Strategies for Management of Natural Red Pine Forests Across Michigan's State Forest System

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We collectively acknowledge that Michigan State University occupies the ancestral, traditional, and contemporary Lands of the Anishinaabeg – Three Fires Confederacy of Ojibwe, Odawa, and Potawatomi peoples. In particular, the University resides on Land ceded in the 1819 Treaty of Saginaw. We recognize, support, and advocate for the sovereignty of Michigan's twelve federally recognized Indian nations, for historic Indigenous communities in Michigan, for Indigenous individuals and communities who live here now, and for those who were forcibly removed from their Homelands. By offering this Land Acknowledgement, we affirm Indigenous sovereignty and will work to hold Michigan State University more accountable to the needs of American Indian and Indigenous Peoples.

We also acknowledge that Indigenous Peoples and their cultural practices were, and are, integral parts of Michigan's ecosystems.

Cover Photo by Jesse M. Lincoln.

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Steve Griffith, Jesse Lincoln, Mike Parker, and Kurt Kipfmueller examining a fire-scarred red pine stump in the Traverse City Forest Management Unit. Photo by Rachel Lincoln.

EXECUTIVE SUMMARY

As part of continued improvement of management within the State Forest system, the Michigan DNR is evaluating management approaches of natural red pine (*Pinus resinosa*). Red pine is an important timber resource for the State Forest system, a major component of several natural communities in the state, and a tree of cultural significance for Indigenous Peoples of the region. The amount of natural red pine on the landscape throughout the Great Lakes Region has declined by an estimated 87% from historic levels. Natural pine stands often fail to meet silvicultural regeneration or stocking goals and many areas of natural forest are being converted to plantation to assure a continued supply of this economically valuable timber. Pine management in the Great Lakes Region is often comprised of thinning followed by complete overstory removal and conversion to plantation. As of 2024, the conversion of natural red pine forests to plantation was halted to develop a more holistic approach to managing red pine forests.

Red pine is uniquely valuable for the interpretation of historical fire regimes in Michigan as it is a long-lived species that oftentimes preserves fire-induced wounds within its annual growth rings. Prior to European colonization, dry forests in the Great Lakes Region were influenced by widespread and frequent low-severity fires fostered by Indigenous land tending practices. These forests contained a diversity of size, age, vertical height, and canopy structures. This heterogeneity is a good reference for silviculture prescriptions and management targets, particularly where objectives extend beyond production forestry.

Over the past 150 years, fire in natural pine stands of the Great Lakes Region has been nearly eliminated. This has resulted in simpler, even-aged forests that are at greater fire and disease risk and lack adequate natural regeneration, leading to the perceived need to convert natural stands to plantations. Reduction of fire in fire-adapted forests has allowed a proliferation of shade-tolerant, fire-sensitive species that facilitate succession towards dense, mesophytic systems with less flammable vegetation and increased risk from severe fires during prolonged droughts. In a 2004 report (Bielecki et al. 2004), the Michigan DNR identified holistic red pine management for ecological and economic objectives as a high priority, including use of prescribed fire to maintain and enhance red pine.

We evaluated relevant literature to develop an approach for the management of natural red pine forests that fosters a stand's potential for timber harvest and non-timber goals such as controlling forest pathogens, enhancing resiliency to climate change and wildfires, conserving biodiversity, and reducing costs associated with intensive management. We recommend the ICO (Individuals, Clumps, and Openings) methodology for achieving structural complexity (Churchill et al. 2013, Razenkova et al. 2025). By combining the ICO approach with prescribed fire in a method that reflects historic disturbance cycles, red pine forests can be managed in a way that promotes natural regeneration and landscape resilience.

We identified 13 potential Project Areas during the 2024 field season where we recommend this approach of ecological silviculture. Most of these project areas have not experienced fire since the late 1800s when fire suppression reduced cultural burning across the region. With the loss of fire as an ecological process, the stands we surveyed generally lacked red pine regeneration and often had a dense understory. We recommend strategically applying fire to the project areas prior to timber harvest to maximize natural regeneration of red pine, reduce mesophytic competitors, consume ladder fuels, condition trees to fire, and facilitate future burns. Generally, our management recommendations for these project areas are to return fire to these project areas and then implement timber harvest treatments that will establish multi-age forests that mimic the natural model for frequent fire forests. The process of alternating prescribed fire and timber harvest will be repeated over long intervals for the foreseeable future.

If implemented, the approach we have outlined would be a dramatic shift in the management of natural red pine forests on Michigan DNR lands. Red pine is one of the most valuable timber resources in the state, and plantation forestry is a proven technique for generating dependable revenue from red pine. We are not suggesting that the DNR attempt our approach everywhere, but we believe this approach is well-calculated and is worthy of attempting in several areas around Michigan. We feel the management approach that we have detailed in this report is a reasonable pathway to return a critical ecological and cultural process to the landscape and in doing so, provide adequate red pine regeneration and resilience against disease, wildfire, and climate change. Our hope is that this will serve as a template for management of dry and dry-mesic forests across the region for a more economically and ecologically stable future.

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INTRODUCTION

There are over four million acres of State Forest across Michigan's Upper and Northern Lower Peninsulas. State Forests are jointly managed by the Forest Resources Division (FRD) and Wildlife Division (WLD) of the Michigan Department of Natural Resources (DNR) for long-term forest health, sustainable forest products, wildlife habitat, recreational opportunities, and ecosystem services. The FRD and WLD are responsible for assuring that management activities do not harm threatened and endangered species and through dual forest certification, the DNR maintains a network of Ecological Reference Areas (ERAs) composed of high-quality and representative natural communities. Michigan Natural Features Inventory (MNFI) is Michigan's Natural Heritage Program and maintains a geospatial database of benchmark natural communities and populations of rare and declining plants and animals. For more than four decades, MNFI has documented and monitored high-quality natural communities on State Forest land including numerous pine-dominated forests that are part of the State's network of ERAs (Cohen et al. 2009, Cohen, Multiple: 2014-2024, MNFI 2025). The maintenance and protection of these ERAs is part of the criteria for sustainable forest certification developed by the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI). Through engagement with these certifying entities, the DNR strives to ensure sustainable forest management practices.

As part of continued improvement of management within the State Forest system, the Michigan DNR is evaluating management approaches of natural red pine (*Pinus resinosa*). Red pine is one of the dominant trees in dry and dry-mesic northern forests in the Great Lakes Region, occupying a relatively small geographic range centered around the 45th parallel north (Figure 1) (Burns and Honkala 1990). It is an important timber resource for the State Forest system, with total timber harvests growing from 17 million ft^3 in 1992 to 31.2 million ft^3 in 2017 (USDA 2017). In addition to being a major component of several natural communities in the state, red pine is a tree of cultural significance for Indigenous Peoples of the region. Michigan's Upper and northern Lower Peninsulas are within the core range of red pine with red pine–dominated natural communities historically covering about 2.6 million acres in the state (Comer et al. 1995). A better understanding of natural red pine forest management in Michigan will inform silvicultural stewardship across its range.

The Ecology of Red Pine

Red pine is a dominant component of two forested natural community types in Michigan: dry northern forest and dry-mesic northern forest (Cohen et al. 2015, Cohen et al. 2020). These natural communities developed as a result of frequent fires, drought-prone sandy soils, and cold temperatures that limited competition from broad-leaved deciduous trees. The

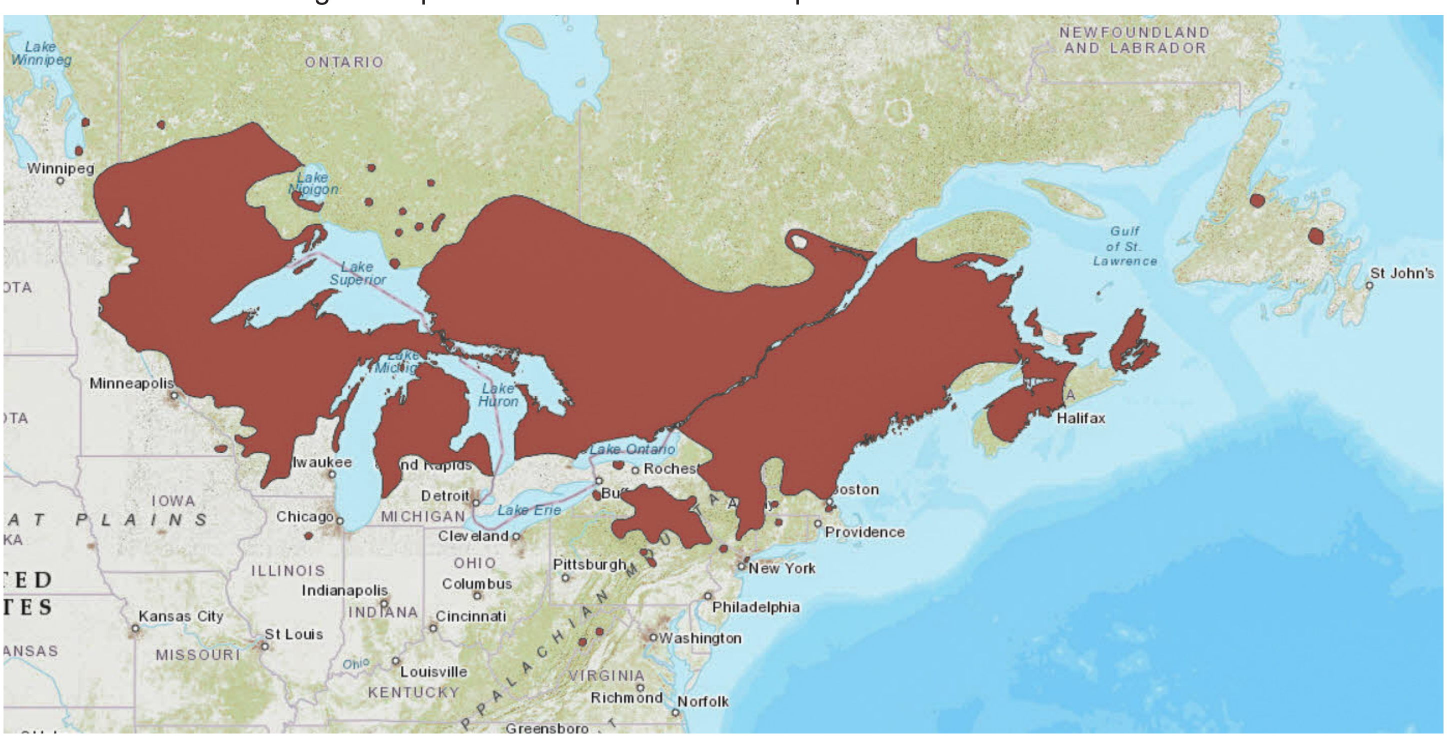


Figure 1. The range of red pine encompasses the Upper Peninsula and northern two-thirds of the Lower Peninsula of Michigan. Map adapted from Little and Viereck (1971).

structure of dry and dry-mesic northern forest is highly dependent on local moisture, soil conditions, and fire history. Red pine is well-adapted to survive fires due to its thick bark and habit of self-pruning lower branches, which limits ladder fuels and susceptibility to crown fire (Van Wagner 1970).

Historically, red pine–dominated forests featured a semi-open canopy of mature trees with multiple or indistinct cohort groupings (Meunier et al., 2019 Razenkova et al. 2025). These forests had complex spatial arrangements and contained a diversity of size, age, vertical height, and canopy crown structures (Franklin and Van Pelt 2004, Meunier et al. 2019, Razenkova et al. 2025). Other species prevalent in natural pine forests include jack pine (*Pinus banksiana*), white pine (*Pinus strobus*), and red oak (*Quercus rubra*). Jack pine is a typical component in drier forests while white pine and red oak are frequent canopy associates on moister sites. Red pine is typically the longest-lived of the canopy dominants in dry and dry-mesic forest and can regularly achieve ages of 300 to 400 years (Burns and Honkala 1990, MNFI 2025). Old red pine stands are still extant, especially where they are inaccessible to logging and protected from severe crown fires. These landscape positions include steep ridges, bedrock knobs, lake and river margins, and areas adjacent to or embedded within wetlands (Bergeron and Gagnon 1987).

Another characteristic feature of natural red pine forests is slow-growing, clonal or suckering shrubs that are adapted to fire. These include blueberries (*Vaccinium* spp.), huckleberry (*Gaylussacia baccata*), serviceberries (*Amelanchier* spp.), and bearberry (*Arctostaphylos uva-ursi*) (Cohen et al. 2015), which form unique associations with the soil microbiome while providing a food source for many birds and mammals (Matlack et al. 1993).

These berry producing species are also important cultural resources for Indigenous Peoples and fire was regularly used to encourage growth and fruiting. In addition to promoting fruit masting, burning was also used for a variety of other social and cultural reasons, including the improvement of wildlife habitat, hunting grounds, and travel corridors across the landscape (Kimmerer and Lake 2001). The use of fire and intentional burning were integral practices of Anishinaabe and other Indigenous cultures (Smith 1923, Cleland 1992, Anderton 1999, Davidson-Hunt 2003).

Historically, red pine forests were characterized by multiple cohorts of canopy trees and abundant natural regeneration. Pictured is Lee South in the Norway Beach Stand, Chippewa National Forest around 1933. Photo provided by John Lampereur, USFS.

Frequent fire maintains heterogeneity in red pine forests, which contributes to the resilience of this natural community type. The application of frequent, low-severity fires kept the forest open, exposed mineral soil, and enhanced regeneration of red pine and also maintained structural complexity of red pine stands. Much of the forest heterogeneity that contributes to ecosystem resilience in pine forests of the Lake States developed from long-term application of fire by Indigenous Peoples (Anderton 1999, Kipfmueller et al 2021). Spatial heterogeneity at the landscape level and stand level, especially forest structure and composition, is a critical factor contributing to ecosystem resilience (Levin 1998, Stephens et al. 2008, North et al. 2009, Moritz et al. 2011). Ecological resilience includes the capacity to persist through and re-organize after disturbance, adapt to shifting environmental conditions, and maintain basic ecosystem structure and function over time (Walker et al. 2004, Churchill et al. 2012). Awareness of historical disturbance regimes is a key factor in developing resilient ecosystems that can adapt in an uncertain future (Landres et al. 1999, Meunier et al. 2019).

The Role of Fire

Red pine is uniquely valuable for the interpretation of historical fire regimes in Michigan as it is a long-lived species that oftentimes preserves fire-induced wounds within the annual rings that can be dated using tree-ring analysis techniques (Kipfmueller et al. 2017, Kipfmueller et al. 2021). Additionally, red pine stumps persist for several decades post-mortem due to high resin content and can be used to reconstruct historical fire regimes (Stambaugh et al 2024). Living red pine that are several hundred years old can provide evidence of historic burning regimes and even preserve evidence of cultural activities such as peel scars and hatchet marks (Turner et al. 2009, Larson et al. 2021). Red pine snags and stumps can provide valuable information about fire regimes and growth rates dating back as far as 1520 in the eastern Upper Peninsula (Sutheimer et al. 2021) and 1439 in the western Upper Peninsula (Muzika et al. 2015). Due to red pine's longevity and resin-preserved wood, most fire histories in the Great Lakes Region have been reconstructed from this species. Living fire-scarred red pine trees, and fire-scarred stumps and snags are cultural and ecological artifacts because they

Natural red pine forests often have a dense layer of clonal shrubs such as huckleberry, lowbush blueberry, and bearberry. These often produce large crops in response to fire. Indigenous land tending practices regulated berry production across the Great Lakes Region through regular application of cultural fire. Photo by J.M. Lincoln.

allow for fire history reconstruction and inform the development of management strategies to increase forest resilience.

While severe fire irregularly influenced the landscape, recent studies of fire histories in the Great Lakes Region suggest a more active and widespread role of Indigenous stewardship of dry and dry-mesic forests than has previously been recognized (Loope and Anderton 1998, Kipfmueller et al 2021, Stambaugh et al. 2024). Fire scars and traditional knowledge suggest that the frequency, intensity, timing, and spatial coverage of historical burns would have varied widely (Chapeskie 2001, Stambaugh et al. 2024). Fires in coastal sites on Lake Superior in Upper Michigan occurred ten times more frequently than would be expected based on lightning-caused ignitions alone (Loope and Anderton 1998). Red pine

Left, A red pine stump recovered from a natural red pine stand in the Traverse City FMU (Photo by J.M. Lincoln). Such samples are useful for developing an area's fire history. The stump shows evidence of at least six fires. These scars are annotated in the image on the right with the number of years between fires indicated (Photo by. K.F. Kipfmueller). This historic fire frequency provides managers with a target for fire return intervals of natural red pine stands. Based on this and other stumps from the area, we urge managers to apply low-intensity prescribed burns at a rate of every 10 to 30 years.

A living red pine with a fire scar showing evidence of surviving multiple fires. Red pine is uniquely valuable for the interpretation of historical fire regimes in Michigan as it is a long-lived species that oftentimes preserves fire-induced wounds. Photo by J.G. Cohen.

stands in the Boundary Waters region of Northern Minnesota show that lower intensity surface fires occurred in pine forests every 5 to 20 years with extensive evidence of intentional management with fire by Indigenous Peoples (Kipfmueller et al. 2017, Kipfmueller et al. 2021). Even remote stands of red pine surrounded by large wetlands were characterized by frequent historical burning in the dormant season when lightning strikes are low (Drobyshev et al. 2008, Sutheimer et al. 2021). Analysis of four sites across the Lower Peninsula revealed fire frequencies that vary through time and across the region with the minimum fire return intervals ranging from 3 to 12 years before European contact (prior to 1630) and mean fire return intervals ranging from 9 to 55 years (Stambaugh et al. 2024). Historic regional fire regime dynamics were influenced by both human cultures and climate but many of the highest observed frequencies in the region are attributed to Indigenous application of cultural fire (Loope and Anderton 1998, Kipfmueller et al. 2021, Stambaugh et al. 2024).

Historically, severe or catastrophic crown fires in pine-dominated forests of Michigan were infrequent and occurred between 100 to 500 years resulting in significant mortality of trees (Heinselman 1973, Flannigan and Bergeron 1998). The estimated return intervals of severe fire were highly variable, with an average of 163 years between stand-replacing fires in mixed pine stands in the eastern Upper Peninsula (Zhang et al. 1999), an estimated fire rotation period of 107 years for red-white pine forests in the northern Lower Peninsula (Cleland et al. 2004), and severe crown fires every 120 years in red-jack-white pine stands (Whitney 1986).

Although severe fires did lead to stand re-initiation, a mixed-severity disturbance regime is a better description of the origin of old-growth red pine in the Great Lakes Region (Palik and D’Amato 2019). The mixed-severity paradigm emphasizes spatially variable intensity of historical fires depending on variable fuels and topography instead of severe

Fires maintain open conditions in forests. This mixed-pine forest is dominated by 120-year-old red and white pine and was burned in the Duck Lake Fire of 2012. Photo by J.M. Lincoln.

fires that had very high mortality over large areas. This means trees of multiple age and size cohorts could survive fires and provide a seed source to perpetuate red pine (Palik and D'Amato 2019). Red pine produces large seed crops every five to ten years, and the coincidence of suitable seedbeds in the aftermath of fire is an important factor in seedling recruitment (Van Wagner 1970, Kozlowski and Ahlgren 1974). Widespread and frequent low-severity fires and variable age classes of pine forests were historically characteristic of these systems, and establishment was not limited by overstory density but instead by mortality of seedling and saplings due to fire intensity (Bond et al. 2005, Brown and Wu 2005, Meunier et al. 2019).

Since Euro-colonization, the application of fire in natural pine stands of the Great Lakes Region has been nearly eliminated. This has resulted in simpler, even-aged forests that are at greater fire and disease risk and lack adequate natural regeneration. The elimination of fire has led to a six- to twelve-fold increase in density of red pine forests compared to historic conditions (Meunier 2019, Razenkova et al. 2025). Moreover, elimination of fire in fire-adapted forests has allowed a proliferation of shade-tolerant, fire-sensitive species that facilitate succession towards dense, mesophytic systems with less flammable vegetation and litter. This conversion further inhibits the spread of fire, reduces the viability of fire-adapted species, and generates uncharacteristically severe fires in the event of prolonged droughts (Nowacki and Abrams 2008, Parks et al. 2025). In the absence of fire, the rapid increase of mesophytic species at all but the driest sites can quickly limit red pine regeneration and result in the decline of red pine over time (Frelich and Reich 1995). Red pine is therefore considered to be a fire-dependent species (Van Wagner 1970, Kipfmueller et al. 2021).

Natural red pine forests that are fire suppressed typically have little red pine regeneration and understories are often dense with white spruce, balsam fir, white pine, and red maple. Photo by J.M. Lincoln.

The Decline of Red Pine

Red pine forests cover over 2,000,000 acres in the Great Lakes states and over 76 percent of this is plantation (Palik et al. 2021). The amount of natural red pine on the landscape throughout the Great Lakes Region has declined by an estimated 87% from historic levels (Gilmore and Palik 2006). The Michigan DNR estimates that red pine cover has declined by 50% to 60% compared to estimated cover within the state in 1800 (Bielecki et al. 2004). Old-growth red pine is one of the rarest forest types in the Great Lakes Region with only 0.2% of red-white pine forests remaining "relatively intact" (Frelich 1995).

In the 19th century, many historically forested areas of Michigan were severely degraded following widespread logging and post-logging slash fires. Land clearing often included preferential cutting of the largest trees which skewed size distributions and continues to influence the current demographics and distribution of pine today. In addition, areas that were intensively logged often experienced intense slash fires that destroyed the seed bank and local seed sources. With limited seed sources these burned areas often became open grasslands or "stump fields" with low diversity and limited capacity for reforestation (Barrett 1995). Red pine plantation forests were established by the Civilian Conservation Corps between the 1930s and the mid-1940s to stabilize degraded areas and reforest millions of acres (Bielecki et al. 2004, Botti and Moore 2006). Past planting efforts and associated management have resulted in many Michigan red pine plantations that are in the 60- to 100-year age range. Natural red pine stands show a similar trend in age range with few stands greater than 100 years old.

Natural pine stands often fail to meet natural regeneration goals and many areas of natural forest are being converted to plantation to assure a continued supply of this economically valuable timber. These plantations lack the structural complexity and biodiversity of natural pine stands (Fraver and Palik 2012, Silver et al. 2013). Red pine regeneration naturally occurs following disturbance events such as prescribed fire and wildfire and in canopy openings following windthrow. In the absence of fire, natural regeneration is largely limited to small areas of the landscape with thin organic soils such as ridge tops, cliffs, dunes, wetland edges, and road margins.
To meet future harvest goals, regeneration of red pine is often attempted by scarifying the soil or by planting with accompanying trenching and herbicide application.

Management of natural red pine forests in the Great Lakes Region is a conservation and management challenge (Fowler 1970, Van Wagner 1970). The State Forestland Red Pine Type Management

A prevalent silvicultural practice on State Forest lands is the conversion of natural pine forests to plantations. These forests are clearcut, trenched, sprayed with herbicide, and planted with nursery stock. Photo by J.M. Lincoln.

Project addressed concerns about loss of red pine and conflicting management objectives for economic and ecological objectives in the 2004 Michigan DNR report. The challenges for red pine management are summarized as follows:

> "Another major issue with the red pine resource on State Forestlands is the overall lack of naturally regenerated stands on ecologically suitable sites. This is contributing to a decline in several wildlife species and the loss of dry-mesic, dry northern forest, and barrens communities. Although fire can significantly help with the natural regeneration of red pine and is a critical part of natural processes, reestablishing red pine stands is still difficult due to inconsistent seed production. Social constraints, such as those that limit the use of prescribed fire, also make it difficult to manage red pine naturally. As a result, this report explores opportunities to establish red pine in a quasi-natural setting through modified planting techniques including the use of fire on a limited basis. The effects of the reduction of natural red pine communities are also explored." (Bielecki et al. 2004)

Following this 2004 report, fire has not been consistently applied to natural pine forests. Further, the assumption that pine forests are solely structured by severe, stand-replacing crown fires has led to the assumption that these systems should be managed as even-aged systems. As a result of this misunderstanding about the foundational dynamics of red pine systems, the prevailing silvicultural strategy has been to convert natural stands to plantations.

Pine management in the Great Lakes Region is often comprised of regular thinning followed by complete stand removal and artificial regeneration (Benzie 1977, Razenkova et al. 2025). We observed several areas where red pines over 150 years old were clear-cut. Retaining large, fire-tolerant trees is a key principle of dry forest restoration and increasing ecological resilience (Meunier et al. 2019). Managers likely do not recognize red pine as an old-growth species, in part due to its rareness, but also a false impression of its ecology as a simple, early-successional, single-cohort species that is prevalent in even-aged systems (Razenkova et al. 2025). The management of red pine is also driven by challenges related to insects, diseases, competition, complications relating to the application of prescribed fire, and irregular seed production. Therefore, density-based thinning and artificial regeneration have become common management approaches in natural and plantation origin pine stands (De Naurois and Buongiorno 1986, Gilmore and Palik 2006).

The decline of natural red pine, the prevalence of plantation management, and the aging of existing stands planted in the 1930s have spurred efforts to better understand how to manage red pine on State of Michigan lands to achieve both economic and ecological objectives and ensure the persistence of resilient and diverse red pine stands (Bielecki et al. 2004). Recent work focusing on documenting high-quality dry and dry-mesic northern forests in the eastern Upper Peninsula provides detailed management recommendations based around the protection of those sites as Ecological Reference Areas where timber harvests should be avoided (Schilke et al. 2024). While the protection of benchmark natural communities is an important element of landscape-scale biodiversity conservation and also required through forest certification, these high-quality sites represent a small fraction of public lands. There is a much larger coverage of natural pine systems that do not meet MNFI's standards for recognition as benchmark natural communities.

This report provides strategies for management of natural red pine forests that do not qualify as high-quality natural communities. We provide site-based management recommendations within this report that we believe will enhance benefits to biodiversity and increase climate resilience while allowing for timber harvest.

A clearcut with a narrow buffer along Lake Superior where several old red pines were taken despite no mention of red pine in the stand notes. Photo by P.R. Schilke.

Project Goals

The management of natural red pine stands is a priority for the DNR. It is a challenging topic complicated by demands for timber, the need to mitigate tree damage from forest pests and pathogens, logistical considerations around the application of fire, and assured regeneration from conversion of natural forests to plantation. Data and analyses of red pine–dominated reference stands suggest the need to revisit the management paradigm for pine systems. We have evaluated relevant literature to develop an approach for the management of natural red pine forests that fosters a stand's potential for timber harvest and other goals such as controlling forest pathogens, enhancing resiliency to climate change and the ability to withstand wildfires, conserving biodiversity, and reducing costs associated with intensive management.

As a counter to standard density-based management approaches, we are proposing a management framework based on the ICO approach (individuals, clumps, and openings) (Churchill et al. 2013). The ICO method uses timber harvest to modify stand structure and pattern in terms of individuals, clumps, and openings rather than using a density-based lens reflected in most current management strategies. This method was developed for dry forests in the western states but can be readily applied to the natural pine forests of the Great Lakes Region (Razenkova 2025).

Additionally, we know that historic red pine forests were less dense, naturally regenerated, featured older trees, and were patterned by frequent, low-intensity burns, often initiated by Indigenous Peoples (Anderton 1999, Meunier et al. 2019, Kipfmueller et al 2021). By combining the ICO approach with prescribed fire in a method that reflects historic disturbance cycles, we can develop a more ecologically based framework for managing red pine forests that considers spatial heterogeneity of forest composition and structure and promotes natural regeneration and landscape resilience. The primary objective of our recommendations is not to re-create pre-colonial forests but to provide an ecologically-informed silvicultural framework for natural pine forests that enhances resilience and non-timber benefits.

With this report, we identify sites of natural pine where we recommend the application of fire and harvesting to extract timber, establish natural red pine regeneration, promote a climate-resilient landscape, and protect regional biodiversity. We are not suggesting that the DNR attempt our approach everywhere, but we believe this approach is well-calculated and is worthy of attempting in several areas around Michigan. Our hope is that after successful implementation, this approach will serve as a template for management of natural red pine forests across the region for a more economically and ecologically stable future.

A site in Grayling that recently burned with natural regeneration and minimal char on boles. Project Area 8, Stand 74. Photo by J.M. Lincoln.

METHODS

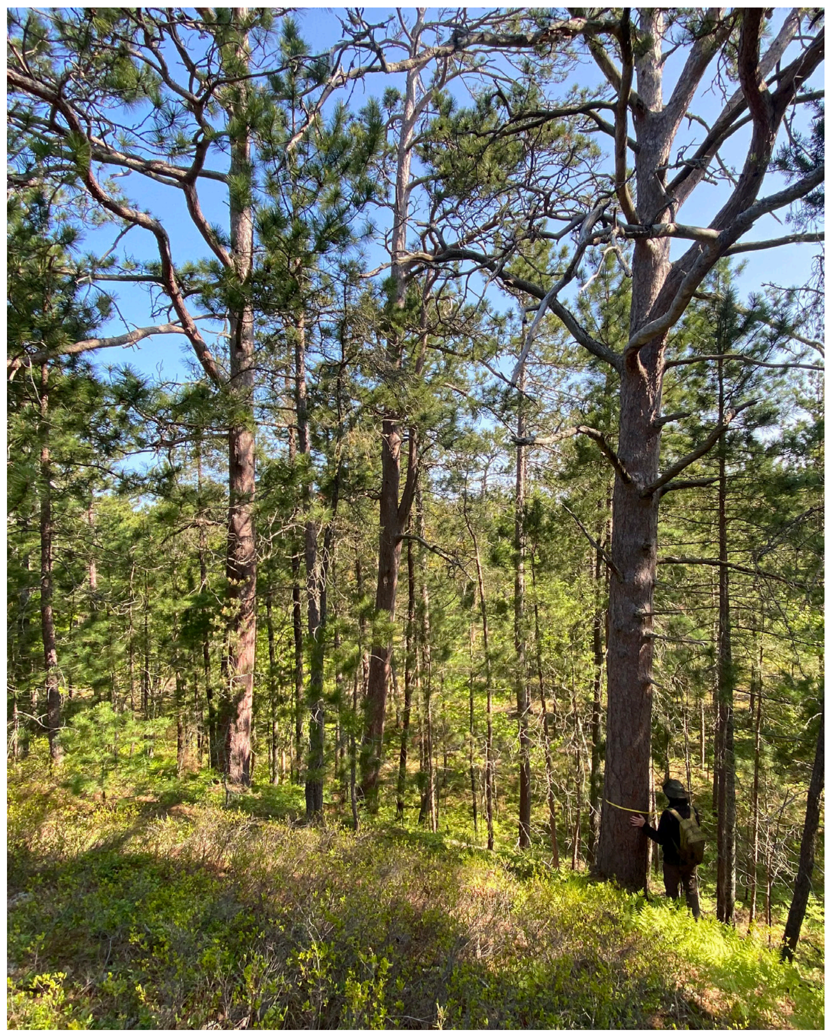
To identify survey areas of interest we used Michigan Forest Inventory (MiFI) stand data and selected stands that were classified as red pine or mixed pine where at least 50 percent of the canopy cover is composed of pine. We also selected stands that were classified as being of natural origin as opposed to stands that were classified as planted. We selected natural pine because we expected that these stands were more likely to have ideal characteristics in terms of vegetation structure, diversity, intact ecological processes, and higher ecosystem integrity. We further narrowed our survey stands to those with a dominant age of 100 years or greater. We expected that stands of this age would be more likely to have higher diversity, more complex structure such as old-growth characteristics, and overall higher conservation value.

