

**Cloquet Forestry Center Management Plan
2016-2025**

by

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Cloquet Forestry Center Management Plan

2016 - 2025



Mike R Reinikainen, Linda Nagel, Carrie Pike, Rachael Olesiak, Greg Cuomo

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1. Mission

Since its establishment in 1909, and true to the mission as an 1862 Land Grant Institution, the University of Minnesota's Cloquet Forestry Center (CFC) strives to be a leader in the development and dissemination of cutting-edge natural resource management practices that meet the contemporary needs of practitioners. The official mission of the CFC is to conduct applied (1) education, (2) research, and (3) outreach related to northern forests. The CFC fulfills its mission by (1) providing graduate and undergraduate students with hands-on field experience essential to professions in natural resources, that aid in developing research skills and knowledge of forest ecosystems and forest practices, (2) supporting and initiating research aimed at improving the management of Minnesota's natural resources, and (3) offering hands-on workshops and education events for natural resource professionals, environmental educators, and the public. The CFC is defined by its exceptional forest resource, and the predictable and responsible stewardship of CFC's forest is critical to supporting and fulfilling our three-fold mission.

2. Objectives

2.1 Education

Objective: To continue providing hands-on and in-woods educational opportunities for students of all ages as well as natural resource professionals.

Strategies: This can best be accomplished by organizing and supporting tours and field activities with student groups and professionals that touch on current issues and provide both time-tested and cutting-edge solutions. Maintaining the value of the forest for these endeavors means managing for a forest that is easily accessible, contains diverse age classes and growth stages, represents regional cover types, contains stands with varied management histories, maintains high economic and ecological value, and demonstrates an array of standard and novel silvicultural techniques.

2.2 Research

Objective: To initiate, attract, and support new and ongoing research related to northern forests, to continue to build credibility through the maintenance of an updated forest inventory, and the application of well-organized and integrated long-term data sets to new problems.

Strategies: Means to achieving this objective include maintaining a diverse forest with accompanying documentation that is representative of regional conditions and management approaches (as stated in “Education”).

2.3 Outreach

Objective: To provide a forest that demonstrates state-of-the-art natural resource management practices, and to improve communication concerning research initiatives, research products and services, annual activities, and changes to policies.

Strategies: We can enhance this aspect of our mission through forest tours and other education events that expose the general public to ecological concepts and sustainable natural resource management, and through close collaboration on salient research with our and other regional natural resource managers.

2.4 Diversity of cover types and growth stages

Objective: To maintain or increase the diversity of cover types (given the capacity of the site), stand age-classes, growth stages, and stand structures, and to incorporate Minnesota’s Ecological Classification System concepts into the management of the forest.

Strategy: This can be achieved by identifying and altering over- and under-abundant growth stages across our cover types and Native Plant Communities (NPCs; MN DNR 2003).

2.5 Habitat

Objective: To increase the quality, functionality, and quantity of habitat.

Strategies: This can be achieved by following, at a minimum, the MN Site-Level Forest Management Guidelines for live-tree, snag, and coarse wood retention, and incorporating the most up-to-date regional wildlife research (e.g., pine marten, fisher, and northern long-eared bat habitat requirements) into management prescriptions. Deliberate efforts to create dead and downed woody structure, and build, install, and maintain artificial habitat (e.g., bat houses) will be made. Maintaining connectivity of forest cover along riparian corridors will be a priority.

2.6 Water and soil quality

Objective: To maintain forest conditions that contribute positively to the health of local water bodies and to ensure that future harvests do not negatively impact site productivity.

Strategies: This can be achieved by incorporating MN Site-Level Forest Management Guidelines (MN Forest Resource Council 2005) into all timber sales; the results can further serve as education and outreach demonstrations.

2.7 Historic and cultural resources

Objective: To document and protect areas of historic and cultural significance.

Strategies: There are several old homestead sites on the property with known locations. Protection of those sites can be achieved through the application of appropriate MN Site-Level Forest Management Guidelines. The contiguous CFC forest has historic and cultural significance to our neighbors on the FDL Reservation; we will continue to work with FDL on maintaining and increasing access and demonstration sites for educational events and those interested in collecting culturally significant forest products.

3. Landscape and site description

3.1 CFC administered properties

The CFC as a whole administers and has the directive to manage a network of six properties covering 4,233.7 acres (Figure 1). These properties are spread across the Arrowhead region of northeastern Minnesota, and anchored to one contiguous property commonly referred to as CFC that

covers 3,391 acres of mostly forested land. The other CFC administered properties include the Hubachek Wilderness Research Center (HWRC; 365 acres) northeast of Ely, MN, the Allred Trust (160 acres) east of Cook, MN, the Boone Trust (200 acres) south of Hibbing, MN, and the Oldenburg (117 acres) and Fritz Trusts (3 acres) in Carlton County (see Table 1 and Figure 1). As there are no scheduled management activities at properties other than the contiguous CFC property, and any activities conducted at HWRC will be governed by a separate plan or amendment to this plan, this plan will pay particular attention to the CFC contiguous property.

CFC lies within the City of Cloquet, is bordered by the Fond du Lac Band of Lake Superior Chippewa Reservation (FDL), and falls within the 1854 Ceded Territory by which FDL and Grand Portage Bands of Lake Superior Chippewa maintain hunting and fishing rights as well as other rights related to land-use. A portion of the contiguous CFC property, approximately 2,215 acres of unallotted Indian land, was originally purchased by the University of Minnesota from the U.S. Government and the St. Louis River Mercantile Company. An additional 447 acres of allotted Indian land was purchased by the University, and the remaining acres were purchased or donated by a number of families that had homesteaded the area.

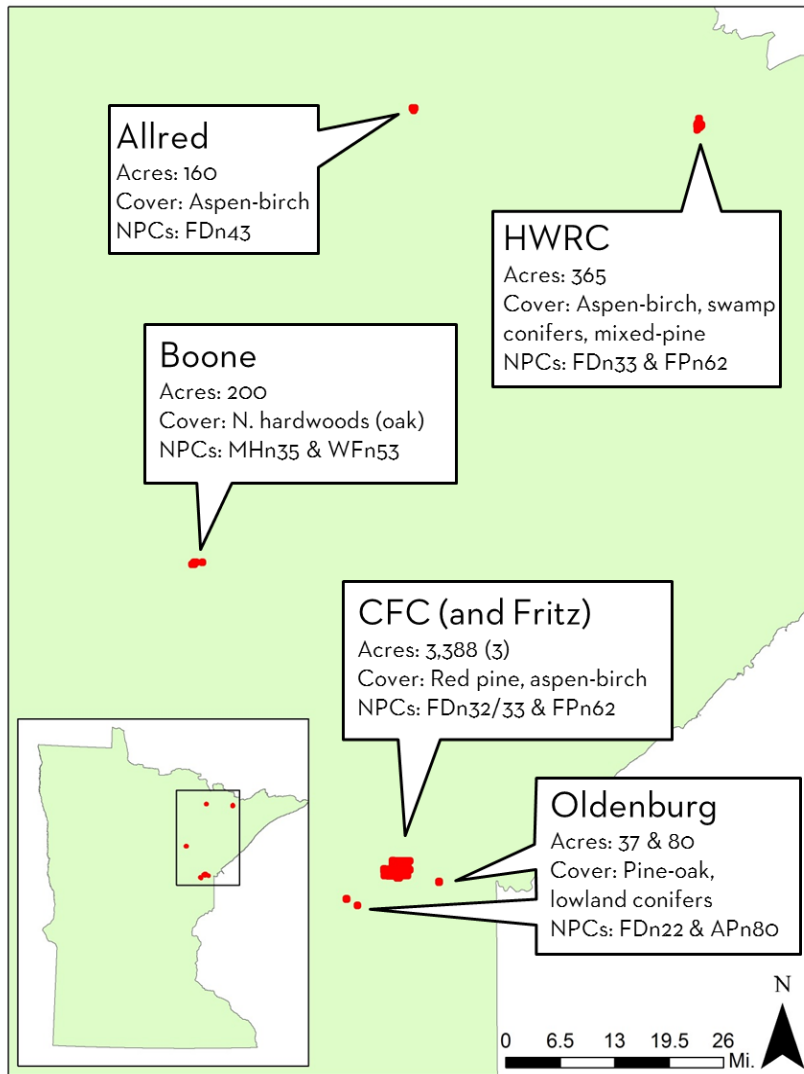


Figure 1. Location of all properties in the Cloquet Forestry Center (CFC) network including the Fritz, Allred, Oldenburg, and Boone trust properties as well as the contiguous CFC property and Hubachek Wilderness Research Center (HWRC).

Table 1. Size and ecological location description for all properties in the Cloquet Forestry Center (CFC) network including the Fritz, Allred, Oldenburg, and Boone trust properties as well as the contiguous CFC property and Hubachek Wilderness Research Center (HWRC).

Property	County	Area (acres)	Ecological Classification System			
			Province	Section	Subsection	Land-type Association
CFC	Carlton	3388	Laurentian Mixed Forest	N. Superior Uplands	N. Shore Highlands	Brimson Sand Plain
Fritz	Carlton	3	Laurentian Mixed Forest	N. Superior Uplands	N. Shore Highlands	Brimson Sand Plain
Allred	St. Louis	160	Laurentian Mixed Forest	N. Superior Uplands	Border Lakes	Myrtle Lake Till Plain
HWRC	Lake	365	Laurentian Mixed Forest	N. Superior Uplands	Border Lakes	Ely-Knife Lake Bedrock
Oldenburg	Carlton	80	Laurentian Mixed Forest	N. Superior Uplands	N. Shore Highlands	Brimson Sand Plain
Oldenburg	Carlton	37	Laurentian Mixed Forest	W. Superior Uplands	Mille Lacs Uplands	Nickerson Moraine
Boone	St. Louis	200	Laurentian Mixed Forest	MN Drift & Lake Plains	St. Louis Moraines	Goodland Delta
TOTAL		4234				

3.2 Ecological Classification System and Native Plant Communities

Since the publication of CFC's previous management plan (see Severs et al. 2002), regional agencies (e.g., MN DNR, USDA Forest Service) have adopted a new ecological approach to organizing the way natural resource managers and scientists think, communicate, and quantify site quality and potential within Minnesota. The Ecological Classification System (ECS), organized as part of a larger national framework, introduces a highly structured way of communicating about areas of land as large as the continent and as small as forested stands. Units are defined by having some level of uniformity related to various biotic and abiotic factors (e.g., climate, parent material, existing vegetation, etc.) and allow natural resource managers to interpret and communicate about management options and issues at various scales.

In the United States there are eight levels of organization in the ECS. In Minnesota six levels of organization are used, but for the purpose of this plan, there are five units of interest. From largest to smallest unit, they are Ecological Province (similar to biome), Section, Subsection, Land-Type Association (LTA), and Native Plant Community (NPC). NPCs are assemblages of native plant populations that interact with the natural environment with only minimal anthropogenic disturbance and can exist across all levels of organization in Minnesota's ECS. NPC typing is another tool, used in conjunction with traditional tools such as cover-type, soils, and site index, for land managers to use to meet site objectives. This is a relatively new way of communicating regionally, and will be important for current and future professionals to share this vernacular related to ecosystem management. Given CFC's role in education of professionals and communication of science related to ecosystem management, this plan marks the introduction of ECS and NPC typing to the management of the CFC landbase.

