2018 Vermont Wood Fuel Supply Study

Prepared for:
Vermont Department of Forests, Parks, and Recreation

FINAL REPORT – March 28, 2019

Prepared by: Biomass Energy Resource Center

VERMONT

State of Vermont
Department of Forests, Parks & Recreation

Agency of Natural Resources

November 21, 2019

Dear Reader,

The Department of Forests, Parks, and Recreation is pleased to release the 2019 update to the Vermont Wood Fuel Supply Study (VWFSS). While this study is conducted periodically with the specific goal of informing how much wood we can sustainably use for wood energy in Vermont, it is also an informative tool for assessing forest health and market opportunity more generally. Our forests are healthy and productive, and we have a robust supply of wood available for both our current and projected future wood energy needs. One significant takeaway from this report is that our forests have the self-renewing capacity to sustain and even benefit from an increased level of intelligent, appropriate harvesting.

We view the VWFSS as an important routine assessment of the capacity of Vermont's forests to support the use of wood for energy. The study builds upon previous editions of the VWFSS, completed in 2007 and 2010. It was the 2010 study that informed the State's goal of reaching 35% of our thermal energy from wood by 2030 as codified in the Comprehensive Energy Plan; that is the amount that was calculated to be able to be sustained from Vermont forestland.

While there are lots of exciting data to dig into in this report, there are two ultimately important takeaways:

- **There is 5% more net available low-grade wood in the forest now than was estimated in the 2010 report.** This is due to several factors that are discussed in the report, but the key finding is that from a wood energy perspective, we have sufficient material available to keep adding to our already impressive portfolio of wood energy systems without risking forest health or sustainability.
- **The average age class of Vermont's forests is increasing, and as a result, the average net annual growth rate is slowing.** In the 2010 report, the average net growth rate was 2.10%. In 2018, it was 1.75%.

For many years, we have talked about how we are "harvesting less than half the net growth in the forest," or in other words, we have a positive growth-to-removal ratio. If the growth rate continues to decline as the forest ages and the removals rate remains constant, then eventually we will cross over into a negative growth to removals ratio (*see Figure 23 in the report*). This may sound dire, but as long as we continue to carry out high-quality forest management as the norm in Vermont, then this is part of a sustainable forest cycle. By removing more trees, there will be a younger age class initiated in response and these trees will grow more quickly, and the average net annual growth rate will once again rise.

Older forests have many desirable attributes. Likewise, a diverse age class distribution produces desirable benefits, including resilience when facing pests, changing weather patterns, and other consequences of climate change. The Department will continue to monitor the health and productivity of Vermont's forests as we conduct high-quality forest management and consider the current and future capacity of Vermont's forests to sustainably harvest wood for a variety of forest products including wood for biomass energy.

Sincerely,

Michael Snyder
Commissioner and Vermont State Forester
Vermont Department of Forests, Parks & Recreation

ACKNOWLEDGMENTS

The primary investigators and co-authors of this report were Adam Sherman, Juliette Juillerat, and David Roberts. The Biomass Energy Resource Center (BERC) is a program of VEIC. Since 2001, BERC has specialized in the design and implementation of programs that stimulate and support wood energy conversion projects. BERC has a long-standing reputation as a source of independent and impartial information and services for modern wood heating. More information at – www.biomasscenter.org

The authors would like to thank the following individuals for their contributions, review, and guidance:

- Randal Morin, Forest Inventory and Analysis program, USDA Forest Service
- Robert Turner, RJ Turner and Associates
- Emma Hanson, Vermont Department of Forest Parks and Recreation
- Paul Frederick, Vermont Department of Forest Parks and Recreation

DISCLAIMER

The information contained in this report represents the findings of this independent study and does not necessarily represent the views of the State of Vermont. It should be noted that forests are extremely complex and dynamic systems and any effort to quantify their inventory, growth, and capacity to supply additional amounts of wood fuel should be interpreted as being an over simplification with a wide margin of error. This study makes a good faith effort, using the best available data, defensible methods, and transparent key assumptions to better understand how much wood could be used for energy without the risk of over burdening our forests given the multitude of functions they provide.

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EXECUTIVE SUMMARY

Vermont's forests are a vital resource that provide a multitude of ecological functions like clean air and water, wildlife habitat, biodiversity, carbon sequestration, and flood resiliency, to name only a few. Forests also provide numerous other non-ecological values – aesthetics, recreation opportunities, timber products, and fuel. Vermont's forests play an important role in meeting Vermont's current and future energy needs. Vermont is a national leader in the use of local wood heating solutions and wood fuels account for over 21% of Vermont's thermal energy needs. To meet Vermont's established long-term goals for renewable energy, GHG emission reduction, economic development, and forest management, expanded use of wood heating is a cornerstone strategy. Routine assessment of forest resource capacity is essential to ensuring any further use of wood for energy is expanded well-within the forest resource capacity. Using most recent data sources, this report presents an updated "snap-shot-in-time" assessment of Vermont's forest resource potential to supply additional amounts of low-grade wood suitable for use as wood fuel. In addition, the report explores longer-term trends that may impact the amount of additional wood fuel resource potential in the years to come.

This study builds upon two previous studies – the first conducted in 2007 and the second in 2010. The original 2007 Vermont Wood Fuel Supply Study examined a wide spectrum of issues affecting the supply of wood fuel and the subsequent study, released in 2010, focused primarily on the recalculation of the potential for further wood fuel from Vermont's forests using updated data made available by the USDA Forest Service. While the 2010 update was spurred by the availability of new federal data, a slightly different method was used for the 2007 study and the 2010 update. As an outcome, the results of the 2007 study and the 2010 update are not comparable on an "apples-to-apples" basis. However, the 2018 update used similar data sources and supply calculation methods allowing the results to be compared to the 2010 update results.

The objective of this study was to estimate the supply of Net Available Low-grade Growth (NALG) wood (wood that would be suitable for use as fuel beyond current levels of harvesting) available annually from within Vermont and the surrounding area. The study assessed Vermont's 14 counties and the adjoining counties of New Hampshire, Massachusetts, and New York. For this calculation, the total forestland area was filtered using GIS data and software to remove inaccessible and ecologically sensitive areas of forestland that would not be harvested. Forest inventory and composition data were applied to this filtered forested footprint and averaged rates of forest growth were applied to the portion of the inventory deemed low-grade. Averaged current demand for low-grade wood was subtracted from this growth, giving the amount of NALG wood. The model used for this assessment, relied on the input of data but also a series of key assumptions. Due to the variability caused by slight changes in assumptions used, this assessment was done in three model run scenarios – "Baseline", "High", and "Low". The Baseline scenario was intended to serve as the best representation of reality, while the Low and High scenarios depict lower and upper limits, respectively. The following table provides the 2018 results of the study for Vermont and the surrounding counties in New York, Massachusetts, and New Hampshire.

Table 1: The estimated annual amount (green tons) of NALG wood under the three model scenarios

	Low Scenario	Baseline	High Scenario
Vermont counties	365,159	939,989	1,720,102
Adjacent counties	1,060,306	1,816,937	2,835,493
Grand Total	1,425,464	2,756,926	4,555,595

Table 1 above, presents the results under each of the three model runs. The Baseline results are the focus of this assessment and the Low and High are included to provide book-ends to the probable range. The 2018 Vermont Wood Fuel Supply Study results suggest there are approximately 940,000 green tons of additional wood fuel capacity in Vermont and another 1.8 million from the surrounding region. One reason for the dramatic increase in NALG wood when the 10 counties of New York, Massachusetts, and New Hampshire are added to the 14 counties of Vermont is that several of these counties are very large in area and are heavily forested—such as Grafton and Coös Counties in New Hampshire and Clinton and Essex Counties in New York.

Figure 1 – Map of NALG wood concentrations for Vermont counties

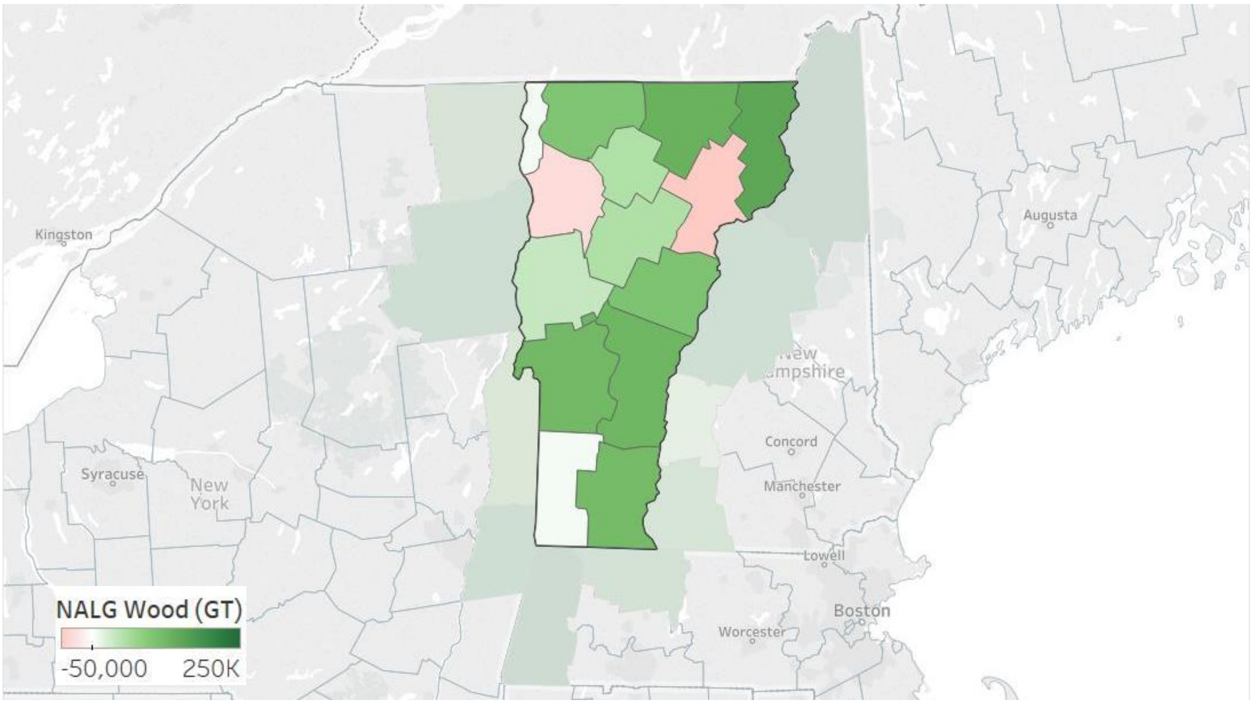

Figure 1 illustrates the county-level geographic distribution of NALG wood for the Baseline model run. As can be seen, the greatest concentrations of NALG wood are in Franklin, Orleans, Essex, Orange, Rutland, Windsor, and Windham counties. In contrast, Caledonia, Chittenden, and Bennington Counties were reported with either negative or neutral amounts for separate reasons reported in further detail in the main body of the report.

The purpose of periodically updating the Vermont Wood Fuel Supply Study and using a consistent methodology for the analysis, is to compare the results of the most recent study against those of previous years. Table 2 provides the results for several key parameters that lead up to the final estimation of NALG wood supply for the 2018 study and the 2010 study.

Table 2 - Comparative results for the 2010 and 2018 studies (reporting just Vermont counties)

	2018	2010
Starting Forestland (Acres)	4,312,127	4,414,884
Unconstrained and Managed Forestland (Acres)	2,053,967	1,911,700
Live-tree Inventory on Timberland (Green Tons)	480,025,426	477,990,154
Low-grade Wood Inventory on Unconstrained and Managed Forestland (Green Tons)	142,417,027	96,718,877
Average Net Annual Growth Rate	1.75%	2.10%
Net Annual Growth of Low-grade Wood on Unconstrained and Managed Forestland (Green Tons)	2,498,627	2,031,096
Current Market Demand for Low-grade Wood (Green Tons)	1,738,631	1,265,194
NALG Bole Wood (Green Tons)	732,959	824,072
NALG Top and Limb Wood (Green Tons)	207,030	70,820
Total NALG Wood (Green Tons)	939,989	894,893

While the total estimate of NALG wood did not vary considerably between 2010 and 2018, several other parameters saw note-worthy changes between the two studies:

- Forestland area decreased by 102,757 acres attributed primarily to land clearing for agriculture and development.
- Unconstrained managed forestland increased by 142,267 acres due to change in assumptions used to avoid double filtering in 2010[1].
- There was a dramatic increase in the amount of low-grade wood on the footprint of unconstrained and managed forestland due to increased number of acres, increased stocking per acre, and an increased percentage of the forest inventory estimated to be "low-grade".
- Averaged net annual growth rate decreased dramatically from 2.15% to 1.75% due to decreased gross growth and increased mortality rate.
- Amount of net annual growth of low-grade on unconstrained and managed forestland increased. Despite lower growth rates, greater stocking levels and more acres resulted in a 23% increase from 2010 to 2018.

While reviewing the key values between the 2010 and 2018 studies, several key trends were noted and explored in further detail. Historical forest data were reviewed for the time-period from 1948 to 2017. Clear, long-term trends of declining rates of net annual growth were identified and increased average age and size class of forests were observed over the 69-year time-period. Also, for much of this time-period, annual harvest volumes were considerably less than the amount of net annual growth. Based on the data gathered and analyzed, there appears to be direct correlations between the three – consistently cutting less volume than is grown over the landscape will result in gradual aging of forests. As forest age, they grow more slowly.

Figure 2 – Bathtub analogy for forest growth, inventory, and removals

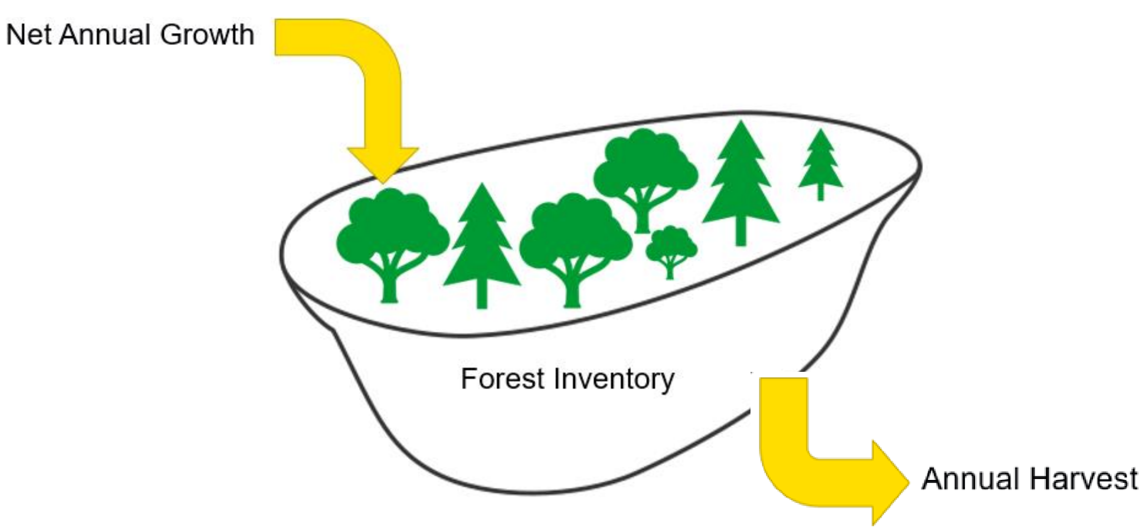

Figure 2 makes an analogy comparing forests to a bathtub, where the amount of water (forest inventory) in the tub is directly tied to how fast water is added (net annual growth) and drained from the tub (annual harvest). Over the past several decades water has been consistently added faster than it was being drained. As a result, the amount of water in the tub was steadily increased. But like the amount of water that can be added to a bathtub, there are limits to how much inventory can be added to forests over time. In fact, Vermont's forests are now experiencing slowing growth rates and increasing mortality rates. Eventually,

[1] The 2010 study applied assumptions regarding how much forestland is managed before the physical and ecological features were filtered using GIS. This essential approach inadvertently over-estimated the amount of forestland area removed.

the amount drained could exceed the amount added annually. While removing more wood than is grown each year, may not sound viable over a long time-period, it may be a necessary means to achieving a more balanced age class distribution (more younger forests) and increased average rate of forest growth.

Based on the most up-to-date information and the model used for this assessment, the results of this study indicate that there is further forest resource capacity to expand the use of wood energy in Vermont and that the amount of NALG wood could increase if traditional markets for low-grade wood, like regional pulpmills, either shut down or further decrease their production in the future.

It should be noted, however, that the concept of NALG wood is based upon the basic application of net annual growth rates to the low-grade wood inventory on a small portion of the total forested footprint. The growth rates used in this assessment are averaged rates of current growth based on the current forest condition. Should forest conditions change significantly over the landscape (such as species and age class composition, and stocking levels), the rates of growth will undoubtedly be affected. Forests are very complex and dynamic and will change significantly over time.

1.0 INTRODUCTION

Vermont has a long history of using wood fuels for producing heat and electricity. Vermont's two wood fired power plants, McNeil and Ryegate Stations generate approximately 6% of Vermont electric needs since the 1980s[2]. In addition, wood fuels like cordwood, chips, and pellets provide approximately 21% of Vermont thermal energy needs.[3]

The State of Vermont has set a long-term goal of meeting 90% of Vermont's total energy needs from renewables by 2050. The 2016 Comprehensive Energy Plan (CEP) calls for an increase in the portion of renewable energy used to heat Vermont's buildings to 30% by 2025, through both efficiency and increased use of renewable fuels (including wood). In addition to renewable energy goals, the State of Vermont has economic development, greenhouse gas reduction, and Working Landscape goals that can be met, in part, through the expanded use of wood heat.