After locating natural pine stands that had a dominant age of 100 years old or greater, we evaluated the landscape context for development of potential Project Areas. We also considered cover in the surrounding landscape and whether landscape-scale management with fire would be practical to implement. We avoided small, isolated stands on dune ridges surrounded by peatlands. We prioritized larger stands that were near water bodies or wetlands as we anticipated these stands would have greater diversity and would be more amenable to fire management due to the natural breaks present.

Areas that were surrounded by several pine-dominated stands were evaluated as potential candidates for the application of fire and implementation of timber management using the Individuals, Clumps, and Openings (ICO) framework to enhance forest resilience and ecological benefits along with timber harvest goals. We also attempted to avoid selecting stands that had treatments scheduled in the next year as well as areas that had recently been harvested. We consulted with Michigan DNR foresters and wildlife biologists to adjust our survey targets.

We conducted field surveys from June 5th to July 20th, 2024. Field surveys involved walking through survey targets and gathering stand-level data on floristic composition and vegetation structure. We noted any outstanding natural or cultural features in stands such as evidence of fire, pest outbreaks, presence of fruiting shrubs, or remaining legacy trees that were spared from the initial timber harvest. Generally, legacy trees are greater than 150 years old and have a unique visual appearance, including concave bark plates separated by relatively wide and deep fissures, large diameter lateral branches, asymmetrical crowns from wind damage, and frequently large cavities. In addition, many older red pines have survived multiple fire events and have fire scars at the base of their boles.

We evaluated the canopy composition in each target stand. We recorded diameter of prominent species and estimated ages of representative trees using an increment borer. We attempted to determine if multiple cohorts were present by also aging trees that appeared to be the oldest based on size and bark characteristics. We made note of wildlife and wildlife habitat in stands including the presence of any priority species and species of greatest conservation need in Michigan.



We prioritized the inclusion of legacy red pine when targeting areas for survey. These have large bark plates, large diameter lateral branching, irregular canopy shape, and canopy deadwood. Many trees were over 170 years old despite having relatively small diameters. Photo by J.M. Lincoln.

RESULTS

We surveyed natural pine stands within 24 Compartments across seven State Forest Management Units (FMU) identified as priority survey areas during the 2024 season. A total of 13 survey areas have been developed as Project Areas and one as a potential ERA (Figure 2, Table 1). These Project Areas are sites of natural pine where we recommend the application of fire and implementation of timber management using the individuals, clumps, and openings framework to enhance forest resilience and ecological benefits along with timber harvest goals.

Within the Upper Peninsula, two Project Areas are in the Newberry FMU, and two are in the Shingleton FMU; within the northern Lower Peninsula, one project area is in the Atlanta FMU, one is in the Cadillac FMU, two project areas are in the Grayling FMU, four project areas are in the Roscommon FMU, and one project area is in the Traverse City FMU (Figure 2, Table 1).

Following the Discussion section of this report, each of the 13 Project Areas are described in the Appendices (Page 44) with cursory data from Michigan Forest Inventory (MiFI) and supplemental descriptions where our observations increase understanding of the site. We also include management recommendations based on the management approach outlined in the *Project Area Management Recommendations* portion of the Discussion. A table of sites that were surveyed but not developed as project areas is included in the Appendices (Appendix 28, Page 72).

Table 1. Potential natural red pine project areas identified during 2024 field surveys. Comprehensive site descriptions and management recommendations are provided for each site in the Appendices.

Site Number	FMU	Compartment	Primary Stands	Other Stands in Project Area	Project Area Size (Acres)
	Upper Peninsula				
*	Newberry	42004	57	55, 56, 58, 60	207
1	Newberry	42011	46	C42017: S22	526
2	Newberry	42044	25, 38		339
3	Shingleton	41030	14	16, 19, 48, 49	163
4	Shingleton	41132	19	24, 26	212
	Lower Peninsula				
5	Atlanta	54169	6, 12, 16	C54164: S119 C54168: S138, 23	380
6	Cadillac	63133	7, 28		475
7	Grayling	72011	34, 46		197
8	Grayling	72258	85	74, 72, 76, 62	150
9	Roscommon	71045	112, 120, 148, 155	108	225
10	Roscommon	71064	124, 128, 129	127, 125	213
11	Roscommon	71064	155	136, 156	112
12	Roscommon	71078	11	12, 13, 14	160
13	Traverse City	61160	106	93, 82, 107, 103	290

* potential ERA

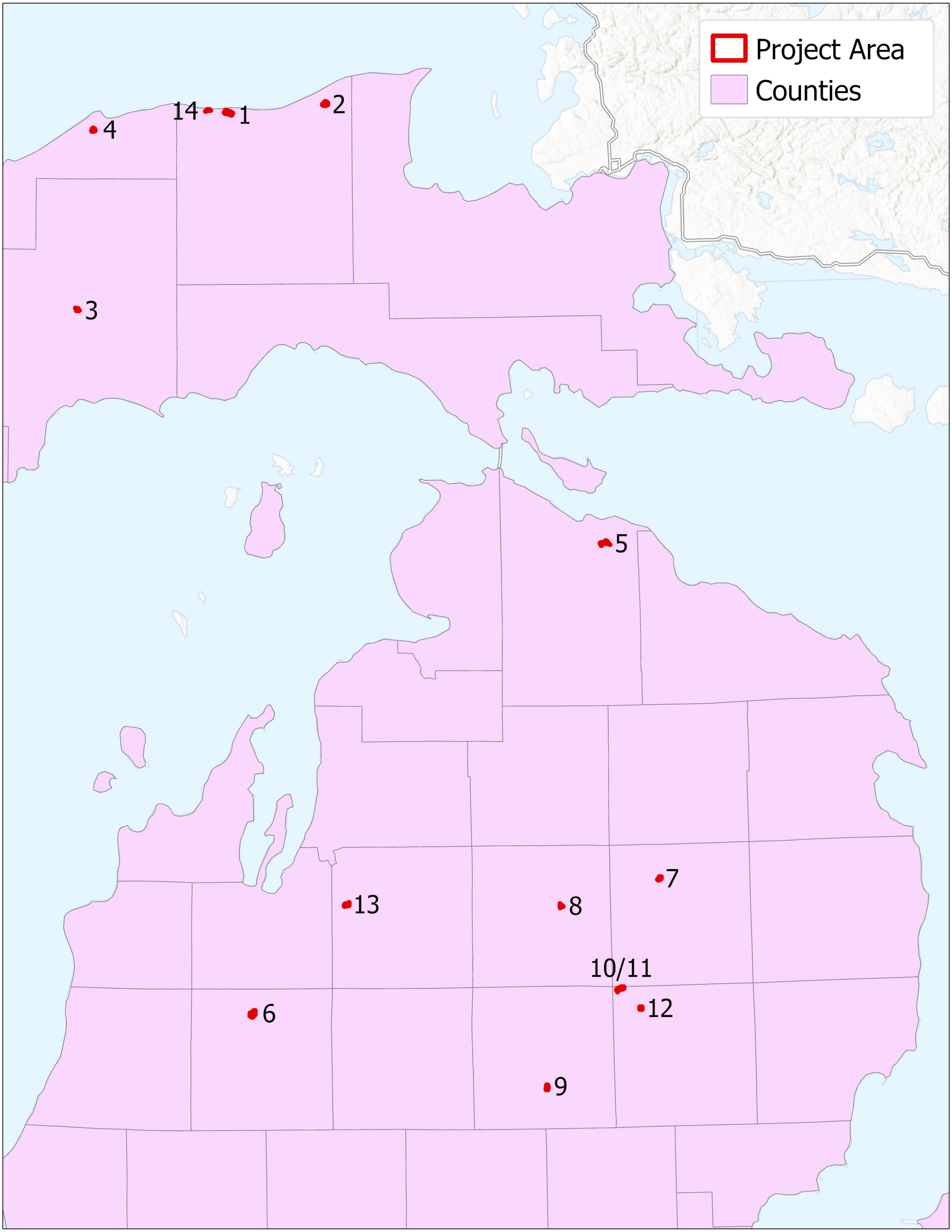


Figure 2. Locations of Project Areas and a potential Ecological Reference Area (ERA) surveyed during 2024. Numeric labels correspond to the following site names within the report: 1 = C42011, 2 = C42044, 3 = C41030, 4 = C41132, 5 = C54169, 6 = C63113, 7 = C72011, 8 = C72258, 9 = C71045, 10 = C71064 S124, 11 = C71064 S155, 12 = C71078, 13 = C61160, and 14 = C42004 (Potential ERA).

DISCUSSION

Red pine regeneration in many Michigan forests is insufficient to meet future timber harvest needs. To address this issue, natural pine forests are being converted to red pine plantations by way of clearcutting, trenching, and herbicide application. The Michigan DNR has expressed an interest in identifying alternative management to promote natural red pine regeneration through pathways that increase ecosystem resilience, protect native biodiversity, and provide for future timber needs. There are numerous areas on Michigan DNR-owned lands where alternative silvicultural practices could be employed to manage stands of natural pine. In this report, we identify sites in Atlanta, Cadillac, Grayling, Newberry, Roscommon, Shingleton, and Traverse City Forest Management Units (FMUs).

This section details management recommendations for 13 sites that contain multiple stands of mature natural red pine in various cover types. Our recommended approach is to first apply prescribed fire prior to overstory thinning, followed by alternating applications of prescribed fire and thinning into the foreseeable future. For sites where fuels prohibit the application of fire, we recommend evaluating the implementation of mechanical treatment of the understory to avoid ladder fuels contributing to a crown fire. Understory thinning through mastication is one viable fuels reduction treatment. We identified potential fire units and associated burn breaks within these project areas. We feel this management approach is critical to maintain these unique forests, support diversity, and mitigate future wildfire risk, ultimately providing sustainable forest resources into the future.

Protecting Priority Conservation Assets

While the primary focus of this report is the development of project areas where we recommend implementing ecological silviculture, we suggest managers and planners continue to focus on the protection of native biodiversity, particularly by: 1) stewarding existing Ecological Reference Areas (ERAs) and benchmark natural communities, 2) applying ecological silviculture techniques in forests near the shorelines of the Great Lakes that do not qualify as ERAs but are currently being converted to plantations, and 3) continuing to identify undocumented ERAs and high-quality natural communities across State Forest lands.

The DNR maintains a network of ERAs composed of high-quality and representative natural communities, and the stewardship of these ERAs is part of the criteria for dual sustainable forest certification. Protecting and managing representative natural communities is critical to biodiversity conservation because native organisms are best adapted to environmental and biotic forces with which they have survived and evolved over millennia (Cohen et

Stands of mature red pine persist near the shorelines of the Great Lakes. We urge the application of less intensive management approaches within 1/2 mile of the Great Lakes. Photo by J.M. Lincoln.

al. 2015). Biodiversity is most easily and effectively protected by preventing high-quality sites from degrading. Our recommended stewardship actions for dry and dry-mesic northern forest ERAs are to prioritize the application of low-intensity prescribed fire in the highest quality sites, reduce fragmentation by limiting trails and recreational development, and provide 150-foot-wide (45.7 meter-wide) buffers between ERAs and intensive forestry operations like clearcuts and herbicide application.

Natural pine forests along Lake Superior in the Newberry FMU and to a lesser extent in the Shingleton FMU are among the most extensive and highest quality in Michigan State Forests and have significant concentrations of red pine over 150 years old. These stands also have relatively high plant diversity, low anthropogenic degradation, and high cultural value with a well-documented history of Indigenous management stretching back centuries (Loope and Anderton 1998). In addition to the concentration of natural pine in the eastern Upper Peninsula, localized natural pine remnants occur along the Lake Michigan shoreline in the Sault St. Marie, Shingleton, and Gaylord FMUs and near Lake Huron in the Atlanta FMU. Across State Forest lands, these natural pine forests have been managed with even-aged silvicultural techniques. Even-aged management does not replicate mixed-severity disturbances which historically shaped dry forest ecosystems, and clearcutting eliminates seed sources needed for natural pine regeneration (Nyamai et al. 2014, Palik and D'Amato 2019). Thinning and clearcutting are the most prevalent forest management techniques used to manage natural red pine forests in the region. Converting these natural pine forests along the shoreline to plantations via clearcutting, trenching, and planting accelerates the loss of old trees and simplifies vegetative composition with decreased value to wildlife and the elimination of culturally significant vegetation that is utilized by local Indigenous communities. Current management is causing degradation of ERA-quality dry and dry-mesic northern forests, particularly along Lake Superior.

While ecological silvicultural techniques should not be restricted to forests near Great Lakes shorelines, we recommend establishing priority conservation areas along the shorelines of the Great Lakes to limit fragmentation and apply prescribed fire. These shoreline forests are vulnerable to fluctuations in Great Lakes water levels. Recent high-water levels and storms have eroded extensive areas of diverse forest and concentrations of old trees along the shoreline over the past decade. To preserve the ecological integrity of these shoreline forests and anticipate future losses to erosion, we recommend applying low-intensity prescribed fire and avoiding the most intensive management pathways such as clearcutting, scarification, herbiciding, and trenching within ½ mile of the Great Lakes. This conservative management approach for shoreline forests will help maintain water quality, protect concentrations of native plant diversity, and allow these forests to function as corridors for wildlife. Along with the use of fire to maintain ERAs and priority conservation areas along the Great Lakes shoreline, we recommend exploring co-management collaborations with local Tribal Nations, particularly to protect and maintain stands with unique characteristics and extensive histories of Indigenous fire management. We include more specific recommendations for implementing fire in the *Applying Fire* section below and for forming partnerships in the *Working With Tribes* section.

Finally, we recommend continuing efforts to identify remaining fire-dependent ERAs on State Forest lands (Lincoln et al. 2024). There are likely multiple undocumented high-quality dry and dry-mesic northern forests, particularly along the Great Lakes shoreline. These should be identified, evaluated, and prioritized for prescribed fire and other stewardship actions.

Clearcutting of natural pine forests and conversion to plantations was frequently observed close to the Lake Superior shoreline. Photo by J.M. Lincoln

Project Area Management Recommendations

Most natural pine forests on State Forest land do not meet MNFI standards for designation as high-quality natural communities or ERAs. State Forest lands are managed for multiple uses, including timber harvest, recreation, and conservation. The *Results* section in this report details 13 proposed Project Areas where we recommend an ecological silviculture approach. The primary objective of our recommendations is to enhance resilience and native biodiversity in areas where timber harvests will occur. We are not proposing the re-creation of pre-colonial forests. The following management recommendations are rooted in the understanding of natural disturbance processes that shape the highest-quality natural pine forests in the region. Benchmark dry northern forests are characterized by structural and compositional heterogeneity developed and maintained largely through frequent, low-intensity fires (Binkley et al. 2007, Meunier et al. 2019, Razenkova et al. 2025). Integration of low-intensity prescribed fire is central to managing for ecosystem resilience in natural dry pine forests in the Great Lakes Region.

Therefore, the general approach to the management of these Project Areas will be to return fire and implement timber harvest treatments that will establish multi-age forests that mimic the natural model for frequent fire forests. There are several names and similar approaches for this type of ecological silviculture, including “mixed-severity silvicultural system” (Palik et al. 2021), “variable harvest retention” (Palik and D’Amato 2019), or “variable density thinning” (Carey 1995, Palik et al. 2021). These approaches approximate varied disturbance severity to generate structural complexity. We recommend the ICO (Individuals, Clumps, and Openings) methodology for achieving structural complexity (Churchill et al. 2013, Razenkova et al. 2025). After the initial applications of prescribed fire, we recommend an overstory thinning. Therefore, we suggest alternating prescribed fire and timber harvest over long intervals for the foreseeable future. We recognize that in some sites (e.g., dry-mesic sites or sites with high soil moisture capacity and high nutrient availability), mechanical treatment to reduce

Complex, uneven-aged forests that approximate historic structural heterogeneity are likely resilient against disease, wildfire, and climate change. Photo by J.M. Lincoln.

understory fuel loads may be necessary before the implementation of burning. We also recognize the need to apply prescriptions that are catered to the unique conditions of each site. A generic or formulaic approach is discouraged, and each site should be evaluated for its distinct attributes. The intended results are complex, uneven-aged forests that approximate historic structural heterogeneity characteristic of pre-colonial conditions for the benefit of natural regeneration and are resilient against disease, wildfire, and climate change.

Developing Project Areas

We identified and surveyed 13 candidate sites across several State Forest management units during the 2024 season (detailed descriptions provided in Appendices 1-26). These project areas feature one or more stands of mature natural red or mixed pine. The project boundaries are intended to serve as maintained burn breaks for the repeated application of prescribed fire. We have provided approximate boundaries that will need to be examined, verified, installed, and maintained by local managers familiar with the sites. Existing roads were chosen for burn breaks when possible, but wetlands and waterbodies were recommended in several instances. Burn break placement is intended to enable fire movement across ecotones and avoid constructing unnecessary burn breaks that may have negative long-term impacts on saturated soils and can be conduits for invasive species. Further, larger project area sizes will contain several stands of multiple age classes, and prescribed fire should provide acceptable levels of red pine regeneration.

The appropriate placement of burn breaks is important in reducing the harmful impacts to sensitive ecosystems, especially ecotones. Ecotones include transitional areas between uplands and wetlands; they are often very diverse and serve as critical habitat for many herptiles at different times of the year for thermoregulation and nesting. They are also important foraging areas for insectivorous birds. In the upland-wetland ecotones of fire adapted landscapes, the absence of regular fire has led to the development of dense shrub thickets that now function as boundaries between wetlands and uplands and do not provide sufficient habitat for herptiles (Lincoln et al. 2023). Standard prescribed burn practices typically either exclude ecotones from prescribed fires or place burn breaks directly in ecotones. We urge managers to avoid placing burn breaks in ecotones and instead include them in larger fire units to prioritize fire management of these critical habitats.

Project areas were developed to include wetlands that are intended to function as natural burn breaks wherever possible. Historically, wetlands burned with adjacent uplands and the ecotones, or margins between upland and lowland, are especially diverse. Photo by J.M. Lincoln.

Applying Fire

Most of these project areas have not experienced fire since the late 1800s. With the loss of fire as an ecological process, the stands we surveyed generally lacked red pine regeneration, had a thick needle/duff layer that hinders red pine establishment, and often had a dense understory with red maple, paper birch, white spruce, white pine, and balsam fir, particularly in moister microsites. While thinning the understory before burns may be necessary in especially dense stands, we generally suggest strategically applying fire to the project areas prior to the overstory thinning to maximize natural regeneration of red pine, reduce mesophytic competitors, consume ladder fuels, condition trees to fire, and facilitate future burns. Mastication or chipping of downed debris can be useful in reducing fuel loading for sites with dense mesic understories. If mechanical treatments are implemented, we urge managers to avoid treatment areas designated as Skips and Clumps. Following the initial timber harvest, fire will again be applied to reduce the impacts of red pine cone beetles, decrease risks from disease, and promote sustainable red pine regeneration.

The reintroduction of fire to fire-adapted communities where it has been absent for over a century poses several challenges. The fire deficit that has accrued during the last two centuries has resulted in fuel accumulation, wildfire risk, and increases in canopy density in natural red pine stands across the Great Lakes Region (Meunier et al. 2019, Razenkova et al. 2025). The lack of recent fires creates a positive feedback loop that makes these forests increasingly resistant to low-intensity surface fires, thereby perpetuating mesophytic species and decreasing regeneration of red pine and other fire-adapted species (Nowacki and Abrams 2008). This shift toward mesophytic species has been observed throughout the Great Lakes Region and is fundamentally destabilizing the landscape as these sites become less resilient to drought and more susceptible to severe wildfires due to dense understories (Magruder

We recommend the application of low-intensity fires with relatively low flame lengths to minimize mortality of red pine seedlings and canopy trees. Photo by Steve Woods, MDNR.

2013, Kipfmueller et al. 2021). Large red pine boles are strongly resistant to mortality from low-intensity surface fires, even with high fuel loads (Scherer et al. 2016), and planning initial fires to be low intensity will reduce mortality risk associated with high density of understory trees such as spruce (*Picea* spp.), white pine, and balsam fir.

With the return of low-intensity surface fire as a predominant ecological process, many natural red pine stands can naturally regenerate and exhibit improved resilience to wildfire while accommodating timber harvest (Scherer et al. 2016, 2018). Due to the irregular masting of red pine every five to ten years, implementation of burning should be synchronized with large seed crops. Managing expectations for the first entry burn can be important. In areas that have had fire excluded for decades, the forest can exhibit low canopy base heights (height of lowest living branches), increased litter and coarse woody fuels, and a heavy moss component. Even low intensity burns can have a transformative effect on reducing the accumulation of litter and difficult fuels and raising the canopy base height. Reducing these fuels can lower the chance for future fires to initiate a crown fire. Additionally, applying low-intensity fires lessens the risk of damage to the roots, particularly in areas where needle duff has accumulated from a prolonged absence of fire (Zeleznika and Dickmann 2004). Therefore we stress the importance of repeated low-intensity prescribed burns over single moderate- to high-intensity burns to achieve fire effects.

Prescribed fire seasonality is an important consideration in achieving the intended low intensity and low severity fire to accomplish targeted ecological objectives. Conducting the first entry during the spring dormant season can have the beneficial effects of conditioning the conifer species and allowing them to recover with minimal stress. Monitoring tree phenology is important and applying the first burn prior to swelling conifer of buds will help ensure dormancy of the trees. Typically, conducting a first entry of fire during the dormant season consumes litter but not much of the duff layer. This allows for a nutrient flush in the soil without impacting the roots of the trees and may stimulate root growth or condition roots to better tolerate future fires (Mallik and Roberts 1994, Zeleznik and Dickmann 2004).

In the absence of consistent fire, needle duff accumulates at the base of trees (top photo). A high-intensity fire can cause severe duff scald and damages buttress roots, making merchantable trees susceptible to insects (bottom photo). Low-intensity fires for the initial entry will consume needle duff and mitigate duff scald on buttress roots. Photos by J.M. Lincoln.

The primary goals of applying prescribed fire in natural pine forests are to promote natural regeneration of red pine, reduce mesophytic competitors, and consume ladder fuels. Achieving this with low-intensity prescribed fire will likely require two applications of fire prior to timber harvest. We recommend these two fires are applied in relatively rapid succession (3 to 7 years apart) for several reasons: to reduce mesophytic competition, problematic fuels, and ladder fuels; to mitigate damage to the root zone; to condition trees for future fires of varying intensity; and to increase canopy base height to minimize risk of future crown fires. Allowing a season or two for the trees to recover prior to harvest activity can help reduce mortality. Fire and harvest are both stresses on the forest and events like drought and disease should be monitored prior to burning or harvest activities to avoid compounding stress events. To promote adequate levels of red pine regeneration, it may be necessary to vary the seasonality of the burns and keep the intensity low. Fires regularly occurred during the dormant season (late fall to early spring) based on fire scar positions relative to growth rings (Muzika et al. 2015, Sutheimer et al. 2021). Spring and early summer burns also regularly occurred but can create more competition from early plant colonizers that become established before the peak of red pine seed rain and may cause higher tree mortality during initial burns (Kozlowski and Ahlgren 1974, Meunier 2022).

Forecasting of bumper crops and timing the second burn with cone production will also help ensure adequate regeneration. Red pine has a two-year cone cycle and cone crop forecasting can be done annually to estimate when adequate crops will be present and allow sufficient lead time to plan burns. Red pine bumper crops occur every 5 to 10 years

It may be difficult to burn some areas, particularly sites with an abundance of red maple which could diminish results of a single low-intensity burn. For sites with high soil moisture and nutrient availability and a dense understory, pre-burn mechanical treatment of the understory may be utilized to reduce fuel loads and prepare the site for the first burn. We recommend engaging with local fire managers to make these determinations on a site basis. Other areas, especially xeric sites or sites that have had a recent fire, may need only a single burn before a overstory thinning. Photo by J.M. Lincoln.

and cone crops often vary from one stand area to the next, suggesting each project may need to be monitored. Red pine cones typically mature in September with seed fall from mid-September through early October (Keith Konen, Silviculturist, United States Forest Service, personal communication). We recommend conducting the second burn just prior to seed fall to avoid fire consuming freshly fallen seeds and eliminate competition from deciduous species. Foresters with the Menominee Tribal Enterprises have had success promoting red pine recruitment by burning in July during a high cone production year (Ron Waukau, Forest Manager Menominee Tribal Enterprises, personal communication).

After the initial timber harvest, we suggest applying fire 3 to 5 years to reduce impacts of red pine cone beetles, decrease risks from disease, and promote sustainable red pine regeneration. While the historic fire return intervals in red pine forests vary by region and across time, low-intensity surface fires regularly occurred across a broad range of roughly every 5 to 40 years in fire-dependent ecosystems across northern Michigan (Loope and Anderton 1999, Drobyshev et al. 2008, Kipfmueller et al. 2017, Stambaugh et al. 2024).

Following the third fire, managers can apply fire at an interval of every 10 to 30 years, between subsequent timber harvests. Ideally, managers would vary the seasonality and adjust the intensity to control understory mesophytes and continue to promote red pine regeneration. To enhance fruiting of understory shrubs, managers can implement a fire return interval of every 5 to 10 years. A proposed treatment schedule is provided (Table 2)

A red pine plantation with at least three burn entries, based on scarring on the base of trees. The fire intensity was relatively high and char on the boles was over 10 ft high. The high-intensity fire and failure to coordinate the fire with a mast year resulted in the lack of red pine recruitment. The only regeneration was of jack pine. Fire must be carefully applied to achieve and maintain natural red pine regeneration. Photo by J.M. Lincoln.

Table 2. Example of a proposed treatment schedule.

Process	Year of Application	Goals	Burn Conditions
First Entry Burn	1	• Condition rhizosphere for future fires • Partial consumption of duff/leaf litter • No mortality of canopy pine • Consume lower ladder fuels • Set back understory mesophytes • Minimal char on boles	• Late dormant season, before terminal buds swell (often around mid-April) • Low flame lengths (below 12") over 60 to 80% of the site • Relative humidity over 30% • Wind speed below 15 mph • Within 5 days of last rain
Monitor		• Identify/treat invaisve species • Evaluate understory response from first fire • Conduct red pine cone crop forecasting to time next burn • Determine intensity of next burn	
Second Entry Burn	4 to 8	• Burn just prior to seed release of bumper crop year • No mortality of canopy pine • Expose soils for red pine regeneration • Consume lower ladder fuels • Set back understory mesophytes • Canopy base height improvement	• Attempt burn just prior to red pine seed release (mid-Sept to early Oct) • Low flame lengths (below 12") over 60 to 80% of the site • Slightly increased intensity
Monitor		• Identify/treat invaisve species • Evaluate understory response • Evaluate red pine regeneration • Develop timber harvest treatment boundaries (ICO) • Determine harvest levels	
First Harvest	8 to 15	• Skips - no harvest, avoid equipment • Individuals - remove 1/3 of BA • Clumps - no harvest this round • Openings - remove all canopy trees, avoid red pine regen	• Provision in timber sale that slash must be pulled several feet from base of leave trees to minimize risk of damage from slash/tops during subsequent fires
Monitor		• Identify/treat invaisve species • Evaluate red pine regeneration • Conduct red pine cone crop forecasting to time next burn • Plan next burn based on regeneration and health of trees	
Third Entry Burn	8 to 10 years after previous burn	• Consume woody debris from harvest to limit bark beetle • Minimal mortality of pine regeneration and canopy trees • Continue to promote red pine regeneration • Continue to set back understory mesophytes • Limit disease risk to red pine seedlings	• Spring or late summer burn • Low to moderate intensity • Flame lengths under 2 ft
Monitor		• Evaluate invaisve species • Evaluate understory response • Evaluate red pine regeneration • Determine need for additional fire before next thinning • Develop next treatment layout (clumps/openings) • Determine harvest level of next thinning, reduce BA by 1/3	
Second Harvest	20 to 40 years post thinning	• Skips - no harvest, avoid equipment • Individuals - thin by 1/3 BA • Clumps - identify which clumps will be removed and where new clumps will be established • Openings - establish new openings including some clumps saved in previous thinning; remove all canopy trees, avoid red pine saplings/seedlings	

Forestry Treatments

Historically, pine-dominated forests had multiple age and size cohorts of pine, often with a substantial proportion of the canopy trees over 200 years old in the oldest stands. Old trees are fire resistant, genetically diverse, and provide habitat for a range of species. To realize those benefits in a forest that incorporates timber harvest, we suggest implementing recommendations adapted from the ICO method (Churchill et al. 2013, Churchill et al. 2016, Razenkova et al. 2025). The project areas we identified for the ICO approach often include several stands and cover types, with the majority of the area comprised of mature natural red pine or mixed pine forests. An example of a project area and proposed treatment areas is provided below (Figure 3).

For each project area, there are four distinct management zones: Individuals, Clumps, Openings, and Skips, with descriptions below. All management zones are intended to be included in every prescribed fire. While the placement of Skips was intentionally considered to protect important features, the delineation of Individuals, Clumps, and Openings was intended to serve as a guide for managers and can be adjusted at each area as site conditions are better understood.

