A Watershed Approach to Site-level Forest Management Guideline Monitoring: Summary Results for 2014 – 2018

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

CLEAN WATER LAND & LEGACY AMENDMENT

DEPARTMENT OF NATURAL RESOURCES

MINNESOTA FOREST RESOURCES COUNCIL

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DEPARTMENT OF NATURAL RESOURCES

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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 on forested lands in Minnesota. Implementation monitoring of these guidelines has been conducted on almost 1400 timber harvest sites across public and private forest lands since 2000. Reports are prepared biennially for specific watershed sample units (WSUs). This report summarizes results for monitoring that occurred between summer 2014 and fall 2018 and examines trends in implementation across WSUs.

For the 5-year period covered in this report, implementation of site-level guidelines was assessed on 434 sites randomly selected from within 15 WSUs (covering 41 of 81 HUC-8 watersheds in MN) encompassing ~92% of Minnesota's forested land. Monitored sites had a timber harvest at some point from late summer of 2012 through summer of 2017. 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 using remote sensing for the same time window. Guideline monitoring sites represented approximately 7% by area of harvesting detected over 5-years in the WSUs.

Hydrologic modeling of watershed risks associated with timber harvests has been a goal of the Guideline Monitoring Program for several years. The shift to a watershed based approach, in alignment with Clean Water Land and Legacy Fund priorities, has further prioritized this work to increase our understanding of the connection between forests and water resources. The hydrologic modeling effort was initiated in 2014, and was recently pushed closer to completion in conjunction with this report. These data and models will likely play a big role in preparation for upcoming monitoring and outreach efforts.

While hydrologic modeling efforts continue, a draft hydrogeomorphological model has been created at the watershed scale, and will undergo additional testing and validation in the coming year. This information will help target outreach efforts to specific guidelines, audiences, and watersheds where the greatest opportunities for innovation and implementation exist. For example, watersheds with higher risk of erosion, greater timber harvest activity, and/or lower filter strip or riparian management zone implementation can be identified, and outreach tailored to local needs. Watersheds with more challenging hydro-geologic conditions may also need specific outreach focused on guidelines for placement of landings, erosion control practices, and avoidance of unnecessary wetland crossings. A goal of the hydrologic modeling effort is production of a statewide raster layer (map) that can be used by land managers to assess site-level risk to water quality from forest management practices.

Guideline monitoring at the watershed scale has proven valuable by increasing understanding of the variation in guideline implementation across the state. An additional benefit has been increased efficiency and cost savings in the monitoring process. These cost savings arise from the clustering of sample sites within watershed units, and the reduction of travel needed to access them. Collection of implementation data at the watershed scale continues to reveal interesting relationships not previously identified with statewide estimates, and dovetails with priorities identified via the risk model mentioned above.

Opportunities for improved implementation at the watershed scale are noted throughout this report. Recommendations include more introductory training opportunities for new foresters and loggers, targeted training related to wetland identification to aid in avoidance of wetland crossings, practices to minimize impacts where crossings are necessary, and identification of situations where water diversion and erosion control practices need to be implemented. Continuing education programs, such as Minnesota Logger Education Program, the Sustainable Forestry Education Cooperative, Minnesota Association of County Land Commissioners, MN DNR Private Forest Management, and Minnesota Forest Industries are encouraged to continue their efforts related to these recommendations, and work to develop new educational opportunities to address the specific topics identified above.

Particular watersheds sample units meriting an individual education and outreach focus due to higher hydrogeomorphological risk and/or high harvest rates combined with lower BMP implementation include:

- VRR (high hydrogeomorphologic risk, relatively high harvest rates, and relatively lower BMP implementation),
- SUP (high hydrogeomorphologic risk, relatively high harvest rates, and moderate BMP implementation),
- RLB (moderate hydrogeomorphologic risk, with high harvest rates and lower BMP implementation),
- LRRR (lower hydrogeomorphologic risk, but relatively high harvest rates combined with lower BMP implementation),
- MRBS (moderate hydrogeomorphologic risk, with lower BMP implementation), and
- SEMN (high hydrogeomorphologic risk, but low forest harvesting and reasonable BMP implementation).

Specific forest management guidelines (FMGs) have also been identified as in need of broader implementation, including additional outreach and education to raise awareness of the guidelines and recommended implementation criteria.

- Leave trees provide wildlife habitat and help to intercept precipitation, encourage infiltration of surface water into forest soils, reduce overland flow, and provide a living anchor for forest soils.
- Vegetated filter strips are widely implemented, but not always managed appropriately. These features intercept and slow the movement of sediment from forest soils into surface waters.
- Erosion control measures on approaches and crossings serve to prevent the movement of soil from these high traffic areas to surface waters.
- Avoidance of unnecessary wetland and waterbody crossings serves to limit interaction with surface water and minimize the potential for delivery of sediment downstream.
- Riparian management zones provide vegetative cover in close proximity to water bodies, serve as important wildlife habitat, and provide benefits associated with filter strips and leave trees.
- Rut avoidance is another operational consideration that can help to reduce the movement of sediment into surface waters.

The GMP further encourages use of information related to soils, terrain, and proximity to surface water to assess and prioritize BMP use at the site and watershed scales. Future trainings provided by GMP will focus on how to utilize these data in concert with other planning tools used by land managers.

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List of Acronyms

BMP: Best Management Practice
DOF: MN DNR Division of Forestry
CWD: Coarse Woody Debris
CWR: Crow Wing River WSU
EC: Erosion Control
ETS: Endangered, Threatened, and Special Concern species.
FIA: Forest Inventory and Analysis Unit; USDA – Forest Service
FMG: Forest Management Guideline
FWD: Fine Woody Debris
GIS: Geographic Information System
GMA: Guideline Monitoring Application (A GIS program for data entry)
GMP: Guideline Monitoring Program
HUC-8: 8 digit hydrologic unit code; major watersheds
LLP: Leech Lake - Pine River WSU
LRRR: Lake of the Woods, Roseau, Rainy River WSU
LTC: Leave Tree Clump
MFRC: Minnesota Forest Resources Council
MGR: Mississippi River Grand Rapids WSU
MH: Mississippi River Headwaters WSU
MN DNR: Minnesota Department of Natural Resources
MPCA: Minnesota Pollution Control Agency
MRBS: Mississippi River Brainerd-Sartell WSU
NASF: National Association of State Foresters
NHD: National Hydrography Dataset
NHIS: Natural Heritage Information System
NIPF: Non-industrial Private Forest
NLCD: National Land Cover Dataset
NOWW: Non Open Water Wetland; a frequently saturated area, either vegetated, or mineral soil
NWI: National Wetlands Inventory
OWW: Open Water Wetland; Lake, River, Stream, or Pond
RA: Resource Assessment, a unit of DOF providing natural resource assessment services
RLB: Rainy River, Little Fork, and Big Fork WSU
RLCW: Red Lake, Red Lake River, Clearwater, and Wild Rice River WSU
RMZ: Riparian Management Zone
ROL: Red Eye, Otter Tail, and Long Prairie WSU
RR: Rum River, Mississippi River St. Cloud WSU
SCKS: St. Croix, Kettle, Snake River WSU
SCN: Saint Louis, Cloquet, and Nemadji Rivers WSU
SEMN: Southeast Minnesota WSU
SFRA: Sustainable Forest Resources Act of 1995
SUP: Superior North and South WSU
TH/FM: Timber Harvest / Forest Management
USDA: United States Department of Agriculture
VRR: Vermillion, Rainy River WSU
WCA: MN Wetlands Conservation Act
WRAPS: Watershed Restoration and Protection Strategy
WSU: Watershed Sample Unit; one or more HUC-8s
WQ: Water Quality

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 supplementing reporting requirements of 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 Council to develop and periodically revise voluntary guidelines for use on public and private forestland in Minnesota to minimize negative impacts of timber harvest and forest management activities. The SFRA also requires the Commissioner of the Minnesota Department of Natural Resources (DNR) to maintain a program for monitoring application of the timber harvesting and forest management guidelines (FMGs) at statewide, landscape, and site levels (89A.07 subd.2). This report is submitted by the DNR to the MFRC and summarizes the results of monitoring for the implementation of FMGs between 2014 and 2018 across Minnesota's forested watersheds.

The 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 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, with additions and changes related to biomass harvesting, riparian management zones (RMZs), allowable infrastructure, and leave trees, included in the 2012 revision (MFRC 2012).

The FMGs address a variety of water quality concerns via best management practices (BMPs) like filter strip implementation, RMZs, road and skid trail management, landing placement and footprint, slash management, and a variety of practices aimed at minimizing wetland impacts.

The DNR's Guideline Monitoring Program (GMP) has monitored guideline implementation at over 1,400 harvest sites since 2000 and has published numerous reports summarizing findings through 2018. Currently, the GMP uses a six year cycle to assess BMP implementation across 15 watershed sample units (32.2 million acres) including 17.3 million acres of forested land. These watersheds also include 2.5 million acres of surface water and innumerable wetlands potentially affected by timber harvest and BMP implementation. Figure 1 provides an overview of the monitoring cycle and process.

- Step 1: Forest Canopy Change Detection
- Step 2: Harvest Site Identification and Selection
- Step 3: Landowner Contact / Permissions
- Step 4: On-site Monitoring / Data Collection
- Step 5: Data Compilation / Management
- Step 6: Analysis of Results
- Step 7: Reporting

https://conceptdraw.com/

Figure 1. Guideline Monitoring Program 6-year Cycle and Process.

Prior to 2014, monitoring sites were randomly selected from all harvests across the state and findings were summarized to estimate statewide implementation levels. In 2013, the program was significantly modified by 1) focusing harvest site monitoring at the HUC-8 (major watershed) scale compared to a statewide sample, 2) incorporating forest disturbance estimates into the assessment, recognizing that the local level of disturbance and its configuration influences interpretation of implementation estimates, and 3) development of water quality risk assessments associated with watershed specific hydro-geologic conditions, forest cover, and rates of disturbance. The overall objective of this new approach is to conduct more targeted and effective education and outreach for improved guideline implementation. Another outcome of this approach is a periodic statistical sample informing our understanding of BMP implementation on timber harvest across all ownerships at a watershed scale.

This report summarizes the monitoring data for 434 harvest sites in 41 forested HUC-8 watersheds (15 watershed sample units) that were monitored from 2014-2018, with emphasis on key guidelines and topics identified as opportunities for improvement in previous reports. Statewide estimates calculated from the mean among watersheds are also presented for comparison to previous years and for application to statewide policy development. We also present a hydro-geomorphic classification that can be used to assess watershed scale risk to water quality impacts, and evaluate how this risk varies across the HUC-8 forested watersheds in Minnesota. This model is currently undergoing additional development for use as a BMP prioritization tool at the site scale.

Methods

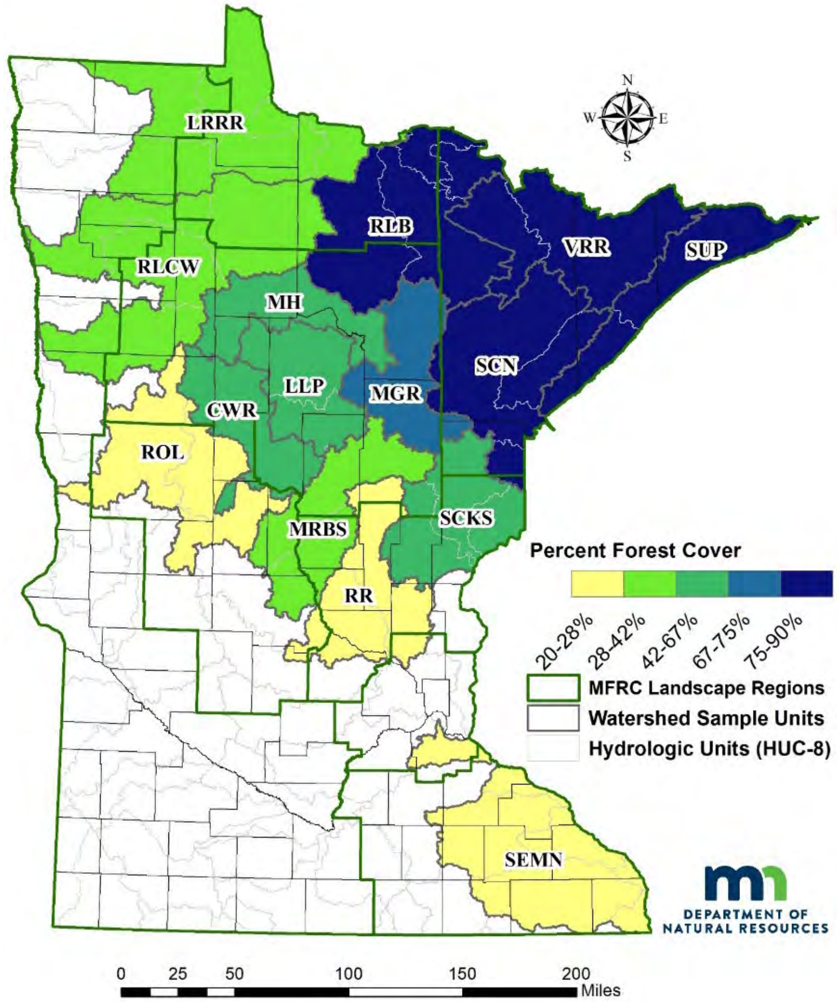
This section outlines the forest cover change detection, site selection, and monitoring data collection methods for monitoring the implementation of forest management guidelines.

Watershed Sample Units

Starting in 2014, the guideline monitoring program (GMP) restructured monitoring efforts to focus on the US Geological Survey defined hydrologic unit code 8 (HUC-8) watershed scale (81 HUC-8s across Minnesota, 41 of which are composed of >20% forest cover). Attempts are made to select watersheds that are concurrently evaluated in the Minnesota Pollution Control Agency (MPCA) Watershed Restoration and Protection Plan (WRAPS) process (ex., MPCA 2017a-c).

Sites monitored from 2014-2018 were selected from forest cover changes detected (see below) within 15 watershed sample units (WSUs), with each unit consisting of either a single watershed or a cluster of watersheds with similar landscape characteristics. Figure 2 provides an overview of these WSUs, and the Appendix provides a series of in-depth maps and statistics related to land use and hydrologic conditions in each of the watershed sample units. Throughout this report, results are presented by watershed sample unit in graphic (map) and tabular form. Where no substantial difference in implementation data is observed, results may be presented in statewide summaries.

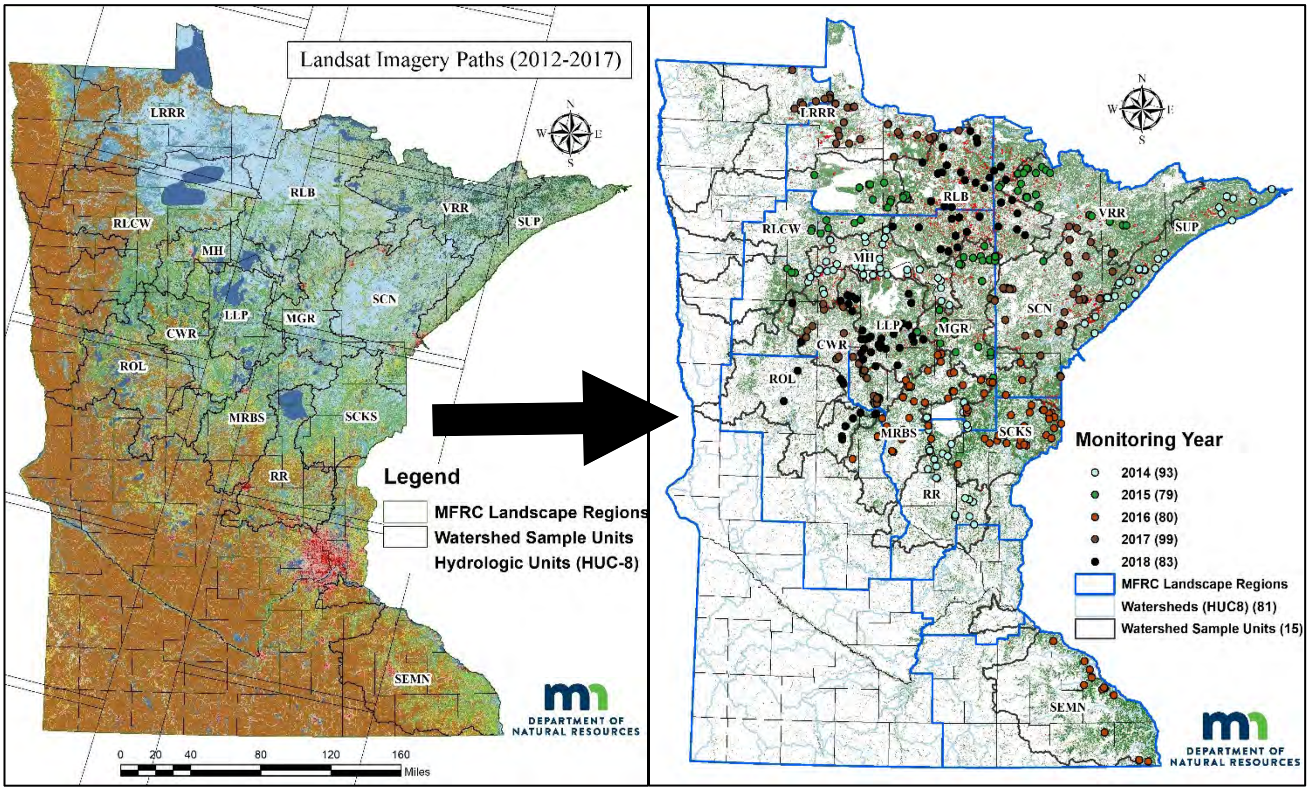
Throughout this document, watershed sample units are abbreviated as follows:



- **MH:** Mississippi River Headwaters (2014)
- **SUP:** Superior North and South Watersheds (2014)
- **RR:** Rum River Watershed (2014)
- **VRR:** Vermillion River, Rainy River Watershed (2015)
- **MGR:** Mississippi River Grand Rapids Watershed (2015)
- **RLCW:** Red Lake, Red Lake River, Clearwater, and Wild Rice River Watershed (2015)
- **MRBS:** Mississippi River Brainerd – Sartell (2016)
- **SE MN:** Southeast Minnesota (2016)
- **SCKS:** Saint Croix River, Kettle and Snake River Watershed (2016)
- **CWR:** Crow wing River Watershed (2017)
- **SCN:** St. Louis, Cloquet and Nemadji River Watersheds (2017)
- **LRRR:** Lake of the Woods, Rapid River, Roseau River and Rainy River Watersheds (2017)
- **LLP:** Leech Lake and Pine River Watersheds (2018)
- **RLB:** Rainy River Headwaters, Little Fork, and Big Fork (2018)
- **ROL:** Red-eye River, Otter Tail River, and Long Prairie River (2018)

Forest Cover Change Detection

Forest cover change detection was performed to 1) identify recent harvest sites for field monitoring (see below), and 2) provide overall estimates of forest disturbance by major watershed to provide additional context for field monitoring findings. For monitoring years 2014 - 2018, DNR Forestry Resource Assessment (RA) staff analyzed forest cover change within all major watersheds in Minnesota with greater than 20% forest cover, as determined by National Land Cover Data (NLCD 2011), using Landsat 8 satellite images from summer 2012 – summer 2017 (Figure 3). For all watershed sample units monitored, RA image analysts visually inspected each area of detected forest change using publicly available and in-house aerial imagery to refine the list of sites and modify their site boundaries as needed. All identified areas of canopy change greater than 2.5 acres (1 hectare) in size were considered for monitoring.



Site Selection

A subset of forest cover change sites (confirmed as harvests) were selected for monitoring (Figure 3). Within each WSU, monitoring sites were selected with an effort to represent the relative proportion of harvest activity by ownership categories. In an effort to monitor an adequate number of sites near open water, stratified sampling was used in each ownership category to ensure selection of sufficient sites (50%) with harvest activity within 200 feet of a known open water feature. Monitoring sites were selected from all forest ownership categories. For purposes of this report, the ownerships have been grouped into the following categories:

State: all state owned lands;

County: all lands owned or managed by a county;

Federal: all U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, or Army Corps of Engineers lands;

Forest Industry: owned by Blandin Paper, Potlatch, Molpus Companies, and Minnesota Power and Light;

Nonindustrial Private Forests (NIPF): all privately owned non-industry and tribal lands.