As energy goals are set and strategies for meeting those goals are developed and fine-tuned over time, close examination and understanding of the changing forest resource capacity is vital. To that end, this study is a reassessment of Vermont's forest resource capacity – building on two previous studies (2007 and 2010) that estimated the sustained amount of additional low-grade wood that could be used for energy without over-burdening the forest resource capacity.

As state-level energy goals are set and strategies for meeting those goals are developed, close examination and understanding of the changing forest resource capacity is vital.

1.1 Department of Forests, Parks & Recreation

The Vermont Department of Forests, Parks and Recreation (FPR) is responsible for the conservation and management of Vermont's forest resources, the operation and maintenance of the state park system, and the promotion and support of outdoor recreation for Vermonters and its visitors. The Forestry Division of FPR coordinates the planning and implementation of all stewardship activities on more than 300,000 acres of state-owned forestland. The division provides technical assistance to private landowners, at their request, to help manage their properties. It administers the Use Value Appraisal program on private land, involving more than 9,000 landowners and 1.4 million acres. The Marketing and Utilization section personnel inventory and promote the manufacture of forest products in the state and assist businesses, communities, and others on issues related to wood products and wood energy generation. More information at - https://fpr.vermont.gov/

1.2 Biomass Energy Resource Center

The Biomass Energy Resource Center (BERC) is a program of VEIC, a mission-driven non-profit organization that works on energy efficiency, renewable energy, and transportation efficiency projects and programs across North America. As a program of a private nonprofit organization, BERC is independent and impartial and conducts fair and objective studies. BERC maintains complete neutrality while conducting routine due diligence on wood resource supply for projects and government agencies throughout the US. More information at – www.biomasscenter.org

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[2] 2016 Vermont Comprehensive Energy Plan
https://outside.vermont.gov/sov/webservices/Shared%20Documents/2016CEP_Final.pdf

[3] 2016 Wood Heat Baseline Study
https://publicservice.vermont.gov/sites/dps/files/documents/Renewable_Energy/CEDF/Reports/AWH%20Baseline%20Report%20FINAL.pdf

1.3 Study Scope and Objectives

This study's main objective was to carefully re-assess the amount of wood fuel Vermont's forests can realistically supply in support of any potential expanded use of wood energy – referred to as "Net Available Low-grade Growth (NALG)" wood. This study developed estimates of the amount of NALG wood for the 14 counties of Vermont, as well as estimates for a larger study area comprised of Vermont and the adjoining counties of New Hampshire, Massachusetts, and New York.

The spreadsheet model used in this assessment was not designed with the sole purpose of providing a single, definitive number, but rather it is designed to establish a probable range of how much wood fuel could be available under various scenarios.

Like the 2010 study, this update used more fined-tuned geographic information system (GIS)-based analysis to quantify and filter the amount of physically and ecologically constrained forestland and to also estimate the portion of the remainder that is actively managed and would be periodically harvested. Much of the groundwork for this report was laid with the original 2007 study and the subsequent 2010 update. Like the 2010 update, this study focuses primarily on the quantification of the current in-forest supply capacity.

As with the previous two studies, the area of analysis for this update is comprised of the 14 counties of Vermont and the 10 adjoining counties of New York, Massachusetts, and New Hampshire. The intent of including the surrounding counties within states neighboring Vermont is not to suggest that this material should be counted for energy planning and policy development in Vermont, but rather to explore the edges of Vermont's borders since wood routinely travels well beyond state boundaries. For this reason, results are often presented for Vermont only and then again for Vermont plus the adjoining 10 counties; this allows a better assessment of what is growing in Vermont versus what could be available in Vermont, given volumes of wood that would likely cross state borders. Lastly, neither this update, nor the previous studies, examined wood supply potential from the Province of Quebec for two main reasons: (1) the amount of harvested roundwood and chips imported from Quebec into Vermont is insignificant and (2) only very limited data are available detailing the inventory, composition, growth, and harvesting of Quebec's forests.

2.0 METHODOLOGY SUMMARY

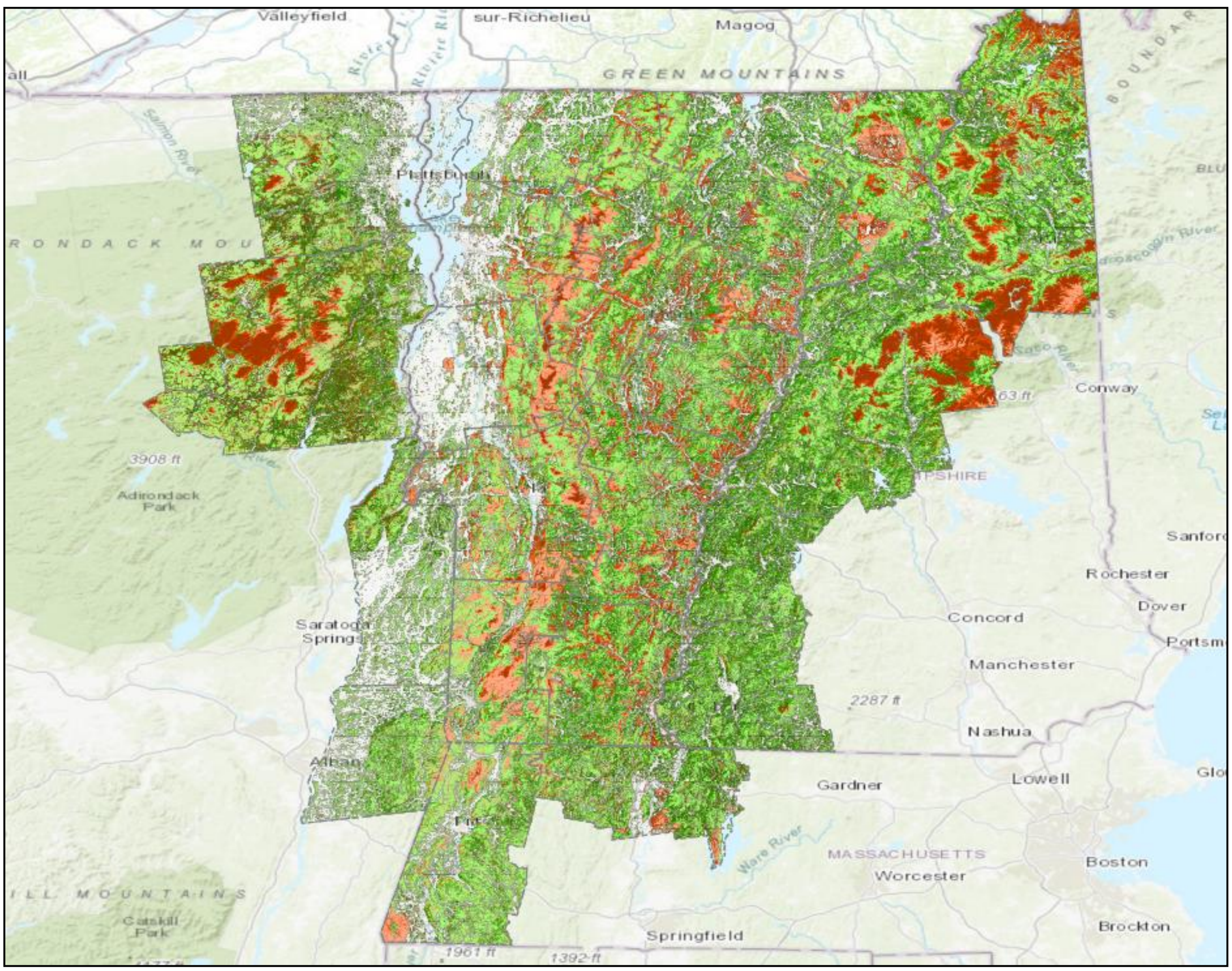
2.1 Determining Study Area

The first step in conducting this assessment of forest supply was to define the study area. This study focuses on the 14 counties of Vermont, but also examines the 10 surrounding counties of New Hampshire, Massachusetts and New York because of their influence on supply in Vermont and due to the common flow of wood over state boundaries.

2.2 Filtering Forestland for Physical and Ecologic Constraints

Within the study area, only the forested footprint that is appropriate for periodic harvesting as part of active forest management was considered in the examination of the total forested land area. To do this, Geographic Information Systems (GIS) software was used to evaluate the forest resource in Vermont and the adjoining counties of neighboring states. Forestland data was obtained from the National Land Cover Dataset (2011)[4] in raster form. The land cover data for deciduous forest, evergreen forest, and mixed forest

Figure 3 – Map of physical and ecological constraints filtered from forestland footprint using GIS



(classification codes 41, 42, and 43, respectively) were selected and were converted to vector form. All forestland, regardless of classification, was treated as the base forested footprint upon which this model

[4] The National Land Cover Dataset (2011) was downloaded from the Multi-Resolution Land Characteristics Consortium (http://www.epa.gov/mrlc/nlcd-2001.html).

was built. Total forestland area was calculated using the 'calculate geometry' feature in ArcView and these areas, in acres, were recorded for each of the counties in the study area.

This starting forestland area was then filtered to account for the areas of forestland that would be physically or ecologically constrained from management and periodic harvesting (as is shown in Figure 3). This critical step in the analysis ensures that areas of forestland that have physical barriers to harvesting or ecological sensitivities are not included in the quantification of wood fuel availability presented here. These filters were identified and vetted by working with forestry and natural resource professionals and they are meant to represent a reasonable approach to responsible forest management and harvesting based on accepted/best management practices for Vermont and neighboring states.[5] This filtering of the forested footprint included the following features, where available, and corresponding buffers, where applicable.

Table 3 – Filtered features and associated buffer areas

Excluded Feature	Associated Buffer Distance
Excessive Slope, greater than 40%[6]	None
High Elevation, greater than 2,500'[7]	None
Developed Areas, by type	50 – 75 feet
Airports	1000 feet
Railways	17 feet
Streams and Rivers	50 feet
Lakes and Ponds	100 feet
Wetlands, by class	25 – 100 feet
Roads, by class	15 – 40 feet
Critical Habitats (deer yards, etc.)	100 feet
Ecologically Sensitive Areas	100 feet

Spatial data were collected for each of these features on a state-by-state and county basis using each state's respective GIS data clearinghouse, other on-line GIS data sources, and standard ESRI data. These specific data files are listed in the appendices of this report alongside its source, any classification scheme used in this analysis, and exact buffers applied to that classification scheme. In several cases, spatial data was not available or not included and that is noted in the appendix.[8] Additionally, web links to each data file available on-line are given in Appendix A.

These features were not rated or weighted by any metric of importance, but rather each feature and its respective buffer distance, where applicable, were merged into one single larger feature layer representing the whole of the area that would be constrained from active forest management that would involve any amount of harvesting activity. This inaccessible area layer was then clipped to the starting forestland layer for each county, yielding the portion of forestland in each county that would be physically and ecologically constrained from management and harvesting. This remaining forestland area became the basis for further analysis of the annual growth and availability of low-grade wood that could be used as fuel.

2.3 Addressing Further Constraints on Active Forest Management

The methodology detailed in the section above only accounts for the physical and ecological limitations on the amount of forestland factored in this analysis. It does not address the more ambiguous limitations that

[5] For a summary of harvesting laws and regulations in Vermont, see - http://www.vtfpr.org/regulate/documents/Timber_Harvest09_web.pdf

[6] Harvesting on excessively steep slopes is difficult, costly, and presents a high risk to the logger and eroding soil.

[7] Harvesting is already somewhat restricted above 2,500 feet because it requires an Act 250 permit. Additionally, above this elevation there is a dramatically higher concentration of sensitive flora and fauna habitat.

[8] In these cases of missing data layers, rough adjustments were made to account for that physical or ecological limitation on the amount of forested area.

stem from forestland ownership categories and the wide-ranging attitudes and objectives of different forestland owners.

To address the social, political, and economic factors that often affect what portion of forestland is under some level of management and therefore is a part of the working "wood basket", forestland ownership data from the FIA National Forestland Owner Survey were used and combined with a series of assumptions as to what percentage of each ownership category is likely actively managed. Supplemental information from the Vermont Woodland Owner Survey 2014 and UVA program were used to develop key assumptions.[9]

While GIS data and software were used to specifically identify the footprint of accessible and ecologically appropriate forestland area, there is, at this time, no comprehensive data source for forestland under management. While several counties have converted their UVA-enrolled parcels into GIS data layers, these data do not exist electronically for a majority of Vermont's counties. Additionally, there are thousands of managed acres of forestland in Vermont that are not enrolled in the UVA program. For these reasons, a series of key assumptions were made to estimate the portion of the unconstrained forestland that is likely under some level of forest management and therefore likely to, at some point in time, see periodic harvesting. The first step in doing this was to categorize Vermont's forestland by owner; the next step was to assign a percentage value to the portion of unconstrained forestland in each ownership category that is estimated to be actively managed. The key assumptions developed for each forestland owner classification represent the percentage of remaining forestland that is actively managed, ***after the physical and ecological constraints have already been filtered, not on the total footprint of forestland area.***

The portion of each ownership category that was estimated as actively managed is shown in the table in section 2.8 for each run of the analysis (low, baseline, and high). These percentages were derived by reviewing best available information on landowner categories and their ownership objectives and behaviors[10] as well as anecdotal feedback from foresters and other experts.

2.4 Assessing Forest Inventory and Composition

The next step in quantifying the amount of low-grade wood available annually from within the study area was estimating both the total inventory on the unconstrained and actively managed portion of timberland and the portion of inventory that is low-grade wood appropriate for wood fuel production. The only source of complete and consistent forest inventory data across the landscape is compiled by the USDA Forest Service.

The inventory data used in this assessment came from the USDA Forest Service's Forest Inventory and Analysis (FIA) program, which generates reliable estimates of the quantity, condition, and health of the forest resource and how it changes over time. The program uses a statistically-designed sampling method to select forest plots for measurement by field crews and includes a minimum number of forest plots that were counted in previous inventories.[11] The re-measurements on the same forest plots yield valuable information on how individual trees grow and serve as the basis for estimating net annual growth. Field crews also collect data on the number, size, and species of trees, and related forest health attributes.

The inventory data used in this assessment came from the USDA Forest Service's Forest Inventory and Analysis (FIA) program, which generates reliable estimates of the quantity, condition, and health of the forest resource and how it is changing over time.

For many years, FIA inventories were conducted in 10-year intervals. However, beginning in 2005, the FIA program moved to a new, continuous method of measuring plots and reporting inventory on an annual basis based on a percentage of the total plots measured. In Vermont, there are a total of 1,126 of these plots

[9] https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Your_Woods/Library/VWOS%202014%20Report.pdf

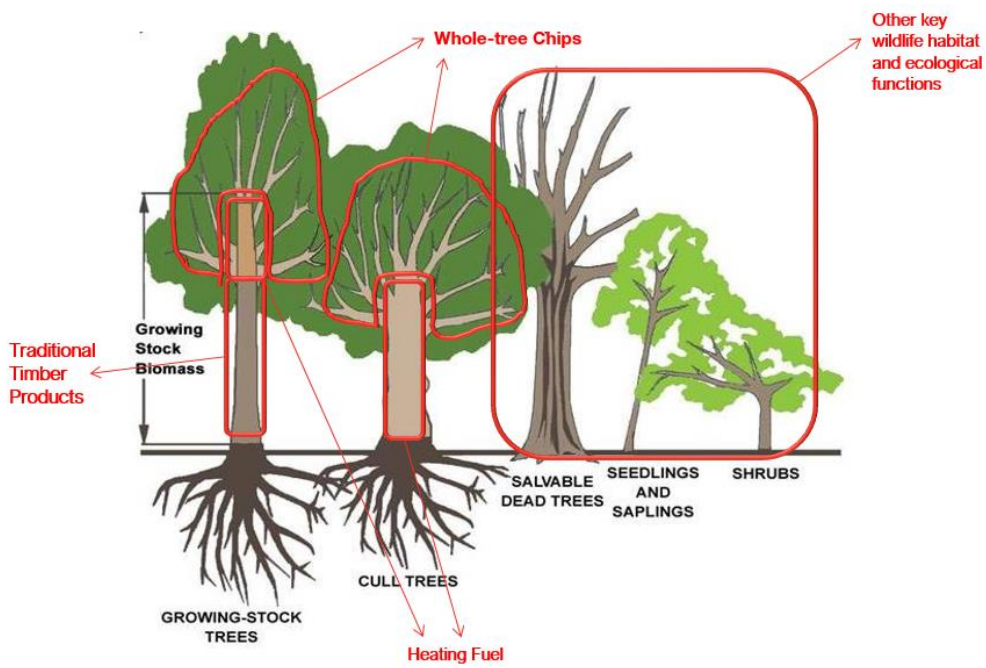
[10] http://www.fia.fs.fed.us/nwos/results/

[11] For further information visit - http://fia.fs.fed.us/library/fact-sheets/data-collections/Sampling%20and%20Plot%20Design.pdf

spread evenly over the landscape.[12] Based on the number of inventory plots measured, sample design, and statistical methods used, these forest inventory data generated by the FIA program have a relatively small margin of error.

Traditional forest inventories have focused on only timber-quality (growing stock) trees and have often measured only the merchantable portion of those trees and excludes a significant amount of tree inventory that would be suitable for fuel production. Meanwhile, data quantifying all forest biomass are far too inclusive. In an effort to hone in on the portion of the forest inventory that is low-grade and suitable for use as wood fuel, this study utilized custom data provided by FIA personnel, detailing the 2017 inventory of all live hardwood and softwood trees five inches DBH (Diameter at Breast Height) and larger for growing stock and cull trees.[13]

Figure 4 – Diagram of forest inventory components and their common uses



These custom inventory data include the tree bole (main stem) as well as the top wood and branches. Standing and downed deadwood were excluded due to their value as wildlife habitat and because it does not represent inventory on which new growth occurs. Seedling and saplings were not counted either, nor were foliage, stumps, or below ground forest biomass, such as roots.