All CFC properties fall within the 23 million acre Laurentian Mixed Forest Province; the southernmost and northernmost properties are roughly 100 miles apart (Table 1 and Figure 1). The properties exist in a variety of Ecological Sections, Subsections, and LTAs, and consequently, there are a variety of NPCs present at each site (Table 2). The contiguous CFC property falls within the Northern Superior Uplands Section, the North Shore Highlands Subsection, and the Brimson Sand Plain Land-type Association. To contrast the contiguous CFC with one of the northernmost properties, HWRC falls within the Northern Superior Uplands Section, the Border Lakes Subsection, and the Ely-Knife Lake Bedrock Complex Land-Type Association. See Table 1 for ECS information on the other five properties.

There are five different LTAs associated with the CFC properties, and while the climate does vary over the broad province (see 3.3 Climate), varied geologic history and parent material contribute to

variation in the NPCs present at each site. Across all properties and with focus on forested NPCs, we have representation of four northern fire-dependent communities (FDn22, 32, 33, 43), three northern wet forest communities (WFn53, 55, 64), two northern mesic hardwood communities (MHn35, 44), six northern forested rich peatland communities (FPn62, 63, 71, 72, 73, 82), and two northern acid peatland communities (APn80 and 81; Table 2).

Table 2 Forested Native Plant Communities (NPC) observed or highly likely to occur at each property in the Cloquet Forestry Center (CFC) network including the Fritz, Allred, Oldenburg, and Boone Trusts as well as the Hubachek Wilderness Research Center (HWRC). The numbers associated with the NPC code refer to the synecological coordinates of the community where the first coordinate refers to moisture (0 – 9, 9 being wettest) and the second number refers to nutrient availability (0 – 9, 9 being richest). See MN DNR 2005 for more details.

Property	Forested Native Plant Communities				
	Fire Dependent (FDn)	Wet Forest (WFn)	Mesic Hardwood (MHn)	Forested Rich Peatland (FPn)	Acid Peatland (APn)
CFC	32*, 33*, 43*	53*, 55*, 64*	44	63, 72, 73, 82	80, 81
Fritz	33	-	-	-	80, 81
Allred	43	53	-	-	-
HWRC	33	53, 55, 64	-	62, 63, 73	80, 81
Oldenburg	-	-	-	73, 82	80, 81
Oldenburg	22	-	-	-	-
Boone	-	53*	35*, 44	71, 73,	80, 81

* NPC confirmed through site inventory, remaining NPC highly likely to occur

3.3 Wildlife

The CFC is home to a diverse fauna, housing a variety of small mammals such as the least shrew and snowshoe hare, and large mammals including gray wolf, black bear and white-tail deer. Research projects been conducted on small mammals, song birds, white-tailed deer, wood-cock, ruffed grouse and black bear.

Research on the ruffed grouse, conducted at CFC, established the biological foundation for the management of this important game species. Research on the ruffed grouse originated in 1929 by Ralph King who published his first paper in 1937 (with encouragement from Aldo Leopold). Following King's research, Gordon Gullion carried on the research project on ruffed grouse from 1958 to 1991. Gullion's research established foundational knowledge on grouse habitat by linking the presence of young aspen with both immature and mature stages of the grouse. Gullion's research also determined the importance of coarse woody debris (CWD) retention in a forest, for its role in creating drumming logs for mating. This research has effectively altered aspen management, by building a science-based approach to enhance grouse habitat through silviculture.

Various aquatic species such as fish, invertebrates, waterfowl, beaver, muskrat, mink, bald eagles and osprey inhabit Otter Creek, a designated trout stream that meanders through the northern portion of the CFC. In a 2010 survey 10 fish species were found with dominant species being black nosed dace and brood stickleback. The most recent opportunistic bird list was created in 2009 and contained 112 species sighted or heard at CFC. Bald eagles and northern goshawks, MN DNR species of special concern, have also been observed nesting at CFC.

3.4 Soils and surface waters

3.4.1 Geologic history

The contiguous CFC property lies within the Brimson Sand Plain land-type association (LTA), originally deposited by meltwater flowing off the Superior glacial lobe approximately 10,000 YBP. It is characterized by rolling to flat topography with occasional esker features and coarse textured, well drained soils derived from deep sand deposits. The upland soils can be somewhat excessively drained and droughty, and the associated plant communities are strongly fire-dependent. Historically, upland forests on the Brimson Sand Plain were dominated by jack and red pine and to a lesser extent aspen and birch.

3.4.2 Soils

The soils at CFC are overwhelmingly sand derived and coarse textured, but there is variation in the upland soil textures ranging from loamy sand to loam (Figure 2). There are 15 distinct soil series with five soil series that dominate the site: Omega loamy sand (0-12% slope; 1,759 acres), Moose Lake mucky peat (402 acres), Loxley muck (355 acres), Cromwell sandy loam (0-6% slope; 255 acres), and Cloquet fine sandy loam (0-12% slope; 218 acres; Table 3).

Typically, there is only minor relief (0 – 6% slope) associated with any of these series. Slopes in excess of 6% do occur occasionally but are most often associated with esker features and some of the finer textured soils on the eastern boundary of the property. The most excessive slope occurs on Cloquet-Emmert complex that covers the Vibert Esker and parts of Camp 8 and along eastern portions of Otter Creek. Nearly two-thirds of the forest soils at CFC are somewhat excessively well-drained. That, in combination with the relatively flat topography, makes CFC quite suitable for summer harvest under dry soil conditions.

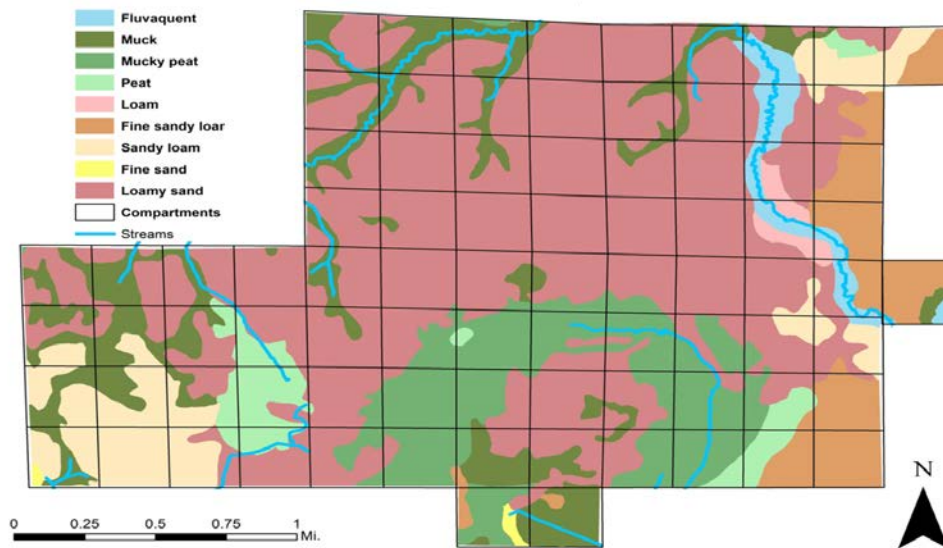


Figure 2. Aerial extent of soils and spatial location of streams at Cloquet Forestry Center (CFC). Soil series were generalized by soil texture.

Table 3. Aerial extent of soil series at Cloquet Forestry Center (CFC) and characteristics.

Soil series	Acres	Drainage class	Vegetation Association	Operability
Omega loamy sand (0-12%)	1759	Somewhat excessively drained	Jack pine, red pine, aspen, birch	Dry/frozen ground
Mooselake mucky peat	402	Very poorly drained	N. white cedar	Frozen ground
Loxley muck	355	Very poorly drained	Sedges, grasses, brush, black spruce, tamarack	Frozen ground
Cromwell sandy loam (0-6%)	255	Somewhat excessively drained	Aspen, paper birch, jack pine and red pine	Dry/frozen ground
Cloquet fine sandy loam (0-12%)	218	Somewhat excessively drained	Aspen, red pine, jack pine, birch	Dry/frozen ground
Greenwood peat	96	Very poorly drained	Black spruce, tamarack	Frozen ground
Dawson muck	82	Very poorly drained	Sedges, grasses, brush, black spruce, tamarack	Frozen ground
Fluvaquents	76	Very poorly drained	Alder, shrubs	Frozen ground
Waskish peat	34	Very poorly drained	Black spruce, tamarack	Frozen ground
Greenwood mucky peat	32	Very poorly drained	Shrubs, hardwoods, reeds, sedges	Frozen ground
Ahmeek loam (0-12%)	27	Moderately well drained	Aspen, paper birch, basswood, maple	Dry/frozen ground
Cloquet-Emmert complex (25-60%)	21	Somewhat excessively drained	Aspen, red pine, jack pine, birch	Dry/frozen ground
Newson mucky loamy sand	18	Poorly drained	Black spruce, tamarack, shrubs	Frozen ground
Nemadji fine sand	7	Somewhat poorly drained	Aspen, paper birch, balsam fir	Frozen ground
Mora fine sandy loam, wet	2	Somewhat poorly drained	Maple, elm	Frozen ground

3.4.3 Surface waters

CFC has few surface water features with the exception of Otter Creek, a MN DNR designated trout stream that meanders for approximately three miles through the northern two sections of the property. Because of Otter Creek's status as a trout stream, forest management activities along the creek will serve to demonstrate MN Forest Management Site-Level Guidelines that pertain to similarly designated waterways. Further, the creek and adjacent forest provide wildlife habitat and travel corridors. In 2014, and within one 10-acre stand adjacent to the creek, field crews identified nesting woodcocks, grouse drumming logs, fisher activity, and a deer kill indicating wolf activity. Harvests that occur in proximity to the creek will be designed with appropriate buffers as to reduce risk of erosion and maintain wildlife habitat connectivity.

3.5 Climate

Climate within the Laurentian Mixed Forest Province is strongly continental and varies widely with a gradient that spans from drier, warmer conditions in the southwest portion of the province, to cooler, wetter conditions in the northeast portion of the province. Average annual temperature ranges from 34-40°F. Total annual precipitation ranges from 21-32 inches with 20-25% of that received as snowfall (MN DNR 2003).

The contiguous CFC property lies approximately 20 miles west of Lake Superior, and as a result, the climate is slightly modified by the lake. This modification positions the property within USDA Cold Hardiness Zone 4a while the colder Zone 3b exists to the south, west, and north of CFC ¹. From 1915-2005, mean annual temperature at CFC was 39.6°F and ranged from 39.6-44.7°F (from CFC daily weather observation data, 1915-2014). Given the continental climate, temperatures can range widely; there have been observed minimum temperatures as low as -44°F (in 1915) and maximum temperatures as high as 105°F (in 1936) at the CFC weather station.

