FOREST STEWARDSHIP PLAN

Audubon Center of the North Woods

PO Box 530
54165 Audubon Drive
Sandstone, MN 55072
(888)-404-7743

Section 15,16,21
Township 42N Range 21W
Pine County
535 Acres, *331 forested*

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The forest stewardship goals for this property are:

- Maintain and improve wildlife habitat favoring a diverse host of species.
- Promote educational and recreational opportunities.
- Promote the growth of native species, including oaks, sugar maple, and white pine.
- Restore native plant communities in areas impacted by past land use.

GENERAL PROPERTY DESCRIPTION

LANDOWNER PROFILE

Established on land donated to the National Audubon Society by Dr. Marguerite Schwyzer in 1968, the Audubon Center of the North Woods is a private, non-profit residential environmental learning center (RELC), a wildlife rehabilitation facility, and conference & retreat center nestled on the shores of Grindstone Lake near Sandstone, MN. The center offers a variety of environmental learning opportunities, with programming in natural history and science, team-building, adventure programming, and outdoor/environmental education. The property boasts a mixture of forests, wetlands, grasslands, and a developed campus including dormitories, dining hall, classrooms, a wildlife center, and lodges. Additional infrastructure around the campus includes an outpost cabin along Cty. Rd 17, a yurt north of the main campus, a National Oceanic and Atmospheric Administration (NOAA) weather station, and a primitive campground. The Audubon Center is committed to promoting biodiversity and long-term ecosystem health on the property.

LOCATION AND ACCESS

This property is located at 54165 Audubon Dr., Sandstone, MN 55072. Taking Interstate 35, the property is situated approximately 1.5 hours north of the Twin Cities metropolitan area, and 1 hour south of Duluth, MN. Access to the property can be found off of both Audubon Dr., and Cty Rd. 17. The property lies approximately 5 miles west of Interstate 35, and is situated on the eastern shore of Grindstone Lake. Interior access is good via the paved Cty Rd. 17, and a privately maintained gravel road leading to the main campus of the center. Additionally, a well-maintained system of ski/hiking trails is prevalent throughout much of the property.

SURROUNDING AREA

The surrounding area consists nearly entirely of private land, in a mixture of forest land and agriculture. The landscape in the immediate area is moderately to heavily fragmented in a matrix of these land-use types. Forest cover and the proportion of public land making up the landscape increases as one travels to the north, east, and west of the property, including the St. Croix, Nemadji, Solana, and Snake River State Forests. In addition, the property is relatively close to both Banning and St. Croix State Parks, placing the Center in a popular recreation area.

PRESENT VEGETATION AND LAND USE

The property currently consists of a mix of mature forests (50-100+ years old), young forest (0-50 years old), abandoned agricultural/pasture lands and wetland marshes. A large proportion of the forest on the property is in a mature growth stage, with some displaying old-growth characteristics. The abandoned agricultural/pasture lands are currently in a variety of states, ranging from restored prairie/savannah, to white pine invaded fields. There are several wetlands on the property, including cattail marshes, sedge meadows, seasonal vernal pools, open water ponds, and a perennial stream.

RARE FEATURES

The property contains forests somewhat unique to the area, including northern hardwood forests that display old-growth characteristics, and a relatively rare plant community along the lake shore portion of the property. Additionally, the property contains scattered white pines, especially along the lakeshore, which likely predate European settlement, and were spared from the exploitative logging that occurred near the turn of the century. Rare plant features on the property include the presence of blue beech or musclewood in the understory, the presence of butternut as a component of the forest, and the abundance of *Botrychium* species (a relatively rare genera of fern, see right). Grindstone Lake itself is quite unique to the area, being over 150 ft in depth, with cool and clear waters. The deep cool waters are rich in oxygen and support a cold water fishery including several species of trout, and a variety of warm water species common to area lakes.

SOILS

Soils on the property are homogenous, consisting mostly of gravely sandy loams. The soils also contain a large amount of boulders, and cobblestones, indicating that it likely lies on a glacial moraine. Soils immediately adjacent to Grindstone Lake contain higher proportions of coarse textured materials like sand and gravel. Drainage is moderate across much of the property, with the exception of well-drained sands near the lakeshore, and the poorly drained soils of the wetlands and vernal pool complexes, which contain higher organic matter content, and are likely seated above semi-impervious layers such as a clay lens (Simmons 1941).

STANDS DELINEATED

Stands were delineated across the property as areas within the property boundaries with similar vegetation composition, structure, and age. Pockets or inclusions may exist within the delineated boundaries where the composition differs slightly. However, in most cases it is impossible to map variations smaller than one acre.

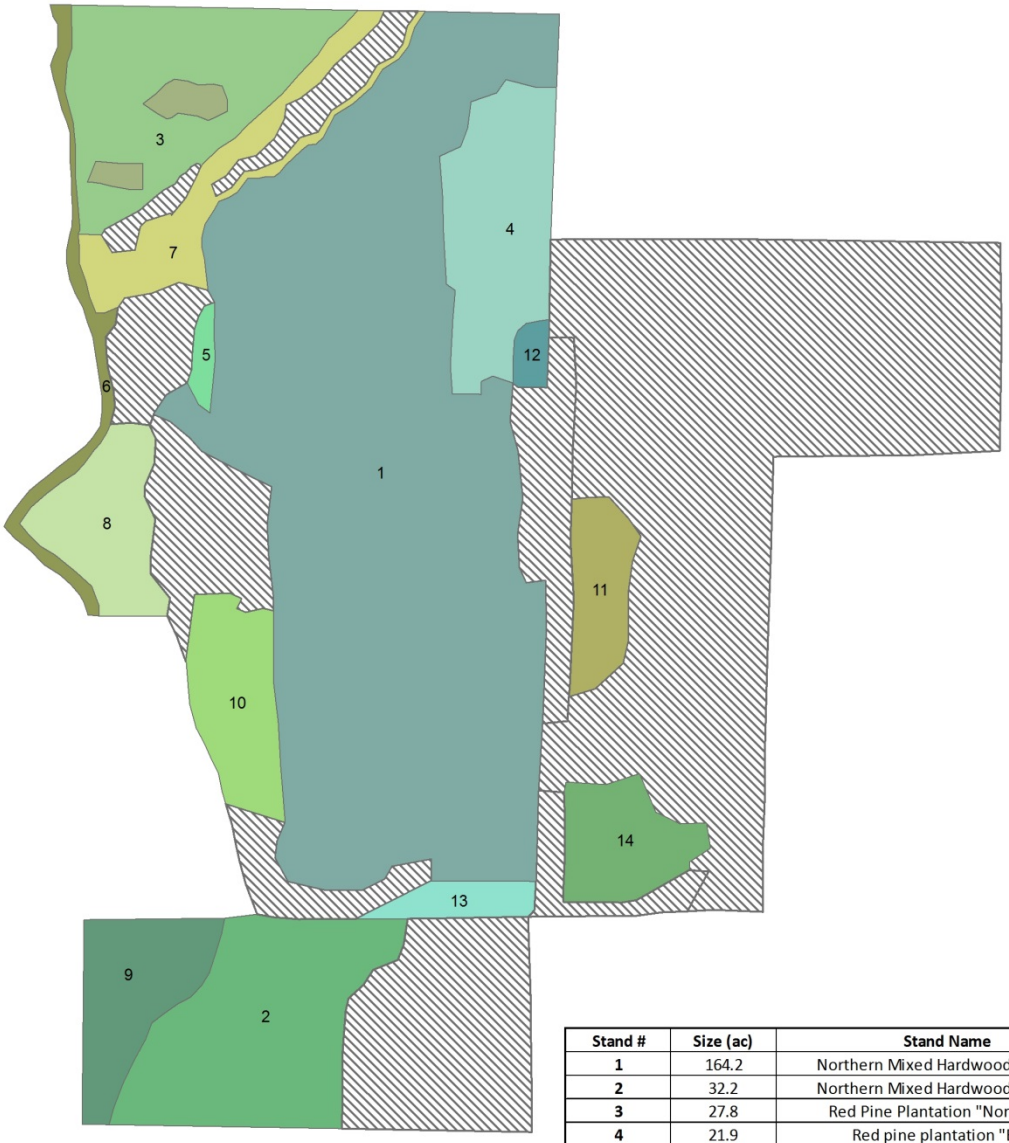
This Forest Stewardship Plan covers 14 different stands.

Table # 1 Stand List

Stand #	Description of Stand	Acreage
1	Northern Mixed Hardwoods, north of entrance road	164.2
2	Northern Mixed Hardwoods, south of entrance road	32.2
3	Red Pine Plantation, N.W. corner of property	27.8
4	Red Pine Plantation, along Cty. Hwy 17	21.9
5	Red Pine Plantation, adjacent to campus parking lot	1.6
6	Mixed Pine Woodland, lakeshore	6.4
7	Riparian Woodland, along Windmill Creek	13.0
8	Sugar Maple-Basswood, surrounding Schwyzer lodge	13.1
9	White Pine, adjacent to primitive campground	13.5
10	White Pine Invaded Field, adjacent to entrance road	13.0
11	White Pine Invaded Field, adjacent to wetland	8.3
12	Regenerating Hardwoods, adjacent to Cty. Hwy 17	1.7
13	Spruce Plantation, adjacent to entrance	4.1
14	Savannah Restoration Area, east of Cty. Hwy 17	10.5

Each stand is described in detail and contains the following information: number of acres; Native Plant Community classification; vegetation composition; and size and stocking of the dominant tree species. The stewardship objectives are identified and recommendations are made to meet the landowner's objectives. Additional and/or alternative objectives and recommendations may be provided as well.

Audubon Center: Stand Map



0 0.25 0.5 Miles

N

Stand #	Size (ac)	Stand Name
1	164.2	Northern Mixed Hardwoods "North"
2	32.2	Northern Mixed Hardwoods "South"
3	27.8	Red Pine Plantation "Northwest"
4	21.9	Red pine plantation "East"
5	1.6	Red pine plantation "Parking Lot"
6	6.4	Lakeshore Mixed Pine
7	13.0	Riparian Woodland
8	13.1	Sugar Maple-Basswood
9	13.5	White Pine "Primitive Camp"
10	13.0	White Pine Invaded Field "Entrance Road"
11	8.3	White Pine Invaded Field "Wetland"
12	1.7	Regenerating Hardwoods
13	4.1	Spruce Plantation "Entrance"
14	10.5	Savannah Restoration
Total	331.2	

Ecological Classification

ECOLOGICAL CLASSIFICATION SYSTEM

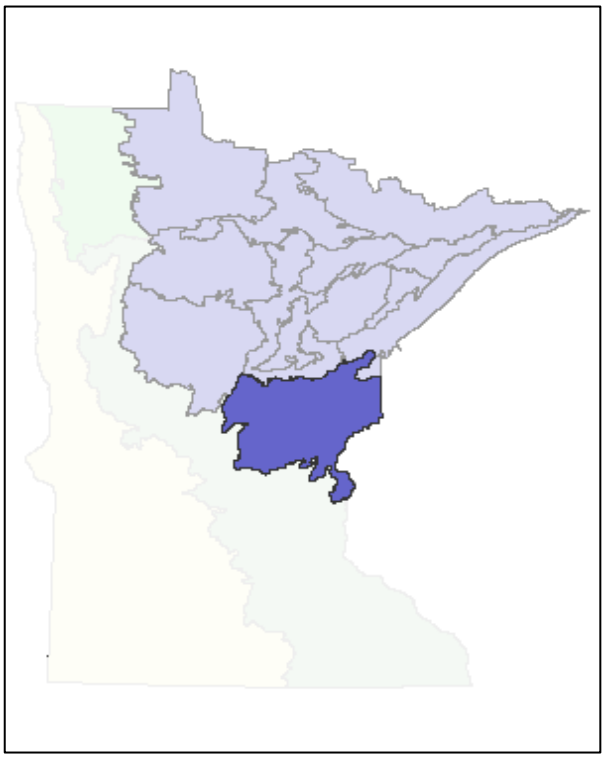
The Ecological Classification System (ECS) is a tool for the management of natural resources based on a statewide mapping system. Minnesota is extremely fortunate to have ECS as a tool to better understand the landscape and better implement natural resources management. Minnesota, Michigan, and Wisconsin are the only states in the country to have habit typing systems, with Minnesota being the only state using the ECS format specifically.

