Timber Harvesting and Forest Management Guidelines on Public and Private Forest Land in Various Watersheds in Minnesota

Photo courtesy of Minnesota Pollution Control Agency

2020 and 2021 Monitoring Implementation Results

A report by the Minnesota Department of Natural Resources,
Forest Management Guideline Implementation Monitoring
Program Respectfully submitted to the Minnesota Forest Resources Council

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Timber Harvesting and Forest Management Guideline Implementation on Public and Private Forest Land in Various Watersheds in Minnesota

Monitoring for Implementation 2020 and 2021

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MN DNR Division of
Forestry

February 2022

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Executive Summary

The Minnesota Forest Resources Council's (MFRC) *Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers,* establishes best management practices (guidelines) for timber harvesting and forest management (TH/FM) on forested lands in Minnesota. Implementation monitoring of these guidelines has been conducted on 1301 timber harvest sites across public and private forest lands since 2000. This report provides results for monitoring that occurred in summer and fall of 2020 and 2021 and attempts to assess trends in implementation levels over time.

For this reporting period, implementation of site-level guidelines was assessed on 181 sites randomly selected from within six watershed sample units (10 major watersheds; eight digit hydrologic unit codes) in the forested portions of MN. Monitored sites had timber harvest occurring during summer of 2018 through summer of 2020. The distribution of sites among the primary ownership categories was in approximate proportion to the acres of timber harvest for each based on forest disturbance analysis for the same time window.

Overall implementation of key guidelines for this reporting period showed improvement in some areas compared to previous reports, while other areas of implementation have declined. Several key guidelines show continuous or substantial improvement when assessed at the statewide scale including riparian management, filter strip management, retention of leave trees and snags, retention of fine woody debris on biomass harvest sites, minimizing infrastructure, and coarse woody debris retention. Guidelines that demonstrate lower or no improvement of implementation include avoidance of wetland crossings, use of erosion control where needed, minimization of excess rutting, development of written management plans on private lands, and implementation of some visual quality guidelines.

Conducting guideline monitoring at the watershed scale has proven valuable for the program by increasing understanding of the variation in guideline implementation across the state, and providing increased efficiency and cost savings in the monitoring process. Implementation data at the watershed scale reveals interesting results and relationships not previously identified with statewide estimates. This additional information will help target outreach efforts to topics and audiences where best opportunities for innovation and improved implementation exist.

Recommendations for targeted outreach at the watershed scale include the guidelines with lower implementation levels mentioned above, as well as a variety of guidelines where opportunities exist within the specific conditions and operational cultures of localized watersheds. Several examples are offered where targeted outreach to land managers and loggers in specific watersheds may improve future compliance including:

- In the Mississippi River Headwaters (MH) watershed unit, opportunities to improve compliance exist for minimizing infrastructure (52% compliance) and use of erosion control (EC) on segments (only two of 15 segments needing EC had it installed).
- In the Lake Superior - North and South (SUP) watershed unit, opportunities exist to improve riparian management zone (RMZ) compliance on streams (66%), avoid stream

and wetland crossings (69% compliance), locating landings away from filter strips and waterbodies (81%), and emphasis on use of erosion control on approaches to stream and wetland crossings. Additional emphasis on avoiding excessive rutting, especially in wetland crossings (22 rutted non-open water wetland crossings were observed) is also needed in this watershed unit.

- In the Rum River (RR) watershed unit, opportunities exist for improvement in RMZ management (67% compliant), placement of landings in wetlands or filter strips where an upland location was available (81% compliance), and for avoidance of unnecessary stream and wetland crossings (41% compliant).
- Key opportunities for improvement in the Mississippi River - Grand Rapids (MGR) watershed unit are related to retention of leave trees (only 77% of acres sampled were compliant), retention of larger trees, reducing rutting on-site, implementation of erosion control on water quality segments (only two of 15 long slopes had erosion control installed), RMZ management (76% total compliance), and avoidance of wetland crossings (28% of observed crossings were avoidable).
- Opportunities for improvement in the Vermilion River and Rainy River - Headwaters (VRR) watershed unit include use of erosion control on approaches and water quality segments (73% compliant) and retention of dominant or codominant trees. VRR also had the lowest average on site infrastructure compliance (46%), with the highest average road acres. Outreach focus should be placed on determining when erosion control is needed, as this unit had the highest proportion of sites where erosion control related to water quality was needed and not installed.
- Opportunities for improvement in the Red Lake, Clearwater River, and Wild Rice River (RLCW) watershed unit include placement of landings away from wetlands and filter strips (81% compliance), RMZ management (67%compliance), and avoidance of excessive rutting (49% of wetland crossings were rutted, with 45 total rutted features observed). Outreach addressing the need and standards for RMZ implementation, wetland identification, the importance of avoiding unnecessary crossings, and methods for reducing rutting may improve awareness and implementation of these guidelines.

Additional opportunities for improved implementation at the watershed scale are noted throughout this report. Recommendations include general introductory training for new foresters and loggers, outreach to stakeholders to increase awareness and implementation of revised (2012) guidelines, targeted training related to wetland identification to aid in avoidance of wetland crossings, and identification of situations where water diversion and erosion control practices need to be implemented. Continuing education programs, such as Minnesota Logger Education Program and the Sustainable Forestry Education Cooperative, are encouraged to continue their efforts related to these recommendations, and work to develop new educational opportunities to address the specific topics identified above.

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Introduction

This report is an update to the Minnesota Forest Resources Council (MFRC) and forest management stakeholders on the implementation of sustainable forest management practices as required by the Sustainable Forest Resources Act (SFRA). The MFRC was established under the SFRA to resolve important forestry policy issues through collaboration among a broad set of forest stakeholders. The SFRA requires the MFRC to develop and periodically revise voluntary guidelines for use on public and private forestland in Minnesota to minimize negative impacts of timber harvest and other forest management activities. This report summarizes the results of monitoring for the implementation of these guidelines.

The timber harvest and forest management guidelines (FMGs) are a set of recommended voluntary practices designed to mitigate harvest-related impacts on water quality, wildlife, soil productivity, cultural resources, biodiversity, visual quality, and other forest resources. These guidelines were initially published in 1999 in the guidebook *Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers* (MFRC 1999). The guidelines have been revised twice since their inception, and new guidelines related to biomass harvesting were added in 2007. Substantial changes in recommendations related to riparian management zones (RMZs), allowable infrastructure, leave trees, and others, were made in the most recent revision (MFRC 2012). Most recently, a subset of the guidelines commonly used during timber harvesting were published in a condensed, user-friendly pocket field guide for use in operational settings.

The SFRA (89A.07, subd. 2.) requires the Minnesota Department of Natural Resources (DNR) to monitor implementation of FMGs on public and private forestlands. The DNR has monitored guideline implementation at over 1,300 harvest sites since 2000 and has published ten reports summarizing the findings through 2018. For those reports, monitoring sites were randomly selected from all harvest sites and findings were summarized to estimate statewide implementation levels. In 2013, the program was modified by 1) focusing harvest site monitoring at the eight digit hydrologic unit code (HUC-8) watershed scale, and 2) incorporating forest disturbance estimates into the assessment, recognizing that local disturbance patterns influence interpretation of implementation estimates. The overall objective of this watershed approach is to use the new assessment to conduct more targeted and effective education and outreach for improved FMG implementation.

The MFRC is currently conducting an in-depth review of past implementation levels and FMG effectiveness to assess if forest resources are being protected. A similar review (Slesak 2014) generally concluded that forest resources were being protected, but several topics related to water quality, soil productivity, and wildlife were identified for further assessment and focus. Recent reports on FMG implementation serve an important role informing the current review effort. This report summarizes the monitoring data for 181 harvest sites in 11 HUC-8 watersheds that were monitored during 2020-21, with emphasis on key topics under MFRC review. Statewide estimates calculated from the mean among watersheds are also presented for comparison to previous years and for application to statewide policy development.

Methods

This section outlines the forest cover change detection, site selection, and monitoring data collection methods for monitoring the implementation of forest management guidelines.

Watershed Sample Units

Starting in 2014, the guideline monitoring program (GMP) restructured monitoring efforts to focus on the US Geological Survey defined HUC-8 watershed scale. Sites monitored in 2020 and 2021 were selected from forest cover change detected within six watershed sample units, with each unit consisting of either a single watershed or a cluster of similar watersheds. Attempts were made to select watersheds that were concurrently being evaluated in the Minnesota Pollution Control Agency (MPCA) watershed Restoration and Protection Plan (WRAP) process. Where appropriate, results have been reported by watershed sample unit. Where no substantial difference in implementation data is observed, results may be presented in statewide summaries. The Appendix provides a series of in-depth maps and statistics related to each of the six watershed sample units.

Throughout this document, watershed sample units will be abbreviated as follows: Mississippi River – Headwaters (MH); Lake Superior – North and South (SUP); Rum River (RR); Mississippi River – Grand Rapids (MGR); Vermillion River and Rainy River – Headwaters (VRR); and Red Lake, Red Lake River, Clearwater, and Wild Rice River (RLCW) watersheds.

Forest Cover Change Detection

Forest cover change detection was performed to 1) identify recent harvest sites for field monitoring (Figure 1), and 2) provide overall estimates of forest disturbance by major watershed to provide additional context for field monitoring findings. For monitoring years 2020 and 2021, DNR Forestry Resource Assessment (RA) staff detected forest cover change within all HUC-8 watersheds with greater than 20% forest cover, as determined by national land cover data (NLCD 2019), using Landsat 8 satellite images from summer 2018 – summer 2020. Sites monitored in these units had timber harvest activity between summer 2019 and summer 2020. For the six watershed sample units, RA image analysts visually inspected a sample of detected forest change to refine the final list of monitoring sites and modify the site boundaries as needed. In addition,RA staff provided ownership and contact information for a selection of sites (site selection procedure is described in more detail below).

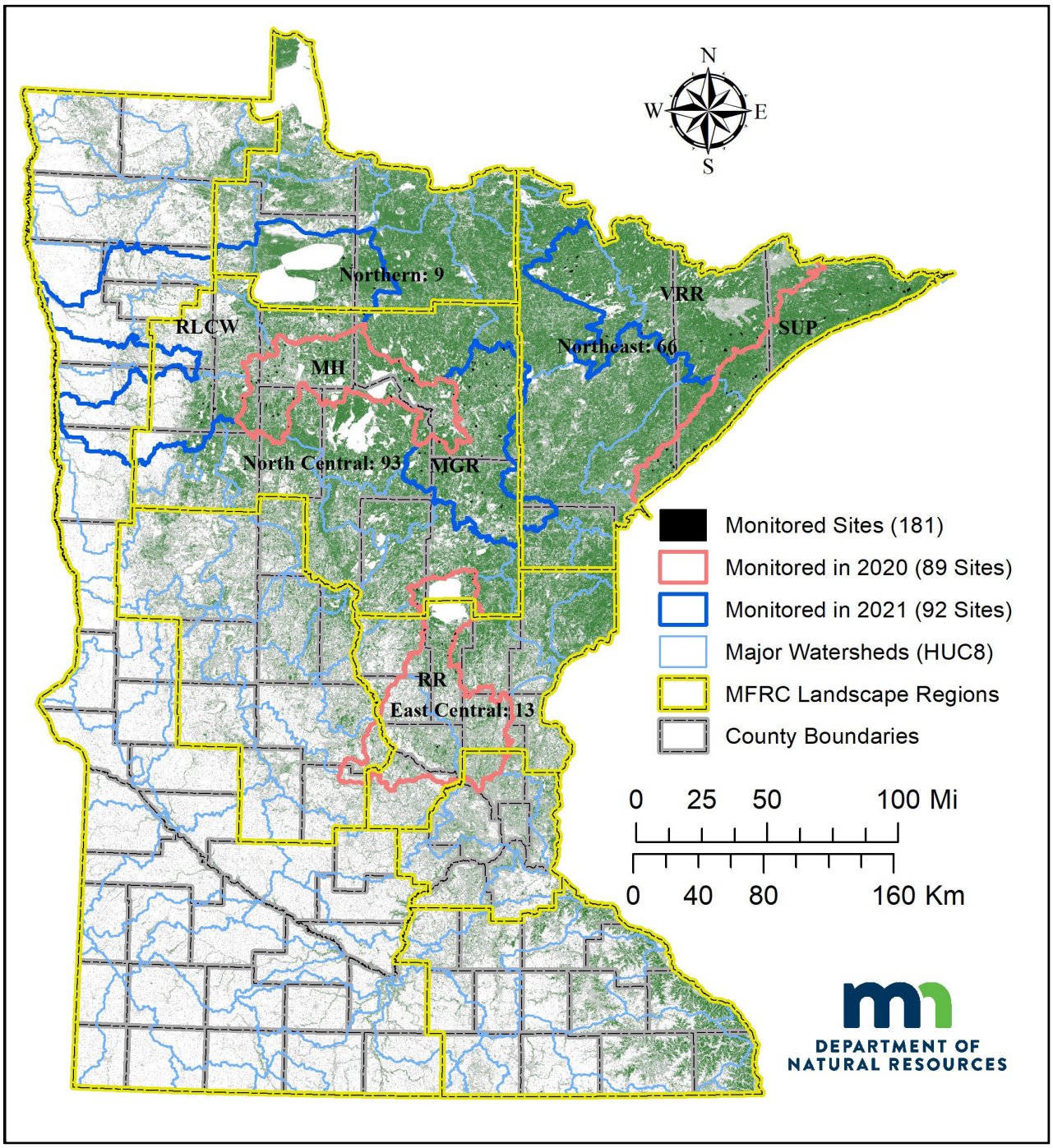


Figure 1. Watersheds where guideline implementation monitoring occurred in 2020 and 2021, and the relative number of sites per MRFC Landscape Region.

Site Selection

For both monitoring years, a subset of detected forest cover change site (and confirmed as harvest sites) were selected for monitoring. Within each watershed unit, monitoring sites were selected with effort to represent the relative proportion of harvest activity by ownership.

Monitoring sites were selected from all forest ownerships. For purposes of this report, the ownerships have been grouped in the following categories:

- State: all lands owned by the state;
- County: all lands owned or managed by a county;
- Federal: all lands owned by the U.S. Forest Service, Park Service, Fish and Wildlife Service, or Corps of Engineers;
- Forest Industry and Corporate: all lands owned by forest industry or corporations;
- Non-industrial Private Forests (NIPF): all privately owned non-industry or corporate lands and tribal lands.

Landowner and/or manager contact was attempted for a large sample of potential monitoring sites (>250 sites) to verify that harvest occurred within target dates, verify that harvest was completed, and secure permission to access the site. Final monitoring sites were selected from this initial pool. Alternate sites were selected to account for instances where sites had to be dropped for unanticipated reasons. A breakdown of site ownership per watershed unit is in Table 1 and site distribution across the seven MFRC landscapes is shown in Figure 1.

Table 1: Monitored watershed unit and number of monitored sites per ownership category.

Watershed Unit	County	Federal	Forest Industry & Corporate	State	NIPF & Tribal	Total
MH	15	6	2	7	3	33
SUP	10	9	0	9	5	33
RR	8	0	0	10	5	23
MGR	9	2	7	11	5	34
VRR	5	22	0	4	2	33
RLCW	7	0	0	8	10	25
Total	54	39	9	49	30	181

Monitoring Data Collection

For both field years represented in this report, DNR-GMP staff used monitoring protocols identical to those described in previous monitoring reports (Rossman, 2011). Field equipment and software were updated to use global positioning system (GPS) enabled Mesa 3 tablets running ArcGIS Collector and Survey123. All field data were uploaded to MNDNR Portal and immediately backed up to an online spatial database engine (SDE) database following field observation. Prior to field monitoring, GMP staff contacted agency, industry, NIPF, and tribal land managers to gather critical background information on the “pre-site data questionnaire” including information about timber harvest planning, harvest practices, season of harvest, and various guideline implementation strategies. The pre-site form provides the opportunity for landowners and managers to relate critical information on how guidelines were implemented on a site. Without this information, GMP staff and field contractors may not be aware of specific reasoning or strategies for guideline implementation. Future program goals include interviewing loggers who conducted harvests on NIPF sites because they may be more aware of guideline implementation strategies than the landowner.

For field monitoring, a contract selected by competitive bid was administered to conduct the work. Bidding contractors were required to provide one or more teams of at least two people each, who collectively met several criteria including expertise and educational background in forestry, soil science, water resources science (including wetland delineation), and GIS and/or remote sensing skills. Contractors were also required to complete calibration training with GMP staff prior to the start of field monitoring. On-site field monitoring was conducted between May and October in both 2020 and 2021.

Monitoring contractors collected detailed information while on-site and delineated spatial features utilizing field observations, air photos, and site documentation. Data collection generally involved a ground survey of the entire site, with detailed measurements recorded for key features including leave trees and clumps, roads, landings, RMZs, filter strips, surface water and wetlands, crossings, and others. On-site features and observations were entered into Collector and Survey123 for upload and later analysis.

Quality Control

Both in-office and in-field review of site data was conducted by GMP staff on approximately 20% of monitoring sites to evaluate consistency and compliance with monitoring protocols. This process confirmed that data were being properly collected and provided useful insight for determining whether monitoring forms and field procedures needed modification. Where appropriate, changes were made to data based on quality control findings.

Results

Data referenced from previous monitoring reports may be found in Dahlman and Phillips (2004), Dahlman (2008), Dahlman and Rossman (2010), Rossman 2012, and Wilson and Slesak 2020. See References on page 46.

Land and Water Characteristics by Watershed

The Appendix contains a wealth of information related to the characteristics of the six watershed sample units monitored for this report. Watershed characteristics such as frequency and types of streams and wetlands, lakes, developed acreage, and percent forest ultimately relate to the number of harvest sites triggering the need for specific BMPs or guidelines such as RMZs, filter strips, and erosion control on crossings, etc. The Appendix to this report contains detailed maps and resource summaries related to many of these important watershed characteristics.