Across Minnesota, climate over the last century for which we have an instrumented record has been changing. Similar trends have been observed at the CFC weather station, where daily observations have been made dating back to 1911. Comparisons of temperature and precipitation values from the first 50-year period (1915-1964) and second 50-year period (1965-2014) of CFC’s instrumented record reveal statistically significant changes. Mean annual temperature (+0.61°F, $p < 0.01$), minimum temperature (+0.84°F, $p < 0.01$), and maximum temperature (+0.38°F, $p < 0.05$) have all increased in the last 50 years when compared to the preceding 50 years. Over the last century, average winter minimum temperature at the CFC weather station has increased 1.0°F every 13 years (Figure 3). Not surprisingly, growing-degree-days (GDD) have also increased (+64.3, $p < 0.01$) with an increase in the growing season of roughly 3.5 days. Positive trends in precipitation have also been observed with mean annual precipitation increases of 1.67 inches ($p < 0.01$) between the two periods.

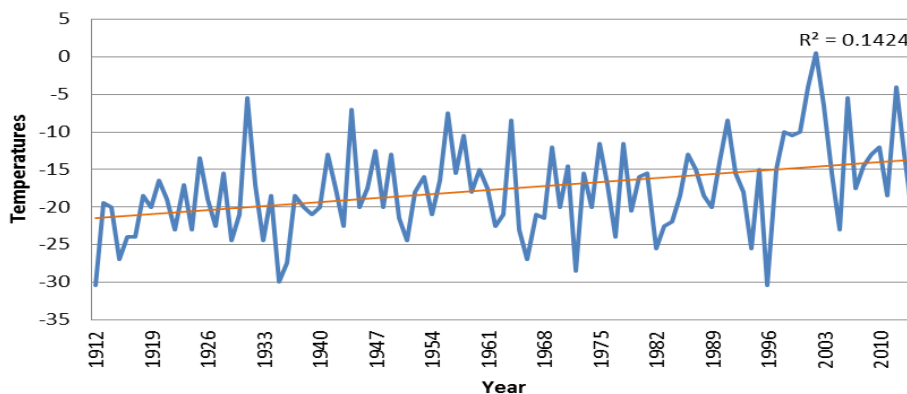


Figure 3. Average winter minimum temperatures at Cloquet Forestry Center (CFC; 1912-2013). Data are from daily observations made by CFC staff at the contiguous property.

¹ USDA Plant Hardiness Zone Map, 2012. Agricultural Research Service, U.S. Department of Agriculture. Accessed from <http://planthardiness.ars.usda.gov>

3.6 Forest disturbance

Management strategies attempt to approximate natural processes. Knowledge of historical disturbance regime (frequency, severity, and agents), whether natural or anthropogenic, provides insight into how the forested system responded to previous disturbance, and how it may respond in the future. Minnesota's ECS describes the disturbance regime and the natural history for each NPC based on analyses of pre-settlement General Land Office surveyor notes that included disturbance descriptions and the species and sizes of trees present at survey corners circa 1850. The resulting information reveals both the agents of disturbance and the frequency and severity with which different NPCs were disturbed by various agents. Both low severity and high severity disturbances such as ground fire and canopy fire were considered. We review the disturbance regimes that govern our major upland and lowland NPCs and associated cover types in the following section.

3.6.1 Historic Disturbance Regimes

The upland cover types present at CFC are nearly completely fire-dependent (FDn) sitting above deep sandy soils deposited on the Brimson Sand Plain. Those communities are, in order of abundance at CFC from greatest to least: FDn33 (Northern Dry-Mesic Mixed Woodland), FDn32 (Northern Poor Dry-Mesic Mixed Woodland), and FDn43 (Northern Mesic Mixed Forest). These sites are characterized by northerly distributed and fire-dependent species. Historically, and depending on the stand initiating disturbance, these sites were dominated early by shade intolerant conifers such as jack pine (*Pinus banksiana*), red pine (*P. resinosa*), as well as shade intolerant hardwoods such as trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Later seral overstory species included eastern white pine (*P. strobus*), black spruce (*Picea marianna*) and white spruce (*P. glauca*).

Fire was the chief disturbance agent in the pre-settlement pine forests on the Brimson Sand Plain and occurred at different frequencies and severities depending on the NPC. Generally across these three fire-dependent NPCs, catastrophic and stand-replacing fire occurred every 120-220 years, ground fires occurred every 75-260 years, and rotation for all severities of fire was 53-115 years (MN DNR 2003). Windthrow was not often observed by surveyors and was estimated to occur every 1,000 years or more. More frequent but less severe disturbances such as bark beetle outbreaks, *Armillaria* root rot mortality, and a host of other insects and pathogens also impacted these forests. Likely, pests and

pathogens played a significant role in the pre-settlement forest, but certainly, the modern forest is more perturbed by wind, insects, and pathogens than fire.

3.6.2 Reconstructed Disturbance at CFC

Fire has played a significant role at CFC. Initially, the forest was dominated by jack pine dating to fires from 1864 through 1894. The old-growth stands that still exist on the property display fire scars as evidence of the frequent fire of the 19th century; six fires were observed in the period spanning 1824-1894 in CFC’s old-growth reserve “Camp 8”. That stand is 191 years old and initiated following a stand replacing fire in 1824. Ground fires of varying severity followed in 1842, 1855, 1864, 1874, and 1894.

In the absence of significant fire, forest harvest has had a prominent role as the chief disturbance agent at CFC dating back to the early 20th century. Since the initial cut-over, the forest has been intensively managed. Historical harvest records indicate that since 1940 (truncated record, actual record spans 1912-2015) harvest has occurred on 3,252 acres, yielding a forest-wide rotation of harvest to be 71.9 years ²(Table 4).

Table 4. Historical harvest levels (area and volume) for the 70 year period spanning 1940-2009 reconstructed from historical harvest records for the contiguous Cloquet Forestry Center (CFC) property. The actual record spans 1912-2015 and was truncated due to sparseness of records prior to 1940.

Decade	Decadal area harvested (ac decade ⁻¹)	Decadal volume harvested (cords decade ⁻¹)	Annual area harvested (ac year ⁻¹)	Annual volume harvested (cords year ⁻¹)
1940 - 1949	210.3	2592.6	21.0	259.3
1950 - 1959	653.3	7244.6	65.3	724.5
1960 - 1969	574.5	3675.2	57.5	367.5
1970 - 1979	178.5	3644.5	17.8	364.4
1980 - 1989	716.9	13618.9	71.7	1361.9
1990 - 1999	453.8	10088.8	45.4	1008.9
2000 - 2009	465.7	10472.9	46.6	1047.3
Minium	178.5	2592.6	17.8	259.3
Mean	464.7	7333.9	46.5	733.4
Maximum	716.9	13618.9	71.7	1361.9
Sum	3252.9	51337.4	-	-

² Calculated from Frelich et al. Disturbance rotation period = T / P where T is the observation period and P is the proportion of area disturbed. From 1940 to 2009 at the CFC, T=69, and from Table 4, P= 3252.9 /3388.0 acres.

3.7 Relationship to surrounding lands

The contiguous CFC property is 3,391 contiguous acres (including the Fritz Trust), and is surrounded by land managed for public interest. Though sparsely surrounded by residential lots, the surrounding area is forested and managed by Tribal, County, or State agencies. The area west of the City of Cloquet is heavily forested. This offers opportunities to manage for objectives at a larger scale than currently, and for objectives shared with our surrounding neighbors on FDL, County, or State land. Those opportunities include invasive species monitoring and control (e.g., emerald ash borer, European buckthorn), and joint efforts to use fire to restore composition and structure typical of fire-dependent native plant communities.

The composition and structure of CFC's forest is due in part to intensive management and designated reserves, but it is also due to the property being spared from the catastrophic 1918 fire. The Cloquet and Hinckley fires of that year decimated surrounding towns and forests, setting regional forests back a quarter century. Many of the forests impacted by the 1918 fire originated following the cut-over or the fire of 1894.

4. Forest Resource Assessment

4.1 History of forest management and research

The record of forest management and research at CFC is extensive owing to the fact that it is one of the oldest continuously operated experimental forests in the United States. Research and demonstration focused on sustainable forestry practices has been a large part of the mission, and these activities were a motivating factor for the conception of CFC at the turn of the century. Over the last 106 years the CFC forest experienced 562 harvests over 3,785 acres. Records for 494 research projects covering 1,280 acres are being maintained. The CFC has supported over 1,000 publications in that time.

Research and forest management have long been intertwined at CFC, but there have been periods where research drove management and periods where forest management cleared the way for new research. For the first 60 years of activity on the forest, research dictated forest management efforts. As CFC forests senesce from their origins in the late 19th century following cut-over and fires,

research questions shifted to address fundamental questions related to the silviculture of northern forests. The number of acres harvested in the late 1970s was markedly lower than the preceding three decades. By the early 1980s, rates of harvest were deemed insufficiently low to maintain a healthy forest, with many of the fire- and cut-over origin upland forests surpassing their regional rotation age.

In the early 1980s, a shift in management philosophy occurred (Severs 2002) so that deliberate and scheduled harvests would be scheduled to inspire and attract new research. This philosophical shift increased harvest levels, which is evident in forest-wide age distributions and harvest records (Figure 4), where peaks exist in the 10-40 year old age classes, and similarly, acres and volume harvested in the period spiked (Table 4).

The management philosophy of the last three decades is a blend; research drives management, but a deliberate harvest schedule is maintained to promote forest health that is more representative of regional conditions. This philosophy has proven compatible with all aspects of our mission. The maintenance of a variety of cover types, growth stages, and management scenarios is critical to teaching, research, and outreach and achieved by deliberately scheduling management activities. Please see Severs et al. (1992 and 2002) for a more extensive review of the history of research and management at CFC. To this day, management is cast in two fundamental roles: as a prototype to test assumptions related to forest management practices, and to regenerate mature stands. The connection between basic research and management provides the CFC with an unusual capacity to effectively engage and improve forest management practices in the state.

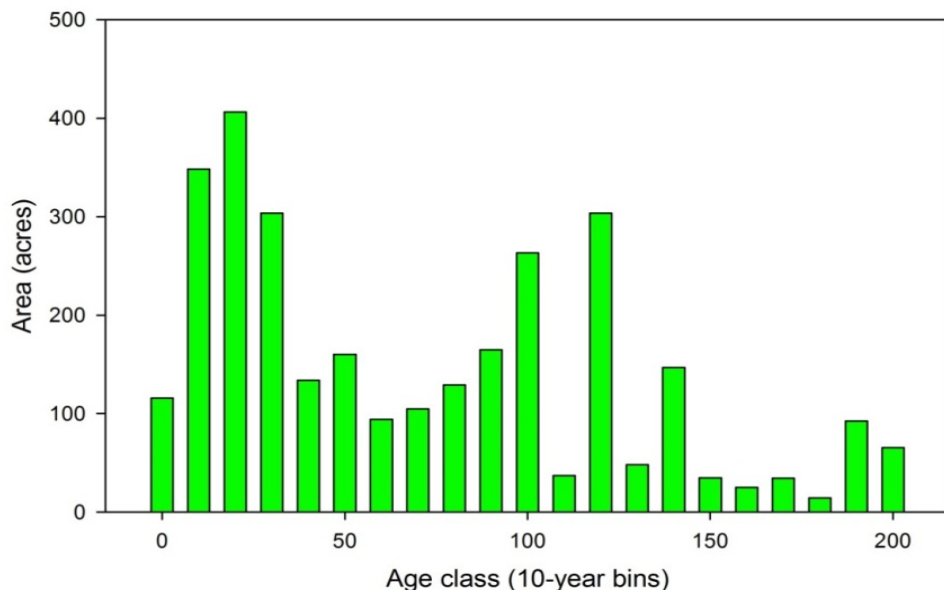


Figure 4. Age-class distribution of Cloquet Forestry Center (CFC) forest by 10-year bins.