The ECS is a hierarchical system with the three upper levels being: Ecological Province, Section, and Subsection. The actual boundaries for the subsections are not as sharp as the lines on the map may imply, these should be viewed as fuzzy boundaries with associated gradients. Inclusions of one subsection type may lie inside another making classification based on key indicator species harder. The major ecological section in the area is known as the West Superior Uplands. Within this section a subsection has be identified as the Mille Lacs Uplands. For our purposes the West Superior Uplands key was used to classify the property. The purpose of providing this ecological information is to help assemble a picture of how this land, the functioning of its ecosystems, and associated management fit into the larger landscape.

The ECS system and its components are described in more detail on page 13.

MILLE LACS UPLANDS SUBSECTION

OVERVIEW



This subsection covers the large area of Superior Lobe ground moraines and end moraine in east-central Minnesota. Gently rolling till plains and drumlin fields are the dominant landforms in this eco-region. Brown and red till forms the parent soil material. It is a diverse area with upland hardwood forests consisting of northern red oak, sugar maple, basswood, and aspen-birch in the south and more conifers such as red pine, jack pine, balsam fir, and black spruce in the north. Occasional large remnant white pine are found across the landscape as well. Presently, forestry, recreation, and some agriculture are the most common land uses.

LANDFORMS

Gently rolling till plains and drumlin fields are the dominant landforms in this eco-region. The depressions between drumlin ridges contain peatlands with shallow organic material. There is a large end moraine that was the dam for the formation of Mille Lacs Lake. In the northeast, there is another series of end moraines, which marked later advances and retreats of the Superior Lobe.

CLIMATE

The climate is continental, with warm summers, and cold winters. Temperatures well below 0° Fahrenheit are common throughout the winter, and snow generally covers the ground during the months of December, January, February, and most of March. The average frost-free season is 122 days, however frosts are known to occur in every month of the year, except July (Simmons 1941).

HYDROLOGY

Major rivers running through this subsection include the St. Croix (which forms part of the eastern boundary) and the Kettle, Snake, Rum, and Ripple rivers. The drainage network is young and undeveloped, with extensive areas of wetlands present. There are 100 lakes greater than 160 acres in size. Most occur on end moraines.

PRE-SETTLEMENT VEGETATION

The original vegetation consisted of a mosaic of forest types. Northern hardwoods dominated much of the subsection, with red oak, sugar maple, and basswood being common components. To the north, and along the sandy terraces of area rivers, pine woodlands were quite common. Remnants of the white pine "big woods" can still be seen throughout the subsection. Peatland areas were inhabited by sedge-fen, black spruce-sphagnum, or white cedar-black ash communities.

NATURAL DISTURBANCE

Both fire and wind throw were and still are important in determining the vegetation of this subsection. Because dense glacial till is present at depths of 20 to 40 inches throughout most of the subsection, rooting depths for trees are shallow and wind throw is common. Historically, fire would have been very ecologically important, especially on areas of coarse

textured soils that were dominated by pine/oak woodlands. In recent years, fire has become less common due to intensive fire suppression efforts by local agencies, changing climate, and urban sprawl. This lack of fire has led to a slow transformation of cover types in the area leading to a dramatic increase in aspen and maple species as components of the local forests.

Native Plant Communities

NATIVE PLANT COMMUNITIES

The native plant community (NPC) is the finest level of classification for an area using the Minnesota Ecological Classification System. *The Field Guide to the Native Plant Communities of Minnesota-The Laurentian Mixed Forest Province* was developed by the Minnesota Department of Natural Resources (DNR) and describes each native plant community found in central and northeast Minnesota. For more information on this guide, visit the DNR web site:

www.dnr.state.mn.us/npc/ index.html.

The native plants and soils in an area and their interaction with each other and with the environment determine a particular native plant community. Native plant communities are classified considering vegetation, hydrology, landforms, soils, and natural disturbance regimes (i.e. wildfires, severe droughts, windstorms, and floods). Assigning a NPC for a given covertype or area tells us what plants are likely to naturally take over the area and what will occur as natural succession continues.

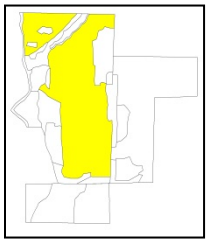
Areas that have been significantly altered by farming, overgrazing, non-sustainable logging, and development or where native species have largely been replaced by exotic or invasive species such as orchards, pine plantations, golf courses, and lawns are often not classified into native plant communities. However, if left idle and given enough time, these areas may possess some of the original plant species. Additionally, one can sometimes infer NPC type for these lands by using soils, landform, adjacent areas of vegetation, and local knowledge of forest ecology.

Minnesota has developed a standard naming system for its Native Plant Communities, using unique alpha-numeric codes to describe each NPC. These codes in themselves are quite descriptive of the NPC itself. For example **MHc36** where: "MH" indicates ecological system (Mesic Hardwoods), "c" indicates floristic region (Central), "3" represents the available moisture on a 0 to 9 scale, and "6" represents available nutrients on a 0 to 9 scale.

The native plant communities Identified on this parcel are the Central Dry-Mesic Oak-Aspen Forest (MHc26), Central Mesic Hardwood Forest (MHc36), Central Wet-Mesic Hardwood Forest (MHc47), Northern Dry-Bedrock Pine (Oak) Woodland (FDn22), Northern Wet Meadow/Carr (WMn82), and Northern Mixed Cattail Marsh (MRn83) and are described below as described in *The Field Guide to the Native Plant Communities of Minnesota-The Laurentian Mixed Forest Province*, a comprehensive guide to ECS in the region published and designed by the Minnesota Department of Natural Resources (MNDNR 2003).

Central Dry-Mesic Oak-Aspen Forest (MHc26)

Generally dominated by hardwood species such as red oak, and present on well-drained loamy or sandy soils. Generally found on stagnation moraines, till plains, and glacial river terraces.



VEGETATION STRUCTURE & COMPOSITION

Ground layer vegetation is often quite variable in cover and consists of a variety of graminoid and herbaceous species such as: large-leaved aster, Pennsylvania sedge, wild sarsaparilla, bracken, early meadow-rue, hog peanut, mountain rice grass, pale bellwort, wood anenome, Canada mayflower, large flowered bellwort, and Maryland black snakeroot.

Shrub layer is generally patchy with beaked hazelnut, chokecherry, downy arrowwood common. Additionally, red oak, red maple, and sugar maple saplings are important components.

Subcanopy is generally dominated by shade tolerant species such as sugar maple, ironwood, and red maple.

Canopy dominated by northern red oak, with paper birch, red maple, aspen, bur oak, and sugar maple common. Scattered white and red pines sometimes present.

NATURAL HISTORY

Catastrophic disturbance events were historically rare in MHn26. It has been estimated that catastrophic fire occurs at intervals of approximately 370 years, and wind throw events taking place on a 910 year rotation. While catastrophic events were uncommon, low intensity disturbances such as gap windthrow, and surface fires may have been much more common, and important in driving the development of this forest type.

NATURAL SUCCESSION

Based on historical composition and age structure of the MHc26 forest, the *Field Guide to the Native Plant Communities of Minnesota* suggests natural succession generally follows a similar trajectory to that described below:

- *Young Forests* (0–35 years*): Young forest recovering from fire/wind, dominated by aspen species, with minor components of northern red oak, and paper birch.

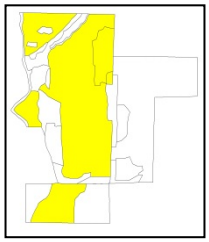
- *Transition Period* (35-55 years*): A transition forest with decline in aspen, and increase in birch and oak cover. White pine and white spruce become established in the understory.

- *Mature Forest* (55-135 years*): Mixed canopy of paper birch, aspen, northern red oak, with minor components of white pine.

- *Old Forests* (>135 years*): Characterized by mixed canopies similar to mature forest stage, however aspen, oak, and birch are maintained in canopy through fine scale or gap disturbance events.

  (* Forest age is measured in years from a ***major*** disturbance. It is not the average age of the trees found in that forest type.)

Central Mesic Hardwood Forest (MHc36)



Generally dominated by hardwood species such as basswood, sugar maple, red oak, and are present on well-drained loamy or sandy soils. Generally found on stagnation moraines, till plains, and glacial river terraces.

VEGETATION STRUCTURE & COMPOSITION

Ground layer vegetation is often quite variable in cover and consists of a variety of graminoid and herbaceous species such as: early meadow-rue, lady fern, large-flowered bellwort, Clayton's sweet cicely, Pennsylvania sedge, large-leaved aster, wild sarsaparilla, zigzag goldenrod, hog peanut, and yellow violets.

Shrub layer is variable with chokecherry, pagoda dogwood, prickly gooseberry, and beaked hazel common components. Additionally, red oak, basswood, ironwood, and sugar maple saplings are important components.

Subcanopy is generally dominated by sugar maple with ironwood, red maple, and basswood being secondary components.

Canopy is continuous and dominated by northern red oak, basswood, and sugar maple. Red maple, aspen, bur oak, paper birch and green ash can also be important components. White pine can be an important super canopy species when present.

NATURAL HISTORY

Catastrophic disturbance events were historically rare in MHn36. It has been estimated that catastrophic fire occurs at intervals exceeding 1000 years, and wind throw events taking place on a 380 year rotation. While catastrophic events were uncommon, low

intensity disturbances such as gap windthrow, and surface fires may have been much more common with occurrence intervals of approximately 40 years, and important in driving the development of this forest type.

NATURAL SUCCESSION

Based on historical composition and age structure of the MHc36 forest, the *Field Guide to the Native Plant Communities of Minnesota* suggests natural succession generally follows a similar trajectory to that described below:

- *Young Forests* (0–35 years*): Young forest recovering from fire/wind, dominated by northern red oak, with minor components of aspen species, and basswood.

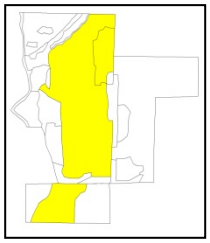
- *Transition Period* (35-95 years*): A transition forest with decline in northern red oak, and replacement by sugar maple. Ironwood, basswood, American elm, and white pine become established in the understory.

- *Mature Forest* (>95 years*): Mixed canopy of sugar maple, northern red oak, and basswood, with minor components of white pine and bur oak.

  (* Forest age is measured in years from a ***major*** disturbance. It is not the average age of the trees found in that forest type.)

Central Wet-Mesic Hardwood Forest (MHc47)

Wet mesic hardwood or mixed forest on loamy somewhat poorly drained soils with clay sub-horizons. Often dominated by basswood or black ash, with dense herbaceous understories dominated by grass and sedge species.



VEGETATION STRUCTURE & COMPOSITION

Ground layer vegetation is continuous and consists of a variety of graminoid and herbaceous species such as: lady fern, early meadow-rue, large-flowered bellwort, Clayton's sweet cicely, Pennsylvania sedge, large-leaved aster, wild sarsaparilla, zigzag goldenrod, hog peanut, yellow violets, nodding fescue, bearded short husk, starry sedge, and graceful sedge.

Shrub layer is sparse to interrupted with chokecherry, nannyberry, prickly gooseberry, and beaked hazel common components. Additionally, black ash, red oak, basswood, ironwood, blue beech and sugar maple saplings are important components.

Subcanopy is generally dominated by sugar maple, ironwood, basswood, with bur oak, blue beech and black ash being minor components.

Canopy is interrupted to continuous and strongly dominated by basswood and black ash. Sugar maple, bur oak, northern red oak, red maple, green ash and white pine can be important when present.

NATURAL HISTORY

Catastrophic disturbance events were historically rare in MHc47 with both fire and wind disturbances occurring at intervals over 1000 years. Lower intensity disturbances occurred at more frequent intervals, with wind created gaps playing a role in development of forest structure.

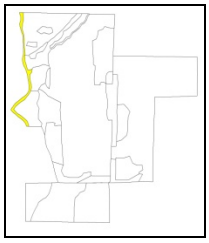
NATURAL SUCCESSION

Based on historical composition and age structure of the MHc47 forest, the *Field Guide to the Native Plant Communities of Minnesota* suggests natural succession generally follows a similar trajectory to that described below:

- *Young & Mature Forests*: species composition of this forest was fairly consistent throughout the age of the stand historically, with black ash and basswood dominating the canopy at all ages. Aspen species generally are more important components when forests are younger than 75 years.