The first step in our process was to delineate Skips (or reserves), which are zones that are intended never to be harvested. Skips vary in size but average between 1 and 3 acres and generally cover approximately 10% of a project area, though this proportion is higher in areas where there are more wetlands. We generally placed Skips along wetlands, steep slopes, pockets of older trees and/or concentrations of fire-scarred trees, and areas of high-quality dry northern forest (e.g., Grayling 72258). Additional Skips can be placed for wildlife retention areas, such as goshawk nests, to retain snags and patches of dead wood, and protect vernal pools. Skips can also be placed in areas of heightened herbaceous diversity that are often damaged with traditional forestry techniques. Skips are intended to be embedded throughout the project area to retain zones of low shrubs and herbaceous composition characteristic of natural red pine forests. By evenly

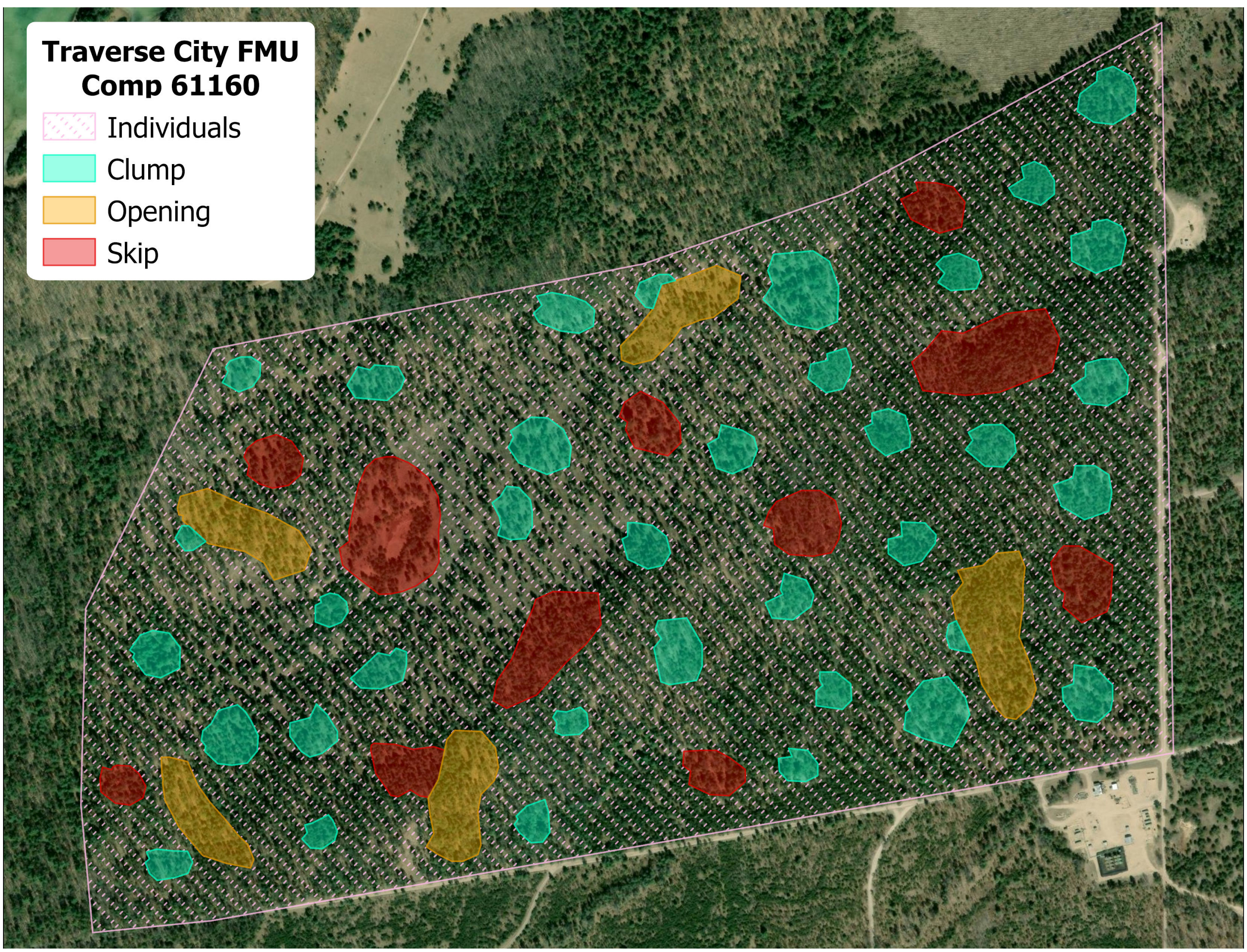


Figure 3. ICO Management zones for Project Area in Traverse City Compartment 61160.

placing Skips, there will be continual supplies of seed from the oldest trees throughout the project areas. These zones will be where the advanced age classes are allowed to develop and perpetuate.

The Individuals management zone comprises the majority of each project area and is essentially the matrix for the project area that will be thinned at the first harvest. Because each project area starts from a different condition, there is no rule for how much to thin during the first treatment. Ideally, there will be a range of tree densities following the treatment, but generally it will be thinned to 50 to 100 square feet basal area (BA) per acre with about a third of existing trees being removed. If the starting density is 110 to 140 BA, the Individuals treatment area could be thinned to between 80 and 110 residual BA. If the site is at 80 to 110 BA prior to first treatment, it could be thinned to 50 to 80 residual BA. The goal of this approach is to periodically harvest much of the site through thinning, so it is important to leave enough trees for the next treatment to remain economically viable within 20 to 30 years. When selecting which individuals to leave, do not count snags as individuals, and retain a range of tree sizes and ages. Because this approach also aims to maintain genetic diversity and resilience to wildfire, we also recommend prioritizing the retention of the oldest trees consistently throughout the Individuals treatment zone at each site whenever possible. Additionally, we recommend retaining fire-scarred trees.

Clumps are similar to Skips and function to retain various age classes and herbaceous composition across the site. Unlike Skips, Clumps are not intended to be permanently omitted from timber harvest, and some of the Clumps will be harvested in subsequent timber harvests. Clumps generally make up about 10% of a project area and are more variable in size than Skips, generally ranging from 0.25 to 1.5 acres (0.1 to 0.6 hectares), but flexibility in determining size is encouraged. It is difficult to predict each project area's response to the management approach, and retention of clumps will provide options for future harvests. The evenly spaced distribution of Skips and Clumps is intended to assure natural regeneration of red pine and retention of culturally relevant shrubs and characteristic herbaceous species. They should therefore be distributed across project areas and not concentrated in one large retention area, at edges, or along riparian areas.

Because red pine regeneration responds positively to open conditions, we have included Openings where all canopy trees will be harvested. Openings comprise roughly 5 to 10% of a site and mimic various disturbances, including windthrow and severe fire. We provide the potential location of Openings for the initial harvest treatment, but these are suggestions and can be altered based on the areas response to fire, particularly red pine regeneration. The ICO implementation guidelines (Churchill et al. 2016) suggest small (<0.5 acre) and large (>0.5 acre) Openings and that these should be "sinuous and amorphous in shape" rather than circular gaps. In stands at risk of infection by shoot blight, large Openings of over 0.75 acres have been shown to act as a natural barrier to spore spread (MDNR 2025). We generally placed Openings in areas of flat topography away from wetlands and in areas with fewer old trees. We also provided 5-acre (2 hectares) targets for implementing each Opening treatment with the intention that managers would operate within those areas to develop appropriate sizes and shapes based on the unpredictable distribution of natural red pine regeneration expected after the initial application of fire. In subsequent harvest treatments, we expect new openings to be developed in areas where there is ample regeneration and, in some cases, existing Clumps will be removed for future openings, and future Clumps will be developed in areas that were previously Openings.

It is essential to implement the ICO treatments when there is adequate regeneration, and various treatments should be applied in a way that does not significantly harm the regeneration achieved through the application of fire. Additionally, because the protection of native biodiversity is a feature of this approach, timber harvests need to avoid excessive soil disturbance through rutting, unnecessary paths, and scarification. Severe soil disturbance should be minimized as much as possible, particularly in and around Skips and Clumps where the ground layer is intended to remain undisturbed. Finally, because fire-scarred red pine stumps and snags contain important site-specific information regarding fire history, we urge managers to avoid their destruction during timber harvests. Indigenous Peoples frequently applied fires, and stumps, as well as living trees that record those fires with scars, should be considered cultural artifacts that can inform future approaches to management, particularly the timing, frequency, and severity of prescribed fires.

Because these project areas are typically large and contain multiple stands of varying age classes, it is difficult to prescribe specific targets regarding basal area and trees per acre. We provide a broad target (1/3 reduction of BA every 30 years) but the success of this methodology will rely on judgment of professionals familiar with each site and a commitment to adaptive management. Likewise, the difficulties around regeneration of natural red pine and complexities of applying prescribed fire may lead to situations where there is too much red pine regeneration and situations where there is too little. In some cases, red pine saplings may need to be reduced and sometimes regeneration may need to be supplemented with hand planting. Finally, it will be critical to administer timber sales in a way that protects leave trees and regeneration. Slash must be kept away from the base of leave trees to reduce damage during future fires. Regeneration is susceptible to harvest related mortality via felling and yarding and measures must be taken to restrict incidental loss.

Challenges

If implemented, the approach we have outlined would be a dramatic shift in the management of natural red pine forests on Michigan DNR lands. Red pine is one of the most valuable timber resources in the state, and plantation forestry is a proven technique for generating dependable revenue from red pine. Although our methods are complex and untried within the Michigan State Forest system, many of these techniques have been implemented both within and outside of Michigan, and we believe the benefits outweigh the drawbacks. We have detailed some of the potential challenges to the proposed approach below. We emphasize the need for monitoring throughout the management cycle to facilitate adaptive management. The objective is to learn from the trials and inform future management.

ICO Implementation in the Great Lakes Region

The ICO method is intended to be an "intuitive, flexible, and efficient approach to restore the mosaic patterns" common in natural pine forests (Larson and Churchill 2012, Razenkova et al. 2025). More detailed treatment approaches are available in the ICO implementation guide (Churchill et al. 2016); however, this system was initially conceived in fire frequent forests of the western United States (Churchill et al. 2013). We, and others, consider dry pine forests of the Great Lakes Region to be analogous enough to successfully apply the ICO methodology (Razenkova et al. 2025). Exact treatment recommendations regarding sizes of clumps and openings, as well as trees per acre following initial harvest, are not perfectly aligned with the ICO method. Further, our approach to applying fire is not the only approach that would work: each site is different and there are likely many routes to success. However, we have provided a method based on our ecological expertise and experience along with extensive support in the literature. We believe that the prescriptions we have detailed will provide enough of a framework for developing site-specific treatments by trained foresters familiar with each project area.

Dense red pine regeneration occurring in a natural red pine stand in northern Wisconsin that burned twice during the dormant season and then burned in July during a red pine bumper crop after cone production was carefully monitored. Monitoring red pine cone production and coordinating application of fire with high seed production years is a critical for promoting red pine regeneration. Photo by J.G. Cohen.

The Need for Prescribed Fire

Despite the extensive distribution of natural red pine forests in Michigan and the clear evidence of fire in these systems, there are few places to visit in the State Forest system where ecological silviculture has been combined with application of prescribed fire. Prescribed fire is not currently being applied to the landscape at a rate that makes our approach feasible. An obstacle to the implementation of the proposed approach is the inability of the Michigan DNR to implement prescribed burning across fire-dependent landscapes due to limitations in personnel and financial resources.

To help the Michigan DNR quantify the need for prescribed fire, MNFI developed a prescribed fire needs assessment model for state lands in Michigan (Cohen et al. 2021). This model is based on the Michigan Forest Inventory data and ascribes a natural community type and fire score that conveys each stand's propensity to burn, with the most fire-dependent natural communities receiving "very high" scores and community types that rarely burned receiving "low" scores. In this way, managers can identify areas where prescribed fire is most in line with the natural proclivities of a site along with areas where prescribed fire should be avoided. The model suggests the state would need to increase the amount of prescribed fire by 2.2 to 13.4 times to burn all sites identified as having the highest need for fire (Cohen et al. 2021).

To demonstrate the need for fire in natural pine forests on State Forest land, we evaluated the MiFI stands from the Newberry Forest Management Unit and organized them by natural community type, dominant age, and size. We identified 128 stands of natural pine that would be good candidates to evaluate for potential ERAs or inclusion in ecological silviculture, as we have outlined in this report (Figure 4). These stands range in size from 15 to 491 acres (6 to 199 hectares), with the smallest stands supporting trees over 181 years old (Appendix 29, Page 73). Together, these stands total 14,882 acres (6,023 hectares). Even if we applied fire at the upper limit of our suggested range of every 30 years, it would require burning nearly 500 acres (202 hectares) a year in the Newberry FMU alone to meet this goal.

This is just one FMU, and a similar need for fire exists across several other regions of the State Forest system, including the Atlanta, Grayling, Shingleton, Roscommon, Traverse City, and Escanaba FMUs. To our knowledge, there have been two fires applied to natural red pine stands in the past three seasons, totaling 494 acres. Prescribed fire is not being

Prescribed fire is being applied across a range of conditions to meet objectives. Photo by Kyle Martin, Kalamazoo Nature Center.

consistently applied to standing natural red pine in the State Forest system. The need for prescribed fire dramatically exceeds the state's current capacity, and a paradigm shift prioritizing the application of prescribed fire in the context of ecological management is needed.

There is a precedent for applying fire to natural red pine stands in Michigan and across the Great Lakes region. Within the Menominee Reservation in northern Wisconsin, Menominee Tribal Enterprises has been managing pine-dominated forests with fire for the past three decades. The US Forest Service has also been successfully implementing prescribed fire in fire-dependent systems within the Tawas, Harrisville, and Mio Ranger Districts of the Huron-Manistee National Forest for decades. Prescribed fire has been applied on over 45,000 acres in those districts, often through both natural and plantation red pine. These districts cover over 438,584 acres and prescribed fire has been consistently applied to thousands of acres of natural red pine forest, often with multiple burn entries and in conjunction with timber harvest, providing an analogue of similar work from which state agencies can reference for red pine regeneration methods, cost estimates, and project planning purposes. Between 2005 and 2021 there have been between 370 and 8,090 acres burned every year across the Huron National Forest, with an average of 2,774 acres per year and as many as 8,088 acres burned in a single season. There were between 5 and 32 burns each year with an average of 10 burns per year and the average size of each burn was 275 acres. As fire begins to be more commonly implemented across State Forests, we recommend the DNR to develop a spatial database where the application of fire in ERAs and natural pine stands is tracked and consistently evaluated.

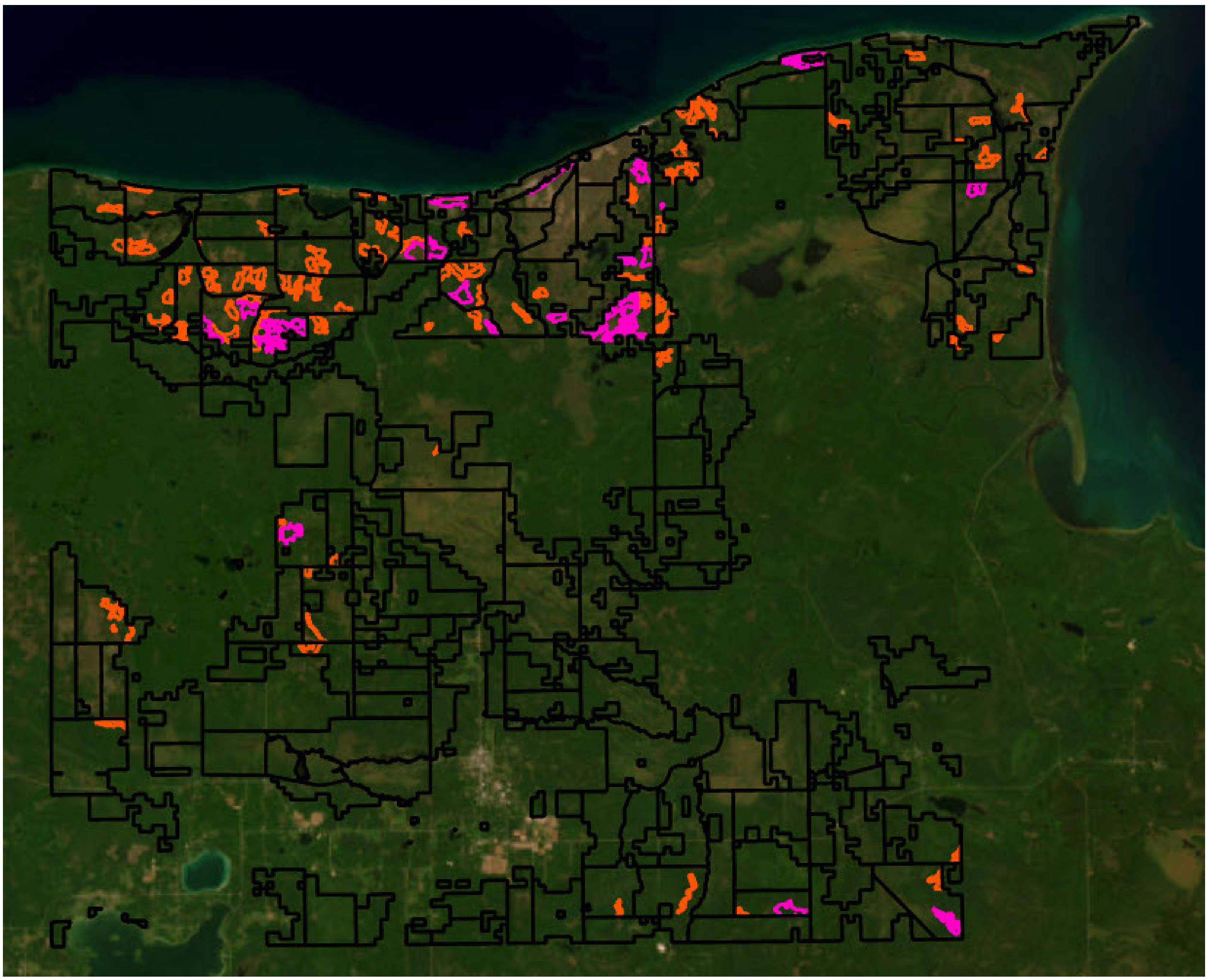


Figure 4. Stands in the Newberry FMU recommended for future evaluation for implementing our approach to managing natural red pine or evaluation for designation as dry to dry-mesic northern forest Ecological Reference Areas. Pink are highest priority stands and orange are lower priority stands based on stand size and age of the representative trees.

Forest Pests and Pathogens

The spread of pests and pathogens is a major concern with the implementation of multi-cohort stands, particularly in regard to shoot blight of red pine (e.g., *Diplodia pinea, D. scrobiculata*, and *Sirococcus conigenus*). Because shoot blight species spread from infected overstory trees to adjacent seedlings via rain drops and possibly stand to stand by cone insects (Stanosz et al. 2013, Smith et al. 2015, Albers 2024), managing for multiple cohorts and heterogeneity as we are proposing has traditionally been discouraged by foresters (Heyd 1984, Palik and D'Amato 2019, Palik et al. 2021). However, traditional plantation approaches may be reinforcing feedback loops that create unhealthy, disease-prone forests (Ostry et al. 2012, Magruder et al. 2013, Palik et al. 2021, Larson et al. 2021). Allowing for legacy trees and natural regeneration to persist on the landscape contributes to stand level diversity and increases the likelihood of naturally resistant individuals to proliferate (Spies and Franklin 1996, Tobias and Guest 2015, Sniezko and Nelson 2022). Evidence also exists that creating gaps and openings can reduce soil pathogen activity compared to adjacent forests via alteration in soil moisture and temperature (O'Hanlon-Manners and Kotanen 2004, Ritter et al. 2005, Reinhart et al. 2010); relatedly, larger gaps over 0.75 acres may be an effective way to reduce the spread of shoot blight into adjacent red pine stands (Ostry et al. 2012, MDNR 2025). Diplodia also spreads by needle cast and equipment and we urge vigilance in cleaning equipment between visiting sites.

Fire is almost never applied to variable harvest techniques on State Forest lands in Michigan and there is evidence that it is an effective means of reducing a number of pathogens and pests. Repeat burning has been shown to successfully decrease populations of multiple species of bark beetles (*Coleoptera* and *Scolytidae* species) and wood-borers (McCullough et al. 1998). Prescribed fire has been most successful in controlling cone or seed-infesting insects (Miller 1978, McCullough et al. 1998); for example, a single prescribed fire can significantly reduce infestations of red pine cone beetle (*Conophthorus resinosae*) (Miller 1978, Dickmann 1993). In addition to insect pest reduction, surface fires may also reduce multiple species of shoot blight (Koch et al. 2009, Palik et al. 2021). For example, a site in the Upper Peninsula exhibited significantly lower spore counts of *Sirococcus conigenus* in burned treatment areas than in harvest only and control plots (Koch et al. 2009). Incidents of shoot blight on the landscape may be higher in general due to the removal of surface fires from the landscape and reintroduction of periodic burns could potentially decrease outbreaks of these species (Palik et al. 2021). The accumulation of pine needles without fire creates an ideal environment for disease. A combination of less needle duff and more open conditions through frequent fire could reduce the incidence of contagion. If shoot blight spores are truly carried from stand-to-stand by cone insects as postulated by some foresters (Albers 2024), then prescribed fires may both directly and indirectly lessen shoot blight occurrences via spore count reduction and cone beetle mortality. In addition, reduction of needle duff and increased air flow created by low intensity burning may reduce suitable substrate for pests and pathogens.

Because of the mitigating impacts of fire on pest and pathogen potential in natural red pine regeneration, we urge land managers to consider the application of fire to be a critical aspect of our management approach. Without the application of prescribed fire, it is unknown how ICO methodology will impact disease and pests in these areas. By combining prescribed fire with the ICO framework, the approach we outline in this report will provide natural red pine regeneration and an improved resilience to climate change, wildfires, and disease for a more stable, biodiverse, and productive landscape.

Reducing Bole Char

Fire on the boles of trees can be undesirable in stands marked for timber sale as it sometimes damages the timber being sold or can cause discoloration for white paper products. We have specifically detailed our fire prescriptions to mitigate charring through the use of low-intensity fires. In particular, the low flame lengths associated with low-intensity fires should greatly reduce char. On sandy soils, fire has been observed to climb the boles of red pine when it has been more than 7 days since last rain (observations made during prescribed burning on the Huron-Manistee National Forest). Conducting the first entry during the dormant season and within 5 days of the last rain can help minimize the char on red pine boles and prevent the occurrence of fire climbing the boles of the trees. As conditions progress past "7 days since last rain" the occurrence of fire climbing the boles increases greatly. Even with high relative humidity, waiting longer than 7 days after rain can lead to increased bole char and greater risk of crown fire. Our prescriptions are intended to limit char to the lower section of the trunk, and the flaky nature of red pine bark typically removes traces of char within 10 to 12 years for low intensity fires. Furthermore, charred portions of the bole can be left in the woods to contribute to coarse woody debris and carbon input. This methodology is intended to allow the harvest of red pine for paper markets to continue in the central Upper Peninsula, where the prospect of fire in natural red pine receives substantial pushback from the timber industry.

These natural red pine forests in the Huron Shores District of the Huron-Manistee National Forest were included in a low-intensity prescribed fire in 2018. As of 2024, there is patchy but consistent natural regeneration throughout the forest, no observed canopy mortality, no seedlings affected by disease, and minimal bole char. Top photo by B.J Stearns. Bottom photo by J.M. Lincoln.

Future Work

Inventory Process

The current state inventory process often does not capture the presence of rare, old red pine trees as we found DNR stand data were not always a reliable indicator of the presence of old red pines in a stand. Although most stands that we surveyed were even-aged with canopy red pine in the 90- to 110-year-old range, we located a few individual red pines that were much older, and multiple stands contained a small percentage (<5%) of red pine trees that were over 150 years old. Trees that are older than 150 years have a unique visual appearance, including concave bark plates separated by relatively wide and deep fissures, large diameter lateral branches, asymmetrical crowns from wind damage, and frequently large cavities. In addition, many older red pines have survived multiple fire events and have fire scars at the base of their boles.

Due to the potential undocumented presence of old pines, we recommend that managers and planners conduct a thorough field survey before developing stand management goals and scheduling treatments in natural pine stands. The absence of older red pine on the landscape and the dearth of natural red pine regeneration necessitate protecting any remaining old trees from harvest to restore demographics that are closer to the range of natural variation and retain genetically, ecologically, and culturally significant legacy trees. Because inventory is often used to develop stand treatments, this is a critical gap, and future inventory would benefit from prioritizing the inclusion of old red pine, either in the notes or as a separate age category.

Burn scars showing repeated fires are a feature of the highest quality examples of natural pine forests and are often Indigenous cultural artifacts as they can help determine a site's unique history of Indigenous cultural fire and should be noted during the inventory process and protected during timber harvest. Photo by J.G. Cohen.

This red pine had a relatively small diameter of 22 inches but the crown shape and the large bark plates suggested an advanced age. An increment borer was used to extract a core and the tree was determined to be at least 280 years old. Photo by J.M. Lincoln.

Old red pines feature irregular canopy shape, canopy deadwood, and cavities. Photo by J.M. Lincoln.

Old red pines are often surprisingly small, relative to expectations. Old trees tend to have large diameter lateral branching and large bark plates. The tree in the foreground had a diameter of 21 inches and the core taken had 220 rings. Photo by J.M. Lincoln.

Monitoring

Monitoring the impacts of prescribed fire treatments is essential for developing the most effective and adaptive management approach and maximizing the ecological benefits and efficiency of fire management. Pre- and post-burn monitoring of plants and animals, particularly rare species, will be valuable to determine ideal burn size, intensity, timing, and frequency in a given project area. Additionally, it is important to evaluate the day of burn parameters and how they affect ecological outcomes. During the day of the burn, records should be kept of the days since rain, temperature, relative humidity, flame lengths, and fire behaviors for each unit. If outcomes are not achieved, the fire prescription can be adapted for future burns to better achieve outcomes. Frequency and timing of fire is particularly important for red pine regeneration as it must be high enough to create suitable conditions for establishment that coincide with large red pine seed crops that occur only every 5 to 10 years (Horton and Bedell 1960, Kozlowski and Ahlgren 1974). Higher fire frequencies also prevent mesophytic species from spreading and keep fuel levels low, reducing the risk of more severe wildfires.

Because the natural regeneration of red pine is a critical component of our proposed approach, forecasting of cone crops should be carefully monitored and used to inform the timing and intensity of burns. Red pine has a two-year cone cycle and cone crops can be monitored to estimate when adequate crops will be present. Managers should revisit sites at least once a year and monitor for cone development with binoculars and assess any canopy mortality. Additionally, natural red pine regeneration can be patchy and stocking surveys will be critical to ascertain how much regeneration there is, where it is, and if it is enough. Stocking surveys will help inform the timing and specific arrangement of ICO treatments. Stands should also be evaluated for shoot blight presence before treatments and response after harvests and prescribed fire. Char on the boles should also be evaluated and recorded.

Consistently monitoring these project areas will be critical for developing the most effective approach for each site. Following the initial fires, treatment zones should be established to capitalize on areas of natural regeneration. The timing and intensity of the second burn can be adjusted based on pine regeneration, mesophyte response in the understory, and health of the residual trees. We recommend monitoring culturally important plants such as blueberries and huckleberry to gauge their response to management. Monitoring should also incorporate consistently surveying for invasive species and treating problematic populations.

Monitoring for rare animal species would ideally be consistently undertaken to evaluate the compatibility of our management approach on rare animal species. The Michigan DNR lists 31 animals that are dependent on red pine and associated natural communities (Bielecki et al. 2004) and several rare animals in Michigan use pine forests as habitat,

Nighthawks are a Focal Species within the State Wildlife Action Plan. They are one of several species of special concern that would benefit from the outlined approach to managing natural red pine. Photo by A.P. Kortenhoven.

including American goshawk (*Accipiter gentilis*, State Threatened and Focal Species within the State Wildlife Action Plan), Kirtland's warbler (*Setophaga kirtlandii*, State Endangered and Focal Species within the State Wildlife Action Plan), black-backed woodpecker (*Picoides arcticus*, Special Concern), common nighthawk (*Chordeiles minor*, Special Concern and Focal Species within the State Wildlife Action Plan), eastern whip-poor-will (*Antrostomus vociferus*, State Threatened), spruce grouse (*Canachites canadensis*, State Threatened), and sharp-tailed grouse (*Tympanuchus phasianellus*, Special Concern) (Derosier et al. 2015, MNFI 2025).

Additional rare species that would also benefit from our recommended management approach include upland sandpiper *(Bartramia longicauda,* State Threatened), evening grosbeak (*Coccothraustes vespertinus*, State Threatened), northern flying squirrel (*Glaucomys sabrinus*, Special Concern), Connecticut warbler (*Oporornis agilis*, Special Concern), smooth green snake (*Opheodrys vernalis*, Special Concern and Focal Species within the State Wildlife Action Plan), and northern blue (*Plebejus idas nabokovi*, State Threatened and Focal Species within the State Wildlife Action Plan) (Derosier et al. 2019).

Understanding Resilience

Climate change poses a threat to the persistence of red pine in the Great Lakes Region and mitigating impacts of an increasingly variable climate and the associated disturbance regimes depends on forest resilience (Forzieri et al. 2022). Increasing drought frequency and intensity may increase susceptibility to pathogens and increase mortality, especially in overstocked stands such as plantations (Magruder et al. 2013, Larson et al. 2021). A warmer and drier climate could favor more frequent wildfires and plantations are at increased wildfire risk and are especially susceptible to severe fire damage.

Resilience to wildfire is essential in preventing catastrophic damage to red pine systems. However, young, densely planted red pine stands have been called the "most flammable pure stand(s) of any northeastern tree species" (Van Wagner 1970). This is due to the continuous, well-aerated fine fuel accumulation and dense understories which often include juvenile pine snags that serve as ladder fuels. The abundant presence of litter, ladder fuels, and flaky bark can initiate fire spread to the canopy, where crown fire can spread quickly across a plantation stand (Scherer et al 2016).

Several natural red pine forests near Lake Superior are being converted to plantations. This stand was converted to jack pine plantation. Following conversion, it was impacted by a wildfire that killed nearly all canopy trees. The only surviving trees were natural red pine that were retained during the conversion process. The jack pine seedlings germinated after the fire, but these plantations have very little resilience to wildfire, thereby jeopardizing the substantial investment of converting natural systems to plantations. Photo by J.M. Lincoln.

The regular application of prescribed fire is critical to ensure natural red pine systems remain resilient to wildfire. The red pine stands identified for this project are currently fire-suppressed and at increased wildfire risk and are especially susceptible to severe fire damage. Severe wildfire damage to these forests may result in significant timber loss and delayed recovery to a productive system as mature seed-producing red pine face mortality (Larson et al. 2021). Forest resilience is an important part of adaptive management as our forests will face increased potential of wildfire, spread of pests and pathogens, severe damage of ice storms to plantations, and invasive species.

Incorporating prescribed fire and thinning of natural red pine systems will reduce wildfire risk, limit severe fire, and support healthier individual trees better equipped to resist stressors. This approach will limit fuel loading and continuity, reduce ladder fuels, and condition boles and roots resulting in reduced tree mortality in the event of a wildfire. The combination of prescribed fire and thinning has been shown to increase individual tree health and increase basal area growth rates (Scherer et al. 2016).