Landowner Contacts

Landowner and/or manager contact was attempted for every potential monitoring site 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 shown in Table 1 and site distribution across the seven MFRC Landscape Regions and fifteen watershed sample units is shown in Figure 4.

In total, 271 harvest sites on public lands were identified for monitoring. In an effort to increase participation by NIPF landowners, a cooperative approach was used to contact NIPF landowners and gain permission to access their sites. GMP collaborated with local foresters in the DNR Cooperative Forest Management Program and with local Soil and Water Conservation Districts (SWCDs) to contact NIPF landowners. These efforts yielded substantially higher numbers of cooperating NIPF landowners (163) compared to past monitoring efforts. Because of the success of this approach, the program has achieved a more representative sample of NIPF sites than it has in past years.

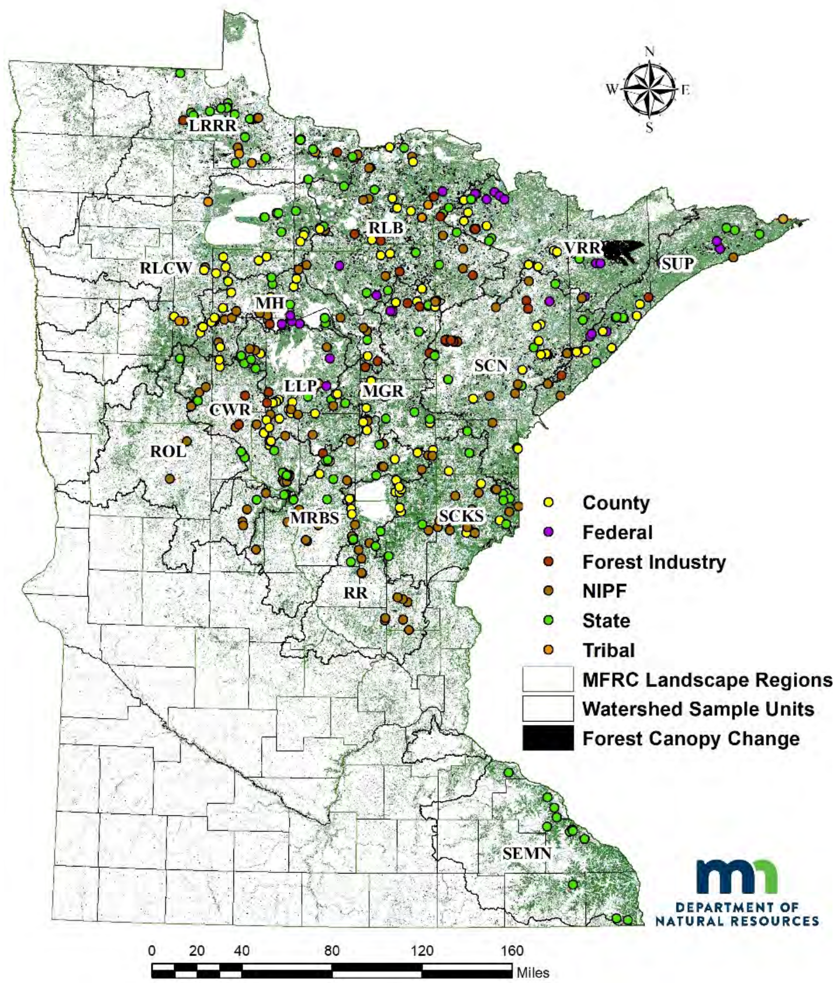


Figure 4. Site ownership and distribution across Minnesota's forested watersheds.

Table 1. Monitoring Sites Tabulated by Ownership and Watershed Sample Unit.

Watershed Unit	County Owned	Federal Lands	Forest Industry	Non-Industrial Private Forest	State Owned	Tribal Forests	Combined Ownerships
CWR	8	0	3	9	11	0	**31**
LLP	11	2	2	11	6	0	**32**
LRRR	1	0	3	3	20	4	**31**
MGR	12	2	3	3	9	0	**29**
MH	12	4	2	11	6	0	**35**
MRBS	8	0	1	17	7	1	**34**
RLB	7	3	5	9	10	2	**36**
RLCW	10	0	0	3	8	3	**24**
ROL	0	0	0	8	7	0	**15**
RR	8	0	0	15	5	0	**28**
SCKS	8	0	0	17	9	0	**34**
SCN	12	1	9	9	6	0	**37**
SEMN	0	0	0	0	12	0	**12**
SUP	8	8	2	3	8	1	**30**
VRR	7	9	3	1	6	0	**26**
Total	***112***	***29***	***33***	***119***	***130***	***11***	***434***

Field Monitoring

GMP staff used monitoring protocols fully described in previous monitoring reports covering the same time period (Rossman et al, 2016 and 2018, Wilson and Slesak, 2020) utilizing the ArcGIS based guideline monitoring application (GMA) software and SurfacePro3 Tablets.

Field monitoring was accomplished through a competitive bid contract. 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. On-site monitoring was conducted June – September, 2014-2018.

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, roads and landings, riparian management zones (RMZs), filter strips, surface water and wetlands, crossings, and others.

Quality Control

Both in-office and in-field review of site data was conducted by the GMP Coordinator on randomly selected 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 additional modification. Where appropriate, changes were made to data based on quality control findings.

Data Management and Analysis

Data management and analysis methods evolved over the course of the 2014-2018 monitoring and reporting cycle. Initially, GMA results were saved as separate Excel spreadsheets for each of approximately 530 unique questions. For monitoring completed from 2014-2016, these spreadsheet based results were used to manually tabulate and summarize results. Starting in 2017, a compiled version of the data became available, providing access to all responses in a single flat table. Additional information related to hydrologic unit, land ownership, MFRC landscape region, county, infrastructure, riparian management zones, and leave tree compliance was associated with records for specific sites. This compilation of data further enabled development of an online reporting application mentioned in the 2018 Guideline Monitoring report (Wilson and Slesak 2020). A preliminary version of the online reporting tool was used as the basis for much of the data analysis and reporting conducted for monitoring completed in 2017 and 2018.

Going forward, the GMA Access database will be discontinued, so ensuring consistency between reporting methods was particularly critical at this stage. A few summaries like riparian management zone implementation, leave tree compliance, and crossings required extra work to ensure accurate reporting. For the most part, this extra work was required in order to summarize multiple linked features across and/or among sites. For example, an open water wetland may be related to multiple riparian management zones implemented on one or more sites. Similarly, leave trees are monitored on sample plots, within clumps, and in riparian management zones. Each type of leave tree occurrence requires a different summarization method followed by combining all data at the site level. These complexities required additional work to create reproducible scripted methodology in the R computing and statistical environment (R Core Team, 2019).

Some minor discrepancies between this and prior reports (particularly for leave trees) are likely the result of differences between scripted and manual analysis methods. Consistent application of the 2012 FMG revisions across all sites monitored may also introduce differences where older standards were used in the original reports.

Hydrogeologic Risk Assessment

A number of factors contribute to overall risk of water quality impacts related to timber harvest. Here, we summarize a variety of physical and hydrogeologic characteristics related to each of our watershed sample units, which may contribute to the potential for sediment and nutrient contribution from harvest sites to surface waters. These characteristics are best viewed as baseline conditions which could influence potential impacts to water quality in the absence of FMG implementation. These factors include percent forest cover within a watershed, soil erosivity, slope, concentration potential for runoff, land use, distance to surface hydrology, and a variety of other factors.

Specific spatial layers used to model and map risk of erosion runoff on a site-level scale across Minnesota include:

- Slope (National Elevation Dataset - NED)
- Soil erosivity (K Factor – SSURGO and STATSGO)
- Flow Accumulating Area (NED)
- Distance to Hydrology, and (NHD, NWI, MNDNR Streams)
- Percent Forest Canopy (National Land Cover Dataset – NLCD 2011)

The factors of slope and flow accumulating area were combined to produce a Stream Power Index (SPI) modified slightly from equations presented in prior research (Moore et al., 1991; Danielson, 2013; Pourghasemi et al., 2013; MNDNR, 2014). Our SPI equation took the form:

$$SPI = \ln(FlowAccumulatingArea + 1) * \ln(Slope + 1),$$

where *FlowAccumulatingArea* is defined by upslope hydrologic catchment area, and *Slope* is measured in degrees.

Slope and soil erosivity were likewise combined to create a slope weighted K factor layer (SWK), describing the inherent tendency for soil particles to dislodge and move with water as amplified (multiplied) by slope.

The SPI and SWK layers were combined to describe the potential for runoff and soil movement across the landscape. These factors were modified by distance to hydrology and percent forest canopy, since distance and vegetative cover tend to reduce delivery of sediment to surface water. The model informing our background risk of runoff to surface water took the form:

$$Risk = \ln\left(1 + \frac{SWK * SPI}{\left(1 + \left(\ln(1 + \%\, Canopy) + \ln(1 + DistanceHydro)\right)\right)}\right).$$

Development of this model followed preliminary work by Jennifer Corcoran (MNDNR – Resource Assessment). The most recent SSURGO data (2015) was used to inform soil erosivity, and was supplemented by STATSGO continental scale data where the most recent update of SSURGO lacked detail.

All geospatial processing and analysis was completed using ArcGIS 10.6.1 Raster Calculator and the Spatial Analyst extension. Preliminary analysis of the digital elevation model (DEM) was completed using the Hydrology toolset. Specific Hydrology tools used include Sink (to identify all sinks and internal drainages), Fill (to fill in sinks and remove small imperfections in the data), and Flow Accumulation (to calculate upstream catchment area). Final and intermediate models were calculated using the Raster Calculator geoprocessing interface.

It is critical to keep in mind that our summaries of the resulting models tend to average conditions across the entire watershed sample unit, while certain conditions may actually be concentrated along stream corridors, steep and narrow valleys, glacial moraine edges, or other physical features present in the watersheds. The series of maps resulting from this analysis shows these factors on a landscape level. Most factors are derived from map layers created at a 30 meter resolution (e.g. pixel size on the ground). Hence, our preliminary hydrogeomorphologic risk model also describes these factors at the 30 meter scale. Here, we provide a summary of background erosion risk for our watershed sample units (Table 6), and a landscape-scale map of our preliminary risk model (Figure 11). Because the risk factor is presented on a logarithmic (*ln*) scale, values present in the data (0 – 7.3) vary in inherent risk of erosion by several orders of magnitude as the risk value increases.

Results

Data from previous monitoring reports may be found on the MFRC website and in Dahlman and Phillips (2004), Dahlman (2008), Dahlman and Rossman (2010), Rossman (2012), and Rossman et al. (2016), Rossman et al. (2018), and Wilson and Slesak (2020).

Land and Water Characteristics by Watershed

The Appendix contains a wealth of information related to the 15 WSUs. Watershed characteristics such as frequency and types of streams and wetlands, lakes, soil erosivity, and slope ultimately relate to the number of harvest sites and influence the need for specific guidelines such as RMZs, filter strips, and erosion control on crossings, etc. Forest cover (including forested wetlands) and surface water extent varied considerably between watershed units (Table 2). A cross-tabulation of watershed units and land cover is provided in Table 3.

Forest cover varied from a high of 84% in SUP to a low of 22% in SEMN. Not surprisingly, SEMN also had the highest percentage of crop/pasture lands at 50%, compared to 1% or less in LLP, RLB, SCN, SUP, and VRR. In terms of water-related features, LLP has the highest percent cover of open water (16.3%) primarily due to surface waters of Leech Lake, followed by MH (14.2%) and VRR (13.6%) with many lakes and ponds contributing to the headwaters of the Mississippi River, and the Boundary Waters chain of lakes, respectively. SCKS and SEMN had the lowest percent cover of open water (1.6% and 1.8%, respectively), but SEMN had much longer total length of rivers and streams (11,896 miles) and the highest proportion of trout streams. The two watershed units with the highest percent cover of emergent and non-open water wetlands are the LRRR and the MRBS units (26.1% and 15.1%, respectively). Watershed units with the lowest percent wetland cover are SUP and SEMN (0.8% and 1.3%, respectively). See the Appendix for more detailed information related to land and water cover, and analysis of the relationship between canopy disturbance and hydrologic features.

Table 2. Land and Water Characteristics by Watershed Sample Unit.

WSU	Total Acres	Acres Forest	Percent Forest	Surface Water (Acres)	% Surface Water	Average Slope (Degree)	Average Slope Weighted
CWR	1,268,960	719,270	56.70%	83,386	2.65%	5.12	1.51
LLP	1,358,855	908,552	66.90%	221,801	9.43%	4.74	1.21
LRRR	3,217,208	1,365,007	42.40%	329,851	4.04%	0.74	0.2
MGR	1,332,791	1,000,237	75.00%	78,424	2.63%	3.88	1.08
MH	1,228,881	825,437	67.20%	174,716	6.16%	4.33	1.09
MRBS	1,732,424	657,348	37.90%	81,173	1.68%	4.3	1.38
RLB	3,096,187	2,564,019	82.80%	189,750	3.85%	3.95	1.16
RLCW	4,015,707	1,329,556	33.10%	361,544	4.33%	2.43	0.66
ROL	2,359,182	666,686	28.30%	236,290	3.48%	5.35	1.81
RR	1,731,190	438,531	25.30%	178,774	4.91%	3.4	0.9
SCKS	1,664,185	1,056,792	63.50%	26,241	0.89%	3.53	1.17
SCN	2,515,879	2,047,949	81.40%	90,119	1.68%	4.13	1.06
SEMN	2,950,817	611,395	20.70%	54,501	0.84%	13.33	3.84
SUP	1,414,893	1,270,569	89.80%	67,797	0.87%	11.13	3.22
VRR	2,269,123	1,828,100	80.60%	308,964	6.59%	9.35	2.8
Total	***32,156,282***	***17,289,447***	***53.80%***	***2,483,330***	***3.30%***	***5.31***	***1.51***

*Slope Weighted K Factor (SWK) is fully described in the Watershed Risk Model section of this report.

Table 3. Land Use Distribution by Watershed Sample Unit (NLCD 2016).

WSU	Agriculture	Barren	Developed	Forest*	Grassland	Open water	Shrub/scrub	Wetland
CWR	130,798	1,376	50,719	676,144	161,028	83,386	26,858	138,637
LLP	14,450	1,032	40,381	899,561	59,117	221,801	20,538	101,980
LRRR	513,751	977	54,468	1,394,819	76,766	329,851	4,859	841,123
MGR	7,566	8,674	37,740	940,707	62,213	78,424	67,624	129,842
MH	30,433	1,364	43,693	797,224	76,149	174,716	24,071	81,269
MRBS	368,020	1,252	87,047	672,380	255,402	81,173	6,181	260,950
RLB	6,061	8,791	50,440	2,449,274	73,086	189,750	156,910	161,743
RLCW	1,594,052	3,905	108,747	1,321,458	135,086	361,544	7,192	483,747
ROL	761,207	3,142	113,876	620,977	312,501	236,290	10,534	300,644
RR	466,543	1,535	137,646	447,288	260,943	178,774	3,019	235,416
SCKS	83,024	1,281	51,804	1,079,423	224,367	26,241	12,071	185,963
SCN	3,651	26,992	91,202	2,046,616	92,155	90,119	87,347	77,793
SEMN	1,481,187	4,379	214,852	657,133	500,348	54,501	1,299	37,146
SUP	558	2,257	40,169	1,190,169	43,142	67,797	59,910	11,082
VRR	28	4,986	28,110	1,717,960	68,232	308,964	109,013	31,474
Total	***5,461,328***	***71,941***	***1,150,896***	***16,911,132***	***2,400,535***	***2,483,330***	***597,427***	***3,078,811***

* Note the slight difference between forested acres identified in the NLCD classification of land use vs. the percent forest canopy analytical/cartographic layer also provided by the Multi Resolution Land Use Consortium (MRLC). The difference arises from a threshold for canopy cover (20% forest cover) used in classifying forest cover for the Land Use layer. Our assessments of forest canopy in other portions of this report (e.g., Table 4) uses the lower 10% classification threshold provided by the analytical forest canopy layer provided separately by MRLC.

Watershed Unit Canopy Disturbance

Changes detected between summers 2012 and 2017 were used to identify sites sampled between 2014 and 2018. Disturbance estimates are depicted visually in Figure 5 and as 5-year totals in Table 4.

Of the 15 WSUs, RLB (3.1 million acres) had the highest number of acres disturbed; 77,611 acres over 5 years. Such high levels of harvest are consistent with the predominantly aspen forest type present in the RLB unit (36%), and increased harvests of tamarack and black ash related to recent insect outbreaks in the region. The SEMN watershed unit (2.95 million acres) had the lowest number of acres disturbed (485 acres).

Although no accuracy assessment has been completed at this time, it is apparent that change detection methods used between 2014 and 2018 only identified approximately half of the total acres affected by timber harvest each year. Statewide (across the 15 WSUs), the average forest canopy disturbance detected between 2013 and 2017 was 83,310 acres per year (roughly 0.45% of the total forested land identified by NLCD). This estimate of disturbance is clearly low, and results partially from our 2.5 acre minimum mapping unit, and partly from exclusion of approximately one million acres of scattered forest land outside of the WSUs. Comparison with USDA-Forest Inventory and Analysis (FIA) figures related to cutting/harvests on forestlands in Minnesota indicates that for the 5-year period ending in 2018, approximately 146,938 acres of clearcut removals occurred annually (USDA-FIA, 2020). Given average annual harvests of 2.95 million cords (MNDNR 2019) reported between 2012 and 2016, this equates to an average yield of approximately 19.5 cords per acre across the state; very close to accepted norms.

Table 4. Forest Canopy Change Summary: 2012-2017.

WSU	Total Acres	Acres Forest	Percent Forest Canopy	Acres Canopy Change	Percent Canopy Change
CWR	1,268,960	719,270	56.70%	10,171	2.48%
LLP	1,358,855	908,552	66.90%	14,575	1.07%
LRRR	3,217,208	1,365,007	42.40%	24,067	1.25%
MGR	1,332,791	1,000,237	75.00%	16,705	0.10%
MH	1,228,881	825,437	67.20%	30,429	0.80%
MRBS	1,732,424	657,348	37.90%	1,658	0.14%
RLB	3,096,187	2,564,019	82.80%	77,611	0.26%
RLCW	4,015,707	1,329,556	33.10%	8,919	0.35%
ROL	2,359,182	666,686	28.30%	3,365	0.02%
RR	1,731,190	438,531	25.30%	4,450	0.22%
SCKS	1,664,185	1,056,792	63.50%	5,796	2.51%
SCN	2,515,879	2,047,949	81.40%	29,639	1.82%
SEMN	2,950,817	611,395	20.70%	485	1.18%
SUP	1,414,893	1,270,569	89.80%	25,700	0.75%
VRR	2,269,123	1,828,100	80.60%	19,463	0.86%
Total	***32,156,282***	***17,289,447***	***53.80%***	***273,033***	***1.58%***

The NLCD threshold for identifying tree canopy cover (10% cover) differs from that used by USDA – FIA (25% canopy), or for land use classification (20% canopy), resulting in the higher estimate of total forested land (18.5 million acres vs. 17.6 million acres). The effect of using a canopy cover threshold in land use classification is also apparent in Table 3 above (NLCD 2016; Jin et al, 2019).