4.2 Cover types

Nearly two-thirds, or 2,215 acres, of the contiguous CFC property may be classified as upland. The other third of the property is lowland with roughly 10% (348 acres) in non-forested conditions including marsh, un-productive swamp, or lowland brush. The contiguous CFC property is mostly forested, with few areas that are capable of growing trees and are not currently growing trees. The greatest concentration of upland forests exists in the northern two sections of land (Figure 5), while the southern three sections are a mix with the greatest concentration of lowland cover types. Less than 2% of that upland area is designated open or not in forest (Table 5). The dominant vegetation cover types include red pine (824 acres), aspen (608 acres), and mixed lowland conifers (309 acres).

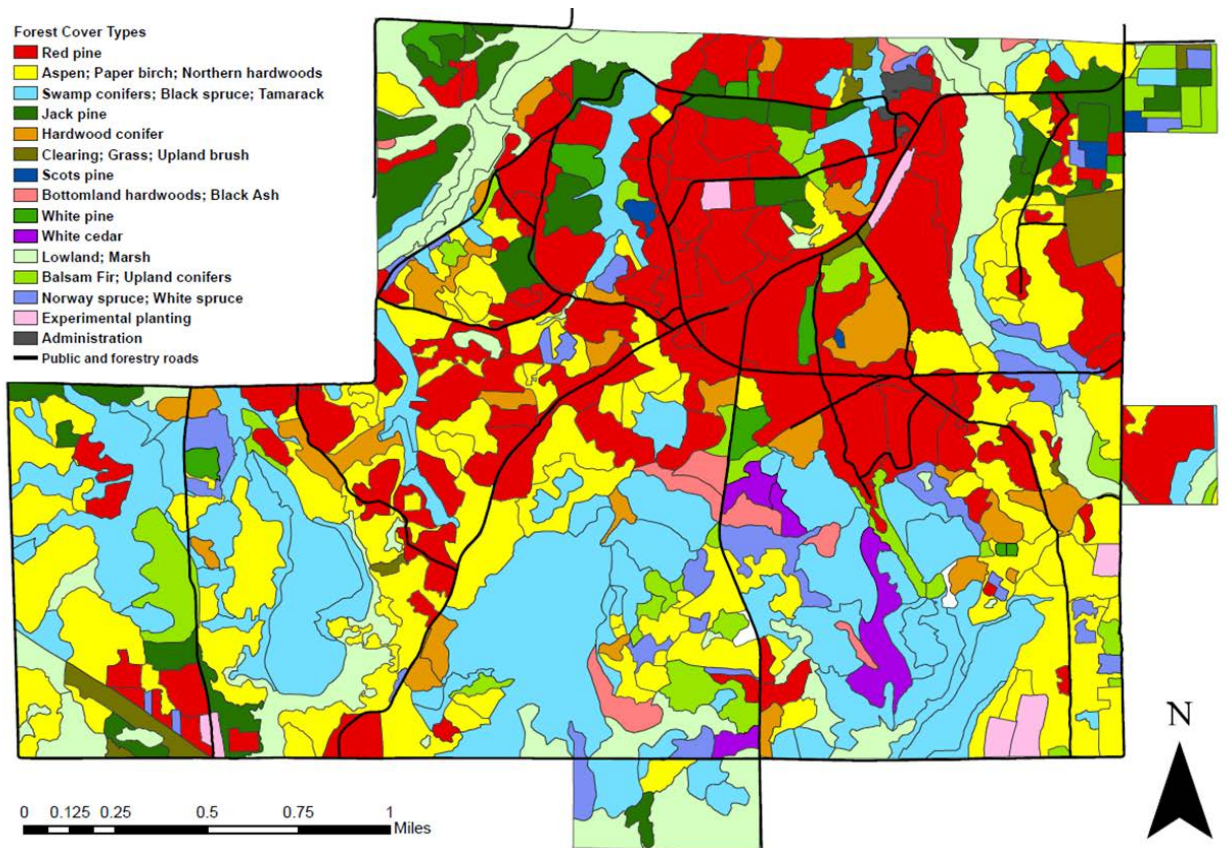


Figure 5. Aerial extent of cover types at the contiguous Cloquet Forestry Center (CFC) property.

Historically, there has been a shift in the abundance of cover types at CFC. This should not be surprising given similar shifts in regional abundance of cover types in the last century (Figure 6). The CFC

property was initially dominated by jack pine, most of which stemmed from fire in 1894 and wide-spread harvest in the following decades. Prior to markets forming, jack pine was targeted for replacement by native and non-native pine, including Scots pine. Scots pine was grown on site from a seed source secured from Riga, Latvia and planted in several experimental trials comparing its competitive ability and growth form to that of native pine species, most notably jack and red pine.

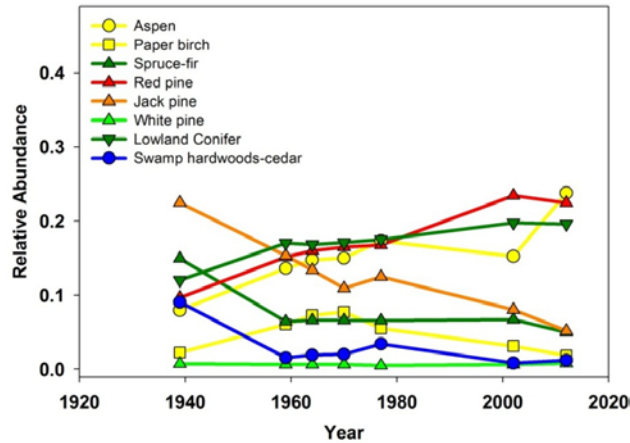


Figure 6. Change in abundance of cover types at Cloquet Forestry Center (CFC) since 1940.

Table 5. Distribution of vegetation cover types at Cloquet Forestry Center (CFC) by acres and as a percentage of the entire contiguous property.

	Cover-type	Acres	Percent Forest Cover
Upland cover-types	Red pine	824	24.3%
	Aspen	608	17.9%
	Jack pine	183	5.4%
	Mixed hardwood-conifer	130	3.8%
	White spruce	98	2.9%
	Upland conifer	83	2.5%
	Northern hardwood	55	1.6%
	Balsam fir	46	1.4%
	Birch	62	1.8%
	White pine	36	1.1%
	Scots pine	9	0.3%
	Open	46	1.4%
	Experimental planting	36	1.1%
	Subtotal	2215	65.4%
Lowland cover-types	Mixed lowland conifers	309	9.1%
	Black spruce	274	8.1%
	Tamarack	159	4.7%
	Marsh/Lowland brush	343	10.1%
	Bottomland hardwoods	40	1.2%
	Cedar	38	1.1%
	Non-productive swamp	5	0.2%
	Subtotal	1169	34.5%
	Grand total	3385	100.0%

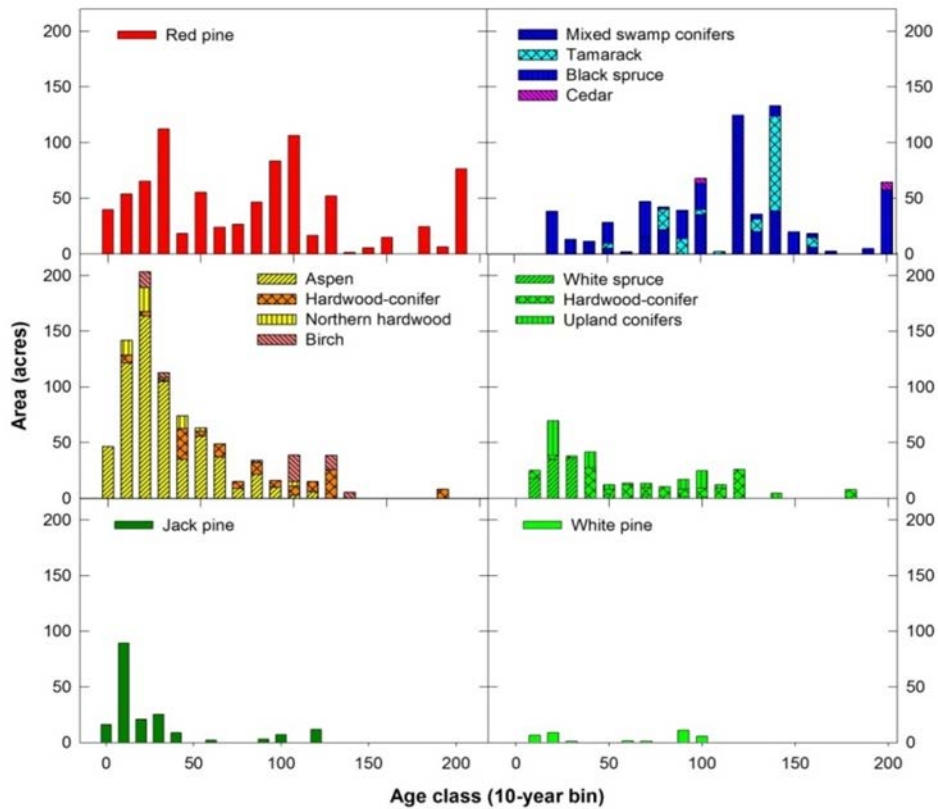


Figure 7. Age distribution of Cloquet Forestry Center by acres and cover type in 10-year bins.

Markets formed for harvested jack pine and, fortunately, the species remained a component of CFC’s forest. Jack pine, however, is in much lower abundance now than historically. Since 1940, CFC has seen a steady decline of the jack pine type, from roughly 20% to 5% abundance by area, and a correspondingly steady increase in the red pine and aspen types, from under 20% to over 40% abundance by combined area (Figure 6). Both species apparently increased at the expense of the jack pine cover-type. As a result, there has been a deliberate push in the last two to three decades to increase representation of historically important and currently under-represented cover types, most notably jack pine and white pine (Figure 7).

4.2 Forest structural features

4.2.1 Age- and size-class

The age distribution of CFC's forest reflects several distinct periods of historical disturbance notably fire, logging, and windstorms. The severity and type of disturbance regimes has shifted in time: stand-replacing fires were common in the 19th century, while disturbance in the early 20th century also included large-scale timber harvests during the cut-over period. These historical disturbance patterns have resulted in a forest-wide age distribution with approximately three modes; those are centered on the 120-130 year old, 100-110 year old, and the 20-30 year old age-classes. These modes reflect the aforementioned stand replacing disturbances and have guided contemporary forest management planning.

The CFC forests have a large swath in both young and mature growth stages, the majority of which is contained in red pine and aspen cover types. Scheduled harvests over the next ten years will focus on tending young age classes of red pine for first commercial entries. Final entries and regeneration harvests will also take place in the red pine type. The aspen type will require regeneration harvest, but the majority of this type will not reach economic or pathological rotation in the next one to two planning cycles.