Forest cover (including forested wetlands) varied considerably between watershed units from a high of 86% in SUP to a low of 26% in RR. Not surprisingly, RR and RLCW had the highest percentages of crop/pasture or urban/open/barren lands at 43% and 36%, respectively, compared to 3.2% in SUP and 1.5% in VRR. These land cover types have been shown to have greater water quality impacts relative to forested land use, and both the RR and RLCW watersheds may be at higher risk of water quality degradation for this reason. In terms of

water-related features, the MH and VRR units have the highest percent cover of lakes and ponds (16.5% and 24.4%, respectively). The SUP and VRR units have the longest total length of rivers and streams (3224 and 4203 miles, respectively) and the highest proportion of trout lakes/ponds and trout rivers/streams). Given the high percentage of open water features and high percent forest cover in these watersheds, there is a higher chance of forest disturbances occurring near water features and presumably more RMZs. Conversely, the MGR unit has one of the lowest percent cover of lakes and ponds (5.6%) and is one of the units with the shortest total length of rivers and streams (2055 miles). Given the high percent forest cover and the low amount of open water features in MGR, it is likely that most disturbances will be relatively further away from water features. The watershed units with the highest percent cover of emergent and open water wetlands are the RR and RLCW units (13.2% and 11.9%, respectively), where the units with the lowest percent cover are SUP and VRR (0.9% and 2.7%, respectively). See the Appendix for detailed information related to land and water cover.

Forest cover change detection (for the purposes of site selection) was done between summer 2018 and summer 2019 in the MH, SUP, and RR watershed units, and between summer 2019 – summer 2020 in the MGR, VRR, and RLCW watershed units. Statewide change detection was compiled for the period from 1975-2020, and relevant periods were used to identify potential recent harvests for monitoring. Disturbance estimates for watershed units described here and in Table 2 are presented as three-year annual averages for comparison purposes.

VRR had relatively high forest disturbance compared to the SUP and RR units during the same detection period. Of all the watershed units, the VRR had the highest number of disturbed sites, largest total acreage of disturbance, and one of the highest percentages of the watershed area disturbed, though the average disturbance size was small (11.6 acres). The RR unit also had a small mean disturbance size, but the overall amount of forest disturbance was much lower and was the lowest of all the watershed units, which is expected with a lower percent forest cover in the watershed. The SUP and MGR watershed units also had a high number of sites and acreage disturbed. MGR had the largest percent of the watershed area disturbed (1.27%). The watershed units with the largest average disturbance size are MGR and SUP (13.3 acres and 15.4 acres, respectively).

Table 2. Annual forest cover disturbance statistics by watershed.

Watershed Unit	Number of Detected Forest Disturbances	Mean disturbance Area (ac)	Standard Deviation of Area (ac)	Total Area (ac)	Disturbed Percent of Forest	Monitored Percent of Disturbances
MH*	505	11.4	15.8	5,754.5	0.72%	6.5%
SUP*	384	15.4	25.1	5,903.8	0.48%	8.6%
RR*	173	9.4	13.7	1,630.6	0.36%	13.3%
MGR*	1,273	13.3	24.4	16,876.2	1.72%	2.7%
VRR*	2,168	11.6	21.2	25,176.7	1.16.%	1.5%
RLCW*	1,369	11.2	18.9	15,392.5	1.17%	1.8%

*Number of detected disturbances, total area, disturbed percent of forest, and monitored percent of disturbances are presented as an annual average base on a three-year window of change detection.

Additional analyses have been done to summarize how close/far forest cover disturbances are from a water feature (ex., river/stream, lake/pond, open water wetland). The shortest distance between boundaries of a forest disturbance area and the nearest waterbody was calculated by using the "Near Tool" in ArcGIS. When a waterbody occurs within or touching the boundary of a disturbance feature, the distance between them is zero.

The watershed unit that has the highest percent of waterbodies within or nearest to disturbance features is the RR unit, where 36% of the disturbances have a water feature that touches or intersects the boundary of a disturbance and 46% of all RR disturbances are within 160 feet of a waterbody (the majority of which are rivers or streams). As expected, based on the land cover characteristics described previously, the units with the second highest percent of disturbances nearest water features are SUP and VRR (32% and 31%, respectively). In the SUP unit, 52% of disturbances were within 160 feet of a waterbody. For VRR, 47% of disturbances were within 160 feet of a waterbody. The MH watershed unit had the fewest disturbances near water features, where only 16% of the disturbances have a water feature that touches or intersects the boundary and more that 63% of the disturbances are greater than 640 feet away from a water feature. Histograms of these proximity analyses per watershed unit can be found in the Appendix.

Monitoring Site Characteristics

Monitoring Site Size

Table 3 reports statistics on monitoring site size by watershed unit. Mean site area of 80.3 acres is much larger than that reported in 2015 (37 acres), likely due to the inclusion of many larger harvest sites in the sample (maximum harvest area was 505 acres). There are clear differences in mean harvest size among the watershed units, but harvests were larger in general for this sample period. This observation correlates well with landscape-scale recommendations aimed at producing larger blocks of habitat in the future forest. Although not a guideline, site size may influence site infrastructure and acreage of leave tree clumps.

Table 3. Monitoring site size by watershed sample unit.

Watershed Unit	Number of Sites	Min Area (ac)	Max Area (ac)	Mean Area (ac)	Standard Deviation of Area (ac)	Total Area (ac)
MH	33	19.3	505	80.3	86.6	2,651
SUP	33	20.7	416	112.1	86.4	3,701
RR	23	10.0	120	43.3	31.3	995
MGR	34	22.9	205	79.2	46.9	2,694
VRR	33	20.0	364	84.5	70.9	2,789
RLCW	25	15.8	237	68.2	55.1	1,706
Total	181	10.0	505	80.3	69.7	14,536

Type and Distribution of Waterbodies

The types and numbers of waterbodies or wetlands associated with the monitoring sites are shown in Table 4. The majority of non-open water wetland (NOWW) types were located on-site, while most open water wetlands (OWW) and streams were located adjacent to harvest sites, which may indicate that most harvests are designed to go around surface water features rather than containing them within the site. Over 92% of all monitoring sites had at least one waterbody or wetland on, adjacent, or along the logging road accessing the site.
NOWW were more common than any other waterbody or wetland type, accounting for 85% of the total.

Table 4. Number of waterbodies by type and watershed sample unit.

Waterbody Type	MH	SUP	RR	MGR	VRR	RLCW	Total
NOWW*	90	135	128	167	89	109	718
Intermittent Streams	-	12	-	2	1	1	16
Perennial Streams – Non-trout	4	13	3	7	6	6	39
Perennial Streams - Trout	-	21	-	1	3	-	25
OWW	2	7	8	9	3	5	34
Lakes	1	-	2	6	2	3	14
Total Waterbodies (#)	97	188	141	192	104	124	846
Sites with Waterbodies (#)	27	32	21	34	32	21	159
Sites with No Waterbodies (#)	6	1	2	-	1	4	14

*Includes mineral soil wetlands, shallow peat wetlands, seeps and springs, beaver ponds, seasonal ponds, wetlands, or waterbodies where just a filter strip is recommended.

Harvest Methods and Planning

The percent of sites that were clear-cut remains similar to past reports at ~91%. Other methods reported include thinning, seed tree, single and group selection, and shelterwood. Some sites utilized mixed harvest methods. Almost all clear cuts included some reserve or leave trees on or adjacent to the clear cut.

Season of Harvest

As in past reports, most sites (56%) conducted all or a significant portion of the harvest (75% or more) during winter season (December 16 to March 15). MGR had the lowest average percentage of winter harvest (77%), while VRR had the highest proportion of site area harvested during the winter (93%). For the other watershed units, winter harvest accounted for 84% to 88% of total harvest area.

Guideline Version Used

For this reporting period, all sites monitored were assumed to have used the 2012 revised guidelines for FMG implementation standards.

Pre-harvest Planning

The FMGs recommend the development of written plans for all forest management activities, including timber harvest. One of the most effective tools for communicating the details of a harvest plan is a site map identifying the location of critical site features. NIPF landowners reported that site maps were developed for only 43.5% of the sites, which is slightly higher than in past reports. Site maps were developed for 99.3% of federal, state, county and forest industry sites. Only one county site did not have a site map developed.

Approximately 62% of NIPF sites indicated that there was a general forest management plan for their property written by a forestry consultant or natural resource professional, and most of these also had a written timber harvest plan for the site. Of the NIPF sites without written plans, four indicated an oral harvest plan was developed by the logger through discussion with the landowner, and six sites indicated no plan was developed. This emphasizes that for many NIPF harvests, the logging professional is key to informing landowners about site-level guidelines and is also the implementer of those guidelines on the site. Targeted outreach to loggers in watersheds with high NIPF harvest activity would be an effective approach to increase implementation of site-level guidelines.

Guideline Implementation Results

Visual Quality

After the development of visual quality BMPs in 1995, visual sensitivity classification maps were developed for the 16 northern counties with land departments and can be found at http://www.dnr.state.mn.us/forestry/visual_sensitivity/index.html. These maps identify features such as roads, rivers, lakes, or recreational trails that are rated as "most," "moderately," or "less," visually sensitive. Visual quality guideline implementation was based on these ratings. Note that the USFS utilizes an existing internal visual quality sensitivity rating that may be different.

Monitoring contractors rated sites for visual quality when components of a harvest site could be viewed from a location frequented by the public including roads, trails, lakes, navigable streams, or campgrounds. Visual quality guidelines were evaluated on 98 monitoring sites located within the 16 counties with established visual sensitivity ratings. For these 98 sites, 81 sites were on state, county, federal, or industry ownerships. Of these professionally managed sites 88% indicated the correct rating for the site.

About two-thirds (122) of sites monitored had one or more visually sensitive features (vistas), and visual quality guidelines were met for ~66% of these features. Common reasons for not meeting the guidelines were related to the apparent harvest size exceeding guideline recommendations, slash piles being visible from vistas, or landings located within the right of way of roads or trails. Multiple methods were used to limit apparent harvest size including placement of leave tree clumps, creating narrow opening into the sale area, and designing natural shaped harvests.

Endangered, Threatened and Special Concern Species

FMGs recommend checking for the presence of endangered, threatened, or special concern species (ETS), sensitive communities, or sensitive sites on or near the site prior to the initiation of management activities and that appropriate actions are taken to protect known occurrences. Self-reported checking for ETS during the planning process was high (99%) for agency and industry lands. Checking for the presence of ETS species was self-reported for only 25% of NIPF lands. For all non-NIPF respondents, two indicated that an ETS species was known to occur on the monitoring site based on review of various sources. For federal, state, county, and industry sites, appropriate management actions were taken to protect the ETS in 89% of cases.

Guideline monitoring program staff independently queried if monitoring sites had ETS species (and other special concern sites) present using the DNR's Natural Heritage Information System (NHIS). The NHIS is a collection of databases that provides information on Minnesota's rare plants, animals, native plant communities, and other rare features. This query identified 18 monitoring sites having a known ETS species on or adjacent (within 660 feet) to the site. The NHIS identified three sites with known special concern species on the sites. For these three

sites, managers had indicated checking appropriate sources in the questionnaire, but failed to correctly identify the known species listed in the NHIS. For 18 sites identified as having known ETS species adjacent to the site, 11 indicated checking appropriate sources and 7 of these failed to identify any known ETS species identified in the NHIS query. One site correctly identified an endangered species (*Botrychium lanceolatum ssp. angustisegmentum,* Narrow Triangle Moonwort) occurring on or adjacent to the site. Twenty-one landowners (all but one were NIPF) reported not knowing if ETS were present, but none of these sites came up on our independent search of NHIS. Three sites reported personal knowledge or the discovery of ETS species.

The reasons for disparity between sites that indicated checking appropriate sources for known ETS species, and the ability to correctly list species identified in the GMP query of NHIS database is unknown. DNR staff that manages the NHIS database indicated that this database is continually being updated, and there may be a time lag between species identification in the field and entry into the database. Because of this, staff recommend a second review of the NHIS database just prior to activity beginning if it has been more than one year since the initial review. Due to frequent updating in recent years, comparison of reported findings by land managers and recent queries by GMP staff may be inappropriate for the purposes of estimating guideline implementation.

The NHIS contains a wealth of information for landowners who utilize it. Outreach to NIPF landowners and loggers is recommended to improve use of the NHIS and implementation of related guidelines. A more publicly accessible version of NHIS providing simple presence / absence information for the broad class of ETS species would help in making these checks easier to accomplish for stewards not directly connected to the DNR Natural Heritage Program. Simply knowing that an ETS is present in the vicinity of a harvest would go a long way towards justifying the additional effort involved with contacting Natural Heritage staff for additional information.

Wetlands and Waterbodies

A major focus of the FMGs is protecting wetlands and waterbodies, including NOWW, OWW, perennial and intermittent streams, lakes, seasonal ponds, and seeps and springs. The filter strip and RMZ guidelines are the primary tools for protecting wetlands and waterbodies by defining specified areas adjacent to a wetland or waterbody where management activities are to be less intrusive than in the general harvest area.

Filter Strips

The function of a filter strip adjacent to a waterbody is to trap and filter out suspended sediment, and chemicals attached to sediment, before it reaches the surface water. The guidelines recommend establishment of filter strips adjacent to all water features. The recommended width of a filter strip is 50 feet with an additional 2 feet for each 1% increase in slope over 10%, to a maximum of 150 feet. Harvesting and other forest management activities

are permitted in a filter strip if the integrity of the filter strip is maintained, and mineral soil exposure is kept to a minimum (MFRC 2012).

During field monitoring, detailed filter strip information is recorded for only those filter strips where contractors observed disturbance(s) that potentially resulted in a compromised filter strip. All other filter strips are counted and labeled as meeting guideline recommendations. Not all filter strips that trigger full data collection are determined to be "non-compliant" with the FMGs. To be effective, soil disturbance should be minimized within a filter strip. The guidelines recommend limiting soil disturbance to less than 5% dispersed (not concentrated) soil exposure throughout the filter strip.

Of 867 total filter strips observed, 733 (85%) were adjacent to NOWW, 95 adjacent to streams, and 39 adjacent to OWW. Detailed filter strip data were recorded for 128 filter strips, 106 of which had no soil exposure recorded despite having roads, skid trails or landings within filter strips. A total of 32 filter strips had greater than 5% soil exposure, with 21 of these caused by roads that existed prior to timber harvest activity. However, only three of the 32 filter strips had observed erosion occurring due to newly constructed roads. Nine filter strips had observed sediment reaching a wetland (3,670 cubic feet) (Table 5). Future training efforts should include implementation of water diversion or erosion control on all roads, whether new or existing. Landings were found in 11 of the filter strips, six of which had greater than 5% exposed soil ranging from 6-50% exposed. None of the seven filter strips with skid trails or the 11 filter strips with landings had erosion occurring. Continued emphasis should be placed on avoiding location of skid trails and landings within filter strips where practical.

Table 5. Soil exposure, erosion, and sediment reaching a waterbody observed in filter strips with and without roads, skid trails, or landings.

Exposure Category	Total Filter Strips	Filter Strips without Roads, Skid Trails, or	Filter Strips with Roads, Skid Trails, or Landings	Filter Strips with Erosion	Filter Strips with Sediment Reaching a Waterbody
No Soil Exposure	843	739	104	0	0
<5% Dispersed	2	0	2	1	1
<5% Concentrated	9	5	4	2	4
≥5% Dispersed	5	0	5	1	0
≥5% Concentrated	8	3	5	6	4
Total	867	747	120	10	9

Despite the existence/placement of roads, skid trails, and landings in 120 filter strips, the guideline to limit disturbance to <5% dispersed was not met on only 32 filter strips, resulting in a 96% total compliance rate (Table 6), where the VRR watershed unit had 100% compliance (zero filter strips with soil exposure and zero new roads). The MH, SUP, and RLCW watershed units had the lowest compliance rates at 95% (a combined total of 22 filter strips had soil exposure, and 72 had roads, skid trails, or landings located within the filter strip).

Table 6. Soil exposure, erosion, sediment reaching a waterbody, and overall compliance rates of filter strips per watershed unit.

WSU	Total Filter Strips	Filter Strips with ≥5% Soil Exposure	Filter Strips with Roads, Skid Trails, or Landings with No Soil Exposure	Filter Strips with Existing Roads	Filter Strips with Erosion	Filter Strips with Sediment Reaching a Waterbody	Overall Compliance*
MH	97	5	5	8	0	0	95%
SUP	189	10	7	19	3	5	95%
RR	145	3	10	5	2	3	98%
MGR	200	7	7	22	0	0	96%
VRR	108	0	12	10	0	0	100%
RLCW	128	7	10	22	5	1	95%
Total	867	32	51	86	10	9	96%

* Non-compliance is based on filter strips having ≥5% exposed soil.

Riparian Management Zones

Riparian area is defined as the area of land and water forming a transition from aquatic to terrestrial ecosystems along streams, lakes, and open water wetlands. RMZ guideline recommendations were modified in 2012 resulting in generally wider, but simplified RMZ recommendations. Current width and basal area recommendations for RMZs are based on type of waterbody and size of waterbody. In this reporting period, land managers should have used the 2012 revised RMZ guidelines on all relevant sites. RMZ compliance evaluation for these sites was based on the revised standards. For each RMZ, data were collected from three representative cross sections to characterize the composition of the full recommended RMZ width based on type and size of waterbody. Basal area (BA) within the RMZ was determined using a variable plot with 10 factor prism. Linear distances and BA were recorded for:

- Non-forest (sedge, brush, and scattered trees with a BA less than 25 ft^2/acre)
- Undisturbed forest (no apparent harvest with BA greater than 25 ft^2/acre)
- Partially harvested forest (harvest retained at least 25 ft^2/acre BA)
- Clear-cut (harvest retained less than 25 ft^2/acre BA) for the rest of the recommended RMZ width for the specific type and size of waterbody

Compliance was based on the combined width of the non-forest, undisturbed forest, and partially harvested forest from the water's edge landward. Basal area compliance was evaluated for the partially harvested portion based on the minimum BA recommended for the size and type (trout or non-trout) of water body (60 ft^2/acre). Some RMZs had significant areas of non-forest vegetation (i.e., grass, sedge, brush, or shrubs) adjacent to water, while others were composed entirely of forest.

A total of 108 RMZs were identified on or adjacent to 62 sites monitored in 2020 and 2021

(Table 7). For this report, authors considered RMZs meeting 95% or more of recommendation to be within our margin of error and compliant. Overall, 79 of 108 (73%) RMZs met guideline recommendations for width and basal area of forest retention. Additionally, 16 non-compliant RMZs (15%) were managed with 50% or more of the recommended RMZ width and basal area, providing significant environmental benefits. 16 RMZs had partially harvested areas, and only two of these failed to meet guidelines due to insufficient basal area retention.