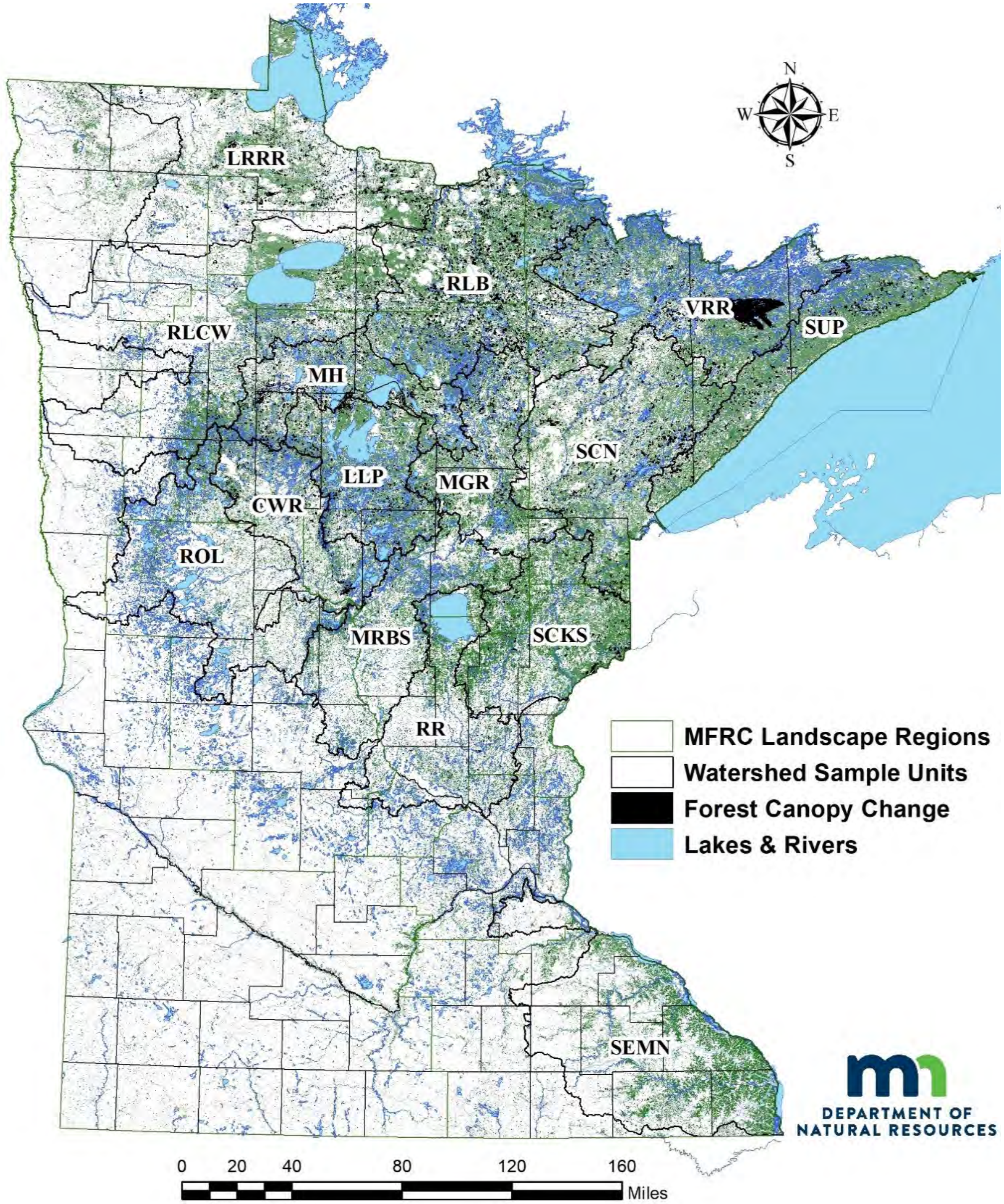


Figure 5. Forest Canopy (green) with Change (black): 2012-2017.

A significant high wind event in Crow Wing County during July of 2016 appears to have contributed substantially to harvest activity in the CWR sample unit. MH also had relatively high forest disturbance compared to the SUP and RR units during the same detection period, due in-part to a high-wind storm event in 2012 causing forest blowdown and subsequent salvage harvesting.

Forest Disturbances and Distance to Water Features

Additional analyses have been done to summarize the relative proximity of forest cover disturbances (2.5 acre minimum mapping unit) to a public waters feature (ex., river/stream, lake/pond, open water wetland; source: the national hydrography dataset - NHD, MN DNR hydrography data layer, and the national wetlands inventory - NWI) (Table 5). For watersheds monitored from 2014 - 2018, the average distance to any hydrologic feature was 544 feet. About 10.8% of all canopy change occurred within 5 feet of a hydrologic feature. 91.5% of all change detected occurred within 0.5 miles of a water feature, underscoring the importance of forest management to maintaining water quality. Histograms of these proximity analyses per watershed unit can be found in the Appendix.

Although the SEMN unit has the highest length of rivers and streams and also the highest slopes and standard deviation of slope, the relative lack of harvest activity means that fewer overall disturbances occur near water features. The watershed unit that has the highest percent of waterbodies (open water) within or nearest to disturbance features is the RR unit, where 18% of the disturbances have a water feature that touches or intersects the boundary of a disturbance and 29% of all RR disturbances are less than 160 feet from a waterbody (the majority of which are streams and open water wetlands).

Table 5. Distance (feet) from Canopy Change Locations (all identified changes) to Hydrologic Features.

WSU	<160	160-639	640-1280	1281-2560	> 2560	WSU Total
CWR	19.1%	18.1%	38.4%	17.6%	6.9%	100%
LLP	16.5%	20.4%	35.4%	19.9%	7.8%	100%
LRRR	22.3%	10.9%	21.4%	22.3%	23.0%	100%
MGR	14.0%	19.8%	38.5%	20.4%	7.2%	100%
MH	11.9%	14.8%	38.4%	24.9%	10.0%	100%
MRBS	8.2%	19.5%	49.1%	19.5%	3.8%	100%
RLB	18.6%	17.3%	34.5%	20.5%	9.0%	100%
RLCW	16.4%	14.8%	36.3%	22.7%	9.7%	100%
ROL	13.6%	21.2%	35.6%	23.5%	6.1%	100%
RR	29.0%	18.0%	37.3%	11.1%	4.6%	100%
SCKS	12.7%	17.7%	40.6%	19.8%	9.2%	100%
SCN	23.3%	19.3%	35.2%	17.5%	4.7%	100%
SEMN	20.7%	24.1%	37.9%	6.9%	10.3%	100%
SUP	22.3%	26.2%	36.8%	13.5%	1.3%	100%
VRR	24.4%	22.1%	32.3%	16.6%	4.7%	100%
Total	***18.4%***	***18.1%***	***35.0%***	***19.8%***	***8.5%***	***100.0%***

As expected based on the land cover characteristics described previously, the units with the next highest percent of disturbances near water features are VRR, SEMN, and SUP (24.4%, 20.7%, and 22.3% respectively are less than 160 feet from a waterbody). The MRBS watershed unit had the fewest disturbances near water features, where only 3.1% of the disturbances have a water feature that touches or intersects the boundary and more that 72% of the disturbances are at least 640 feet away from a water feature.

Hydrogeologic Risk to Surface Water Quality

Figures 6-10 depict a variety of physical and hydro-geologic characteristics which contribute to the potential for sediment and nutrient contribution from harvest sites to surface waters. Together, these characteristics determine baseline conditions which influence potential impacts to water quality across the landscape in the absence of FMG implementation (Figure 11). These factors include:

- Slope Weighted Erosivity (Figure 6-8)
- Slope (Figure 7)
- Stream Power Index (SPI) (Figure 9), and
- Distance to Hydrology (Figure 10).

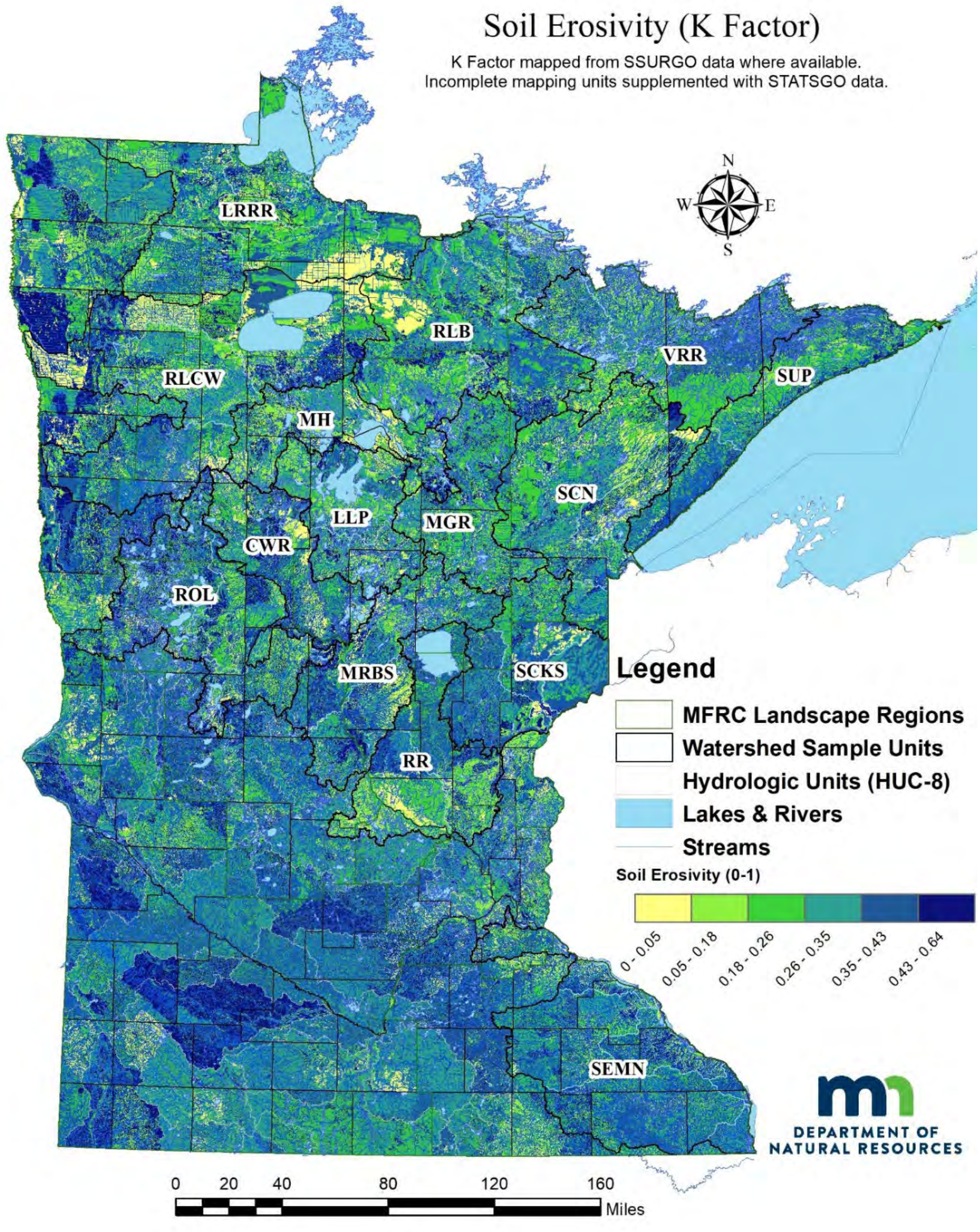


Figure 6. Soil Erosivity (K Factor) (blue is highly erosive, yellow in less erosive) Mapped from SSURGO and STATSGO Data Sources.

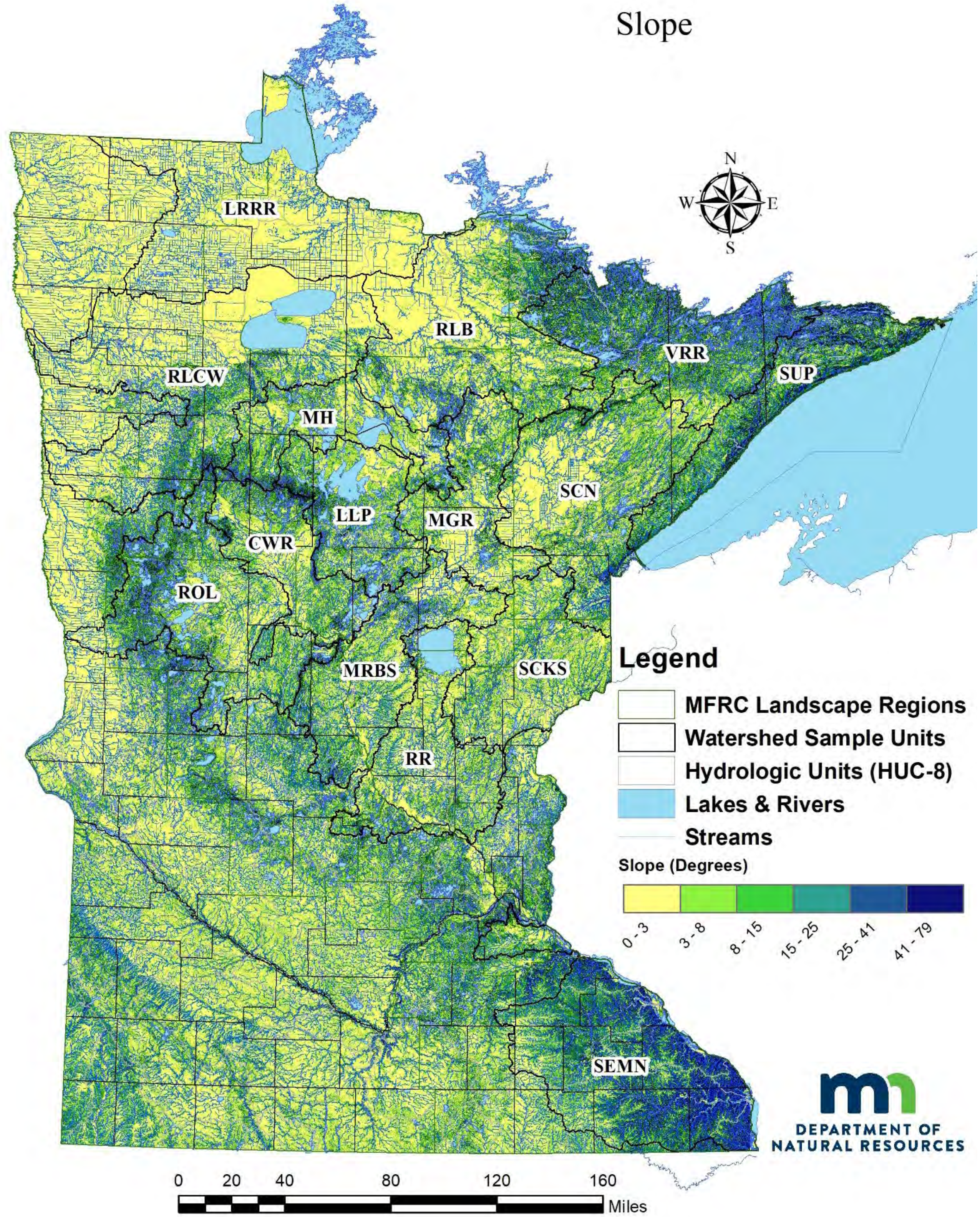


Figure 7. Topographic Slope (blue indicates steep terrain, yellow areas are relatively flat) Mapped from National Elevation Data.

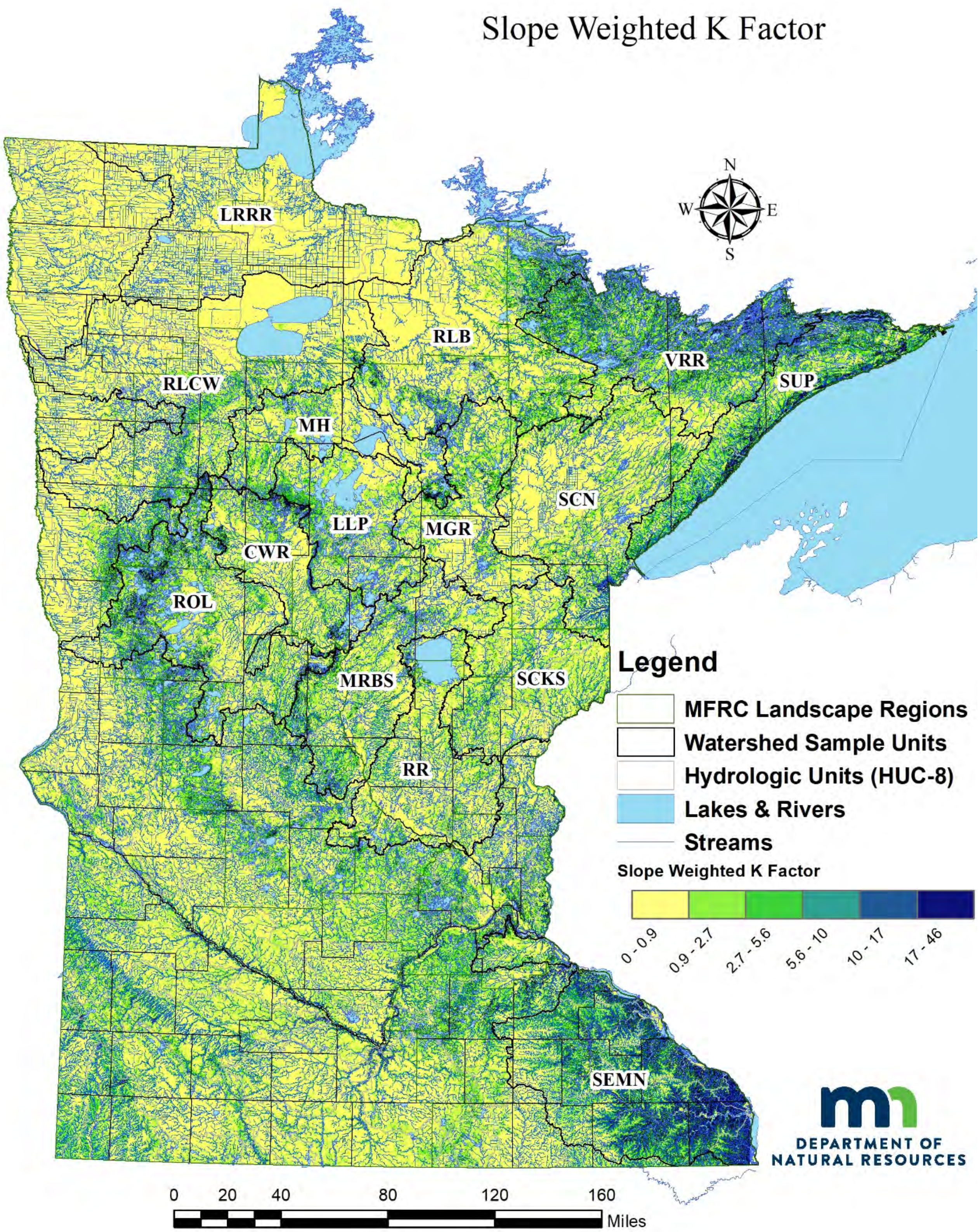


Figure 8. Slope Weighted K Factor (SWK) Combines Effects of Soil Erosivity and Terrain (blue indicates high SWK, yellow indicates low SWK).

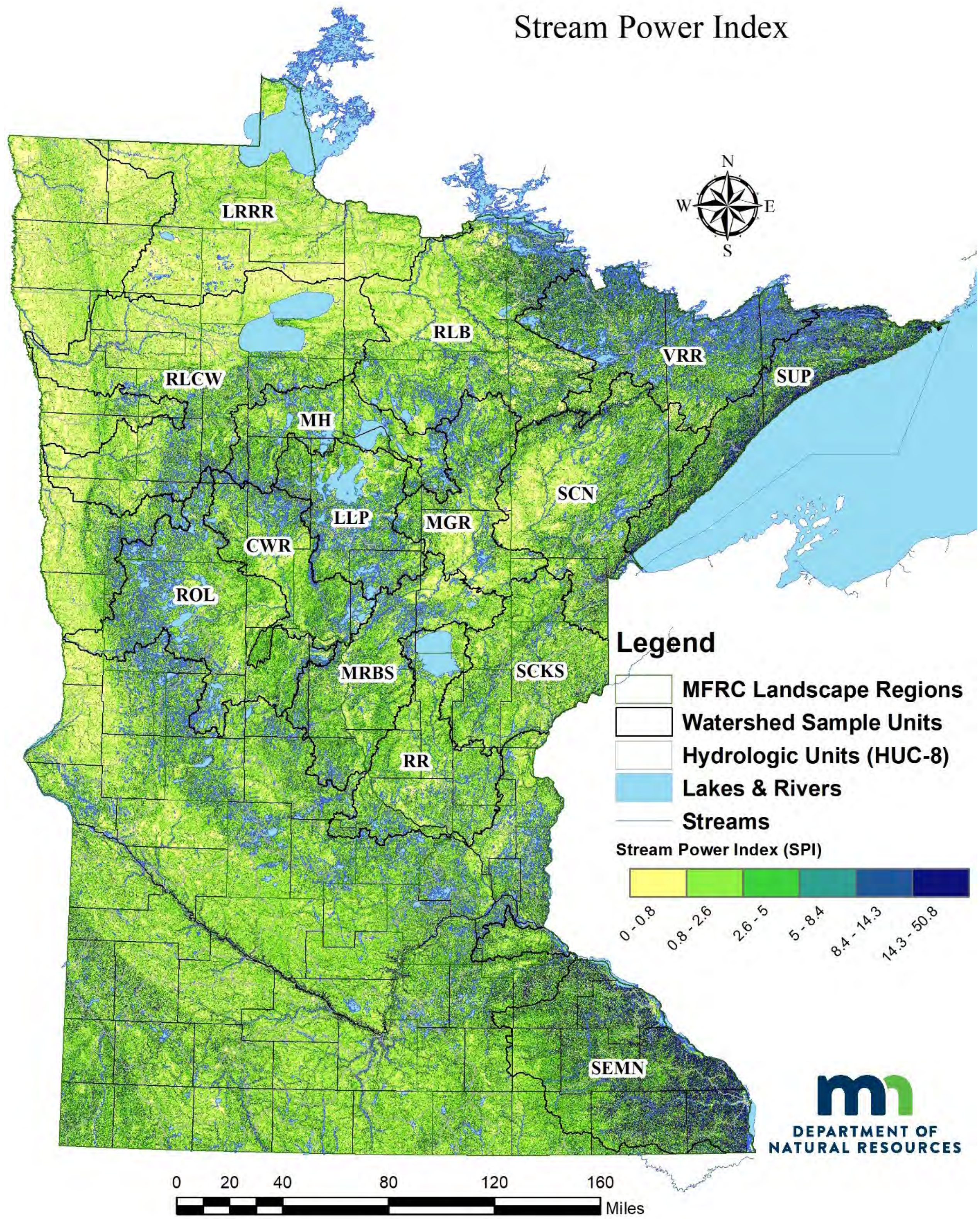


Figure 9. Stream Power Index Uses Flow Accumulation Area and Slope to Identify Areas with High Potential for Overland flow (blue) vs. Low flow Areas (yellow).