An additional concern is the ability of plantations to withstand storms. An ice storm in March of 2025 caused substantial damage to the forests of northern Michigan. Aerial flights following the ice storm across northern Michigan indicated higher vulnerability of pine plantations in comparison to natural pine stands (Derek Hartline, Little Traverse Bay Bands of Odawa Indians Natural Resources Department, personal communication). Storm severity may be increasing due to climate change and pine plantations appeared to be especially vulnerable to ice storms. We recommend evaluating the difference in resilience to ice storms between natural forests and plantations.

Finally, herbicide application is frequently used to reduce competition with planted pines; however, the long-term effects of herbicide use on biodiversity and ecosystem function in pine stands have not been fully studied. There is evidence that herbicide use may disturb or deplete soil microbial communities, and lingering residues in soil and water continue to negatively impact biosynthetic pathways that mediate plant resistance to pathogens and the attraction of beneficial insects (Fuchs et al. 2021). Red pine forms mycorrhizal associations that increase its growth rate (Burns and Honakala 1990). Tests of herbicides on mycorrhizal colonization of conifers have been mixed with some studies finding reduced mycorrhizal colonization and others finding no difference in soils treated with herbicide compared to those without (Chakravarty and Chatarpaul 1990, Sidhu and Chakravarty 1990). Studies have also shown that a

An ice storm in March of 2025 caused historic damage to the forests of northern Michigan, especially red pine plantations. Plantations are likely more vulnerable to extreme weather events that are projected to increase with climate change. Photo by J.M. Lincoln.

single application of herbicide can cause significant shifts in soil bacterial community composition (Caggia et al. 2023). Specifically, beneficial rhizobacteria can be negatively impacted while pathogenic bacteria and fungi can benefit, leading to higher risk of root diseases (Fuchs et al. 2021). Because of these complex, below-ground interactions, negative impacts to soil microbiota via herbicide applications may be detrimental to red pine health and overall forest resilience and thus warrant further research.

Evaluating the Economics

Over the five most recent burn seasons, the Michigan DNR has applied between 5,099 and 10,797 acres of prescribed fire per year, averaging 7,695 acres each season across 4 million acres of DNR lands. During that time, there was an average of 83 burns each year and the average size of burns was 91 acres. Implementing fire can pose unique logistical challenges. Management decisions would be aided by more information about the cost of prescribed burning, particularly compared to the cost of current management such as scarification, herbicide application, and trenching and planting. Our current understanding is that the application of prescribed fire by the Michigan DNR to natural pine stands around 200 acres in size would cost around $75 to $100 per acre (Michigan DNR). Other estimates are more than double those figures. The Forest Service has been able to reduce the costs of applying prescribed burns to $40 per acre by establishing larger burns, often over 600 acres. Fostering cross-agency dialogue about burning strategies is recommended to help identify efficiencies and reduce costs. Tribal agencies often have experience with applying fire and often have an interest in co-managing ancestral lands. Partnering with Tribes to apply prescribed fire on State Forest land is a potential strategy to reduce costs and apply fire to more areas of natural red pine.

An estimated 4,000 acres of red pine plantations are being established every year on Michigan’s State Forest lands. Most plantations are developed to regenerate harvested stands that were already plantation. However, a portion of plantations are converted from natural forests. One estimate for the cost for conversion from natural pine to plantation with trenching and herbicide is estimated at $120 per acre and an additional $600 per acre to install the trees. Another estimate was $500 per acre for conversion. The costs of site preparation, nursery stock, and contract tree planters have risen substantially in recent years.

While these figures are estimates from sources within the Michigan DNR, we did not have access to the budgets or the actual acreage of natural forest converted to plantation over the past decade. These estimates need to be appraised and accurate numbers provided for a more meaningful assessment of the various methodologies. Considering the vulnerability of plantations to wildfire and ice storm damage, it is critical to evaluate the long-term economic advantages and disadvantages of converting natural pine forests to plantations. Our assertion is that the method we have outlined in this report will provide a more stable economic revenue stream at a lower cost and for a longer time when compared to the creation of new plantations. We recommend research comparing the economic and ecological costs and the evaluation of ecosystem services of both management systems.

A prescribed fire of moderate intensity being applied in the Pigeon River FMU in May of 2025. There is a statewide recognition of the need for more prescribed fire on state lands. Photo by Steve Woods, MDNR.

Carbon Storage

Increased forest structural complexity, such as would be derived from treatments based on the ICO model, has been linked to greater resilience to catastrophic wildfire (Koontz et al. 2020) and to increased ecosystem productivity, carbon assimilation, and biodiversity (Gough et al. 2019). In the context of climate change, forest resilience is increasingly viewed as a metric of carbon stock stability; data have suggested that in certain cases, carbon losses due to forest degradation may be as or more significant than that lost from outright deforestation (Qin et al. 2021). Carbon stocks in managed natural red pine forests can thus be maximized while optimizing other objectives such as timber production, increased canopy complexity, and biodiversity (Powers et al. 2012). Managing our State Forest for resilience is therefore also a framework by which to view and manage forest longevity and long-term carbon storage.

Additional Project Areas

Old-growth red pine forests were once widespread in Michigan but are now one of the rarest forested community types in the Great Lakes Region. Due to the increasing rarity of natural red pine in Michigan, surveys to identify remaining stands with high ecological integrity should be a regional conservation priority. We surveyed a fraction of the existing natural red pine stands in the Atlanta, Grayling, Newberry, Roscommon, Shingleton, and Traverse City Forest Management Units during the 2024 field season and there are doubtless additional sites across the State Forest system where our approach would be appropriate. This project is going to continue for at least one more year and we will work to identify stands of natural pine where our approach can be implemented, including within the Sault Ste. Marie FMU, Pigeon River FMU, and the Escanaba FMU.

Old-growth red pine forests were once widespread in Michigan but are now one of the rarest forested community types in the Great Lakes Region. Increased forest structural complexity of old-growth forests has been linked to greater resilience to wildfire and to increased ecosystem productivity, carbon assimilation, and biodiversity. In the context of climate change, forest resilience is increasingly viewed as a metric of carbon stock stability. The management approach outlined in this report is a reasonable starting point for addressing these issues and there are several suitable areas in Michigan's State Forest system to attempt it. Photo by J.M. Lincoln.

Working With Tribes

Engaging with local Tribal Government natural resources departments is an important component in ensuring forest management activities are aligned with stakeholders. According to the Treaty of 1836, Tribal entities maintain treaty rights to hunt, fish, and gather, and retain co-management within the 1836 Ceded Territory that extends throughout the region of the northern Lower Peninsula through the eastern Upper Peninsula. These treaty rights are protected by federal law and have been reaffirmed through court decisions and negotiated agreements. Through the Treaty of 1836, Tribes retained their “usual privileges of occupancy”, which include the wide range of sophisticated land-tending practices. Cultural fire is one of these practices and was historically and continues to be a source of cultural expression and sovereign right of Indigenous Peoples throughout this region. The historical use of fire in red pine forests was frequent and persistent through time until European colonization. The decline of natural red pine can be closely attributed to the cessation of Indigenous cultural fires which were outlawed in the late 1800s and actively suppressed beginning in the early 1900s (Anderton 1999, Botti and Moore 2006).

Tribal influenced co-management has been successfully achieved and implemented between Tribes and federal agencies in Michigan. A good example of Tribal collaboration in this region is the Inter-agency Ishkode Stewardship Plan of the Hiawatha National Forest between the United States Forest Service and the Sault Sainte Marie Tribe of Chippewa Indians Natural Resources Department – Wildlife program. This co-developed plan blends shared stewardship goals to prioritize prescribed fire applications in specific locations to benefit culturally important resources.

To begin facilitating a relationship with local Tribes, we recommend that natural resource managers introduce themselves to tribal natural resource department staff to learn more about their program goals and identified shared interests. Tribal natural resource departments within this region work to maintain their legally mandated treaty rights and promote management approaches that facilitate access for their community members to hunt, fish, and gather. Within the area of focus in this report, active tribal governments include the Little River Band of Ottawa Indians, Little Traverse Bay Bands of Odawa Indians, Grand Traverse Band of Odawa and Chippewa Indians, Sault Sainte Marie Tribe of Chippewa Indians, and the Bay Mills Indian Community. The Chippewa Ottawa Resource Authority (CORA) is an intertribal organization of the previously mentioned tribal governments that was established to manage and protect the 1836 Ceded Territories natural resources including fish, wildlife, and forests within the ceded territory.

MNFI lead ecologist Joshua Cohen (right) learning about the management of red pine from Ron Waukau (left) of The Menominee Tribal Enterprises in northern Wisconsin. The Tribe has managed several thousand acres of natural red pine with fire for the past three decades. Their breadth of experience is invaluable for land managers of the Great Lakes Region. Photo by M.R. Parr.

CONCLUSIONS

Red pine forests encompass over two million acres across the Great Lakes Region with more than 76% of this acreage now consisting of plantations (Palik et al. 2021). Red pine plantations are being established every year on Michigan's State Forest lands. Most plantations are developed to regenerate harvested stands that were already plantation. However, a portion of plantations are converted from natural forests. As of 2024, the conversion of natural red pine forests to plantation was halted to develop a more holistic approach to managing red pine forests.

Plantation management approaches emphasize fiscal efficiency over long-term ecological integrity, leading to the management of natural red pine systems as plantations in lieu of more ecologically focused strategies. The impact of ecological services is difficult to calculate, despite their relevance to human welfare and benefits provided over the long-term that can amount to substantial economic value. Lost ecological services affect the public and are typically not easily observed or quantified, whereas lost revenue associated with altered management practices can be easily defined. Thus, forest managers often place greater emphasis on short-term, quantifiable gains and losses when making decisions about how to manage natural systems.

Over 99% of old-growth red pine forests in Michigan have been cleared (Frelich 1995). The few examples that remain are isolated, fire-suppressed, and often unrecognized during the DNR Michigan Forest Inventory vegetation mapping process. Because of their rarity, it is difficult to quantify their full ecological value. These systems had persisted for centuries through dynamic interactions among fire, climate, and Indigenous Peoples but the continual loss of natural red pine forests presents an irreversible degradation of our natural and cultural heritage. Without a shift in forestry practices, we risk continuing the loss of biodiversity and critical ecosystem services in an increasingly uncertain future.

The Public Trust Doctrine compels management of public lands in a way that serves both present and future generations. This means balancing timber production with protecting biodiversity, supporting climate resilience, and maintaining the cultural and ecological character of our landscapes. Although even-aged management of natural pine forests through clearcutting, scarification, spraying herbicide, and planting nursery stock reliably generates marketable timber production, these techniques simplify the forest structure, reduce native plant diversity, and suppress natural red pine regeneration, resulting in a less diverse and less resilient landscape.

We observed several areas of natural red pine that were clearcut, trenched, sprayed with herbicide, and converted to plantation during our 2024 surveys. Photo by J.M. Lincoln.

Through work on this project, we have identified 13 areas of natural red pine across northern Michigan that offer an excellent opportunity for ecological silviculture. Many of these sites, particularly along the southern shore of Lake Superior, retain key ecological features and support high ground-layer plant diversity. These areas have experienced less intensive forestry in recent decades and retain higher ecological integrity, thus making them especially well-suited to a management model that integrates low-impact timber harvest with the reintroduction of fire. Importantly, we recommend greater protection for natural red pine stands within at least ½ mile of the Great Lakes shoreline. Management here should emphasize ground-layer protection, avoid scarification and herbicide use, and consider partnerships with Tribal Nations and local communities to enhance both ecological and cultural values.

Our report details an approach based on principles of ecological silviculture. We recommend a management approach employing Individuals, Clumps, and Openings (ICO) that incorporates spatial heterogeneity and the strategic use of prescribed fire. This model mimics the structural complexity found in natural red pine systems, supports native biodiversity, and facilitates the natural regeneration of red pine by the process that historically structured these systems: fire. The management approach also aims to improve resilience to wildfire, mitigate insect and disease outbreaks, and lessen climate-related stress while maintaining opportunities for sustainable timber harvest. It meets both ecological and economic objectives in a way that plantation-style management cannot.

The accelerating simplification of Michigan's remaining natural red pine stands is transforming the landscape in ways that will be impossible to reverse. The continued prioritization of perceived short-term fiscal stability over natural processes and ecological services threatens to erase a forest system that has defined this region for centuries. With thoughtful stewardship and a renewed commitment to the Public Trust Doctrine, Michigan can shift course and rebuild a more resilient, biodiverse, and culturally relevant forested landscape that honors the past, serves the present, and prepares for the uncertainties of the future. While this management framework presents new challenges, we believe the benefits of this approach are clear.

Red pine is an iconic species that is economically valuable, culturally significant, and ecologically essential. The future of red pine forests in Michigan depends on the decisions we make today. Photo by J.M. Lincoln.

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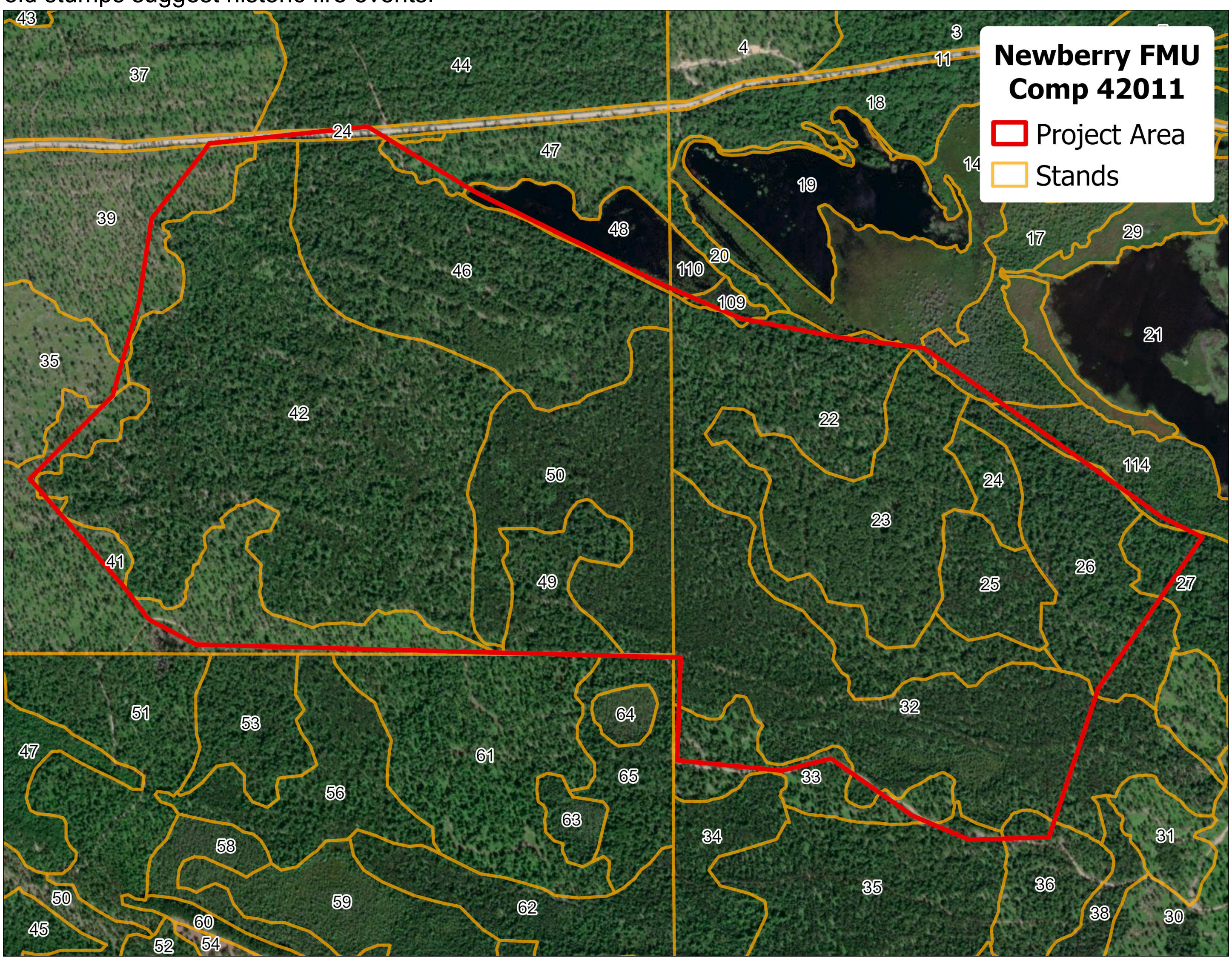
PROJECT AREAS IN THE UPPER PENINSULA

1. Newberry FMU: C42011
Location: Compartment 42011, Stand 46 and Compartment 42017, Stand 22.
Size: 526 acres (227.4 ha)

This site is characterized by several stands of mature pine on old dune ridges. Despite being thinned, many stands have retained advanced age classes of scattered red pine over 170 years old that were not in the MiFI notes. Stand 46 has primarily a red and white pine canopy with the occasional red oak, paper birch (*Betula papyrifera*), bigtooth aspen (*Populus grandidentata*), and jack pine comprising approximately 15% combined cover. There are also zones of abundant huckleberry (*Gaylussacia baccata*) in the understory. This stand was thinned in 1986 and retains several red pine in older cohorts. One representative mature red pine was measured at 18 inches DBH with 127 growth rings. Several charred, old stumps suggest historic fire events.

The canopy of Stand 22 is mostly scattered, large red pine with mature jack pine in the subcanopy. This stand also appears to have been thinned, otherwise it could be considered a high-quality natural community. One older red pine was measured at 22.5 inches DBH and 162 growth rings were counted on a partial core that was rotten at the center. The understory displays many characteristic dry northern forest species but is dominated by bracken fern (*Pteridium aquilinum*) instead of huckleberry. The lakeshore is dense with paper birch and balsam fir (*Abies balsamea*). There is generally minimal red pine regeneration, with white pine and red maple regeneration prevalent in the understory.

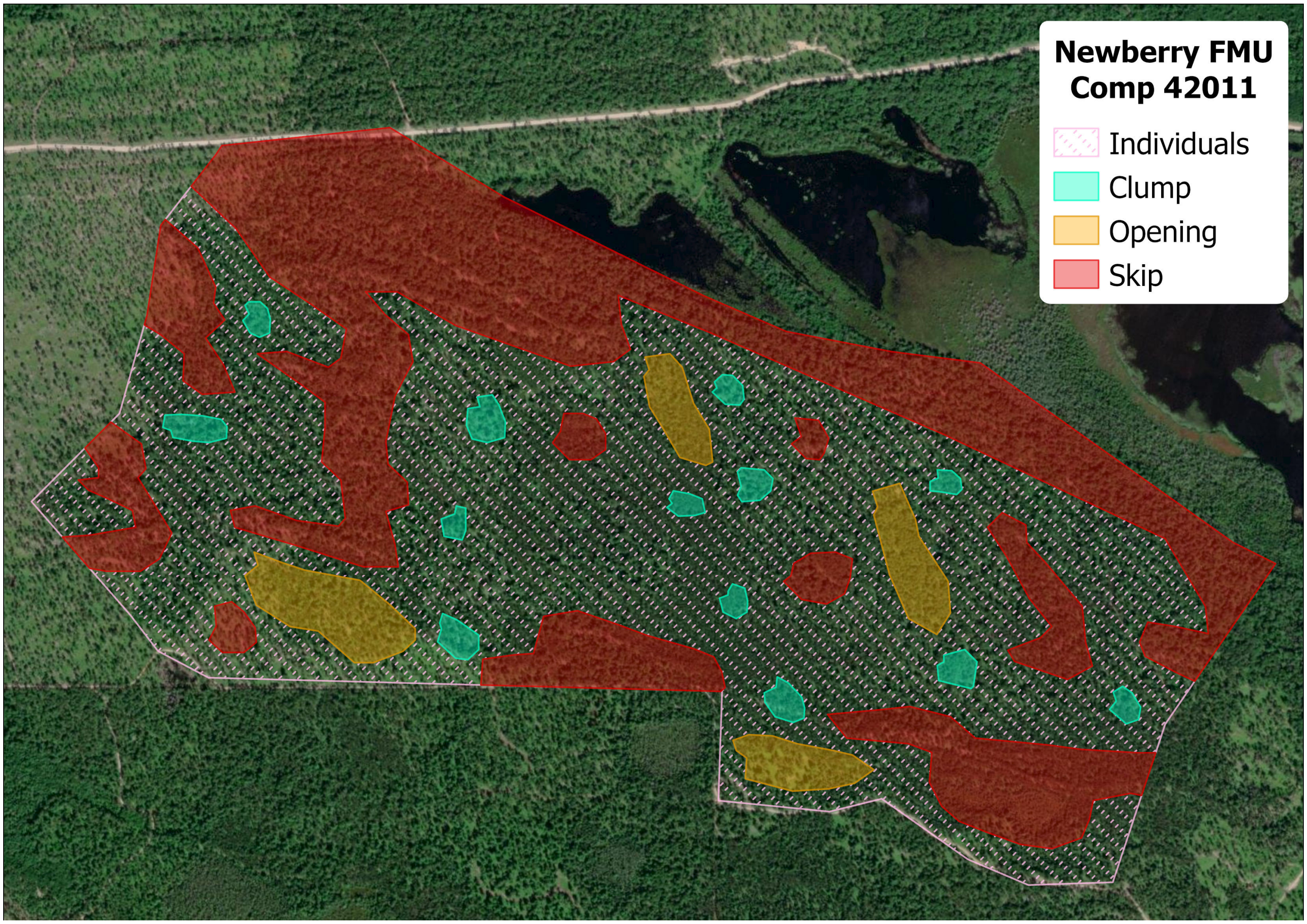


Appendix 1. Potential Project Area in Newberry Compartment 42011.

Management Recommendations
Apply two low-intensity fires across the entire project area using the wetland to the north as a natural burn break. Time the second burn to correspond with a red pine mast year. Thin *Individuals* zone of the project area by 1/3 BA and treat harvest *Openings* zones following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks.

Avoid timber harvest on steep dunes and along wetland margins. Retain the oldest trees across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails. This is a large project area divided across two compartments which could be split into two smaller management units.

Mature red pines persist on the slopes of steep dune ridges throughout. Photo by P.R. Schilke.



Appendix 2. ICO Management zones for Project Area in Newberry Compartment 42011.

2. Newberry FMU: C42044

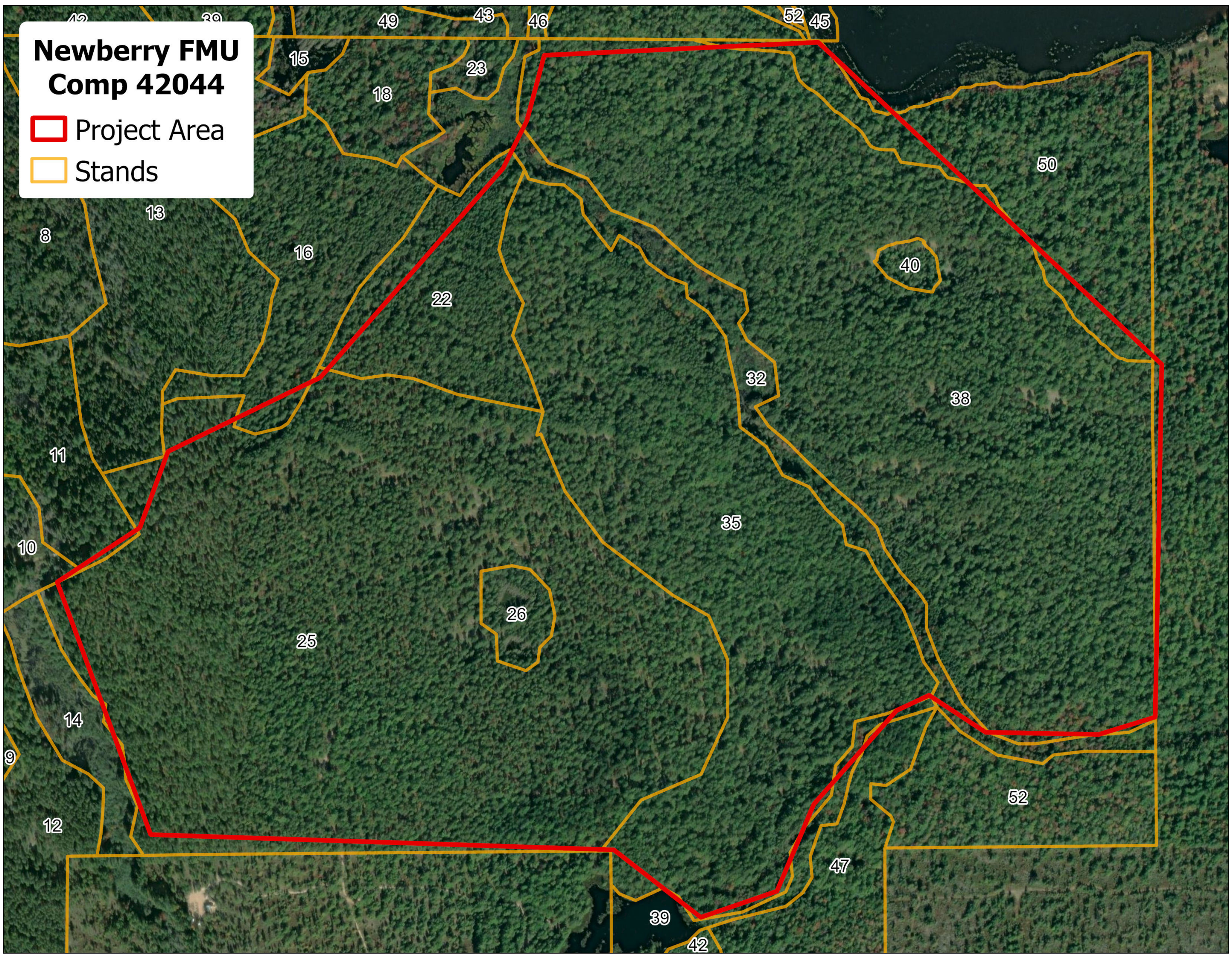
Location: Compartment 42044, Stands 25 38, and 35.

Size: 339 acres (137.2 ha)

This is a relatively large project area with stands of interest on either side of a small creek in Stand 32. The topography is relatively flat besides a steep ridge to the north. Stands 25 and 38 have been thinned but are still dominated by natural red pine with occasional mature jack pine and young red oak. Red pine in the center of the stands are thinner in girth than those found along the edges, possibly due to variations in microclimate, and the oldest red pine are approximately 110 to 120 years old. The understory features dense patches of huckleberry with scattered red maple, white pine, red oak, and paper birch saplings. Fire in these stands will likely enhance natural regeneration and reduce red maple saplings in the understory.

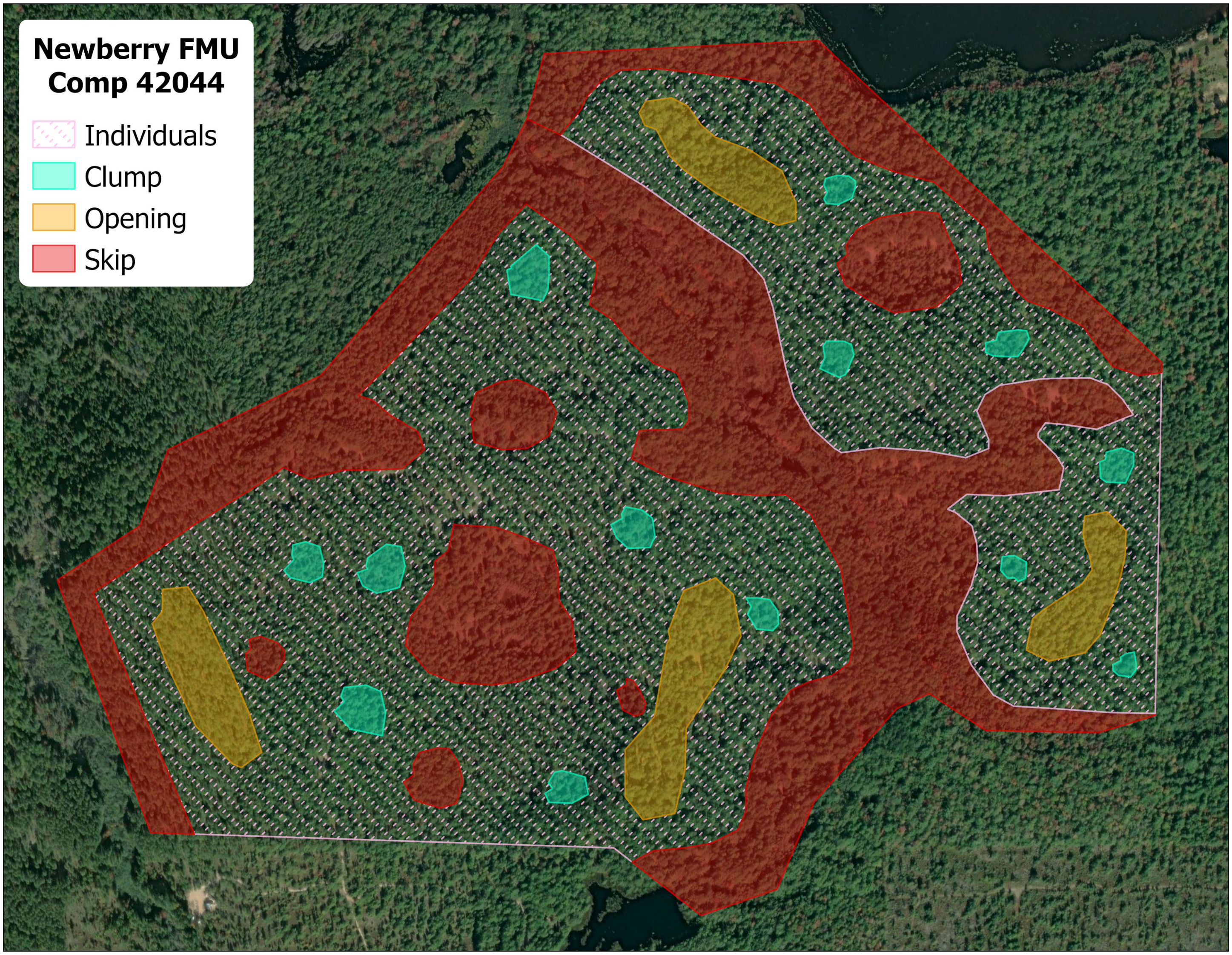
Management Recommendations

A burn line will likely need to be installed along the northern end of Stand 25. Apply two low-intensity fires across the entire project area using the stream in the center of the project area as a natural burn break. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Avoid timber harvest on steep dunes and along wetland margins, using much of Stands 35 and 32 as a Skip. Retain the oldest trees across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails. Due to its large size, this project area could be split into management units on either side of Stand 32.