Northern Dry-Bedrock Pine (Oak) Woodland (FDn22)

Dry pine woodlands on shallow, or excessively drained soils, often in association with hillsides, rock ledges and terraces. Occasionally oak is common in the canopy.



VEGETATION STRUCTURE & COMPOSITION

Ground layer is patchy to nearly continuous with common plants including Canada mayflower, wild sarsaparilla, large-leaved aster, poverty grass, wintergreen, and bracken fern. Lichens and mosses can also be important components of the system.

Shrub layer commonly include lowbush blueberry and juneberries on most sites. Red maple saplings and bush honeysuckle are most common and important components.

Subcanopy is often missing from the system as an effect of fire, however when present paper birch and red maple can be important.

Canopy dominated by red and white pine with oaks playing a role on some sites. Canopy is patchy to continuous, often with open areas exposing the ground to direct sunlight.

Catastrophic disturbance events were occasional throughout FDn22, with both canopy and surface fires occurring at rotations over 100 years (195 & 255 respectively). Together combined these two types of fire brought fire to FDn22 at a rotation of about 107 years. Windthrow is thought to be uncommon and occurring at intervals of over 1,000 years.

NATURAL SUCCESSION

Based on historical composition and age structure of the FDn22 forest, the *Field Guide to the Native Plant Communities of Minnesota* suggests natural succession generally follows a similar trajectory to that described below:

- *Young Forests* (0–55 years*): Young forest recovering from fire dominated by mixed pine with components of aspen and paper birch common.

- *Transition Period* (55-75 years*): A transition forest with decline in jack pine and an increase in red and white pines.

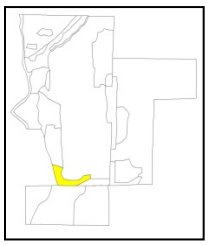
- *Mature Forest* (75-115 years*): Mature woodlands dominated by red and white pine, with scattered large jack pines common. Quaking aspen, paper birch, and northern red oak may be important on some sites.

- *Old Forests* (>115 years*): Characterized by mixed canopies of red, white, and jack pines. White pine seedlings may be very abundant in the understory.

  (* Forest age is measured in years from a ***major*** disturbance. It is not the average age of the trees found in that forest type.)

Northern Wet Meadow/Carr (WMn82)

Open wetland dominated by graminoid species, or tall shrubs on mineral soil or peat, and along riparian areas.



VEGETATION STRUCTURE & COMPOSITION

Ground Layer brown and sphagnum mosses common with variable cover. Dense graminoid cover with Canada bluejoint, lake sedge, tussock sedge, and beaked sedge being dominant. Forb cover is patchy and generally consists of marsh bell-flower, tufted loosestrife, marsh skullcap, great water dock, northern marsh fern, smartweeds, and willow herbs.

Shrubs are variable with willows, red-osier dogwood, speckled alder, and meadowsweet most common.

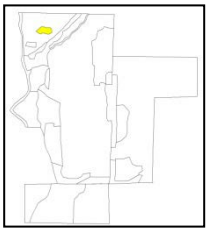
Trees have low cover and rarely exceed 6 ft, and consist nearly entirely of American elm and black ash.

NATURAL HISTORY

WMn82 floods commonly with spring runoff and heavy rain events. Periodic drawdown events throughout the summer can be important in the promotion of the wide species variety. Inundation is common enough to prevent forest from being established, however for much of the year standing water is not present.

Northern Mixed Cattail Marsh (MRn83)

Open wetland dominated by graminoid species, or tall shrubs on mineral soil or peat, and along riparian areas.



VEGETATION STRUCTURE & COMPOSITION

Aquatic species such as duckweed, and bladderwort commonly present

Ground Layer bluejoint grass, woolgrass, and cattails dominate. Forb species commonly present include marsh cinquefoil, tufted loosestrife, and willow-herbs.

Shrubs sparse with willows being the only notable component.

Trees rarely present with black ash being a minor component in some systems.

NATURAL HISTORY

MRn83 develops on soils that are inundated for the majority of the year. Hydrophytic plants thrive, while upland species are generally excluded.

Site Productivity, Stand Inventory & Management

SITE PRODUCTIVITY

SITE INDEX

Site indices were calculated using the ages and heights of several samples of dominant species on the property. Site index represents the expected height of dominant trees on a site at 50 years of age. To determine site index, heights were measured with a clinometer and ages were determined from tree-ring samples collected using an increment borer. The site index values in Table 2 highlight that the property has relatively high productivity for all of the common tree species, but they should be examined with some limitations in mind. First, the equations used to determine these numbers were not site specific, and were developed elsewhere within the Lake States region. Second, there were also a limited number of trees examined, in the case of white pine and white oak only one tree was measured. Despite these limitations, these numbers are impressive for the region.

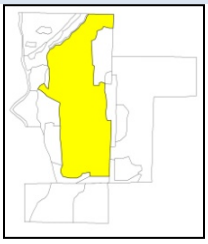
Table 2. Site index values in feet for common species at Audubon Center of the Northwoods.

Species	Site index	Standard Deviation	Typical Site Index Range in MN
red pine	67	5.1	40-75
white pine	61	NA	40-75
red oak	61	2.6	40-70
sugar maple	54	1.4	30-70
white oak	54	NA	40-75

STAND #1: Northern Mixed Hardwood "North"

Acres: 164.2

NATIVE PLANT COMMUNITIES



MHc26 Central Dry-Mesic Oak-Aspen Forest

MHc36 Central Mesic Hardwood Forest

MHc47 Central Wet-Mesic Hardwood Forest

TYPE DESCRIPTION

Stand 1 is the biggest stand on the property; and may best resemble the pre-settlement forest. It is primarily a mesic hardwood stand dominated by red oak and maple, with a gradient from dry mesic systems on hilltops to wet mesic systems in depressions. There are moderately well-drained soils with loamy to fine sandy texture on the site. Stem counts are relatively well distributed amongst several species, with sugar and red maple, balsam fir, trembling aspen, and red oak being most dominant. Higher areas were dominated by red oak, with lower areas dominated more heavily by maple, ash and balsam fir. Some vernal pools are present, which are dominated by black ash.

Despite there being much more sugar maple in terms of density, red oak has a similar value for basal area reflecting its presence in the stand primarily as large mature trees. This would be expected in a mature MHc36 or MHc26 forest, where the sugar maple matures to create a mixed canopy with red oak. From the site index measurements derived from trees in this stand, it is evident that both these species exhibit strong growth traits in the area. The stem distribution (Figure 1) and regeneration data (Table 3) are both characteristic of a mature stand with some old- growth characteristics. The sapling and seedling distribution reflects that this stand is in a late successional stage, with shade tolerant species like maple, balsam fir, and ironwood dominating the understory. Mid and low tolerant species such as red oak and trembling aspen are much less common in the understory, which would be expected.

Although there is a seemingly high amount of sugar maple regeneration, deer browse is severely limiting the establishment of a young cohort of sugar maple. The deer exclosure in the northeast portion of the stand has effectively promoted sugar maple regeneration – sugar maple seedlings are roughly twice as abundant within the exclosure and sapling counts were on the order of 20 times higher than in the rest of the stand (based on one plot within the deer exclosure).

Another interesting note from the understory data is the abundance of musclewood, or blue beech, this is fairly uncommon in Minnesota and is an indicator of pristine sites with little human intervention or other past disturbance. One more unique feature of this stand was the presence of *Botrychium* species, a somewhat rare genus of ferns that also serve as an indicator for pristine sites. Adult butternut is another unique feature to this stand. Butternut has largely been decimated by butternut canker in Minnesota and with this disease present on site it may not be a prominent component of the stand in the future.

Table 2. Overstory tree summary for Stand #1.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area (ft^2/Acre)**	**Avg. Diameter (in)**
balsam fir	46	9.1	5.8
red maple	36	17.9	8.8
sugar maple	53	31.9	9.0
yellow birch	2	0.6	7.2
paper birch	13	4.8	7.3
black ash	27	8.2	6.7
green ash	11	6.6	9.7
butternut	1	0.5	12.1
ironwood	6	0.9	5.1
white spruce	3	0.5	5.6
white pine	1	1.0	13.0
bigtooth aspen	4	5.5	15.2
trembling aspen	17	10.7	10.2
white oak	1	0.5	10.7
bur oak	4	2.0	8.9
red oak	18	25.0	14.7
basswood	12	7.6	9.5
American elm	5	1.3	6.2
Total:	**258**	**152.9**	**8.62**

Figure 1. Diameter distribution for Stand #1.

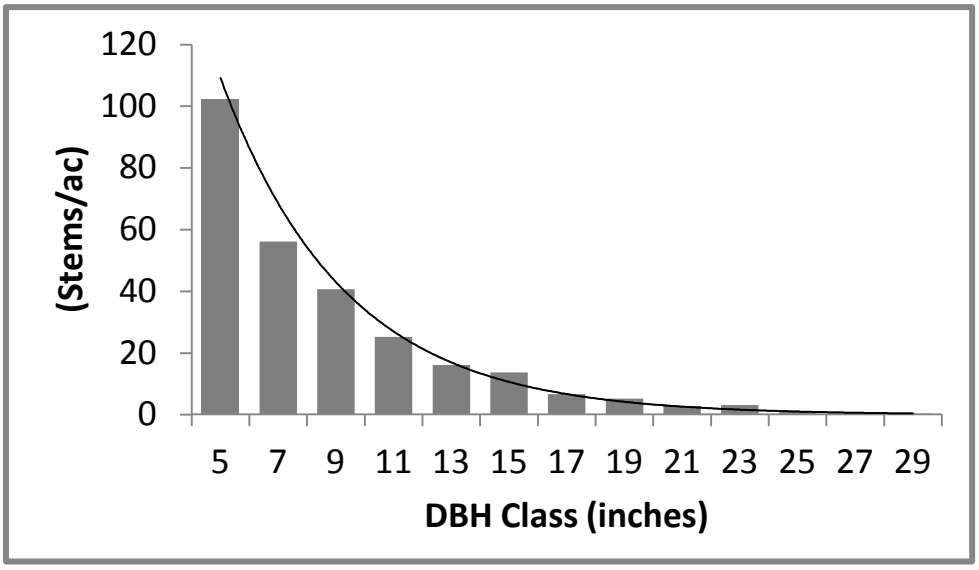


Table 3. Regeneration— Seedlings and saplings in the understory for Stand #1 (stems/acre). Seedlings were defined as stems < 4.5 ft whereas sapling were stems > 4.5 ft and < 4 in. DBH.

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
balsam fir	86	446
sugar maple	250	13,769
red maple	37	5,046
red oak	6	708
black ash	122	1,923
trembling aspen	5	523
ironwood	79	246
basswood	14	123
green ash	13	862
musclewood	23	123
gooseberry	0	123
paper birch	42	138
yellow birch	2	0
bur oak	2	31
American elm	3	46
juneberry	1	31
white spruce	1	15
butternut	3	0
honeysuckle spp.	0	15
Total:	**690**	**24,169**

STEWARDSHIP OBJECTIVES

Management goals for this site are to maintain the integrity of important mesic hardwood species such as sugar maple and red oak, along with promoting wildlife habitat.

RECOMMENDATIONS

There are several different directions in which this stand could be taken in the future – the management approach will depend upon the desired species composition of the stand, and the consideration of rare and sensitive species on site. The stem distribution graph (Figure 1) shows the current distribution of trees by diameter class and the overall shape of the curve indicates a stand characterized by a high number of young/small trees and a low number of large mature trees. The current conditions will perpetuate the dominance of sugar maple as older trees die and open small gaps in the canopy, creating suitable conditions for suppressed and intermediate sugar maple saplings to enter the canopy.

Species like northern red oak and paper birch are likely to decline as a result of low light availability to advanced regeneration.

Creating ¼-acre to ¾-acre gaps interspersed throughout the stand will aid the establishment of young cohorts of mid-tolerant and intolerant species such as northern red oak, American basswood, black and green ash, bigtooth aspen, white pine, and yellow birch. These gaps could be achieved through group selection harvests ideally in the winter (to minimize soil compaction). In order to create suitable soil conditions for regeneration of the aforementioned species, the surface should be scarified (exposing mineral soil) in the gaps following harvest, paying special attention to areas with heavy sedge cover – this could be achieved with a 4-wheeler and a chain-rake.