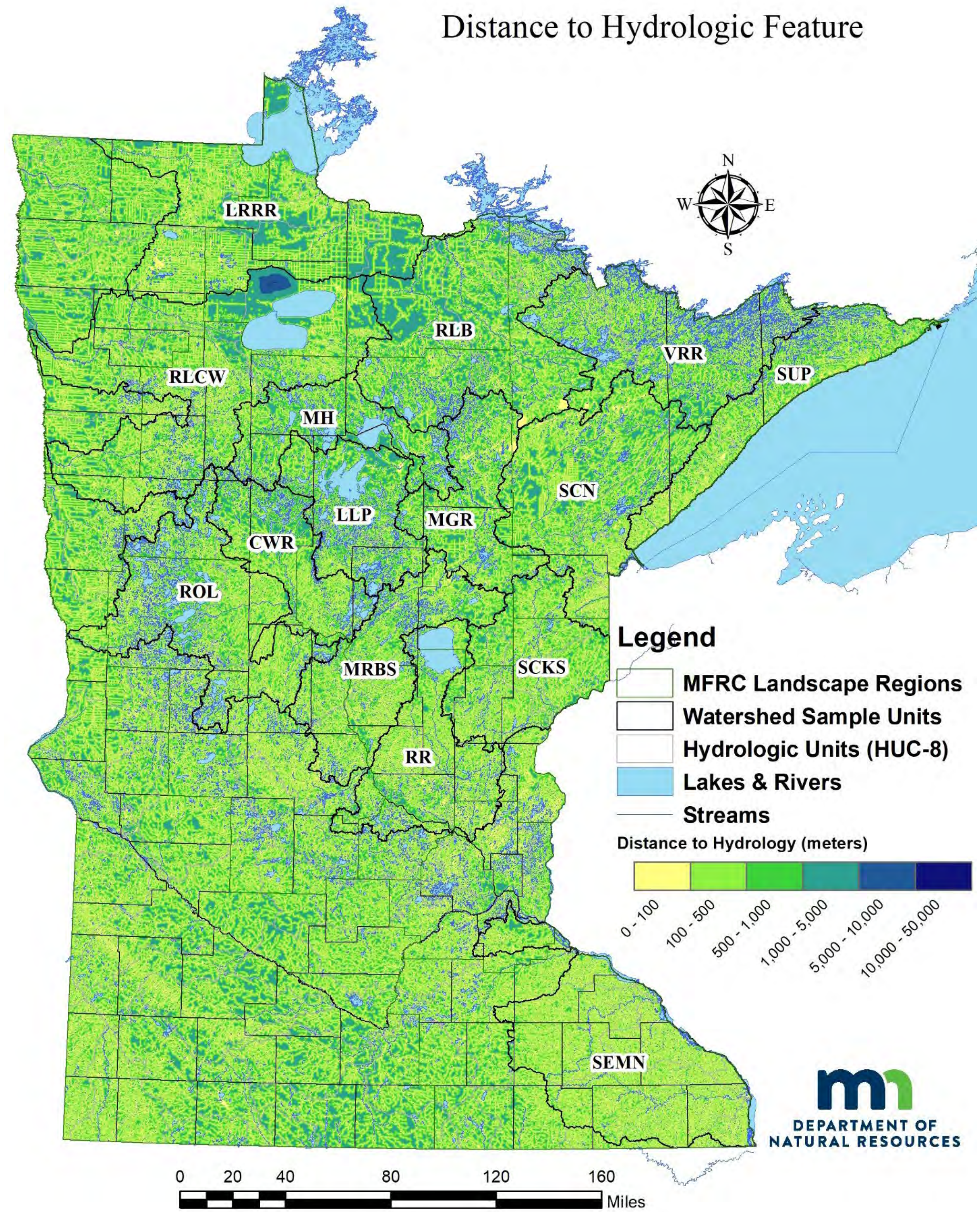


Figure 10. Distance (meters) to Hydrologic Features, Including Lakes, Rivers, Streams, and Wetlands (NWI-2019).

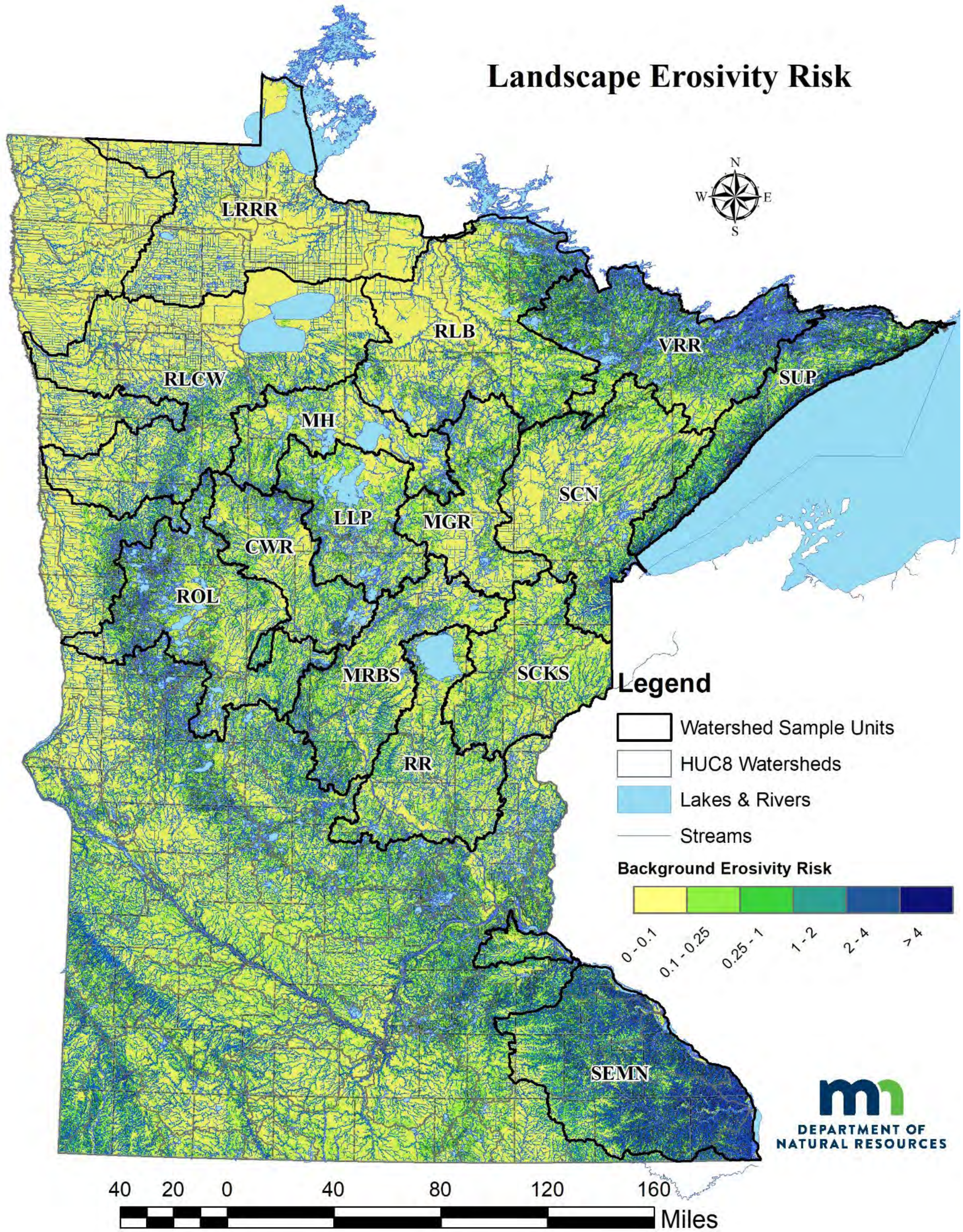


Figure 11. Hydrogeologic Risk of Erosion to Surface Water Quality (blue indicates high risk, yellow indicates low risk) Modeled from Slope, Soil Erosivity, Stream Power Index, Forest Canopy Cover, and Distance to Hydrology (Table 6).

Table 6. Landscape Factors Contributing to Background Runoff Risk to Surface Water Quality Summarized by Watershed Sample Unit (WSU).

WSU	Acres Forest	Percent Forest	Acres Canopy Change	Percent Forest Change	Average Slope (Degrees)	Surface Water (Acres)	% Surface Water	Soil Erosivity Avg (SD, Range)	Background Runoff Risk to Water Quality Avg (SD, Range)
CWR	719,270	56.70%	10,171	2.48%	5.12	83,386	2.65%	0.32 (0.16, 0.62)	0.23 (0.43, 5.81)
LLP	908,552	66.90%	14,575	1.07%	4.74	221,801	9.43%	0.27 (0.15, 0.62)	0.2 (0.39, 5.62)
LRRR	1,365,007	42.40%	24,067	1.25%	0.74	329,851	4.04%	0.28 (0.15, 0.53)	0.04 (0.16, 5.74)
MGR	1,000,237	75.00%	16,705	0.10%	3.88	78,424	2.63%	0.3 (0.14, 0.62)	0.19 (0.39, 6.1)
MH	825,437	67.20%	30,429	0.80%	4.33	174,716	6.16%	0.27 (0.17, 0.62)	0.18 (0.37, 5.88)
MRBS	657,348	37.90%	1,658	0.14%	4.3	81,173	1.68%	0.32 (0.16, 0.62)	0.24 (0.44, 5.76)
RLB	2,564,019	82.80%	77,611	0.26%	3.95	189,750	3.85%	0.32 (0.14, 0.53)	0.2 (0.43, 6.31)
RLCW	1,329,556	33.10%	8,919	0.35%	2.43	361,544	4.33%	0.29 (0.16, 0.62)	0.12 (0.32, 5.95)
ROL	666,686	28.30%	3,365	0.02%	5.35	236,290	3.48%	0.33 (0.16, 0.62)	0.28 (0.51, 5.92)
RR	438,531	25.30%	4,450	0.22%	3.4	178,774	4.91%	0.28 (0.14, 0.62)	0.17 (0.35, 5.67)
SCKS	1,056,792	63.50%	5,796	2.51%	3.53	26,241	0.89%	0.33 (0.13, 0.62)	0.19 (0.36, 6.08)
SCN	2,047,949	81.40%	29,639	1.82%	4.13	90,119	1.68%	0.27 (0.16, 0.62)	0.19 (0.41, 6.36)
SEMN	611,395	20.70%	485	1.18%	13.33	54,501	0.84%	0.31 (0.14, 0.62)	0.64 (0.8, 6.7)
SUP	1,270,569	89.80%	25,700	0.75%	11.13	67,797	0.87%	0.29 (0.12, 0.53)	0.55 (0.71, 7.28)
VRR	1,828,100	80.60%	19,463	0.86%	9.35	308,964	6.59%	0.33 (0.12, 0.53)	0.46 (0.65, 6.16)
Overall	***17,289,447***	***53.80%***	***273,033***	***1.58%***	***5.31***	***2,483,330***	***3.30%***	***0.3 (0.15, 0.62)***	***0.26 (0.45, 7.28)***

The combined information provided by acres of canopy change and background runoff risk can be used to help prioritize watersheds where additional outreach could make real differences to water quality outcomes. Prioritization of FMG implementation at a site level will require additional development and vetting of the risk model (underway). Current implementation rates further inform this prioritization at the watershed scale. A comparison of sampled canopy change relative to total canopy change is provided in Table 7.

Table 7. Harvested and Sampled Acres by Watershed Sample Unit.

Watershed Sample Unit	Monitored Sites	Minimum Acres	Average Acres	Maximum Acres	Standard Deviation	Acres Sampled	Total Canopy Change	Sample Intensity
CWR	31	8.9	35.3	122.6	23.6	1,093	10,171	10.70%
LLP	32	10.2	49	495.4	85.4	1,567	14,575	10.80%
LRRR	31	6.8	41	245.2	43.4	1,270	24,067	5.30%
MGR	29	6	31.8	162.6	32.8	922	16,705	5.50%
MH	35	6.8	33.1	193.1	35.8	1,158	30,429	3.80%
MRBS	34	8	37.4	96.5	25.6	1,270	1,658	76.60%
RLB	36	6.4	38.5	253.6	48.5	1,386	77,611	1.80%
RLCW	24	6.6	32.3	76.4	21.5	774	8,919	8.70%
ROL	15	7.8	25.1	51.1	13.3	376	3,365	11.20%
RR	28	6.3	34.8	392.8	70.9	976	4,450	21.90%
SCKS	34	7.1	82.1	300	69.3	2,793	5,796	48.20%
SCN	37	5.3	70.9	246.5	64.8	2,622	29,639	8.80%
SEMN	12	3.5	25	41	10.8	300	485	61.90%
SUP	30	6.2	41.4	181.3	37.7	1,243	25,700	4.80%
VRR	26	7.5	49.1	177.9	38.6	1,276	19,463	6.60%
Total	***434***	***3.5***	***43.8***	***495.4***	***50.9***	***19,025***	***273,033***	***7.00%***

Although the target sampling rate was approximately 30 harvest sites per WSU, sampling intensity varied substantially by WSU due to large regional differences in forest cover/land use, proximity to timber markets, and resulting harvest intensity. This observation may indicate a need to adjust sample allocation based on observed harvest rates, instead of distributing the sample relatively evenly across watershed sample units. This consideration will need to be weighed against the benefits of additional information related to observation of timber harvests, hydrology, and other factors present in lightly harvested watersheds.

Guideline Implementation

Best management guideline implementation help to mitigate risk of sediment delivery to surface waters, especially in high risk watersheds (Figure 11 and Table 6). Here, we explore and summarize key guideline implementation themes related to water quality, riparian management, leave tree characteristics, wildlife habitat, infrastructure management, visual quality and endangered, threatened, and special concern species.

Waterbody and Wetland Occurrence

One hydrogeologic characteristic of watersheds intimately related to potential impacts of timber harvest on surface water quality is the amount of open water and wetlands related to canopy disturbance (Table 8). Filter strip and RMZs 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. Overall, non-open water wetlands (NOWW) account for 86% of hydrologic features observed on or adjacent to monitored sites. SCKS had more NOWWs on or adjacent to sites (317) than any other watershed unit, followed by LLP (181) and MRBS (153). This frequency of wetland occurrence means that guidelines related to wetland crossings, approaches, and erosion control (e.g. filter strips, road profile management, vegetative cover, and infrastructure placement) will be especially important in these watersheds (Figure 12).

Table 8. Wetland and Surface Water Occurrence in Relation to Monitored Timber Harvest Sites.

WSU	Sites w/Water (n)	Sites w/out Water	Water-bodies (n)	Non-open Water Wetland	Trout Stream	Non-trout Stream	Intermittent Stream	Open Water Wetland	Lake
CWR	18	13	171	**145**	0	3	0	17	6
LLP	26	6	215	**181**	0	9	2	17	6
LRRR	29	2	118	**103**	0	14	1	0	0
MGR	26	3	134	**111**	0	9	2	6	6
MH	29	6	107	**95**	0	0	0	3	9
MRBS	34	0	183	**153**	0	12	3	10	5
RLB	32	4	167	**104**	1	44	16	1	1
RLCW	20	4	108	**105**	0	2	0	0	1
ROL	14	1	42	**36**	0	2	0	3	1
RR	27	1	156	**148**	0	1	0	7	0
SCKS	34	0	335	**317**	0	11	1	4	2
SCN	33	4	161	**109**	3	33	5	0	11
SEMN	9	3	27	**4**	3	20	0	0	0
SUP	29	1	122	**101**	14	5	1	0	1
VRR	26	0	120	**85**	2	26	6	0	1
Total	***386***	***48***	***2,166***	***1,797***	***23***	***191***	***37***	***68***	***50***

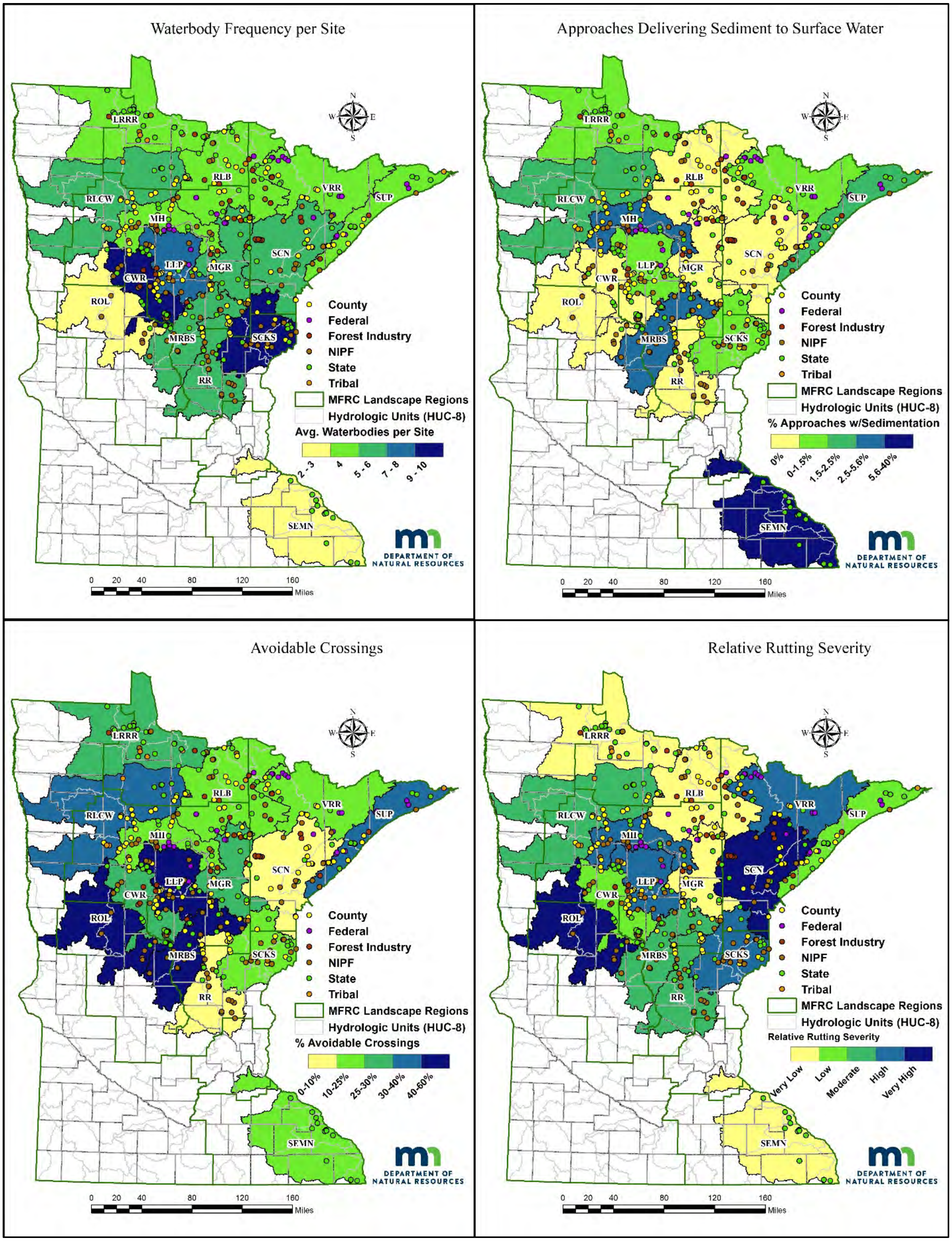


Figure 12. Wetlands, Waterbodies, Approaches, Crossings, and Rutting Best Management Implementation in Sampled Watersheds.