The retention of snags, live trees, and dead wood is an important component for managing wildlife habitat. Snags provide a critical food source for woodpeckers and also habitat for cavity-nesting species. Cavities created by Pileated woodpeckers are used by many secondary cavity-nesters, including birds and mammals. Snags also provide roosting habitat for birds of prey, a special consideration along the riparian zones of Otter Creek. As snags fall, they provide substrate for fungi, liverworts, lichens, amphibians, insects, small mammals and birds. Snags are also important as moisture reserves for the forest and their decomposition releases nutrients into the soil. The CFC will actively maintain snags and other coarse woody debris, meeting or exceeding recommendations in the MN site-level forest management guidelines.

About one-quarter of the forest, or 750 acres, are understocked (Figure 8). That number includes the 400 acres designated as open and the approximately 100 acres currently regenerating and less than one inch in diameter at breast height. The age-class distribution show approximately 100 acres in the 0 – 10 year old age class and just under 15% of the forest is in open or early successional habitat with no trees or trees <1.0" diameter at breast height (DBH) (Figure 9). Jack pine and birch are underrepresented relative to historic and regional abundances (Figure 7). Previous plans increased the

number of acres of jack pine by tree planting or facilitating natural regeneration. Efforts to increase the presence of jack pine will continue in the next decade. Similarly, the birch type is a relatively small but important part of the land base, with young stands in low in abundance based on age-class and stocking levels.

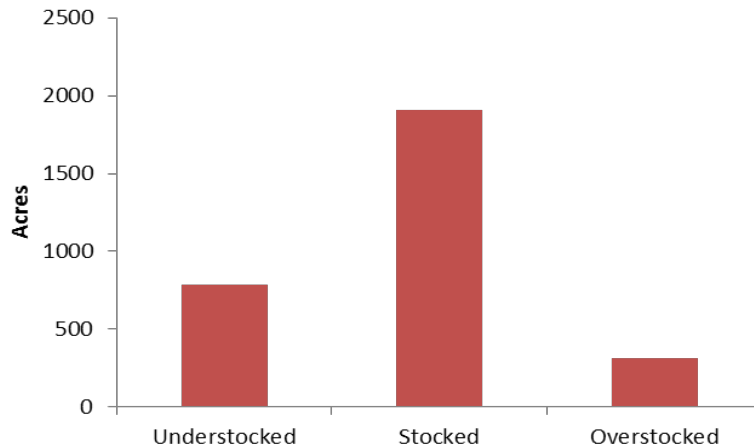


Figure 8. Stocking levels of Cloquet Forestry Center (CFC) forest by acres.

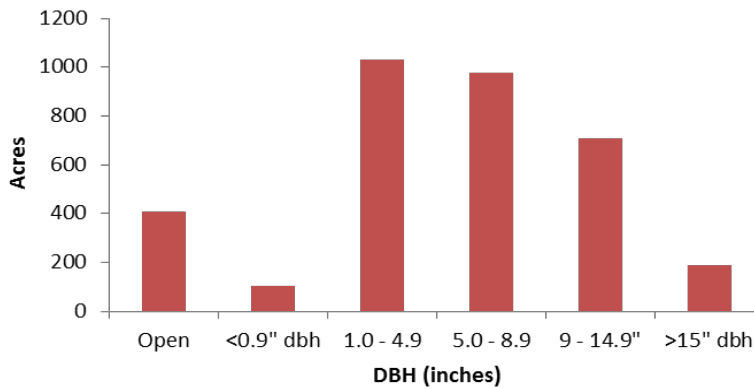


Figure 9. Size class of forest at Cloquet Forestry Center (CFC) by acres.

4.3 Reserve areas

Recent management plans (Severs et. al 1992 & 2002) identified a need for forests designated as reserve areas. All designated reserve areas advance our mission by sustaining areas for teaching and demonstration, long-term or active research. Given our limited land-base and the variety of stakeholders we serve through the various aspects of our mission, reserve areas will be maintained to meet various objectives. Reserve areas that include areas of high conservation value are set aside to

avert resource conflicts (e.g., harvesting in an active research area). Reserves are also in place for known bald eagle and northern goshawk nesting areas and other raptor nests. Reserves are also considered for buffers along riparian zones, specifically along Otter Creek, and serve to protect areas with unique biodiversity, and areas with cultural value or historical significance.

4.3.1 Reserves for Teaching and Demonstration

Teaching and demonstration reserves are critical to maintain features for instruction during the many field-based tours and courses held at CFC. Instructors were contacted to identify areas or features that are needed for instruction, either for current use or areas that may desired to create through future management. For this plan, 37 teaching reserves were designated covering 390 acres (Figure 10). This inventory is fluid as forests change, markets shift, and new research questions arise. The GIS inventory at CFC allows a clear view of areas used for teaching or research. Management activity may occur within teaching and demonstration reserves if alternative stands can be identified to provide the educational value needed. In many cases, the results of forest management are showcased in stands designated for teaching use.

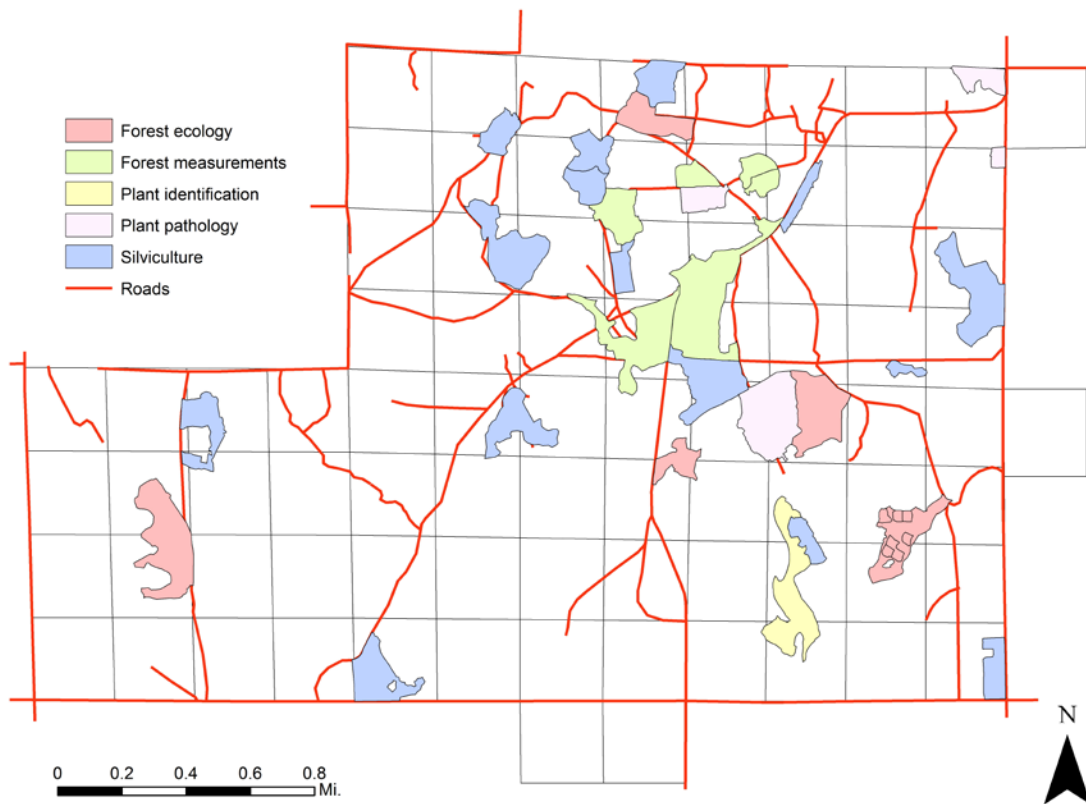


Figure 10. Cloquet Forestry Center's teaching and demonstration reserves. Stands are color coded to match the course type that uses each area.

4.3.2 Reserves for Long-term and Active Research

There are currently 57 active and long-term (running greater than 10 years) research projects at the CFC in stands comprising 369 acres (Figure 11). The maintenance of long-term active research projects is critical to fulfilling our mission and to maintain credibility as a research forest, including the trust of researchers and funding agencies. CFC has successfully maintained 14 projects that have been in place for greater than 50 years with several projects originating to the 1910's. This has been accomplished through vast institutional knowledge, but like many organizations, that knowledge is easily erodible and difficult to replace. All records of research available for the forest dating back to 1912 were recently digitized and geo-referenced to improve access to their location. Diligence and attention to the location of long-term and active research is needed to avoid potential conflicts between research and forest management activities.

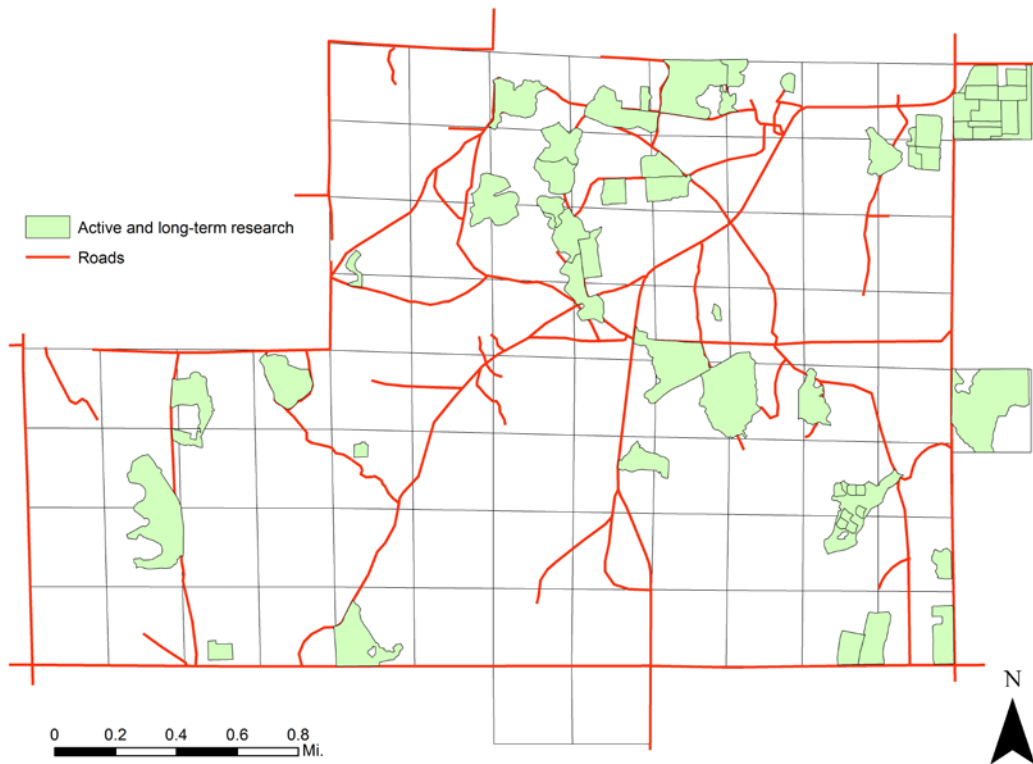


Figure 5. Stands containing long-term and active research at Cloquet Forestry Center.

