rapid_assessment,
          trees.statecd,
          trees.countycd,
          trees.plot,
          trees.subp,
          trees.tree,
          trees.measyear,
          trees.measyear_t1,
          trees.remper,
          trees.spcd,
          trees.statuscd,
          trees.agentcd,
          trees.dia,
          trees.dia_t1,
          (trees.dia - trees.dia_t1) / trees.remper AS dia_chng,
          trees.ht,
          trees.ht_t1,
          (trees.ht - trees.ht_t1) / trees.remper AS ht_chng,
          trees.common_name,
          trees.class,
          grm.component,
```

```
          grm.subptyp_grm,
          grm.tpagrow_unadj,
          grm.tparemv_unadj,
          grm.tpamort_unadj,
          grm.ann_net_growth,
          grm.mortality,
          grm.removals,
          grm.est_begin,
          grm.est_midpt,
          grm.est_end,
          (grm.g_s + grm.i + grm.g_i + grm.g_m + grm.g_c + grm.r + grm.g_r +
          grm.g_d) / grm.remper AS gross_growth,
          grm.g_s,
          grm.i,
          grm.g_i,
          grm.m,
          grm.g_m,
          grm.c,
          grm.g_c,
          grm.r,
          grm.g_r,
          grm.d,
          grm.g_d,
          grm.cd,
          grm.g_cd,
          grm.ci,
          grm.g_ci
     FROM tree_grm_estn grm
     JOIN trees
       ON trees.tre_cn = grm.tre_cn
    WHERE grm.land_basis = 'TIMBERLAND'
      AND grm.estn_type = 'SL'
      AND grm.estn_units = 'CF'
      AND grm.estimate = 'VOLUME'
      AND grm.component != 'NOT USED'),
dat_aug AS -- Estimates from the augmented 2019 data
 (SELECT pop.evalid,
          grm.plt_cn,
          grm.tre_cn,
          grm.rapid_assessment,
          grm.statecd,
          grm.measyear,
          grm.measyear_t1,
          grm.measyear || '-' || grm.measyear_t1 AS meas_period,
          grm.remper,
          grm.countycd,
          grm.plot,
          grm.subp,
          grm.tree,
          grm.component,
          grm.dia,
          grm.dia_t1,
          grm.dia_chng,
          grm.ht,
          grm.ht_t1,
          grm.ht_chng,
          SUM(grm.gross_growth) AS gross_growth_raw,
          /*to_char(*/
          round(SUM(grm.gross_growth * grm.tpagrow_unadj *
                    decode(grm.subptyp_grm,
                           1,
                           pop.adj_factor_subp,
                           2,
```

```
                      pop.adj_factor_micr,
                      0) * pop.expns) / 100,
           1) /*,

'999,999,999.9')*/ AS ann_gross_growth,
         /*to_char(*/
         round(SUM(grm.ann_net_growth * grm.tpagrow_unadj *
                   decode(grm.subptyp_grm,
                          1,
                          pop.adj_factor_subp,
                          2,
                          pop.adj_factor_micr,
                          0) * pop.expns) / 100,
           1) /*,

'999,999,999.9')*/ AS ann_net_growth,
         /*to_char(*/
         round(SUM((grm.ann_net_growth * grm.tpagrow_unadj -
                   grm.removals * grm.tparemv_unadj) *
                   decode(grm.subptyp_grm,
                          1,
                          pop.adj_factor_subp,
                          2,
                          pop.adj_factor_micr,
                          0) * pop.expns) / 100,
           1) /*,

'999,999,999.9')*/ AS ann_net_change
    FROM pop
    JOIN pop_plot_stratum_assgn ppsa
      ON ppsa.stratum_cn = pop.ps_cn
    JOIN plot_vw plt
      ON ppsa.plt_cn = plt.cn
    JOIN grm
      ON grm.plt_cn = plt.cn
   WHERE plt.bhnf_suitable_land = 'Y' -- filter for only suitable lands
     AND plt.statecd = 46
   GROUP BY pop.evalid,
            grm.plt_cn,
            grm.tre_cn,
            grm.rapid_assessment,
            grm.statecd,
            grm.measyear,
            grm.measyear_t1,
            grm.remper,
            grm.countycd,
            grm.plot,
            grm.subp,
            grm.tree,
            grm.component,
            grm.dia,
            grm.dia_t1,
            grm.dia_chng,
            grm.ht,
            grm.ht_t1,
            grm.ht_chng),
-- This second set of objects pulls data from the public FIADB data set
pop_fiadb AS -- Assemble the stratification data for estimation
 (SELECT pe.evalid,
         peu.estn_unit_descr,
         peu.cn              AS peu_cn,
         ps.cn               AS ps_cn,
         peu.area_used       AS estn_unit_area,
```

EXHIBIT F