Waterbody Approaches, Crossings, Erosion, and Rutting

A variety of monitoring observations collected on each site relate to the occurrence of waterbodies and wetlands, approaches to these hydrologic features, crossings of these features, and erosion and rutting associated with site infrastructure and management. Here, we provide summaries and additional details related to conditions observed at the site level across sampled watersheds.

Approaches

Recommendations on the use of erosion control (EC) have been a primary component of the forest management guidelines related to maintaining water quality. In particular, use of EC 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. Approaches have a high potential to funnel surface water, sediment, organic debris, and contaminants into the water. Guidelines recommend that water diversion/erosion control practices be installed immediately when approaches are created and then maintained until the location is stabilized.

A total of 1,592 approaches were identified and evaluated by monitoring contractors. The vast majority (94%) of these approaches were in good condition and did not require further EC practices for sediment control (Table 9). Generally, EC 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. The high estimate of approaches not needing EC may reflect high levels of guideline implementation through good selection of crossing locations, or may be associated with the relatively forgiving operating conditions that occur in much of the state (e.g., winter harvesting, relatively level topography, etc.). However, for the 97 approaches where EC was deemed necessary, only 23 (24%) had practices appropriately installed. More importantly, erosion was frequently (59%) observed when EC practices were needed but not installed. Additionally, in 61% of instances when erosion was occurring on approaches to a waterbody (Total Volume = 3,621 cubic feet from 57 approaches), contractors found evidence of sediment reaching the associated waterbody (Table 9). Utilization of soil and slash 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).

These results reinforce the need to emphasize the importance of EC practices on approaches to minimize erosion potential, and a need to identify when EC practices are needed during training programs for loggers, land managers, and landowners. For example, all but one (RR) of the watershed units had sites with approaches needing EC (Table 9). Targeted outreach on how to identify the need for EC installation, and what practices to install, would help to increase guideline implementation and reduce the potential for water quality impacts.

Table 9. Approaches and Erosion Control Implementation.

WSU	Sites w/Approach (n)	Approaches (n)	Approaches Needing Erosion Control	Approaches With Erosion Control	Approaches With Erosion	Approaches With Sediment to Waterbody
CWR	10	48	1	1	0	0
LLP	12	66	6	2	3	1
LRRR	19	205	2	0	2	2
MGR	19	91	6	3	1	0
MH	20	161	12	0	12	8
MRBS	21	108	9	0	8	6
RLB	24	131	4	0	1	0
RLCW	12	48	3	0	2	1
ROL	4	12	2	2	0	0
RR	18	87	0	0	0	0
SCKS	29	220	6	0	6	2
SCN	19	58	3	2	1	0
SEMN	5	20	11	5	8	8
SUP	21	203	13	0	7	5
VRR	20	134	19	8	6	2
Total	***253***	***1592***	***97***	***23***	***57***	***35***

Water Quality Segments

During the monitoring field assessments, contractors documented segments of roads and skid trails with steep slope and longer lengths that had potential for erosion to occur. For the majority of these segments, contractors simply documented whether erosion was occurring or not. For those segments near wetlands or surface water that have a higher potential to impact water quality compared to other portions of the harvest site, contractors collected more detailed data. Because of their proximity, these "water quality (WQ) segments" may impact water quality if EC practices are not properly installed.

Only a small number of sites (11.8%) had WQ segments present, which may reflect proper locating of roads and skid trails away from wetlands and surface water. However, similar to approaches, those WQ segments that needed EC installed generally did not have it and the occurrence of erosion in those situations was common (Total Volume = 6,896 cubic feet from 67 WQ segments) (Table 10). Most WQ segments occurred on skid trails, likely due to challenges associated with logging operations in warmer winters for sites with many NOWW. Although erosion is more commonly observed on WQ segments than on approaches, delivery to a water body is lower than documented for approaches because WQ segments are not a direct conduit to wetlands and waterbodies like approaches are. Although there is clearly a need to focus efforts on improving EC use in general, the overall small number of times that sediment reaches a wetland or waterbody from approaches and WQ segments limits water quality impacts associated with forest harvesting.

Table 10. Water Quality Segment, Erosion Control, and Sediment Delivery Summary.

Watershed Sample Unit	Total Sites (n)	Sites w/ Segments (n)	Segments (n)	Segments With Erosion Control	Segments With Erosion	Segments With Sediment to Waterbody
CWR	31	3	6	1	5	0
LLP	32	1	5	5	2	1
LRRR	31	0	0	0	0	0
MGR	29	6	10	3	6	1
MH	35	9	16	0	16	0
MRBS	34	7	10	0	9	1
RLB	36	2	2	0	1	0
RLCW	24	1	3	1	3	0
ROL	15	1	2	0	1	0
RR	28	2	3	0	3	0
SCKS	34	5	14	0	13	3
SCN	37	0	0	0	0	0
SEMN	12	4	9	7	4	0
SUP	30	3	5	1	1	0
VRR	26	7	13	8	3	0
Total	***434***	***51***	***98***	***26***	***67***	***6***

Crossings

Crossings are sections of roads or skid trails, and in some instances landings, where equipment crosses a wetland or waterbody. Logging equipment crossings are the forest management features that have the greatest potential for disturbing wetlands and waterbodies. The majority of crossings (61%) occurred as a result of skid trials traversing a hydrologic feature.

One of the key guidelines to avoiding impacts to wetlands and waterbodies is to avoid crossings whenever practical. Contractors were asked to determine whether a crossing could have been avoided without unreasonable costs or reduced safety. Contractors reported that overall 27.4% of observed crossings could have been avoided (Table 11), with most instances due to skid trails crossing NOWWs (85.4% of all skid trail crossings). Only 6.6% of all crossings observed were related to streams.

In 2016, 2017, and 2018, contractors recorded reasons why crossings might have been avoided. In total, 120 of the 219 avoidable crossings were documented in this manner. Of the fully documented avoidable crossings, 93 were observed in situations where the operator could have easily driven around a wetland (i.e. where logging operators cut across the tip of a wetland rather than driving fully around), or crossed small isolated wetlands that could easily have been avoided. Of the remaining avoidable crossings, 25 occurred where contractors judged that there were two or more crossings where one crossing would have been sufficient. Improved avoidance of unnecessary crossings will reduce wetland impacts and improve overall guideline implementation.

All watershed sample units except SCN had avoidable crossings identified. The ROL, MRBS, and LLP sample units had 57%, 54% and 42% of all crossings identified as avoidable, respectively (Table 11). Remaining sample units had from 10-37% of crossings identified as avoidable. This highlights a continuing need for focused outreach addressing the importance of avoiding crossings and techniques for identifying wetlands. A continued focus on wetland identification and avoidance of unnecessary crossings would serve to leverage existing outreach resources while producing real water quality benefits.

Table 11. Total Crossings, Stream Crossings, and Wetland Crossings Observed on Monitored Sites.

Watershed Sample Unit	Total Sites (n)	*Crossings (n)	Stream	Wetland / Peatland	Average Length (feet)	Avoidable (n)	% Avoidable
CWR	31	24	3	21	119.1	7	29.2%
LLP	32	33	6	25	62.4	14	42.4%
LRRR	31	104	0	104	193.9	29	27.9%
MGR	29	45	0	38	236.8	13	28.9%
MH	35	78	0	76	85	19	24.4%
MRBS	34	54	4	50	80.5	29	53.7%
RLB	36	67	12	53	200.9	7	10.4%
RLCW	24	24	0	24	269.7	9	37.5%
ROL	15	7	1	6	82.9	4	57.1%
RR	28	42	0	41	181.4	4	9.5%
SCKS	34	114	5	108	160.9	28	24.6%
SCN	37	29	6	21	230.4	0	0.0%
SEMN	12	10	1	1	211.3	2	20.0%
SUP	30	99	4	94	127	37	37.4%
VRR	26	69	11	55	194.8	17	24.6%
Total	***434***	***799***	***53***	***717***	***162.5***	***219***	***27.4%***

*Crossings of beaver ponds, open water wetlands, seeps and springs, and dry washes are not shown separately, but are included in the total count of crossings shown here. Seasonal ponds are counted in the wetland column.

Rutting

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 tears the root mat when the soil is not strong enough to support the vehicle load.

The presence or absence of rutting ≥6 inches deep was recorded for a variety of features. In previous reports we have focused on the occurrence of rutting by various feature types (such as crossings, approaches, landings) across all sites. For this report, we also assessed the cumulative amount of rutting identified on all features of sites including the general harvest area.

When evaluated at the site level, rutting is clearly focused on a minority of monitored sites and minor amounts when compared to the entire site (14% of sites had rutting > 6" deep) (Table 12).

From the watershed perspective; some rutting occurred in all watersheds. The number of sites with rutting ranged from one each in CRW, SCN, and SEMN, to eight in MGR and ten in MH. The MFRC has established no guidelines related to the percent rutting on a site or specific features on a site. Guidelines recommend avoiding rutting through careful planning related to season of operation and monitoring of day to day conditions. However, a relative rutting severity measure is presented in Table 12 (0 = Low Severity, 6 = High Severity). Anecdotally, operations on sites with rutting at multiple feature locations (especially in general harvest area) likely occurred because operating conditions, including season of harvest and hydro-geomorphological risk, were conducive to rutting. In these situations, guidelines recommend changing operations or curtailing operations until conditions improve.

Table 12. Rutting Distribution and Severity on Monitored Sites.

WSU	Total Sites (n)	Rutted Sites (n)	Non-open Water Wetland	Crossing	Landing	Skid Trail	Road	Rutted Features (n)	Average Percent of Feature Rutted	Rutting Severity*
CWR	31	1	0	1	0	0	0	1	30	**0.97**
LLP	32	2	3	3	0	1	0	7	30.7	**3.36**
LRRR	31	5	2	4	0	1	0	7	11.4	**0.51**
MGR	29	8	1	3	2	3	3	12	7.4	**0.38**
MH	35	10	6	18	2	0	2	29	37.7	**3.12**
MRBS	34	3	1	4	0	0	0	5	48.3	**2.37**
RLB	36	4	3	3	0	1	0	7	5	**0.24**
RLCW	24	6	1	2	0	2	4	9	28.2	**1.76**
ROL	15	2	1	2	0	0	0	3	45	**4.5**
RR	28	2	2	1	0	0	0	3	33.7	**1.81**
SCKS	34	5	4	4	1	1	2	12	44.5	**3.14**
SCN	37	1	0	2	0	0	1	3	75	**6.08**
SEMN	12	1	0	0	0	1	0	1	0	**NA**
SUP	30	7	0	13	2	0	1	16	10.9	**0.83**
VRR	26	4	0	8	0	1	1	10	33.4	**3.21**
Total	***434***	***61***	***24***	***68***	***7***	***11***	***14***	***125***	***29.41***	***2.15***

* Relative rutting severity is calculated as:

$$\frac{\left(\frac{Rutted\ Features}{Rutted\ Sites}\right)(\%\ Feature\ Rutted)}{Total\ Sites}$$

Filter Strip Use and Performance

Filter Strip Implementation

The function of a filter strip adjacent to a waterbody is to trap and filter out suspended sediment, and potential pollutants attached to sediment, before it reaches surface water and wetlands. 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 as long as the integrity of the filter strip is maintained and mineral soil exposure is kept to a minimum (MFRC 2012). The guidelines recommend limiting soil disturbance to less than 5% dispersed soil exposure throughout the filter strip. Concentrated soil exposure is to be avoided. Guidelines further recommend locating landings, roads and other infrastructure outside of filter strips in order to maintain the integrity or functionality of the filter strip.

During field monitoring, detailed filter strip information including location is recorded for only those filter strips where contractors observed disturbance(s) that potentially resulted in a compromised filter strip function. All other filter strips are counted and labelled as meeting guideline recommendations and summarized at the site scale. Of 2,312 total filter strips (Figure 13) observed across sites, detailed filter strip data were recorded for 387 filter strips that triggered expanded data collection. Most (82.6%) filter strips for which detailed observations were recorded were located adjacent to NOWW, 12.3% were adjacent to streams, and only 5.1% were adjacent to OWW.

For all filter strips recorded, 2.6% had exposed mineral soil within the filter strip at the time of monitoring visits, with most of these due to presence of roads or landings within the filter strip. Only 0.26% of filter strips (six strips) had erosion occurring within the filter strip, resulting in sediment being deposited into the adjacent wetland (Total Volume = 60 cubic feet) (Table 12). Overall, 97.4% of filter strips met the minimum disturbed soil recommendations of no concentrated soil exposure or less than 5% dispersed soil exposure. However, infrastructure placement reduced overall compliance on filter strip implementation to 83.3%; mostly due to placement of landings, skid trails, or roads within the filter strip (often with an alternative upland site available).

The RR and CRW watershed sample units had over 90% compliance with filter strip guidelines. LRRR, SEMN, and VRR had lower compliance (52-67%), and may demonstrate either difficulties with filter strip implementation in steep landscapes (SEMN), landscapes composed substantially of NOWW (e.g., LRRR and VRR), or differences in weather related soil conditions, timing of harvest among units, or filter strip management practices among WSUs.

Filter Strip Performance

- Of 2,312 filter strips monitored:
  - 387 (16.7%) had problems,
  - 6 (0.26%) resulted in sediment delivery to surface water.
- Problem Examples:
  - Landing in filter strip (242)
  - Road in filter strip (62)
  - Skid trail in filter strip (60)
  - Erosion in filter strip (6)
  - Sediment deposited into wetland or waterbody (6)

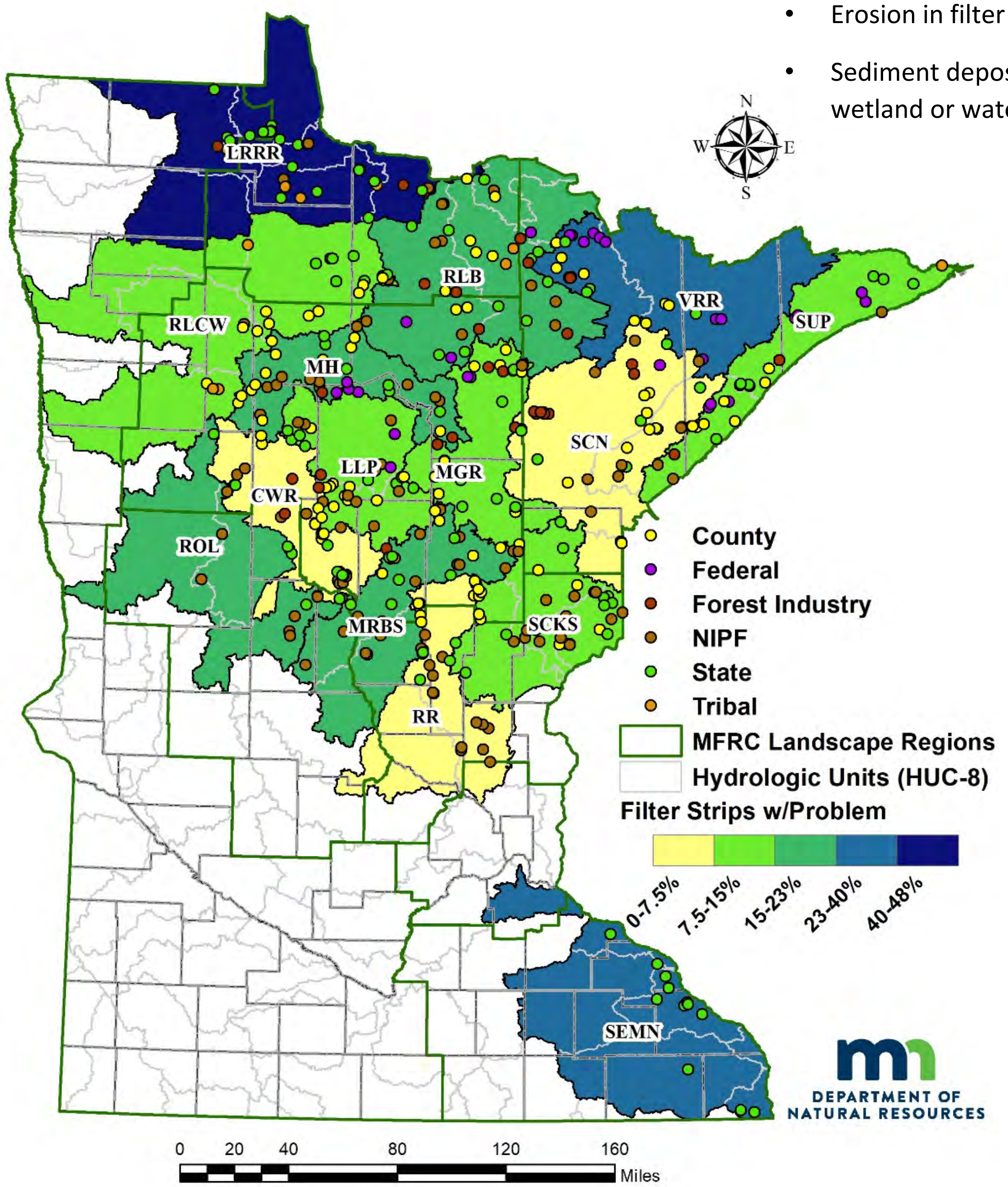


Figure 13. Filter Strip Use and Performance in Monitored Watersheds.

Table 13. Filter Strip Performance, Soil Exposure, Erosion, and Sediment Reaching a Waterbody.

WSU	Filter Strips (n)	Strips w/ Soil Exposure	Strips w/ Landing & No Soil Exposure	Road or Skid Trail on Strip	Strips w/ Erosion	Strips w/ Sediment to Waterbody	Percent Compliant*
CWR	170	1	8	8	0	0	92.4%
LLP	218	7	14	21	1	1	87.2%
LRRR	151	4	39	22	0	0	51.7%
MGR	139	2	9	3	2	1	89.2%
MH	126	5	9	7	0	0	81.7%
MRBS	178	8	12	11	4	3	82.6%
RLB	172	4	24	7	0	0	80.2%
RLCW	114	0	11	2	0	0	88.6%
ROL	43	0	7	5	0	0	76.7%
RR	162	0	3	0	0	0	98.1%
SCKS	350	7	35	13	2	1	86.6%
SCN	163	0	6	0	0	0	96.3%
SEMN	30	3	1	7	1	0	66.7%
SUP	149	6	7	7	0	0	85.2%
VRR	147	13	24	15	1	0	59.9%
Total	***2,312***	***60***	***209***	***128***	***11***	***6***	***83.3%***

*Compliance calculation includes some problems not summarized here. These conditions include issues like pre-existing infrastructure, slash piles, or windrows placed on the filter strip, or repeated rutting. Additionally, more than one issue can exist for a given filter strip, further modifying calculated compliance rates.