Commercial timber harvest operations in the region typically use the lower section of tree bole of a high-quality tree for veneer or sawlog and the upper section of the same tree bole for pulpwood. For lower quality, yet merchantable, trees, the lower bole section becomes pulpwood and the upper bole is used for firewood.

In addition to the inventory data fed into the spreadsheet model, a series of key assumptions regarding the portion of the bole wood inventory that is low-grade were applied. Similarly, a series of key assumptions

[12] For the 2017 inventory, estimates for current variables, such as area, volume, and biomass, are based on 1,125 (925 forested) plots inventoried from 2011–2017. Change variables, such as net growth, removals, and mortality, are based on 970 (775 forested) plots inventoried in 2008-2012 and resampled in 2011–2017.

[13] The term "growing stock tree" refers to live trees =/>5" DBH containing traditionally merchantable wood. "Cull trees" refers to growing stock tree species that are rough or rotten or otherwise un-merchantable. "Non-commercial species" is small category of tree species that fall into neither the Growing Stock or Cull category.

regarding the portion of the top and limb wood that can be utilized as wood fuel were applied. Further details on the key assumptions used in this analysis will be given later in this report (Section 4.1).

2.5 Projecting Net Annual Growth of Wood on Inventory

Once the low-grade wood inventory has been estimated, rates of net annual growth are applied to that inventory. FIA defines forest net annual growth as "the change, resulting from natural causes, in growing-stock volume during the period between surveys (divided by the number of growing seasons to produce average annual net growth)." The simplified FIA formula for net growth is:

In-growth (new trees) + Accretion (growth of existing trees) – Mortality (natural death) = Net growth

For the purpose of this assessment, net annual growth was chosen as the indicator of how much wood the forests of Vermont can provide on a sustained-yield basis without reducing the forest inventory levels. That said, it is important to note that there may be situations where reducing forest inventory levels across the landscape with harvesting could be silviculturally justified or may happen naturally via pest outbreak, like the Emerald Ash Borer's (EAB) expected impact on ash tree inventory in Vermont over the next 5-10 years. EAB is a destructive and invasive forest pest that feeds on all species of ash trees, killing over 99% within four years of infestation. The state's forested land is made up of about 5% ash, yet up to 50% of downtown trees in Vermont are ash. All said, Vermont is home to an estimated 160 million ash trees. At the time this report was first released, EAB was confirmed in Orange, Washington, Caledonia, Grand Isle, and Bennington Counties and is expected to spread rapidly.

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Similar to the forest inventory and composition data used, this study utilized data on net annual growth from the USDA Forest Service FIA program. FIA maintains a network of semi-permanent ground plots for measuring forest inventory. After initial plot measurement, plots are periodically re-measured over time. Individual trees are re-measured until they die and new trees are measured as they grow into the plots. Forest plots are re-measured in cycles of approximately 5 to 7 years in the eastern U.S.

In Vermont, there are twelve years (2005 to 2017) of plot measurements using the newer methods, resulting in useable and up-to-date net annual growth data. However, these data have a slightly greater margin of error at the county level than typical inventory data, due to fewer re-measurement plots -- resulting in a smaller sample size.

Young trees and stands of trees grow at faster rates and older trees and stands grow at slower rate. The rates used in this assessment are averaged rates of growth for all the various forest stands sampled and measured by FIA. It is important to note, the net annual growth rates used in this assessment are averaged rates of ***current*** growth based on the ***current*** forest condition. Should forest conditions (species and age class composition, and stocking levels) change significantly over the landscape, the rates of growth will undoubtedly be affected. Forests are very complex and dynamic and will change significantly over time.

2.6 Accounting for Current Removals

Data on harvesting of pulpwood, firewood, and whole-tree chips in Vermont were provided by the Vermont Department of Forests, Parks and Recreation (FPR)[14]. While data for whole-tree chips and pulpwood are

[14] http://www.vtfpr.org/util/for_utilize_harvsumm.cfm

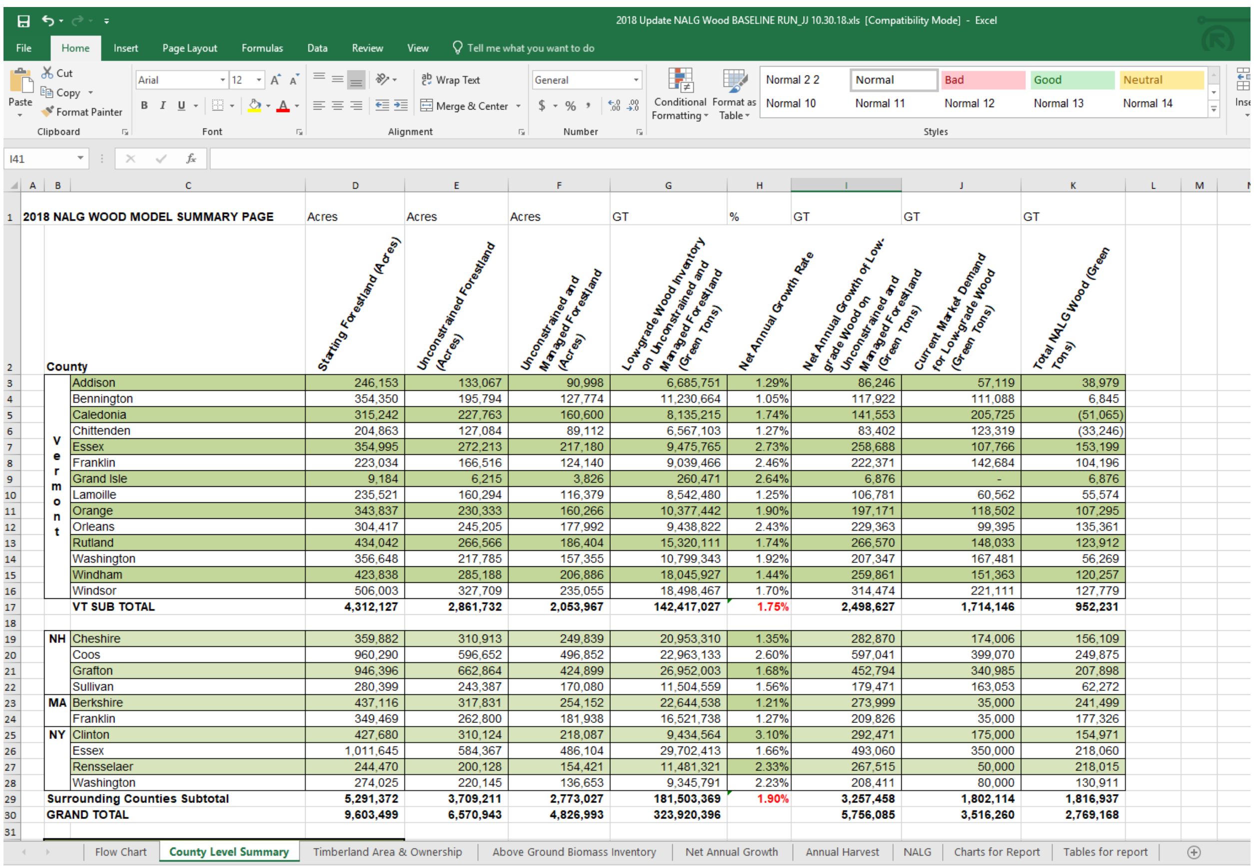
gathered annually as part of an annual survey of primary wood consumers throughout the region, the data for the harvest of firewood are derived from the 2014/2015 Residential Fuel Assessment. Estimates for county-level harvest of pulp, chips and firewood in New Hampshire, Massachusetts, and New York were presented to wood utilization foresters from each state and revised based on their input. These estimates were also compared against the FIA program's Timber Products Output (TPO) data.

Given the inconsistent nature of the amount of wood harvested annually due to changes in weather and fluctuating market demand, a three-year (2006, 2007, and 2008) average was used. These harvest data were then subtracted from the amount of net annual growth of low-grade wood, thus providing an estimate of the amount of Net Available Low-grade Growth (NALG) wood in each county.

2.7 Model Framework

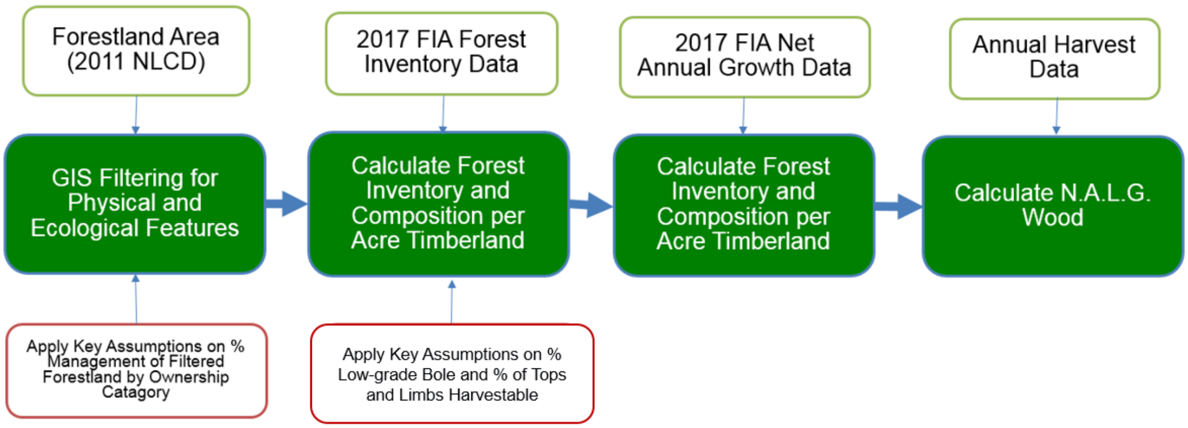
All of these data and key assumptions were plugged into a large spreadsheet matrix based in Microsoft Excel. Figure 5 is an example computer screen shot of the model.

Figure 5 – Screenshot of Excel-based NALG model



	County	Starting Forestland (Acres)	Unconstrained Forestland (Acres)	Unconstrained and Managed Forestland (Acres)	Low-grade Wood Inventory on Unconstrained and Managed Forestland (Green Tons)	Net Annual Growth Rate	Net Annual Growth of Low-grade Wood on Unconstrained and Managed Forestland (Green Tons)	Current Market Demand for Low-grade Wood (Green Tons)	Total NALG Wood (Green Tons)
		Acres	Acres	Acres	GT	%	GT	GT	GT
Vermont	Addison	246,153	133,067	90,998	6,685,751	1.29%	86,246	57,119	38,979
	Bennington	354,350	195,794	127,774	11,230,664	1.05%	117,922	111,088	6,845
	Caledonia	315,242	227,763	160,600	8,135,215	1.74%	141,553	205,725	(51,065)
	Chittenden	204,863	127,084	89,112	6,567,103	1.27%	83,402	123,319	(33,246)
	Essex	354,995	272,213	217,180	9,475,765	2.73%	258,688	107,766	153,199
	Franklin	223,034	166,516	124,140	9,039,466	2.46%	222,371	142,684	104,196
	Grand Isle	9,184	6,215	3,826	260,471	2.64%	6,876	-	6,876
	Lamoille	235,521	160,294	116,379	8,542,480	1.25%	106,781	60,562	55,574
	Orange	343,837	230,333	160,266	10,377,442	1.90%	197,171	118,502	107,295
	Orleans	304,417	245,205	177,992	9,438,822	2.43%	229,363	99,395	135,361
	Rutland	434,042	266,566	186,404	15,320,111	1.74%	266,570	148,033	123,912
	Washington	356,648	217,785	157,355	10,799,343	1.92%	207,347	167,481	56,269
	Windham	423,838	285,188	206,886	18,045,927	1.44%	259,861	151,363	120,257
	Windsor	506,003	327,709	235,055	18,498,467	1.70%	314,474	221,111	127,779
	VT SUB TOTAL	**4,312,127**	**2,861,732**	**2,053,967**	**142,417,027**	**1.75%**	**2,498,627**	**1,714,146**	**952,231**
NH	Cheshire	359,882	310,913	249,839	20,953,310	1.35%	282,870	174,006	156,109
	Coos	960,290	596,652	496,852	22,963,133	2.60%	597,041	399,070	249,875
	Grafton	946,396	662,864	424,899	26,952,003	1.68%	452,794	340,985	207,898
	Sullivan	280,399	243,387	170,080	11,504,559	1.56%	179,471	163,053	62,272
MA	Berkshire	437,116	317,831	254,152	22,644,538	1.21%	273,999	35,000	241,499
	Franklin	349,469	262,800	181,938	16,521,738	1.27%	209,826	35,000	177,326
NY	Clinton	427,680	310,124	218,087	9,434,564	3.10%	292,471	175,000	154,971
	Essex	1,011,645	584,367	486,104	29,702,413	1.66%	493,060	350,000	218,060
	Rensselaer	244,470	200,128	154,421	11,481,321	2.33%	267,515	50,000	218,015
	Washington	274,025	220,145	136,653	9,345,791	2.23%	208,411	80,000	130,911
Surrounding Counties Subtotal		**5,291,372**	**3,709,211**	**2,773,027**	**181,503,369**	**1.90%**	**3,257,458**	**1,802,114**	**1,816,937**
GRAND TOTAL		**9,603,499**	**6,570,943**	**4,826,993**	**323,920,396**		**5,756,085**	**3,516,260**	**2,769,168**

Figure 6 – Flow diagram of the NALG model inputs and sequence of calculations



The flow chart above (Figure 6) illustrates the methodology used for this study and the basic framework of the linear model used for calculating the amount of NALG wood.

Over a landscape, maintaining more net annual growth of wood than is removed is widely considered a fundamental metric of sustainability. Growth to removals is a fairly-crude metric of sustainability yet was the best available indicator of sustained-yield capacity for the 2010 study. However, if growth continues to exceed removals across Vermont, the result is older, overstocked forests with greater risk of increased mortality and declining rates of net annual growth. It is incorrect to assume that as long as removals stay below current growth, the forests will continue to yield a constant amount of wood in perpetuity. In reality, forest inventory, composition and averaged rates of growth will continue to change over time—they do not remain constant.

2.8 Model Scenarios Developed

This spreadsheet model wove the various data together, but in the absence of hard data in several key areas (how much forestland is under management, how much of the forest inventory is low-grade, how much top and limb wood to include) a series of key assumptions were developed and fed into the model. Due to the sensitivity of the results to minor changes in the various key assumptions, this study does not present a singular result, rather three main scenarios were designed to present the possible range of results. A “baseline” scenario was developed to identify the most probable amount of wood fuel available today. A “low” scenario was developed from a coupling of adjustments to the various key assumptions for the purpose of exploring the lower limits of how much wood fuel could be available. And lastly an “high” scenario was developed with the purpose of testing the possible upper reaches of the wood supply while still within many of the real constraints. For all three scenarios, both the net annual growth rate and the amount of annual harvest of low-grade wood remained the same.

Further discussion of key assumptions can be found in Section 4.1 of this report.

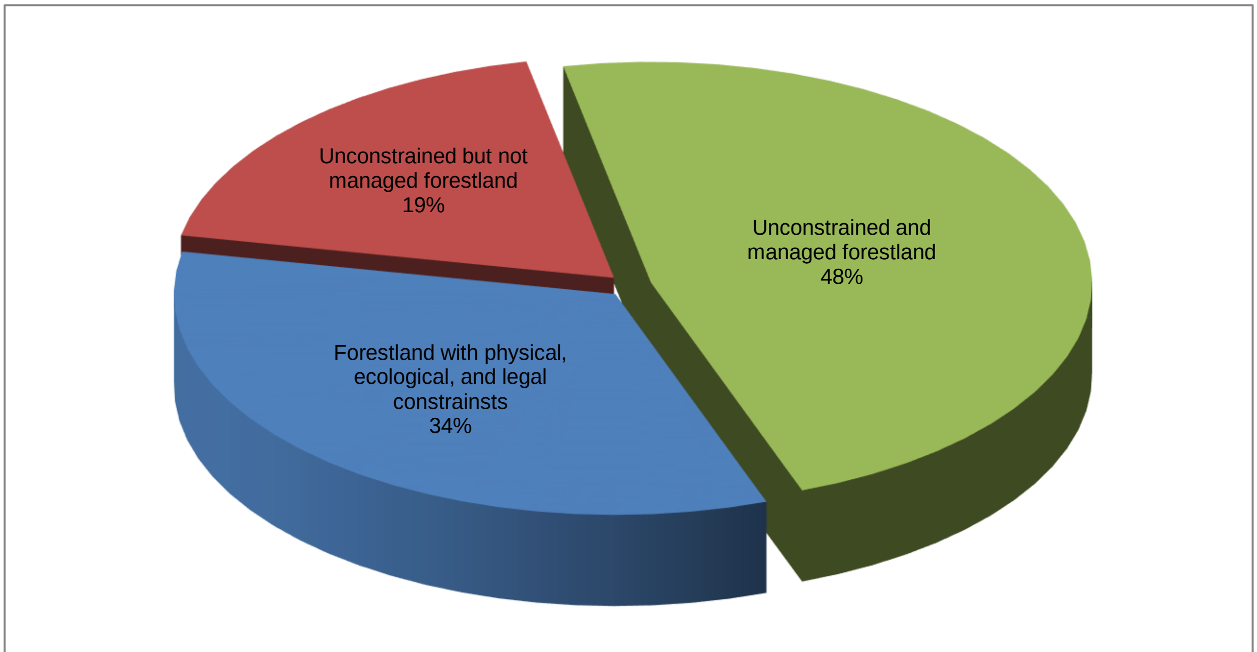
3.0 RESULTS

The following section gives the results of the analysis for the Baseline scenario. Results of the Low and High scenarios are presented in Section 4.0 of this report.

3.1 Forestland Area

The following pie graph (Figure 7) presents the total amount of forestland area (all three wedges), the constrained forestland area (blue wedge), the estimated amount of unconstrained forestland not under management (red wedge), and the remainder of forestland area that is unconstrained and estimated to be under some level of forest management (green wedge).