These results represent a continuing trend of good RMZ guideline implementation. Over half (15) of the RMZs that did not meet guideline recommendations were in the SUP watershed. Of the 29 non-compliant RMZs, 12 were found on county owned sites and 11 were found on NIPF sites. Outreach targeting county and NIPF landowners in the SUP watershed focusing on the benefits of implementing RMZ recommendations for streams and other waterbodies may improve compliance in this watershed.

RMZs provide direct shading to streams and lakes as well as shading to soils and ponded water that result in cooling or maintaining temperatures in runoff and internal drainage that is particularly important for cold water habitats. Compliance on trout waters was 64% for this reporting period; 23 of 36 RMZs fully met recommendations. Only four RMZs adjacent to trout waters failed to meet at least the partial compliance thresholds (Table 7).

Guidelines also recommend retention of coarse woody debris (CWD) (e.g., sound logs at least six feet in length and 12 inches in diameter on the narrow end) within RMZs where partial harvest is occurring. For 16 sites that conducted partial harvest (retained >25 ft^2 BA/acre) within RMZs, all except three retained four or more CWD logs per acre within the RMZ (Avg = 19.5). Retaining CWD within RMZs can sometimes be confused with guidelines that recommend avoiding placement of slash within filter strips. Clear communication in guideline training could contribute to improved implementation.

Table 7. RMZs meeting guideline recommendations by watershed sample unit.

Watershed Unit	Total Sites	Sites with RMZ	Total RMZs (#)	Trout Streams (%)	Non-trout Streams	Lakes & OWW	Total Compliance (%)	Partial Compliance (>50%)
MH	33	4	7	-	100%	100%	100%	-
SUP	33	24	45	62%	68%	-	66%	24%
RR	23	8	10	-	67%	50%	67%	33%
MGR	34	11	20	100%	71%	86%	76%	-
VRR	33	10	13	100%	90%	100%	91%	9%
RLCW	25	5	13	-	67%	50%	67%	22%
Total	181	62	108	68%	75%	79%	73%	17%

Crossings

Crossings are sections of roads or skid trails, and in some instances landings, where equipment crosses a wetland or water body. Logging equipment crossings are the forest management features that have the greatest potential for disturbing wetlands and water bodies.
The types and relative proportion of water bodies and wetlands crossed changed little compared to the previous report. Most crossings (64%) occurred as a result of skid trails, with 92% occurring on NOWW (Table 8). Frozen crossings continue to be the most frequently used type of crossing due to the high frequency of winter harvests.

One of the key guidelines to avoiding impacts to wetlands and water bodies is to avoid crossings whenever practical. Contractors were asked to determine whether a crossing could have been avoided and site objectives still accomplished without unreasonable costs or reduced safety. Contractors reported that 30% of all observed crossings could have been avoided, with most occurring on skid trails (Table 8). Three stream crossings were determined by the contractors as being avoidable, but none of these were rutted. Overall, 32% of crossings identified as avoidable had rutting within the crossing. Situations where crossings were determined to be avoidable include multiple crossings of a wetland were one crossing would suffice, cutting across the tip of a wetland rather than driving around the edge, or crossing small, isolated wetlands that could easily have been avoided. With the exception of MH at 81%, all watersheds range from 61-77% compliance rate for avoidance of crossing wetlands suggesting an overall implementation rate of 70%, a slight drop from the 72% reported for 2014-2015 despite an overall reduction in crossings. Continued and improved avoidance of unnecessary crossings will reduce wetland impacts and improve guideline implementation.

Table 8. Number of crossings by infrastructure component and avoidance potential.

Infrastructure	Crossings (#)	NOWW	Shallow Peat	Dry Wash	Stream	Could Have Been Avoided
Roads	90	81	3	-	6	5
Landings	5	5	-	-	-	1
Skid trails	167	154	2	1	10	73
Total	262	240	5	1	16	79

At the watershed scale, number of crossings per site appears to be unrelated to implementation or ability to avoid crossings. The watershed with the lowest number of observed NOWW on or adjacent to sites (MH) had the highest compliance rate for avoidance of crossings.

The relationship between the number of wetlands on or adjacent to sites and the number of crossings is dependent on both care in avoiding crossings as well as the characteristics of those wetlands themselves. In most cases the number of crossings is much lower than the number of NOWWs observed indicating that many of the observed wetlands were not crossed and thus avoided. This may reflect that small, isolated wetland (such as many in MH) are easier

to avoid than large linear or long narrow wetlands such as found in VRR or SUP. Outreach related to avoiding wetland crossings should consider the characteristics of wetlands and terrain in the targeted watershed to best relate to on-the-ground conditions.

Table 9. Non-open water wetland (NOWW) crossings (CRS) by watershed sample unit.

Watershed Unit	# Sites	# Sites with Crossing	Total # of NOWW Observed	# of NOWW Crossed	Mean # CRS per site (all sites)	# of Avoidable Crossings	# of Crossings Rutted
MH	33	14	90	18	0.55	4	2
SUP	33	23	135	64	1.94	23	22
RR	23	13	128	38	1.65	15	5
MGR	34	17	167	42	1.24	13	13
VRR	33	22	89	40	1.21	10	9
RLCW	25	15	109	38	1.52	14	19
Total	181	104	718	240	1.33	79	70

Figure 2 below is a common example where one of the two crossings was determined to be avoidable. The red line indicates the harvest site boundary, the blue polygon with hash marks indicate wetland boundaries, and inside the red circle the brown line with 'x' underneath the IDs (FID:CRS5451 and FID:CRS5452) indicate crossings.

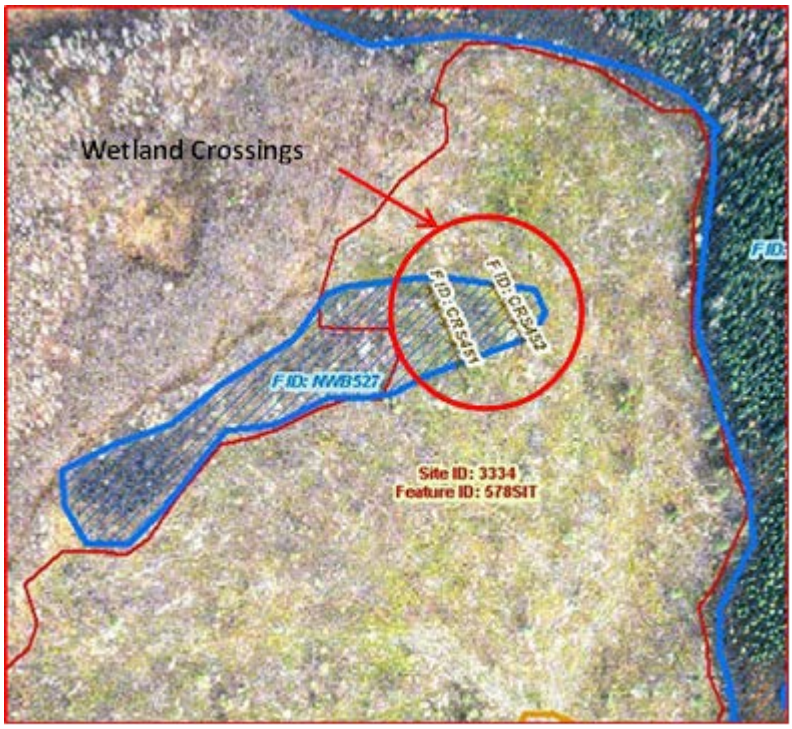


Figure 2. Example of multiple crossings of a wetland.

Rutting on NOWW Crossings

NOWW are the most frequently crossed wetlands during harvesting operations in Minnesota. During this reporting period, 240 NOWW crossings were observed. Rutting occurred on 4.6% of all NOWW crossings (14% of sites). This is down substantially from the 13% reported in the last report. Four of these rutted crossings were due to ATV traffic presumably post-harvest. Of the 33 NOWW crossings that were rutted, four (12%) were identified as having rutting exceeding 50% of the NOWW width. A substantial portion (52%) of the crossings that were rutted occurred on just seven sites. The seven sites with the majority of rutted crossings were harvested primarily during the winter season, possibly indicating a need for adjusted guidelines related to minimizing rutting in response to warming winters. Skid trail crossings accounted for 64% of all crossings and 70% of all rutted crossings. Crossings of NOWW by forest roads accounted for 29% of all rutted crossings.

Rutting in crossings continues to be an opportunity for outreach focused on avoiding crossings and utilization of temporary crossing structures. Avoiding crossings of wetlands where possible would help to reduce the occurrence of rutting simply by reducing vehicle traffic in wetlands. Monitoring contractors indicated that 25 of the 70 rutted crossings (36%) could have been avoided.

Because 70% of rutted crossings occurred on skid trails, the use of slash mats, wood mats or other crossings structures may reduce occurrence of rutting when crossing non-frozen wetlands. For rutted crossings, 39 of 70 occurred on purportedly frozen ground. Slash mats, wood mats, corduroy, or other temporary crossings structures were used on 27 of the 70 rutted crossings, while three rutted crossings were completely unfrozen or did not use any temporary crossing structure that that was apparent. Corduroy, slash mats, and frozen ground prevented rutting on 70% of the crossings where they were used.

The highest percentage of crossings rutted occurred in the RLCW watershed unit (19 of 38). The highest frequency of sites with some rutting on crossings occurred in the SUP watershed unit (22 of 73). Overall, 75% of sites with rutted crossings were harvested predominantly during the winter season. This compares to only 58% of sites with no rutted crossings being harvested in the winter months, a suggestive but not significant difference (p-value = 0.0758, Fisher's Exact Test).

Focusing outreach on techniques to avoid rutting in NOWW crossings such as timing of operations and use of temporary crossings structures may improve future implementation.

Stream Crossings

Guideline implementation at stream crossings is particularly important due to the potential to directly impact stream water quality. During this reporting period, contractors recorded 64 total streams, with 15 crossings occurring on nine sites. Five of these crossings were found on forest roads, with the remaining 10 occurring on skid trails. Three of the 15 crossings were deemed as avoidable, indicating 80% compliance in avoiding stream crossings where possible.

Additional stream crossings may have been avoided through site planning given that 77% of streams were located either off-site (21) or adjacent to (28) harvest sites.

One of the key guidelines related to crossings is implementation of water diversion and erosion control practices on approaches so that runoff and sediment does not move down the approach and into the waterbody. Only three of the 15 stream crossings met guideline recommendations related to erosion control and water diversion practices on approaches to the crossing. All three of these crossings were skid trail crossings. Only one of the stream crossings was observed to have evidence of any sediment (0.1 ft^3) reaching the stream itself.

Most (eight of 15) stream crossings monitored occurred in the SUP watershed unit with four additional stream crossings in the MGR unit, two in the VRR unit, and one in the RLCW unit. The VRR and SUP watershed units appear to have a relatively higher stream density and therefore present the need to cross streams more frequently. Although stream crossing is relatively infrequent overall, outreach focusing on appropriate implementation of water diversion and erosion control practices in watersheds with a high stream density should continue to be a priority.

Approaches and Segments

Recommendations on the use of erosion control have been a primary component of the forest management guidelines related to maintaining water quality. Use of erosion control at areas in close proximity to water resources is important in minimizing sedimentation of wetlands and streams. Approaches are the portion of a skid trail or road immediately leading into a wetland or waterbody, making them a key feature when assessing the use of erosion control because of potential to funnel surface water, sediment, organic debris, and contaminants into the water. Guidelines recommend that water diversion/erosion control (EC) practices be installed as soon as approaches are created and maintained until the location is stabilized.

104 sites had at least one approach to a waterbody identified by contractors. Approximately 90% of all approaches met guideline recommendations. Approaches that did not meet guideline recommendations were observed on 34 sites. Problematic approaches (54) required practices for sediment control, while only 14 of those (26%) had erosion control installed (Table 10).

Generally, erosion control is not needed on approaches that have low slope (<2%), little or no exposed mineral soil, or where natural roughness and/or breaks in terrain negate the need. Although lower than in past reports, the high estimate of approaches not needing EC may reflect good guideline implementation through selection of favorable crossing locations or may be associated with the relatively forgiving operating conditions that occur in the state (ex., winter harvesting, level topography, etc.). The fact that almost half of all approaches needing erosion control occurred in the relatively rugged SUP watershed unit may serve as an indication that additional outreach related to approach and crossing placement is needed for watersheds with more challenging topography.

Over 94% of all approaches were associated with NOWWs. Of 512 approaches to NOWWs, 49

required erosion control practices to meet guideline recommendations. Only 14 of these 49 (31%) had erosion control practices installed, which is higher than previous estimates (20% in 2014-2015). Erosion was frequently observed when practices were needed but not installed, although the actual occurrence of sediment delivery to wetlands and streams was small (Table 10). Utilization of water bars or scattered slash on approaches would reduce potential impacts to wetlands and surface water, but the establishment of vegetation appears to play an even larger role in minimizing erosion (Slesak et al. 2016, McEachran et al. 2018). Regardless, results reinforce the need to emphasize the importance of erosion control practices on approaches to minimize erosion potential, and a need to identify when erosion control practices are needed during training programs for loggers, land managers, and landowners. Targeted outreach on how to identify the need for erosion control would help to increase guideline implementation and reduce the potential for water quality impacts.

Table 10. Erosion control (EC) and use on approaches (APP) for all water features by watershed unit.

WSU	Total Sites	Sites with APP	Total APP (#)	Sites Where EC on APP was Needed	# APP Needing EC	# APP with EC Installed	# APP with Erosion	# APP Sediment Reached Waterbody
MH	33	14	37	0	0	0	0	0
SUP	33	23	148	15	24	11	4	2
RR	23	13	77	3	6	0	1	0
MGR	34	17	113	4	6	0	2	2
VRR	33	22	87	9	12	1	1	1
RLCW	25	15	82	3	6	2	2	0
Total	181	104	544	34	54	14	10	5

In addition to approaches, segments of skid trails and roads near wetlands or surface water also have higher potential to impact water quality compared to other portions of the harvest site. Because of their proximity, these “water quality segments” may impact water quality if erosion control practices are not properly installed. Only a small number of sites (~20%) have water quality segments present, which may indicate good guideline implementation regarding locating roads and skid trails away from wetlands and surface water. However, similar to approaches, those water quality segments that needed erosion control installed generally did not have it and the occurrence of erosion in those situations was common (Table 11). There were no observations made where sediment reached a wetland or water body from a water quality segment, which may be because water quality segments are not a direct conduit to surface water like approaches are. Notably, the VRR watershed unit had the highest percentage of sites with WQ segments present and the lowest percentage with erosion control installed. The MGR watershed unit also had low erosion control implementation and had the greatest number of water quality segments with erosion present. The VRR and MGR watershed units are prime candidates for targeted efforts to improve erosion control use and application. Although there is clearly a need to focus efforts on improving erosion control use in general, the small number of times that sediment reaches a wetland or waterbody from approaches and water quality segments limits water quality impacts associated with timber harvesting.

Table 11. Use of erosion control (EC) and erosion occurrence on skid trail and road segments that have potential to impact water quality (WQ) by watershed unit.

Watershed Unit	Total Sites	Sites with WQ Segments	# WQ Segments	Segments with EC Installed	Segments with Erosion	# Sediment Reached
MH	33	6	15	2	8	0
SUP	33	8	30	15	2	0
RR	23	5	18	14	5	0
MGR	34	5	15	2	9	0
VRR	33	10	27	0	2	0
RLCW	25	3	10	6	1	0
Total	181	37	115	39	27	0

Infrastructure

Equipment traffic can compact and rut soil, damage or remove vegetation whose root systems hold the soil in place, reduce movement of air and water into and through the soil, and redirect surface water flow. These impacts restrict plant root growth, reduce the availability of nutrients and moisture for plant growth, increase the potential for erosion, and can change surface and subsurface hydrology.

One way to minimize impacts of traffic on soil productivity during timber harvest operations is to limit the amount of high traffic area in roads and landings (i.e., infrastructure). Site-level guidelines recommend:

- Sites less than 20 acres should have one acre or less of the harvest site in infrastructure.
- Sites 20-30 acres should have less than 5% of the harvest area in infrastructure.
- Sites greater than 30 acres should have 3% or less of the harvest area in infrastructure.

Monitoring contractors determined total on-site infrastructure by measuring area occupied by landings and roads within the site. The estimated mean infrastructure per site for this report dropped to 2.1% (Figure 3) continuing a sharp decrease in percent of site occupied by infrastructure since the reported high of 4.2% in 2009. While variable, the decrease in percent infrastructure has occurred primarily in landing area and to a lesser degree in road infrastructure. Mean on-site total landing area per site in this reporting period was 1.47 acres. Mean on-site road acreage for this reporting period was 0.65 acres. Fifty-six of the 358 total landings observed were pre-existing landings utilized on 38 sites. Of the 38 sites that utilized pre-existing landings, 23 used only pre-existing, while 15 of them used a mix of old and new. Utilizing existing infrastructure is recommended in the site-level guidelines but is not always possible.

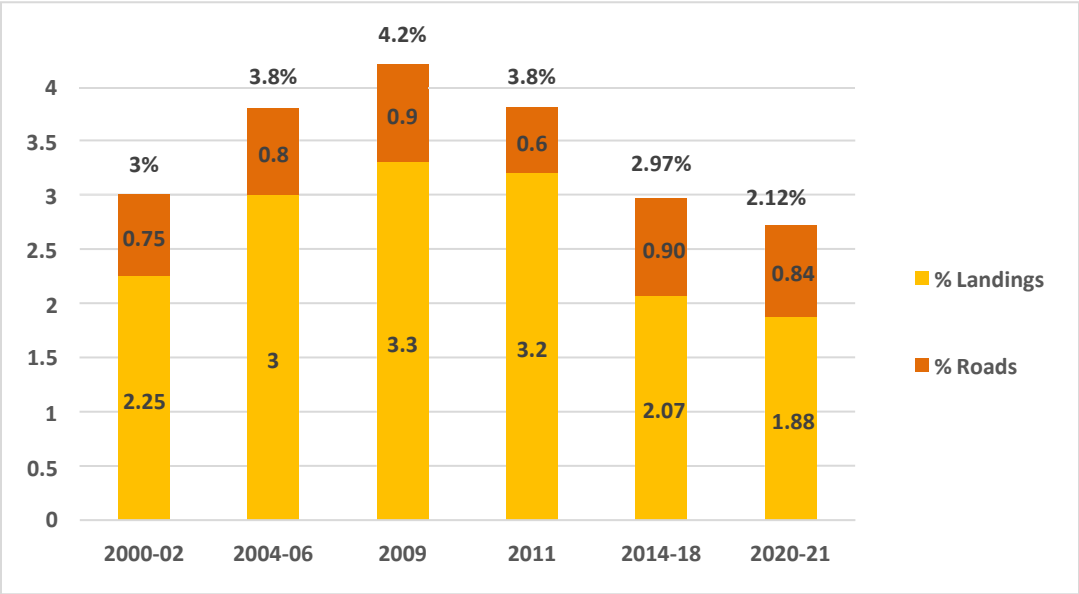


Figure 3. Mean Percent Infrastructure by reporting period.