```
          peu.p1pntcnt_eu,
          ps.p1pointcnt,
          ps.p2pointcnt,
          ps.expns,
          ps.adj_factor_subp,
          ps.adj_factor_micr
     FROM fs_fiadb.pop_eval pe
     JOIN fs_fiadb.pop_eval_typ pet
       ON pet.eval_cn = pe.cn
     JOIN fs_fiadb.pop_estn_unit peu
       ON peu.eval_cn = pe.cn
     JOIN fs_fiadb.pop_stratum ps
       ON ps.estn_unit_cn = peu.cn
    WHERE pet.eval_typ = 'EXPGROW'
      AND pe.evalid IN ( /*461603, 461703, 461803,*/ 461903)),
bhnf_fiadb AS -- bring in suitability tags
 (SELECT cn, bhnf_suitable_land FROM plot_vw),
trees_fiadb AS -- Assemble tree and condition data and pre-filter trees
 (SELECT tre.plt_cn,
          bhnf.bhnf_suitable_land,
          decode(std.nppt_cn, NULL, 'N', 'Y') AS rapid_assessment,
          plt.statecd,
          plt.countycd,
          plt.plot,
          plt.measyear,
          plt1.measyear AS measyear_t1,
          plt.remper,
          tre.condid,
          tre.cn AS tre_cn,
          tre.subp,
          tre.tree,
          tre.spcd,
          tre.statuscd,
          tre.agentcd,
          tre.dia,
          tre1.dia AS dia_t1,
          nvl(tre.actualht, tre.ht) AS ht,
          nvl(tre1.actualht, tre1.ht) AS ht_t1,
          rs.common_name,
          rs.sftwd_hrdwd AS CLASS
     FROM fs_fiadb.plot plt
     LEFT JOIN bhnf_fiadb bhnf
       ON bhnf.cn = plt.cn
     LEFT JOIN std
       ON std.nppt_cn = plt.cn
     JOIN fs_fiadb.tree tre
       ON plt.cn = tre.plt_cn
     JOIN fs_fiadb.cond cnd
       ON tre.plt_cn = cnd.plt_cn
      AND tre.condid = cnd.condid
     JOIN fs_fiadb.ref_species rs
       ON tre.spcd = rs.spcd
     LEFT JOIN fs_fiadb.tree tre1
       ON tre.prev_tre_cn = tre1.cn
     LEFT JOIN fs_fiadb.plot plt1
       ON plt.prev_plt_cn = plt1.cn
    WHERE tre.spcd = 122 -- only Ponderosa pine
      AND cnd.owngrpcd = 10 -- only forest service conditions
  /* AND (cnd.cond_status_cd = 1 AND cnd.reservcd = 0 AND cnd.siteclcd < 7)*/ --
timberland only
  ),
grm_fiadb AS -- Combine tree-condition data with change data and apply analysis
parameters
```

EXHIBIT F

```
 (SELECT grm.plt_cn,
         grm.tre_cn,
         trees.rapid_assessment,
         trees.statecd,
         trees.countycd,
         trees.plot,
         trees.subp,
         trees.tree,
         trees.bhnf_suitable_land,
         trees.measyear,
         trees.measyear_t1,
         trees.remper,
         trees.spcd,
         trees.statuscd,
         trees.agentcd,
         trees.dia,
         trees.dia_t1,
         (trees.dia - trees.dia_t1) / trees.remper AS dia_chng,
         trees.ht,
         trees.ht_t1,
         (trees.ht - trees.ht_t1) / trees.remper AS ht_chng,
         trees.common_name,
         trees.class,
         grm.component,
         grm.estn_units,
         grm.subptyp_grm,
         grm.tpagrow_unadj,
         grm.tparemv_unadj,
         grm.tpamort_unadj,
         grm.ann_net_growth,
         grm.mortality,
         grm.removals,
         grm.est_begin,
         grm.est_midpt,
         grm.est_end,
         (grm.g_s + grm.i + grm.g_i + grm.g_m + grm.g_c + grm.r + grm.g_r +
         grm.g_d) / trees.remper AS gross_growth,
         grm.g_s,
         grm.i,
         grm.g_i,
         grm.m,
         grm.g_m,
         grm.c,
         grm.g_c,
         grm.r,
         grm.g_r,
         grm.d,
         grm.g_d,
         grm.cd,
         grm.g_cd,
         grm.ci,
         grm.g_ci
    FROM /*fs_fiadb.tree_grm_estn grm*/ fs_nims_nrs.nims_grm_estn_debug grm
    LEFT JOIN trees_fiadb trees
      ON trees.tre_cn = grm.tre_cn
   WHERE grm.land_basis = 'TIMBERLAND'
     AND grm.estn_type = 'SL'
     AND grm.estn_units = 'CF'
     AND grm.estimate = 'VOLUME'
     AND grm.component != 'NOT USED'),
dat_fiadb AS -- Estimates from FIADB
 (SELECT pop.evalid,
         grm.plt_cn,
```

EXHIBIT F