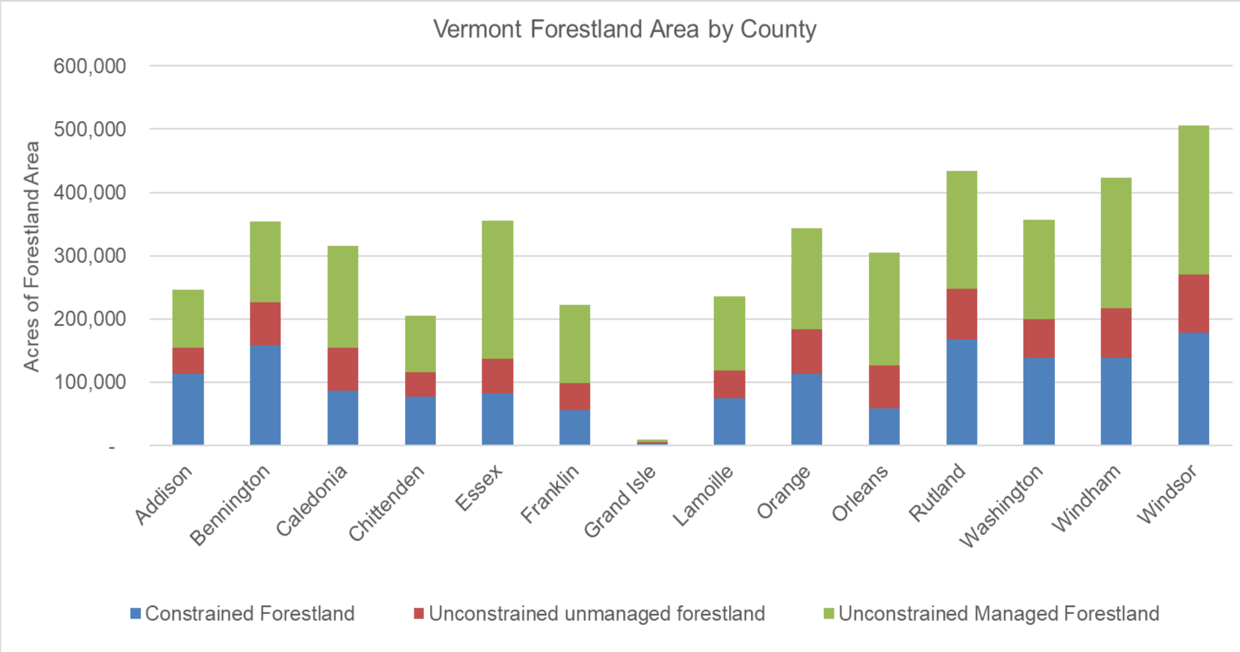
Figure 7 – Estimated distribution of Vermont forestland area



In Vermont there are 4.3 million acres of total forestland. Fifty-three percent of the total forestland area is not included as part of the analysis of what is available in the baseline scenario. This is because 34 percent of the overall forestland is physically and ecologically constrained (approximately 1.45 million acres) and another 19 percent of the unconstrained forestland is not likely to be actively managed (800,000 acres). This leaves approximately 2.0 million acres of unconstrained and likely managed forestland.

Figure 8 illustrates the proportions of forestland categories broken out by county. While some counties had higher and lower proportions of constrained, unconstrained unmanaged, and unconstrained managed forestland, the ratios did not vary widely from county to county.

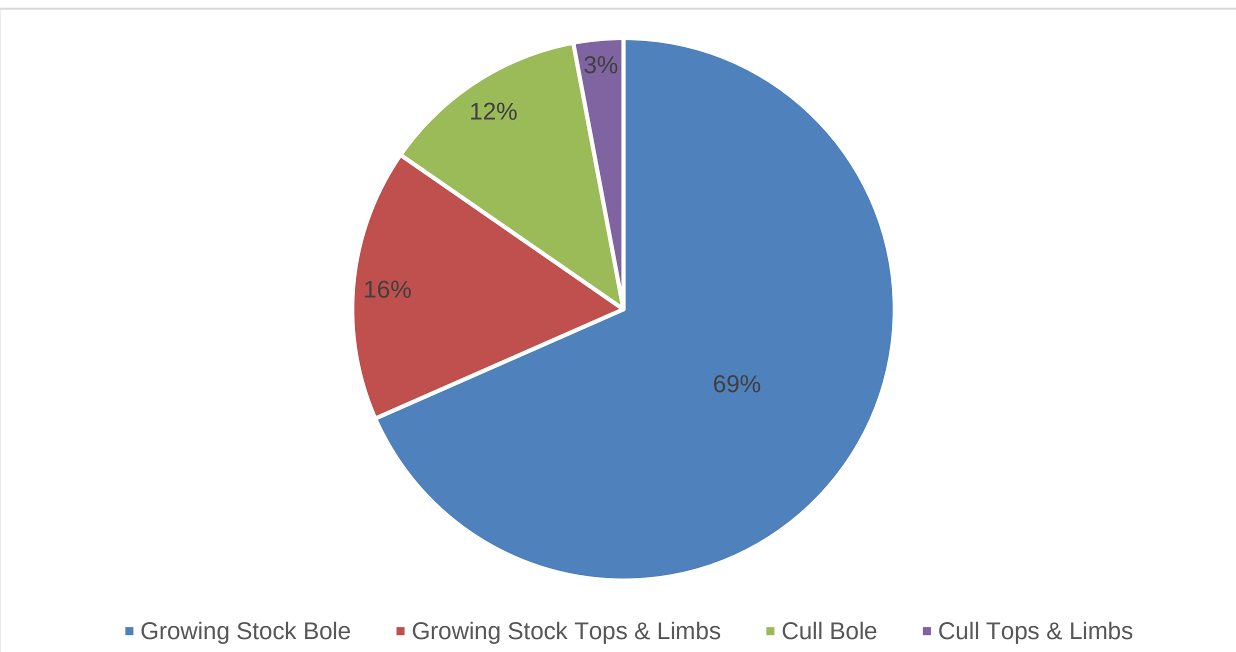
Figure 8 – County-level distribution of forestland categories



3.2 Forest Inventory and Composition

Figure 9 illustrates the breakdown of the various forest inventory components considered for this study.

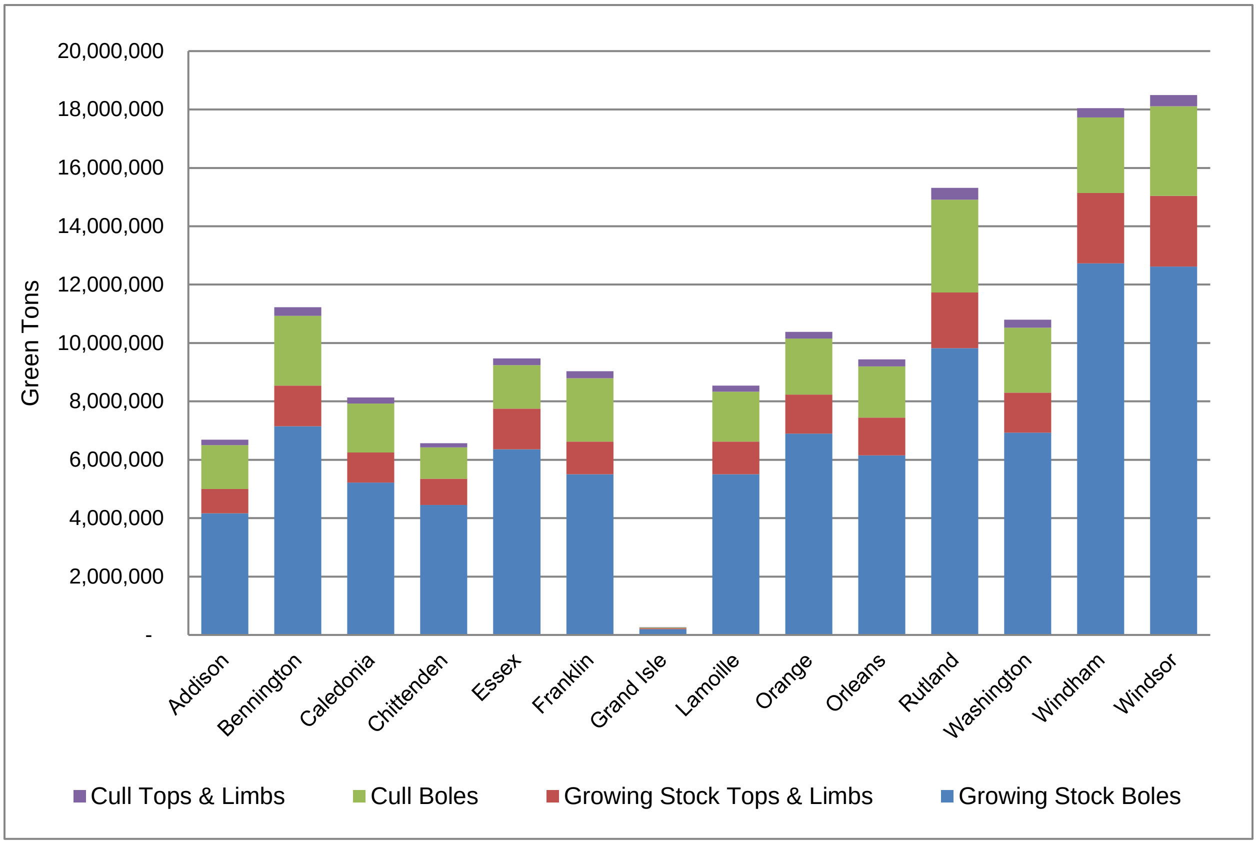
Figure 9 – Breakdown of forest inventory components considered for this study



A large majority of wood inventory resides in the bole section of growing stock and to a lesser extent cull trees. The top and limb wood amounts to a very small percentage of the total inventory.

Understanding the total amount of inventory is useful context, but the purpose of this study is to examine the low-grade portion of this inventory. Figure 10 gives the amounts of low-grade wood, by county, of all live trees in the study area, on the portion of timberland that was estimated to be accessible and managed as described earlier.

Figure 10 – Low-grade wood inventory of live trees on unconstrained and managed forestland in Vermont

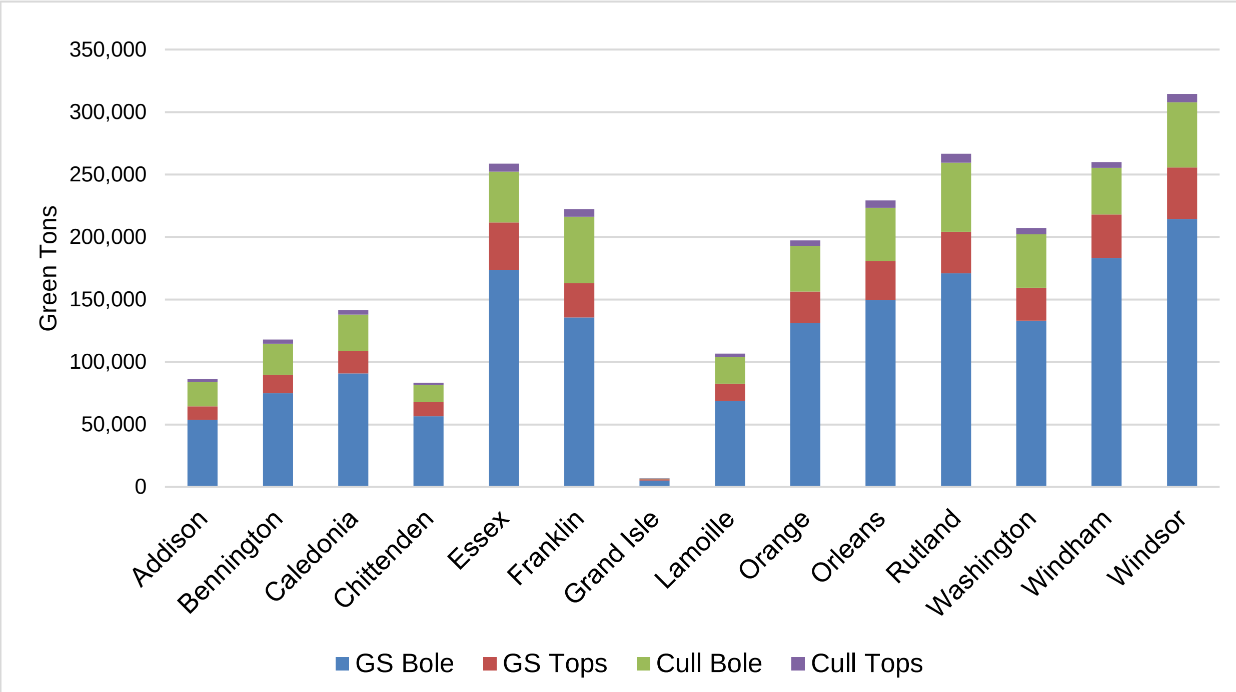


Rutland, Windham, and Windsor Counties have the greatest amounts of low-grade inventory, whereas Grand Isle County has the least due to the low number of acres of forestland.

3.3 Net Annual Growth

Figure 11 depicts the projected net annual growth of low-grade wood on the accessible, appropriate, managed footprint of forestland in Vermont.

Figure 11 – Net annual growth of low-grade wood on unconstrained and managed forestland in Vermont

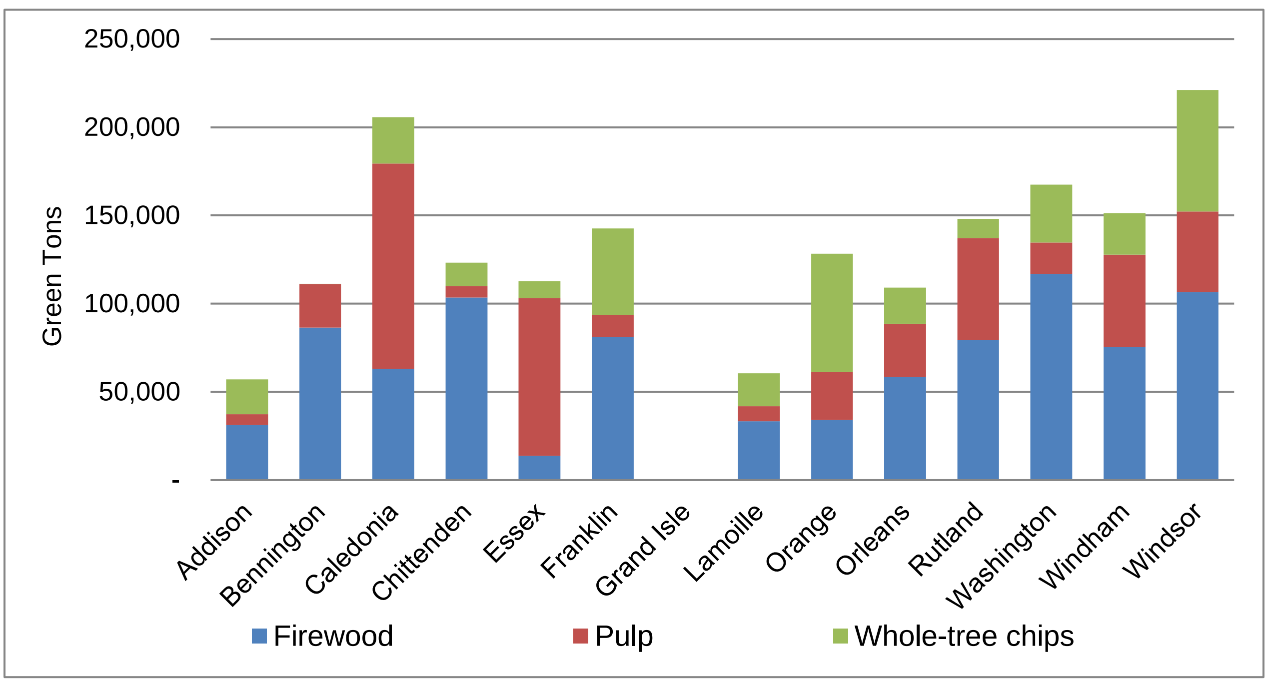


As Figure 11 illustrates, the counties of Essex, Rutland, Windsor, and Windham have the greatest amounts of annual net growth of low-grade wood.

3.4 Current Removals

There are three primary product categories for existing demand for low-grade wood in the region – pulpwood, firewood, and whole-tree chips. Pulpwood used by regional papermills has been a long-term

Figure 12 – Three-year average of low-grade wood harvest in Vermont by county (green tons)



mainstay of the timber market. Firewood demand (includes fuel wood used as feedstock for bole chip) has been gradually increasing. Figure 12 depicts the average annual amounts harvested from Vermont counties in the three years of 2014, 2015, and 2016.