Overall, 82% of sites monitored in 2014 and 2015 met the recommended infrastructure amounts based on 2012 guidelines. This is substantially higher than past reports and reflects revised guidelines as well as reduced mean infrastructure on monitoring sites. When comparing on-site infrastructure with site size, highest compliance to infrastructure guidelines was achieved on sites <20 acres in size, followed by sites in the 20-30 acre range, and finally sites greater than 30 acres.

At the watershed scale RR had 16 of 28 sites with on-site infrastructure. RR also had the smallest average on site infrastructure as well as the highest percent of sites meeting 2012 guideline recommendations for infrastructure. In contrast, VRR had 24 of 26 sites with on-site infrastructure, and the highest average on site infrastructure and mean site size, with one of the lowest compliance rates for meeting infrastructure guidelines. The VRR watershed is much more remote with less developed access than RR and this may suggest that the level of developed land with existing access may have influenced the need to develop on-site infrastructure for logging operations.

Landing Location

In addition to limiting the area occupied by landings within reasonable safety and operational limits, guidelines recommend locating landings outside of wetlands, filter strips, and RMZs to maintain water quality. Overall, 92 landings (26% of total) were located at least partially in a wetland or filter strip, with most wetlands potentially affected being NOWW. Even in winter operations, wetlands should be avoided for landing locations if possible. Monitoring contractors judged whether suitable upland area was available for alternative location of landings that would still accomplish the site objectives without unreasonable costs or reduced safety. Of those landings located within wetlands and/or filter strips, 51 were judged to have upland locations available for landing, suggesting an overall implementation rate of 86% for

locating landings outside of wetlands and filter strips when possible (Table 13). This result is an improvement over the 80% reported from 2014-2015, and 10% better than the same figure from 2011. When evaluating this information at the site scale, 22% of all sites had at least one landing located in a filter strip or wetland where an alternative upland location was deemed available. Several sites have multiple landings with only one within a wetland or filter strip.

Table 12. Acreage of on-site infrastructure by watershed sample unit.

Watershed Unit	Sites Meeting Infrastructure Guidelines (%)*	Total # Sites with On-site Infrastructure	Mean On-site Infrastructure	Mean On- site Landing Acres	Mean On site Road Acres	Mean Harvest Acres
MH	51.5%	33	2.76	2.13	0.63	80
SUP	66.7%	33	2.61	1.98	0.63	112
RR	73.9%	22	1.26	0.85	0.41	43
MGR	70.6%	34	1.81	1.08	0.73	79
VRR	45.5%	33	2.54	1.71	0.84	85
RLCW	76.0%	25	1.76	1.08	0.68	68
Total	64.0%	180	2.12	1.47	0.65	78

*Compliance is based on 2012 infrastructure guidelines.

Most sites (81%) with landings located in wetlands were harvested during winter operations. Operating on landings under frozen conditions reduces the potential for rutting but may not reduce the risk of depositing landing debris (i.e., slash, culls, and chipping debris) onto frozen wetland surfaces and subsequently into the wetland itself. Additionally, fueling, maintaining equipment or leakage from equipment, increases the potential to place contaminants directly into frozen wetland surfaces. Outreach addressing wetland identification tips and the importance of locating landings away from wetlands and waterbodies may improve awareness and implementation of guidelines in all watersheds.

Table 13. Landing location related to wetlands and filter strips.

Watershed Unit	Total # Sites	Total # Landings	Landing Located in Wetlands or Filter Strips where Upland Available	Sites with a Landing Located in Wetlands or Filter Strips where Upland Available
MH	33	61	4.9%	9.1%
SUP	33	57	19.3%	24.2%
RR	25	27	18.5%	21.7%
MGR	34	63	14.3%	23.5%
VRR	33	93	12.9%	27.3%
RLCW	25	57	19.3%	32.0%
Total	181	358	14.2%	22.1%

Landing Conditions

Landings were generally in good condition. Many landings (44%) were more than 50% vegetated while 10% had no vegetation at the time of monitoring. Although not a specific guideline, re-vegetated landings are less susceptible to erosion. Only 8 landings had evidence of rutting, with total rutting occupying less than 10% of the landing area in all but one case. Only three landings had indication of erosion occurring, but no sediment reaching a wetland or water body in any of those cases.

Most landings (74%) had greater than 10% of the landing covered with organic debris, ranging from logs to wood chips, bark, or sawdust. 37% of landings were greater than 50% covered with organic debris. Guidelines recommend avoiding concentration of organic debris on landings due to the potential to inhibit growth of seedlings and other vegetation is these locations following harvest activities.

Only 3.4% of all landings had evidence of fueling and equipment maintenance activity as evidenced by visible oil/petroleum product stains (oil spots) on the landing. Guidelines recommend keeping equipment in good repair, and that spills up to five gallons be thin spread over the upland part of a site, with spills over five gallons reported to MPCA duty officer for recommended action. Lack of observable evidence of spills on landings suggests high compliance to these guidelines.

Only four landings had logging trash present. Several landing (18) had other trash present,with likely sources listed as locals, parties, people leaving trash, public road users, or a few beer bottles/cans.

Rutting Analysis at the Site Level

The FMGs recommend minimizing rutting on roads, skid trails, and landings, and avoiding rutting in the general harvest area. Rutting occurs when tires or tracks of equipment displace and compact soil and tear the root mat when the soil is not strong enough to support the load applied by the vehicles.

The presence or absence of rutting six inches deep or deeper was recorded for a variety of features (Table 14). For this report, we assessed the cumulative amount of rutting identified on all features of sites including the general harvest area. As in past reports the frequency of rutting was highest in NOWW skid trail crossings, but the highest surface area of rutting occurs when there is rutting identified in skid trails within the general harvest area (not associated with any one feature). This suggests that these sites have soils or soil conditions conducive to rutting (too wet for operations or weak soils).

When evaluated at the site level, rutting is clearly focused on a minority of monitored sites. Even then, sites that had some rutting identified had minor amounts when compared to the entire site. Of the 181 sites monitored, 64 sites had rutting identified somewhere on the site, and two thirds of these (40 sites) had rutting identified at more than one feature type. One site had total area rutted at ~7.5% of the general harvest area, 12 additional sites had rutting estimated at 1-4% of the site, and the remaining rutted sites had no repeated rutting observed in the general harvest area.

Table 14. Rutted sites and features with mean percent of feature rutted.

WSU	Sites	Sites Rutted	Water-body	Crossing	Landing	Skid Trail	Road	Filter Strip	Total Features	Mean % Rutting (SD)
MH	33	3	0	2	1	1	1	0	5	16.9(19)
SUP	33	16	10	22	1	5	4	9	51	10.8(18)
RR	23	4	4	5	1	1	1	1	13	13.9(22)
MGR	34	15	5	13	2	6	8	4	38	16.7(19)
VRR	33	13	6	9	1	6	3	1	26	4.8(4)
RLCW	25	13	10	19	2	7	5	2	45	10.9(16)
Total	181	64	35	70	8	26	22	17	178	12.3(4)

From the watershed perspective, some rutting occurred in all watersheds. The number of sites with rutting ranged from 3 in MH to 16 in SUP.

The MFRC has established no threshold for guidelines related to percent rutting on a site or for specific features. Guidelines recommend avoiding rutting through careful planning related to season of operation and monitoring of day-to-day conditions. Anecdotally, operations on sites with rutting of multiple features, especially in general harvest area, likely occurred because operating conditions were conducive to rutting. In these situations, guidelines recommend changing operations or curtailing operations until conditions improve.

Biomass, Slash Management & Fine Woody Debris Retention

Retaining slash or fine woody debris (FWD) on harvest sites contributes to sustaining soil productivity, and provides habitat for small mammals, amphibians, and other organisms. Guidelines recommend favoring practices that allow for dispersed slash on the site, rather than piling slash, where dispersed slash does not conflict with management objectives or reforestation. For this report period, 152 of 169 sites not utilizing biomass had slash relatively evenly distributed on the site. Twelve sites utilized slash as biomass product. Seven of these sites retained at least 33% of tops and limbs from harvested trees as well as FWD from incidental breakage during harvest operations. The remaining five did not retain the intentional 33% of tops and limbs, but three of these did retain incidental breakage.

Wildlife Habitat

Coarse Woody Debris

Coarse woody debris (CWD) provides important habitat for forest animals and plants. The FMGs recommend creating or retaining two to five bark-on down logs (>6 foot pieces > 12 inches diameter) per acre in the general harvest area and at least four bark-on down logs per acre in riparian areas. General harvest areas met the guideline of two or more “sound” down logs per acre 98% of the time (Table 15). Only three sites did not meet the minimum recommended number of CWD while 22% of sites monitored had 50 or more pieces of CWD per acre. Estimates reported here include large branches as CWD rather than just logs (boles).

Table 15. Number of pieces of CWD in general harvest area of monitoring sites by ranges. Sites in the NS column were not sampled because they were either thinned or uneven-age harvests.

Watershed Unit	NS	0-5	5-20	20-30	30-40	40-50	≥50	Total Sites
MH	4	0	6	9	4	2	8	33
SUP	2	1	5	12	5	3	5	33
RR	4	3	3	7	3	2	1	23
MGR	6	0	5	6	8	2	7	34
VRR	2	0	10	4	1	4	12	33
RLCW	2	1	5	6	4	1	6	25
Total	20	5	34	44	25	14	39	181

Leave Tree Distribution

The FMGs recommend retaining mature, live trees on clear-cut timber harvests to provide vertical structure and habitat for wildlife while harvested stands regenerate. The guidelines provide two options for meeting the leave tree (or green tree retention) recommendations:

- Scattered - retain six or more scattered individual trees greater than 6" DBH per acre in the harvest area (scattered leave trees).
- Leave tree clumps (LTC) - retain at least 5% of a clear-cut harvest area in patches at least ¼ acre.

In both cases, scattered and LTC, leave trees should be at least six inches DBH. Leave tree clumps are most frequently located on site; however, areas adjacent to a harvest may be considered in evaluating leave tree acreage. Adjacent leave tree clumps are typically located between the harvest site and an adjacent RMZ, non-forested wetland, or previously harvested area, and where the leave tree clump is not large enough to be economically manageable by itself. In the 2012 revisions to the site-level guidelines, the MFRC modified the guidelines to include the area managed within RMZs as leave tree clumps. Of the 181 sites monitored, 145 sites were evaluated for implementation of the leave tree guidelines. The remaining 36 sites were completely managed through selective harvest, thinning, seed tree and shelterwood harvests that retain abundant vertical structure and were therefor not evaluated for leave tree guideline compliance.

Overall, there were 163 sites monitored which used an even aged harvest system and did not apply an exception to the leave tree retention guidelines. Of these sites, 146 employed some form of clearcut harvest and were monitored for scattered leave tree retention. Of the 146 sites monitored for implementation of leave tree guidelines, 109 had adequate leave trees to meet recommended guidelines. Additionally, two sites identified silvicultural or safety reasons for not retaining leave trees such as managing dwarf mistletoe (*Arceuthobium pusillum*) in black spruce stands. Considering these sites, the estimated compliance to leave tree retention guidelines was 76%. These statewide results show reduced implementation rates over numbers reported for 2014-2015 (Table 16). Overall, the most common strategy utilized on sites meeting guideline recommendations is now through retention of leave tree clumps and riparian management zones (51%) followed by sites using scattered leave tree retention (42%) or a combination of

LTCs, RMZs, and scattered leave trees. Statewide, a total of 37 sites (24%) did not meet the leave tree retention guidelines. Of these sites, all but four had some leave trees retained, with fifteen of these sites retaining 50% or more of the recommended leave trees by one or both methods demonstrating significant attempt at implementing guidelines. As a state, from 2014-2018, Minnesota averaged 396% of the recommended reserves across 434 sites (weighted mean with respect to site acres). For the 2020-2021 monitoring period, this same statistic averaged 280% across 181 sites.

Table 16. Percent of sites that meet or exceed leave tree guidelines.

Monitoring Year	Number of Sites for Which Guidelines Apply	Sites With ≥6 Scattered Leave Trees / Acre	Sites With ≥ 5% of Site in Leave Tree Clumps (at least ¼ acre)	Sites with ≥ 6 Scattered LTs/ Acre or ≥ 5% of Site in LT Clumps, both, or in combination	Sites Citing Silviculture or Safety Reasons	Total
2000-02	293	49%	31%	61%	-	61%
2004-06	266	41%	13%	47%	-	47%
2009	74	50%	22%	61%	2	61%
2011	71	55%	32%	83%	1	83%
2014-18	373	54%	28%	92%	13	95%
2020-21	146	42%	51%	75%	2	76%

At the watershed scale, rates of implementation ranged from a high of 98% in SUP to a low of 67% in MGR which was substantially below the average (Table 17). A comparison of overall site-level compliance against site acres meeting guidelines and percent net compliance (Table 17) indicates that failure to meet guideline recommendations is more common on smaller sites (p-value = 0.0041, Wilcoxon Rank Sum Test). Also, as indicated above, many sites not fully meeting leave tree retention guidelines do retain a substantial number of leave trees. Considering these results, outreach on leave tree guidelines to the MGR and VRR watersheds targeting smaller harvests would likely increase statewide implementation of leave tree guidelines.

Table 17. Number (%) leave tree compliance by watershed sample unit. Weighted by site acres.

WSU	Total Sites	Sites Evaluated for LTs	Scattered LTs	LTC	Both	Combo	% Site Acres Meeting Guidelines	% Net Compliance (Acres)
MH	33	26	23	13	11	1	79%	86%
SUP	33	30	30	21	21	2	98%	99%
RR	23	12	10	2	2	1	78%	88%
MGR	34	25	23	12	11	1	67%	77%
VRR	33	29	29	12	12	3	71%	88%
RLCW	25	22	22	12	12	1	92%	97%
Total	181	144	137	72	69	9	83%	90%

Leave Tree Clumps

Contractors identified and evaluated 206 LTCs on 81 sites (some of these did not meet the 5% recommendation in guidelines). The average size of a LTC was reported as 1.3 acres – substantially larger than the minimum of 0.25 acres. Since 2004, the percentage of monitored sites utilizing LTCs to satisfy leave tree retention guidelines has increased steadily and is now at 51% (Table 16). Blowdown occurred in 13% of LTCs, but the amount of blowdown in most (>96%) of these clumps was less than 5%. Overall average of blowdown in LTCs is ~2.7%.

Guidelines recommend that a mix of species is desirable for retention as leave trees and that preference should be given to certain species for their longevity, wind firmness, cavity potential and value to wildlife species. Guidelines also recommend that retention of a mix of naturally occurring species is desired, recognizing that it is necessary to work with what is available on a particular site. Table 18 shows the frequency of the most common mature tree species identified in LTCs. Three of the five most frequently occurring species in LTCs are ranked as having excellent or good value to wildlife.

Table 18. Common species identified in LTCs by frequency of occurrence, across all monitored sites.

Species	# of LTCs with Species Listed in 5 Most Frequent	% of LTCs	Rating of Species for Value to Wildlife
Trembling aspen	137	66%	Excellent
Paper birch	135	65%	Fair
Balsam fir	123	59%	Fair
Red maple	93	45%	Good
Black ash	52	25%	Excellent
N. White cedar	33	16%	Good
N. Red oak	32	15%	Excellent
Basswood	27	13%	Excellent
Sugar maple	26	13%	Excellent
White spruce	24	12%	Good
Black Spruce	22	11%	Fair
Norway Pine	22	10%	Good
White Pine	19	9%	Excellent
Burr Oak	16	8%	Excellent
Tamarack	14	7%	Good
Balm of Gilead	11	5%	Excellent
Jack Pine	8	4%	Fair
White ash	7	3%	Excellent
Black cherry	6	3%	Excellent
White oak	6	3%	Excellent
Other	10	5%	N/A

Scattered Leave Tree Characteristics

In addition to documenting presence or absence of scattered leave trees on monitoring sites, species composition of leave trees was also noted as well as additional characteristics including presence of cavity trees (or trees with rot in stem), and presence of dominant/co-dominants as leave trees (indicating that the larger trees were retained).

Scattered leave tree characteristics related to diversity, preference for wildlife suitability (on a scale of 0 to 3), and relative size were estimated from plot data at each site and averaged to determine mean values per watershed unit. A leave tree species preference metric for wildlife ranged from 1.9 to 2.6 with a statewide mean of 2.3 (Table 19), indicating that on average species with good or excellent wildlife characteristics are being retained in all watershed units. Both species richness and presence of large trees retained were variable across watershed units, being greatest in the RR and SUP, intermediate in the MH, MGR, and RLCW, and lowest in the VRR. The MFRC has not established levels of suitability for these metrics, but the guidelines do suggest leaving a mix of species, size classes, and conditions. Given that the MGR unit had the lowest estimates for species preference, species richness, and presence of large trees, this unit is a likely candidate where improvements in implementation of leave tree guidelines could be attained with outreach and education efforts.

Although leave tree characteristics have been included in previous reports (2014-2018), data was also available to calculate these same metrics for a statewide sample conducted in 2011. Compared to the 2014-2018 report, the mean statewide estimates among HUC-8 watersheds for 2020-21 indicated similar retention of leave trees with more favorable characteristics. This maintains the improvement over similar numbers calculated for the 2011 report (ex., sites on average had 30% more large tree coverage than 2011). For all years and watersheds, it appears that utilizing just single species retention is not common, as mean values for species richness were all greater than three. Further interpretation and trends of leave tree characteristics will be possible as more data is collected and reported over time.

Table 19. Scattered leave tree and snag characteristics, where values in parentheses are standard error.