Following harvest and site preparation in the gaps, there should be no need for planting to achieve regeneration goals. The surrounding forest should contribute a desirable mix of seed to the gaps and if competing vegetation (sedges, shrubs, etc.) are successfully controlled, the establishment of a young cohort should be fairly painless. It is possible that some advanced regeneration will be released immediately following harvest.

If the desired structure of the stand includes a canopy dominated by sugar maple, single tree selection harvests will facilitate the development of saplings in the understory. This type of harvesting operation is used to emulate small scale wind disturbance events, and is quite effective at promoting the recruitment of shade tolerant species. Tree species that would benefit from this harvesting method include sugar maple, red maple, American basswood, black ash, and green ash. This method will rely on the ability of advance regeneration to grow into the overstory following gap creation and will perpetuate the current stand structure.

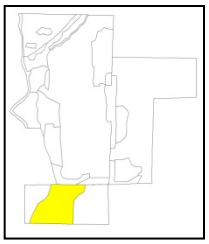
STAND #2: Northern Mixed Hardwoods "South"

Acres: 32.2

NATIVE PLANT COMMUNITIES

MHc36 Central Mesic Hardwood Forest

MHc47 Central Wet-Mesic Hardwood Forest



TYPE DESCRIPTION

Stand 2 is the mesic hardwood stand south of Audubon road. In terms of stand structure and composition it is very similar to Stand 1. It consists of moderately well drained, loamy or fine sandy soils. It has a lower stand density and fewer saplings per acre, but these discrepancies could be due to higher sampling variability from measuring fewer plots. It contains a variety of mesic hardwood species, with the highest stem counts in red and sugar maple by far, followed by aspen, ash, and red oak. As with Stand 1, red oak primarily exists as large, overstory individuals contributing the highest basal area per acre in the site. As is typical in the MHc36 system, red oak is the most important canopy species alongside maple. The significant presence of ash and aspen indicates that there may be some lower, more wet-mesic depressions in this site. This would suggest some NPC inclusions of MHc47 within the predominantly MHc36 site. The sapling data is typical of a mature fine hardwood stand. There is a strong presence of shade tolerant species like maple, balsam fir, ironwood, and musclewood, and a lower abundance of mid and low tolerant species like oak and aspen. Seedling data was not collected on this site because field data was collected well into fall when leaf out had long since occurred, but numbers similar to that of Stand 1 could be expected.

Table 4. Overstory tree summary for Stand #2.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
aspen spp.	37	17.6	8.5
ash spp.	28	12.4	8.1
maple Spp.	78	28.5	7.6
red oak	22	29.6	14.7
balsam fir	15	1.9	8.7
other hardwoods*	27	12.9	8.3
Total:	**207**	**96.9**	**8.7**
*American basswood, ironwood, American elm, white oak, bur oak			

Table 5. Regeneration— Saplings in Stand #2 (stems/acre).

Regeneration Summary	
Species	**Saplings/Acre**
sugar maple	75
red maple	77
balsam fir	85
ash spp.	153
basswood	17
aspen spp.	5
musclewood	22
ironwood	35
white spruce	2
bur oak	3
red oak	2
Total:	**475**

STEWARDSHIP OBJECTIVES

Management goals for this site are to maintain the integrity of important mesic hardwood species such as sugar maple and red oak, along with promoting wildlife habitat.

RECOMMENDATIONS

If left alone, this site will likely progress to a late successional forest composed primarily of shade tolerant species such as red/sugar maple and balsam fir, with mid-tolerant species like red oak disappearing from the site. This is reflected in the sapling data, showing red maple, sugar maple, and balsam fir dominating the understory while red and bur oak occur infrequently. In order to promote oak regeneration it would be advisable to cut half-acre

gaps. This would allow more sunlight to reach the understory and would aid the growth of young, mid-tolerant trees. When choosing areas to cut gaps for regeneration, areas with existing oak regeneration, or oak "grubs" would be most suitable. The quality of sugar maple could also be improved by using a single tree selection approach to promote small canopy gaps to release understory sugar maple. Deadwood and non-hazardous snags could be left on site to provide wildlife habitat. The gap cutting could also provide some shrubs such as raspberry and blackberry for wildlife, along with mast production from oaks in the future.

STAND #3: Red Pine Plantation "Northwest"

Acres: 27.8

NATIVE PLANT COMMUNITIES

*MHc36 Central Mesic Hardwood Forest

*MHc26 Central Dry-Mesic Oak-Aspen Forest

*MRn83 Northern Wet Meadow/Carr

*Classification based on estimation using topography, soils, and understory. Wetland community occupies the lowland depression, an inclusion within the stand.

TYPE DESCRIPTION

This red pine plantation resides north of the visitor's center and extends from the lakeshore to the northeast end of the property. This stand includes a sedge meadow surrounded by oak, green alder, and paper birch in the central area of the red pine plantation. The entire stand except for the far northeast corner has had some variable-density thinning conducted in the past – this method is based on ecological principles that promote heterogeneous densities across the stand. Dominant trees in the main canopy are red pine. The understory has many different species, including balsam fir, red maple, sugar maple, red oak, white pine, red pine, butternut, and paper birch. White pine is especially abundant in the small gaps near the lake where there is seed available from adjacent white pines along the shoreline. The shrub layer includes a patchy distribution of elderberry, honeysuckle species, and red maple. Soils are loamy sands, similar to the soils across the property. This area was likely a rich northern hardwood forest (MHc26, MHc36, MHc47) before the plantation was established.

Table 6. Overstory tree summary for Stand #3.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
red pine	224	137.3	10.4
paper birch	4	0.5	4.6
Total:	**229**	**137.8**	**7.5**

Table 7. Regeneration— Seedlings and saplings in Stand #3 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
sugar maple	129	3222
red maple	64	1778
paper birch	264	1556
red oak	49	1111
red pine	264	556
green ash	7	333
white pine	218	153
balsam fir	202	111
chokecherry	4	111
ironwood	4	0
winterberry	31	0
white oak	11	0
honeysuckle	4	0
black cherry	4	0
big tooth aspen	42	0
Total:	**1082**	**8778**

STEWARDSHIP OBJECTIVES

Goals for this stand would be to promote growth and development of red and white pine for educational opportunities, create wildlife cover, provide wildlife food sources, increase species diversity, and increase structural heterogeneity.

RECOMMENDATIONS

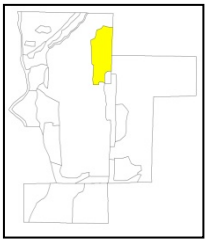
Thinning out the overstory of red pine will be needed to recruit white pine seedlings and saplings into the overstory and create more of a heterogeneous structure that is less vulnerable to natural disturbances. Different sized gaps could be used to promote various

tree and shrub species as well. Smaller gaps possibly ¼ to ½ of an acre can be used to promote white pine regeneration and larger gaps of ½ to ¾ of an acre may be used to promote red oak in the stand. It is advised to promote white pine and red oak on this site given the presence of the fungal pathogens *Diplodia spp. and Sirococcus spp.* which attack red pine and can cause failure in regeneration. Scarification, or disturbance of the topsoil, may also be used to promote white pine regeneration as there is a serious herbaceous/grass ground layer that may impede seedling establishment. These different sized gaps will also provide increases in wildlife cover and food sources. In the case of a gap opening or thinning, pine seedlings should be bud capped annually to provide protection from deer browse, until they reach 5 ft in height. By incorporating gap harvests, and thinning into this stand, there may be additional educational opportunities for the study of ecology, species diversity, forest tree pathogens, and increased growth caused by forest management.

STAND #4: Red Pine Plantation "East"

Acres: 21.9

NATIVE PLANT COMMUNITIES



*MHc36 Central Mesic Hardwood Forest

*MHc47 Central Wet-Mesic Hardwood Forest

*Classification based on estimation using topography, soils, and understory.

TYPE DESCRIPTION

The red pine plantation on the east end of the property near Fox Rd. is smaller than the plantation on the north end of the property. The stand resides on an east-facing slope. This stand has had row thinnings conducted recently. The species composition in the canopy is dominated by red pine while the understory composition varies with the topography of the site. In upland areas, the understory communities are mainly composed of sugar maple, red maple, red oak, aspen, ash, and ironwood. The understory near the bottom of the slope is composed primarily of balsam fir with minor components of red maple, ash, and paper birch. The red pine plantation also partially includes a deer exclosure on the upper portion of the slope. Soils are consistent with those found in the hardwood communities on the property, indicating that the stand was likely historically mesic-hardwood forest prior to the establishment of the plantation.

Table 8. Overstory tree summary for Stand #4.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area(ft.^{2}/acre)**	**Avg. Diameter (in.)**
Red pine	183	118.0	10.7
butternut	3	0.3	4.1
trembling aspen	3	2.7	12.8
American elm	2	0.3	5.6
boxelder	2	0.2	4.3
basswood	3	0.4	4.9
Total:	**195**	**122.0**	**7.0**

Table 9. Regeneration— Seedlings and saplings in Stand #4 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
sugar maple	26	692
red maple	185	1385
paper birch	78	231
red oak	14	692
red pine	78	77
green ash	0	0
balsam fir	23	154
chokecherry	9	231
ironwood	3	0
winterberry	17	308
white oak	2	0
honeysuckle	25	538
black cherry	3	0
big tooth aspen	0	0
white pine	218	154
black ash	14	462
amur maple	2	0
red-berried elder	14	0
raspberry	0	2154
Total:	**711**	**7077**

STEWARDSHIP OBJECTIVES

Goals for this stand include wildlife habitat, promotion of understory species, timber production, and increased diversity of tree species.

RECOMMENDATIONS

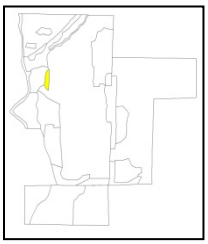
It may be in the interest of ACNW to plan for additional thinnings in this stand to allow further growth and development of the red pine and promote more species diversity in the understory. Thinning allows more sunlight to reach the forest floor, which would promote species such as red oak, red pine, paper birch, and white pine to take hold. This will also provide more food for wildlife species and provide cover for ruffed grouse and other bird species, as shrub species will proliferate and provide additional structure and food sources. Increasing the species diversity of the stand also ensures that it will have great adaptation potential in regards to global changes and fluctuations in natural disturbance regimes.

STAND #5: Red Pine Plantation "Parking Lot"

Acres: 1.6

NATIVE PLANT COMMUNITY

N.A. (Lacking sufficient native vegetation for classification)



TYPE DESCRIPTION

This stand is a small red pine plantation immediately adjacent to the visitor parking lot on the main campus. The stand is well-stocked with well-formed red pine. The understory is strongly dominated by green ash saplings and weedy grasses.

Table 10. Overstory tree summary for Stand #5.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area (ft.²/acre)**	**Avg. Diameter (in.)**
red pine	160	163.44	13.60

Table 11. Regeneration—Seedlings and saplings in Stand #5 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
green ash	4,360	9,000
basswood	60	0
boxelder	60	0
American elm	20	0
iron wood	20	0
honeysuckle	20	1,000
Total:	**4,540**	**10,000**

STEWARDSHIP OBJECTIVES

The primary objectives of this stand are to maintain aesthetic value near the main campus of the ACNW. Additional objectives include, retaining conifer cover, promoting forest health, and providing timber income.

RECOMMENDATIONS

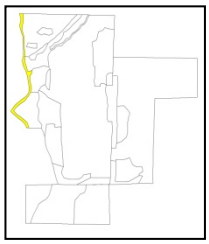
The inventory data shows a basal area of ~163 sq. ft./acre, suggesting that the stand may benefit from a thinning operation in the near future. Thinning would reduce competition and promote radial growth of remaining red pine, increasing carbon storage, and timber production. In the event of a final harvest, site preparation to remove green ash seedlings is recommended. Green ash is not commercially valuable and due to the impending invasion of emerald ash borer, it may be in the ACNW's interest to diversify the regenerated stand with planting. It is presumed that this area was a mixed hardwood stand based on the soils present, and restoring to this condition may be beneficial. Planting species such as sugar maple, red oak, basswood, and white pine following any final harvest is recommended.