On-site Infrastructure

Equipment traffic can compact and rut soil. It can also damage or remove vegetation and associated root systems, which 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). The FMGs recommend:

- *Sites less than 20 acres should have 1 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.*

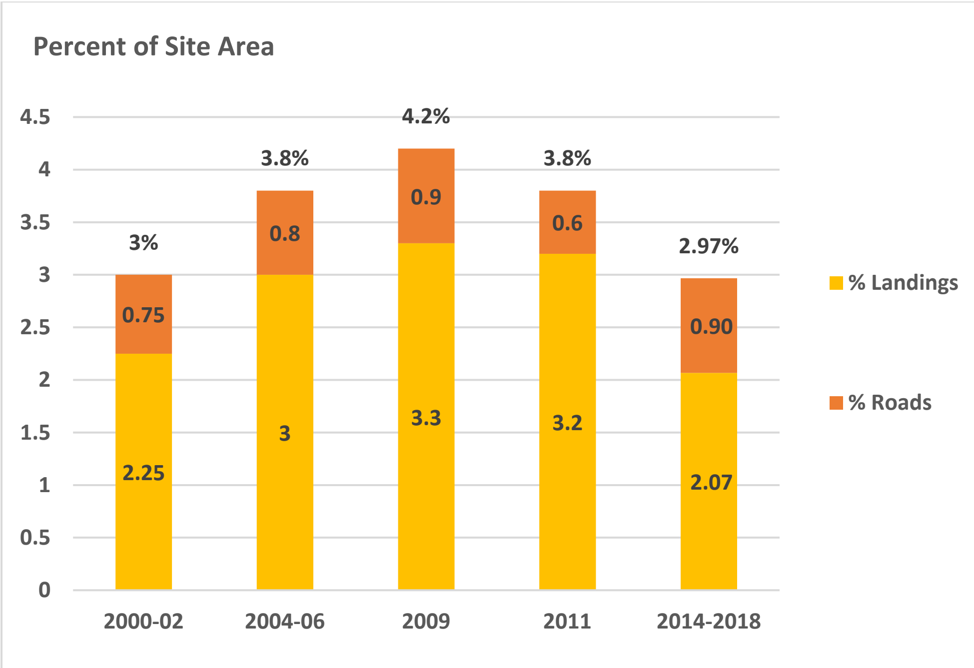


Figure 14. Percent of Site Area Occupied by Infrastructure Statewide (2000-2018).

Monitoring contractors determined total on-site infrastructure by measuring area occupied by landings and roads within the site. The estimated mean infrastructure per site is 2.97% (Figure 14), reflecting a decrease in infrastructure since the reported high of 4.2% in 2009. The variability in percent infrastructure from past reports appears to occur primarily in landing infrastructure, with road infrastructure remaining relatively stable ranging from 0.6 to 0.9 percent while percent landing infrastructure has ranged from a high of 3.3% to a low of 2.07%. Mean on-site landing area per site in this reporting period is 0.79 acres. Mean on-site road acreage for this period is 0.39 acres (Table 14).

From a watershed perspective: The mean percent infrastructure by watershed sample unit ranged from a low of 0.3% in SEMN to a high of 5.4% in LRRR. The LRRR watershed sample unit had both the highest mean acres of sites in landings, and the third highest in roads. SEMN had the lowest amount of acres in landing and roads. These two sample units represent very different terrain and challenges for managing landings. While sites in SEMN are frequently located on steep terrain, or in narrow valleys, with cropland occupying most flat ground, the LRRR is nearly level topography dominated by wetlands and offering few good landing opportunities. Further, due to the flat landscape and frequency of winter harvests in LRRR, infrastructure tends to sprawl across the site. Additional effort should be made to limit the footprint of on-site infrastructure in this watershed unit.

Overall, 78.6% of sites monitored from 2014-2018 met the recommended infrastructure amounts based on 2012 guidelines (Table 14). When comparing on-site infrastructure with site size, compliance was highest for larger than average sites. Compliance was lowest for sites less than 24 acres. Mean site size (41.8 acres) was smaller for watersheds summarized in this report compared to the long-term average (55 acres), but overall compliance was similar.

Table 14. Infrastructure Installation, Percent Area, and Compliance with Guideline Recommendations on Monitored Sites.

Watershed Sample Unit	Total Sites (n)	Sites w/ Infrastructure (n)	Average Acres	Standard Deviation	Total Acres	Average Infrastructure Acres	Average Landing Acres	Average Road Acres	Percent Compliant
CWR	31	26	35.3	23.6	1,093	0.92	0.67	0.25	**83.9**
LLP	32	31	49	85.4	1,567	1.8	1.4	0.4	**71.9**
LRRR	31	30	41	43.4	1,270	2.22	1.63	0.59	**45.2**
MGR	29	24	31.8	32.8	922	0.79	0.46	0.33	**82.8**
MH	35	31	33.1	35.8	1,158	1.27	0.67	0.61	**74.3**
MRBS	34	29	37.4	25.6	1,270	1.1	0.78	0.31	**73.5**
RLB	36	35	38.5	48.5	1,386	1.66	1.05	0.61	**55.6**
RLCW	24	23	32.3	21.5	774	1.01	0.58	0.43	**83.3**
ROL	15	11	25.1	13.3	376	0.38	0.34	0.05	**93.3**
RR	28	16	34.8	70.9	976	0.41	0.28	0.13	**96.4**
SCKS	34	32	82.1	69.3	2,793	2.16	1.41	0.75	**67.6**
SCN	37	33	70.9	64.8	2,622	1.32	0.77	0.56	**94.6**
SEMN	12	5	25	10.8	300	0.08	0.05	0.03	**100**
SUP	30	24	41.4	37.7	1,243	1.04	0.66	0.38	**80**
VRR	26	24	49.1	38.6	1,276	1.53	1.05	0.48	**76.9**
Total	***434***	***374***	***41.8***	***50.9***	***19,025***	***1.18***	***0.79***	***0.39***	***78.6***

Landing Location

In addition to limiting the area occupied by landings within reasonable safety and operational limits, FMGs recommend locating landings outside of wetlands, filter strips, and RMZs to maintain water quality, even in winter operations. Operating on landings under frozen conditions reduces the potential for some impacts, 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 that often occurs on landings, increases the potential to place contaminants directly into frozen wetland surfaces. Reduced vegetation growth on landings can last for decades, and will occur regardless the harvest season (Slesak and Kaebisch 2016).

Overall, 406 landings (30.5% of total) were located at least partially in a wetland (primarily NOWWs) or filter strip (Table 15). In addition to documenting landing locations, 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. In 2017-2018, software/ hardware limitations precluded responses related to landing location, and none were judged to have upland locations available for placement. Additional facets of the landing location data are exposed here (Table 15, Table 16, and Table 17).

Table 15. Landing Location and Monitoring Year: Upland Site (US) or Wetland/Filter strip/RMZ (WFR).

Watershed Sample Unit	Monitoring Year	Total Sites (n)	Total Landings (n)	Landings in WFR (n)	# in WFR Where US available	% WFR where US available	% Sites w/landing in WFR where US available
CWR	2017	31	72	12	NA	NA	NA
LLP	2018	32	125	13	NA	NA	NA
LRRR	2017	31	199	75	NA	NA	NA
MGR	2015	29	95	30	15	15.79	37.9
MH	2014	35	137	22	15	10.95	22.9
MRBS	2016	34	25	25	13	52	35.3
RLB	2018	36	157	47	NA	NA	NA
RLCW	2015	24	73	20	13	17.81	45.8
ROL	2018	15	30	6	NA	NA	NA
RR	2014	28	48	14	10	20.83	32.1
SCKS	2016	34	49	45	35	71.43	67.6
SCN	2017	37	99	18	NA	NA	NA
SEMN	2016	12	3	3	0	0	0
SUP	2014	30	85	9	6	7.06	16.7
VRR	2015	26	135	67	41	30.37	61.5
Total	***2014-2018***	***434***	***1,332***	***406***	***335****	***25.14***	***35.53***

* Total number estimated from percent of observation in 2014-2016 with landings placed in wetland (NOWW) or filter strip (FIS) where upland sites were available.

The SCKS and LLP sample units had the highest total number of waterbodies observed on or adjacent to monitoring sites (Table 15 and Figure 15) as well as the highest mean number per site. Comparatively, ROL and SEMN had the lowest total number of wetlands and waterbodies on sites (43 and 17, respectively) as well as the lowest per site mean. The RLB sample unit had the greatest number of landings located within wetlands or filter strips (47). However, the SCKS unit had the highest percentage of sites located in wetlands or filter strips (92%). Interestingly, LLP and SUP had the lowest percentage (10% in each unit) of landings located in wetlands, waterbodies or filters strips. It appears that while the density of surface water and wetlands may influence the relative times when landings are located in a wetland or filter strip, local practices and operational norms may also play a role in implementation of BMPs related to landing location. For example, on landscapes with wetlands covering most sites, it may be considered 'normal' to place landings partially or completely on these features during frozen ground conditions.

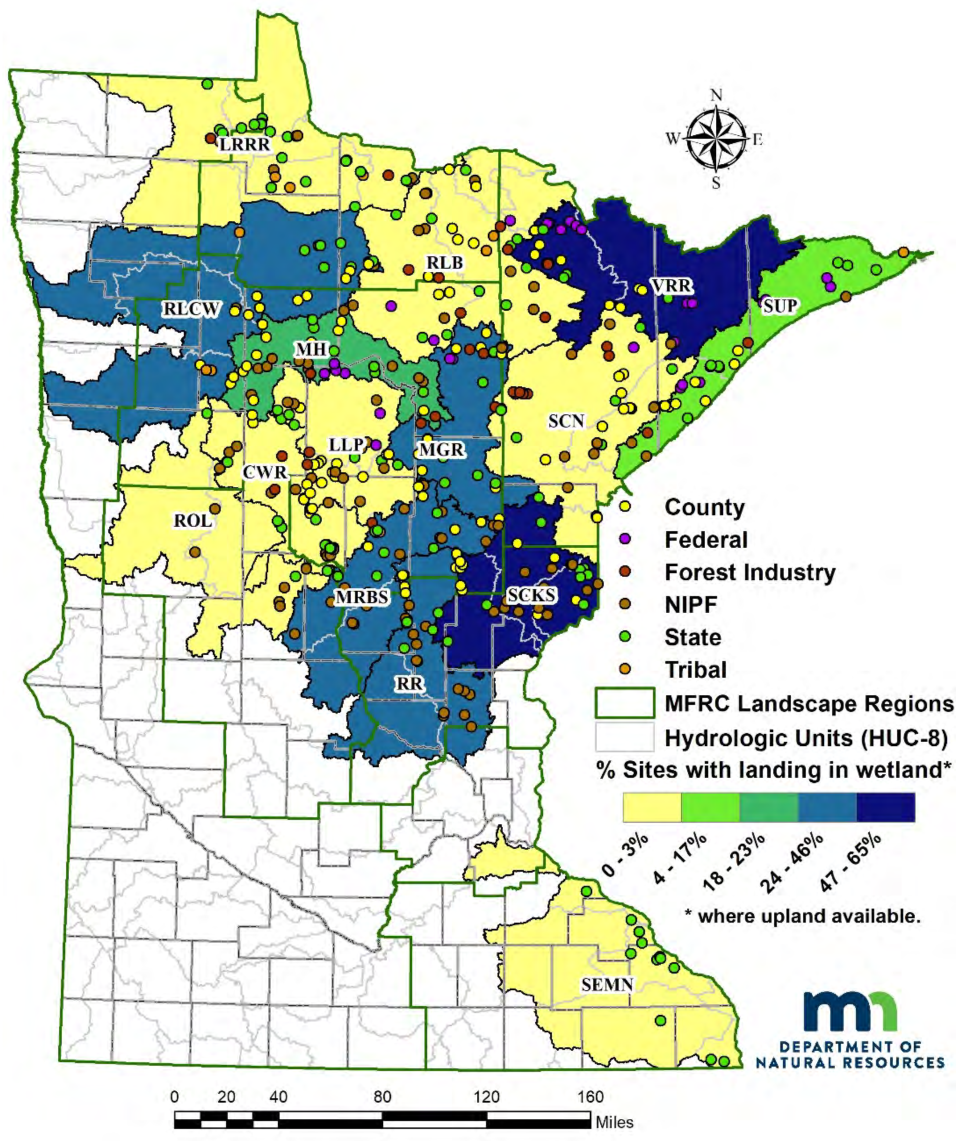


Figure 15. Distribution of Sites with Landings in Wetland or Filter Strip Where an Upland Site was Available.

Table 16. Distribution of Landing Placement (2014-2018).

Placement	# Landings	Percent
Open field	2	0.15%
Grass opening	1	0.08%
Old gravel pit	1	0.08%
Pasture	4	0.30%
Upland	919	68.99%
Wetland	153	11.49%
In filter strip	243	18.24%
Within RMZ	9	0.68%
Total	***1,332***	***100%***

For 2014-18 an overall implementation rate of 75% for locating landings outside of wetlands and filter strips when possible was observed. From past reports, and as made apparent in Table 16, it is clear that the most common (over half) avoidable situation was when landings were located in filter strips. When evaluating this information at the site scale (Table 15), 35.5% of all sites had at least one landing located in a filter strip or wetland where an alternative upland location was deemed available, indicating a site compliance rate of 64.5%. Several sites had multiple landings with only one in, or partially within a wetland or filter strip.

It is unknown if landing location is related to ability to identify wetlands under variable harvest conditions, watershed characteristics, or harvest site planning and operations. Outreach addressing wetland identification tips and the importance of locating landings away from wetlands and waterbodies would likely improve implementation of this guideline in all watersheds.

Table 17. Ownership Distribution for Sites with Landings in Wetland or Filter Strip.

Ownership	Total Sites (n)	Total Landings (n)	% in NOWW/ FIS where upland available	% Sites with LND in NOWW/FIS w/upland available
County	112	338	14.5	23.2
Federal	29	110	9.1	20.7
Forest Industry	33	138	5.8	12.1
NIPF	119	266	15.4	26.9
State	130	427	8.7	19.2
Tribal	11	53	5.7	18.2

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 recommendations for RMZs are based on type and size of waterbody, with a standard recommended residual basal area of 60 ft^2 for all types. RMZ compliance for this report was based on the 2012 revised guidelines, thus results may differ slightly from previous reports using older 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)
- Undisturbed forest (no apparent harvest)
- Partially harvested forest (harvest retained partial canopy)
- Clear-cut (for remaining recommended RMZ width)

Compliance was based on the combined width of non-forest, undisturbed forest, and partially harvested forest (where reserve trees met the BA recommendations) from the water's edge landward. Basal area compliance was evaluated for all but the clear cut area and is based on the minimum recommended basal area of 60 ft^2. RMZs meeting 95% or more of recommended width and basal area are within the margin of error and considered compliant. 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 243 RMZs were identified on or adjacent to 166 sites monitored from 2014-2018 (Table 18 and Figure 16). Overall, 175 of 243 (72%) RMZs fully met the guideline recommendations for width and basal area of forest retention. Another 18.4% of sites with RMZs implemented an average of 75% of the recommended RMZ width and/or BA. From a watershed perspective, compliance for RMZ implementation is highest for the ROL watershed sample unit. ROL provided a small sample (5 sites with RMZs), but had 100% compliance on all RMZs adjacent to OWWs and streams (Table 18). The LLP, SUP, SCN, and MH units also had high rates of guideline implementation for riparian management (> 80%). The RR, VRR, LRR, MGR, RLB, and SEMN units had lower rates of riparian BMP implementation (<70%). Outreach including the importance of RMZ management methods may improve awareness and implementation of RMZ guidelines in these sample units.

RMZs provide direct shade to streams and lakes as well as shade 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 streams was 87%, while compliance on lakes was 79%, and 72% on non-trout waters (Table 19).

Table 18. Riparian Management Zone Implementation in Monitored Watershed Units.

WSU	Sites (n)	Sites w/RMZ (n)	RMZs (n)	Average RMZ Width (ft)	Average Guideline Width (ft)	Totally Compliant	Partially Compliant	Mean Partial Compliance*
CWR	31	12	24	180	216	75%	12%	57%
LLP	32	15	25	182	209	80%	12%	92%
LRRR	31	13	14	137	151	64%	36%	78%
MGR	29	13	16	231	257	69%	19%	60%
MH	35	9	14	277	286	86%	14%	83%
MRBS	34	13	17	251	268	76%	24%	71%
RLB	36	15	18	128	160	50%	22%	82%
RLCW	24	4	4	142	155	75%	25%	82%
ROL	15	5	7	189	196	100%	0%	0%
RR	28	4	9	-	50	22%	44%	73%
SCKS	34	11	16	214	229	81%	12%	67%
SCN	37	22	30	280	286	87%	13%	78%
SEMN	12	2	3	191	243	67%	33%	52%
SUP	30	16	17	169	171	88%	12%	87%
VRR	26	12	29	193	227	48%	24%	66%
Overall	***434***	***166***	***243***	***196***	***218***	***71.6%***	***18.4%***	***74.9%***

*Average level of compliance with width and BA recommendation on partially compliant sites. (Partial Compliance * Mean Partial Compliance = Weighted Partial Compliance)

Table 19. Riparian Management on Lakes, Trout, and Non-trout Waterbodies in Monitored Watershed Units.

WSU	Sites (n)	RMZs (n)	Percent Trout Compliance	Percent Non-Trout Compliance	Percent Lake Compliance	Percent Total Compliance
CWR	31	24	0	75	70	75
LLP	32	25	100	80	100	80
LRRR	31	14	0	64	0	64
MGR	29	16	0	69	67	69
MH	35	14	0	86	85	86
MRBS	34	17	67	76	67	76
RLB	36	18	50	50	100	50
RLCW	24	4	0	75	0	75
ROL	15	7	0	100	100	100
RR	28	9	0	22	0	22
SCKS	34	16	0	81	100	81
SCN	37	30	100	87	100	87
SEMN	12	3	67	67	0	67
SUP	30	17	92	88	100	88
VRR	26	29	100	48	43	48
Overall	***434***	***243***	***87***	***71.6***	***78.6***	***71.6***

RMZ compliance across ownerships was similar, ranging from 82% for state ownership, to 60% for NIPF/Tribal. Federal compliance with RMZ guidelines was 79%, County was 71%, and Industry was 69%. When taking into consideration partial compliance (<95%, but >50% compliance with width and BA recommendations), 18.4% of sites had some level of RMZ implementation; with a mean partial compliance of 75% of recommended width in those instances. Fully and partially compliant RMZs accounted for 90% of all RMZs that were monitored over 2014-2018.

Guidelines also recommend retention of coarse woody debris (CWD) within RMZs where partial harvest is occurring (Table 20). For 144 sites that conducted partial harvest (but still retained > 60BA) within RMZs, 78 retained four or more CWD/acre within the RMZ as recommended by the guidelines. Of the remaining 66 sites, 47 did not retain any CWD within the partially harvested area of the RMZ, and 19 retained fewer than the recommended four logs per acre. 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. See the section on slash, coarse woody debris, and snags (page 49) for additional assessment of this important consideration at the site and watershed scales.

Table 20. Riparian Management Zone Descriptive Statistics.

WSU	Sites (n)	RMZs (n)	Residual Basal Area* (SqFt)	Coarse Woody Debris (n/Acre)	Width (ft)	Average Guideline Width (ft)	Average Width (ft) of Stream	Average Lake/ OWW Acres
CWR	31	24	52	28	180	216	10	3
LLP	32	25	71	33	182	209	20	6
LRRR	31	14	52	32	137	151	21	0
MGR	29	16	44	14	231	257	9	8
MH	35	14	45	1	277	286	0	52
MRBS	34	17	42	3	251	268	231	8
RLB	36	18	96	10	128	160	17	0
RLCW	24	4	30	28	142	155	8	38
ROL	15	7	94	1	189	196	42	0
RR	28	9	-	-	-	50	6	0
SCKS	34	16	36	4	214	229	13	3
SCN	37	30	66	4	280	286	18	159
SEMN	12	3	64	28	191	243	16	0
SUP	30	17	55	9	169	171	12	18
VRR	26	29	28	27	193	227	7	0
Overall	***434***	***243***	***55***	***15***	***196***	***218***	***31***	***29***

*Residual basal area is calculated as the average of remaining basal area on the forested, partial cut, and non-forested portions of the RMZ. Thus, the average residual BA may appear to be less than the recommended 60 square feet while still meeting guideline recommendations.