Watershed Unit	Mean Snags/ac	Range	Mean Richness[a]	Range	Mean Preference Index[b]	Range	Mean Proportion Large[c]	Range
MH	3.3(0.2)	0–13.6	4.4 (0.4)	1-8	2.3 (0.2)	0–3.0	0.7 (0.05)	0.1–1.0
SUP	3.6(0.1)	0.7-10.4	5.1 (0.3)	1-8	2.1 (0.2)	0–3.0	0.8 (0.05)	0.2–1.0
RR	2.2(0.2)	0–8.0	4.9 (0.5)	1-10	2.6 (0.2)	0–3.0	0.9 (0.07)	0.3–1.0
MGR	2.4(0.2)	0–8.3	3.4 (0.5)	1-10	1.9 (0.2)	0–3.0	0.7 (0.06)	0–0.9
VRR	2.4(0.3)	0–27.6	3.4 (0.3)	1-7	2.3 (0.2)	0–3.0	0.6 (0.06)	0–1.0
RLCW	2.5(0.1)	0–6.8	4.3 (0.6)	1-9	2.4 (0.2)	0–3.0	0.7 (0.06)	0.1–1.0
Total	2.8(0.08)	0–27.6	4.3 (0.4)	1-10	2.3 (0.1)	0–3.0	0.7 (0.06)	0–1.0
2014-18	2.6(0.05)	0-25	3.7(0.05)	1-6	2.2 (0.04)	0–3.0	0.7 (0.02)	0–1.0

[a] Mean total number of species listed at each site.

[b] Calculated as the mean preference value per tree at each site, with values of 1, 2, and 3 corresponding to the categories “fair”, “good”, and “excellent” shown in Table GG-3 of the FMG Guidebook.

[c] The proportion of measurement plots at a given site where contractors indicated dominant or co-dominant trees were present.

Snag Distribution

Snags provide habitat for wildlife requiring tree cavities, perches, and bark foraging sites. For monitoring purposes, a snag is defined as a dead tree stem standing at least eight feet tall and ≥ 6 inches DBH. Snags were commonly recorded at nearly all harvest sites, ranging from a mean of 2.2 to 3.6 per acre across watersheds monitored this cycle. MFRC guidelines generally recommend leaving all snags possible, but also have recommendations to remove snags for visual quality concerns in some instances. Regardless, the suitability of these estimates is not clear, as guidance has not been provided on what level of snag density is needed to support snag-dependent wildlife populations. Based on the US Forest Service's Forest Inventory and Analysis (FIA) data, mean snag density for timberland in Minnesota is 18 per acre, indicating that these levels are lower than what exists in intact stands, but the implication of this difference is unclear.

Ninety three percent of the sites retained some snags, with 76% retaining at least one snag per acre. Fifty seven percent of sites had two or more snags per acre (Table 19). Out of the 181 sites monitored, 18 indicated that snags were not retained due to specific silvicultural, safety, or visual quality concerns. The remaining sites had no further explanation. Since monitoring was initiated, snag retention has consistently increased.

Conclusions and Recommendations

Overall guideline implementation has remained high in most of the focal areas evaluated in this report. One of the primary measures of success of the site-level guidelines is monitoring results that document continuous improvement in guideline implementation over time, and maintaining that high level once achieved. Results from this report show that statewide implementation of many guidelines is generally high with most reflecting continuous or substantial improvement including those related to managing RMZs, retaining leave trees and snags for wildlife, limiting disturbance in filter strips, minimizing total infrastructure, condition and location of landings (outside of wetlands and filter strips where uplands are available), and retention of FWD on biomass harvest sites.

The use of HUC-8 watersheds to focus monitoring site selection and analysis has proven valuable to the guideline monitoring program by increasing our understanding of variation in guideline implementation levels across the state, and by providing efficiencies and cost savings in the monitoring process such as reduced travel between monitoring sites. The guideline monitoring program is optimistic that additional benefits will be realized through targeted outreach resulting in improved levels of implementation.

Five guideline topics were found to show no improvement or decreasing level of implementation at the statewide scale including wetland crossings that could have been avoided, use of water diversion/erosion control on approaches, occurrence of sites with rutting (primarily on wetland crossings), implementation of visual quality guidelines, and the use of written plans on NIPF lands. Given the critical role that the above guidelines play in mitigating impacts to water quality, wildlife, and soil productivity, landowners, managers, and logging operators should strive to improve implementation to avoid negative impacts on Minnesota's forest resources. Use of erosion control continues to be inadequate and there is a need for concerted effort to implement erosion control practices when potential impacts to water quality are high (e.g., on approaches and segments near wetlands and surface water). The following recommendations are intended to be used as a framework to improve the overall level of guideline implementation.

Implementation of Revised Guidelines

The MFRC published the revised site-level forest management guidelines in January of 2013. Future monitoring will continue to assume that the 2012 revised guidelines are being used on all sites.

Outreach and Education Statewide

Outreach is one of the primary tools available for improving guideline implementation and is essential to successful voluntary implementation. Future outreach should acknowledge successes in guideline implementation as well as focus on areas where opportunity for improved implementation exists. Continued effort to publish and distribute the on-line

introduction to site-level guidelines course will assist with this, but additional in-depth programs targeting specific guidelines should also be considered. Specific topics to consider for focused training could include 1) introduction of site-level guidelines to new land managers and loggers, 2) outreach to increase awareness and encourage implementation of the revised (2012) guidelines and any future revisions, 3) continued training for improved wetland identification, 4) methods of effective water diversion and erosion control practices and how to recognize when these practices are needed, and 5) continued vigilance in minimizing rutting on wetland crossings and the general harvest area. The above topics are recommended for all watershed units. Outreach efforts should include NIPF landowners, loggers who work on NIPF lands and natural resource professionals who advise NIPF landowners.

Summaries and Opportunities for Improvement at the Watershed Scale

The use of watershed scale monitoring introduces a structure to focus outreach and education efforts in localized areas with the highest opportunities for improved implementation. The following summaries provide an overall review of guideline implementation (rates provided) and opportunities for focused outreach for each watershed unit. Potential exists for MFRC staff, GMP staff, and others to work with local partners and efforts (e.g., MFRC's Regional Landscape Committees and the Minnesota Pollution Control Agencies' Watershed Restoration and Protection plans) to develop strategies and acquire funding for this outreach.

Mississippi River – Headwaters (MH):

Located prominently at the head of the Mississippi River, this unit is predominantly forested with several large lakes within the unit. Sites in MH had high compliance in several categories, notably, implementing filter strips (88%), locating landings outside of wetlands or filter strips (95%), low occurrence of water quality segments (15 segments total), good choice of approach locations (0 observed needing erosion control), minimizing avoidable wetland crossings (only four observed), and RMZ management (100%). Opportunities to improve compliance exist for managing (minimizing) infrastructure (52%) and use of erosion control on segments (only two of 15 segments needing erosion control had it installed).

Lake Superior – North and South (SUP):

The Lake Superior Watersheds, encompassing the north shore area has the greatest total length of streams (many of them trout streams) in any of the watershed units (4,875 shoreline miles). Sites in this watershed had high compliance for retention of adequate leave trees (99% net compliance), and retention of large trees (80% of sample plots had dominant or codominant trees present), and retention of distributed slash, coarse woody debris, and snags. Opportunities exist to improve RMZ compliance on streams (66%), avoid stream and wetland crossings (69% compliance), locating landings away from filter strips and waterbodies (81%), and emphasis on use of erosion control on approaches to stream and wetland crossings (24 approaches and 30 water quality segments needing erosion control were observed) given the high density of trout streams and steep terrain that occur in this unit. Additional emphasis on avoiding excessive rutting, especially in wetland crossings (22 rutted NOWW crossings were observed) is also needed in this watershed unit.

Rum River (RR):

The Rum River Watershed is the most southern watershed sample unit addressed in this report and has the highest component of developed and agricultural land use. This watershed has a high number of wetlands but fewer streams than other units. Despite the small average harvest size (10 acres), sites in the RR watershed accomplished exemplary performance in multiple categories. Even with the highest number of observed wetlands of all sample units, RR had high implementation rates for filter strips (98%), condition of approaches (98%), use of erosion control on water quality segments (14 of 18 segments had erosion control installed), and leave tree retention (88% net compliance with 90% of sample plots having large trees present). However, RR demonstrated lower compliance for RMZ management at only 67% (a large improvement from 2014-15), placement of landings in wetlands or filter strips where an upland location was available (81% compliance), and for avoidance of unnecessary stream and wetland crossings (41%). Outreach targeting NIPF landowners and loggers in the RR watershed focusing on the benefits of implementing RMZ recommendations and avoiding wetland crossings when feasible may improve compliance in this watershed.

Mississippi River – Grand Rapids (MGR):

The second watershed unit on the Mississippi River has one of the lowest percent cover of lakes and ponds (6%) and is one of the units with the shortest total length of rivers and streams. MGR had the highest number of water bodies associated with harvest sites (192). Sites in this watershed accomplished high compliance in filter strip implementation (87%) and in avoiding placement of infrastructure on long steep slopes (only 15 total water quality segments were observed). Key areas of improvement in this watershed are related to retention of leave trees (only 77% of acres sampled were compliant) with overall number and characteristics of retained trees (i.e., higher species diversity/richness, retention of larger trees), reducing rutting on-site, implementation of erosion control on water quality segments (only two of 15 long slopes had erosion control installed), RMZ management (76% total compliance), and avoidance of wetland crossings (28% of observed crossings were avoidable).

Vermillion River and Rainy River – Headwaters (VRR):

The VRR includes parts of the Boundary Waters Canoe Area Wilderness (BWCAW). The VRR unit has the highest percent cover of lakes and ponds (24%) and is one of the units with the longest total length of rivers and streams (4,096 shoreline miles). Sites in this sample unit demonstrated high rates for implementation of filter strips (100%), implementation of RMZs (91%), avoidance of wetland crossings (82%), and 88% net leave tree compliance with over 40% of sites utilizing leave tree clumps. Sites also did better than average on locating landings away from wetlands and filter strips (87%) and avoiding wetland crossings and rutting in crossings (80%). Opportunities for improvement include use of erosion control on approaches and water quality segments (73%) and retention of dominant or codominant trees. VRR also had the lowest average on site infrastructure compliance (46%), with the highest average road acres. Outreach focus should also be placed on determining when erosion control is needed, as this unit had the highest proportion of sites where erosion control related to water quality was needed and not installed.

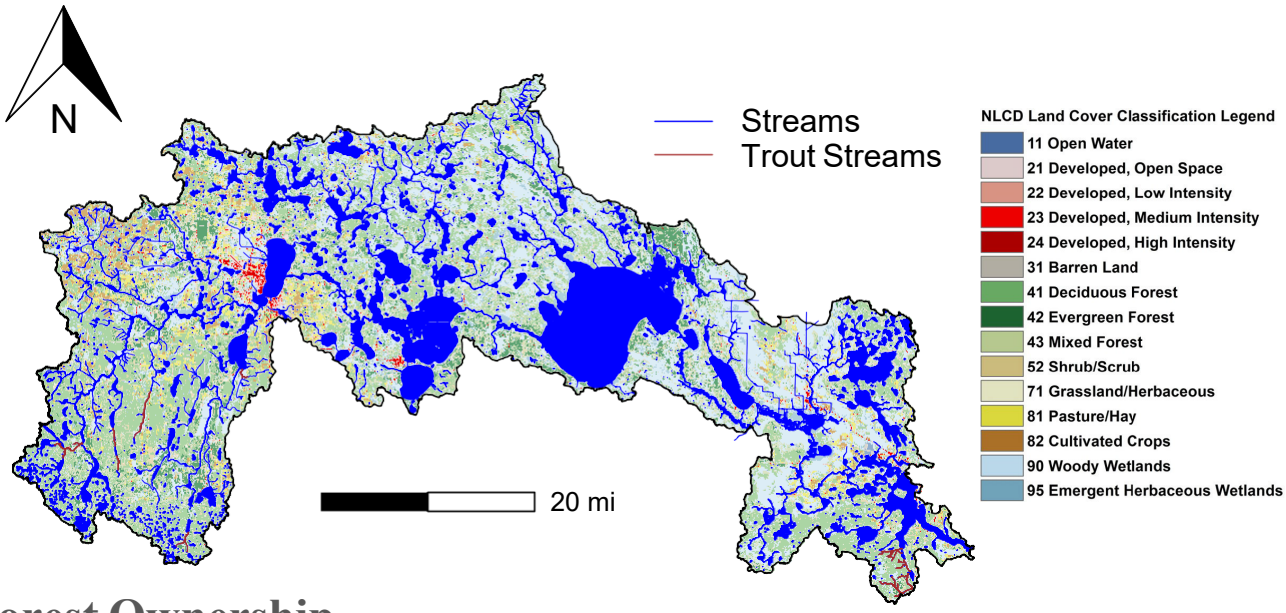
Red Lake, Clearwater River, and Wild Rice River (RLCW):

The RLCW watershed has the second highest percent of developed and agricultural land use and the highest percent cover in emergent and open water wetlands. This unit is critical to the health of one of the premier walleye fisheries in Minnesota as well as Clearwater River and Wild Rice River all flowing into the Red River of the North. Although the Appendix shows this unit as having the highest number of shoreline miles associated with rivers and streams (6,886 miles), the total figure includes a high proportion of drainage ditches (2,600 miles) and intermittent streams (2,334 miles). Sites monitored in this watershed unit demonstrated excellent implementation rates in several categories including: leave tree retention (97%) and placement of infrastructure to avoid long steep slopes (only ten water quality segments were observed). Opportunities for improvement include placement of landings away from wetlands and filter strips (81% compliance), RMZ management (67% compliance), and avoidance of excessive rutting (49% of wetland crossings were rutted, with 45 total rutted features observed). Outreach addressing the need and standards for RMZ implementation, wetland identification, the importance of avoiding unnecessary crossings, and methods for reducing rutting may improve awareness and implementation of these guidelines.

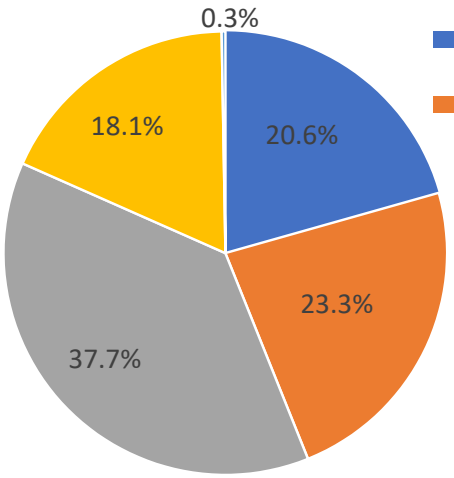
Appendix

Maps, tables, and figures provided herein detail important information related to watershed characteristics such as frequency and types of streams and wetlands, lakes, developed acreage, and percent forest. These resource priorities ultimately relate to the number of harvest sites triggering the need for specific BMPs or guidelines such as RMZs, filter strips, and erosion control on crossings, etc. for each watershed. Land cover characterizations are derived from National Land Cover Data (NLCD) 2019. Forest inventory data are summarized by watershed from USDA-Forest Inventory and Analysis (FIA) observed over a 5-year cycle ending in 2019. FIA estimates of percent forest are scaled to the total forest cover indicated by NLCD to provide an estimate of acres in each forest type. Forest canopy is mapped using the most recently available forest canopy layer from NLCD (2016). Information related to rivers and streams, trout streams, and other hydrological features are summarized from Minnesota Department of Natural Resources spatial data layers.

MH Watershed Unit: Mississippi River – Headwaters



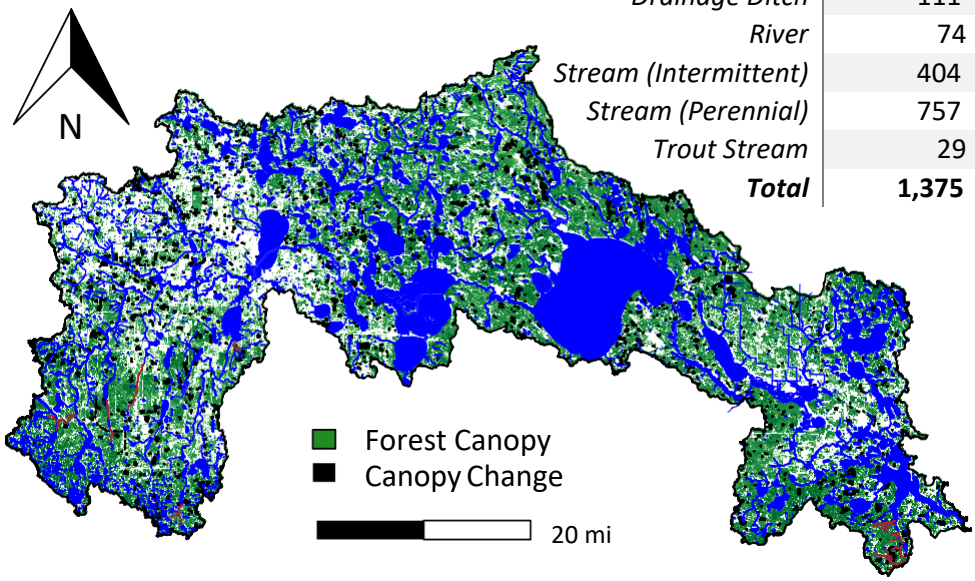
Forest Ownership



Land Cover	Acres
Agriculture	29,453
Barren	1,818
Developed	50,302
Forest	799,264
Grassland	67,514
Open water	173,031
Shrub/scrub	24,862
Wetland	82,650
Total	**1,228,894**