STAND #6 : Lakeshore Mixed Pine

Acres: 6.4

NATIVE PLANT COMMUNITY

FDn22 Dry-Bedrock Pine (Oak) Woodland



TYPE DESCRIPTION

This stand consists of a narrow strip of land along the entire length of the property's lakeshore. The soils within this narrow band are coarser, consisting of a higher gravel and sand component. This, coupled with generally steep slopes falling toward the lake, and a west aspect give the stand very well-drained soils, leading to a forest significantly different from other forests on the property. The drier, warmer microclimate in this stand has made this stand express qualities of a fire dependent woodland, something not seen in any of the other stands on the property. The forest cover consists of a mixture dominated by red and white pines in a mixture of size classes. Additionally, this stand has components of red oak, red maple, sugar maple, and other mesic hardwood species. Typically these mesic species would not be components of a fire-dependent woodland, however, proximity to the neighboring hardwood stands, lake effects, and recent fire suppression efforts have likely allowed these species to establish themselves in this unique stand.

Table 12. Overstory tree summary for Stand #6.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
red pine	185	170.83	12.08
white pine	70	90.94	13.79
paper birch	45	10.94	6.42
hardwood spp. *	30	16.31	7.73
Total:	**330**	**289.02**	**11.38**
* red maple, boxelder, American elm, bigtooth aspen			

Table 13. Regeneration—Seedlings and saplings in Stand #6 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
red pine	0	1,500
white pine	65	750
balsam fir	240	0
paper birch	30	500
green ash	10	0
sugar maple	5	0
Total:	**350**	**2,750**

STEWARDSHIP OBJECTIVES

The primary objectives of this stand are to maintain aesthetic value along the shore of Grindstone Lake, protect water quality, provide wildlife habitat, and promote forest health and longevity of the present stand.

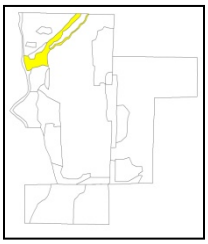
RECOMMENDATIONS

Our inventory data shows that this stand is quite densely stocked, with high basal area and trees per acre values for a woodland of this type. The high stocking is likely a reflection of the high quality soils, increased sunlight from a West aspect, and lack of management. It may be wise to consider light thinnings in this stand in the future to promote radial growth in the reserved trees, and to increase regeneration and recruitment of saplings into the canopy. Removal of a portion of the canopy may help to provide suitable conditions for pine seedlings to proliferate. Given the proximity to Grindstone Lake, any timber harvest in this area should be done with extreme care, and should be performed in the winter only to reduce potential erosion. All dead standing trees should be retained when possible, especially tall red and white pines. These trees can provide exceptional nesting and perch sites for birds of prey. An alternative to traditional harvesting/thinning operations may include the girdling of trees. This method would target and kill selected trees to open the canopy, however would leave the standing bole as vertical structure for wildlife habitat.

STAND #7: Riparian Woodland

Acres: 13.0

NATIVE PLANT COMMUNITIES



MRn83 Northern Mixed Cattail Marsh

WMn82 Northern Wet Meadow/Carr

Various Forested NPC types (highly mixed, and not well differentiated)

TYPE DESCRIPTION

The area described as the "riparian stand" is located along the edge of Windmill Creek, running through the northern portion of the property. It does not really function as a contiguous stand in the traditional sense but is more so a collection of small areas that did not fit uniformly in other covertype classifications. In the far eastern edge of the stand, it is mosaic of swamp, sedge meadow, and patches of low productivity aspen and balsam fir. As it progresses further west there are patches of low density meadows dominated by sedge ground cover with scattered green ash, bur oak, and American elm. The western portion of the stand near the bridge is more characteristic of a mesic hardwood stand, with stronger components of red oak and sugar maple. Tag alder was present as a shrub component in most areas.

Table 14. Overstory tree summary for Stand #7.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
red oak	33	19.0	9.5
white pine	3	9.2	22.5
paper birch	13	4.2	7.2
maple spp.	53	15.7	6.1
aspen spp.	80	32.8	8.0
balsam fir	67	9.8	5.1
white spruce	3	1.8	9.9
Other hardwoods*	30	13.6	8.3
Total:	**283**	**106.0**	**7.3**
* butternut, basswood, green ash, ironwood, bur oak, American elm			

Table 15. Regeneration— Seedlings and saplings in Stand #7 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
sugar maple	163	1000
red maple	20	0
balsam fir	153	0
ash spp.	17	167
basswood	3	0
aspen spp.	33	167
ironwood	63	333
American elm	3	0
paper birch	3	0
red pine	3	0
red oak	17	0
Total:	**480**	**1667**

STEWARDSHIP OBJECTIVES

Benefits of this site include the presence of wildlife habitat, protection of water quality and use as a wildlife corridor.

RECOMMENDATIONS

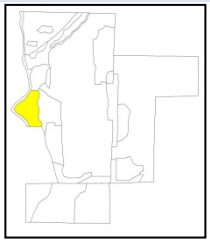
This stand does not require any management activity. The presence of alder on site provides habitat for several wildlife species such as ruffed grouse and woodcock. This area can act as a riparian buffer from any harvesting activities in adjacent stands, preventing erosion and runoff into the stream and indirectly Grindstone Lake. As a corridor, it could provide habitat and a travel route for wildlife if harvesting takes place in the red pine plantation or the main hardwood stand. This stand provides a unique water resource for the site and will serve the surrounding environment best if left alone. Any harvesting within this stand may lead to erosion problems, and sedimentation to Grindstone Lake.

STAND #8: Sugar Maple-Basswood

Acres: 13.1

NATIVE PLANT COMMUNITY

MHc36 Central Mesic Hardwood Forest



TYPE DESCRIPTION

This stand has been delineated to include the sugar maple dominated forest that lies to the west of the sugar shack, and extends west to include the sugar maple dominated forest surrounding the Schwyzer Lodge and Intern House. The stand is strongly dominated by mature sugar maple, with components of red oak, basswood, green ash, and black ash. The understory is patchy, with sugar maple seedlings and saplings being the major component in recently opened canopy gaps. Cover in the understory is lower than the potential for this forest type, likely an effect of browsing by white-tailed deer.

Table 16. Overstory tree summary for Stand #8.

Overstory Summary			
Species	**Density Trees/Acre**	**Basal Area(ft.²/acre)**	**Avg. Diameter (in.)**
sugar maple	84	89.43	12.03
basswood	20	23.90	13.96
black ash	4	11.24	22.70
white pine	8	31.15	26.70
Total:	**116**	**155.72**	**13.74**

Table 17. Regeneration— Seedlings and saplings in Stand #8 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
sugar maple	508	51,600
basswood	44	0
black ash	56	0
green ash	12	1,400
boxelder	8	0
red oak	32	0
ironwood	36	0
paper birch	0	400
white pine	0	200
balsam fir	0	200
misc. shrubs*	24	2,600
Total:	**720**	**56,400**
*juneberry, honeysuckle, gooseberry, raspberry, winterberry		

STEWARDSHIP OBJECTIVES

Primary goals of this stand are to promote and sustain sugar maple as a dominant component of the stand, maintain existing white pine, and promote regeneration of white pine.

RECOMMENDATIONS

Given high seedling counts for sugar maple in this stand, regeneration of the species is attainable for the ACNW. The main impediment to the recruitment of sugar maple in this stand seems to be predation by white tailed deer, and a lack of gap openings. This stand is densely stocked and may benefit from the opening of gaps using a single-tree selection harvest. This type of harvest opens small gaps in the forest to emulate small-scale wind disturbance events, and is quite effective at promoting the recruitment of shade tolerant species such as sugar maple. Opening these gaps would provide increased sunlight to the seedling "bank" causing a release (rapid growth). This release may additionally allow regeneration to grow above the browse level of the white tailed deer, promoting a free-to-grow condition for saplings. White pine regeneration will benefit from any gap formation as well, and should respond to increased light levels following any harvest operation. White pine is a preferred browse species for deer, and is targeted especially throughout the fall.

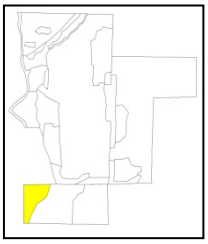
To fully promote white pine, bud capping should be implemented annually in gaps or other high light areas in the fall until the trees grow above the browse line (about 5 ft).

STAND #9: White Pine "Primitive Camp"

Acres: 13.5

NATIVE PLANT COMMUNITY

N.A. (lacking sufficient natural vegetation for classification)



TYPE DESCRIPTION

This stand resides on the far southwestern corner of the property, adjacent to and surrounding the primitive campground. The stand is strongly dominated by white pine, with scattered amounts of red pine, paper birch, and aspen. The trees in the stand are tightly spaced, very "branchy", and quite vigorous. Given the understory species composition, it is suspected that this area was a hardwood stand previously. The soils are consistent with the rest of the property, and display a moderate moisture regime, and high fertility. This stand surrounds the primitive campground, and there are remnants of campsites throughout the standing timber. The understory is sparse, due to the highly shaded condition of the dense stand.

Table 18. Overstory tree summary for Stand #9.

Overstory Summary			
Species	**Density Trees/Acre**	**Basal Area (ft.²/acre)**	**Avg. Diameter (in.)**
white pine	220	177.79	11.63
red pine	10	1.62	5.35
paper birch	40	9.64	6.59
big tooth aspen	5	4.61	13.00
Total:	**275**	**193.66**	**10.58**

Table 19. Regeneration— Seedlings and saplings in Stand #9 (stems/acre).

Regeneration Summary		
Species	Saplings/Acre	Seedlings/Acre
white pine	40	3,250
red oak	0	500
bur oak	0	250
balsam fir	5	250
speckled alder	170	0
misc. shrubs	0	1,750
Total:	215	6,000
* raspberry, nannyberry, red berried elder		

STEWARDSHIP OBJECTIVES

Maintain conifer cover, promote forest health, and provide aesthetic value to visitors to the primitive campground.

RECOMMENDATIONS

This stand is very highly stocked, with a basal area over 190 sq ft/acre, and would benefit greatly from a thinning in the near future. A thinning would open the canopy to allow for increased radial growth, and proliferation of an understory community. Canopy openings would allow for the release of some regeneration, including the white pine and oak seedlings found in much of the stand. Thinning would promote a healthier forest, and increase heterogeneity in the understory (a great benefit to wildlife). Additionally, pruning of the lower branches may help to increase aesthetic value of the stand, as well as future

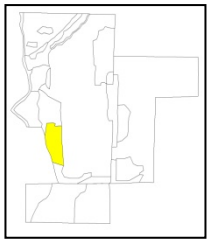
value of any timber harvests because branchy trees produce low quality, low value timber. Pruning should aim to remove approximately the bottom 1/3 of branches from all trees. An added benefit of thinning and pruning in this stand would be the lowering of risk for white pine blister rust invasion. White pine blister rust is an exotic fungal pathogen common throughout the region and it can cause high levels of mortality in densely planted stands. Thinning and pruning are methods that have been shown to lower the risk of infection by altering the moisture levels in the understory.

STAND #10: White Pine Invaded Field "Entrance Road"

Acres: 13.0

NATIVE PLANT COMMUNITY

N.A. (lacking sufficient natural vegetation for classification)



TYPE DESCRIPTION

This stand represents an abandoned field that is being invaded by white pines. The source of the seed for the invasion is presumed to be from the large scattered white pines to the west of this stand. The cover is highly variable, with patches of extremely high density pines, and open areas with no tree canopy at all. Over all, basal area on the site is relatively low, but it is not evenly distributed. Trees are growing vigorously, however, they are generally poorly formed and "branchy". The ground layer is patchy with dense grass and raspberry cover in openings, and barren in dense tree patches.

Table 20. Overstory tree summary for Stand #10.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
white pine	152	90.31	9.79
white spruce	4	2.36	10.40
Total:	**156**	**92.67**	**9.81**

Table 21. Regeneration—Seedlings and saplings in Stand #10 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
white pine	32	400
white spruce	8	0
willow spp.	20	0
green ash	0	1,600
maple spp.*	0	800
basswood	0	200
raspberry	0	1,400
Total:	**60**	**4,400**
* sugar maple, red maple		

STEWARDSHIP OBJECTIVES

Promote conifer cover, provide wildlife habitat, and maintain forest health.