Appendix 3. Potential Project Area in Newberry Compartment 42044.

This project area features forests containing mature red pine with an understory dominated by red maple and white pine and infrequent red pine regeneration. Photo by P.R. Schilke.



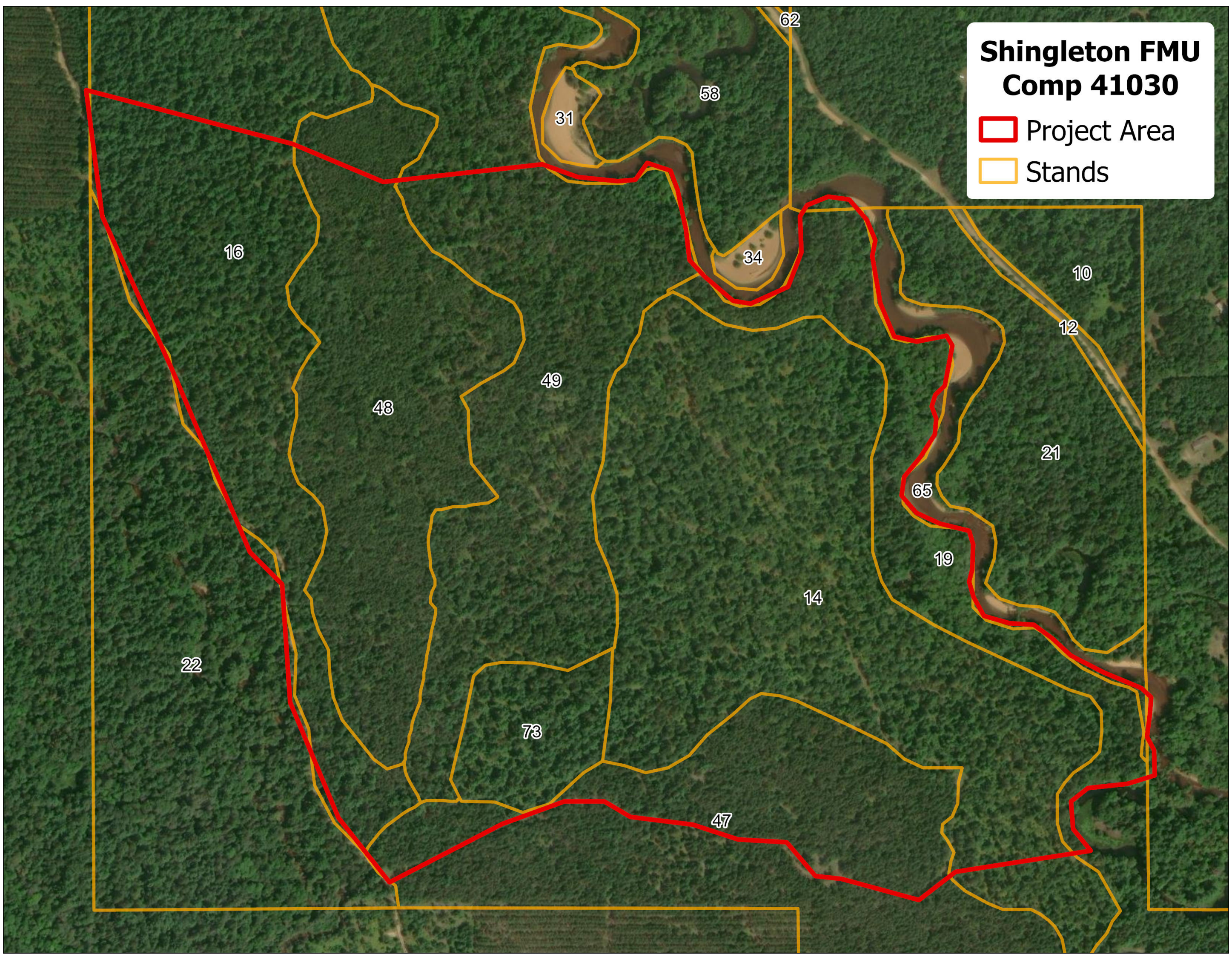
Appendix 4. ICO Management zones for Project Area in Newberry Compartment 42044.

3. Shingleton FMU: C41030

Location: Compartment 41030, Stand 14. Also contains Stands 16, 19, 48, and 49.
Size: 163 acres (66 ha)

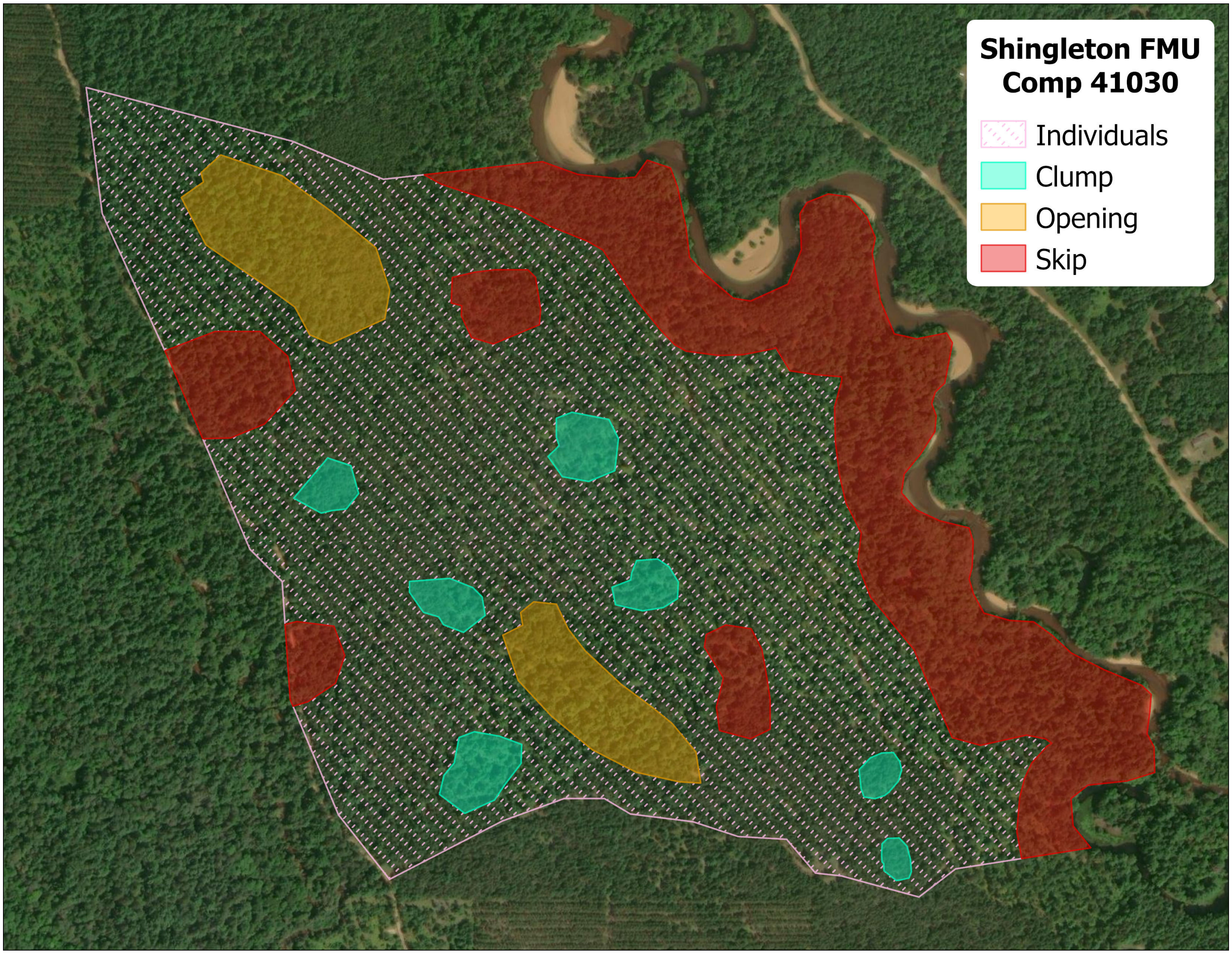
This project area is along the West Branch of the Manistique River. Much of the site burned in 1983 and was subsequently salvage harvested in 2010. Stand 14 is a natural pine stand with roughly 15% cover by white pine and contains limited jack pine in the understory. The maximum age of trees is about 112 to 120 years with no legacy trees found. There are high levels of red and white pine regeneration and limited hardwood competition. Stand notes from MiFI indicate "amazing mixed pine regeneration and zero hardwood competition. Stand is red pine but will end up converting to a white pine stand with a red pine component." This area would benefit from low-intensity fire to reduce white pine competition and minimize needle/duff accumulation and promote red pine germination. Stand 19 is similarly comprised of larger red pine measured at 18 inches DBH with 118 growth rings. Stand 49 contains a mature jack pine canopy of mainly three to eight inches DBH with scattered red pine in the overstory and a small number of charred stumps. Low ground layer diversity in this stand and a dense canopy might make burns difficult, though natural burn breaks including a large river and may help facilitate prescribed fire efforts.

Management Recommendations
Because of existing natural regeneration, this site likely would need only one fire to condition the site prior to thinning. After the first fire, harvest *Openings* zones and thin *Individuals* zone by 1/3 BA. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Time the second burn to correspond with a red pine mast year. The eastern boundary of this project is the West Branch of the Manistique River, which can be used as a natural burn break. Avoid timber harvests along the riparian area and any inclusions of dunes. Retain the oldest trees across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails.



Appendix 5. Potential Project Area in Shingleton Compartment 41030.

This project area occurs along the West Branch of the Manistique River, which would ideally serve as a natural burn break. Photo by P.R. Schilke.



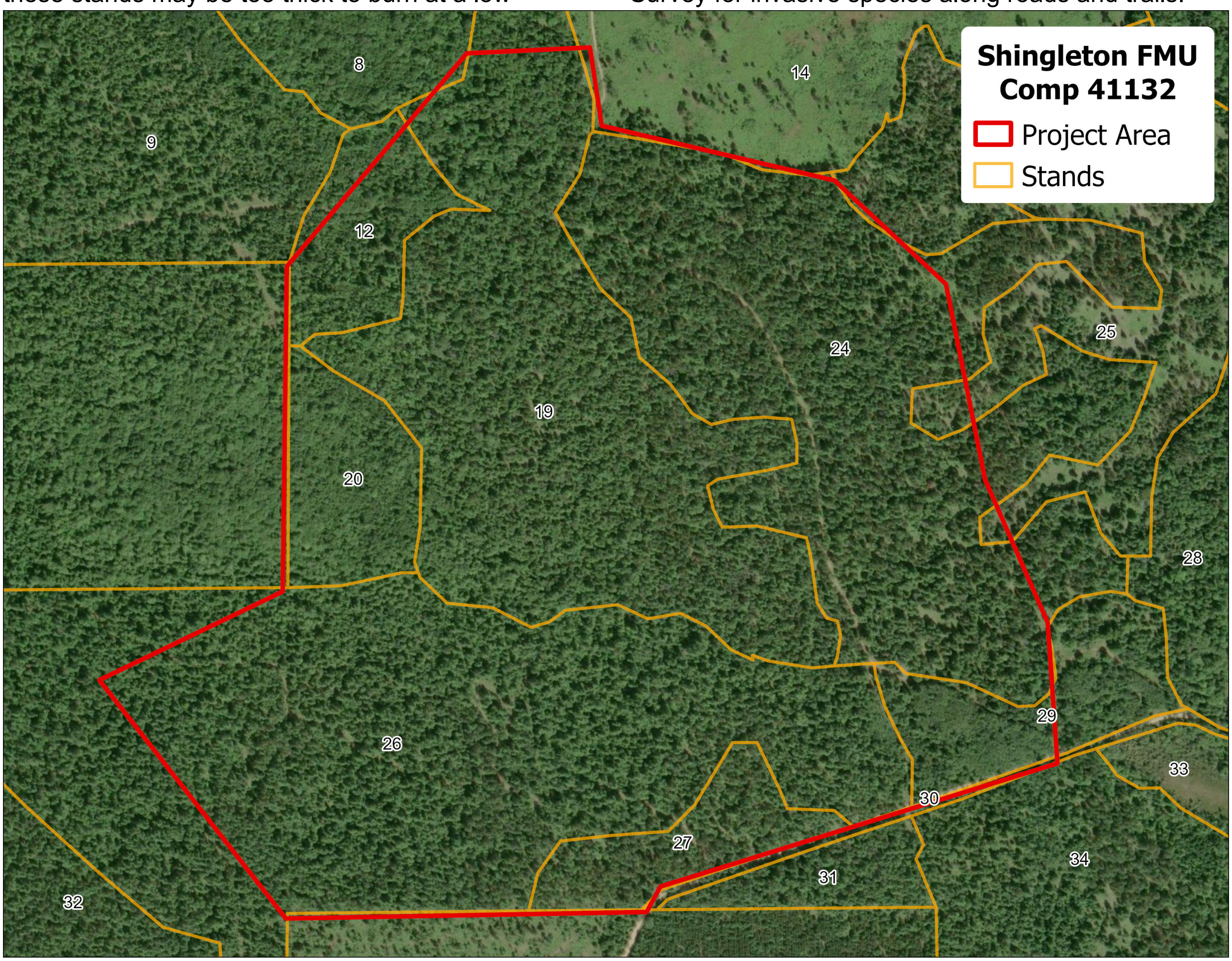
Appendix 6. ICO Management zones for Project Area in Shingleton Compartment 41030.

4. Shingleton FMU: C41132

Location: Compartment 41132, Stand 19. Also contains Stands 24 and 26.
Size: 212 acres (85.8 ha)

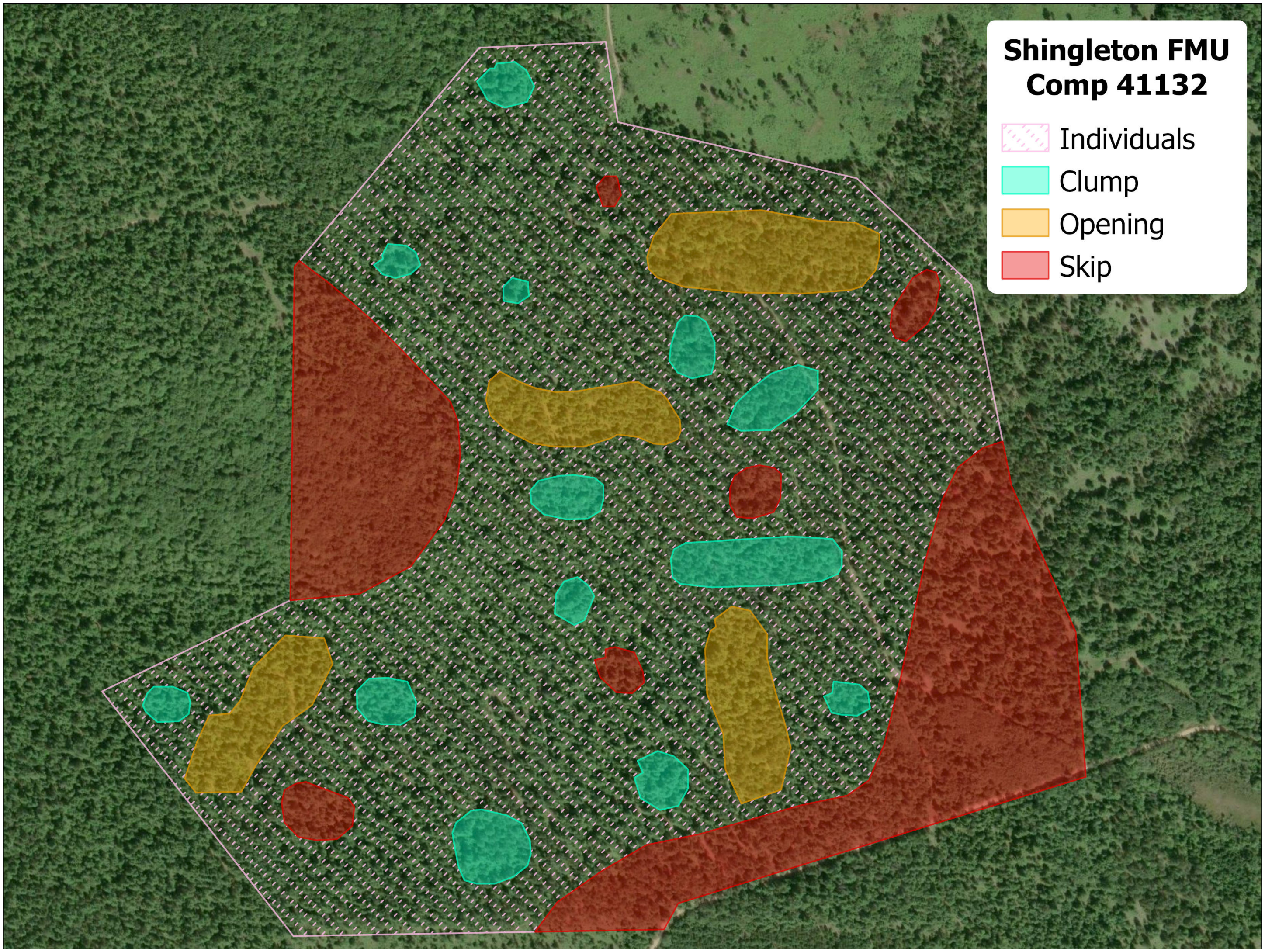
Compared to the other project areas in the Upper Peninsula, this site has relatively low conservation value with no trees in the 150-year-old cohort. Despite lack of high-quality site indicators, this is a relatively large, flat, and accessible area where ICO management techniques could be easily attempted. The overstory of Stand 19 is primarily comprised of white pine and approximately 100-year-old red pine as a codominant species. Occasional 10-inch DBH jack pine also exist in the overstory but these are beginning to senesce. Prolific white pine and balsam fir regeneration has made the understory dense throughout most of the stand. While the dominant woody vegetation is that of a dry northern forest, occasional hemlock (*Tsuga canadensis*) and beech (*Fagus grandifolia*) suggest that this stand grades towards dry-mesic conditions. Old, charred stumps are present throughout this compartment like many natural red pine stands of this region. All three of these stands may be too thick to burn at a low-moderate intensity without thinning the understory first.

Management Recommendations
Apply two low-intensity fires across the entire project area. Consult with fire managers to determine if understory thinning is needed prior to application of prescribed fire. Understory thinning through mastication is one viable fuels reduction treatment that may be merited in portions of this Project Area. If implemented, protect red pine regeneration and avoid *Skips* and *Clumps* with the mechanical treatment. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain the oldest trees across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails.



Appendix 7. Potential Project Area in Shingleton Compartment 41132.

This site features a canopy of mixed pine with natural red pine in the 100- to 120-year-old cohort throughout. No legacy trees were observed, though there were several fire-scarred stumps. Photos by P.R. Schilke.



Appendix 8. ICO Management zones for Project Area in Shingleton Compartment 41132.

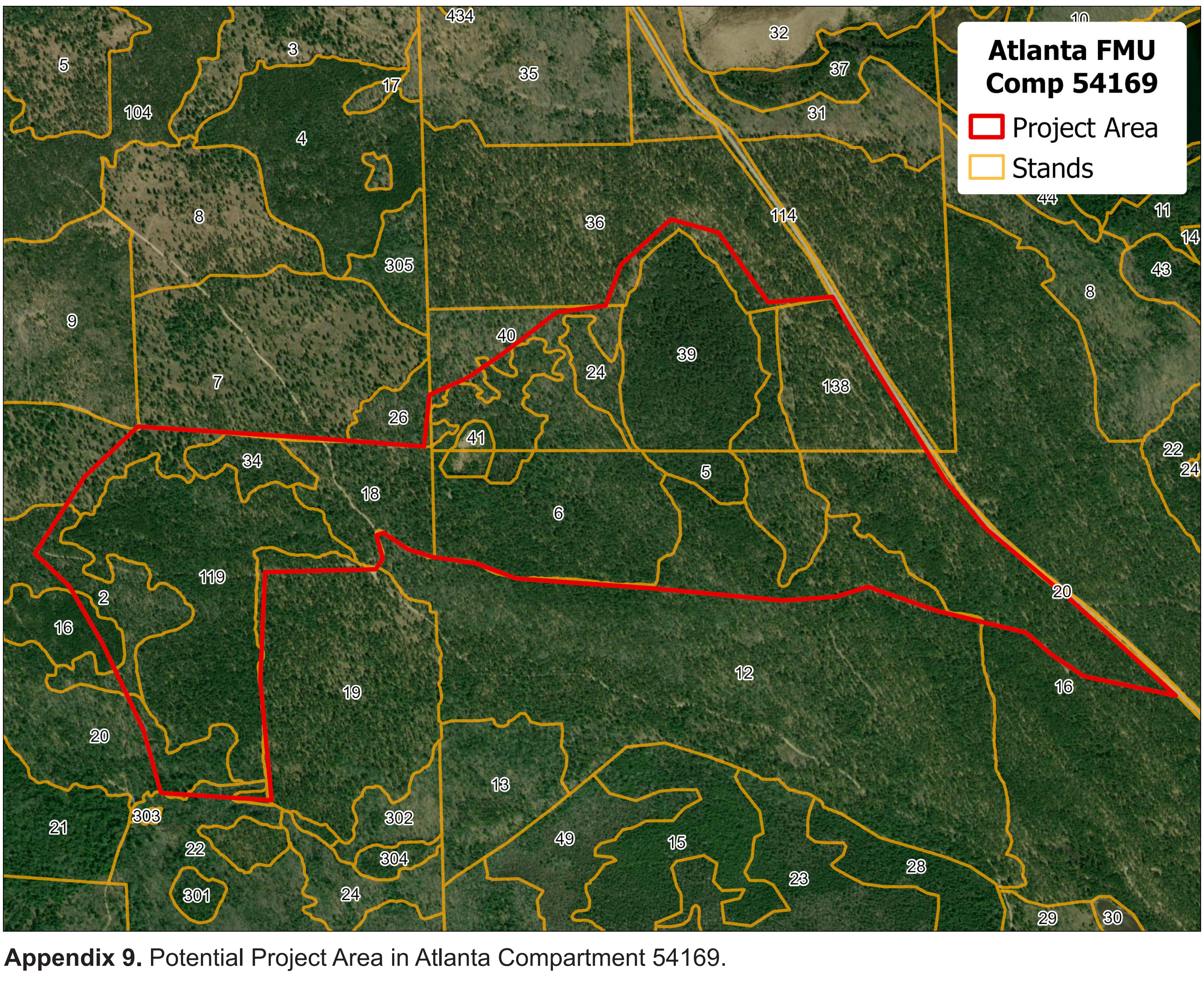
PROJECT AREAS IN THE LOWER PENINSULA

5. Atlanta FMU: C54169

Location: Compartment 54169, Stands 6, 12, and 16. Also contains Compartment 54164, Stand 119, and Compartment 54168, Stands 23 and 138.
Size: 380 acres (153.8 ha)

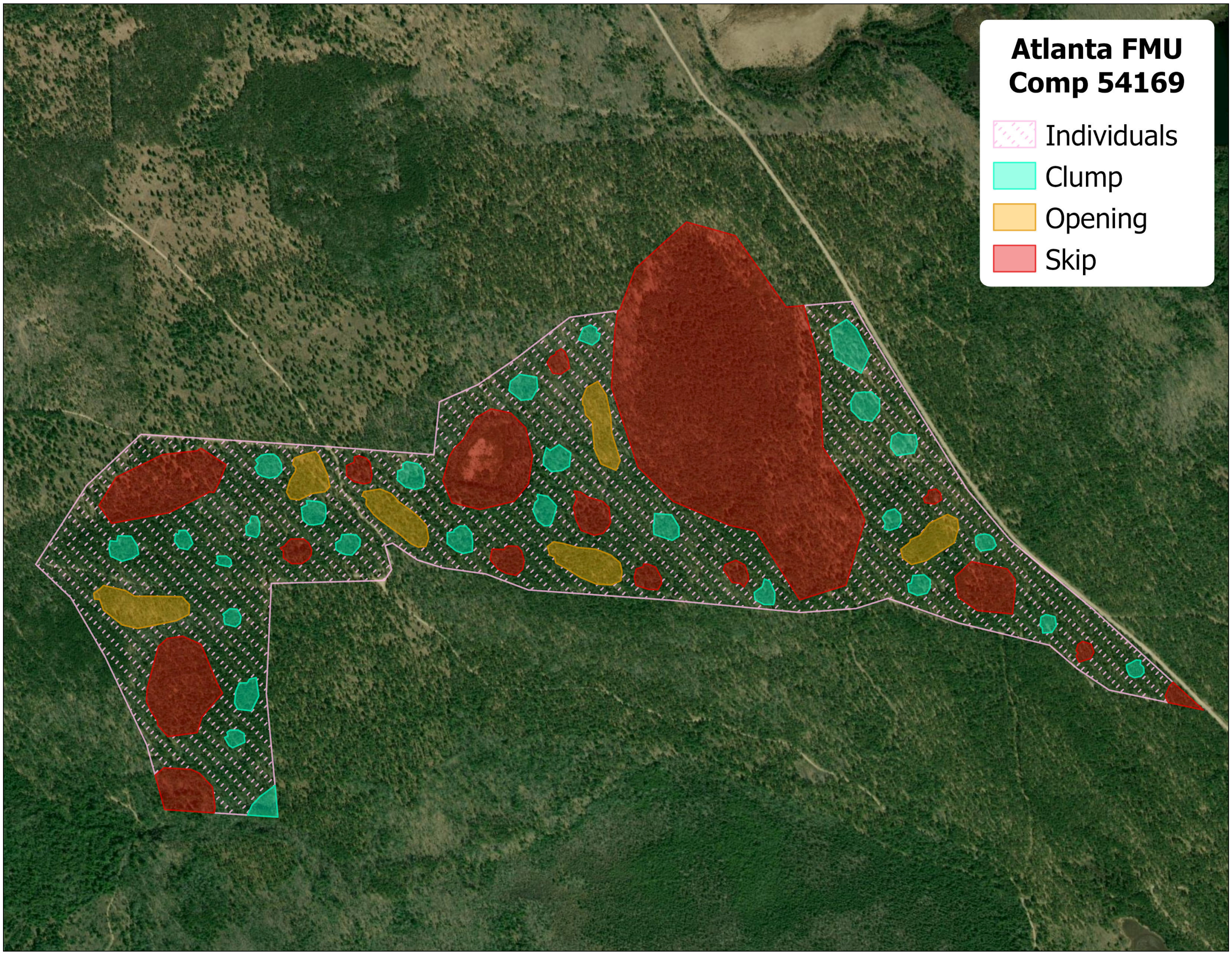
This project area encompasses a large forest of natural red pine with varying age classes, including a 130-year-old cohort present in Stands 6, 23, 40, and 119 that was not recorded in MiFI notes. While red pine is the dominant overstory species, jack pine, white pine, bigtooth aspen, and red oak are also common but never exceed 40% of the total canopy cover. Two wetlands were included within the project area, one which contains a red pine stump with evidence of two distinct fire events. Stand 138 (Compartment 54168) is listed as a plantation in MiFI but appears to be natural and has several fire-scarred stumps. Numerous trails span the project area as well as ideal fire breaks such as two-tracks. Stumps with fire scars were noted in most stands.

Management Recommendations
Apply two low intensity fires across the entire project area, including wetlands. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain the oldest trees across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails.



Appendix 9. Potential Project Area in Atlanta Compartment 54169.

This project area features several age classes of red pine across the entire site. There is generally little natural regeneration with thick huckleberry and lowbush blueberry. Photo by J.M. Lincoln.



Appendix 10. ICO Management zones for Project Area in Atlanta Compartment 54169.

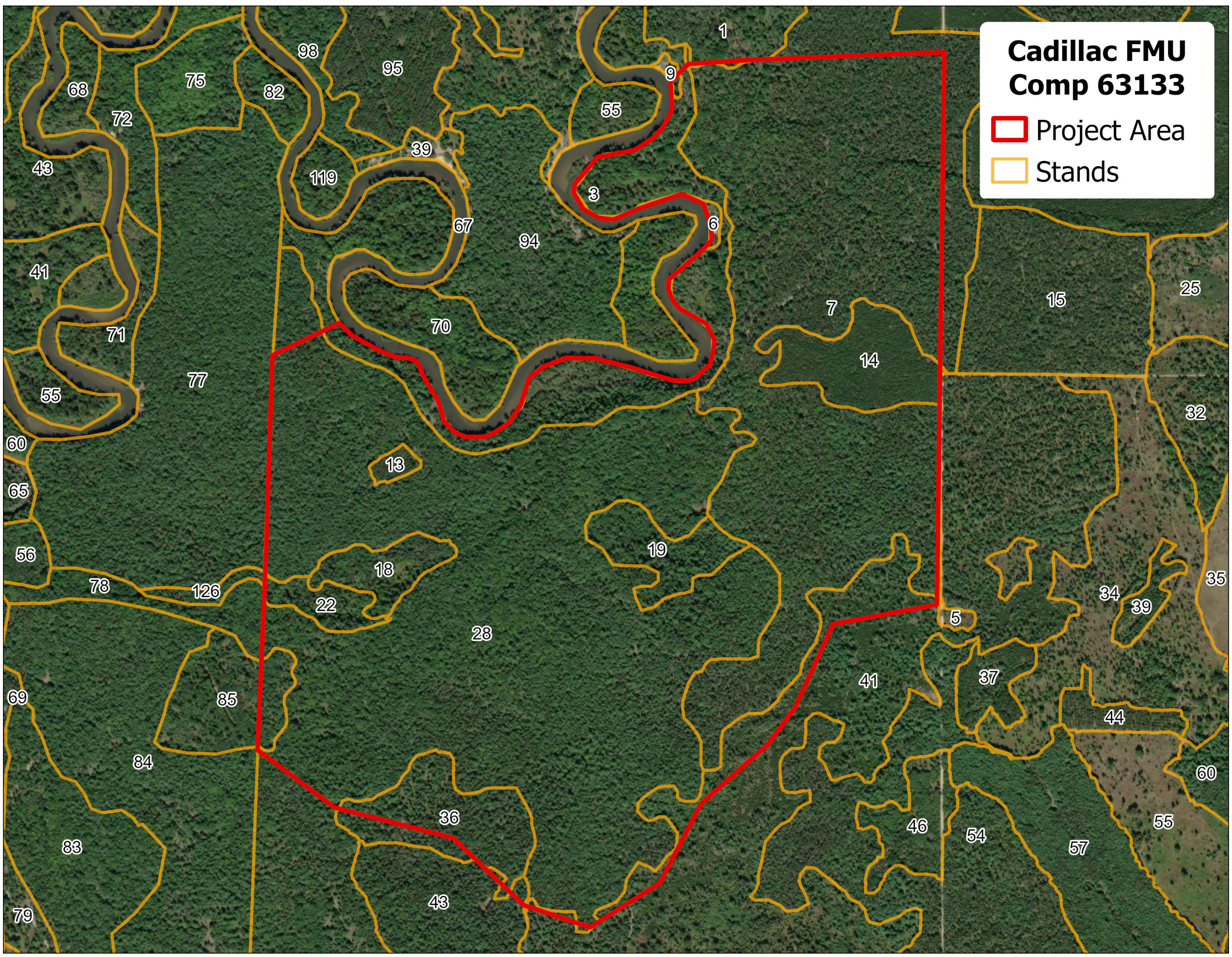
6. Cadillac FMU: C63133

Location: Compartment 63133, Stands 7 and 28.
Size: 475 acres (192.2 ha)

This is a large project area along the Manistee River, and the project area is designed to provide forested buffers protecting the steep slopes along the river. The forests are primarily dominated by white pine with jack pine and red pine throughout. Most are likely in a 70- to 80-year-old cohort, but one 18” DBH red pine had 130 growth rings and there are several trees in this cohort. Scattered white oak (*Quercus alba*), red oak, quaking aspen (*Populus tremuloides*), and red maple are less prevalent throughout. Many areas of red pine have been thinned with some retention islands containing older white oak over 100 years old. The adjacent Stand 8 to the northeast was not evaluated but contains forests of natural red and white pine that could be added to this project area.