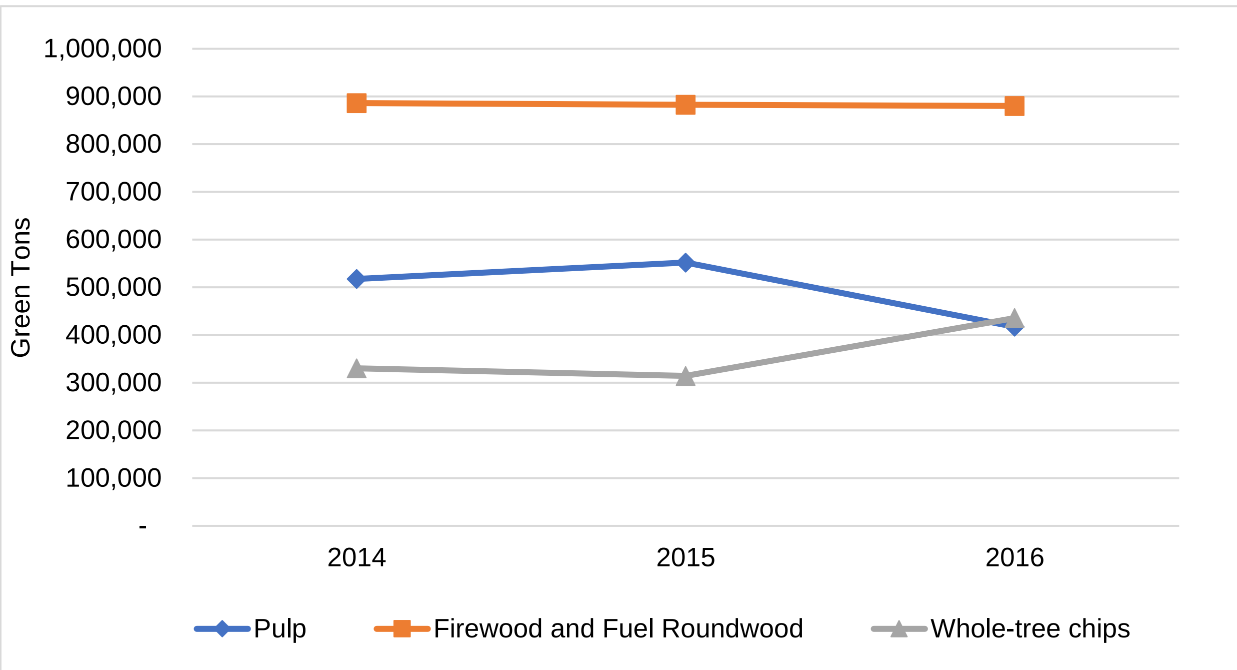
Firewood is often overlooked as a wood market, yet it is a considerable portion of the total harvest. Firewood accounts for a majority portion (51%) of the low-grade harvest in Vermont. Pulpwood accounts for 29% and whole-tree chips represents 18% of the total harvest of low-grade wood.

Note the high levels of harvest in Caledonia, Orange, and Windsor Counties. These high levels of reported low-grade wood harvest will influence the outcome of the NALG wood later in this report.

As illustrated in Figure 12, several distinct spatial patterns can be seen. For pulpwood, the counties in the Northeast Kingdom, that are the closest to the pulpwood markets in Maine and Quebec have the largest percentages of pulpwood harvest – especially Essex and Caledonia Counties. The relatively low percentage of pulpwood harvest levels in Orleans County is not fully understood although these results may be influenced, in part, by the location of concentration yards and errors in reporting by the regional mills. Firewood harvest percentage is greatest in Washington County, where there are high levels of residential wood heating. For whole-tree chip harvest Franklin, Orange and Windsor Counties have the highest levels and are located near large whole-tree chip markets (chip yard serving McNeil is located in Franklin County, Orange and Windsor Counties are close to the Ryegate Power Station and markets in New Hampshire).

Figure 13 below illustrates the 3-year harvest amounts for low-grade wood in Vermont.

Figure 13 – Three-years of low-grade wood harvest in Vermont



As indicated in Figure 13, total harvest levels for all low-grade wood have remained steady. Yet, there was a decline in pulpwood and an increase of whole-tree chip harvest levels from Vermont in 2016.

For the calculations of net available low-grade wood, only the pulpwood, firewood, and whole-tree chip data were used, since higher-quality wood capable of yielding sawlog or veneer grade products was already excluded from the inventory data early in the process.

3.5 NALG Wood

The amount of NALG wood is the model's output and represents the best estimation of additional forest resource capacity to support further wood energy market expansion in the region.

Table 4 – Baseline NALG wood results (green tons)

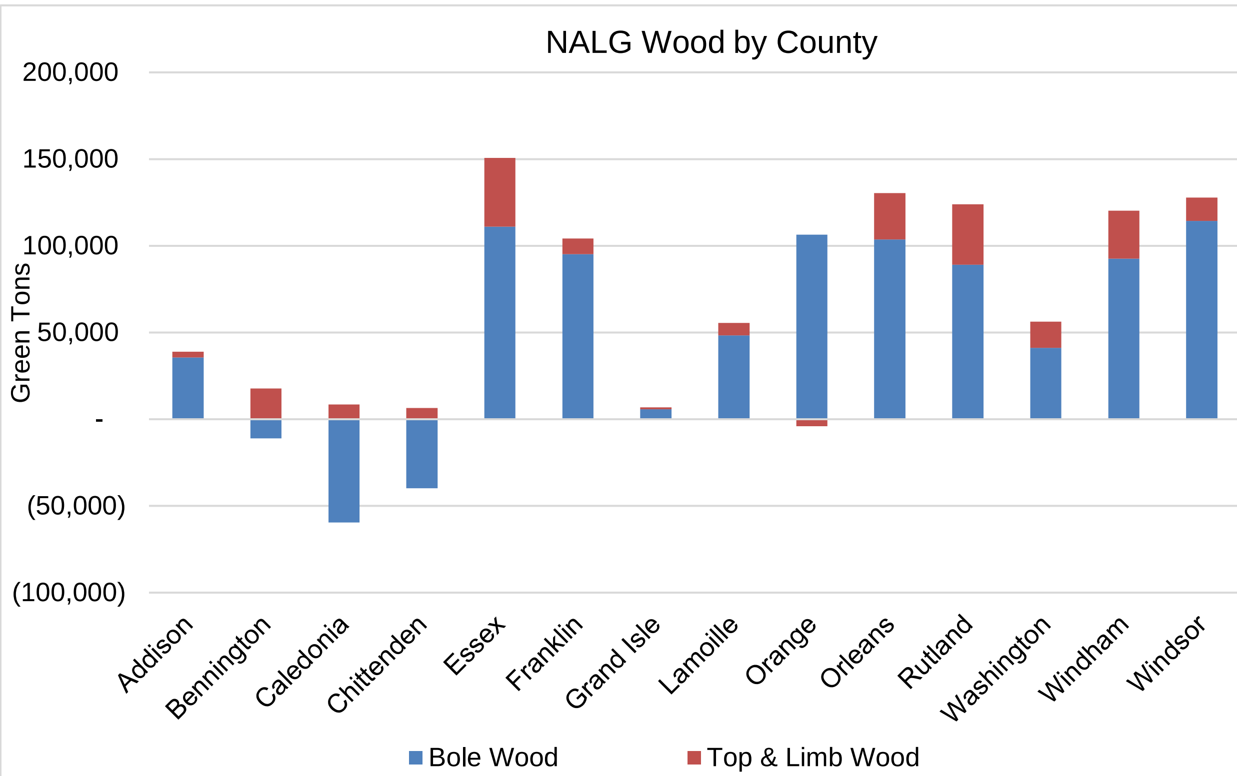
	Bole Wood	Top and Limb Wood	Total
Vermont counties	732,959	207,030	939,989
Surrounding counties of NY, MA, and NH	1,670,296	146,639	1,816,936
Total	**2,403,255**	**353,669**	**2,756,925**

Table 4 indicates that, for the baseline scenario, there is currently slightly less than a million green tons of NALG wood from within the fourteen counties of Vermont. However, if the surrounding counties of New York, Massachusetts, and New Hampshire are included, the resulting amount of NALG wood increases dramatically to over 2.7 million green tons annually.

It is very important to note, that while the total amount of NALG wood is important, closer examination of the amount that is bole wood versus top and limb wood is essential. Many markets – including the expanding woodchip and pellet market, prefer the resulting fuel quality achieved by using bole wood. By contrast, the traditional market for wood fuel produced from tops and limbs are the large wood-fired power plants that are able to utilize less uniform fuel.

Figure 14 below presents the NALG results broken out bole and top and limb wood by county.

Figure 14 - NALG wood results by Vermont county

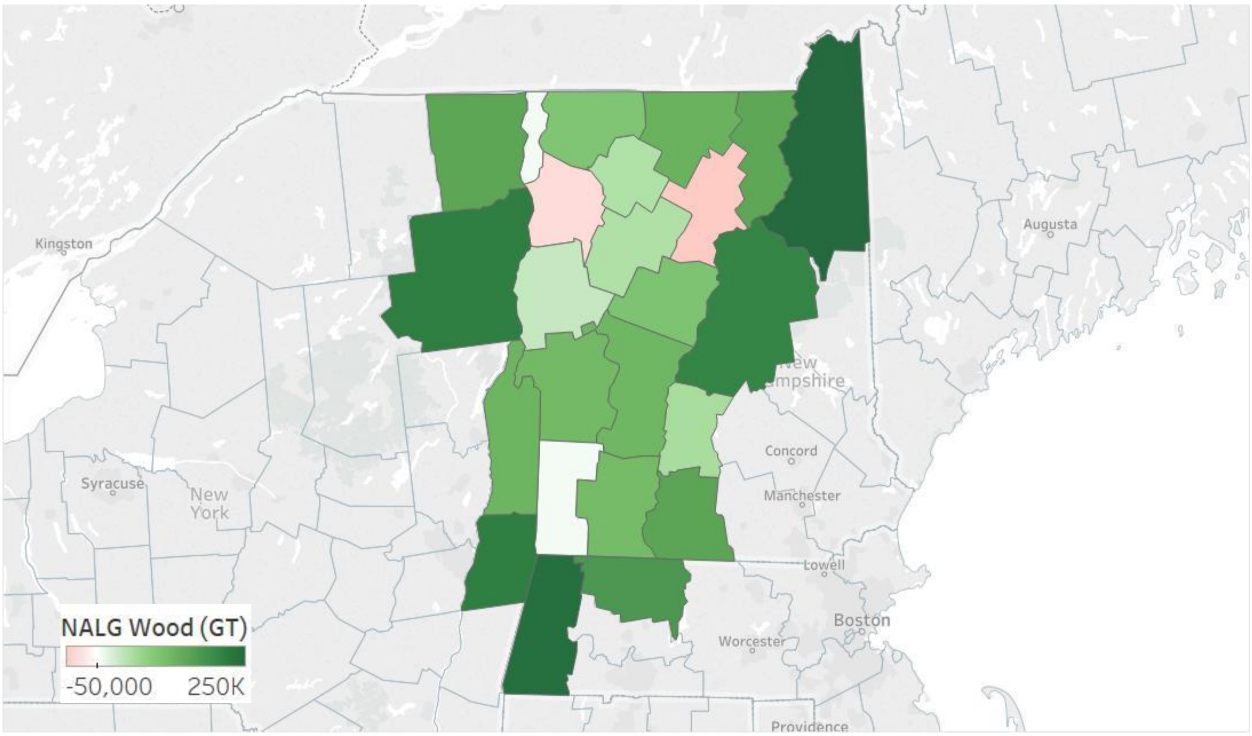


Based on the data used, key assumptions applied, and the methodology employed, the results indicate Essex and Orleans Counties contain the highest concentrations of NALG wood while Rutland, Windsor and Windham Counites also have large amounts. Conversely, Caledonia, Chittenden, and Bennington Counties show negative values for the NALG bole wood resources. This is due to different combinations of factors for each county. Caledonia County saw higher levels of pulpwood harvesting in the time-period from 2014 to 2016. Chittenden County's NALG wood resource estimate is negative due to a larger percentage of forestland with parcel sizes less than 50 acres (limiting the footprint of forestland) and the firewood harvesting estimates directly stem from the consumption of firewood. Chittenden County has the greatest human population and as a result, the estimates for firewood harvest are high.[15] The negative value for Bennington County is likely due to the portion of forestland in the Green Mountain National Forest and comparatively high estimates for firewood and pulpwood annual harvest.

One reason for the dramatic increase in NALG wood when the 10 counties of NY, MA, and NH are added to the 14 counties of Vermont is that several of these counties are large and are heavily forested—such as Grafton and Coös Counties in New Hampshire as well as Clinton and Essex Counties in New York.

The map presented in Figure 15 below presents the NALG wood results of the baseline run of this analysis to better illustrate the spatial distribution of the NALG wood resource.

Figure 15 – Map of NALG wood concentrations within the study area counties

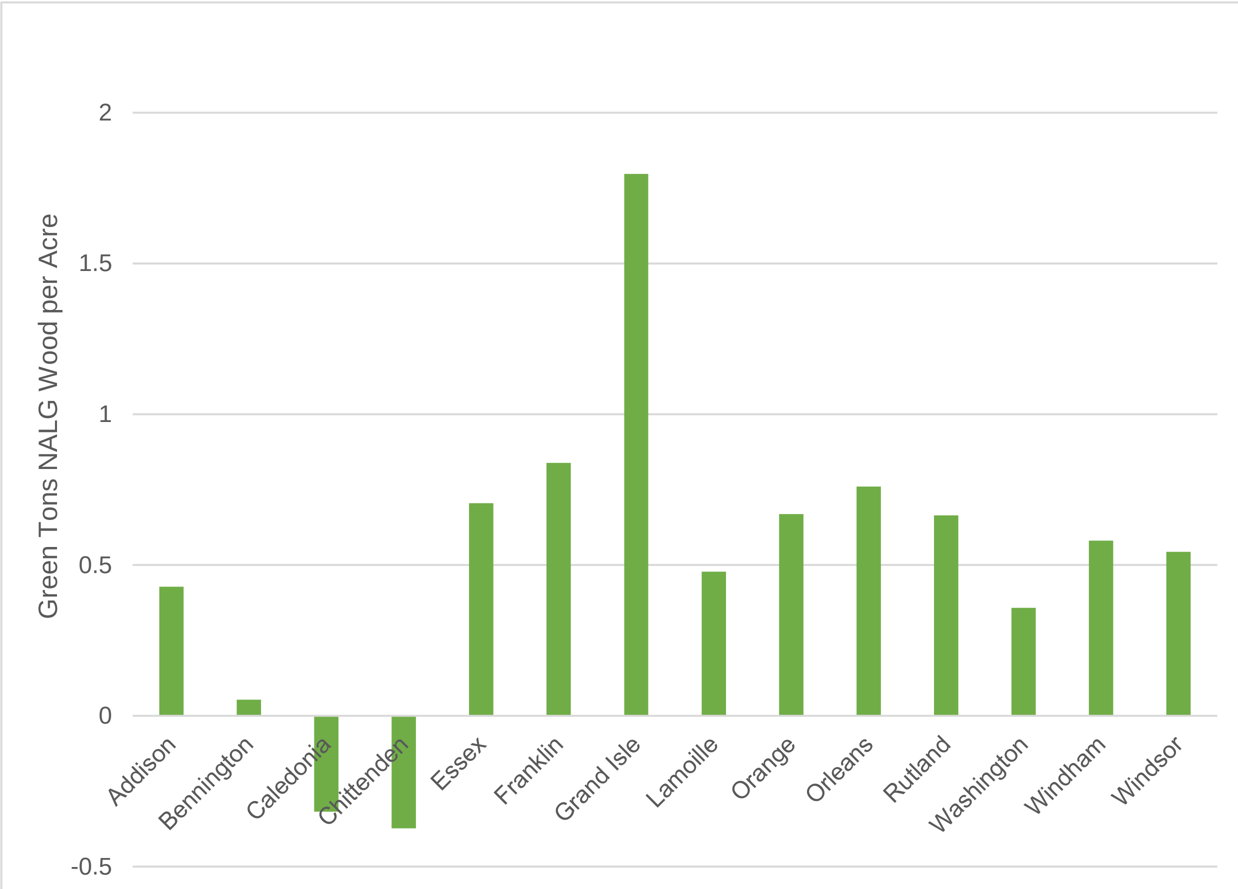


It is important to note, that many of the counties with the greatest concentrations of estimated NALG wood are those with the largest forestland areas. Another important factor is the 2014 opening of Burgess Power station in Berlin, New Hampshire that back-filled a hole left by the closure of the pulpmill in the previous decade. Burgess Power consumes mostly whole-tree chips, but also some roundwood and they affect the amount of low-grade wood now being harvested in Coös, Grafton, Essex, and Caledonia Counties. Also, the harvest demand for New York counties may have been underestimated given the size of the potential demand from the International Paper pulpmill in Ticonderoga, New York and the Finch Paper pulpmill in Glens Falls, New York.

To look at the amount of NALG wood in the various counties from a different angle, Figure 16 was included to illustrate the concentration of NALG wood on a per acre basis.

[15] Harvest of firewood in Chittenden County is likely overestimated due to the assumption that firewood is harvested from the same county it is consumed. It is highly likely that considerable amounts of firewood used in Chittenden County is imported from surrounding counties.

Figure 16 - Per acre amounts of NALG wood by county



Rather than showing the counties with the most NALG wood that is often a function of the amount of forestland area in that county, this bar graph shows the counties with the highest concentrations of NALG on a per-acre basis.

As is illustrated in Figure 16, modeling results suggest that Caledonia and Chittenden Counties have no remaining NALG wood in total or on a per acre basis and very little remains in Bennington County at this moment in time. In contrast, Grand Isle County, that has few acres of managed timberland, has the highest per acre amount of NALG wood as calculated as part of this study.

4.0 DISCUSSION

The results provided above are the result of a model that is fed forest inventory data, but also relies on a series of key assumptions that, when adjusted, can dramatically change the results. The following section provides further conceptual framing, discussion of the variability of the results, and explores longer-term trends.

When considering the changes in forest inventory, growth, and removals over time, thinking about forests by making comparisons to other familiar objects or systems is often helpful. Previous Vermont Wood Fuel Supply Study reports made the comparison between forests and financial investments, where a principal amount of money is invested and that sum earns interest each year. As long as the investor takes out less money each year than is earned in interest, the principal will continue to grow over time. Unfortunately, this analogy is too simple.