```
        grm.tre_cn,
        grm.rapid_assessment,
        grm.statecd,
        grm.measyear,
        grm.measyear_t1,
        grm.measyear || '-' || grm.measyear_t1 AS meas_period,
        grm.remper,
        grm.countycd,
        grm.plot,
        grm.subp,
        grm.tree,
        grm.component,
        grm.dia,
        grm.dia_t1,
        grm.dia_chng,
        grm.ht,
        grm.ht_t1,
        grm.ht_chng,
        SUM(grm.gross_growth) AS gross_growth_raw,
        /*to_char(*/
        round(SUM(grm.gross_growth * grm.tpagrow_unadj *
                  decode(grm.subptyp_grm,
                         1,
                         pop.adj_factor_subp,
                         2,
                         pop.adj_factor_micr,
                         0) * pop.expns) / 100,
              1) /*,

'999,999,999.9')*/ AS ann_gross_growth,
        /*to_char(*/
        round(SUM(grm.ann_net_growth * grm.tpagrow_unadj *
                  decode(grm.subptyp_grm,
                         1,
                         pop.adj_factor_subp,
                         2,
                         pop.adj_factor_micr,
                         0) * pop.expns) / 100,
              1) /*,

'999,999,999.9')*/ AS ann_net_growth,
        /*to_char(*/
        round(SUM((grm.ann_net_growth * grm.tpagrow_unadj -
                  grm.removals * grm.tparemv_unadj) *
                  decode(grm.subptyp_grm,
                         1,
                         pop.adj_factor_subp,
                         2,
                         pop.adj_factor_micr,
                         0) * pop.expns) / 100,
              1) /*,

'999,999,999.9')*/ AS ann_net_change
    FROM pop_fiadb pop
    JOIN fs_fiadb.pop_plot_stratum_assgn ppsa
      ON ppsa.stratum_cn = pop.ps_cn
    JOIN fs_fiadb.plot plt
      ON ppsa.plt_cn = plt.cn
    JOIN grm_fiadb grm
      ON grm.plt_cn = plt.cn
   WHERE grm.bhnf_suitable_land = 'Y' -- filter for only suitable lands
     AND plt.statecd = 46
   GROUP BY pop.evalid,
```

```
        grm.plt_cn,
        grm.tre_cn,
        grm.rapid_assessment,
        grm.statecd,
        grm.measyear,
        grm.measyear_t1,
        grm.remper,
        grm.countycd,
        grm.plot,
        grm.subp,
        grm.tree,
        grm.component,
        grm.dia,
        grm.dia_t1,
        grm.dia_chng,
        grm.ht,
        grm.ht_t1,
        grm.ht_chng)
------------------------------------------------------------------------------------------
-- MAIN SQL LOGIC STARTS HERE
------------------------------------------------------------------------------------------
SELECT dat_aug.evalid AS aug_evalid,
       dat_aug.plt_cn AS aug_plt_cn,
       dat_aug.tre_cn AS aug_tre_cn,
       dat_aug.rapid_assessment AS aug_rapid_assessment,
       dat_aug.statecd AS aug_statecd,
       dat_aug.measyear AS aug_measyear,
       dat_aug.measyear_t1 AS aug_measyear_t1,
       dat_aug.meas_period AS aug_meas_period,
       dat_aug.remper AS aug_remper,
       dat_aug.countycd AS aug_countycd,
       dat_aug.plot AS aug_plot,
       dat_aug.subp AS aug_subp,
       dat_aug.tree AS aug_tree,
       dat_aug.component AS aug_component,
       dat_aug.dia AS aug_dia,
       dat_aug.dia_t1 AS aug_dia_t1,
       dat_aug.dia_chng AS aug_dia_chng,
       dat_aug.ht AS aug_ht,
       dat_aug.ht_t1 AS aug_ht_t1,
       dat_aug.ht_chng AS aug_ht_chng,
       dat_aug.gross_growth_raw AS aug_gross_growth_raw,
       dat_aug.ann_gross_growth AS aug_ann_gross_growth,
       dat_aug.ann_net_growth AS aug_ann_net_growth,
       dat_aug.ann_net_change AS aug_ann_net_change,
       dat_fiadb.evalid AS fiadb_evalid,
       dat_fiadb.plt_cn AS fiadb_plt_cn,
       dat_fiadb.tre_cn AS fiadb_tre_cn,
       dat_fiadb.rapid_assessment AS fiadb_rapid_assessment,
       dat_fiadb.statecd AS fiadb_statecd,
       dat_fiadb.measyear AS fiadb_measyear,
       dat_fiadb.measyear_t1 AS fiadb_measyear_t1,
       dat_fiadb.meas_period AS fiadb_meas_period,
       dat_fiadb.remper AS fiadb_remper,
       dat_fiadb.countycd AS fiadb_countycd,
       dat_fiadb.plot AS fiadb_plot,
       dat_fiadb.subp AS fiadb_subp,
       dat_fiadb.tree AS fiadb_tree,
       dat_fiadb.component AS fiadb_component,
       dat_fiadb.dia AS fiadb_dia,
       dat_fiadb.dia_t1 AS fiadb_dia_t1,
       dat_fiadb.dia_chng AS fiadb_dia_chng,
       dat_fiadb.ht AS fiadb_ht,
```

EXHIBIT F