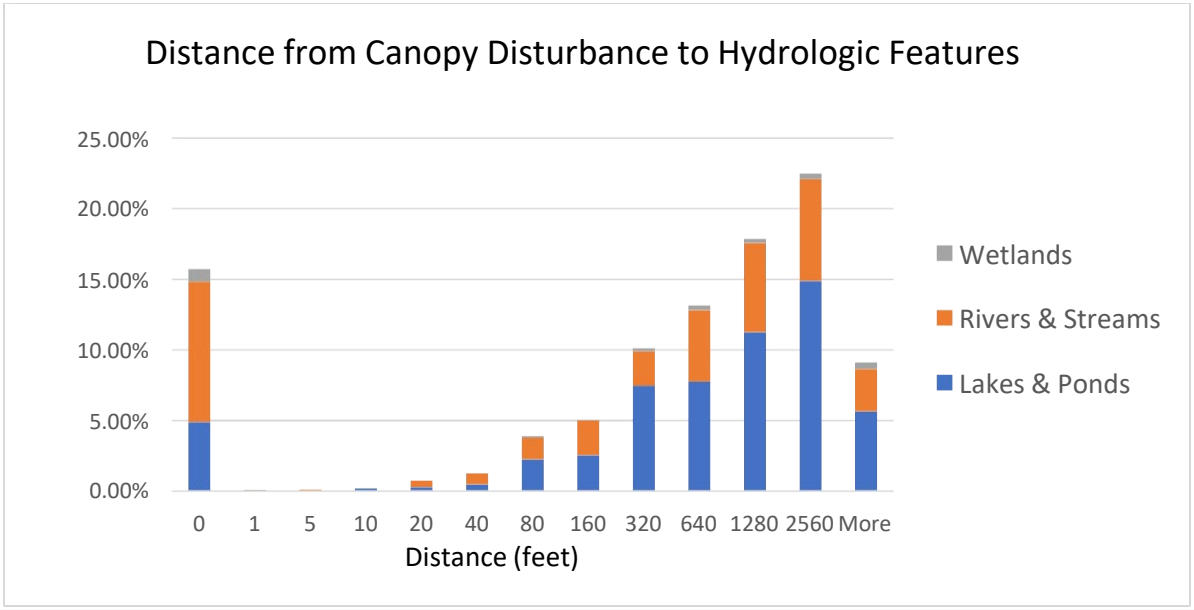
Forest Type	Acres	Percent
Aspen	255,496	32.0%
Red pine	73,059	9.1%
Northern hardwoods	61,044	7.6%
Tamarack	58,165	7.3%
White oak - red oak - hickory	55,181	6.9%
Paper birch	51,210	6.4%
Oak - pine	40,684	5.1%
Black ash	38,290	4.8%
Northern white-cedar	34,571	4.3%
Central hardwoods	29,503	3.7%
Balsam fir	25,114	3.1%
Black spruce	24,153	3.0%
Jack pine	16,413	2.1%
Lowland hardwoods	11,373	1.4%
Other	9,803	1.2%
Non-stocked	7,625	1.0%
Eastern white pine	7,580	0.9%
Total Forest	**799,264**	**100.0%**

Forest Canopy Change 2018–2020

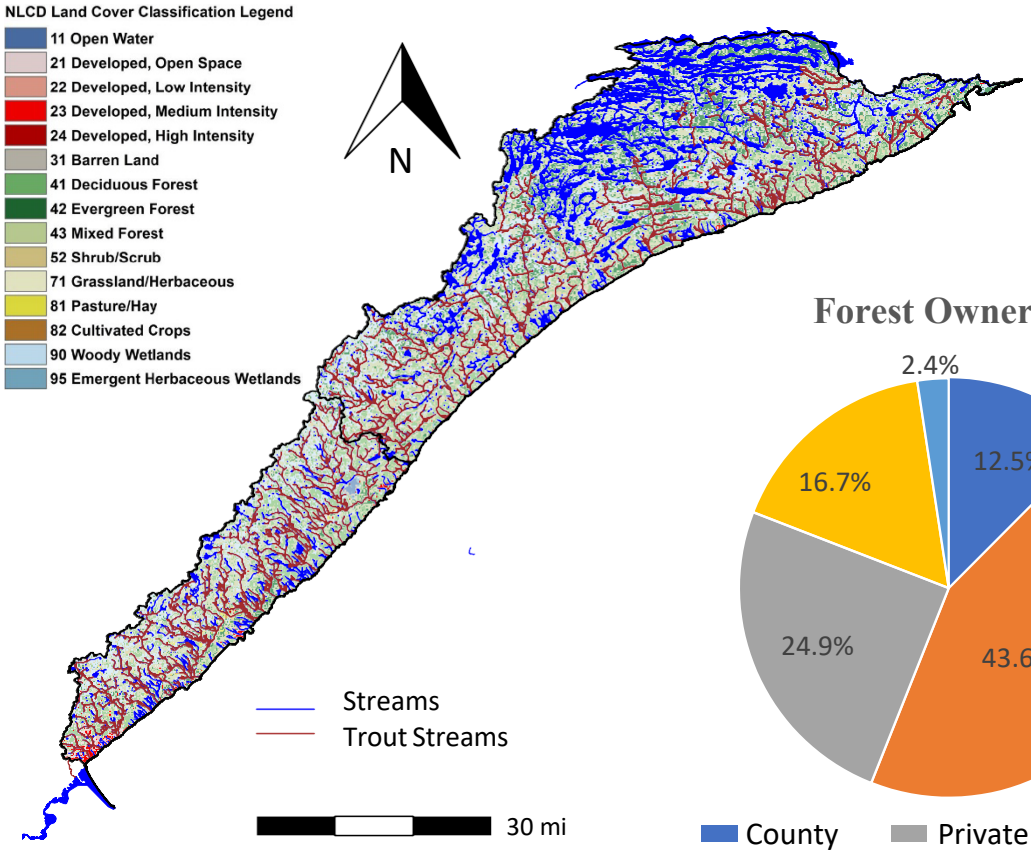


Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	111	83
River	74	229
Stream (Intermittent)	404	278
Stream (Perennial)	757	502
Trout Stream	29	48
Total	**1,375**	**1,140**

Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Artificial Basin	6	16	1
Fish Hatchery Pond	9	17	3
Inundation Area	12	580	41
Intermittent Water	34	242	15
Lake or Pond	2,634	202,493	1,980
Natural Ore Mine	1	49	1
River Channel	28	149,799	9,259
Wetland	63	2,682	98
Total	**2,787**	**355,876**	**11,399**



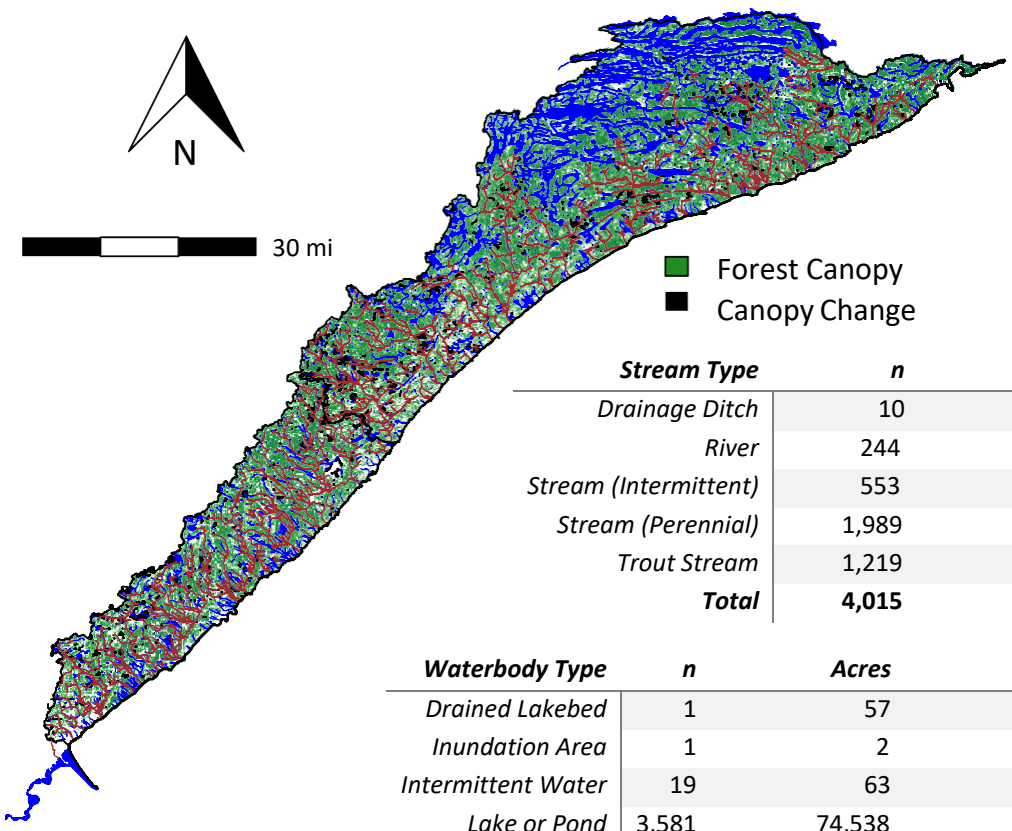
SUP Watershed Unit: Lake Superior – North and South



Forest Type	*Acres*	*Percent*
Aspen	393,227	32.2%
Paper birch	215,815	17.6%
Balsam fir	137,358	11.2%
Northern hardwoods	135,323	11.1%
Northern white-cedar	83,806	6.9%
Black ash	59,830	4.9%
Black spruce	58,665	4.8%
White spruce	40,059	3.3%
Other	31,387	2.6%
Red pine	20,470	1.7%
Jack pine	16,932	1.4%
Eastern white pine	14,062	1.1%
Tamarack	6,982	0.6%
Lowland hardwoods	5,445	0.4%
Oak - pine	3,603	0.3%
Total Forest	**1,222,966**	**100.0%**

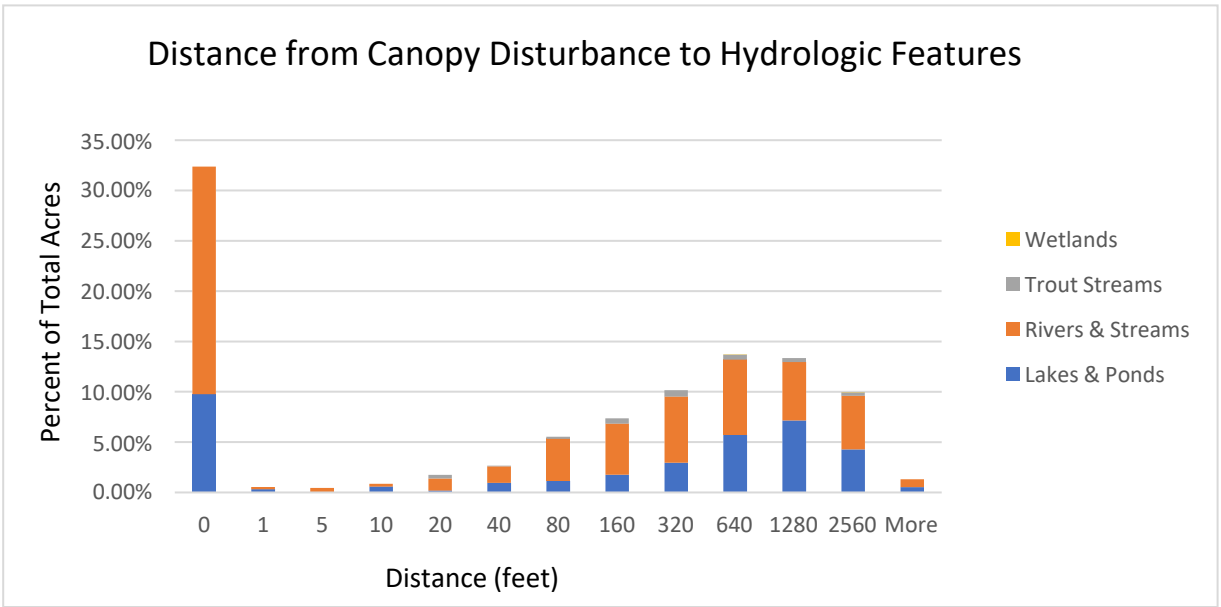
Land Cover	*Acres*
Agriculture	463
Barren	1,990
Developed	43,098
Forest	1,222,966
Grassland	15,030
Open water	66,515
Other	358
Shrub/scrub	52,494
Wetland	12,324
Total	**1,415,238**

Forest Canopy Change 2018–2020

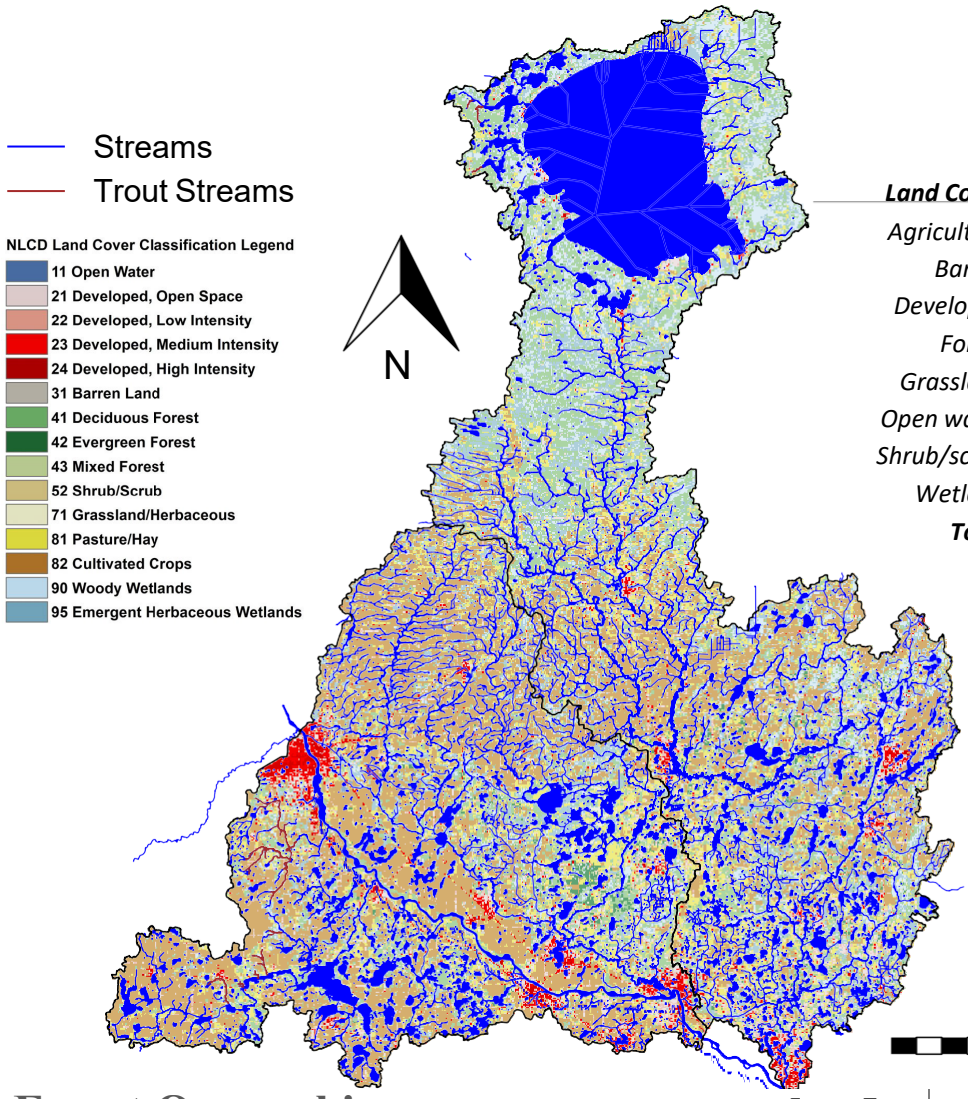


Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	10	12
River	244	682
Stream (Intermittent)	553	412
Stream (Perennial)	1,989	1,702
Trout Stream	1,219	2,067
Total	**4,015**	**4,875**

Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Drained Lakebed	1	57	2
Inundation Area	1	2	0
Intermittent Water	19	63	6
Lake or Pond	3,581	74,538	2,189
Mine Pit Lake	1	26	1
Reservoir	1	165	25
River Channel	48	7,469	399
Wetland	9	261	10
Total	**3,661**	**82,581**	**2,633**

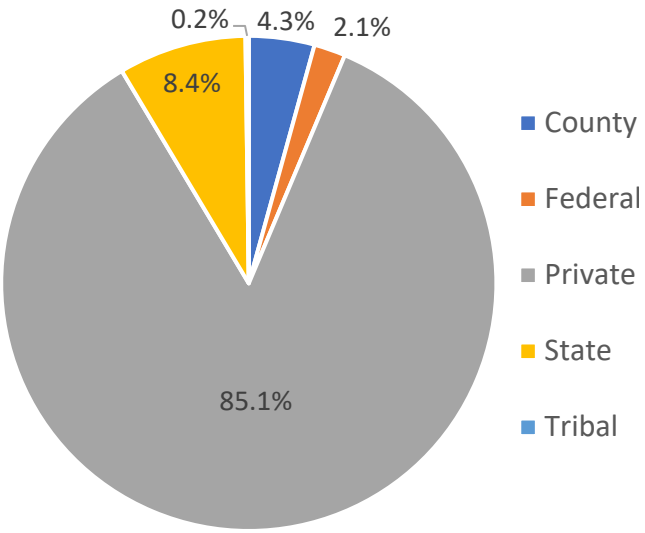


RR Watershed Unit: Mississippi River – St. Cloud, Rum River



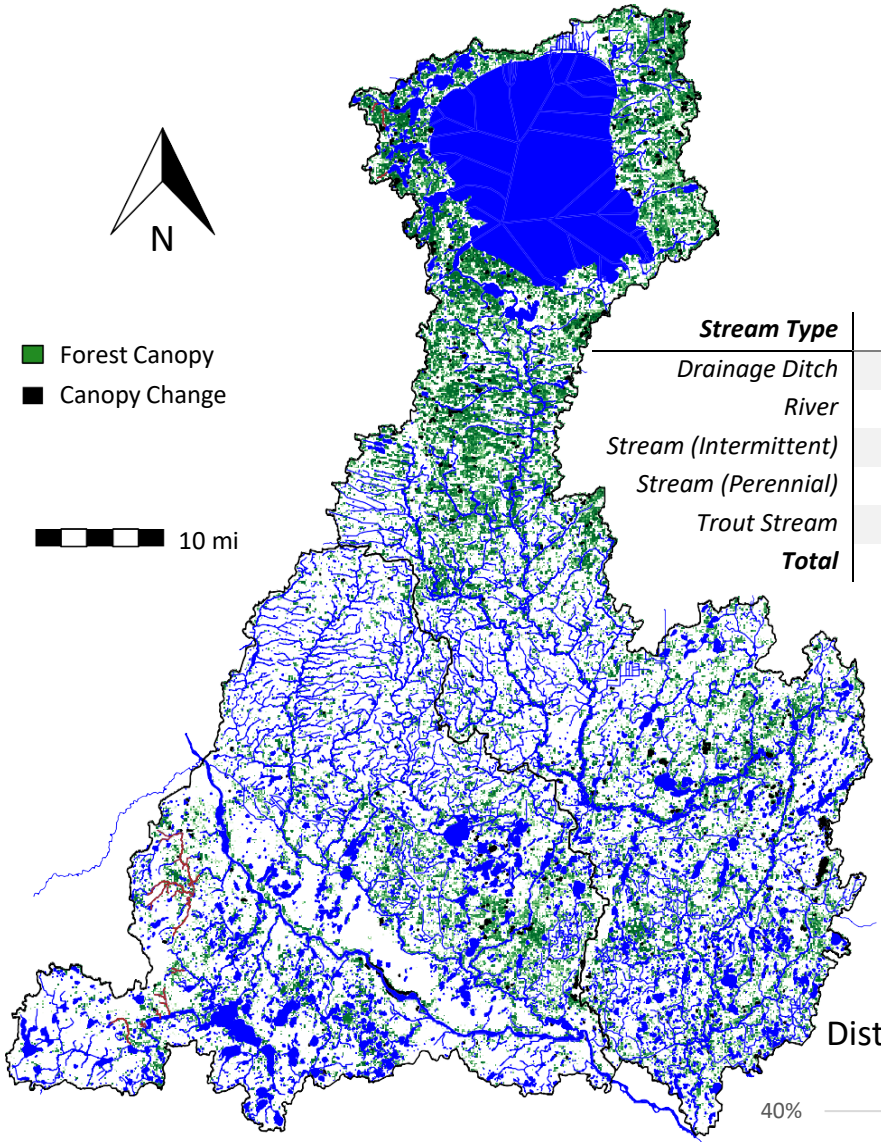
Land Cover	Acres
Agriculture	459,778
Barren	1,581
Developed	161,788
Forest	450,815
Grassland	247,199
Open water	177,890
Shrub/scrub	3,389
Wetland	228,733
Total	**1,731,174**