Figure 17 – Bathtub analogy for forest growth, inventory, and removals

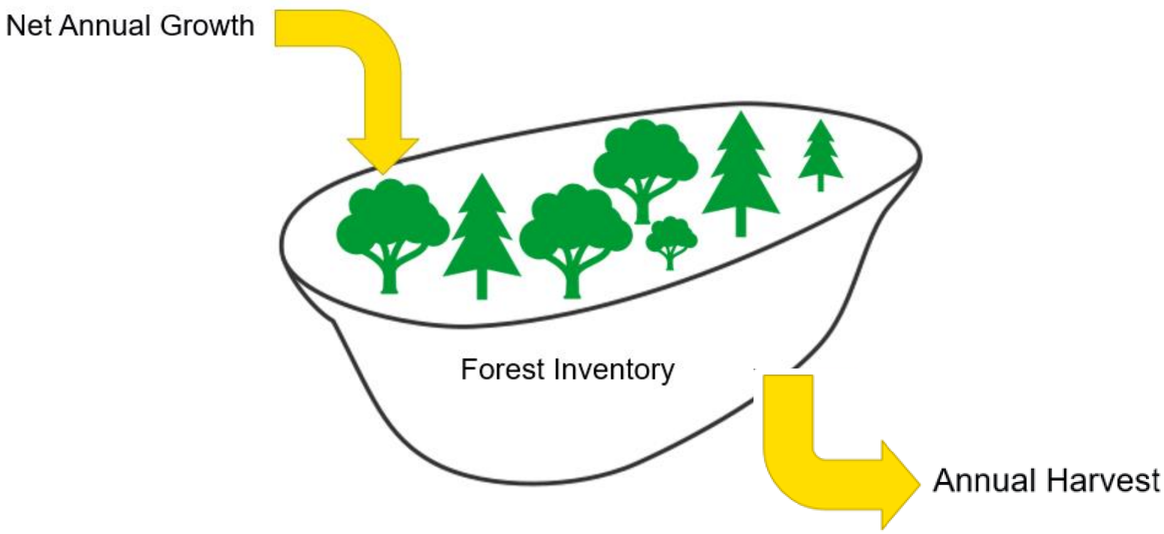


Figure 17 above provides a more suitable analogy comparing forests to a bathtub, where the amount of water (forest inventory) in the tub is directly tied to how fast water is added (net annual growth) and drained from the tub (annual harvest). Over the past several decades water has been consistently added faster than it was draining. As a result, the amount of water in the tub was steadily increased. Like the amount of water that can be added to a bathtub, there are limits to how much inventory can be added to forests over time. In fact, Vermont's forests are now experiencing slowing growth rates and increasing mortality rates. Eventually, the amount drained could exceed the amount added annually. While removing more wood than is grown each year, may not sound viable over a long time-period, it may be a necessary means to achieving a more balanced age class distribution (more younger forests) and increased average rate of forest growth.

4.1 Key Variables

For each of the variables used in this assessment, a best estimate was made based on published studies and the input and review of foresters and experts. The packaged best estimates for each variable represent the "baseline" scenario or best representation of conditions in Vermont today.

Table 5 below provides the key assumptions used for the three model runs.

Table 5 - Packaged series of key assumptions used for the three scenarios

KEY VARIABLES				
% of physically and ecologically unconstrained forestland estimated to be managed and periodically harvested		Low	**Baseline**	High
Ownership	National Forest	35%	50%	65%
	State	50%	65%	80%
	Municipal	40%	50%	60%
	Forest Industry	80%	90%	100%
	Farmer	70%	80%	90%
	Corporate	80%	90%	100%
	Individual < 50 Acres	20%	30%	40%
	Individual > 50 Acres	75%	85%	95%
	Other	45%	55%	65%
% of the forest inventory component designated as "low grade" and suitable for use as wood fuel				
Low-grade Designation	% Growing Stock Bole	50%	60%	70%
	% Cull Bole	75%	85%	95%
	% Growing Stock Top and Limb Wood	40%	50%	60%
	% Cull Top and Limb Wood	40%	50%	60%

Forest Management Levels by Ownership Category

Forestland owners in Vermont span numerous categories (individuals, families, farmers, forest products industry, corporations, and municipal, state and federal government) and each have wide ranges of objectives, perspectives, priorities regarding forest management that affect their management decisions. Assumptions estimating the portion of forestland area actively managed by ownership category were developed. Minor deviations in the percentages of forestland considered actively managed have minimal impact on the resulting model outputs for NALG wood.

Low-Grade Portion of Forest Inventory

Another key variable in the NALG model is how much of the forest inventory is designated as "low-grade wood" suitable for wood fuel harvest. Within the FIA protocol, there are numerous designations of tree components and assigned quality. "Growing stock trees" includes all live tree stems over 5 inches DBH that are capable of eventually yielding a minimum of an 8-foot sawlog. "Cull trees" are those that are 5 inches DBH and larger that have been deemed incapable of yielding traditionally merchantable timber. Within the net annual growth accumulating in each category annually, a portion is low-grade wood. The next step in this analysis was to estimate, using some assumptions, the portion of net annual growth that is low-grade in each category.

Further, the extent to which different portions of the tree can be utilized for wood fuel was also quantified. Assumptions were made on the proportions of net annual growth in the bole and top and limb wood categories that would be appropriate for use as wood fuel.

As can be seen in Table 5 above, 50 to 70 percent of the growing stock bole was assumed to be appropriate for use as wood fuel. It is important to note, that not all volume of growing stock trees is high-quality—a significant portion of the classification is low-grade wood (pulpwood grade). Given the declining demand and price value of pulpwood over the past few decades, pulpwood was intentionally included as the quantified amount of wood that could possibly be used for wood fuel. This represents a shift which has recently been seen in Vermont where pulpwood quality material has gone to energy markets.

In the cull category, a higher proportion, ranging from 75 to 95 percent, was assumed to be appropriate for use as wood fuel. Ninety percent of cull was used as the upper limit rather than 100 percent because cull retention is important as cull trees frequently become future snag trees (dead standing trees) that are vital habitat for a wide range of wildlife. Again, it is important to remember it is only the net annual growth of these components that are being counted for potential wood fuel use.

Another important variable in the NALG analysis is the extent to which the tops and limbs of harvested trees would be used as wood fuel. Tops and limbs are removed as part of whole-tree harvesting, while they are commonly left behind on the forest floor as part of traditional, stem-only harvesting. Determining how much top and limb wood can be removed is a complex issue and there are a wide range of data and opinions within the fields of forestry and forest ecology as to how much of this material is suitable to extract versus leaving behind for wildlife habitat and nutrient cycling. Broad sweeping generalities are extremely difficult to pin down, due to the fact that how much top and limb wood can be removed depends highly on the stand-level details (soils, species and age class composition, site harvest history, etc.). Ideally, the removal or retention of top and limb wood is determined by a forester after site-specific factors are considered (such as soil health and productivity, harvesting histories, and landowner objectives). A range from 40 to 60% was used for the scenarios modeled.

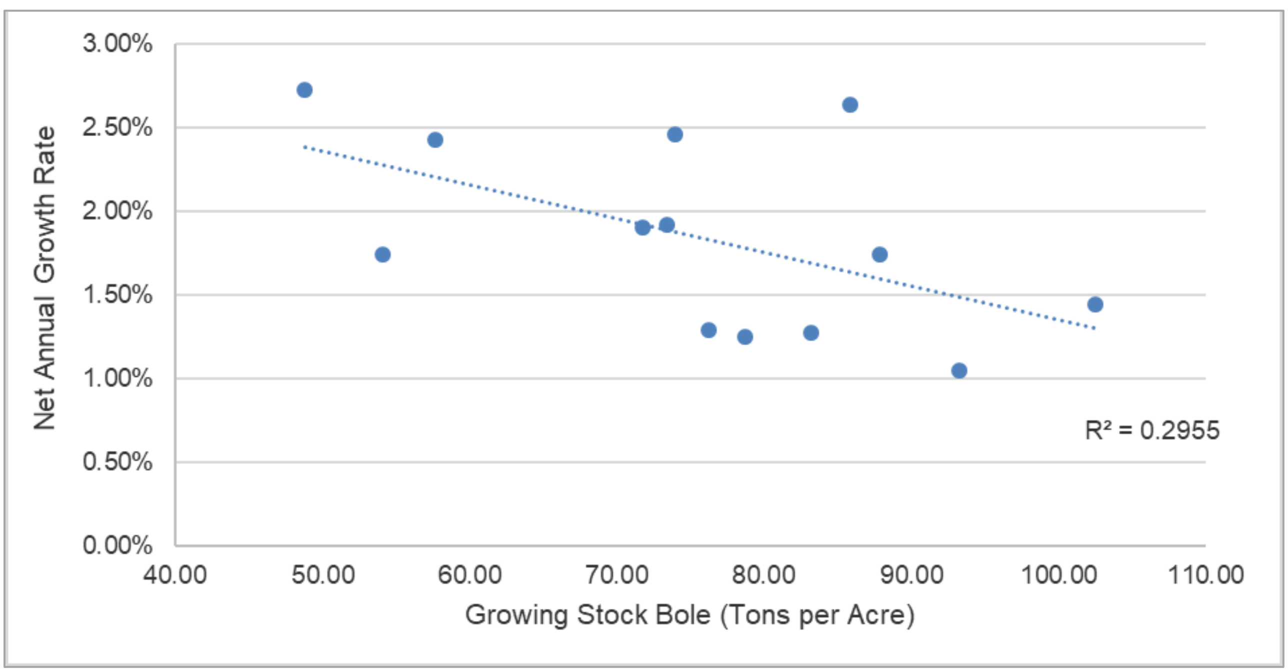
It is vital to note, that the percentages assigned to the low-grade bole inventory and the top and limb wood inventory should not be misconstrued as the percentages of the wood that could should be removed as part of a typical harvest. These percentages are assigned to a portion of the inventory for the express purpose of projecting an amount of net annual growth on that inventory of potential wood fuel.

Net Annual Growth Rate

In previous assessments, one of the most significant variables was the average rate of net annual growth that was applied. For the 2010 study, there were insufficient remeasurement plot data for each county and so a single average rate of 2.11% was applied to each county. However, for this updated assessment, actual county-level values for rates of annual growth from FIA data were used because there were more years of remeasurement data to work from. Due to the fact, that actual data were used, no variation to the rates of net annual growth were tested between the high and low scenarios.

While no variation was tested between the model scenarios, significant variability was observed in the rates of growth for each of the Vermont counties. Furthermore, correlation between the rates of growth and forest stocking levels were observed.

Figure 18 – County-level relationship between average growth rate and average per acre stocking



Those counties with lower stocking levels generally had higher net annual growth rates and vice versa – overstocked forests grow at a slower rate on average. Figure 18 shows the clear correlation between average tons per acre and rate of net annual growth for Vermont counties.

Those counties with lower stocking levels generally had higher net annual growth rates and vice versa – overstocked forests grow at a slower rate on average.

Harvest Levels

All three scenarios used the same current three-year averaged level of harvesting for low-grade wood. This variable was kept the same for the baseline, low, and high scenarios because historical harvest data have indicated fairly-stable trends in annual demand for low-grade wood and to avoid any demand scenarios being misinterpreted as forecasts for future market conditions. While this was not included in the core analysis presented in this report, further sensitivity analysis can be conducted using the NALG tool to explore the impacts of increases and decreases in regional demand for low-grade wood.

4.2 Baseline, High, and Low Scenario Results

Table 6 below reports the results of the baseline scenario with the bookend results of the low and high scenarios.

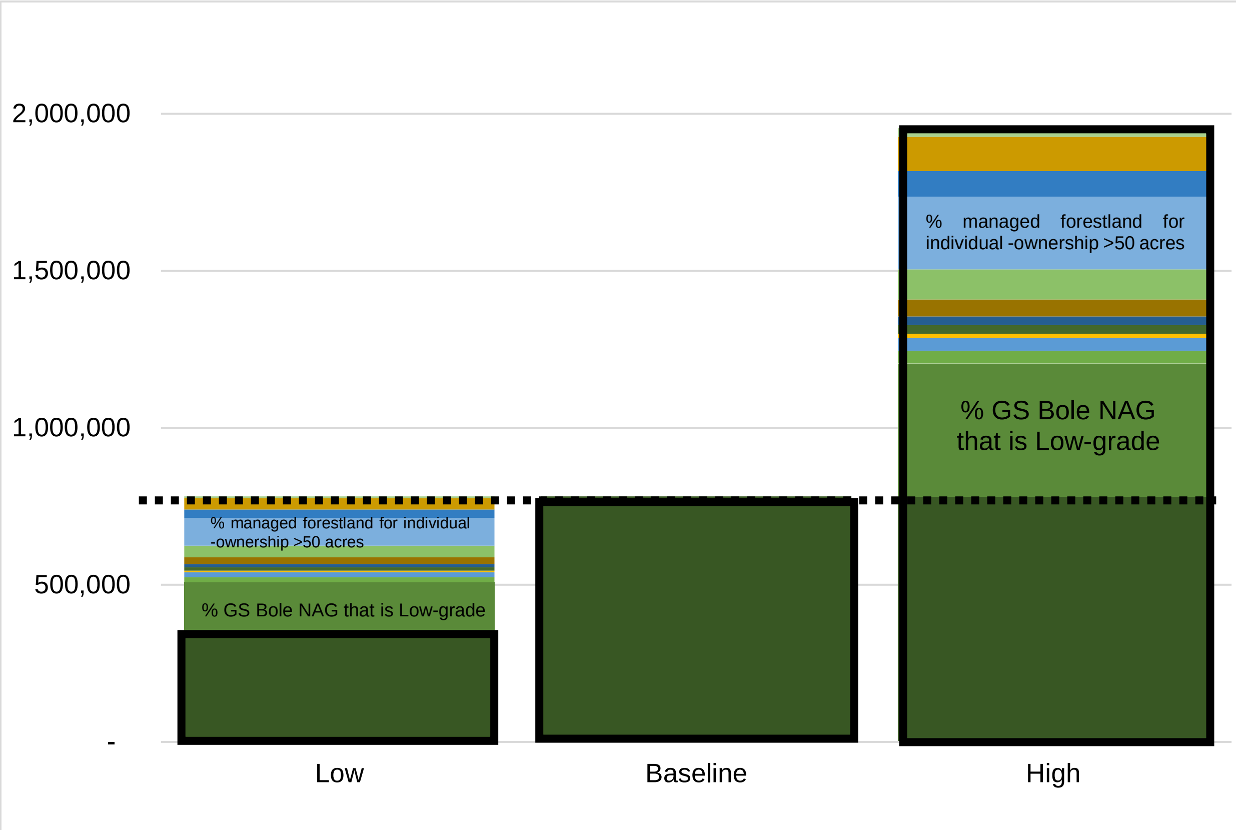
Table 6: The estimated annual amount (green tons) of NALG wood under the three model scenarios

	Low Scenario	Baseline	High Scenario
Vermont counties	365,159	939,989	1,720,102
Adjacent counties	1,060,306	1,816,937	2,835,493
Grand Total	1,425,464	2,756,926	4,555,595

As depicted in the table above, there is nearly a five-fold spread between the amount of estimated NALG wood between the low and high scenarios. Despite the wide range between the low and high scenarios, it is the Baseline scenario that best depiction of the current conditions.

Further examination of each independent variable was conducted to determine which input variables have the greatest impact on the output amount of NALG wood when minor adjustments were made as part of the High and Low scenarios. Figure 19 shows how NALG results were affected by slight changes in the various key assumptions between the Baseline, Low, and High scenarios.

Figure 19 - Factors influencing the net change for High and Low scenarios



The variable that caused greatest increase in the High scenario and greatest decrease in the low scenario was change in the portion of the growing stock bole inventory that is deemed as "low grade". The variable with the second greatest impact was the percentage of forestland in individual ownership category for parcels greater than 50 acres that are assumed to be actively managed. The combination of numerous other variables makes up the remainder of the increased amount of NALG wood in the High scenario and the decrease in the Low scenario. Of the various forest inventory components included in the accounting for this study, the bole wood of growing stock trees made up the largest percentage of total inventory and, accordingly, the assumption used for the portion of growing stock bole that is low-grade wood proved to have a great impact on NALG results. "Low-grade wood" is a highly subjective term and is influenced heavily by market forces. The decision to set the percentage of the total volume of growing stock trees deemed "low-grade" was supported by review and analysis of FIA inventory data. Every effort was made to clearly define low-grade wood, for the purposes of this study, as pulp-quality and lower grade wood (while excluding many other forest inventory components such as a large portion of top and limb wood, as well and all stumps, standing dead trees, seedlings, and saplings for ecological and site productivity reasons).

The broad range of results occurring from these relatively minor adjustments to the key assumptions illustrates the high variability of this type of analysis. However, the main purpose is to identify those key variables that have the greatest impact on the calculated amount of NALG wood.

4.3 Comparison to 2010 Study

One of the values of using the same methodology between the 2010 study and the 2018 study is the ability to compare and contrast the output amounts of estimated NALG wood, but also the various other parameters that feed into the estimation of NALG wood. The table below presents the results for several key parameters between the 2010 and 2018 studies.

Table 7 - Comparative results for the 2010 and 2018 studies (reporting just Vermont counties)

	2018	2010
Starting Forestland (Acres)	4,312,127	4,414,884
Unconstrained and Managed Forestland (Acres)	2,053,967	1,911,700
Live-tree Inventory on Timberland (Green Tons)	480,025,426	477,990,154
Low-grade Wood Inventory on Unconstrained and Managed Forestland (Green Tons)	142,417,027	96,718,877
Average Net Annual Growth Rate	1.75%	2.10%
Net Annual Growth of Low-grade Wood on Unconstrained and Managed Forestland (Green Tons)	2,498,627	2,031,096
Current Market Demand for Low-grade Wood (Green Tons)	1,738,631	1,265,194
NALG Bole Wood (Green Tons)	732,959	824,072
NALG Top and Limb Wood (Green Tons)	207,030	70,820
Total NALG Wood (Green Tons)	939,989	894,893

While the total estimate of NALG wood did not vary considerably between 2010 and 2018, several other parameters changed significantly between the two studies:

- Forestland area decreased by 102,757 acres attributed primarily to land clearing for agriculture and development.
- Unconstrained managed forestland increased by 142,267 acres due to change in assumptions used to avoid double filtering in 2010[16].
- There was a dramatic increase for the inventory of low-grade wood on the footprint of unconstrained and managed forestland due to increased number of acres, increased stocking per acre, and an increase of the percentage of inventory estimated to be "low-grade"
- Averaged net annual growth rate decreased dramatically from 2.15% to 1.75% due to decreased gross growth and increased mortality rate.
- Amount of net annual growth of low-grade on unconstrained and managed forestland increased. Despite lower growth rates, greater stocking levels and more acres resulted in a 23% increase from 2010 to 2018.