4.3.3 Areas of High Conservation Value

CFC is home to natural areas that contain high conservation value that may include the presence of sensitive species, unusually high species diversity, or other unique qualities. These distinctive areas emulate forest development stages that are not easily re-generated such as old-growth red pine or old-growth paper birch. Older, mature reserved stands may harbor significant floral and faunal diversity. As reserve areas senesce, new stands should be set aside to maintain diversity of age-classes on the property. The current plan has designated 16 stands covering 186 acres as having high conservation value (Figure 12).

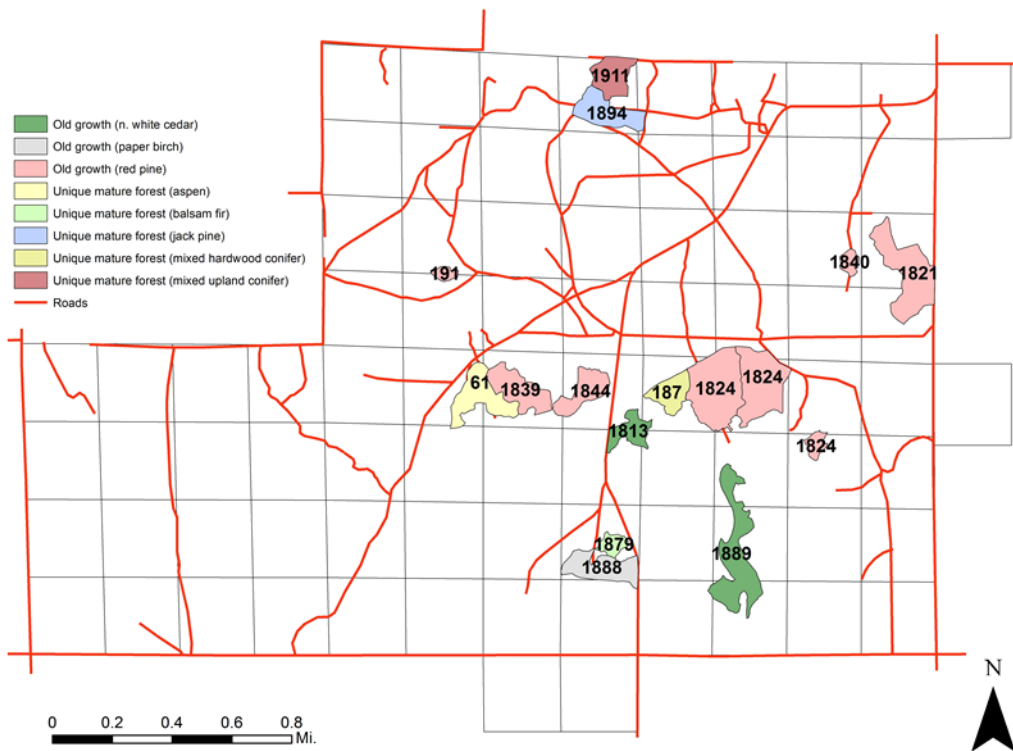


Figure 12. Designated high conservation value forest stands at Cloquet Forestry Center.

4.3.4 Areas of Cultural Value and Historical Significance

Forests of the CFC contain several sites of cultural and historical value on the contiguous property. These include numerous old homestead sites (Koch, Newton, Prull, Ryan, and Vibert), logging camp sites (Camp 8), an old root cellar, and several miles of old logging railroad grade (Fig. 13). Management activities will, to the extent possible, avoid disturbing culturally sensitive sites. The presence and protection of cultural sites has a two-fold benefit: intrinsic values for protection of historical remnants, and exemplification of the MN Voluntary Site-level Forest Management Guidelines towards the education of future forest managers.

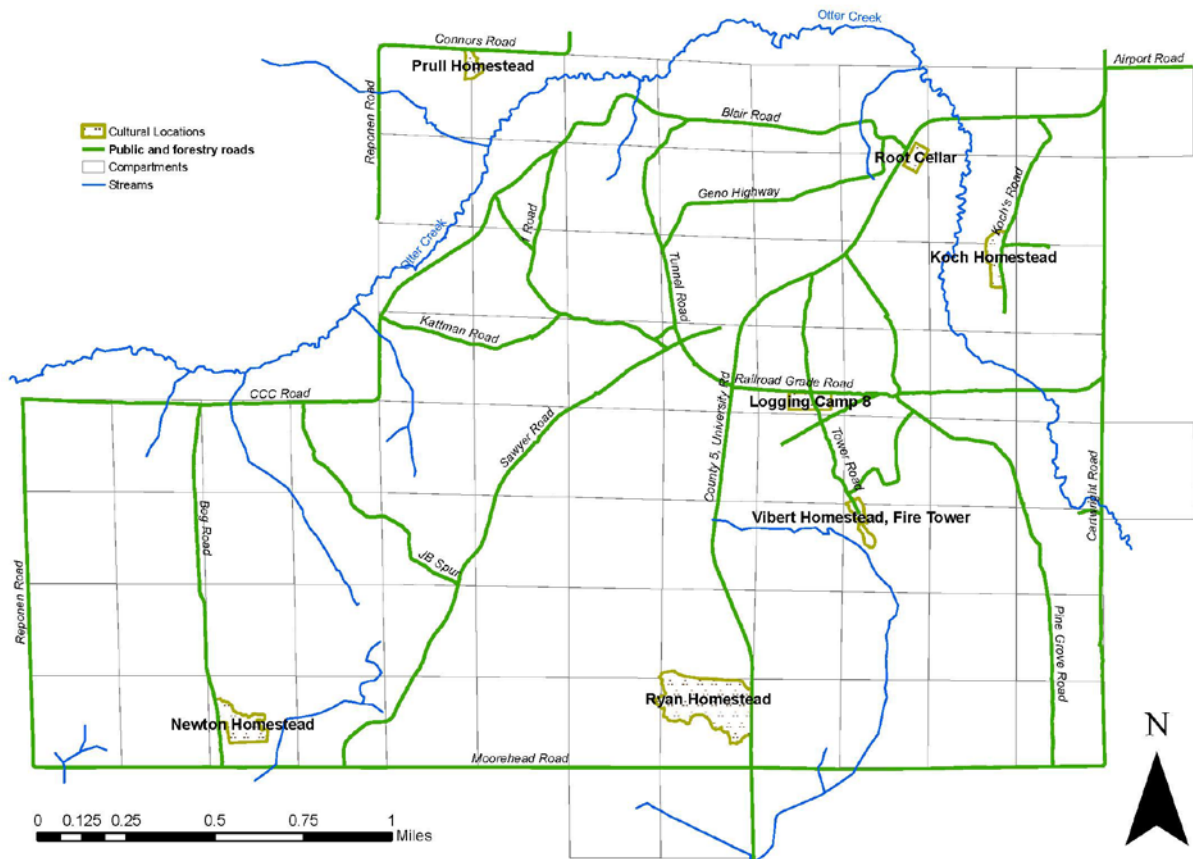


Figure 13. Sites of cultural value and historic significance in the forests of Cloquet Forestry Center

4.4 Species of concern

4.4.1 Native species

The Minnesota DNR lists 439 native species as endangered, threatened, or of special concern within the state. Twenty-three of those species are known to occur in Carlton County in habitat types that are abundant at the contiguous CFC property (Table 6). None of these species were positively identified from the Natural Heritage Information System that was recently consulted. Given the possibility that some rare species or features exist at CFC, a GIS layer is being developed to include rare species or features as they are identified by field technicians on the property.

As an example, several small populations of Canada yew (*Taxus canadensis*) have been located on the property while inventorying both wet forest and fire-dependent habitat types. The locations of these populations have been added to a GIS layer. Already, one population of Canada yew, present in a recently harvested stand (see appendix for file directory path), was avoided during management. A reserve patch was designated both to meet state recommended reserve guidelines and mitigate damage to the plant population.

Native plant species with cultural and medicinal importance to local residents, primarily Fond du Lac Band members, are occasionally sought for ethnobotanical collections. These non-timber forest products have included birch bark, bearberry, princess pine, and balsam boughs. Staff at CFC track the location of these populations to provide information for newcomers, to manage the health and size of those populations. Culturally important species will be monitored much like the rare species on the property through a resource-specific GIS.

Table 5. State of Minnesota endangered, threatened, and special concern species that occur in Carlton County and occur in habitat-types present at Cloquet Forestry Center (CFC) contiguous property. Habitat-types included fire-dependent forest, wet forest, forested and open rich peatland, forested and open acid peatland, wet meadows, sedge meadows, marsh, and small rivers or streams

Common name	Scientific name	Group	State status
Four-toed Salamander	<i>Hemidactylium scutatum</i>	amphibian	special concern
Spotted Salamander	<i>Ambystoma maculatum</i>	amphibian	-
Bald Eagle	<i>Haliaeetus leucocephalus</i>	bird	special concern
Northern Brook Lamprey	<i>Ichthyomyzon fossor</i>	fish	special concern
Southern Brook Lamprey	<i>Ichthyomyzon gagei</i>	fish	special concern
Northern long-eared bat	<i>Myotis septentrionalis</i>	mammal	special concern
Tricolored Bat	<i>Perimyotis subflavus</i>	mammal	special concern
Black Sandshell	<i>Ligumia recta</i>	mussel	special concern
Creek Heelsplitter	<i>Lasmigona compressa</i>	mussel	special concern
Elktoe	<i>Alasmidonta marginata</i>	mussel	threatened
Fluted-shell	<i>Lasmigona costata</i>	mussel	special concern
Mucket	<i>Actinonaias ligamentina</i>	mussel	threatened
Blanding's Turtle	<i>Emydoidea blandingii</i>	reptile	threatened
Wood Turtle	<i>Glyptemys insculpta</i>	reptile	threatened
Jumping Spider	<i>Marpissa grata</i>	spider	special concern
Bog Rush	<i>Juncus stygius var. americanus</i>	vascular plant	special concern
Canada yew	<i>Taxus canadensis</i>	vascular plant	-
Carey's Smartweed	<i>Persicaria careyi</i>	vascular plant	special concern
Clustered Bur-reed	<i>Sparganium glomeratum</i>	vascular plant	special concern
Eastern Hemlock	<i>Tsuga canadensis</i>	vascular plant	special concern
Small Shinleaf	<i>Pyrola minor</i>	vascular plant	special concern
St. Lawrence Grapefern	<i>Botrychium rugulosum</i>	vascular plant	threatened
Torrey's Manna-grass	<i>Torreyochloa pallida</i>	vascular plant	special concern
Twig-rush	<i>Cladium mariscoides</i>	vascular plant	special concern
White Adder's-mouth	<i>Malaxis monophyllos var brachypoda</i>	vascular plant	special concern

4.4.2 Non-native invasives

The management of non-native invasive insect and plant species has not been explicitly discussed in previous plans, with the exception of white pine blister rust disease. The invasive insect species, gypsy moth (GM: *Lymantria dispar dispar*) and emerald ash borer (EAB: *Agrilus planipennis*), and the non-native invasive pathogen, white pine blister rust (BR: *Cronartium ribicola*), cause extensive damage to upland and lowland forests in this region and on CFC property. Several plant species, notably Siberian peashrub and European buckthorn, have emerged or experienced population increases in the region and onsite.