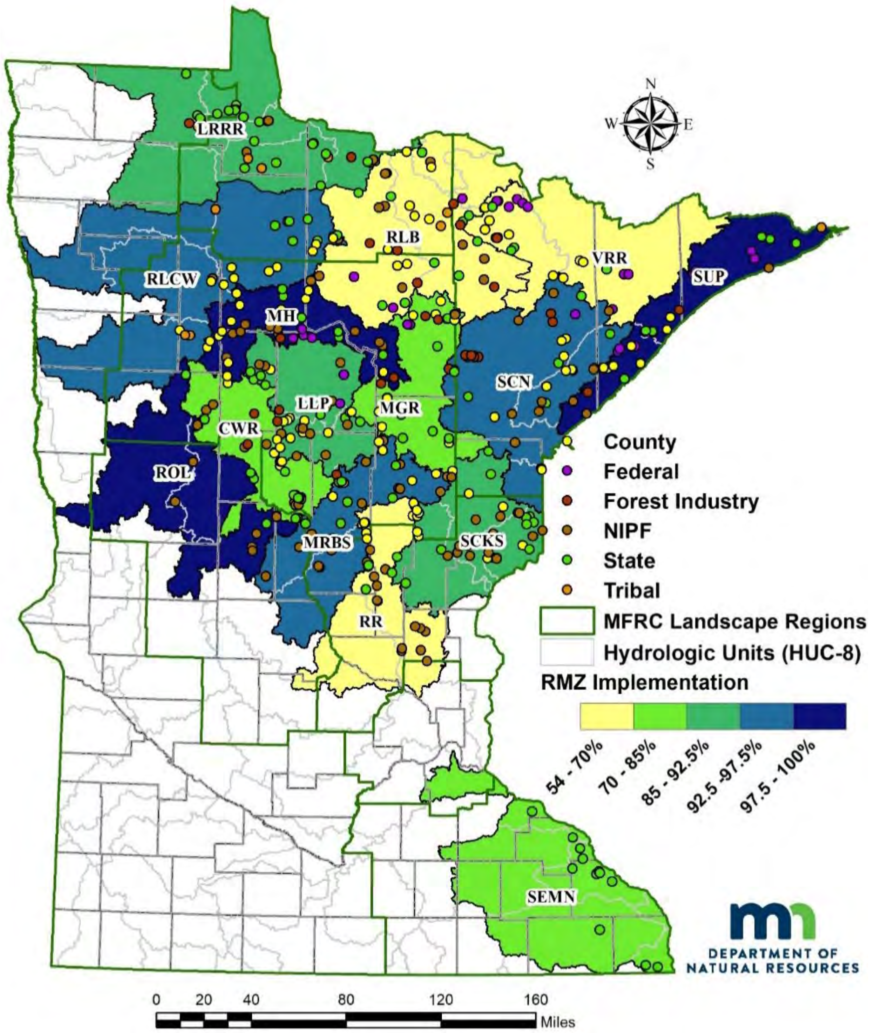


Figure 16. Riparian Management Zone Implementation (Total Compliance + Weighted Partial Compliance) in Monitored Watershed Units.

Wildlife Habitat and Forest Regeneration

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 6-12 scattered individual trees greater than 6” diameter at breast height (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.

Table 21. Management Strategies Applied at the Site Level (Multiple Selections Allowed).

Observed site harvest method?	Count
Clearcut (All strategies combined)	373
Group selection	3
Seed tree	2
Shelterwood	8
Single tree selection	11
Thinning (All strategies combined)	19
TSI	1
Salvage/Sanitation cut	19
Conversion to pasture	1
Total Treatments Observed	***434****

*Three sites were observed with multiple treatments applied.

In both cases (scattered and LTC) leave trees should be at least six inches DBH. Due to enhanced wind firmness and more favorable wildlife habitat characteristics, leave tree clumps are the preferred method and ideally would be located on site; however, areas adjacent to a harvest may be considered in evaluating leave tree acreage. 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. Scattered leave trees are evaluated on a sample plot basis, using a number of ½ acre circular plots dependent on the size of the harvest site. Total scattered leave trees per acre is then calculated as $TPA = \frac{\sum trees}{0.5*n}$, where *trees* includes all trees counted on all plots and *n* is the number of plots sampled on the site.

Overall, 357 sites were evaluated for implementation of the leave tree guidelines. Of the remaining 77 sites, 44 were managed with selection harvests, thinning, seed tree, or shelterwood strategies (Table 21). These silvicultural prescriptions retain abundant vertical structure and were therefore not evaluated for leave tree guideline compliance. An additional 19 sites involved salvage or sanitation harvests, so leave tree guidelines were not applied. Sixteen sites indicated no leave trees were retained due to a silvicultural or safety reason, and applied an exception to the leave tree guidelines (Table 22). Overall, 335 of the 357 sites to which leave tree guidelines applied (93.8%) had adequate leave trees remaining on site. Of the 22 sites with fewer leave trees than recommended, 11 sites had between 75% and 95% of

Table 22. Reasons Cited for Exception to Leave Tree Guidelines.

Reason for Leave Tree Exception	Sites
No Exception Applied (Clearcut sites only)	357
Forest insects and diseases (e.g., dwarf mistletoe on black spruce, bark beetles).	4
Operator safety (e.g., loggers, aerial spray applicators).	1
Fire Damage Salvage	3
Lakes, homes, cabins. Black spruce stands extended buffer areas	1
Small sale area	1
Wind damage/blow down	1
Public safety (e.g., hazard trees near rights-of-way, recreation sites, airports).	1
Specific forest management applications (e.g., genetic considerations for seed).	4
Total Sites Considered for Evaluation (Clearcut Sites)	***373***
Total Sites Not Considered for Evaluation (Non-Clearcut Sites)	***61***

Table 23. Watershed Scale Compliance with Leave Tree Guideline Recommendations.

WSU	Total Sites (n)	Total Acres	Sites w/Leave Tree Retention (n)	Scattered Leave Trees per Acre (n)	Percent of Site in Leave Tree Clumps	Percent of Site in RMZ	Percent Net Compliance
CWR	31	800	22	5.01	5.45	12.24	96.1
LLP	32	1,449	28	6.08	8.01	6.93	96.1
LRRR	31	1,059	26	5.29	5.51	6.71	82.9
MGR	29	922	27	2.79	2.05	7.85	86.6
MH	35	981	30	28.11	2.05	6.17	97.8
MRBS	34	882	26	8.15	5.12	9.36	95
RLB	36	1,323	30	5.79	2.7	7.1	96.1
RLCW	24	746	23	9.41	3.97	2.96	100
ROL	15	272	10	7.47	10.2	2.86	100
RR	28	342	17	19.72	3.3	2.16	97.8
SCKS	34	2,021	25	6.63	4.53	3.65	87.7
SCN	37	2,578	34	2.59	3.65	14.4	96.2
SEMN	12	263	9	10.58	2.09	4.37	100
SUP	30	872	22	7.58	5.04	12.35	97.1
VRR	26	1,196	24	3.6	6.73	9.65	92.6
Total	***434***	***15,708***	***353***	***8.6***	***4.7***	***7.2***	***93.8***

the recommended trees retained. In total, 353 evaluated sites had some level of leave tree retention. The weighted average (weighting by site acres) of net compliance per WSU is shown in Table 23.

Overall, 73% of sites met the retention guidelines utilizing leave tree clumps and/or RMZs alone or in combination. The use of scattered leave trees alone accounted for compliance on 70% of sites. Many sites met the guideline for leave tree retention in multiple ways (LTCs, RMZs, and/or Scattered). The increase in reported utilization of leave tree clumps is likely due to the revisions made to the guidelines in 2012 that widened RMZs and included forested portions of RMZs as qualifying for the 5% goal of LTC retention. Of the 163 sites that utilized the LTC strategy, 142 fully met the guideline via RMZs and 106 fully met the guideline via stand-alone LTCs. Thirty one sites fully met the guideline via both methods, and 4 required a combination of the two (scattered leave trees not considered). The inclusion of the generally wider RMZs as qualifying leave trees has substantially increased the number of sites meeting the guideline via leave tree clumps. In total, 127 sites retained less than 5% of the site in LTCs, but met leave tree guidelines by also retaining scattered leave trees.

At the watershed scale, rates of full leave tree guideline implementation on sites ranged from a high of 100% in RLCW, ROL, and SEMN to a low of 83% in LRRR (Table 23 and Figure 17).

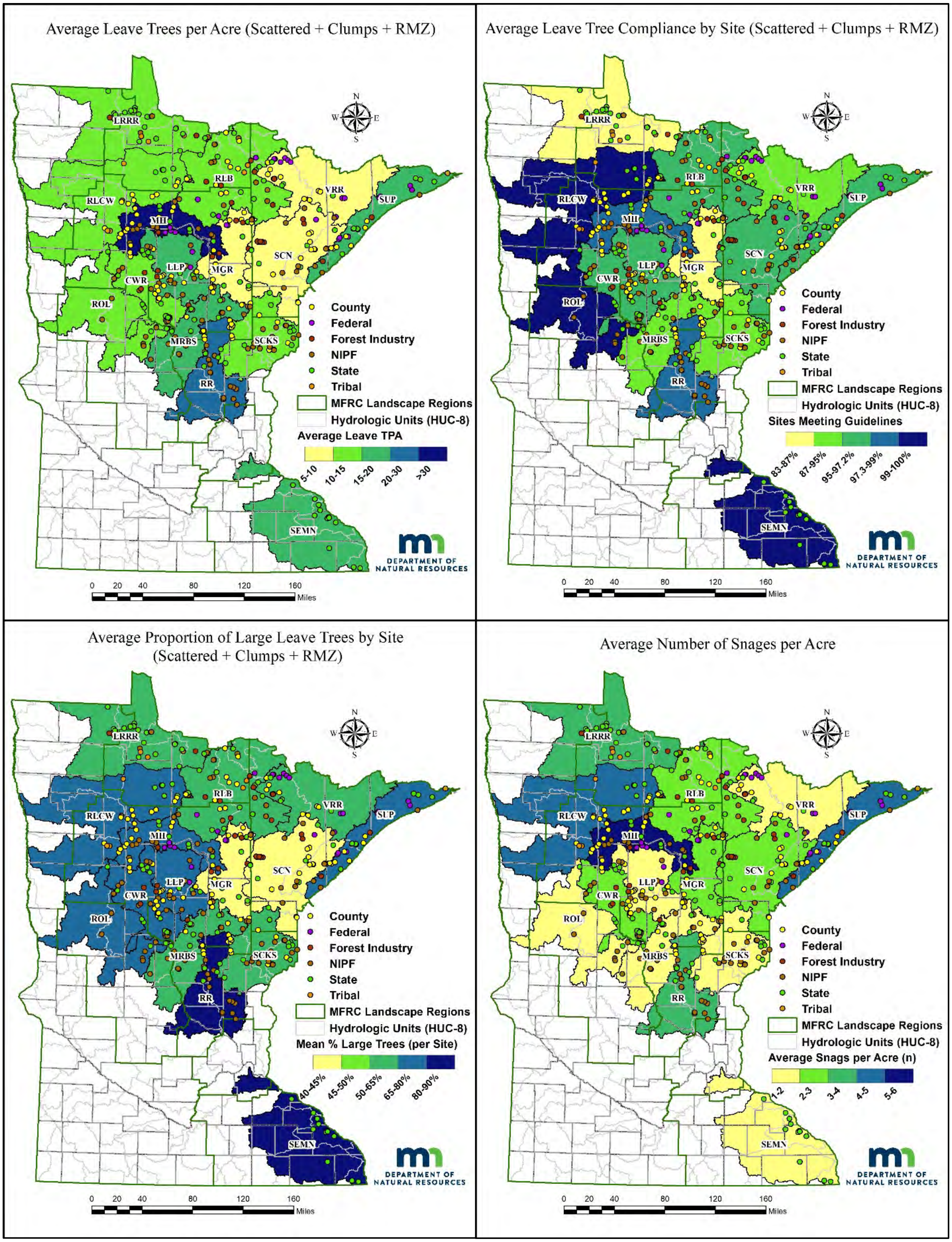


Figure 17. Watershed Sample Unit Distribution of Leave Tree and Snag Retention and Compliance.

Leave Tree Clump Characteristics

Contractors identified and evaluated 543 leave tree clumps (LTCs) on 244 sites during this monitoring cycle.

Blowdown occurred in only 12% of LTCs (66 of 543 clumps) with an average of 6.9% of trees within LTCs being impacted. In comparison, blowdown affected 8.1% of scattered leave trees on 143 sites (33% of sites) where blowdown of scattered leave trees was reported. A non-parametric Wilcoxon/Mann – Whitney Rank Sum Test (Mann and Whitney, 1947; Wilcoxon, 1945) indicates that there is a significant difference in percentage of leave trees experiencing blowdown within clumps vs scattered leave trees on sites. Scattered leave trees are approximately 39.5% more likely to experience excess blowdown over the level found in leave tree clumps. However, this comparison may be clouded by differences in spatial scale when comparing between sites and clumps. In future monitoring, this comparison will be made on a sample plot basis.

Although LTCs are preferred for wind firmness, the preference for LTCs for wildlife is not so straight forward. While small mammals may be more common in LTCs, the preference for clumps vs. scattered leave trees differs for various bird species (Grinde et al., 2020). For example, the golden-winged warbler appears to prefer scattered LTCs, but species like the chestnut-sided warbler and American redstart are more common in clumps with more mature trees.

In this reporting period, contractors also noted when LTCs were used to protect or enhance sensitive feature on the harvest site. Approximately half of the LTCs were used to protect or enhance another feature. Almost 83% of LTCs used to protect another feature were associated with non-open water wetlands by being located in or around these features (Table 24).

Guidelines recommend that a mix of species is desirable for retention as leave trees and that preference should be given to particular species for their longevity, wind firmness, cavity potential and value to wildlife species, recognizing that it is necessary to work with what is available on a particular site. Table 25 shows the frequency of the most common mature tree species identified in LTCs. Eight of the top ten species listed as the most common species found in a LTC are ranked as having excellent or good value to wildlife. 33% of the LTCs had aspen in the top five most common species in the LTC, possibly reflecting recent outreach emphasizing the importance of retaining aspen for den habitat. Several species including paper birch, black ash, red maple, and white cedar are frequently found in LTCs but not as frequently as the main species in the LTC. Other common species included white pine, burr oak, white spruce, basswood, tamarack, sugar maple, northern red oak, elm, and jack pine.

Table 24. Use of Leave Tree Clumps for On-site Feature Protection.

Protected Feature	Count	Percent
Lake/pond	1	0.70%
Non-open water wetland	115	82.70%
Open water wetland	5	3.60%
Steep slope	6	4.30%
Stream/river	7	5.00%
Visual quality corridor	5	3.60%
Total	***139***	***100.00%***

Table 25. Leave Tree Clump Species Distribution and Wildlife Value.

Species	# of LTCs with Species as Most Common	# of LTCs with Species in Top 5	% of LTCs with Species Present	Wildlife Rating for Tree Species
Aspen	106	179	28.96	Excellent
White Cedar	92	101	16.34	Good
Elm	90	99	16.02	Excellent
Black Ash	79	119	19.26	Excellent
Jack pine	73	88	14.24	Fair
Red pine	35	76	12.3	Good
N. Red Oak	28	87	14.08	Excellent
Black	16	32	5.18	Fair
Red maple	15	122	19.74	Good
Sugar maple	14	80	12.95	Excellent
Paper birch	13	138	22.33	Fair
White pine	13	22	3.56	Excellent
White Ash	8	12	1.94	Excellent
Balsam Fir	8	57	9.22	Fair
White	7	29	4.69	Good
Basswood	5	35	5.66	Excellent
Tamarack	4	15	2.43	Good
Hickory	3	9	1.46	Good
Pin Oak	3	12	1.94	Excellent
Other	3	12	1.94	N/A
Balm of	1	11	1.78	Excellent
Burr Oak	1	23	3.72	Excellent
Tag alder	1	1	0.16	Excellent
Black cherry	0	10	1.62	Excellent
Hackberry	0	1	0.16	Good
White oak	0	8	1.29	Excellent

Slash, Coarse Woody Debris, and Snags

Coarse woody debris (CWD) provides important habitat for forest animals, plants, fungi, and micro-organisms, and contributes important elements to forest soils (Harmon et al., 1986). The FMGs recommend creating or retaining two to five bark-on down logs (pieces >6 ft. long and > 6 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 96% of the time (Figure 18). High compliance results may be partially due to a change in plot measurement protocols in 2014 for CWD which includes large branches as CWD rather than just logs (boles). Slash or fine woody debris (FWD) retained on harvest sites further helps to sustain soil productivity, and also provides habitat for small mammals, amphibians, and other organisms. Guidelines recommend practices that allow for dispersed slash on the site if it does not conflict with management objectives, rather than piling slash. The distribution of sites retaining slash and FWD on biomass harvest is shown in Table 26.

Half of the sites monitored fell into the range of 16-53 pieces of CWD/ acre in the general harvest area, with a weighted average of 36.5 pieces of CWD per acre. From the watershed perspective, sites in the LRRR (Avg. = 66 logs per acre), RLCW (Avg. = 80 logs per acre), MH (Avg. = 67 logs per acre), and VRR (Avg. = 51 logs per acre) sample units appeared to have higher number of recorded CWD on site (Table 25). One hundred and nine sites had 53 or more pieces of CWD per acre.

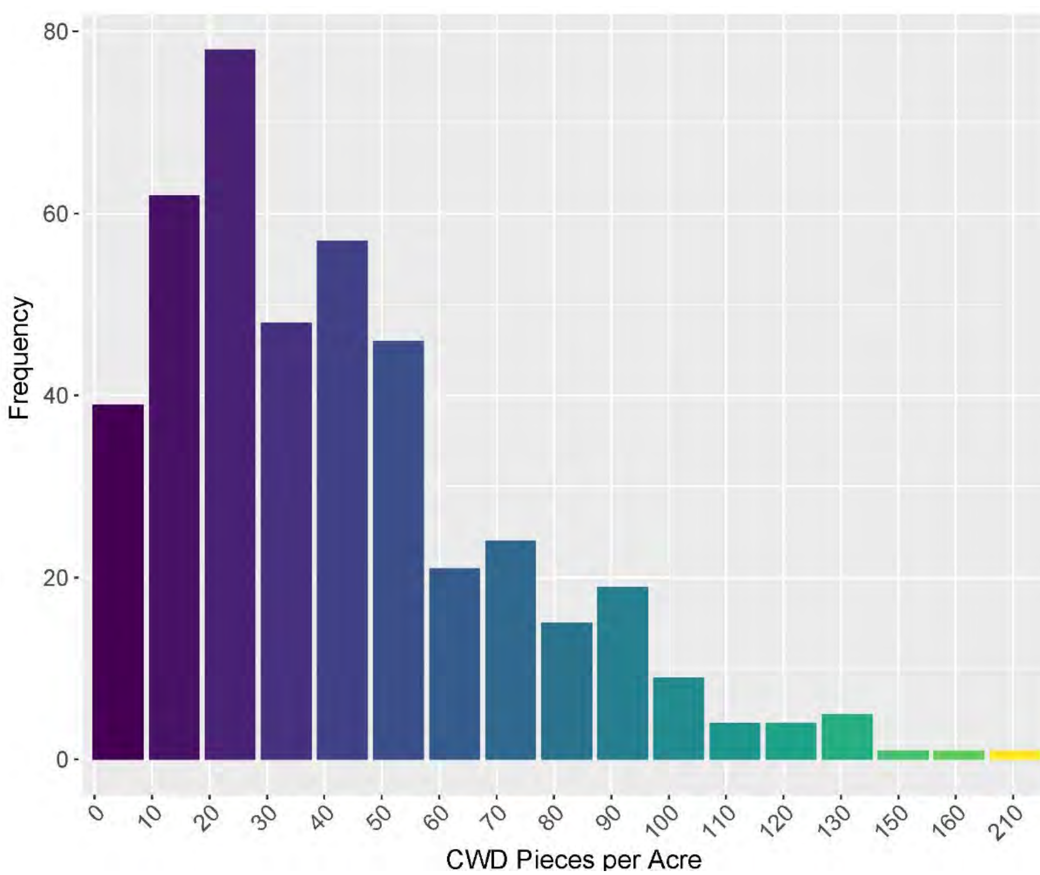


Figure 18. Distribution of Coarse Woody Debris (CWD) Retention on Monitored Sites.

Table 26. Slash and Coarse Woody Debris Retention on Monitored Sites.