4.4 Exploring Long-term Trends

While reviewing the key values between the 2010 and 2018 studies, several important trends were noted and were examined further to put the 2018 data into the context of a longer timeframe.

Forestland Area

Forests cover 75% of the landscape in Vermont. Vermont is the fourth most forested state in the United States. In the mid-1800s Vermont was nearly 80% deforested for agriculture and over the course of a century, Vermont saw steady increases in the amount of forestland. While the amount of forestland area in Vermont has been relatively stable since the 1990s, there has been a slight decline since 2012. Between 2012 and 2016 there was a 1.9 percent decrease.[17] This slight decrease in acres of forestland and timberland in Vermont is primarily due to suburban development and some agricultural activities to reclaim pasture land.[18] It is not attributed to silvicultural practices or increased demand for wood products.

[16] The 2010 study applied assumptions regarding how much forestland is managed before the physical and ecological features were filtered using GIS. This essential approach inadvertently over-estimated the amount of forestland area removed.
[17] https://www.fs.fed.us/nrs/pubs/ru/ru_fs119.pdf
[18] http://vnrc.org/wp-content/uploads/2015/04/FOREST-FRAGMENTATION_FINAL-11.pdf

Figure 20 – USDA Forest Service FIA graph of long-term trends for forestland area in Vermont

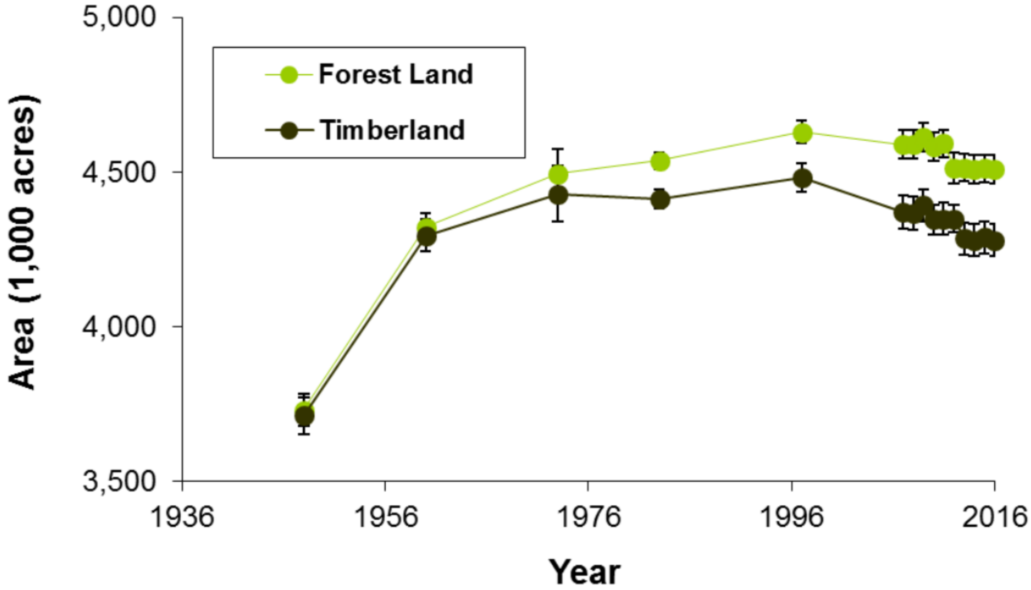
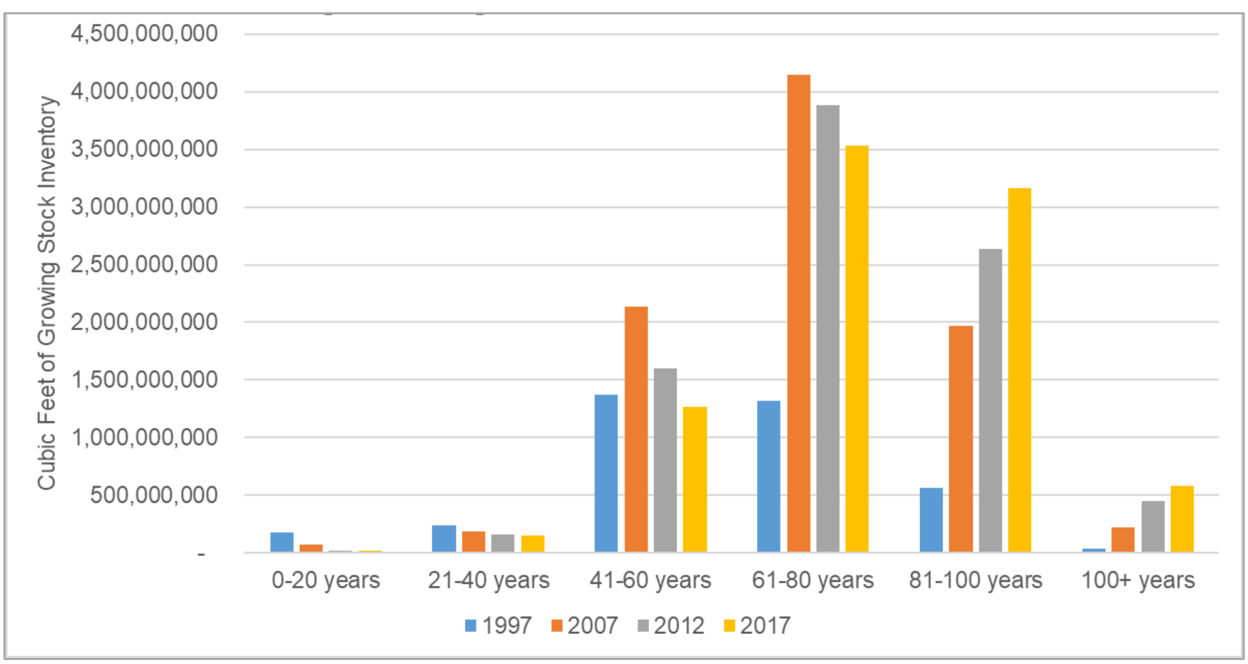


Figure 20 above depicts the amount of forestland and timberland acres in Vermont over an 80-year time-period.

Stand Age Class Distribution

For the past six decades, records indicate Vermont has harvested less wood than is grown each year. As a direct result, the average age of Vermont's forests is increasing. The bar graph below shows FIA data from 1997, 2007, 2012, and 2017 and the amount of growing stock inventory in each age class bin.

Figure 21 – Average stand age class distribution in Vermont over two decades



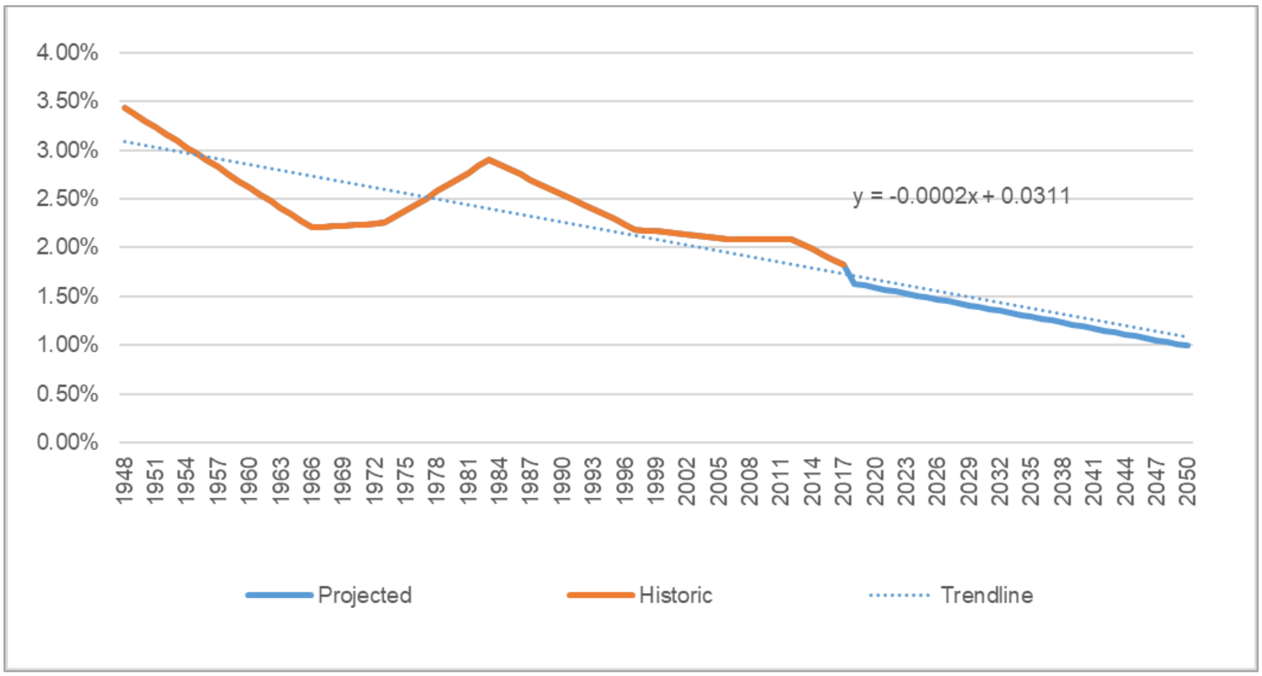
As can be seen in Figure 21 above, in just the last 20 years, there have been declines in the younger age classifications, and increases in the older age classifications.

Net Annual Growth Rate

As forests grow older, the rates of growth decrease and mortality rates increase. As mentioned previously in this report, the average net annual growth rate reported by the USDA Forest Service FIA program has declined between the 2007, 2010, and 2018 Vermont Wood Fuel Supply Studies. Upon further examination of historical FIA data going back to 1948, there has been a clear decline in the state-wide average rate of net growth. Figure 22 illustrates the decline from 3.5% in 1948 to 1.7% in 2017 (shown in orange). While there was a considerable increase 1980s and 1990s in response to a period of increased timber market demand, the longer-term trendline has been on a clear decline.

When the trend line is projected into the future (blue line), regression analysis indicates that at the current rate of decline that net annual growth rate could reach 1.0% by the year 2050.

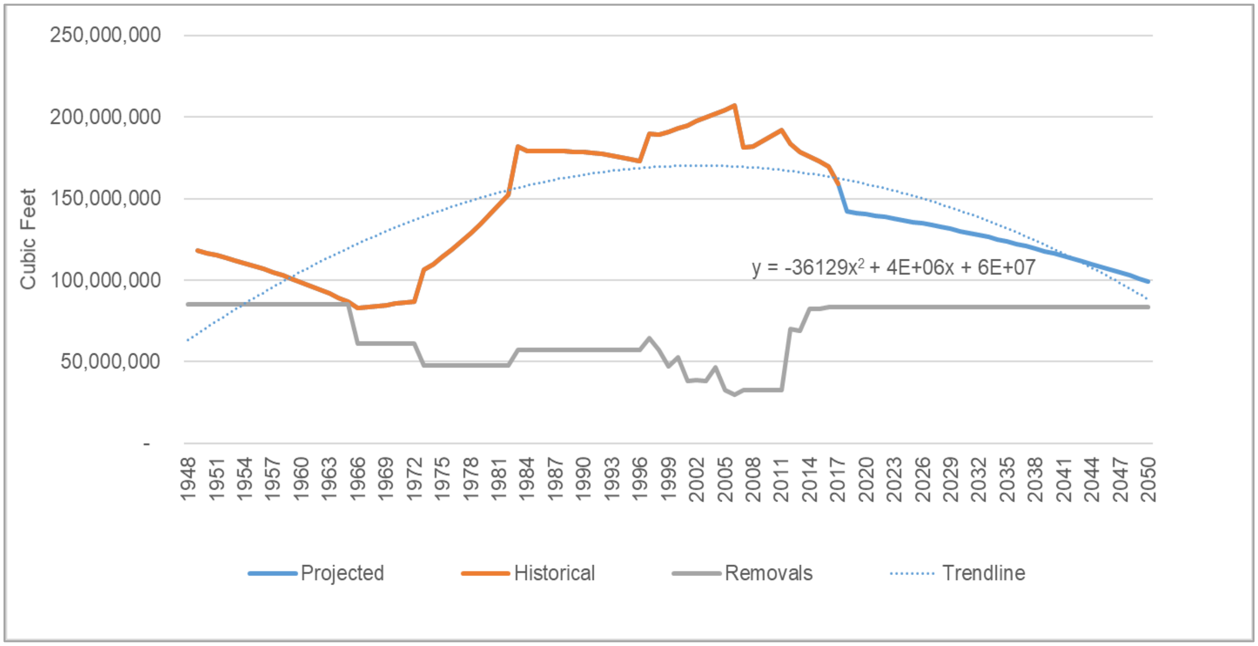
Figure 22 – Historic trend and projection of net annual growth rate for growing stock on timberland in Vermont



Volume of Annual Growth and Removals

While the rate of net annual growth has been continually declining from 1948 to 2017, the amount of wood grown annually was initially increasing, plateaued, and then began to decline over that same time period. Historic FIA data were used to further examine the long-term trends for the total amounts of wood grown and harvested in Vermont. Figure 23 below illustrates the volume of growing stock wood grown each year (orange line), the amount of reported wood harvest (grey line), and the projected amount of annual growth through the year 2050.

Figure 23 – Historic trend and projection of net annual growth volume for growing stock on timberland in Vermont

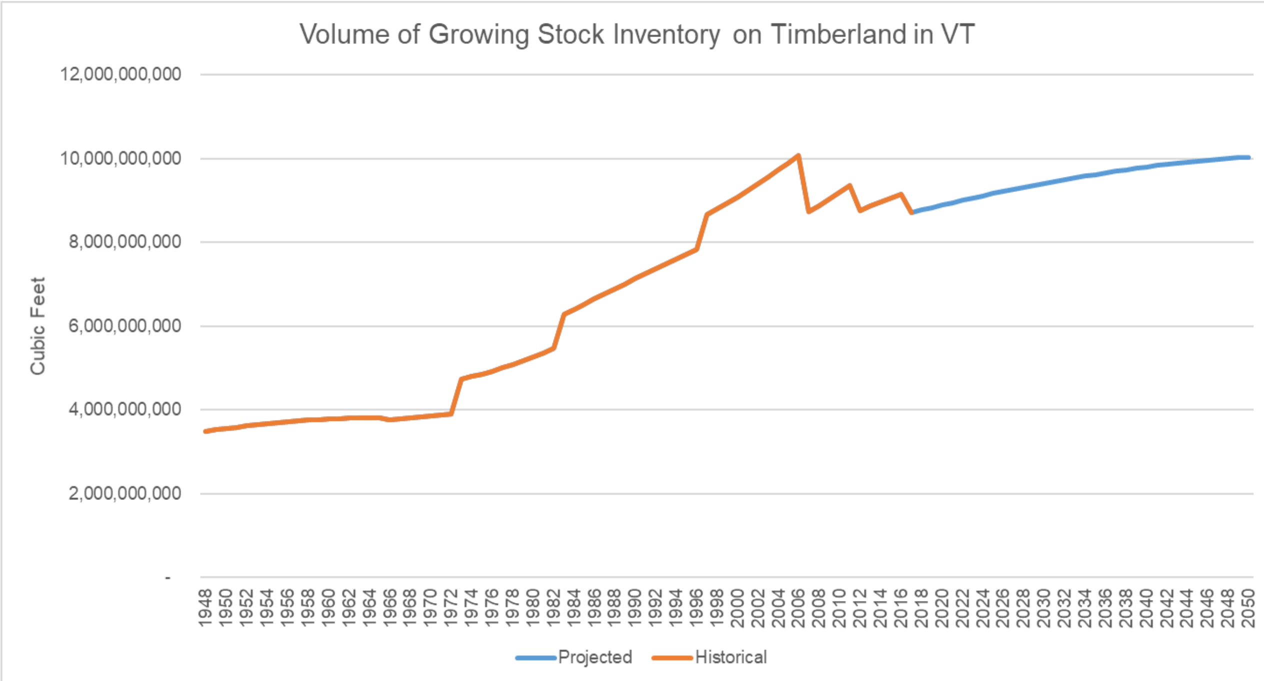


Assuming demand for wood remains constant from 2017 levels through 2050 and forecasting the continued declining volume of wood grown each year, it is estimated that growth to removal ratios will remain positive beyond 2050. However, the projected estimates suggest that the growth to removal ratio could become negative not long after 2050.

Volume of Forest Inventory

Despite the historic trend of decreasing amounts of wood grown each year, Vermont is still projected to continue to harvest less wood than is grown through 2050. As a result, the total inventory will continue to increase during that time-period. Figure 24 below illustrates the historic trend for the volume of growing stock inventory from 1948 through 2017 and the projection of the inventory through the year 2050.