```
       dat_fiadb.ht_t1 AS fiadb_ht_t1,
       dat_fiadb.ht_chng AS fiadb_ht_chng,
       dat_fiadb.gross_growth_raw AS fiadb_gross_growth_raw,
       dat_fiadb.ann_gross_growth AS fiadb_ann_gross_growth,
       dat_fiadb.ann_net_growth AS fiadb_ann_net_growth,
       dat_fiadb.ann_net_change AS fiadb_ann_net_change,
       dat_aug.gross_growth_raw - dat_fiadb.gross_growth_raw AS gross_growth_diff,
       CASE
         WHEN sign(dat_aug.dia_chng) = 1 AND sign(dat_fiadb.dia_chng) = 1 THEN
          dat_aug.dia_chng - dat_fiadb.dia_chng
         WHEN sign(dat_aug.dia_chng) = -1 AND sign(dat_fiadb.dia_chng) = 1 THEN
          dat_aug.dia_chng + dat_fiadb.dia_chng
         WHEN sign(dat_aug.dia_chng) = 1 AND sign(dat_fiadb.dia_chng) = -1 THEN
          dat_aug.dia_chng + dat_fiadb.dia_chng
         WHEN sign(dat_aug.dia_chng) = -1 AND sign(dat_fiadb.dia_chng) = -1 THEN
          dat_aug.dia_chng - dat_fiadb.dia_chng
         ELSE
          dat_aug.dia_chng - dat_fiadb.dia_chng
       END AS dia_chng_diff,
       CASE
         WHEN sign(dat_aug.ht_chng) = 1 AND sign(dat_fiadb.ht_chng) = 1 THEN
          dat_aug.ht_chng - dat_fiadb.ht_chng
         WHEN sign(dat_aug.ht_chng) = -1 AND sign(dat_fiadb.ht_chng) = 1 THEN
          dat_aug.ht_chng + dat_fiadb.ht_chng
         WHEN sign(dat_aug.ht_chng) = 1 AND sign(dat_fiadb.ht_chng) = -1 THEN
          dat_aug.ht_chng + dat_fiadb.ht_chng
         WHEN sign(dat_aug.ht_chng) = -1 AND sign(dat_fiadb.ht_chng) = -1 THEN
          dat_aug.ht_chng - dat_fiadb.ht_chng
         ELSE
          dat_aug.ht_chng - dat_fiadb.ht_chng
       END AS ht_chng_diff
  FROM dat_aug
 RIGHT JOIN dat_fiadb
    ON dat_aug.statecd = dat_fiadb.statecd
      --AND dat_aug.measyear = dat_fiadb.measyear
   AND dat_aug.countycd = dat_fiadb.countycd
   AND dat_aug.plot = dat_fiadb.plot
   AND dat_aug.subp = dat_fiadb.subp
   AND dat_aug.tree = dat_fiadb.tree
--AND dat_aug.measyear = 2019 AND dat_aug.measyear_t1 = 2013
 ORDER BY dat_aug.statecd,
          --dat_aug.measyear,
          dat_aug.countycd,
          dat_fiadb.countycd,
          dat_aug.plot,
          dat_fiadb.plot,
          dat_aug.subp,
          dat_fiadb.subp,
          dat_aug.tree,
          dat_fiadb.tree,
          dat_fiadb.statecd
--dat_fiadb.measyear,
;
```