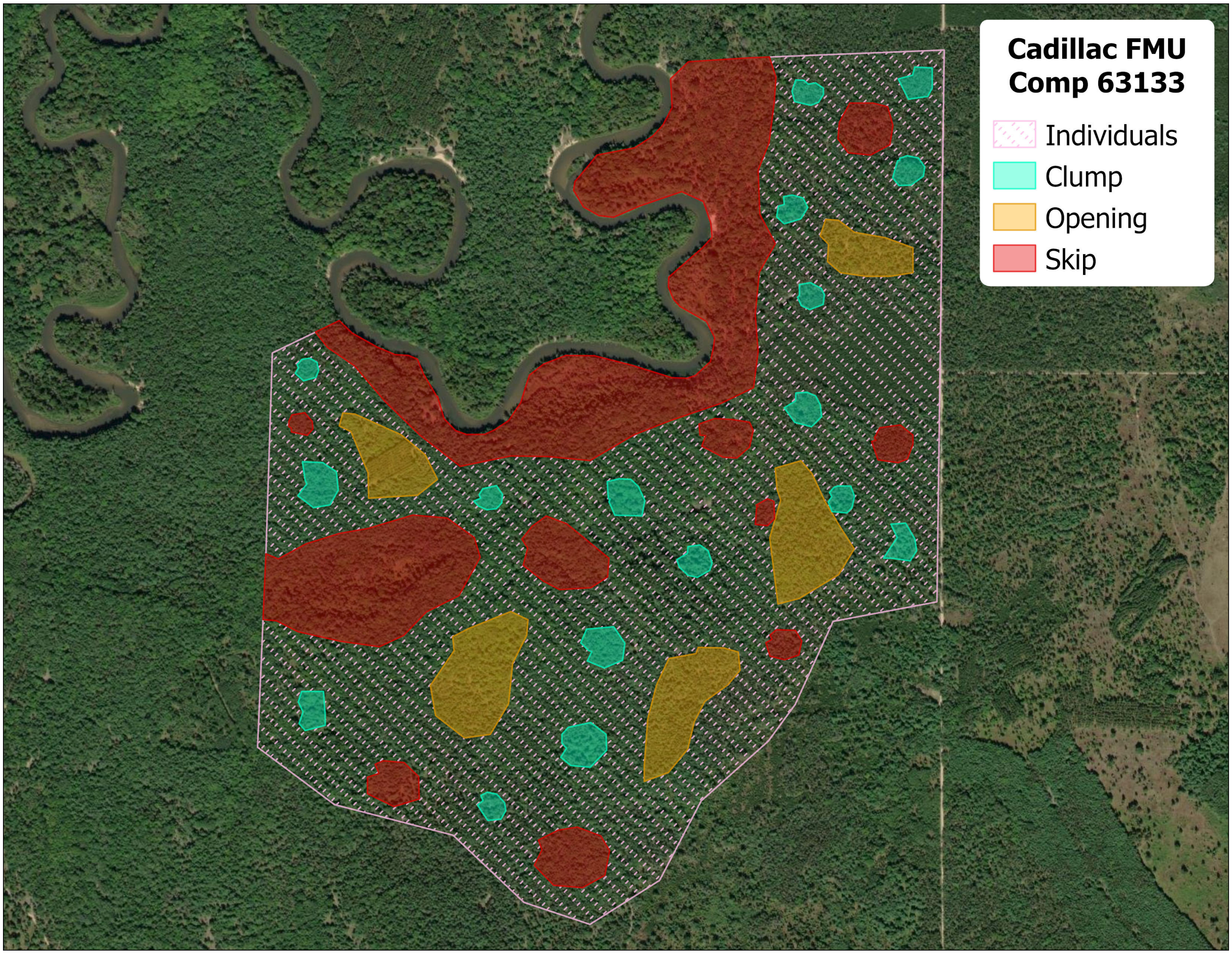
Management Recommendations

Apply two low-intensity fires across the entire project area, including steep slopes and wetlands. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin the *Individuals* zone by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain white oaks in all forest strata and the oldest red pine across the site and protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails.



Appendix 11. Potential Project Area in Cadillac Compartment 63133.

This site features natural red pine with white oak in the canopy. Photo by J.M. Lincoln.



Appendix 12. ICO Management zones for Project Area in Cadillac Compartment 63133.

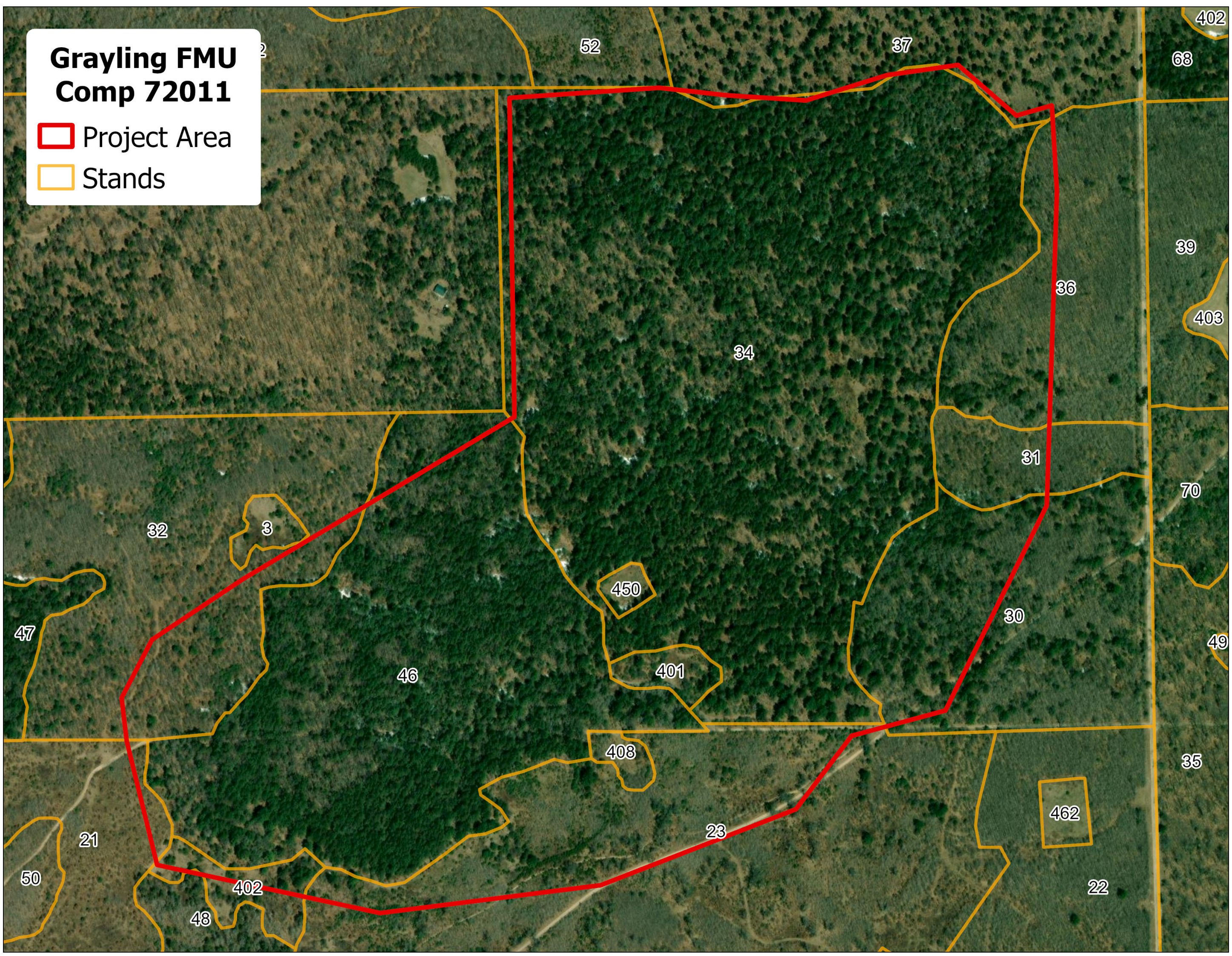
7. Grayling FMU: C72011

Location: Compartment 72011, Stands 34 and 46.
Size: 197 acres (79.7 ha)

The canopy of Stand 34 is primarily red and white pine with large northern pin oak (*Quercus ellipsoidalis*), red maple, and white oak occasional in the overstory. There is a variety of age classes, but regeneration of red pine is poor because of dense red maple in the understory. This stand was harvested in 2004 with 300-foot openings created throughout the stand; these openings have since been colonized by red maple while the remainder of the stand is characterized by pockets of dense white pine and white oak growing under mature red and white pine. The average red pine DBH is 16 inches, but an older age class of 132 to 164 years with 22- to 28-inch DBH is commonly scattered throughout. This stand, along with stands 37, 46, and 47, all contain these scattered, super-canopy, legacy conifers. The canopy of Stand 46 is primarily white pine with red pine as a codominant species. Red maple accounts for roughly 10% of the overstory in this stand along with occasional northern pin oak and quaking aspen.

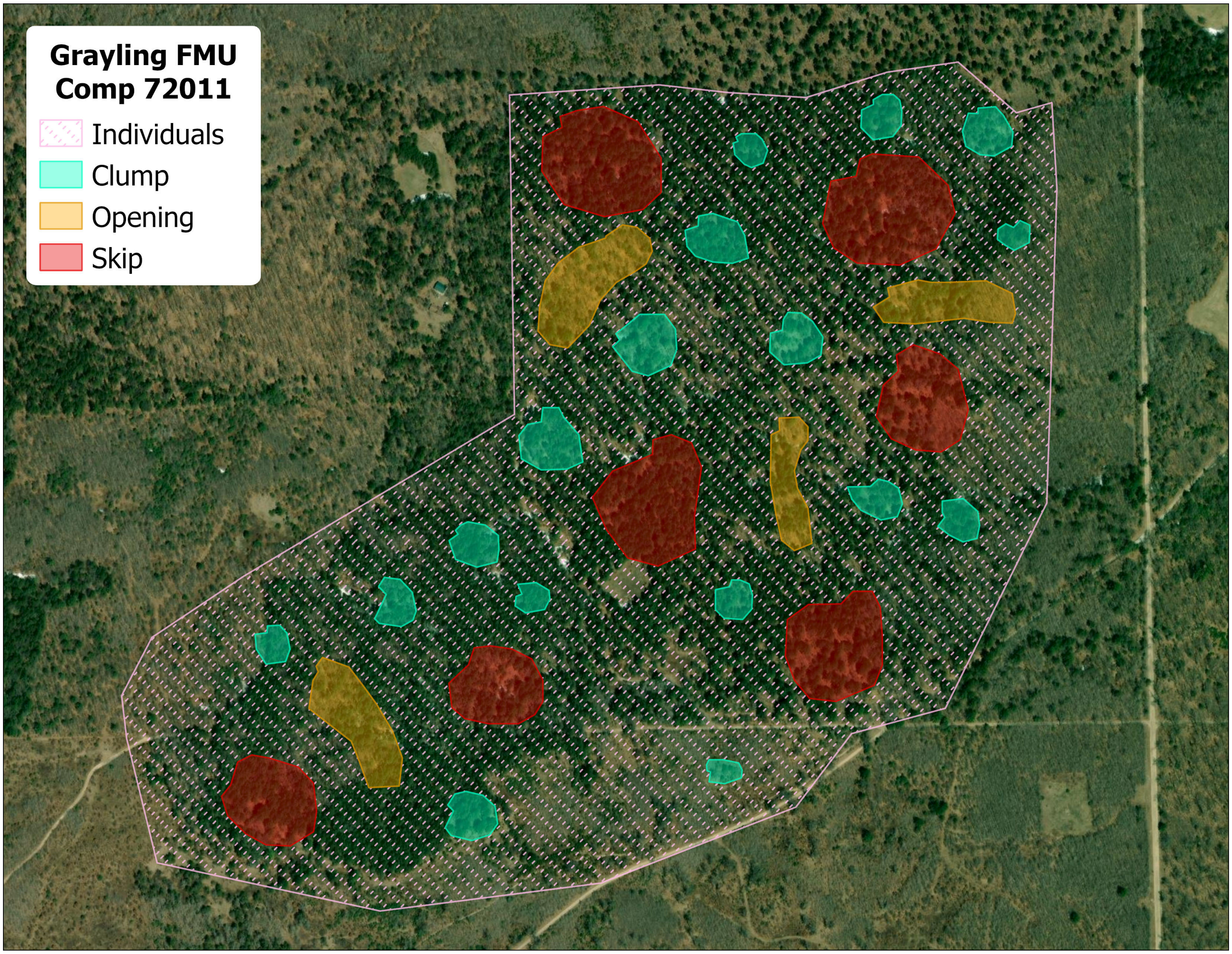
Management Recommendations

Apply two low-intensity fires across the entire project area. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain legacy red and white pine and most canopy white oaks. Protect fire-scarred living trees and stumps to establish fire history. Survey for invasive species along roads and trails.



Appendix 13. Potential Project Area in Grayling Compartment 72011.

The understory of this project area has some natural red pine regeneration but it is mostly dominated by white pine, red maple, beech, and red oak. Photo by J.M. Lincoln.

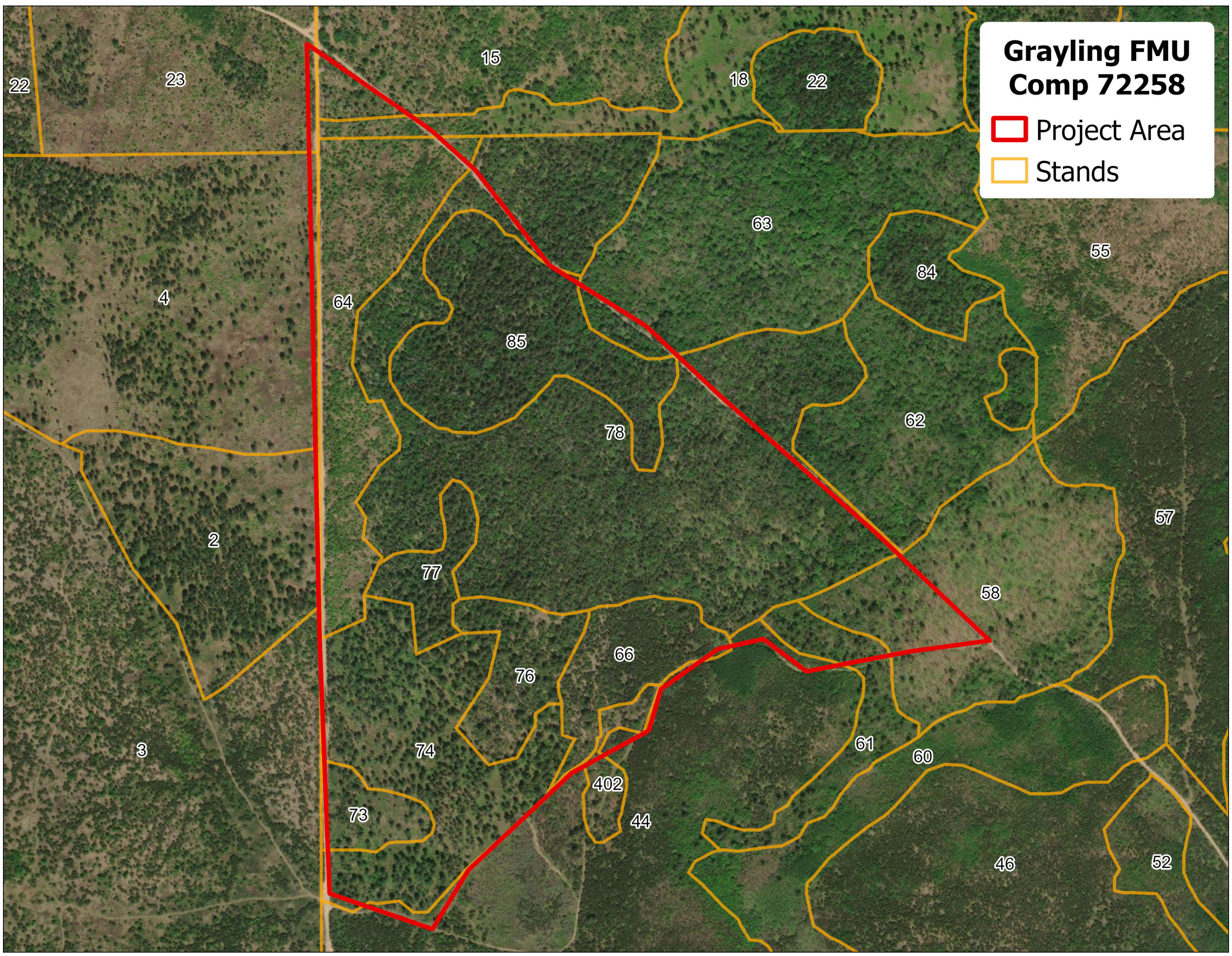


Appendix 14. ICO Management zones for Project Area in Grayling Compartment 72011.

8. Grayling FMU: C72258
Location: Compartment 72258, Stand 85. Also contains Stands 62, 72, 74, and 76.
Size: 150 acres (60.7 ha)

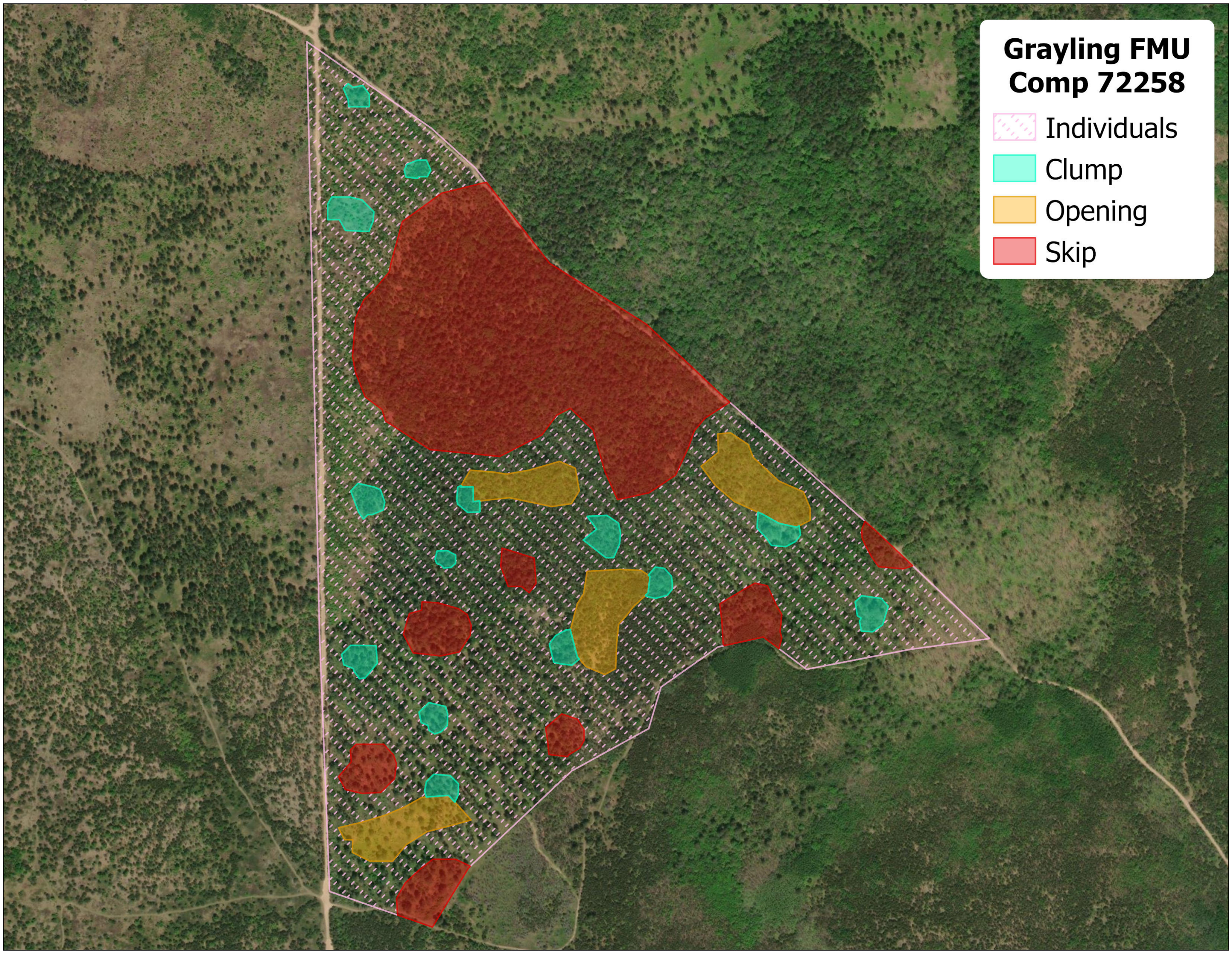
This project area is developed around Stand 85, which is a documented high-quality dry northern forest. Most trees are in Stand 85 are part of the 80- to 100-year-old cohort, including jack pine estimated to be at least 93 years old based upon growth rings of a representative individual. An estimated 20% of the canopy is part of this cohort. Additionally, an older cohort exists in the canopy with one red pine containing 148 growth rings and one 20-inch DBH white oak containing 157 grow rings; most canopy white oak appear to be part of this age class. A recent fire in Stand 74 has encouraged natural regeneration of red pine. The entire project area is surrounded by roads that would serve as ideal burn breaks.

Management Recommendations
Apply at least one low-intensity fire across the entire project area. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Time the second burn to correspond with a red pine mast year. Avoid damage to natural red pine regeneration during harvest. No thinning should take place within Stand 85, and we encourage a large buffer to minimize fragmentation around the high-quality forest. Survey for invasive species along roads and trails.



Appendix 15. Potential Project Area in Grayling Compartment 72258.

The southern portion of this project area has been impacted by two fires and there is patchy but abundant red pine regeneration where the fire occurred in and around Stand 74. Photo by J.M. Lincoln.



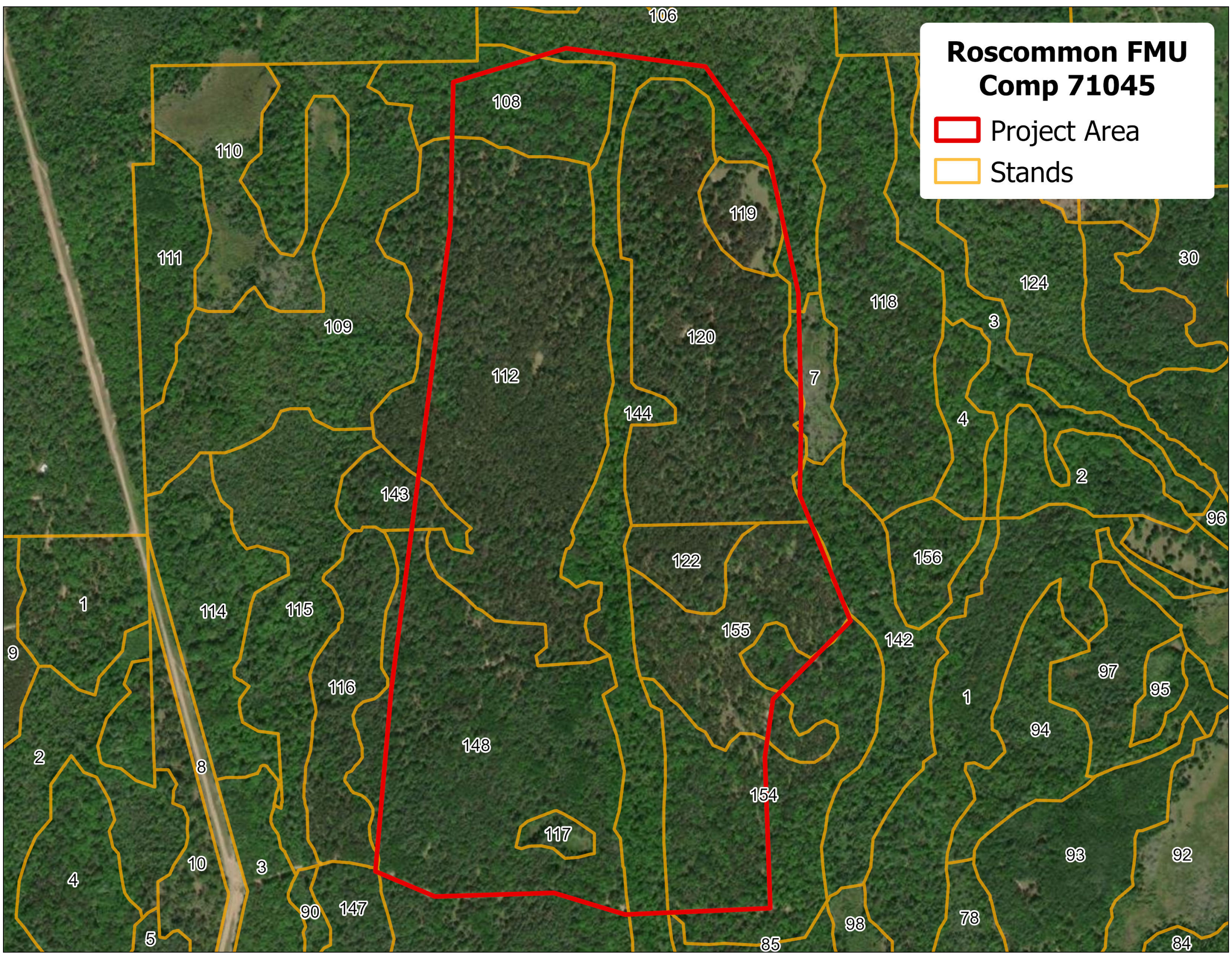
Appendix 16. ICO Management zones for Project Area in Grayling Compartment 72258.

9. Roscommon FMU: C71045

Location: Compartment 71045, Stands 112, 120, 148, 154, and 155.
Size: 225 acres (91.1 ha)

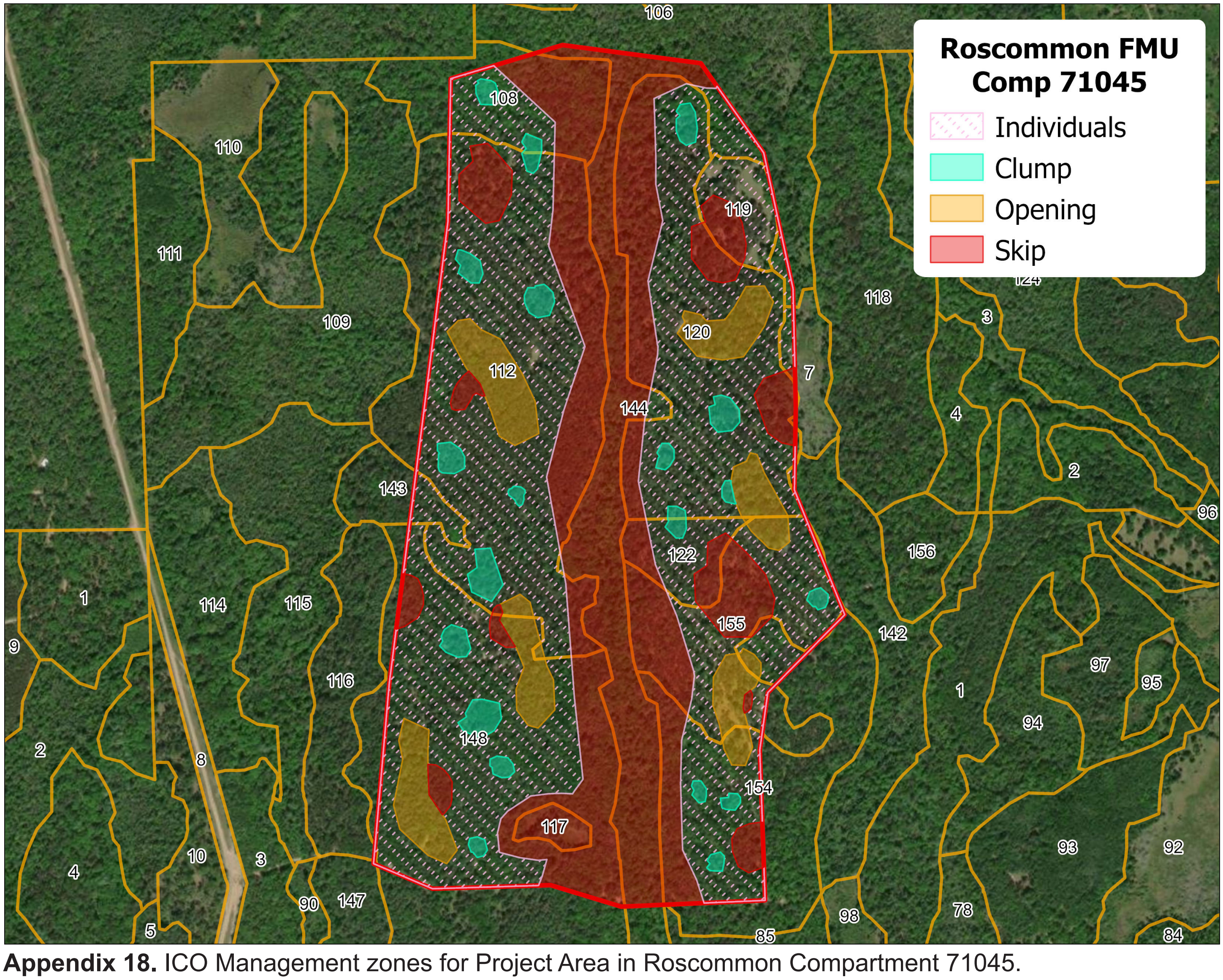
This project area is comprised of several natural red and white pine stands with an elevated water table. There are several zones of saturated soils where the use of heavy equipment should be avoided. The *Skip* zones were placed around areas of saturated soils. Stands 112 and 120 were thinned between 1994 and 1995, leaving no red pine individuals that are over 120 years old. Dense balsam fir and white pine saplings were noted in portions of Stand 108 along with low regeneration of red pine. Abundant coarse woody debris occurs throughout this project area.