RECOMMENDATIONS

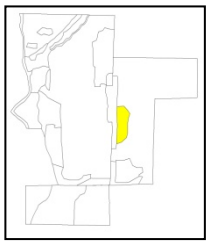
This stand would benefit from some management in the future, including thinning/pruning and planting within gaps. Within dense patches of existing white pine, it may be beneficial to harvest and/or fell some trees to increase growing space for neighboring trees and increase sunlight to the forest floor for proliferation of herbaceous species. Additionally, pruning of branches from the lower 1/3 of these pines may help to increase their economic and aesthetic values, because pruned trees will more likely achieve the tall iconic status often desired from white pine. As mentioned in previous management recommendations, pruning and thinning can also help to reduce the incidence of white pine blister rust and may be of interest in this stand. Within the very open gaps of this stand, it may be beneficial to plant additional trees to help maintain the area as forest. Species such as white pine, red oak, or white oak would be great additions to the stand. Planting seedlings and weeding around them to remove weedy competition, coupled with annual bud capping would help to establish these seedlings.

STAND #11: White Pine Invaded Field "Wetland"

Acres: 8.3

NATIVE PLANT COMMUNITY

N.A. (lacking sufficient natural vegetation for classification)



TYPE DESCRIPTION

This stand is dominated primarily by white pine with some white spruce and red pine also present. This area has patchy cover with grass patches in between small groups of white pine. The pine is invading a grassy field, and likely seeded naturally. It is mostly composed of pole-sized white pine with an average diameter of 13.5 inches, however, some individuals are reaching a larger size of about 16 to 17 inches. The understory contains white pine with a strong presence of balsam fir. White pine and balsam fir are also the most abundant seedling species.

Table 22. Overstory tree summary for Stand #11.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
white pine	125	130.6	13.5
white spruce	5	0.9	5.8
red pine	5	0.6	4.7
Total:	**135**	**132.1**	**12.9**

Table 23. Regeneration— Seedlings and saplings in Stand #11 (stems/acre).

Regeneration Summary		
Species	**Saplings/Acre**	**Seedlings/Acre**
white pine	35	250
balsam fir	25	250
honeysuckle	10	500
red osier dogwood	5	0
Total:	**75**	**1000**

STEWARDSHIP OBJECTIVES

This stand has the potential for some timber production, and provides important conifer cover for wildlife.

RECOMMENDATIONS

There was evidence of some pruning in these stands, but more could be done to improve the quality of the white pine. Thinning could also promote the growth of the higher quality individuals on-site, but this might be not be economically viable considering the small acreage of the stand. One important management action could be some planting in the non-forested gaps to assist in conversion to forest. White pine has high productivity on the site and could be planted, but bud capping would be advised to prevent deer browse. Red oak would likely be productive as well since the land and soil type is similar to the hardwood stand where it had a high site index; bud capping would be advisable for this species as well.

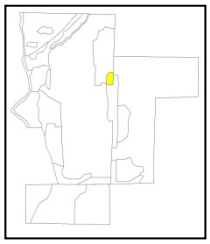
STAND #12: Regenerating Hardwoods

Acres: 1.7

NATIVE PLANT COMMUNITY

*MHc36 Central Mesic Hardwood Forest

*Classification based on estimation using topography, soils, and understory. Wetland community occupies the lowland depression, and inclusion within the stand.



TYPE DESCRIPTION

This small stand is located east of the visitor's center just off of Fox Rd. and was recently harvested. The stand is now regenerating quite vigorously. A few large aspen have been left onsite towards the north end of the stand. The regeneration within the site is composed of mostly balsam fir, aspen, white oak, paper birch, ironwood, sugar maple, and red oak. The presence of white oak is quite interesting because it is component minor component in other stands on the property. White oak is an exceptional mast species and should be promoted on the property whenever possible. The new growth was dominated by sapling regeneration, with some seedlings also prevalent. Soils are sandy loams comparable to the large hardwoods stand adjacent to the west of the clearcut.

Table 24. Overstory tree summary for Stand #12.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
sugar maple	10	1.1	4.5
trembling aspen	40	34.2	12.4
paper birch	10	1.5	5.3
Total:	**60.0**	**36.9**	**7.4**

Table 25. Regeneration— Seedlings and saplings in Stand #12 (stems/acre).

Species	Saplings/Acre	Seedlings/Acre
white oak	260	6000
red maple	110	3000
red oak	70	1500
sugar maple	230	1500
trembling aspen	470	1000
black ash	100	0
green ash	90	0
balsam fir	320	0
honeysuckle	130	0
paper Birch	130	0
basswood	50	0
ironwood	180	0
American hazel	50	0
Total:	**2190**	**13000**

STEWARDSHIP OBJECTIVES

Create a white pine regeneration area, provide wildlife habitat and food sources, and provide learning opportunities.

RECOMMENDATIONS

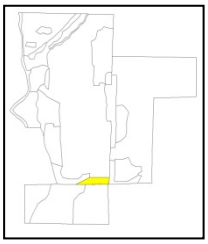
The best thing to do for this stand is to let it grow with occasional monitoring for invasive species. Invasive species will often enter a site following harvest, however, monitoring will provide an early warning system for removal. No management actions are needed until the trees are large enough to justify a harvest. When the stand is mature enough to warrant a harvest, it is advised to use thinnings to promote white oak. Another potential management activity would include scarification of the topsoil for more white pine regeneration, as the species prefers exposed soil. If the main goal of this site is white pine regeneration then transplanting seedlings from another area of the center may aid in increasing the presence of the species. This area could be used to help students learn about forest regeneration mechanisms and growth following timber harvest.

STAND #13: Spruce Plantation "Entrance"

Acres: 4.1

NATIVE PLANT COMMUNITY

N.A. (lacking sufficient natural vegetation for classification)



TYPE DESCRIPTION

This stand occupies an old field that was planted with excess seedling stock from a local resource manager. The stand is mainly composed of white spruce along with a minor component of white pine that most likely seeded in from neighboring stands. The spruce trees are tightly-spaced and are small, ranging from 4 to 5.5 inches in diameter at breast height. The white pines present are slightly larger than the spruce and likely seeded into the field around the same time that the spruce trees were planted. This area was most likely a hardwood forest before it was cleared based on soil composition, which is similar to the hardwood forests that surround the plantation.

Table 26. Overstory tree summary for Stand #13.

Overstory Summary			
Species	**Density (Trees/Acre)**	**Basal Area ($ft.^2$/acre)**	**Avg. Diameter (in.)**
white spruce	300	38.3	4.8
white pine	40	11.1	7.1
All species:	**340**	**49.3**	**6.0**

STEWARDSHIP OBJECTIVES

This stand can provide great wildlife habitat, timber production, and learning opportunities.

RECOMMENDATIONS

The density of the spruce provides thermal shelter for wildlife in the winter. It also provides great nesting sites for many bird species, including neo-tropical warblers. The spruce and white pine do have some value for possible timber harvesting in the future. White pine

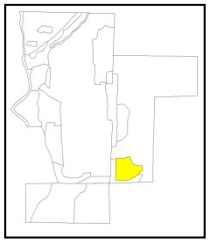
could be promoted on this site by thinning out the spruce and scarifying the soil to create suitable conditions for regeneration. The few white pines within the stand are mature enough to provide plenty of seed. There are opportunities here for student learning opportunities in habitat restoration. Students could also use this area as a forest restoration project by introducing species more common to the area such as those found in the adjacent hardwoods.

STAND #14: Savannah Restoration

Acres: 10.5

NATIVE PLANT COMMUNITY

N.A. (lacking sufficient natural vegetation for classification)



TYPE DESCRIPTION

This "stand" is currently being managed to develop an oak savannah ecosystem. A tall grass prairie has been established, and bur oaks are scattered throughout at extremely low density (<5 per acre). The oaks were planted from ball and burlap stock, and are currently 2-4 inches in diameter. Unfortunately, the planted oaks seem to be suffering from stresses of planting, and a possible infection of bur oak blight (a fungal pathogen).

STEWARDSHIP OBJECTIVES

Restore a bur oak savannah ecosystem by promoting low density bur oak proliferation, and maintenance of a tall grass prairie. The stand will help to provide learning opportunities for understanding the variety of ecosystems and natural disturbance regimes in Minnesota.

RECOMMENDATIONS

In order to restore this area to a viable savannah system, it will be necessary to first establish oak on site at a suitable density. We recommend increasing the planting of oak on site, to account for mortality, and to increase densities to a more desirable level. Additionally, it may be beneficial to diversify the species composition of the tree species. Northern pin oak, white pine, and jack pine also occur in savannah ecosystems in the region, and may be appropriate to plant in this restoration project. Once established, a fire management regime will need to be implemented to maintain proper structure, reduce weedy invasions, and reduce woody invaders. Extreme care will need to be taken during early burns, until trees reach a size where they are at less risk of mortality from fire. Prescribed burns on a rotation of 3-5 years is common in many prairie restoration programs. Alternatively, mowing of grass may provide similar benefits, with a lower cost, and lower risk than burning, especially in early years when trees are at risk of fire injury.

Additional attributes of the forests at ACNW

DEADWOOD INVENTORY

IMPORTANCE OF DEADWOOD LEGACIES

The importance of biological legacies in forest ecosystems following disturbance has become widely recognized in forest ecology and management. One of the most prevalent, versatile, and important biological legacies in forest systems is the presence of deadwood (Franklin et al. 2007). This deadwood, both standing "snags" and fallen logs play a crucial role in forest ecosystems by providing wildlife habitat, nutrient retention, and suitable substrate for plants, trees, fungi, and lichens.

Standing deadwood components are especially important as vertical structure for wildlife. This vertical structure provides nesting, denning and perching sites for a variety of animals. The dead, and often decadent wood of these "snags" promotes the proliferation of many insects, providing additional food sources animals, namely insect feeding birds.

Downed wood plays a crucial role in the understory of many forests. Downed logs provide habitat for many animals, birds, and amphibians such as salamanders. These downed logs can be used as denning sites, ground level nest sites, or refuges from moisture stress. Additionally, downed wood can be an extremely important substrate for many other plant and fungi species. Some species of forest trees (yellow birch, spruce, hemlock) require wood debris in the form of downed logs for effective regeneration. Fungi can play a critical role as decomposers of organic material, and symbionts of many plant species.

STANDING DEAD WOOD INVENTORY

This data represents the inventory of standing dead trees within all inventoried stands on the property. Attributes where collected during the same survey plots as the overstory tree inventory, using the same protocol.

Table 27. Standing deadwood (snag) summary for all forested stands.

Standing Deadwood Inventory			
Stand #	**Basal Area\Acre**	**Stems/Acre**	**Avg. Diameter**
1	9.6	18	8.5
2	7.9	12	9.8
3	0.7	2	4.9
4	2.1	2	8.8
5	N.A.	N.A.	N.A.
6	18.3	20	11.8
7	4.4	17	6.7
8	8.0	4	19.1
9	4.1	10	8.5
10	N.A.	N.A.	N.A.
11	6.7	15	8.9
12	7.2	10	11.5
13	N.A.	N.A.	N.A.
14	N.A.	N.A.	N.A.

DOWNED DEAD WOOD INVENTORY

This data represents the downed coarse woody debris inventory collected in stand one. This was only collected in Stand 1; given it was an addition inventory with a separate protocol. This particular stand was chosen given the old-growth characteristics observed.

Table 28. Coarse woody debris (CWD) abundance in Stand #1.

	Stand #1	**Typical Range in MN Mature Managed Hardwoods**	**Typical Range in MN Old-Growth Hardwoods**
Volume of CWD (Cubic Ft./Acre)	638.47	171 - 1271	372 - 2086

MANAGEMENT IMPLICATIONS

Given the crucial role of deadwood legacies in forest systems, they should be a consideration in all ecological forestry actions. In terms of management, most actions will be targeted at retaining current structures, or creation of new structures. In terms of structure retention, all future timber harvest should limit the felling and removal of "snags" whenever feasible and safe. Additionally, downed un-merchantable logs should be retained on site, as downed woody debris. Creating these structures may also be of interest, especially in stands with noticeable deficits in deadwood (Franklin et al. 2007). Girdling trees to be left standing as artificial decadent snags may create standing deadwood structures. These trees will decline slowly, and remain standing to provide vertical structure in the stand. Additionally, intentionally felling trees, and retaining logs on site may create downed wood features. Whenever creating artificial deadwood structures, it is recommended to select poorly formed, and un-merchantable trees. These trees are often more suitable and preferred as habitat, and will minimize economic impacts to future timber harvests.