Forest Ownership



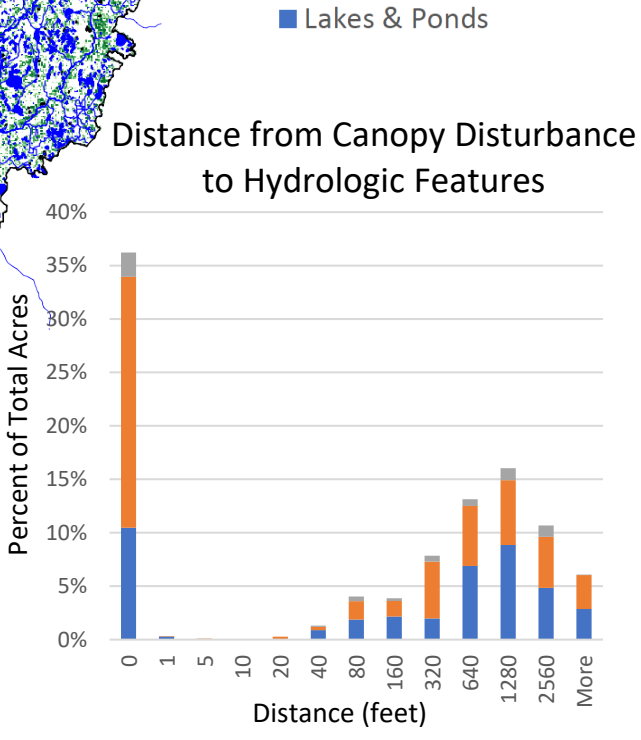
Forest Type	Acres	Percent
White oak - red oak - hickory	150,764	33.4%
Aspen	56,564	12.5%
Central hardwoods	54,798	12.2%
Lowland hardwoods	49,066	10.9%
Northern hardwoods	46,572	10.3%
Black ash	45,146	10.0%
Red pine	17,804	3.9%
Black spruce	8,212	1.8%
Paper birch	6,400	1.4%
Other	5,755	1.3%
Oak - pine	4,324	1.0%
Non-stocked	3,942	0.9%
Jack pine	1,469	0.3%
Total Forest	**450,815**	**100.0%**

Forest Canopy Change 2018 - 2020

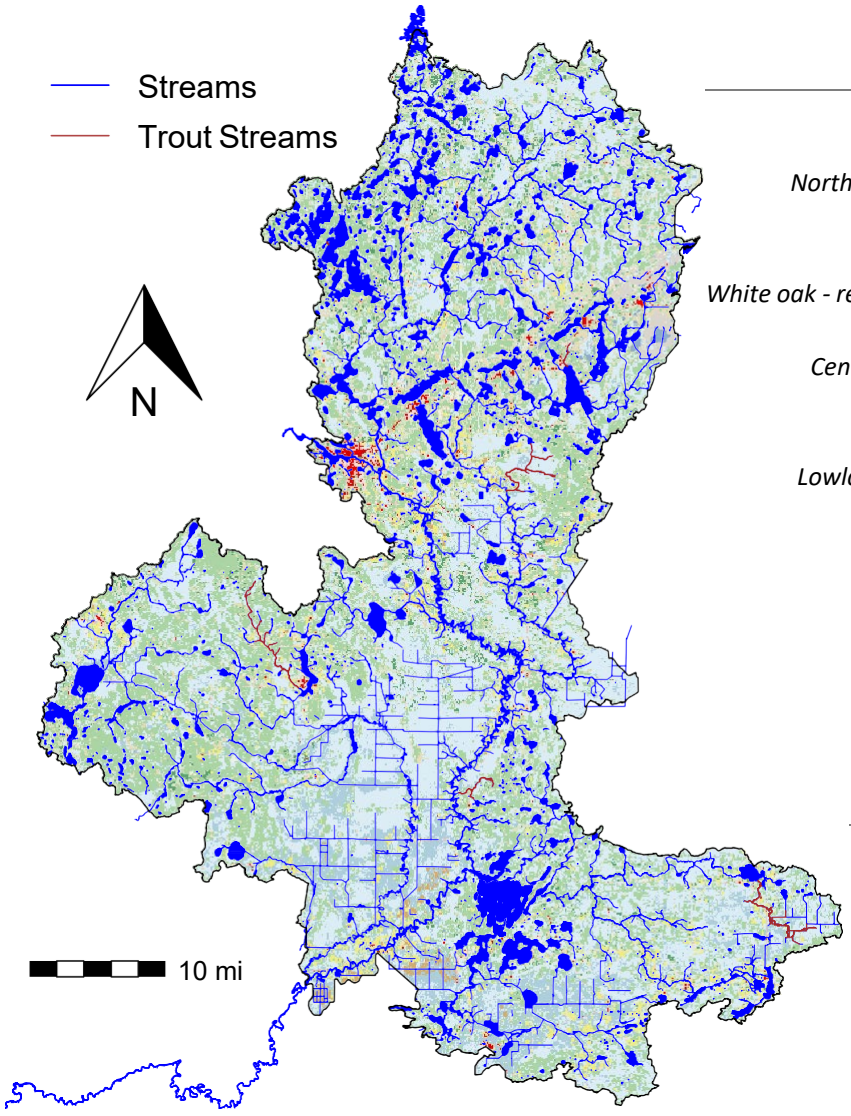


Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	853	781
River	123	681
Stream (Intermittent)	1,082	905
Stream (Perennial)	826	604
Trout Stream	31	47
Total	**2,915**	**3,018**

Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Artificial Basin	47	180	13
Drained Wetland	20	1,308	40
Inundation Area	7	1,084	29
Intermittent Water	158	1,303	86
Lake or Pond	7,041	181,451	1,853
Mine Pit Lake	10	246	9
River Channel	14	35,971	2,518
Sewage/Filtration Pd	14	256	9
Wetland	388	14,158	536
Total	**7,699**	**235,957**	**5,094**



MGR Watershed Unit: Mississippi River – Grand Rapids



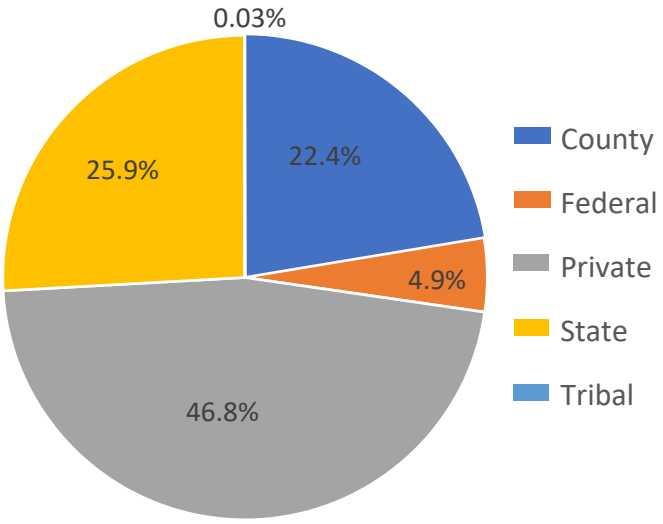
Forest Type	Acres	Percent
Aspen	413,431	42.2%
Tamarack	105,740	10.8%
Northern hardwoods	99,891	10.2%
Black ash	87,051	8.9%
Black spruce	82,915	8.5%
White oak - red oak - hickory	38,657	3.9%
Paper birch	26,102	2.7%
Central hardwoods	25,344	2.6%
N. white-cedar	21,349	2.2%
Balsam fir	14,533	1.5%
Lowland hardwoods	14,425	1.5%
Other	13,902	1.4%
Red pine	12,033	1.2%
Non-stocked	8,074	0.8%
White spruce	7,987	0.8%
Oak - pine	5,301	0.5%
Jack pine	2,694	0.3%
Total Forest	**979,429**	**100.0%**

Land Cover	Acres
Agriculture	7,359
Barren	9,017
Developed	43,252
Forest	979,429
Grassland	57,440
Open water	75,125
Shrub/scrub	34,482
Wetland	126,701
Total	**1,332,804**

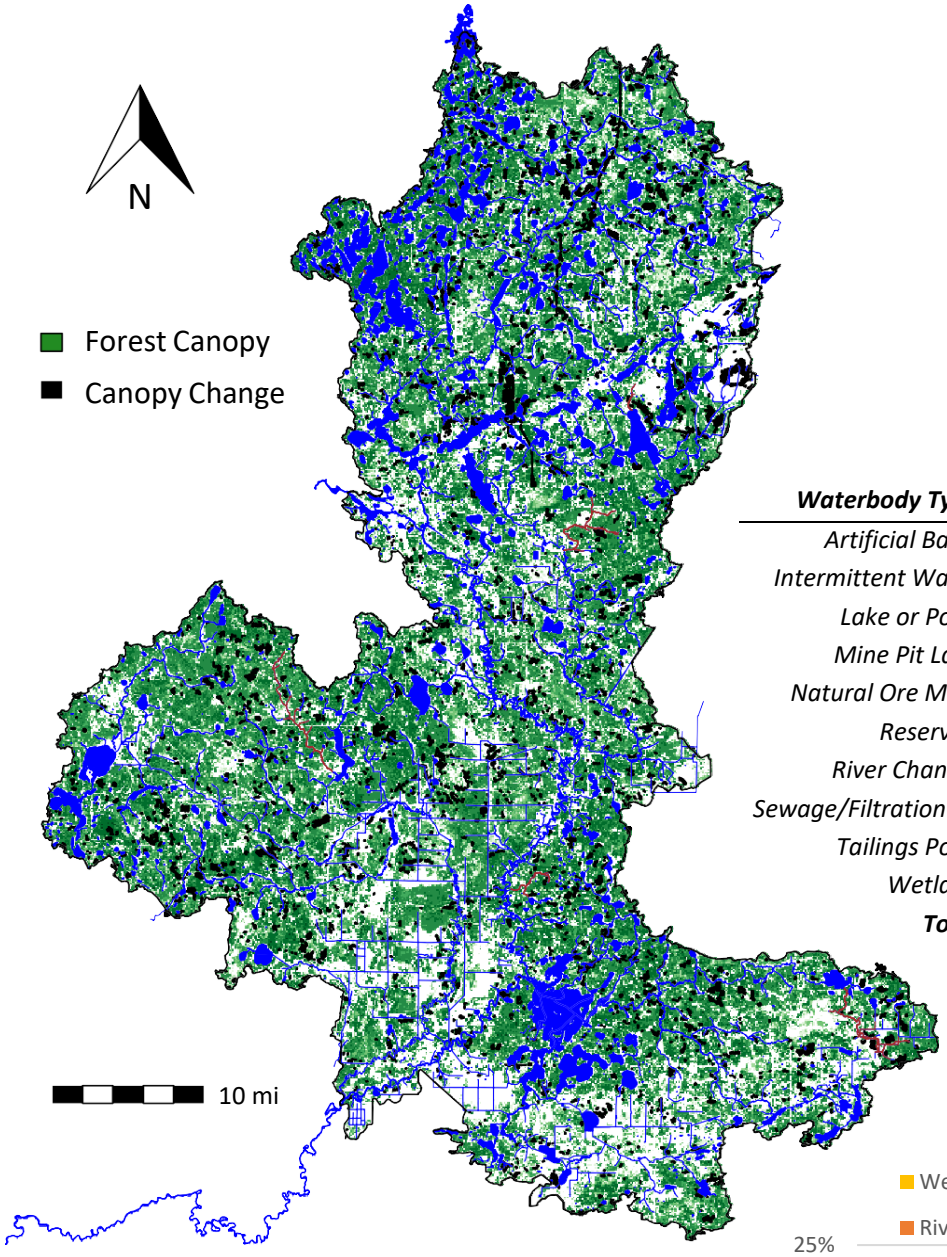
NLCD Land Cover Classification Legend

- 11 Open Water
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

Forest Ownership



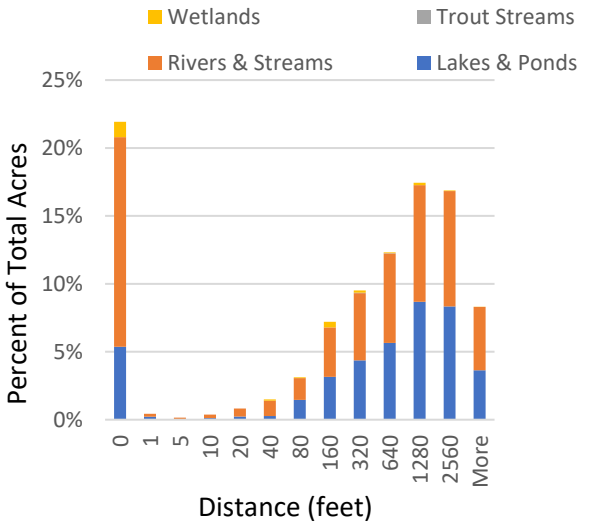
Forest Canopy Change 2018–2020



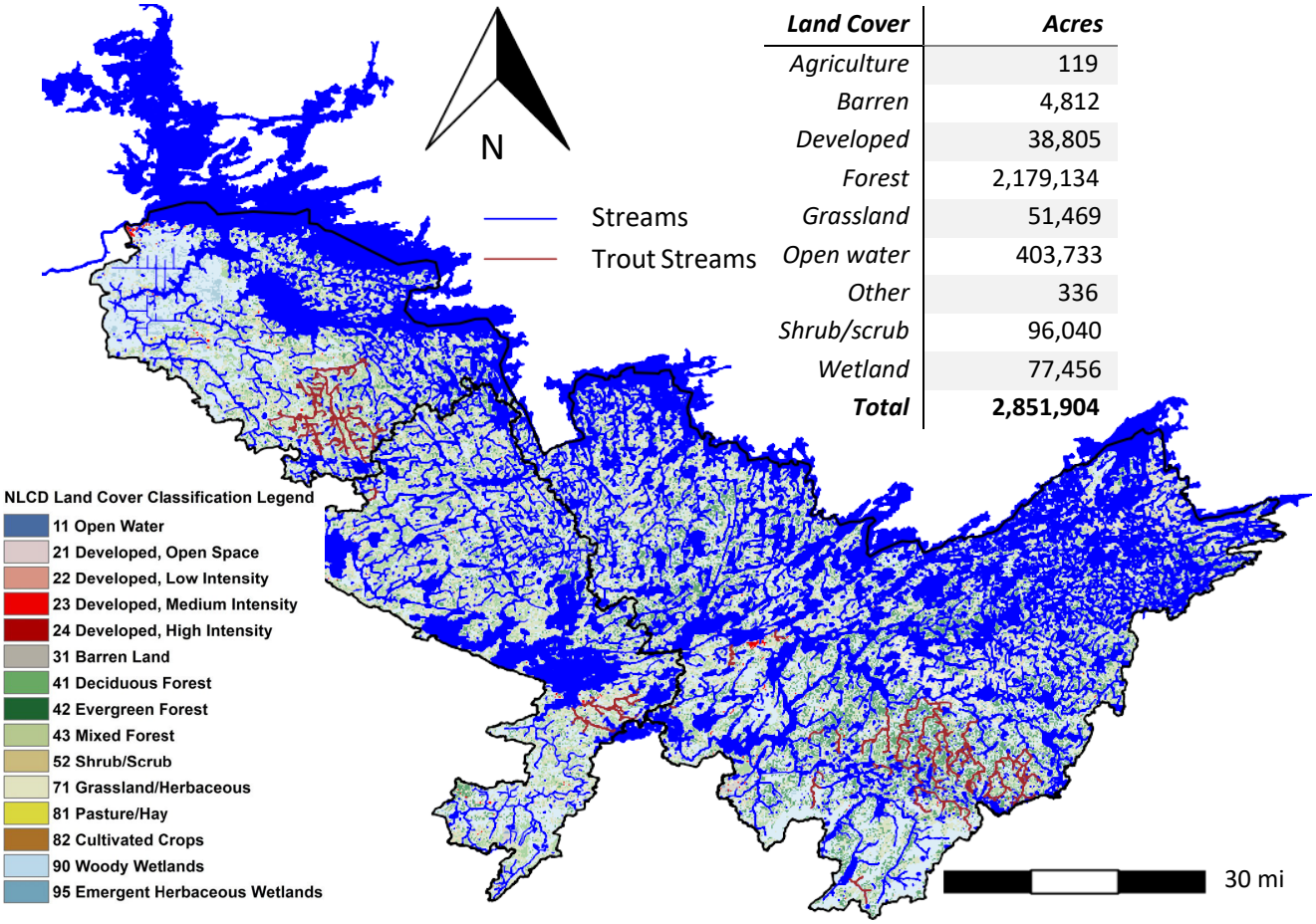
Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Artificial Basin	3	420	7
Intermittent Water	17	157	8
Lake or Pond	2,086	79,080	1,620
Mine Pit Lake	3	202	4
Natural Ore Mine	21	4,603	79
Reservoir	2	886	19
River Channel	30	33,867	2,125
Sewage/Filtration Pd	4	18	1
Tailings Pond	7	374	14
Wetland	11	2,065	45
Total	**2,184**	**121,672**	**3,923**

Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	331	391
River	86	585
Stream (Intermittent)	498	319
Stream (Perennial)	731	538
Trout Stream	51	62
Total	**1,697**	**1,895**

Distance from Canopy Disturbance to Hydrology

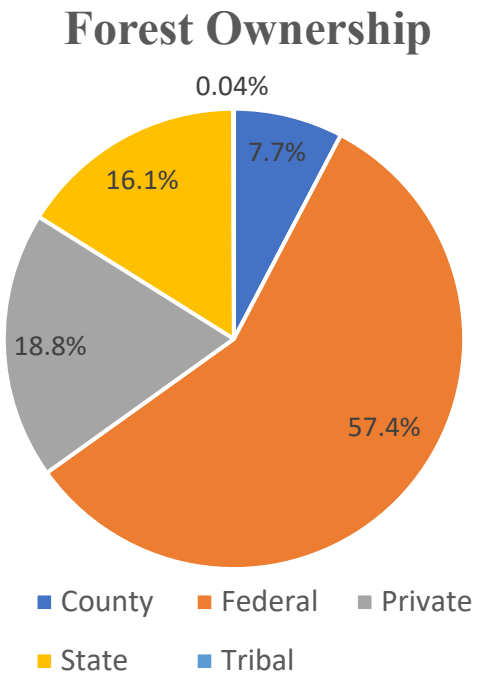


VRR Watershed Unit: Vermilion River, Rainy River – Headwaters and Rainy Lake

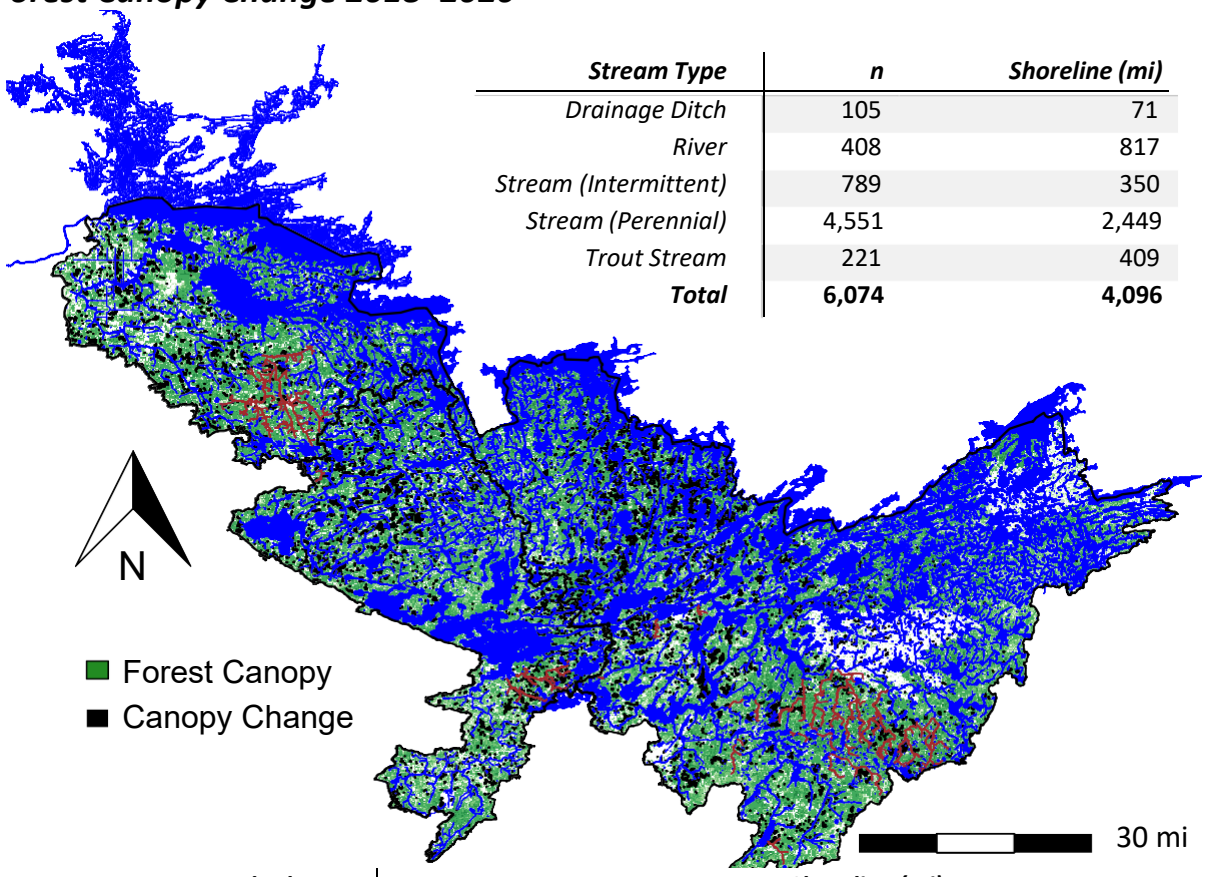


Land Cover	*Acres*
Agriculture	119
Barren	4,812
Developed	38,805
Forest	2,179,134
Grassland	51,469
Open water	403,733
Other	336
Shrub/scrub	96,040
Wetland	77,456
Total	**2,851,904**

Forest Type	*Acres*	*Percent*
Aspen	644,707	29.6%
Black spruce	329,195	15.1%
Paper birch	199,541	9.2%
Jack pine	192,189	8.8%
Balsam fir	190,024	8.7%
Northern hardwoods	106,553	4.9%
Red pine	88,022	4.0%
Tamarack	75,999	3.5%
Black ash	73,986	3.4%
Oak - pine	69,958	3.2%
Northern white-cedar	62,480	2.9%
Eastern white pine	48,958	2.2%
White spruce	37,420	1.7%
Other	22,740	1.0%
Non-stocked	19,221	0.9%
Central hardwoods	8,398	0.4%
Lowland hardwoods	5,445	0.2%
White oak - red oak - hickory	4,296	0.2%
Total Forest	**2,179,134**	**100.0%**

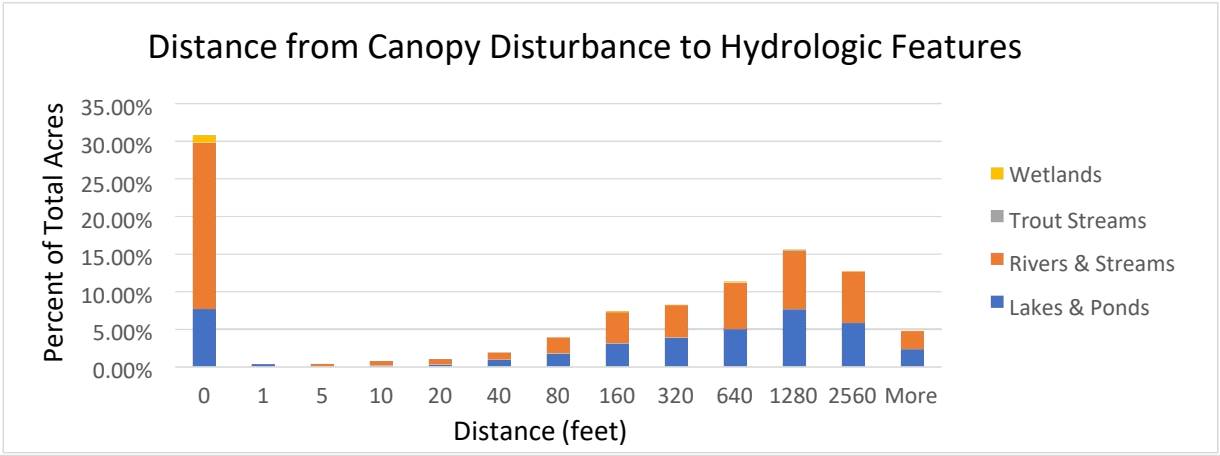


Forest Canopy Change 2018–2020

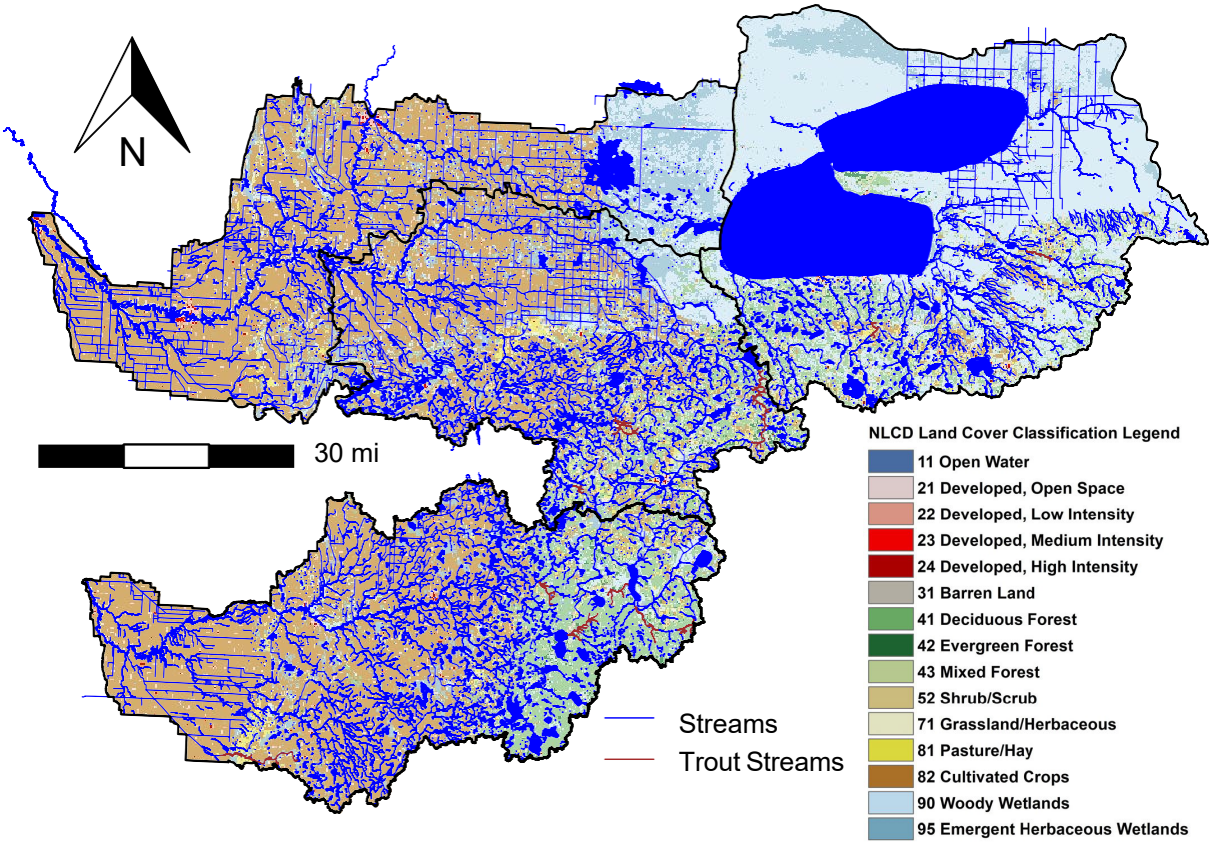


Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	105	71
River	408	817
Stream (Intermittent)	789	350
Stream (Perennial)	4,551	2,449
Trout Stream	221	409
Total	**6,074**	**4,096**

Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Drained Wetland	1	20	1
Inundation Area	11	68	6
Intermittent Water	179	620	59
Lake or Pond	7,986	696,788	11,890
Mine Pit Lake	3	557	11
River Channel	133	43,665	1,353
Sewage/Filtration Pd	2	25	1
Tailings Pond	1	85	4
Wetland	27	9,461	170
Total	**8,343**	**751,287**	**13,495**

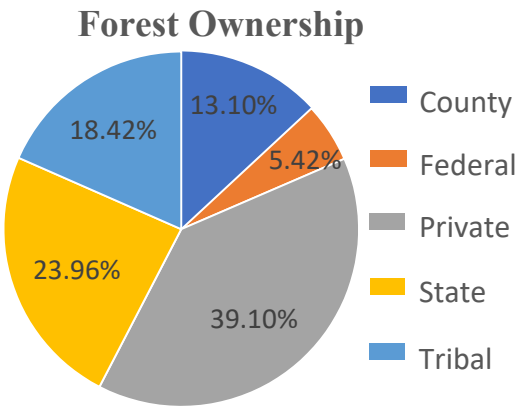


RLCW Watershed Unit: Wild Rice River, Red Lake, Red Lake River, Clearwater River

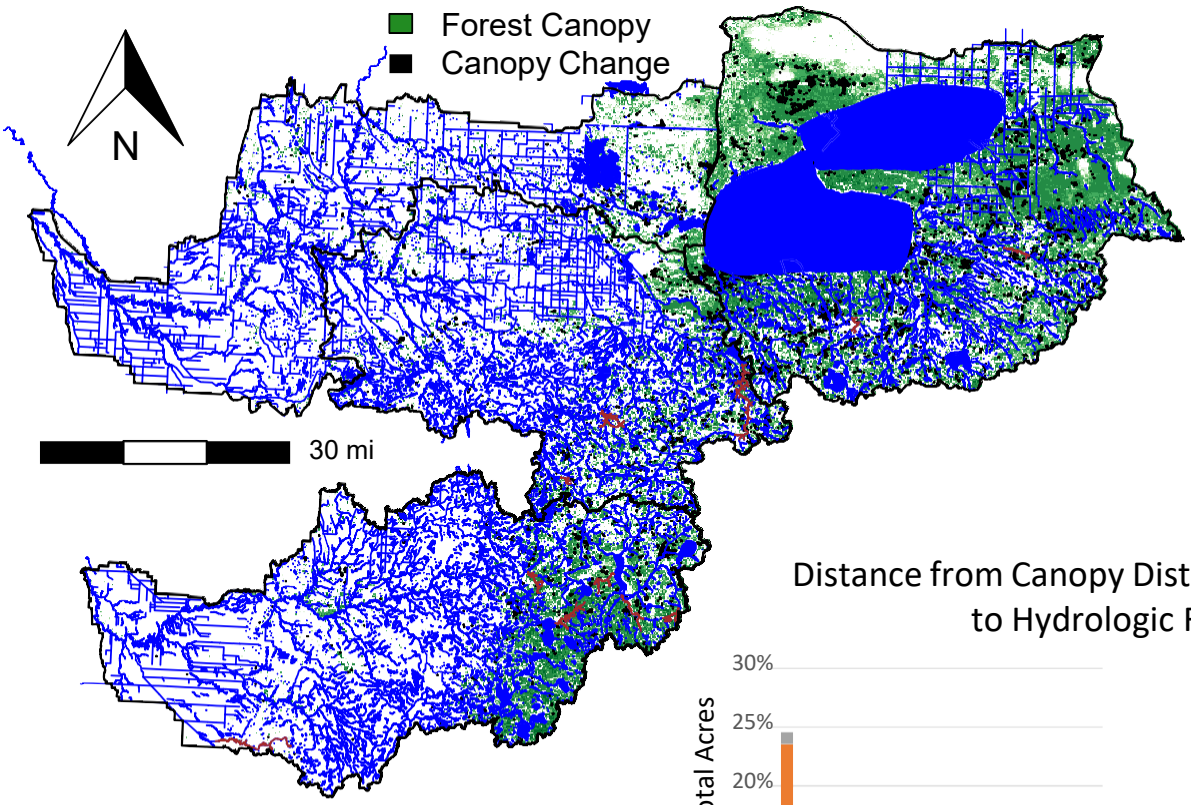


Forest Type	Acres	Percent
Aspen	449,731	34.3%
Tamarack	156,969	12.0%
Black ash	126,501	9.7%
Northern white-cedar	112,027	8.5%
White oak - red oak - hickory	94,657	7.2%
Black spruce	87,598	6.7%
Northern hardwoods	87,253	6.7%
Central hardwoods	63,035	4.8%
Paper birch	29,034	2.2%
Lowland hardwoods	23,962	1.8%
Other	18,820	1.4%
Oak - pine	17,181	1.3%
Red pine	11,984	0.9%
White spruce	11,040	0.8%
Eastern white pine	8,046	0.6%
Jack pine	5,106	0.4%
Non-stocked	4,207	0.3%
Balsam fir	3,312	0.3%
Total Forest	**1,310,464**	**100.0%**

Land Cover	Acres
Agriculture	1,599,800
Barren	3,411
Developed	117,022
Forest	1,310,464
Grassland	137,817
Open water	359,350
Shrub/scrub	10,686
Wetland	477,181
Total	**4,015,731**

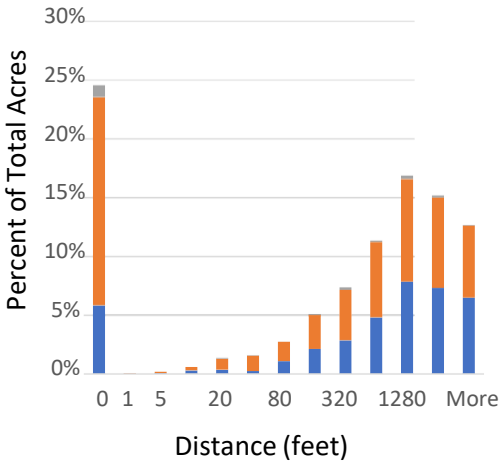


Forest Canopy Change 2018–2020



Stream Type	*n*	*Shoreline (mi)*
Drainage Ditch	2,501	2,600
River	110	1,066
Stream (Intermittent)	2,924	2,334
Stream (Perennial)	977	762
Trout Stream	93	124
Total	**6,605**	**6,886**

Distance from Canopy Disturbance to Hydrologic Features



Waterbody Type	*n*	*Acres*	*Shoreline (mi)*
Artificial Basin	17	341	8
Drained Wetland	9	1,129	31
Fish Hatchery Pond	7	4	1
Inundation Area	4	814	28
Intermittent Water	65	559	36
Lake or Pond	7,475	650,007	2,901
Mine Pit Lake	5	98	4
Reservoir	1	97	7
River Channel	20	7,724	965
Sewage/Filtration Pd	27	825	20
Wetland	248	28,724	591
Total	**7,878**	**690,322**	**4,592**

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