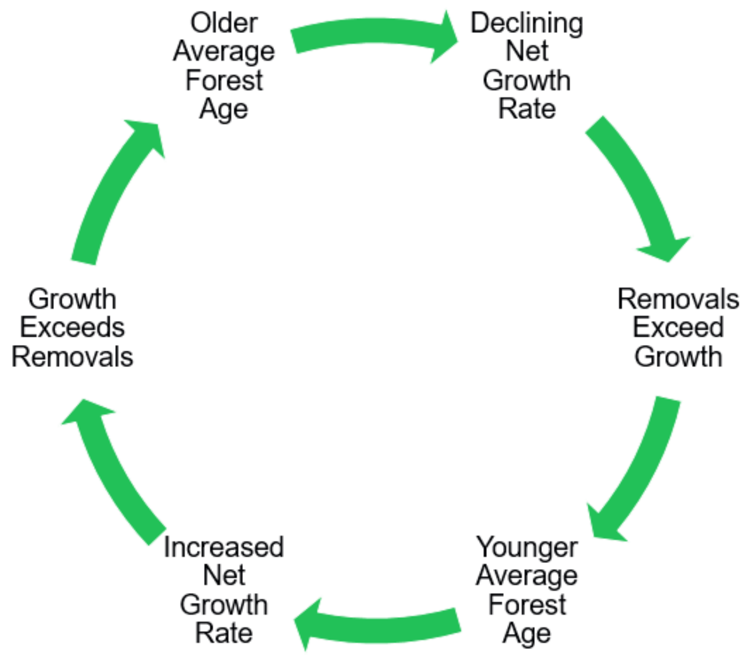
Figure 24 – Historic trend and projection of volume of growing stock on timberland in Vermont



While this is an overly-simplistic projection of historic trends, it is within reason to conclude that at some point in the near future when the amount of annual harvest exceeds the amount of annual growth, forest inventory will begin to decrease. For the past several decades, a positive growth to removal ratio has been used as a crude indicator of landscape-level sustained-yield capacity. If each year, we harvest less than the forests grow, it is widely viewed as confirmation we are not over burdening our forest resource. However, forests are extremely complex systems and crude indicators of sustained-yield capacity are not always effective. There is a cyclical nature to forest growth, maturation, and senescence.

Whether played out at the forest stand-level or across a much larger landscape, continually harvesting less wood than is grown each year, will result in increases in average stand age. Older trees and stands will grow more slowly than young ones and, if harvest levels remain constant year-in and year-out, it will lead to eventually harvesting more wood than is grown. This, in turn, will slowly decrease the average age of trees and stands across the landscape. As a result, the younger trees and stands will grow faster and the amount of wood grown each year may eventually surpass the level of annual harvest again. The following diagram illustrates this simple cycle.

Figure 25 – Diagram depicting simple cycling of positive and negative growth to removal ratios over time



In the long-term, harvesting less wood than is grown annually cannot be sustained and historic FIA data present clear trends to support this conclusion. Furthermore, when net amounts of wood grown annually decline below the amount of wood harvested, the resulting negative growth to removal ratio may be a necessary means for eventually achieving a positive growth to removal ratio further in the future.

5.0 CONCLUSIONS

Using the most recently available data for forest inventory, composition, net growth, and harvesting, the results of the 2018 Vermont Wood Fuel Supply study indicate Vermont has approximately 940,000 green tons of additional annual wood resource capacity that could be used to support further energy market development. However, if the surrounding counties of New York, Massachusetts, and New Hampshire are included, the resulting amount of NALG wood increases dramatically to over 2.7 million green tons annually.

This additional wood fuel potential would go a long way toward meeting the energy needs of Vermont – especially if used locally and for high-efficiency thermal energy applications. Factoring the energy content of wood, its moisture content, and conversion efficiencies, 940,000 green tons can replace the equivalent of approximately 66 million additional gallons of heating oil annually.

This study's results indicate Essex and Orleans Counties contain the highest concentrations of NALG wood while Rutland, Windsor and Windham Counites also have large amounts. Conversely, Caledonia, Chittenden, and Bennington Counties show negative values for the NALG bole wood resources.

While the total amount of NALG wood is important, closer examination of the amount that is bole wood versus top and limb wood is essential. Approximately 23% of the estimated amount of NALG wood was top and limb wood. Many markets, including the steadily growing woodchip and pellet heating market, prefer the fuel quality achieved by using bole wood. By contrast, the traditional market for wood fuel produced from tops and limbs are the large wood-fired power plants that are less concerned about fuel quality.

The single greatest factor that caused increase in the amount of NALG wood for the High scenario and decrease in the Low scenario was change in the portion of the growing stock bole inventory that is deemed as "low grade". While the amount of NALG wood increased by 6% between the 2010 and 2018 studies, several other parameters differed significantly.

The NALG wood estimate is a single snapshot in time. Looking at longer-term trends in forest data revealed several important trends – relatively stable forested land area, increasing forest inventory, older average age classifications of stands, decreasing gross growth rates, increasing mortality rates, and declining harvest levels from 20 years ago (but relatively steady over past 5 years). Simple analysis to project historic trends into the future, indicate the likelihood that amounts of wood grown annually will decrease to levels below removals, if market demands and harvesting levels remain steady for the next few decades.

In addition to declining growth and increased mortality rates, projected impacts of invasive pests on select tree species will be significant (i.e. a 5% reduction in forest inventory from the loss of ash trees to Emerald Ash Borer over the next decade).

In conclusion, there is further capacity to expand wood energy in Vermont, but how much supply there is, how sustainably it can be extracted, and how healthy our forests are questions that need continual monitoring and assessment as a safeguard against the possibility of over burdening our forests with too much wood fuel demand.

APPENDIX A – DETAILED METHODOLOGY

Following is a description and listing of the many data sources used to complete the spatial analysis portion of this analysis.

Forestland Data

Forestland data was derived from the National Land Cover Dataset (NLCD) developed by the Multi-Resolution Land Characteristics Consortium (MRLC). The latest dataset available was used: NLCD 2011. This data can be found on-line at https://www.mrlc.gov/nlcd11_data.php. This data is available in raster GIS format with grid cells measuring 30 meters by 30 meters. Forest areas were selected out using the following values:

> *41 Deciduous Forest* - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
>
> *42 Evergreen Forest* - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
>
> *43 Mixed Forest* - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.

Elevation Data

Elevation data was derived from the USGS 3D Elevation Program Standard Seamless Digital Elevation Model (DEM) in 1/3 arc-second resolution. This is the highest resolution DEM dataset with full conterminous U.S. coverage. Data tiles covering the study area were downloaded from USGS and processed into an mosaiced GRID format in ArcGIS Pro. Areas with elevation greater than or equal to 2,500 feet and areas with geodesically calculated slopes greater than or equal to 40 percent were used as a region-wide constraint on forest harvesting activities.

https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services

Hydrography Data

All hydrography data was obtained from the USGS National Hydrography Dataset (NHD).

https://nhd.usgs.gov/data.html

Vermont

All data used for spatial analysis of forestland in Vermont was obtained from the Vermont Center for Geographic Information. The Center and the data files listed below can be found at http://geodata.vermont.gov/ .

The following data files can be searched and downloaded from this site:

- Deer wintering yards (ECOLOGIC_DEERWN_POLY.shp)
- Conserved/natural communities (ECOLOGIC_RTENATCOMM_POLY.shp)
- Trails (TOURISM_TRAILS_LINE.shp)
- E911 sites (Emergency_ESITE_point.shp)
- E911 roads (Emergency_RDS_line.shp)
- Airports (TRANS_AIRPORTS_POINT.shp)
- Railroads (TRANS_RR_LINE.shp)
- Hydrography
    - Lakes and ponds (NHDWaterbody.shp)
    - Streams and rivers (NHDflowline.shp)
- Wetlands (Water_VSWI_poly.shp)
- Slope (rastert_slope_21.shp)

- High elevation (ELEVATION_CON2500_POLY.shp)

The following table shows how each of these data files was used, classified, and buffered (where applicable).

VERMONT				
Feature	**Data File**	**Source (VCGI)**[19]	**Classes**	**Buffer Applied**
Slope greater than 40%	rastert_slope_21.shp			n/a
Elevation above 2,500'	ELEVATION_CON2500_POLY.shp			n/a
Developed Areas	Emergency_ESITE_point.shp	Emergency 911 Data	Residential	75 feet
			Commercial	50 feet
			Industrial	50 feet
Airports	TRANS_AIRPORTS_POINT.shp	VT Dept Transportation		1000 feet
Railways	TRANS_RR_LINE.shp	VT Dept Transportation		17 feet
Streams and Rivers	NHDflowline.shp	National Hydrography Dataset		50 feet
Lakes and Ponds	NHDWaterbody.shp	National Hydrography Dataset		100 feet
Wetlands	Water_VSWI_poly.shp	Vermont Significant Wetland Inventory	Exceptional	100 feet
			Significant	50 feet
			Not evaluated/not significant	25 feet
Roads	Emergency RDS_line.shp	Emergency 911 Data	Town Highway, Class 1	34 feet
			Town Highway, Class 2	17 feet
			Town Highway, Class 3	16 feet
			Town Highway, Class 4	15 feet
			Interstate Highway	30 feet
			National Forest Highway	17 feet
			Private Roads	15 feet
			State Forest Highway	17 feet
			US Highway	25 feet
			Vermont State Highway	25 feet
Critical Habitats	ECOLOGIC_DEERWN_POLY.shp			30 meters
Ecologically Sensitive Areas	ECOLOGIC_RTENATCOMM_POLY.shp			30 meters

[19] All data was obtained from Vermont Center for Geographic Information (VCGI), which serves as Vermont's GIS data and information clearinghouse. Many of these data files originated outside of VCGI, and this is what is intended in the above listing of sources. Please see appendix for links to online data sources.

VERMONT				
Feature	**Data File**	**Source (VCGI)**[19]	**Classes**	**Buffer Applied**
Trails	TOURISM_TRAILS_LINE.shp	VT Dept Tourism		50 feet

New York

Data for analysis of the portion of forestland in this study area falling in New York was obtained from several sources. These are noted for each data file listed below.

- Streets (NYS Streets_Statewide\StreetSegmentPublic.shp), http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=932)
- Streams and Rivers, selected from the NYS Hydrography - 1:24,000 file (LinearHydrography.shp and AreaHydrography.shp, http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=928)
- Lakes and Ponds, selected from the NYS Hydrography – 1:24,000 file (AreaHydrography.shp, http://www.nysgis.state.ny.us/gisdata/inventories/details.cfm?DSID=928)
- Wetlands, collected from the following sources:
    - National Wetland Inventory Data (NY_geodatabase_wetlands.gdb, https://www.fws.gov/wetlands/Data/State-Downloads.html)
    - Adirondack Park Agency Official NYS Freshwater Wetlands for Promulgated Counties of the Adirondack Park https://apa.ny.gov/gis/ApaData.html
- Conserved lands and wildlife habitat were accounted for using the Protected Areas Database from the Conservation Biology Institute and the World Wildlife Fund (http://consbio.org/what-we-do/protected-areas-database-pad-version-4)
- Airports, ESRI data
- Railroads, ESRI data

The following table shows how each of these data files was used, classified, and buffered (where applicable). Also noted is which characteristics were not included due to data not being available (noted as "not available") or requiring editing tasks beyond the scope and timeline of this update (noted as "not included").

NEW YORK				
Feature	**Data File**	**Source**[20]	**Classes**	**Buffer Applied**
Slope greater than 40%	derived from NED			
Elevation above 2,500'	NED			
Developed Areas	Not available			
Airports	ESRI data	ESRI Transportation Data		1000 feet
Railways	http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=904	NYS GIS Clearinghouse		17 feet
Streams and Rivers	NHD	NYS Hydrography 1:24,000		
Lakes and Ponds	NHD			
Wetlands – partial coverage[21]	NWI NY_Geodatabase_wetlands.gdb		Wetlands, Lakes, and Ponds	100 feet

20 Data was obtained from New York State Geographic Information Systems Clearinghouse, Cornell University Geospatial Information Repository (CUGIR), the Adirondack Park Agency (APA), and ESRI.
21 NY State GIS Clearinghouse did not offer comprehensive wetland coverage for the study area. This is because the wetlands that are within the boundaries of Adirondack State Park are monitored and mapped by the Adirondack

NEW YORK				
Feature	**Data File**	**Source**[20]	**Classes**	**Buffer Applied**
			Other	25 feet
Wetlands – Adirondack State Park	RegWetlandAreasParkPromulgated_UTM83.shp	Adirondack Park Agency	Type 1	100 feet
Roads	NYS Streets_Statewide\StreetSegmentPublic.shp http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=932	NYS GIS Clearinghouse	Primary Roads, with limited access	34 feet
			Primary Roads, without limited access	17 feet
			Secondary and Connecting Roads	16 feet
			Local, Neighborhood, and Rural Roads	15 feet
			Vehicular Trail	15 feet
			Other	15 feet
Critical Habitats and Ecologically Sensitive Areas	USGS GAP Analysis https://gapanalysis.usgs.gov/padus/data/download/	USGS	IUCN Category 1a Strict Nature Reserves Ib Wilderness Areas	30 meters
Trails	DECRoadsTrails.shp http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1167	NYS GIS Clearinghouse		50 feet

Massachusetts

Data for analysis of the portion of forestland in this study area falling in Massachusetts was obtained from several sources. These are noted for each data file listed below.

- Priority habitats or rare species habitats and ecologically sensitive areas (PRIHAB_POLY.shp, https://docs.digital.mass.gov/dataset/massgis-data-nhesp-priority-habitats-rare-species)
- Airports (Airports.mdb, http://www.eot.state.ma.us/default.asp?pgid=planning/airports&sid=about)
- Surface waters, including lakes and ponds, from the National Wetlands Inventory (NWI_POLY.shp, http://www.mass.gov/mgis/nwi.htm)
- Hydrography datasets (hydro25k_arc.shp, http://www.mass.gov/mgis/hd.htm)
- Trails:
    - Trails (TRAILS_ARC.shp, https://docs.digital.mass.gov/dataset/massgis-tracks-and-trails)
    - Long-distance Trails (LONGDISTTRAILS_ARC.shp, https://docs.digital.mass.gov/dataset/massgis-data-long-distance-trails)
- Railroads (TRAINS_ARC.shp, https://docs.digital.mass.gov/dataset/massgis-data-trains)
- All roads (EOT_Roads_Class.lyr, https://docs.digital.mass.gov/dataset/massgis-data-massachusetts-department-transportation-massdot-roads)

The following table shows how each of these data files was used, classified, and buffered (where applicable). Also noted is which characteristics were not included due to data not being available (noted as

Park Agency (APA). Therefore, wetland data was downloaded from multiple sources (NYGIS Clearinghouse, CUGIR, and APA).

“not available”) or requiring editing tasks beyond the scope and timeline of this update (noted as “not included”).

MASSACHUSETTS				
Feature	**Data File**	**Source (MGIS)[22]**	**Classes**	**Buffer Applied**
Slope greater than 40%	derived from NED			
Elevation above 2,500’	NED			
Developed Areas	Not available			
Airports	ESRI			1000 feet
Railways	TRAINS_ARC.shp			17 feet
Streams and Rivers	NHD			50 feet
Surface Waters (Lakes, Ponds, and Wetlands)	NWI_POLY.shp	National Wetland Inventory	Type 1-4	100 feet
			Type 6	25 feet
Roads	EOT_Roads_Class.lyr	Mass EOT	Class 1	34 feet
			Class 2	17 feet
			Class 3	17 feet
			Class 4	16 feet
			Class 5	15 feet
			Class 6	15 feet
Critical Habitats and Ecologically Sensitive Areas	PRIHAB_POLY.shp			30 meters
Trails	TRAILS_ARC.shp; LONGDISTTRAILS_ARC.shp			50 feet

New Hampshire

Much of the data for analysis of the portion of forestland in this study area falling in New Hampshire was obtained from New Hampshire’s Statewide Geographic Information System Clearinghouse called NH GRANIT. Some data also came from ESRI. The Clearinghouse and the data files listed below can be found at http://www.granit.unh.edu/data/downloadfreedata/category/databycategory.html.

Rivers and Streams

- NHDArea.shp (rivers)
- NHWFlowline (streams and rivers)

- Lakes and ponds (NHDWaterbody)
- Wetlands (Nwinh polygon.shp)
- Roads (NH Public Roads)
- Railways (Railroads)
  - http://www.granit.unh.edu/data/search?dset=rr
- Trails
  - http://www.granit.unh.edu/data/search?dset=nhtrails/nh
- Conserved areas and wildlife habitats from the Wildlife Action Plan dataset (Ridge_talus, Pitchpine, Peatlands_250complex, Alpine, Cliffs, Highelev_sprucefir)

22 All data was obtained from Massachusetts Office of Geographic Information (MassGIS), which serves as Massachusetts’s GIS data and information clearinghouse, and from ESRI. Many of these data files originated outside of MassGIS, however; this original source is what is intended in the above listing of sources.

The following table shows how each of these data files was used, classified, and buffered (where applicable). Also noted is which characteristics were not included due to data not being available (noted as "not available") or requiring editing tasks beyond the scope and timeline of this update (noted as "not included").

NEW HAMPSHIRE				
Feature	**Data File**	**Source**[23]	**Classes**	**Buffer Applied**
Slope greater than 40%	derived from NED			
Elevation above 2,500'	NED			
Developed Areas	Not available			
Airports	ESRI data			
Railways	rr.shp			17 feet
Streams and Rivers	NHD			50 feet
Lakes and Ponds	NHD			100 feet
Wetlands	NWI	National Wetland Inventory	consistent across all states	100 feet
Roads	Roads_DOT.shp	NH DOT	Federal (VII)	34 feet
			Private (0)	15 feet
			Not Maintained (VI)	15 feet
			Local (V)	15 feet
			State (IV)	16 feet
			Recreation (III)	15 feet
			State (II)	17 feet
			State (I)	34 feet
Critical Habitats and Ecologically Sensitive Areas	Wildlife Action Plan Dataset (WAPTIERS_P)	NH Fish & Game	Rocky Ridge (Tier I)	30 meters
				30 meters
			Peatlands (Tier I)	30 meters
			Alpine (all)	30 meters
			Cliff and Talus (all)	30 meters
			High elevation spruce-fir (all)	30 meters
Trails	nhtrails.shp			50 feet

23 All data was obtained from New Hampshire's Statewide Geographic Information System Clearinghouse called NH GRANIT and from ESRI. Many of these data files originated outside of NH GRANIT, however; this original source is what is intended in the above listing of sources.