Management Recommendations
Apply two low-intensity fires across the entire project area, using the stream in Stand 144 as a natural burn break. Consult with fire managers to determine if understory thinning is needed prior to application of prescribed fire. Understory thinning through mastication is one viable fuels reduction treatment that may be merited in portions of this Project Area. If implemented, protect red pine regeneration and avoid *Skips* and *Clumps* with the mechanical treatment. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Survey for invasive species along roads and trails.



Appendix 17. Potential Project Area in Roscommon Compartment 71045.

The understory of this site is generally dominated by white pine. Photo by J.M. Lincoln.

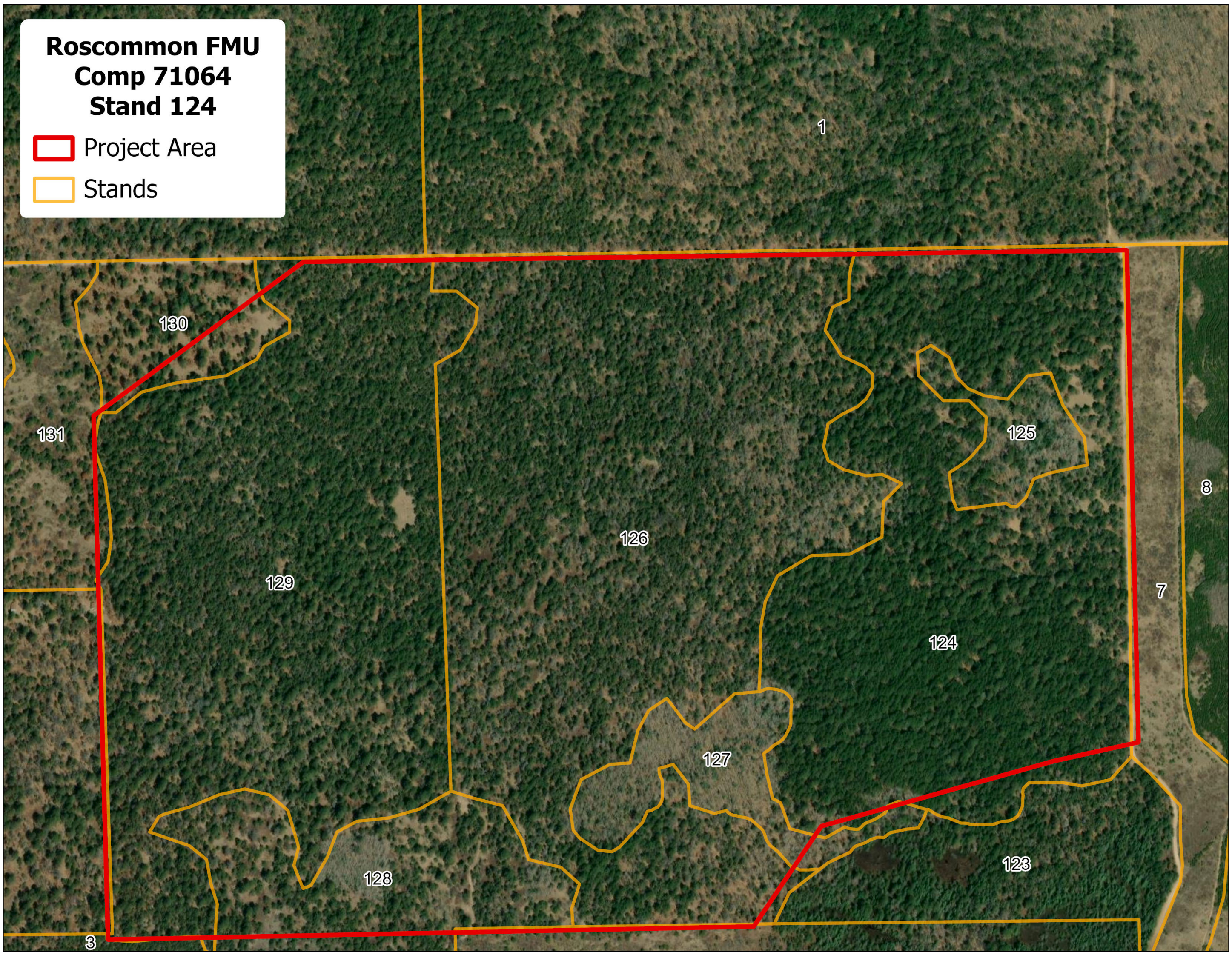


Appendix 18. ICO Management zones for Project Area in Roscommon Compartment 71045.

10. Roscommon FMU: C71064 S124
Location: Compartment 71064, Stands 124, 126, and 129. Also contains Stands 125, 127, and 128.
Size: 213 acres (86.2 ha)

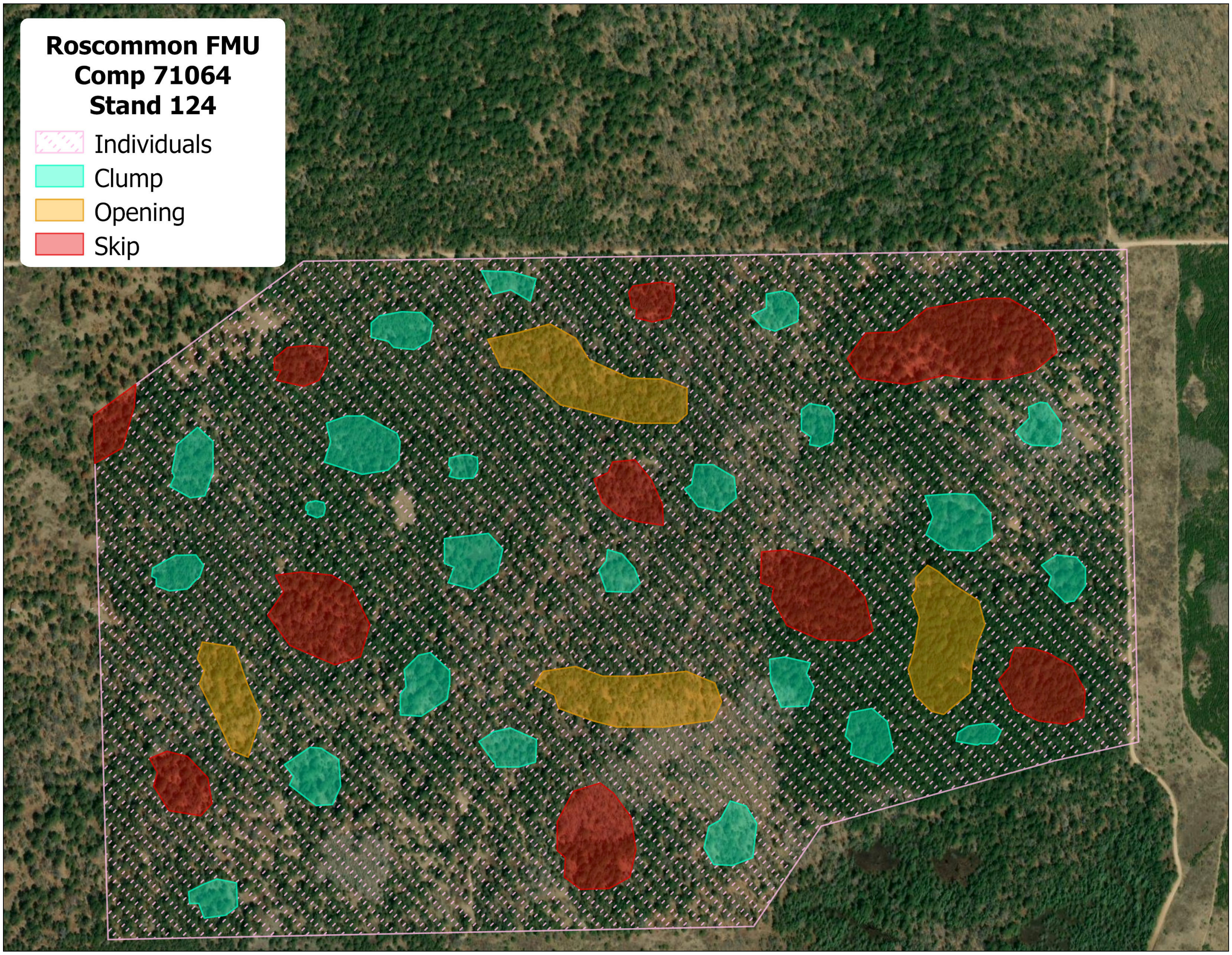
This project area contains several stands of varying composition and age classes. Stand 124 is dominated by red pine in a 70- to 90-year-old cohort but also has a cohort of 120-year-old trees throughout. Stands 126 and 129 have components of pine barrens vegetation though they appear to have been thinned and northern pin oak is prevalent. Stand 126 is relatively young and could be included in future timber harvests. There are a few open-grown legacy trees in Stand 129. Low-intensity, infrequent fires will encourage red pine and white oak regeneration throughout all stands and will likely enhance the barrens composition in Stand 126. In addition, an active goshawk nest was observed in Stand 124.

Management Recommendations
Apply two low-intensity fires across the entire project area. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain the oldest red pine and all white oak throughout. Thin Stand 124 to a basal area of 90 to 110 per acre. Avoid damaging pockets of pine barrens vegetation that express following these fires and survey for pine barrens indicator species, nesting goshawks, and invasive species.



Appendix 19. Potential Project Area in Roscommon Compartment 71064 (Stand 124).

This project area features a relatively dense stand of natural red pine in Stand 124 with little regeneration. There was a goshawk observed in this stand. Photo by J.M. Lincoln.



Appendix 20. ICO Management zones for Project Area in Roscommon Compartment 71064 (Stand 124).

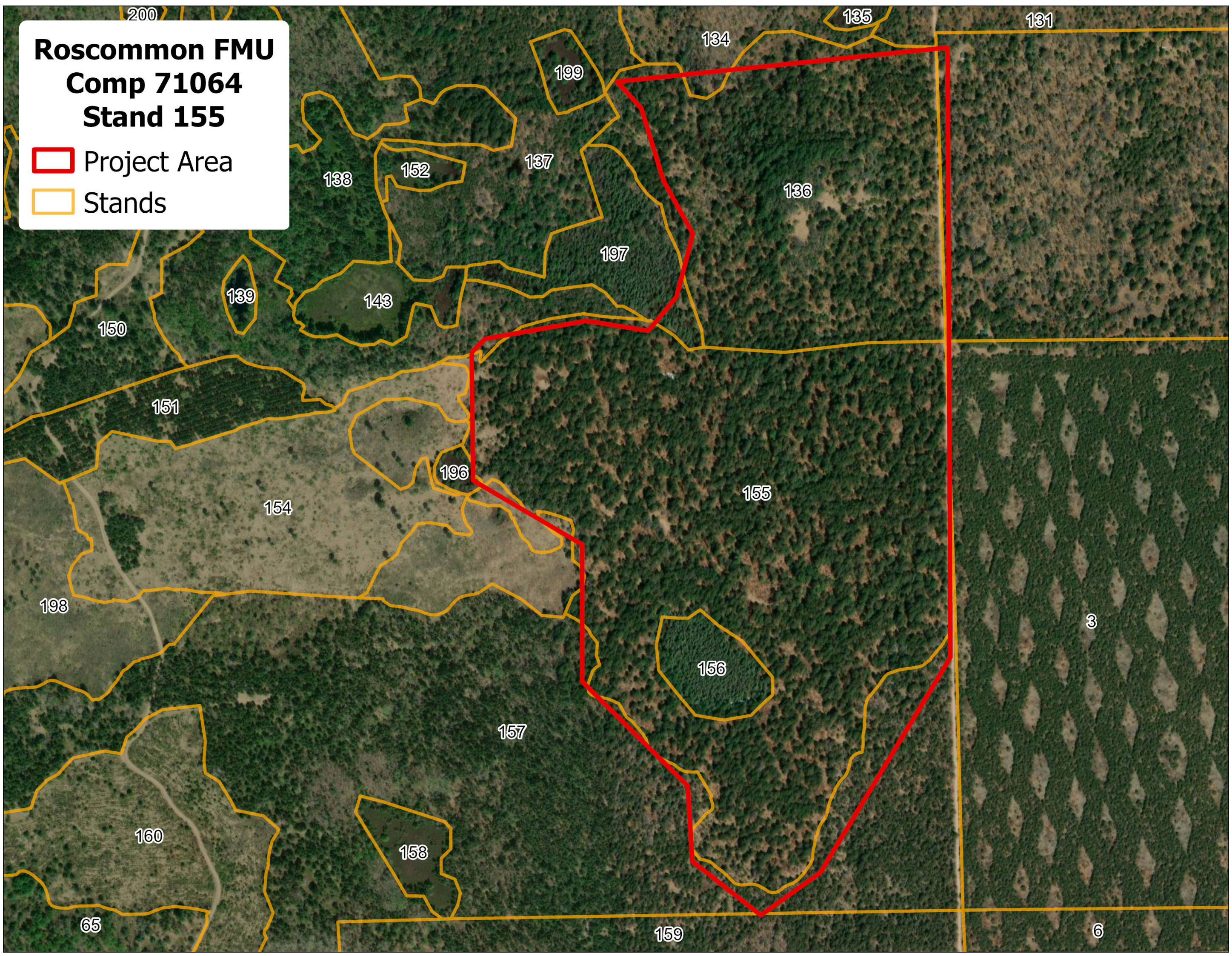
11. Roscommon FMU: C71064 S155

Location: Compartment 71064, Stand 155 and 136.
Size: 112 acres (45.3 ha)

The two red pine stands in this project area feature variable age class distribution. These stands had been thinned but include multiple red pine in a cohort around 120 years old. Both stands have moderate to low levels of red pine regeneration and a high density of white pine saplings and occasional red maple saplings. Stand 155 has a relatively diverse ground layer similar to that of high-quality dry northern forests. Stand 156 is notable as a black spruce (*Picea mariana*) swamp containing low to medium cover of woody bog species such as leatherleaf (*Chamaedaphne calyculata*) and labrador tea (*Rhododendron groenlandicum*) and should not be included in timber management activities.

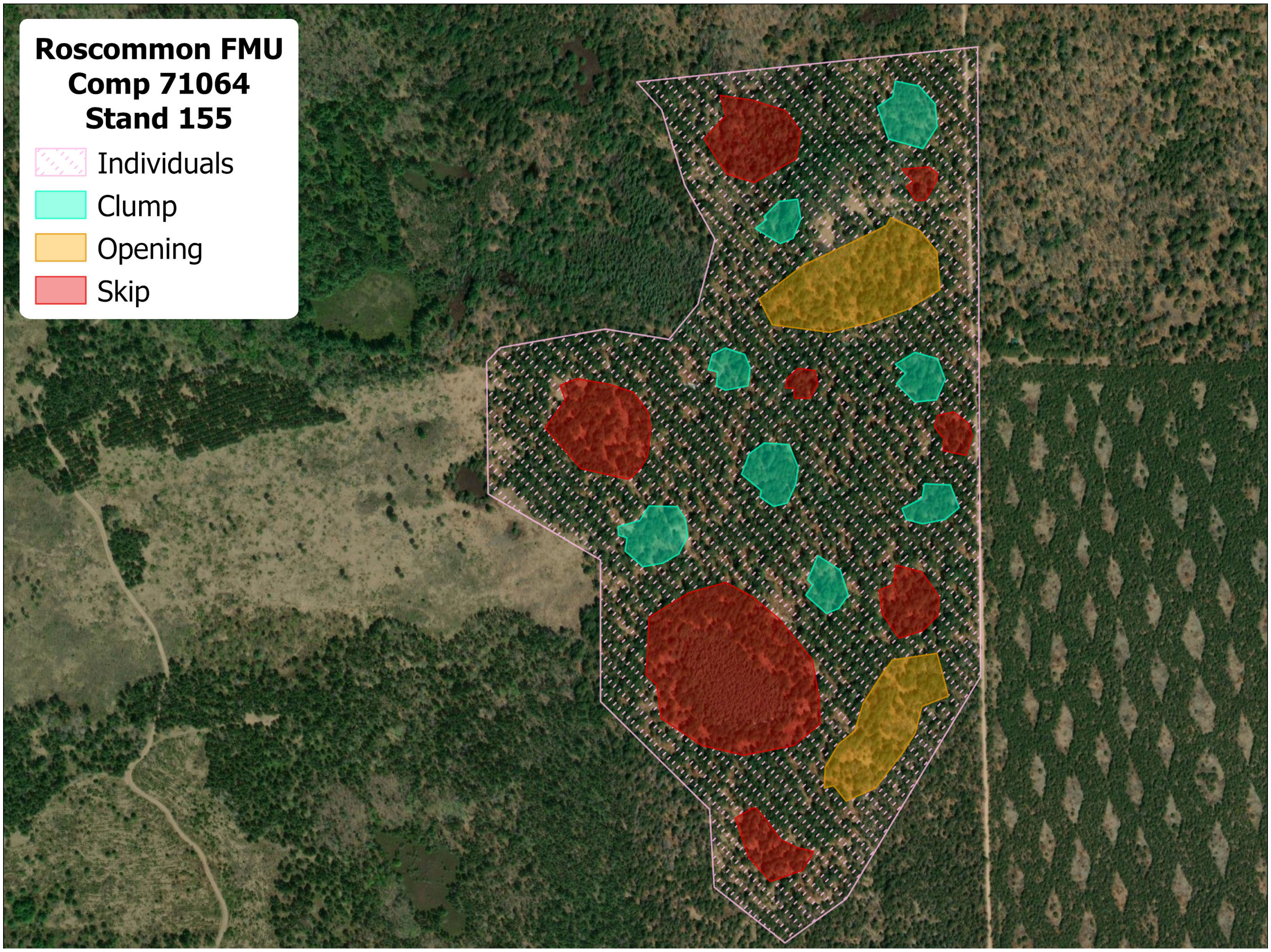
Management Recommendations

Apply one to two low-intensity fires across the entire project area, including the black spruce wetland in Stand 156. Time the second burn to correspond with a red pine mast year. Consult with fire managers to determine if understory thinning is needed prior to application of prescribed fire. Understory thinning through mastication is one viable fuels reduction treatment that may be merited in portions of this Project Area. If implemented, protect red pine regeneration and avoid *Skips* and *Clumps* with the mechanical treatment. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Thin stands 155 and 136 following the fire, leaving the oldest red pine, and survey for invasive species.



Appendix 21. Potential Project Area in Roscommon Compartment 71064 (Stand 155).

This site has been thinned and the understory has some red pine regeneration although it is dominated mostly by white pine. The site may need only one fire to reduce understory competition for red pine regeneration. Photo by J.M. Lincoln.



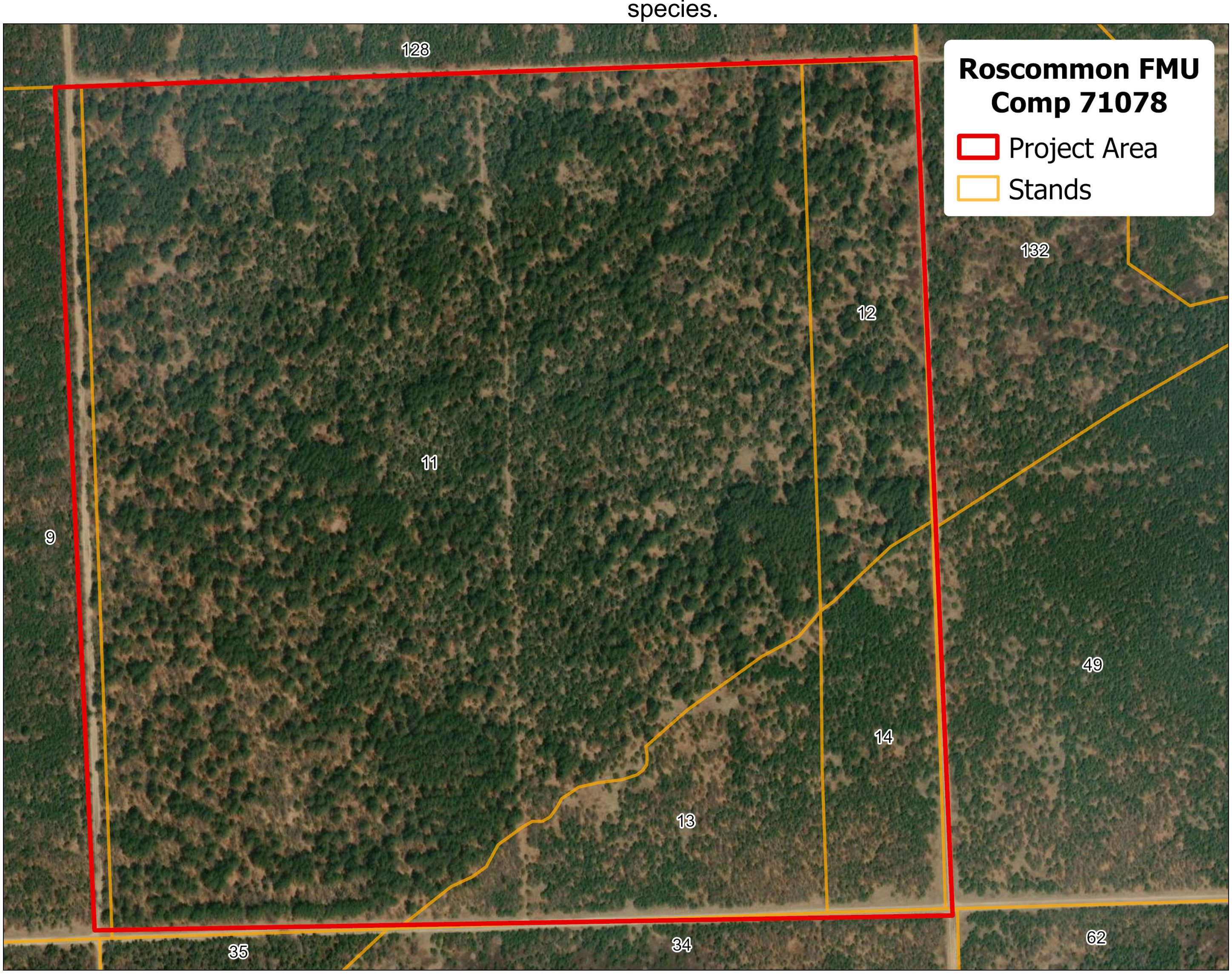
Appendix 22. ICO Management zones for Project Area in Roscommon Compartment 71064 (Stand 155).

12. Roscommon FMU: C71078

Location: Compartment 71078, Stand 11. Also contains Stands 12, 13, and 14.
Size: 160 acres (64.7 ha)

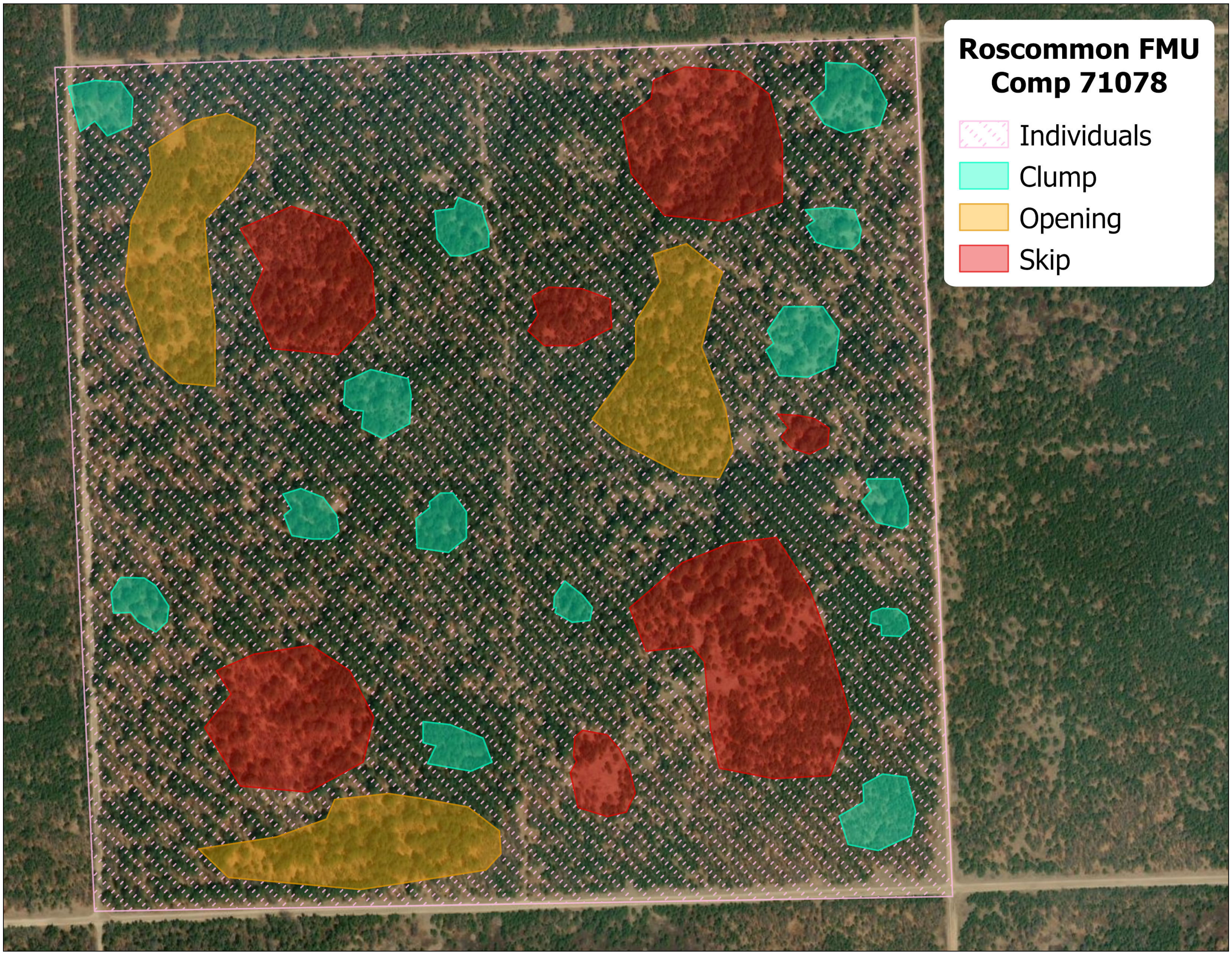
Stand 11 is listed as natural red pine in the MiFI database but several areas appear to have been planted with furrows visible. Many portions of this project area have an open pine barrens structure and some barrens indicator species. Some sections contain low to moderate natural red pine regeneration. Fine fuels such as hair grass (*Avenella flexuosa*) and sedge species (*Carex* spp.) are consistent throughout these stands, and low-intensity fire may therefore be easy to implement. Because of the relatively uniform nature of this site and the existence of several trails, this project area could be broken into two to four burn units to create a functioning experiment in which fire is applied at different seasons, frequencies, and intensities.

Management Recommendations
Apply two low-intensity fires across the entire project area. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone by roughly 1/3 BA following the second fire and create openings where concentrations of barrens species are expressed. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. We also recommend surveying for additional pine barrens indicator species and invasive species.



Appendix 23. Potential Project Area in Roscommon Compartment 71078.

This project area features mature pine, some of which may have been planted based on the presence of obscure furrows. There was a concentration of pine barrens indicator species throughout (hair grass pictured above). The sedges and grasses may facilitate low intensity burns. Photo by J.M. Lincoln.



Appendix 24. ICO Management zones for Project Area in Roscommon Compartment 71078.