GM has expanded its range south and west towards Duluth and the interior of the state despite active monitoring and pest management. GM poses a threat to most broad-leaved canopy species and can cause significant mortality following multiple years of defoliation or combined with other stressors (e.g., native insects, drought). Regional monitoring and management for GM is carried out by Minnesota Department of Agriculture, and data is typically shared with affected landowners. In 2013, traps on CFC property showed a high increase in the frequency of GM adults. As a result, MDA intensively sampled the area in the spring of 2014, placing 12 traps on CFC property. Given MDA's robust and intensive sampling and treatment plan for GM, CFC will rely on MDA monitoring to inform future management decisions with respect to GM.

New quarantines against the invasive Emerald Ash Borer beetle (EAB) are demarcated each year as new EAB populations are found. The eight counties in Minnesota that have active quarantines to reduce the movement of ash wood are concentrated in the southern part of the state. The discovery of EAB-infected trees in nearby Douglas County Wisconsin, however, portends to its presence near the CFC. The MDA has placed traps to detect EAB at the CFC and in Carlton County. The ash resource at CFC is a relatively minor component of the forest type, so staff will continue to rely on MDA to monitor for presence of EAB. Firewood is provided to registered visitors free of charge to reduce the likelihood of accidental introductions of the beetle.

Invasive terrestrial plants such as buckthorn (BT) and Siberian pea (SP) have also increased in abundance on the property. While BT is likely spreading from the adjacent city of Cloquet, SP has been in the CFC arboretum for decades and has escaped into adjacent managed stands. SP should be removed from the arboretum to eliminate the major seed source and stem the spread at CFC. BT eradication is planned to continue wherever populations are located.

White pine blister rust (BR) remains a major non-native pathogen of concern for juvenile eastern white pine seedlings across the CFC. It will continue to impact white pine seedlings into the foreseeable future as little resistance occurs in native white pine. Cultural tools are typically employed to minimize the effect of BR on young stands of white pine. These practices consist mainly of sanitation pruning to eliminate infection sites on seedling and sapling white pine, and to improve air flow through the understories of mature forests. *Ribes* populations should also be included in future GIS layers to improve forecasting probability of infection.

This plan marks the beginning of an effort to inventory, treat, and monitor these invasive species at CFC in order to actively mitigate their effects on native plant communities and forest development. This property-wide effort will result in an inventory and field map to facilitate treatment and monitoring efforts. A GIS layer will be created that identifies invasive populations and includes abundance of those species pre- and post-treatment and the applied treatment.

5. Inventory, monitoring, silviculture, harvesting, and roads

5.1 Continuous forest inventory

CFC is one of the most intensively monitored forest resources in the region owing to an extensive network of Current Forest Inventory plots (CFI) and multiple long-term studies of forest growth and development. These data sets have value for informing silviculture regionally and scheduling forest harvest at CFC. CFC's continuous forest inventory (CFI) consists of approximately 400 1/7th acre plots where all live and dead trees of merchantable size are measured with nested 1/100th acre plots to monitor sapling and seedling development. Physiographic characteristics of each plot are also recorded, and downed woody debris is measured. The CFI network has been measured eight times, roughly every 5 to 10 years, starting in 1959 (Dieser et al. 2011). The most recent measurement, made in 2014, was used to complement stand-level data for harvest scheduling in this planning cycle (Shrestha et al 2015).

5.1.2 Stand-level monitoring

Annually, CFC staff inventory 10-30 stands to assess growth and health of trees prior to, and following, management activities. This type of stand-level monitoring is carried out to complement our CFI network of plots and ensure stand-level actions are achieving results. Stands selected for monitoring are generally either within 2-3 years of the 10-year harvest schedule or received of harvest activity in the previous 10 years. Recently harvested stands are surveyed to ensure residual trees are responding

to treatment (e.g., release). Recently regenerated stands are surveyed to assess health and ensure adequate stocking and growing conditions for crop species. CFC's GIS inventory is used to track success of regeneration and serves as a reminder to conduct regeneration surveys 4-5 times over the first 10 years following harvest. Regeneration surveys typically take place after 1, 2 (sometimes), 3, 5, and 10 years.

5.1.3 Silvicultural prescriptions

Long-term management of a forest resource is challenging given generational changes in staffing along with rapid changes in technology. The CFC resource represents a relatively small land-base with the numerous demands placed on the forest. This intense use requires careful maintenance of harvesting records and objectives. CFC has maintained harvesting records that include the volume and product extracted, dating back to 1911. This plan marks an initial effort to develop detailed management prescriptions that document harvest objectives, pre-treatment conditions, desired future conditions, and the timing of future management and monitoring activities. CFC's standard prescription form is modeled after local, state, and federal prescription forms that are currently used in other commercial operations. This form is used to prepare timber sales, with approval by the Director of Operations prior to advertising the sale.

5. 2 Forest harvests

Forest management at CFC is set to achieve multiple objectives, like other public land-managing agencies in the region. These objectives include economic and ecologic considerations, such as retaining snags for wildlife, or harvesting at an optimum rotation age to ensure sufficient financial return. In addition CFC is tasked with providing stands that represent both managed and unmanaged states for instruction on numerous topics related to forest and wildlife ecology and management. Reserves (see section 4.2 above) are used for maintaining areas for teaching and research. Outside these reserves, most other parcels are slated to receive a harvest treatment in the next 10 years. Instead of actively managing every parcel, harvests will be limited to ensure that forest conditions suitable for instruction and future study are maintained. Management activities in this plan are fairly broad in their scale to accommodate future research prospects. For example, regeneration harvests may be managed for coppice, clearcuts, clearcuts with reserves, seed trees, or shelterwoods (any variant), at the discretion of the forest manager, the director, or to address research questions.

5.2.1 Selection of stands for harvest

Stands were selected for harvest over the next ten years based on the CFC GIS inventory, the Continuous Forest Inventory and numerous stand examinations. Area-based targets for harvest were informed by age distributions by acreage and cover-type, along with stocking levels (Figure 14). Selected stands were grouped in time based on cover, age, and previous management history to accommodate replicated future research projects at CFC. Historical harvest data from the last 70 years was used to set harvesting norms for the contiguous CFC property (mean decadal forest harvest: 464.7 acres; max decadal forest harvest: 716.9; Table 3).

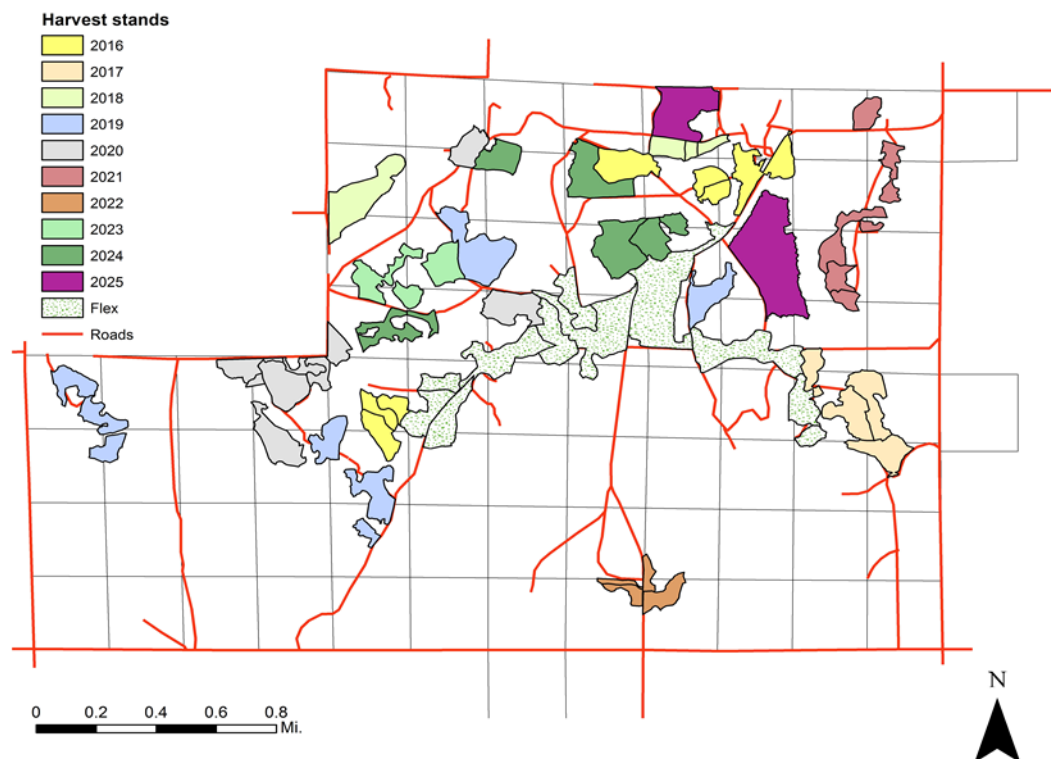


Figure 14. Stands at Cloquet Forestry Center to be harvested by year in the period 2016-2025. Harvesting treatments vary from first to fourth thinnings, and a variety of regeneration harvests in multiple cover-types. "Flex" refers to 10 stands totaling 152 acres that were selected for potential harvest but not assigned years because of the potential to accommodate future large-scale research projects. Total area to receive harvesting treatments is 588 acres including all "Flex" acres.

In all, 53 stands covering 435 acres and averaging 8.2 acres in size were selected and scheduled for harvest this decade. The harvests are comprised of 18 regeneration harvests, 19 first thinnings, 11 second thinnings, and five third thinnings. An additional 152 acres could be harvested, but have been

assigned to the “Flex” category to accommodate a potential large-scale study (see Prescription 6 below). In order to maintain a diversity of species composition, structure, age, and management history (see Management Objective 2.4), efforts were made to ensure that no age-class bins were depleted of less than 50% of the original acres present in that bin. The cover-type and age-class targets for areas slated for harvesting in the upcoming decade (2015-2025), and justifications for those targets, are described below.

Prescription 1. Regeneration harvests for three red pine stands comprising roughly 25 acres (Table 6, stand IDs: 51, 139, 153).

Explanation. Over the last 30 years, an average of 50 acres of red pine was regenerated every 10 years. The age distribution for red pine has two peaks, one at 100 and another at 120 years, the latter corresponding to fire origin stands. Half of the 120 year-old stands were targeted for a regeneration harvest in the next ten years. Given the rarity of natural fire-origin red pine stands, researchers may desire to study natural regeneration on this scarce resource.

Prescription 2. Aspen, hardwoods and hardwood conifer stands in the 50-70 year age class are slated for regeneration harvest, encompassing 90 acres. (Stand ID numbers = 20, 103, 113, 137, 197, 199, 167, 209, 236, 376, 409, 411, 432).

Explanation. Over the last 30 years, approximately 120 acres of aspen, hardwood, and hardwood-conifer stands were regenerated per decade. Aspen and hardwoods in this age class have approached their commercial rotation age, where regeneration is appropriate. Trees in the 20-30 year age class represent a major peak in the age-class distribution for broad-leaf trees. This younger cohort will not require additional management this decade

Prescription 3. A first thinning, before age 35, will be conducted on 106 acres of young red pine. (Table 6, Stand ID numbers = 195, 65, 440, 200, 253, 453, 377, 66, 408, 62, 149, 401, 104, 64)

Explanation. The red pine age distribution shows a peak in the 20-40 year age class as a result of increased regeneration harvests in the 1980s. Early thinnings are recommended in these stands to maintain diameter growth and a sufficient live crown ratio.