CARBON & BIOMASS STORAGE INVENTORY

IMPORTANCE OF CARBON STORAGE IN FORESTS

We used biomass equations to determine the total aboveground biomass on site, which is displayed as a weight per unit area in Table 29. Biomass estimates allow for an estimate of carbon storage on site, an objective of growing importance in forestry. Increasing amounts of carbon dioxide in the atmosphere is one of the major drivers of global warming, with forests and other plant communities sequestering and storing carbon through the processes of photosynthesis. Enhancing the growth of forests and promoting carbon storage is a strategy used to mitigate the effects of climate change. Despite the small scale of this property in the scope of global climate change, this measurement still gives an insight into the carbon storage in the area. With the increasing importance of climate change in society, carbon storage will likely become a more prevalent part of forest management.

There is some significant variation in carbon and biomass estimates within stands. These variations are fairly predictable however, with lower values in areas with the lowest stand density (Table 30). Values were highest in the naturally regenerated white pine and lake shore stands, which also had the highest basal area per acre values. Hardwood stands, which typically have lower stocking densities, show lower biomass and carbon values (Table 29). The values on this property are similar to those noted in prior studies (Baumgras 1980, Yost 2010). Stands like the regenerating hardwoods area and the savannah restoration had understandably low biomass estimates. From a standpoint of carbon sequestration, all of the mature forested stands displayed typical values and will serve their ecological role well.

Table 29. Aboveground biomass and carbon storage for Audubon Center of the Northwoods.

Stand #	Biomass (KG)	Biomass (tons)	Biomass/Acre (tons)	Carbon/Acre (tons)	BA/acre (sq. ft)
1	230934	255	78	39	153
2	35378	39	65	32	97
3	31536	35	53	27	138
4	24344	27	60	30	122
5	1979	2	44	22	163
6	27553	30	152	76	289
7	15310	17	56	28	106
8	23921	26	105	53	156
9	18383	20	101	51	194
10	10986	12	61	30	93
11	11706	13	65	32	132
12	2278	3	25	13	37
13	865	1	19	10	49
14	0	0	0	0	0

Table 30. Biomass storage for Audubon Center of the Northwoods in tons/acre.

	All Stands	Fully Stocked*
Mean	63	76
Range	0-152	44-152
*excludes stands that are non forested or sparsely vegetated with adult trees		

Appendix

EXPLANATION OF TERMS

Within each forested covertype there is a **Timber Summary** chart with the dominant tree species names, basal area/acre, and stems per acre, average DBH, along with stocking, site index, and timber size class. Additionally, a **Regeneration Summary** chart is included containing the dominant species occupying the subcanopy, and seedling layers, with associated stems per acre values for each. The definition of these terms follows:

AVERAGE DIAMETER AT BREAST HEIGHT (DBH)

DBH is the diameter of a tree species at breast height (4.5 feet). This metric helps to minimize variation in inventory data by reducing the effect of taper and buttress in the bole of the tree. Additionally, this standardizes procedure for measurement.

BASAL AREA/ACRE

Basal area (BA) is the cross-sectional area (in square feet) of a tree's bole (stem) at breast height (4.5ft). The total of all trees in an acre will give the basal area per acre. Each tree in each acre for each forest type is not actually measured, rather estimated using tested methods and instrumentation.

Basal area is used to estimate stand volume and is a useful measure of the degree of competition in the stand. For example, a BA below 80 sq. ft./acre usually means low overstory stocking for many forest types while normal stocking is usually between 110 to 160 sq. ft./acre. Once the BA is over 170 sq. ft./acre stocking is becoming high and competition between the trees is restricting growth. Higher soil productivity can hold a higher BA than less productive soils, something that is observed throughout this property.

STEMS (TREES)/ACRE

Total stems (including seedlings or saplings*) estimated per acre.

A *seedling* is defined as any shrub or tree species within the inventory plot that is less than 4.5ft in height. *Saplings* include all shrub or tree species greater than 4.5ft in height, and less than 4 inches in diameter at DBH.

STOCKING

Stocking is the total of all basal areas or stems/acre.

SITE INDEX (SI)

Site index is the relative measure of forest site quality based on the height of a dominant, main species tree in the overstory at a specific age (50 years). This measure represents the potential for growth for a given species on the site. Using the current age and height of a given tree, the SI is estimated using an equation developed for that species within the

region. Each species has a different equation, which may also change with geographic location.

Example: An SI of 62 means the tree should be 62 feet tall at 50 years of age, this represents the potential for all trees in the stand. For example: an aspen tree with an SI of 90 is very good while an SI of 45 is poor; a tamarack tree with an SI of 60 is considered very good while an SI of 20 is considered poor. SI cannot be calculated accurately on trees younger than 20 years of age, and is therefore estimated using trees of the same species found in the immediate area.

SIZE CLASS

Each forest type is assigned into one of four basic size classes:

- ***Seedling****:* Trees less than 5 feet tall.
- ***Sapling*****:** Trees over 5 feet in height , but less than 5 inches in diameter with no merchantable volume.
- ***Pole*****:** A young forest with diameters between 5 to 12 inches in diameter.
- ***Sawlog*****:** A majority of the trees are over 12 inches in diameter.

TIMBER SALE OVERVIEW

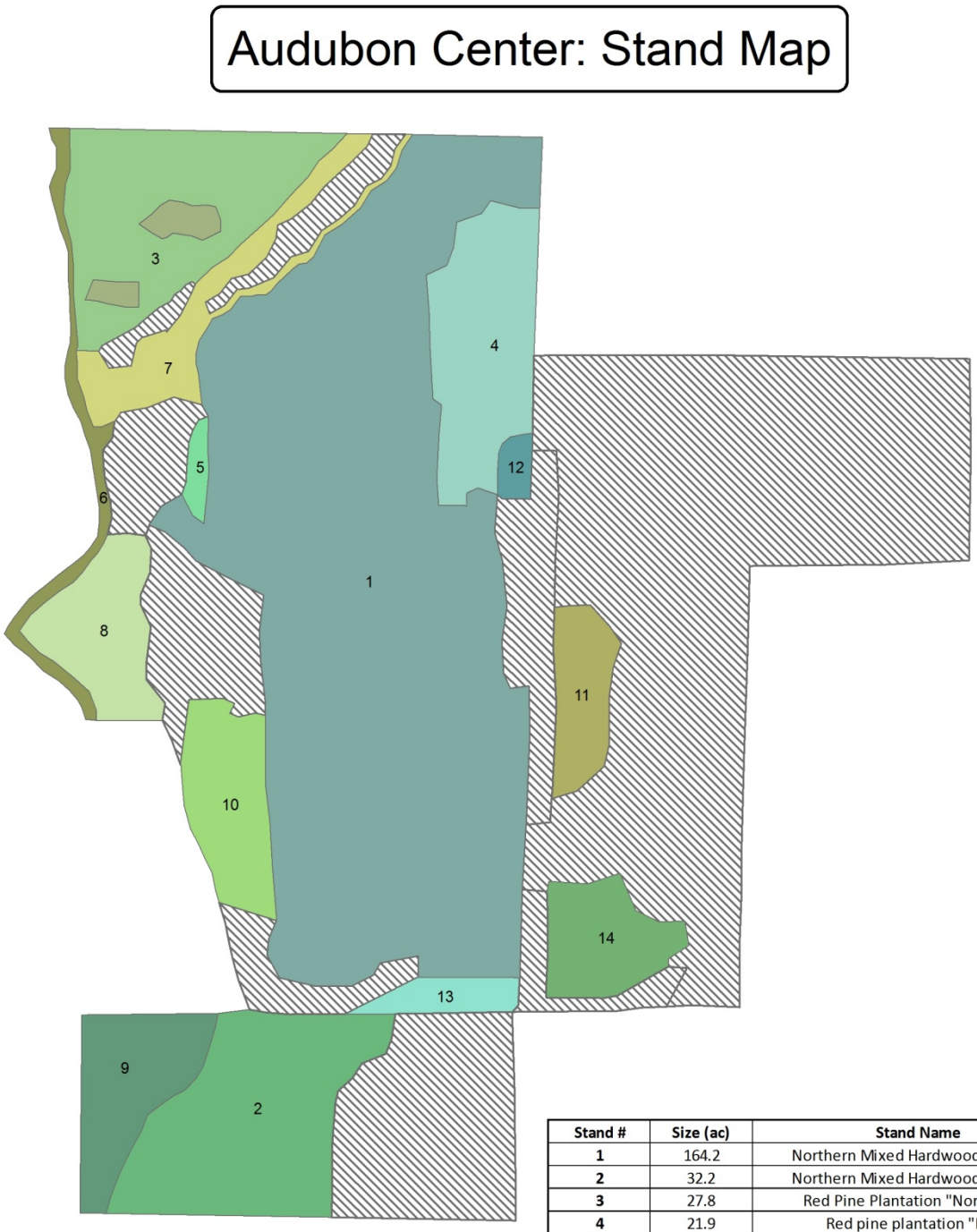
If you choose to harvest your timber, there are some steps you should take. Most people are not familiar with logging or the forest products industry, so it is advisable to hire a professional forester to handle the following:

- Inventory or "Cruise" the property, and appraise the value of timber.
- Contact a suitable logger.
- Produce a written contract including harvest guidelines that protect your interests.
- Designate the timber to be harvested, and plan for regeneration of the forest.
- Mark the harvest boundaries.
- Oversee the harvesting, administer contracts, and evaluate any potential concerns.

To find a forester, you could contact your Forest Stewardship Plan writer. Setting up private timber sales is one of the services provided by most foresters, which includes all of the items listed above. Alternatively, you can call the state DNR Forestry office in your area to obtain a list of other consulting Foresters.

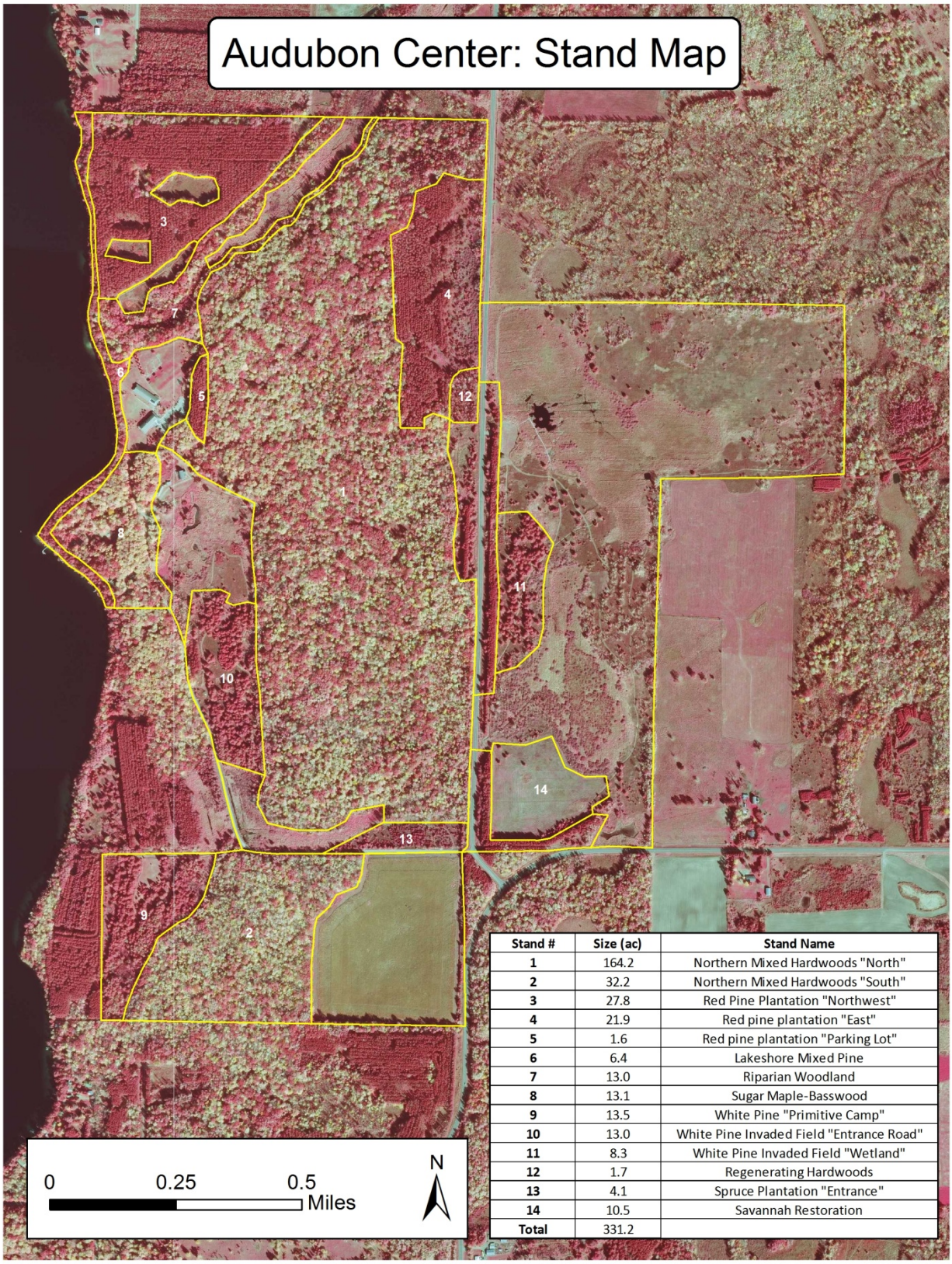
While it is not advised, if you plan on selling the timber yourself, many of the items above should be done before the logging is started. The most important thing is to ***obtain a written contract outlining your desired outcomes, schedule of payments, and length of the contract.***