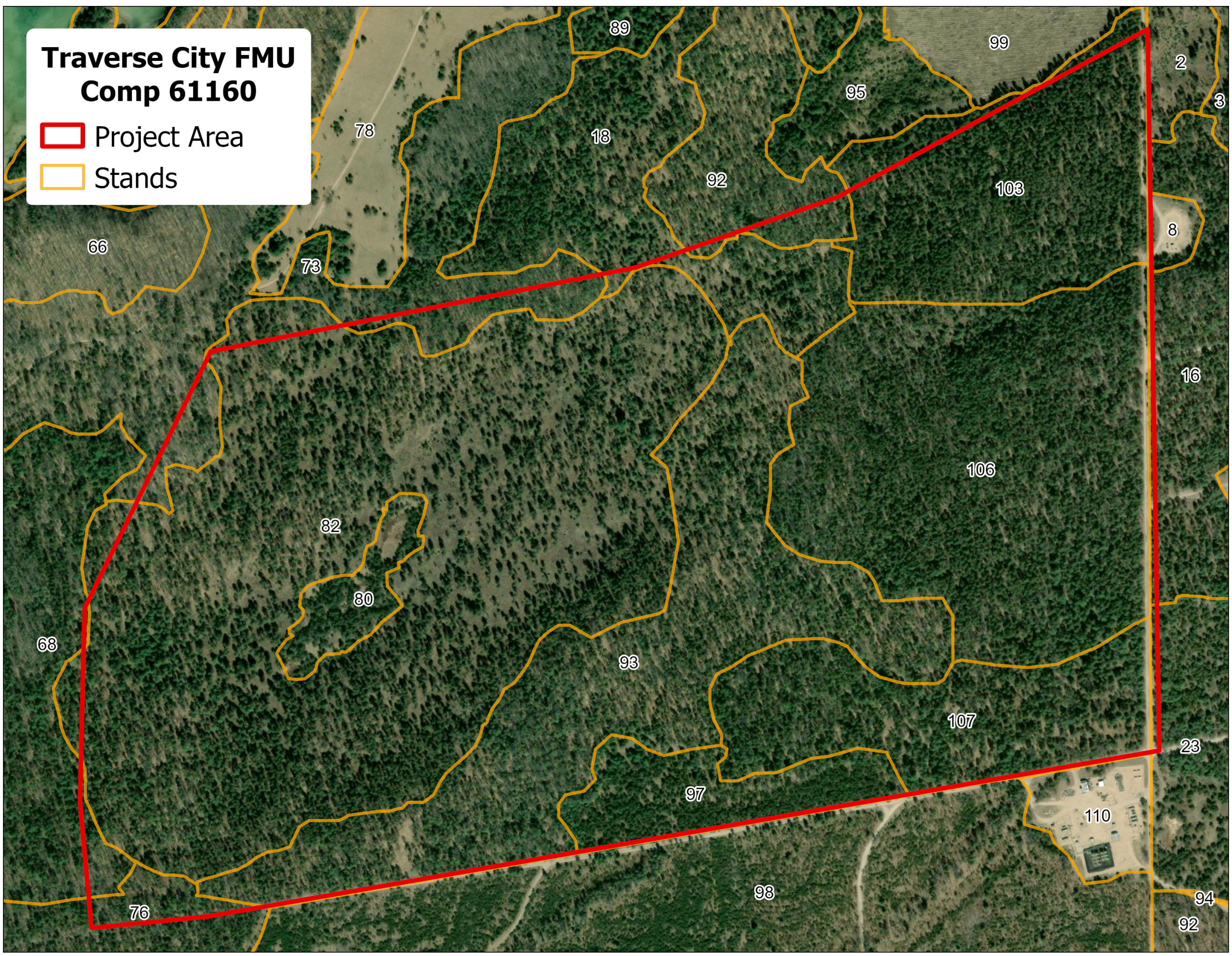
13. Traverse City FMU: C61160

Location: Compartment 61160, Stand 106. Also contains Stands 82, 93, 103, and 107.
Size: 291 acres (117.8 ha)

The canopy of Stand 106 is primarily red pine with white pine, jack pine, red oak, and red maple occasional in the overstory. It was thinned in 2017 and a representative red pine was aged at over 100 years. There are a few red pine in a cohort over 150 years old. There are also several fire-scarred stumps, making it an ideal area to reconstruct the local fire history; one such stump was given to a University of Minnesota researcher to help with the process (Photos on Page 4). The stump shows evidence of at least six fires with a range of 6 to 16 years between fires (average 11.2).

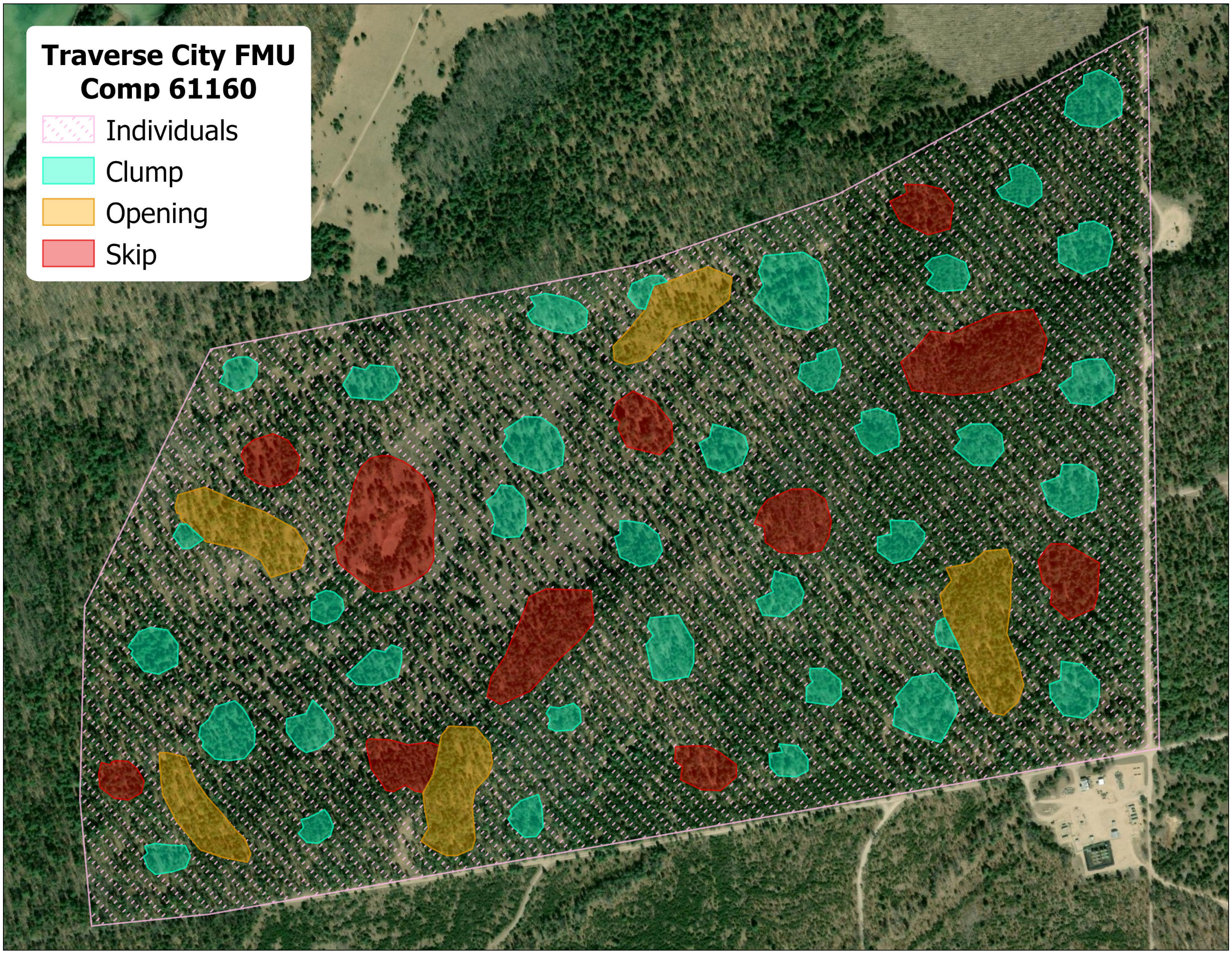
Stand 82 was recently thinned and is dominated by white pine although several widely spaced red pine are in the canopy. Stand 82 also surrounds a small wet-mesic sand prairie and would be an excellent site to include in the project area. The North Country Trail runs through this site making it highly visible and further attractive as a project area.

Management Recommendations
Apply two low-intensity fires across the entire project area. Time the second burn to correspond with a red pine mast year. Harvest *Openings* zones and thin *Individuals* zone in Stands 93, 103, and 106 by roughly 1/3 BA following the second fire. Apply a low-intensity fire within 5 to 10 years of thinning to mitigate disease risks. Retain legacy red and white pine and white oaks in all forest strata. Avoid damage to fire-scarred living trees and protect old fire-scarred stumps to establish fire history. We also recommend surveying for invasive species along roads and trails.



Appendix 25. Potential Project Area in Traverse City Compartment 61160.

This site has been thinned and the understory features white pine and white oak with little red pine regeneration. Stand 106 had several fire-scarred living trees and stumps. Photo by J.M. Lincoln.



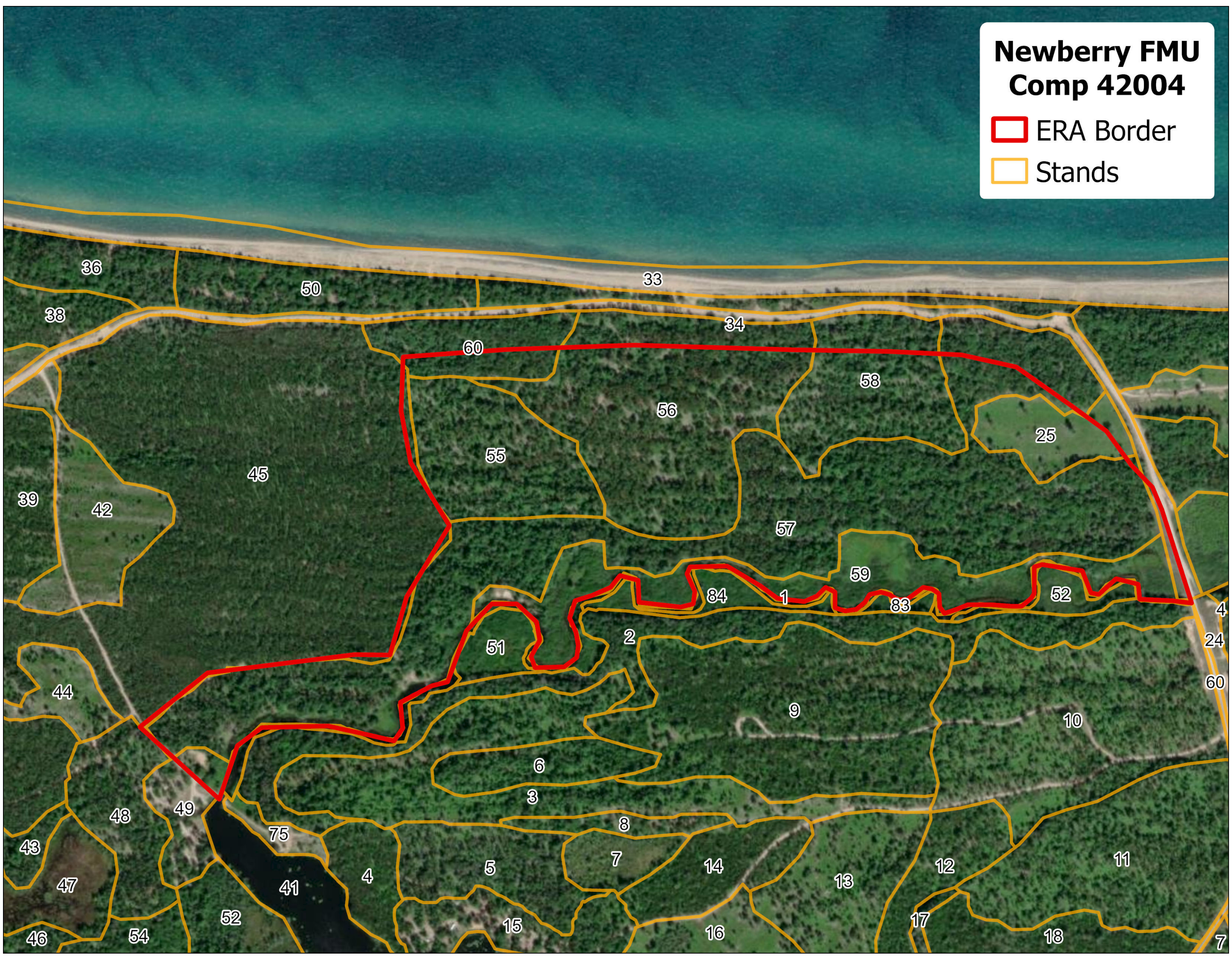
Appendix 26. ICO Management zones for Project Area in Traverse City Compartment 61160.

POTENTIAL ECOLOGICAL REFERENCE AREA

Newberry FMU: C42004
Location: Compartment 42004, Stand 57. Also contains Stands 55, 56, 58, and 60.
Size: 118 acres (47.8 ha)

This site is not designated as a project area but instead should be considered as a potential ERA due to existing legacy trees, natural red pine regeneration, areas with dense huckleberry and blueberry, and a diverse herbaceous layer. The canopy is comprised primarily of uneven-aged red, white, and jack pine with occasional red oak. Sections of this site include dune ridges and areas with dense red pine regeneration. Huckleberry is common to abundant and tall bilberry (*Vaccinium membranaceum*) is present but rare. Much of this site could be categorized as a high-quality natural community and there are several red pine in a cohort over 170-year-old that were not noted in the MiFI data. In Stand 57, a jack pine had 118 growth rings while a 22-inch DBH red pine had 191 growth rings. Stand 60 has occasional 150+ year old red pines and a similar character to Stand 57 besides being bisected by a road. Despite a lack of older trees in much of this site, ground cover is undamaged and the stand exhibits little disturbance. Several old stumps are also present and should be evaluated for fire scars.

Management Recommendations
This site is very accessible with existing features that can serve as burn breaks. It is an ideal area to practice implementing fire in natural red pine with advanced age classes and natural burn lines along wetlands and could therefore serve as a template for managing dry and dry-mesic northern forest ERAs with fire. Our primary management recommendations are to prevent logging and apply low-intensity fire across the entire project area and use the river to the south as a natural burn break. We also recommend surveying for invasive species along roads and trails.



Appendix 27. Potential Ecological Reference Area in Newberry Compartment 42004.

Stand 57 in Compartment 42004 had several trees in a cohort greater than 150 years old. The presence of old trees, proximity to Lake Superior, prevalence of culturally relevant shrubs, and steep topography have led us to recommend this site for managing as an ERA and avoiding future timber harvests. Photo by J.M. Lincoln.

Appendix 28. Additional sites surveyed in 2024 field season that were not developed into natural red pine Project Areas.

FMU	Compartment	Primary Stands	Notes
Atlanta	54176	46, 53	• Fire-scarred stumps in S46 and 53 • Very old red pine in S53. One cored to 237 • Stand 53 could be a project area
Atlanta	54167	48 and 20	• Thinned, could be project area. • No legacy pine or fire-scarred stumps
Atlanta	54172	52 and 49	• Natural red pine but more mesic minimal merchantable red pine in S49 • Could work as a project area
Cadillac	63132	85 and 104	• Natural pine along the river with fire scars • Stand 104 was planted • Overall too mesic for fire project, not fire-adapted
Grayling	72012	29	• Could work as a project area • No legacy pine, very mesic and dense • Adjacent to private property
Grayling	72026	37 and 57	• Stand 57 already harvested, several legacy trees eliminated • Stand 37 has good pine barrens structure, okay composition, and trees over 170 yo
Grayling	72071	8	• Nice structure and composition, hydric soils • Not quite EO quality, worthy of protection • Would be good project but difficult to create burn units next to enormous wetland complex and accessibility issues
Grayling	72072	37 and 5 (C72071)	• Hydric soils in western portion of stands. • Old trees but difficult to create project area due to saturated soils
Traverse City	61246	56	• Already thinned, miminal evidince of fire, small, adjacent to private property • Not a great project area
Shingleton	41133	8, 9, 12, 17	• Stands were clearcut, trenched, sprayed, and planted

Appendix 29. Stands from the Newberry FMU that could be evaluated for natural red pine management.

Unit Name	Compartment	Stand Number	Dominant Age	CoverType	Acres	MNFI Community	Rx Fire Score	Fire Need	Priority
Newberry	42042	29	97	42210 - Natural Red Pine	491	Dry-mesic Northern Forest	2.19	Moderate	1
Newberry	42020	27	118	42200 - Natural White Pine	481	Dry-mesic Northern Forest	2.73	High	1
Newberry	42027	59	80	4311 - Pine, Aspen Mix	397	Dry-mesic Northern Forest	2.31	High	1
Newberry	42025	22	79	42210 - Natural Red Pine	340	Dry-mesic Northern Forest	2.47	High	1
Newberry	42037	63	89	42260 - Natural Pine, Mixed Deciduous	326	Dry-mesic Northern Forest	2.58	High	1
Newberry	42029	11	65	42220 - Natural Jack Pine	262	Dry Northern Forest	2.81	High	1
Newberry	42051	45	90	4319 - Mixed Upland Forest	258	Dry-mesic Northern Forest	2.22	Moderate	1
Newberry	42029	43	80	42290 - Natural Mixed Pine	238	Dry-mesic Northern Forest	2.31	High	1
Newberry	42134	45	80	429 - Mixed Upland Conifers	237	Dry-mesic Northern Forest	1.73	Moderate	1
Newberry	42091	53	102	42290 - Natural Mixed Pine	222	Dry-mesic Northern Forest	1.93	Moderate	1
Newberry	42031	58	109	42200 - Natural White Pine	215	Dry-mesic Northern Forest	2.51	High	1
Newberry	42033	17	90	42290 - Natural Mixed Pine	204	Dry Northern Forest	3.23	High	1
Newberry	42041	25	135	42290 - Natural Mixed Pine	187	Dry-mesic Northern Forest	2.66	High	1
Newberry	42041	40	132	42210 - Natural Red Pine	184	Dry Northern Forest	3.76	Very High	1
Newberry	42062	8	89	42290 - Natural Mixed Pine	180	Dry Northern Forest	3.55	Very High	1
Newberry	42042	60	97	42210 - Natural Red Pine	175	Dry-mesic Northern Forest	2.74	High	1
Newberry	42015	71	79	42210 - Natural Red Pine	169	Dry-mesic Northern Forest	2.38	High	1
Newberry	42040	29	99	42210 - Natural Red Pine	159	Dry-mesic Northern Forest	2.66	High	1
Newberry	42044	57	118	42210 - Natural Red Pine	155	Dry-mesic Northern Forest	2.24	Moderate	1
Newberry	42015	25	71	42210 - Natural Red Pine	153	Dry-mesic Northern Forest	2.56	High	1
Newberry	42075	79	97	429 - Mixed Upland Conifers	150	Dry-mesic Northern Forest	2.33	High	1
Newberry	42025	11	79	42210 - Natural Red Pine	147	Dry-mesic Northern Forest	2.48	High	2
Newberry	42102	5	102	42200 - Natural White Pine	145	Dry-mesic Northern Forest	2.53	High	2
Newberry	42042	97	97	42290 - Natural Mixed Pine	145	Dry-mesic Northern Forest	2.58	High	1
Newberry	42043	4	64	42220 - Natural Jack Pine	145	Dry Northern Forest	3.00	High	2
Newberry	42029	6	107	42290 - Natural Mixed Pine	141	Dry Northern Forest	2.92	High	2
Newberry	42020	9	96	4319 - Mixed Upland Forest	140	Dry-mesic Northern Forest	2.49	High	2
Newberry	42004	1	68	42220 - Natural Jack Pine	137	Dry Northern Forest	2.79	High	2
Newberry	42020	4	116	42200 - Natural White Pine	136	Dry-mesic Northern Forest	2.43	High	2
Newberry	42021	11	89	42200 - Natural White Pine	136	Dry-mesic Northern Forest	2.43	High	2
Newberry	42045	36	106	42290 - Natural Mixed Pine	135	Dry-mesic Northern Forest	2.47	High	1
Newberry	42018	35	119	42210 - Natural Red Pine	135	Dry-mesic Northern Forest	2.11	Moderate	1
Newberry	42018	28	108	42210 - Natural Red Pine	131	Dry-mesic Northern Forest	2.10	Moderate	1
Newberry	42126	43	70	4191 - Mixed Upland Deciduous/Conifer	129	Dry-mesic Northern Forest	1.80	Moderate	2
Newberry	42019	41	97	42210 - Natural Red Pine	129	Dry Northern Forest	3.24	High	2
Newberry	42027	33	95	42200 - Natural White Pine	129	Dry-mesic Northern Forest	2.62	High	2
Newberry	42044	25	118	42210 - Natural Red Pine	129	Dry-mesic Northern Forest	2.68	High	2
Newberry	42024	33	101	42210 - Natural Red Pine	128	Dry-mesic Northern Forest	2.50	High	2
Newberry	42017	3	114	41299 - Oak (OI)	128	Dry-mesic Northern Forest	1.83	Moderate	2
Newberry	42043	39	101	42290 - Natural Mixed Pine	123	Dry Northern Forest	3.38	Very High	2
Newberry	42046	7	74	4191 - Mixed Upland Deciduous/Conifer	121	Dry-mesic Northern Forest	2.34	High	2
Newberry	42020	13	100	42290 - Natural Mixed Pine	120	Dry-mesic Northern Forest	2.33	High	2
Newberry	42031	54	63	42220 - Natural Jack Pine	118	Dry Northern Forest	3.02	High	2
Newberry	42031	3	98	42210 - Natural Red Pine	118	Dry-mesic Northern Forest	2.45	High	2
Newberry	42019	70	77	42210 - Natural Red Pine	118	Dry-mesic Northern Forest	2.58	High	2
Newberry	42031	10	103	42200 - Natural White Pine	116	Dry-mesic Northern Forest	2.46	High	2
Newberry	42129	4	120	429 - Mixed Upland Conifers	114	Dry-mesic Northern Forest	2.24	Moderate	1

Appendix 29 (Continued). Stands from the Newberry FMU that could be evaluated for natural red pine management.

Unit Name	Compartment	Stand Number	Dominant Age	CoverType	Acres	MNFI Community	Rx Fire Score	Fire Need	Priority
Newberry	42043	26	98	42210 - Natural Red Pine	112	Dry Northern Forest	2.93	High	1
Newberry	42090	2	93	42200 - Natural White Pine	112	Dry-mesic Northern Forest	2.07	Moderate	2
Newberry	42015	30	71	42210 - Natural Red Pine	112	Dry-mesic Northern Forest	2.50	High	2
Newberry	42007	44	66	42200 - Natural White Pine	111	Dry-mesic Northern Forest	2.39	High	2
Newberry	42098	36	88	429 - Mixed Upland Conifers	111	Dry-mesic Northern Forest	2.32	High	2
Newberry	42044	38	110	42210 - Natural Red Pine	110	Dry-mesic Northern Forest	2.61	High	2
Newberry	42014	15	89	42210 - Natural Red Pine	109	Dry-mesic Northern Forest	2.49	High	2
Newberry	42005	28	136	429 - Mixed Upland Conifers	108	Dry-mesic Northern Forest	2.39	High	2
Newberry	42061	19	90	42210 - Natural Red Pine	108	Dry Northern Forest	3.36	Very High	2
Newberry	42043	12	106	42210 - Natural Red Pine	108	Dry Northern Forest	3.23	High	2
Newberry	42065	120	92	42499 - Jack Pine (OI)	107	Dry Northern Forest	3.10	High	2
Newberry	42091	51	72	429 - Mixed Upland Conifers	103	Dry-mesic Northern Forest	1.93	Moderate	2
Newberry	42075	35	87	429 - Mixed Upland Conifers	103	Dry-mesic Northern Forest	2.18	Moderate	2
Newberry	42027	69	85	4311 - Pine, Aspen Mix	102	Dry-mesic Northern Forest	2.34	High	2
Newberry	42007	28	80	42210 - Natural Red Pine	102	Dry-mesic Northern Forest	2.49	High	2
Newberry	42014	63	79	42210 - Natural Red Pine	101	Dry-mesic Northern Forest	2.03	Moderate	2
Newberry	42015	70	104	42200 - Natural White Pine	100	Dry-mesic Northern Forest	2.48	High	2
Newberry	42014	44	106	42200 - Natural White Pine	99	Dry-mesic Northern Forest	2.36	High	2
Newberry	42005	21	85	42290 - Natural Mixed Pine	99	Dry-mesic Northern Forest	2.35	High	2
Newberry	42035	47	88	42200 - Natural White Pine	98	Dry-mesic Northern Forest	2.27	High	2
Newberry	42014	38	88	42290 - Natural Mixed Pine	97	Dry-mesic Northern Forest	2.52	High	2
Newberry	42015	67	79	42220 - Natural Jack Pine	96	Dry Northern Forest	3.26	Very High	2
Newberry	42059	110	83	42210 - Natural Red Pine	96	Dry Northern Forest	3.10	High	2
Newberry	42001	58	77	4310 - Pine, Oak Mix	96	Dry Northern Forest	2.84	High	2
Newberry	42098	44	88	42290 - Natural Mixed Pine	95	Dry-mesic Northern Forest	2.12	Moderate	2
Newberry	42053	82	88	42290 - Natural Mixed Pine	95	Dry-mesic Northern Forest	2.38	High	2
Newberry	42019	103	77	42210 - Natural Red Pine	94	Dry-mesic Northern Forest	2.25	High	2
Newberry	42031	41	98	42210 - Natural Red Pine	94	Dry-mesic Northern Forest	2.45	High	2
Newberry	42043	51	78	42210 - Natural Red Pine	94	Dry Northern Forest	3.23	High	2
Newberry	42041	10	132	42210 - Natural Red Pine	93	Dry Northern Forest	3.38	Very High	2
Newberry	42024	14	76	42210 - Natural Red Pine	93	Dry-mesic Northern Forest	2.48	High	2
Newberry	42014	16	100	42200 - Natural White Pine	93	Dry-mesic Northern Forest	2.40	High	2
Newberry	42045	19	94	42290 - Natural Mixed Pine	92	Dry-mesic Northern Forest	2.35	High	2
Newberry	42015	2	81	42210 - Natural Red Pine	91	Dry-mesic Northern Forest	2.60	High	2
Newberry	42012	60	89	42210 - Natural Red Pine	90	Dry Northern Forest	3.34	Very High	2
Newberry	42019	60	87	42210 - Natural Red Pine	90	Dry-mesic Northern Forest	2.48	High	2
Newberry	42054	65	88	42210 - Natural Red Pine	90	Dry-mesic Northern Forest	2.09	Moderate	2
Newberry	42067	62	88	42210 - Natural Red Pine	90	Dry Northern Forest	3.63	Very High	2
Newberry	42043	24	118	42290 - Natural Mixed Pine	89	Dry Northern Forest	2.98	High	2
Newberry	42044	69	123	42210 - Natural Red Pine	88	Dry Northern Forest	2.74	High	2
Newberry	42061	13	78	42220 - Natural Jack Pine	88	Dry Northern Forest	3.18	High	2
Newberry	42060	15	77	42499 - Jack Pine (OI)	87	Dry Northern Forest	2.94	High	2
Newberry	42002	10	115	42200 - Natural White Pine	86	Dry-mesic Northern Forest	2.26	High	2
Newberry	42044	12	108	42210 - Natural Red Pine	86	Dry-mesic Northern Forest	2.23	Moderate	2
Newberry	42037	85	89	42260 - Natural Pine, Mixed Deciduous	85	Dry-mesic Northern Forest	2.54	High	2
Newberry	42089	57	73	42497 - White Pine (OI)	84	Dry-mesic Northern Forest	1.99	Moderate	2
Newberry	42064	78	90	4191 - Mixed Upland Deciduous/Conifer	83	Dry-mesic Northern Forest	2.29	High	2

Appendix 29 (Continued). Stands from the Newberry FMU that could be evaluated for natural red pine management.

Unit Name	Compartment	Stand Number	Dominant Age	CoverType	Acres	MNFI Community	Rx Fire Score	Fire Need	Priority
Newberry	42015	23	101	42200 - Natural White Pine	82	Dry-mesic Northern Forest	2.54	High	2
Newberry	42040	59	103	42210 - Natural Red Pine	82	Dry-mesic Northern Forest	2.11	Moderate	2
Newberry	42008	15	103	42497 - White Pine (OI)	82	Dry-mesic Northern Forest	2.25	Moderate	2
Newberry	42014	79	72	42210 - Natural Red Pine	81	Dry-mesic Northern Forest	2.49	High	2
Newberry	42021	24	117	42200 - Natural White Pine	80	Dry-mesic Northern Forest	2.43	High	2
Newberry	42018	25	111	42290 - Natural Mixed Pine	80	Dry Northern Forest	2.92	High	2
Newberry	42031	19	109	42200 - Natural White Pine	78	Dry-mesic Northern Forest	2.41	High	2
Newberry	42044	64	123	42210 - Natural Red Pine	74	Dry-mesic Northern Forest	2.68	High	2
Newberry	42024	29	107	42201 - Natural White Pine, Mixed Deciduous	74	Dry-mesic Northern Forest	2.40	High	2
Newberry	42044	35	115	42210 - Natural Red Pine	72	Dry-mesic Northern Forest	2.37	High	2
Newberry	42074	59	181	42497 - White Pine (OI)	70	Dry-mesic Northern Forest	2.18	Moderate	2
Newberry	42041	37	111	42210 - Natural Red Pine	69	Dry-mesic Northern Forest	2.47	High	2
Newberry	42030	24	90	42290 - Natural Mixed Pine	69	Dry Northern Forest	3.37	Very High	2
Newberry	42093	45	181	42497 - White Pine (OI)	68	Dry-mesic Northern Forest	2.19	Moderate	2
Newberry	42008	57	181	42497 - White Pine (OI)	65	Dry-mesic Northern Forest	2.50	High	2
Newberry	42069	28	153	42290 - Natural Mixed Pine	58	Dry-mesic Northern Forest	2.25	High	2
Newberry	42024	41	138	429 - Mixed Upland Conifers	55	Dry-mesic Northern Forest	2.41	High	2
Newberry	42134	16	143	429 - Mixed Upland Conifers	54	Dry-mesic Northern Forest	1.75	Moderate	2
Newberry	42093	26	181	42498 - Red Pine (OI)	53	Dry-mesic Northern Forest	2.14	Moderate	1
Newberry	42060	22	181	42497 - White Pine (OI)	47	Dry-mesic Northern Forest	2.50	High	2
Newberry	42093	54	181	42497 - White Pine (OI)	39	Dry-mesic Northern Forest	2.24	Moderate	2
Newberry	42090	87	128	429 - Mixed Upland Conifers	38	Dry-mesic Northern Forest	1.68	Moderate	2
Newberry	42008	9	181	42498 - Red Pine (OI)	32	Dry-mesic Northern Forest	2.34	High	2
Newberry	42093	35	181	42497 - White Pine (OI)	32	Dry-mesic Northern Forest	2.01	Moderate	2
Newberry	42093	30	181	42498 - Red Pine (OI)	29	Dry-mesic Northern Forest	2.13	Moderate	2
Newberry	42023	36	165	42498 - Red Pine (OI)	28	Dry Northern Forest	2.86	High	2
Newberry	42065	14	181	42498 - Red Pine (OI)	26	Dry Northern Forest	3.18	High	2
Newberry	42004	146	157	42210 - Natural Red Pine	21	Dry Northern Forest	3.13	High	2
Newberry	42074	61	120	42498 - Red Pine (OI)	20	Dry-mesic Northern Forest	2.20	Moderate	2
Newberry	42023	32	165	42498 - Red Pine (OI)	20	Dry Northern Forest	2.79	High	2
Newberry	42013	1	181	429 - Mixed Upland Conifers	17	Dry-mesic Northern Forest	1.70	Moderate	2
Newberry	42028	54	115	42210 - Natural Red Pine	17	Dry-mesic Northern Forest	2.18	Moderate	2
Newberry	42008	65	181	42497 - White Pine (OI)	16	Dry-mesic Northern Forest	2.50	High	2
Newberry	42093	81	181	42498 - Red Pine (OI)	15	Dry-mesic Northern Forest	2.48	High	2