Prescription 4. Second and third entry commercial thinnings will be conducted on 175 acres of red pine covertype. (Stand ID =13, 52, 57, 75.1, 101, 132, 159, 208, 215, 314.1, 325, 432, 424, 469, 525)

Explanation. This recommendation is based on age and thinnings that occurred within the previous 10-20 years.

Prescription 5. Four stands of jack pine (40 acres total) between 20 and 40 years of age will receive first thinnings. (Stand IDs = 58, 60, 70, 100, 112)

Explanation. These represent successful stocked or overstocked jack pine stands that were regenerated since the late 1970s.

Prescription 6. Eight red pine stands, in a mature age-class (approaching 100 years from origin), encompassing over 140 acres, are designated as “Flex” (flexible) stands where management options can be considered as needed. (Stand ID numbers = 141, 84.5, 109.2, 428, 154, 213, 154.1, 84.4, 84.2, 84.1)

Explanation. Red pine trees of approximately 100 years in age are relatively abundant on the CFC. Eight red pine stands of similar age (~100 years), of relatively large size (~17 acres), and with good access for research and instruction are designated as Flex acres. These were reserved to create novel research opportunities that may include additional thinnings or regeneration. Management of these flexible acres is at the discretion of the forest manager, based on the potential to accommodate novel research. These acres may be managed as part of a larger research project to study novel silvicultural techniques or climate adaptation strategies. The “Flex” designation allows for these acres to be employed in a project at any time in the next 10 years and it allows time for internal planning and collaboration to seek funding for the design and implementation of a large-scale silvicultural project at CFC.

5.2.2 Harvest schedule

The harvest schedule was determined by three criteria: stands in need of treatment based on stand age, regionally accepted rotation ages, and current growing conditions. Selected stands were then grouped in time (e.g., 2016) and space (i.e., location on property adjacent to roads). Special consideration was made to ensure that young pine stands receive timely first thinnings (i.e., prior to 35-40 years of age). When possible, harvest treatments were synchronized by year to provide replication for future research projects, by grouping stands of similar composition, structure, age, and management history.

In six different years, the harvest schedule is slated to include 30-70 acres and 7-8 stands per year (2016, 2019, 2020, 2024, and 2025). The other five years are predicted to see 13-29 acres harvested, ranging from 2-4 stands per year (2017, 2018, 2021, 2022, and 2023). Thinning will occur in all years, with first thinnings in all but 3 years (2016, 2022, 2025). Regeneration harvests occur in all but three years (2018, 2024, and 2025). Flex acres could be harvested anytime in the next 10 years, but are recommended for years of lower harvest activity to bridge income gaps (2017, 2018, 2021, 2022, and 2023).

5.2.3 Forest roads

CFC harbors exceptional access for timber harvesting, research, and recreation with a combination of public and forest-roads. Approximately ten miles of external roads are managed by the City of Cloquet, Carlton County, or the Fond du Lac Band. Additionally, CFC has nearly 27 miles of internal forest roads with access at 15 points, gated by cable or round pipe gates. Internal access is maintained for research, instruction, and management.

Road improvements, mainly widening and crowning, occur with nearly every timber sale with the assistance of the company and operator that purchases the sale. The agreement is made with the contracted logger to harvest mature rows of trees adjacent to roads, and is typically bundled with larger timber sales. For smaller road-widening projects, relationships with local groups that include Sentence to Serve (STS), the Boy Scouts of America, and Conservation Corp Minnesota have been utilized to brush roadsides. Occasionally, CFC dedicates internal resources for re-grading roads where appropriate, and a portion of timber sale revenue is spent annually on 1-3 loads of gravel to repack and fill water-damaged roads.

Table 6. Harvest schedule and stand descriptions for CFC stands to receive harvest treatment in the period 2016-2024. "Flex" stands are stands selected for potential harvest but could accommodate large-scale research projects. Type of regeneration harvest was not specified but will be restricted to coppice, clearcut, clearcut with reserves (clumped or scattered), seed tree, or shelterwood.

Year	Stand ID	Size (ac)	Cover	DBH (in)	Stocking	Origin	Age	Age at harvest	Scheduled Activity
2016	75	4.5	Red pine	9.0 - 14.9	Stocked	1949	67	67	Thinning (second)
2016	197	4.3	Aspen	5.0 - 8.9	Under stocked	1965	51	51	Regeneration harvest
2016	199	3.8	Aspen	5.0 - 8.9	Stocked	1953	63	63	Regeneration harvest
2016	208	7.1	Red pine	9.0 - 14.9	Under stocked	1930	86	86	Thinning (second)
2016	52	15.0	Red pine	> 15.0	Stocked	1858	158	158	Thinning (second; fire-wise)
2016	75.1	3.6	Red pine	5.0 - 8.9	Stocked	1949	67	67	Thinning (second)
2016	57	12.2	Red pine	9.0 - 14.9	Stocked	1944	72	72	Thinning (second)
2017	195	10.6	Red pine	9.0 - 14.9	Stocked	1954	62	63	Thinning (first)
2017	159	5.5	Red pine	9.0 - 14.9	Under stocked	1937	79	80	Thinning (second)
2017	236	9.6	Hardwood	9.0 - 14.9	Under stocked	1947	69	70	Regeneration harvest
2017	376	10.6	Aspen	9.0 - 14.9	Stocked	1962	54	55	Regeneration harvest
2018	58	5.2	Jack pine	5.0 - 8.9	Stocked	1973	43	45	Thinning (first)
2018	60	2.4	Jack pine	5.0 - 8.9	Stocked	1977	39	41	Thinning (first)
2018	65	1.6	Red pine	5.0 - 8.9	Stocked	1978	38	40	Thinning (first)
2018	70	20.2	Jack pine	5.0 - 8.9	Over stocked	1982	34	36	Thinning (first)
2019	132	10.4	Red pine	9.0 - 14.9	Stocked	1962	54	57	Thinning (third)
2019	167	6.9	Aspen	9.0 - 14.9	Under stocked	1950	66	69	Regeneration harvest
2019	440	4.6	Red pine	5.0 - 8.9	Under stocked	1984	32	35	Thinning (first)
2019	200	6.4	Red pine	5.0 - 8.9	Stocked	1984	32	35	Thinning (first)
2019	215	7.9	Red pine	9.0 - 14.9	Stocked	1963	53	56	Thinning (second)
2019	253	11.4	Red pine	5.0 - 8.9	Over stocked	1984	32	35	Thinning (first)
2019	453	2.4	Red pine	5.0 - 8.9	Stocked	1984	32	35	Thinning (first)
2019	101	20.8	Red pine	9.0 - 14.9	Under stocked	1956	60	63	Thinning (second)
2020	432	12.1	Red pine	5.0 - 8.9	Stocked	1968	48	52	Thinning (second)
2020	139	11.9	Red pine	> 15.0	Under stocked	1893	123	127	Regeneration harvest
2020	153	4.8	Red pine	> 15.0	Under stocked	1894	122	126	Regeneration harvest
2020	432	3.8	Aspen	5.0 - 8.9	Stocked	1965	51	55	Regeneration harvest
2020	377	6.2	Red pine	> 15.0	Under stocked	1934	82	86	Thinning (first)
2020	432	3.7	Aspen	5.0 - 8.9	Stocked	1965	51	55	Regeneration harvest
2020	209	11.5	Aspen	9.0 - 14.9	Stocked	1965	51	55	Regeneration harvest
2020	51	7.2	Red pine	> 15.0	Stocked	1894	122	126	Regeneration harvest
2021	20	5.2	Aspen	9.0 - 14.9	Stocked	1960	56	61	Regeneration harvest
2021	66	5.7	Red pine	5.0 - 8.9	Stocked	1988	28	33	Thinning (first)
2021	408	1.4	Red pine	5.0 - 8.9	Under stocked	1985	31	36	Thinning (first)
2021	103	9.1	Aspen	5.0 - 8.9	Stocked	1940	76	81	Regeneration harvest
2021	409	4.6	Aspen	5.0 - 8.9	Over stocked	1959	57	62	Regeneration harvest
2021	411	3.0	Aspen	9.0 - 14.9	Over stocked	1962	54	59	Regeneration harvest
2022	469	2.5	Red pine	9.0 - 14.9	Stocked	1931	85	91	Thinning (third)
2022	314.1	6.1	Red pine	5.0 - 8.9	Stocked	1935	81	87	Thinning (third)
2022	461	1.4	White spruce	9.0 - 14.9	Stocked	1944	72	78	Regeneration harvest (shelterwood)
2022	325	2.9	Red pine	9.0 - 14.9	Stocked	1944	72	78	Thinning (third)
2023	112	8.9	Jack pine	1.0 - 4.9	Stocked	1987	29	36	Thinning (first)
2023	137	3.8	Aspen	5.0 - 8.9	Over stocked	1964	52	59	Regeneration harvest
2023	113	9.9	Hardwood-conifer	9.0 - 14.9	Stocked	1965	51	58	Regeneration harvest
2024	62	15.4	Red pine	1.0 - 4.9	Under stocked	1990	26	34	Thinning (first)
2024	100	3.1	Jack pine	1.0 - 4.9	Stocked	1990	26	34	Thinning (first)
2024	149	8.2	Red pine	5.0 - 8.9	Under stocked	1989	27	35	Thinning (first)
2024	401	8.3	Red pine	5.0 - 8.9	Stocked	1989	27	35	Thinning (first)
2024	104	16.1	Red pine	5.0 - 8.9	Under stocked	1989	27	35	Thinning (first)
2024	424	2.2	Red pine	> 15.0	Under stocked	1929	87	95	Thinning (third)
2024	64	8.1	Red pine	1.0 - 4.9	Stocked	1990	26	34	Thinning (first)
2025	13	19.4	Red pine	9.0 - 14.9	Stocked	1980	36	45	Thinning (second)
2025	525	42.4	Red pine	5.0 - 8.9	Stocked	1976	40	49	Thinning (second)
Flex	141	11.1	Aspen	5.0 - 8.9	Stocked	1933	83	-	Regeneration harvest
Flex	84.5	20.7	Red pine	9.0 - 14.9	Stocked	1917	99	-	Regeneration harvest
Flex	109.2	8.9	Red pine	9.0 - 14.9	Stocked	1911	105	-	Regeneration harvest
Flex	428	4.5	Red pine	9.0 - 14.9	Stocked	1917	99	-	Regeneration harvest
Flex	154	24.0	Red pine	9.0 - 14.9	Stocked	1917	99	-	Regeneration harvest
Flex	213	3.1	Aspen	9.0 - 14.9	Stocked	1953	63	-	Regeneration harvest
Flex	154.1	10.0	Red pine	9.0 - 14.9	Stocked	1917	99	-	Regeneration harvest
Flex	84.4	8.0	Red pine	9.0 - 14.9	Stocked	1918	98	-	Thinning (third)
Flex	84.2	25.3	Red pine	9.0 - 14.9	Stocked	1910	106	-	Thinning (third)
Flex	84.1	36.4	Red pine	> 15.0	Stocked	1910	106	-	Regeneration harvest