MAP OF STEWARDSHIP PARCEL (STANDS DELINEATED)



Stand #	Size (ac)	Stand Name
1	164.2	Northern Mixed Hardwoods "North"
2	32.2	Northern Mixed Hardwoods "South"
3	27.8	Red Pine Plantation "Northwest"
4	21.9	Red pine plantation "East"
5	1.6	Red pine plantation "Parking Lot"
6	6.4	Lakeshore Mixed Pine
7	13.0	Riparian Woodland
8	13.1	Sugar Maple-Basswood
9	13.5	White Pine "Primitive Camp"
10	13.0	White Pine Invaded Field "Entrance Road"
11	8.3	White Pine Invaded Field "Wetland"
12	1.7	Regenerating Hardwoods
13	4.1	Spruce Plantation "Entrance"
14	10.5	Savannah Restoration
Total	331.2	

AERIAL PHOTOGRAPH OF THE PROPERTY (with stand covertype delineations)



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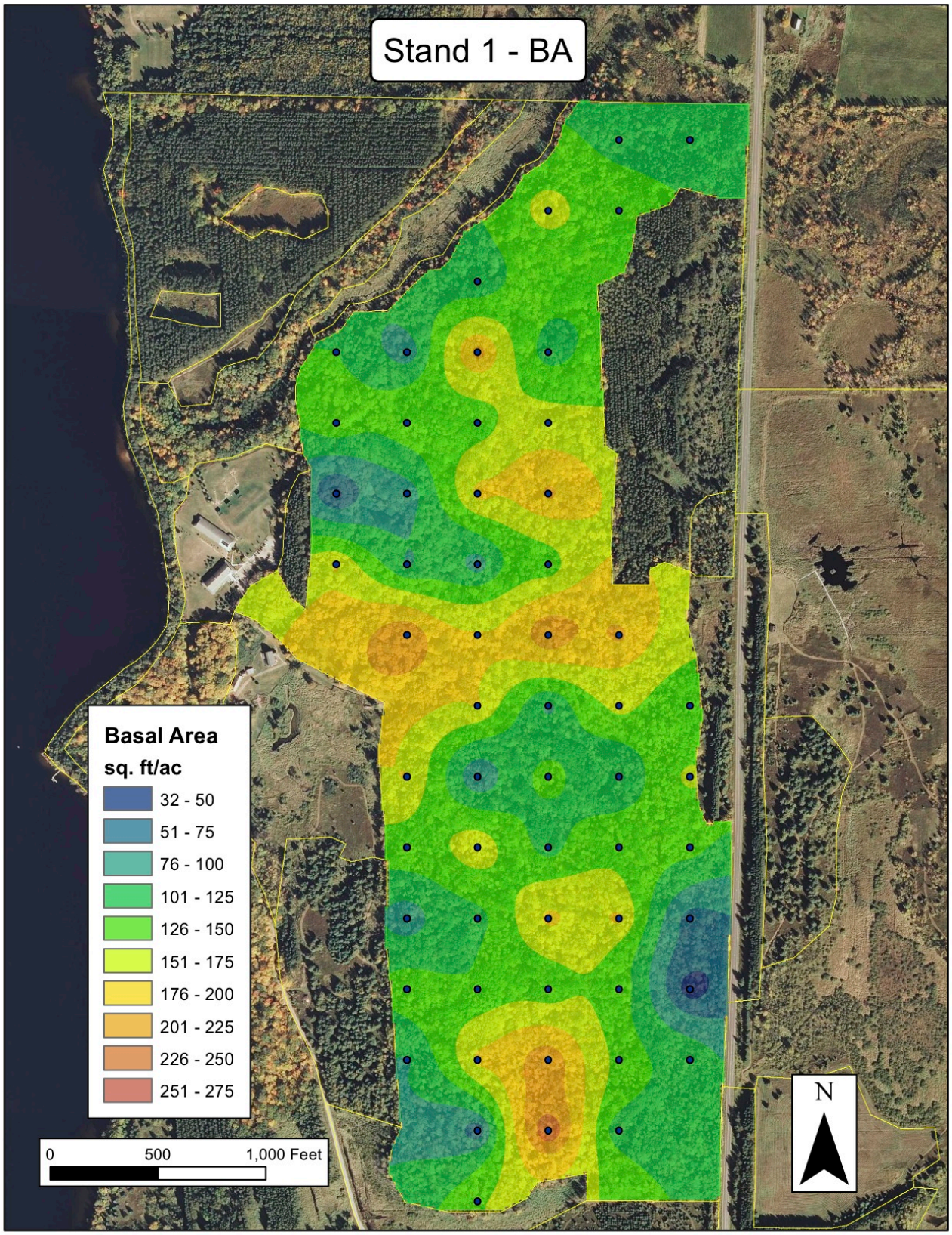
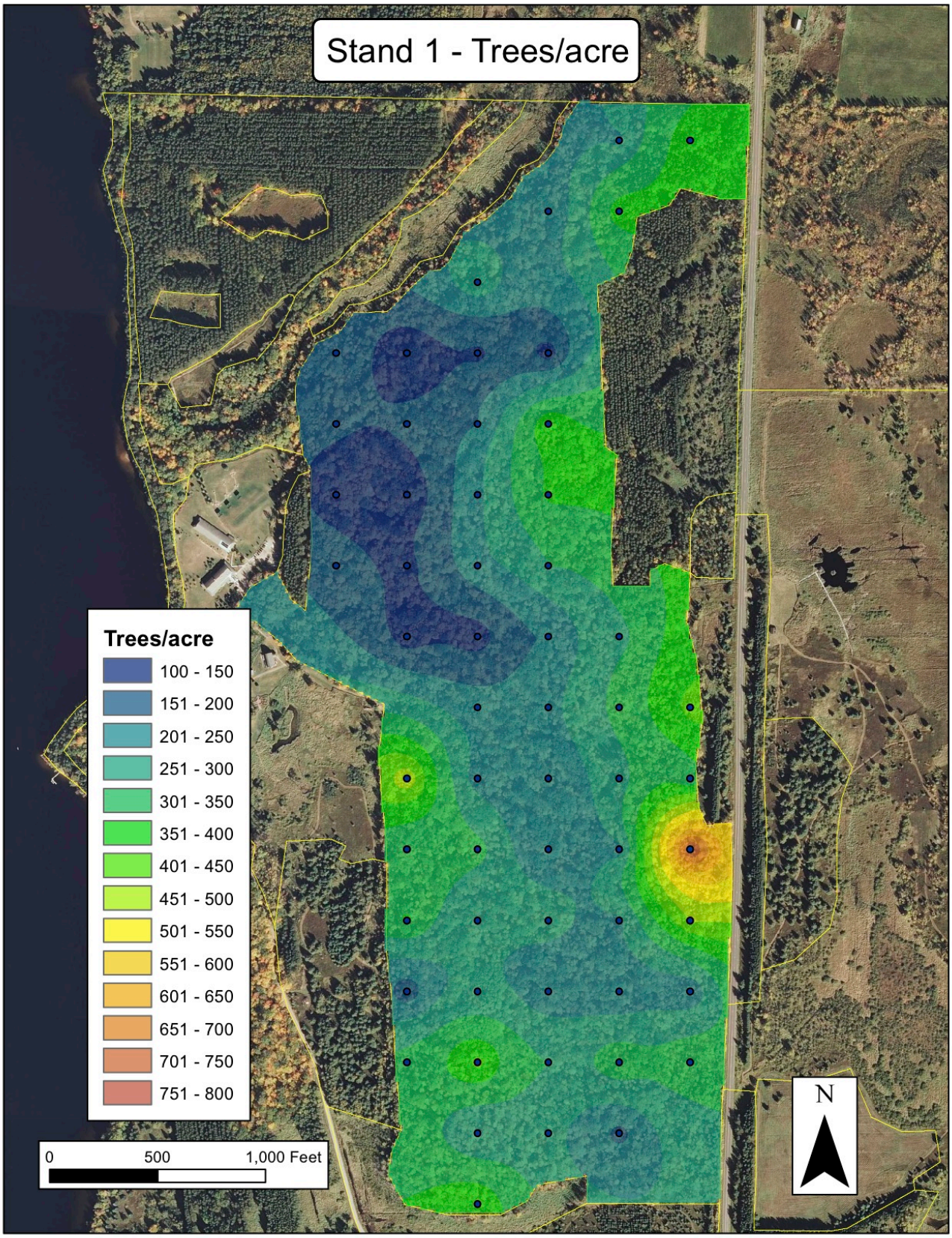
9	13.5	White Pine "Primitive Camp"
10	13.0	White Pine Invaded Field "Entrance Road"
11	8.3	White Pine Invaded Field "Wetland"
12	1.7	Regenerating Hardwoods
13	4.1	Spruce Plantation "Entrance"
14	10.5	Savannah Restoration
Total	331.2	

SPATIAL REPRESENTATION OF BASAL AREA FOR STAND #1



SPATIAL REPRESENTATION OF DENSITY FOR STAND #1



REFERENCES

Baumgras, John. 1980. Biomass yields from Allegheny hardwood thinning. USDA Forest Service: Northeastern Forest Experiment Station. Forest Service Research Paper NE-466.

Carmean, Willard, et al. 1989. Site index curves for forest tree species in the Eastern United States. USDA Forest Service: Northern Research Station. General Technical Report NC-128.

Franklin, Jerry, et al. 2007. Natural Disturbance and Stand Development Principles for Ecological Forestry. USDA Forest Service: Northern Research Station. General Technical Report NRS-19.

Hale, C.M., et al. 1999. Comparison of structural and compositional characteristics in old-growth and mature, managed hardwood forests of Minnesota, U.S.A. Candadian Journal of Forest Research: 29:1479-1489.

Jenkins, Jennifer, et al. 2003. National-Scale Biomass Estimators for United States Tree Species. Forest Science 49(1):12-35

MNDNR, 2003. Field guide to the native plant communities of Minnesota: the Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota Biological Survey, and Natural Heritage and Nongame Research Program. MNDNR, St. Paul, MN.

Simmons C.S, et al. 1941. Soil Survey: Pine County Minnesota. USDA Bureau of Plant Industry/University of Minnesota Agricultural Experiment Station.

Yost, Andrew. 2010. Carbon Estimates of forest biomass for the Clatsop State Forest. Oregon Dept. of Forestry: Resources Planning Program.