WSU	Sites (n)	Sites w/Distributed Slash (n)	Sites w/Biomass Harvest (n)	Biomass Sites w/ FWD Retention Strategy (n)	Average CWD Logs per Acre (n)	Average Snags per Acre (n)
CWR	31	26	10	3	41.6	2.2
LLP	32	26	24	10	20	1.7
LRRR	31	20	4	1	66.3	3.4
MGR	29	27	2	1	37	2.8
MH	35	29	9	4	67.3	5.1
MRBS	34	14	13	5	29.5	1.8
RLB	36	33	2	0	30.7	2.3
RLCW	24	23	0	0	80.2	4.2
ROL	15	15	4	2	12.3	1.9
RR	28	25	7	2	36.4	3.4
SCKS	34	30	22	7	24.1	1.5
SCN	37	30	12	3	15.4	2.3
SEMN	12	12	0	0	25.1	1.7
SUP	30	22	8	1	47.2	4.7
VRR	26	23	4	2	51.2	2
Total	***434***	***355***	***121***	***41***	***36.5***	***2.7***

Snags provide habitat for wildlife requiring tree cavities, perches, and bark foraging or hibernacula 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 0 to 20 snags per acre (average = 2.7 snags per acre) across watersheds monitored this cycle (Table 25 and Figure 17). MFRC guidelines generally recommend leaving all snags possible, but also have recommendations to remove snags for visual quality concerns in some instances. The suitability of these results is not clear, as the level of snag density needed to support snag-dependent wildlife populations is an active area of research. Based on recent FIA data, mean snag density for timberland in Minnesota is 18 per acre, indicating that levels observed here are generally lower than what exists in intact stands.

Endangered, Threatened, and Special Concern Species

The FMGs recommend checking for the presence of endangered, threatened, or special concern species (ETS), sensitive communities, or sensitive sites on or near management sites prior to the initiation of activities. Additionally, the guidelines recommend that appropriate actions are taken to protect known occurrences. Over 90% of agency and industry owned sites reported that they checked for known ETS prior to initiating activities. Land managers reported that 20 of 292 agency and industry sites checked had known ETS species on or adjacent to the harvest site. Management activity was modified on 11 of these 20 sites with 4 of the remaining instances not needing modification and the rest in situations where the species was off-site and not impacted by harvest activity. Checking for the presence of ETS species is largely unknown for NIPF lands because the abbreviated pre-site questionnaire for this group did not include a similar question. Nonetheless, 6% of NIPF owners reported having checked for ETS species (Table 27).

The DNR’s Natural Heritage Information System (NHIS) is frequently used to determine if monitoring sites have known ETS species present. The NHIS is a collection of databases that provides information on Minnesota's rare plants, animals, native plant communities, and other rare features. The NHIS contains a wealth of information, and outreach to land owners, land managers, and loggers is recommended to improve use of the NHIS and implementation of related guidelines. Additionally, a more publically accessible version of NHIS providing simple presence / absence information for the broad class of ETS species would help greatly 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.

Table 27. Sites Checked for Threatened and Endangered Species (ETS) Listed by Ownership.

Ownership	Sites (n)	% Checked	% Protected
County	112	87.5	42.9
Federal	29	93.1	100
Industry	33	90.9	0
NIPF	119	**5.9**	0
State	130	93.1	83.3
Tribal	11	81.8	100
Total	***434***	***67.3***	***55***

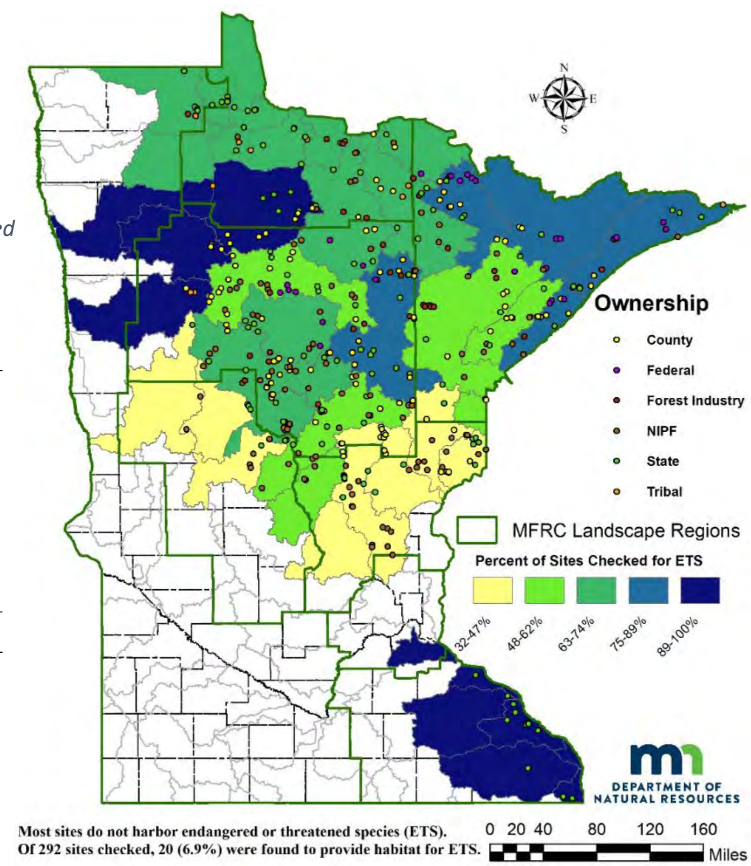


Figure 19. Percent of All Sites Checked for ETS Species in Monitored Watersheds.

Visual Quality

Associated with 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 [Visual Sensitivity Classifications Link](). These maps and narratives 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. One caveat is that the online only visual sensitivity maps have not been updated in many years, and are incomplete with respect to recreational trails, waterways, and even some surface roads.

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 269 monitoring sites located within 29 counties. For these 269 sites, 74.6% managed visual sensitivity in compliance with guidelines related to leave trees, snags, landing and infrastructure management, and other aesthetic values (Table 28 and Figure 20). For the 16 northern counties with visual quality guidelines, average compliance was 81.4% (228 vistas) (Table 29).

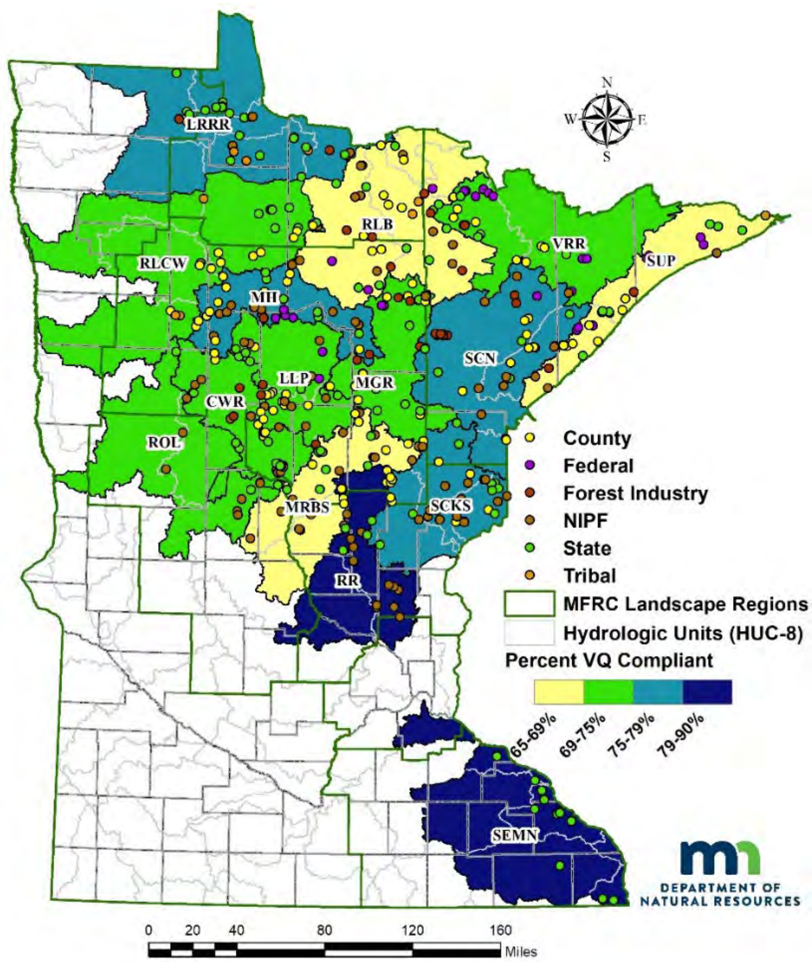


Figure 20. Visual Quality (VQ) Compliance in Monitored Watersheds.

Table 28. Visual Quality Management in Monitored Watersheds.

WSU	Sites (n)	Vistas (n)	Less Sensitive	Moderate Sensitivity	More Sensitive	Percent Sensitive	Percent Compliant
CWR	31	21	15	4	2	27.3	82.3
LLP	32	26	8	7	11	69.2	80.5
LRRR	31	19	19	0	0	0	84.3
MGR	29	15	12	1	2	20	83.4
MH	35	30	23	4	3	23.3	84.3
MRBS	34	23	12	11	0	47.8	79.6
RLB	36	21	8	6	8	63.6	77.7
RLCW	24	11	10	1	0	9.1	80.7
ROL	15	12	11	1	0	8.3	81
RR	28	16	9	3	4	43.8	93.5
SCKS	34	19	17	2	0	10.5	85.1
SCN	37	23	14	6	3	39.1	85.4
SEMN	12	6	2	4	0	66.7	92.7
SUP	30	17	11	4	2	35.3	78.6
VRR	26	10	6	4	0	40	78.6
Total	***434***	***269***	***177***	***58***	***35***	***33.6***	***83.2***

Table 29. Visual quality sensitivity and guideline compliance for 16 northern counties with VQ standards.

County	Sites (n)	Vistas (n)	Less Sensitive	Moderate Sensitivity	More Sensitive	Percent Sensitive	Percent Compliant
Aitkin	32	19	16	2	1	15.8	78.9
Becker	6	2	2	0	0	0	80
Beltrami	20	15	11	2	2	26.7	82.9
Carlton	5	1	1	0	0	0	66.7
Cass	53	41	23	10	8	43.9	80.7
Clearwater	8	2	2	0	0	0	88
Cook	10	7	3	2	2	57.1	74.7
Crow Wing	19	21	9	10	2	57.1	82.9
Hubbard	15	10	3	0	6	60	73.6
Itasca	36	23	13	5	5	43.5	85.4
Koochiching	37	16	9	3	4	43.8	79.1
Lake	23	9	8	1	0	11.1	76.9
Lake Of Woods	10	5	5	0	0	0	83.6
Mille Lacs	7	5	4	1	0	20	95.3
Pine	24	12	10	2	0	16.7	89.8
St Louis	65	40	25	11	4	37.5	83.6
Total	***370***	***228***	***144***	***49***	***34***	***36.4***	***81.4***

Conclusions

Implementation Level Risk to Water Quality

The watershed approach to guideline implementation monitoring has demonstrated several advantages to understanding implementation rates and challenges. Reports prior to 2014 targeted a statewide assessment. This summary report can also be considered a statewide assessment and can be compared to previous reports as an indicator of trends in guideline implementation at a statewide level.

Overall implementation of FMGs related to water quality is an important consideration related to how well the voluntary guideline implementation approach is working. Here, we select and evaluate overall implementation risk using six quantitative factors measured as percent compliance with various FMGs pertaining to water quality outcomes. Implementation is expressed on a scale of 0-100, where 100 indicates total compliance with FMGs or other sustainability standards.

- Leave trees provide valuable wildlife habitat, structure for a regenerating stand, help to intercept precipitation, encourage infiltration of precipitation into forest soils, reduce overland flow, and provide a living anchor for forest soils.
- Vegetated filter strips intercept and slow the movement of sediment from forest soils into surface waters. Avoiding placement of infrastructure on these features helps to maintain their intended function.
- Both placement of approaches and use of erosion control are important considerations to prevent the movement of soil from these high traffic areas to adjacent surface waters.
- Avoidance of unnecessary wetland and waterbody crossings serves as an operational measure to limit interaction with surface water and minimize the potential for delivery of sediment downstream.
- Riparian management zones provide vegetative cover and serve the same purposes as both filter strips and leave tree clumps.
- Rut avoidance is another operational consideration that can help to reduce the movement of sediment into surface waters.

Given the set of FMGs listed above, $\text{FMG Implementation Risk Factor } = 100 - \frac{\sum x_i}{n}$, where x_i is a FMG implementation rate and *n* is the number of FMGs considered. These factors are summarized and compared in Table 29 as the FMG Implementation Risk Factor describing total deviation from recommended practices (0 = Good implementation, 100 = Poor implementation). A FMG Implementation Risk Factor of 100 indicates high relative risk due to lack of FMG implementation.

Statewide implementation rates of some key guideline categories are presented in Table 30 alongside rates from 2009 and 2011 reports and data. Each WSU can be compared to the statewide rates from this and previous reports as an indicator of how current compliance rates compare, perhaps reflecting relative levels of implementation (local diligence) as well as challenges to implementing guidelines within specific WSUs due to landscape and watershed conditions. In total, five of the 15 watershed sample units stand out due to the risks involved with relatively lower FMG implementation. These

Table 30. FMG Implementation for Watersheds (2014-2018) and Statewide (2009, 2011 and 2014-2018).

WSU	Leave Tree Comp*	Filter Strip Mgmt	Approach Location and EC**	Crossing Mgmt.***	Net RMZ Comp****	Rut Avoidance *****	FMG Implementation Risk Factor
CWR	96.1	92.4	100	99.4	81.8	98.4	5.3
LLP	96.1	87.2	93.9	97.2	91	95.2	6.6
LRRR	82.9	51.7	99	94.1	92.1	97	13.9
MGR	86.6	89.2	96.7	92.5	80.4	96.5	9.7
MH	97.8	81.7	92.5	70.1	97.6	48.4	18.6
MRBS	95	82.6	91.7	96.7	93	87.3	9
RLB	96.1	80.2	96.9	95.8	68	98.9	10.7
RLCW	100	88.6	93.8	92.6	95.5	89.6	6.7
ROL	100	76.7	100	92.9	100	95.3	5.9
RR	97.8	98.1	100	98.1	54.1	98.2	8.9
SCKS	87.7	86.6	97.3	96.7	89	83.6	9.9
SCN	96.2	96.3	98.3	98.1	97.1	88.2	4.3
SEMN	100	66.7	70	100	84.2	100	13.2
SUP	97.1	85.2	93.6	87.7	98.4	91.4	7.8
VRR	92.6	59.9	91.8	92.5	63.8	84.2	19.2
2014-2018	***93.8***	***83.3***	***95.4***	***94.4***	***85.7***	***89.2***	***10***
2011	***96***	***85***	***92.1***	***97.8***	***75.5***	***90***	***10.6***
2009	***88.7***	***90***	***83.6***	***92.8***	***66.6***	***93***	***14.2***

*Because leave tree guidelines have evolved, data from 2009, 2011, and 2014-2018 have been re-analyzed consistent with 2012 recommendations for leave trees, LTCs and trees retained in RMZs to allow comparison across years. Leave Tree Compliance = Scattered + LTC + RMZ Leave Tree Compliance.

**All approaches are considered. Only those needing EC and not having it detract from the score.

***Crossing Management considers both the occurrence of rutting on established crossings and the avoidance of crossing waterbodies unnecessarily. The formula used is $Score = 100 * (1 - \frac{N_{rutted}}{N_{waterbodies}})$, where N_{rutted} is the number of badly (>25%) rutted crossings on a site and $N_{waterbodies}$ is the total number of waterbodies occurring on the site.

****Because RMZ guidelines have changed, RMZ data from 2009, 2011, and 2014-2018 have been re-analyzed consistent with 2012 FMG recommendations for width and basal area to allow comparison across years. Net RMZ Compliance = Total Compliance + Weighted Partial Compliance.

*****Rut Avoidance is calculated excluding waterbody crossings, since those are considered separately under Crossing Management. $Rut\ Avoidance = 100 * \left(1 - \left(\frac{\left(\frac{n_{rutted}}{S_{rutted}}\right) * (\hat{x}) / (S_{Total})}{\left(\frac{\hat{n}}{S_{rutted}}\right) * (100) / (S_{Total})}\right)\right)$, where S_{Total} is the total number of sites observed, S_{rutted} is the number of rutted sites observed, n_{rutted} is the number of rutted features observed, $\hat{n}$ is the average number of non-waterbody crossing features per site (~19), $\hat{x}$ is the average observed percentage of each feature that was rutted, and 100 is an assumption that 100% of the average rutted feature was affected. This rather complex formula boils down to the inverse ratio of observed rutting divided by potential rutting expressed as a percentage.

watershed sample units include LRRR (leave tree retention and filter strip management are lower than average), MH (leave tree and filter strip management are relatively lower), RLB (filter strip management and RMZ implementation are low), SEMN (filter strip management, approach compliance, and RMZ management are relatively low), and VRR (filter strip management and RMZ implementation are relatively low). Additional outreach focused on leave tree practices, filter strip use, erosion control on approaches, unnecessary crossing avoidance, and RMZ implementation in these watersheds may provide improvements to water quality, wildlife habitat, and forest regeneration outcomes associated with timber harvest.

Leave Trees: *5 year report indicates good implementation of leave tree guidelines. When evaluated using the current criteria, this FMG has been consistently applied across many years. All WSUs show relatively high compliance.*

Filter Strips: *5 year overall filter strip compliance at 83.3% is slightly lower than the 85% reported in 2011 statewide report which was slightly lower than the 90% reported in 2009. This suggests a downward trend in filter strip guideline implementation! It is unclear why this is trending down but is clearly a concern as the filter strip guidelines is a foundational guideline in protecting water quality. Watershed sample units reflecting substantially lower than average implementation include LRR, SEMN, and VRR.*

Approach Location and EC: *5 year implementation of erosion control on approaches where needed (95.4%) is better than the 92.1% assessed for 2011 and substantially better than the 83.6% reported in 2009. Note that this compliance measure has been re-evaluated since the original reports using slightly different criteria more in line with the way this is monitored nationally.*

Crossing Avoidance: *Avoidance of unnecessary crossings was 94.4% in the 5 year report which is lower than the 2011 report at 97.8%, but higher than the 92.8% measured in 2009. This compliance is based on evaluation of existing crossings compared against total potential crossings (e.g. 1 per hydrologic feature or wetland). Note that this compliance measure has been re-evaluated since the original reports using slightly different criteria more in line with the way this is monitored nationally.*

RMZ Use: *5 year rate of implementation (85.7%) is better than the 2011 report (75.7%) which was substantially better than the 2009 report. Compliance to this guideline continues to improve, perhaps driving the overall improved implementation risk factor.*

Rut Avoidance: *5 year reported avoidance of rutting is similar to both the 2009 (93%) and the 2011 (90%) reports suggesting continued awareness and good implementation.*

Addressing Watershed Hydro-geologic Risks to Water Quality

A primary conclusion of this report is that the focus on monitoring by major watershed units has provided additional clarity related to landscapes where more outreach and education on specific FMGs could produce water quality benefits. In particular, outreach related to FMGs with lower implementation levels in watersheds where the average and/or variability of hydro-geomorphologic risk of erosion and runoff is relatively high (Table 6) can be expected to improve FMG implementation rates where extra effort is most needed. While a usable model depicting hydro-geomorphic risk of erosion at the watershed and site scale has been developed, additional analysis is underway using emerging data to further characterize and assess these risks as they relate to timber harvest and forest management.

Throughout this report, we have focused on specific watersheds where FMG implementation has been relatively high or low. Here, we provide additional emphasis on those watershed units where a convergence of lower implementation and higher background risk to water quality dictate the need for extra effort. The short list of watershed sample units where background risk of erosion to surface water exceeds the average includes SEMN, SUP, and VRR. High variability of background erosion risk is another hallmark of these geo-morphologically varied landscapes. Lower FMG implementation may exacerbate water quality outcomes on the complex terrain of the SUP and VRR watershed sample units.

Additionally, lower levels of FMG implementation in LRRR, MRBS, RLB, and VRR may indicate a need for greater outreach to forest managers and loggers operating in these watersheds. Specific practices needing additional focus include: leave tree retention, filter strip management, erosion control on approaches, unnecessary crossing avoidance, and RMZ implementation.

In terms of outreach and education priorities, LRRR, SUP and VRR should be listed as watersheds of concern. Specific outreach focused on leave trees, erosion control, crossing avoidance, filter strip use, and RMZ implementation in these watersheds may provide added benefits to surface water quality associated with timber harvests.

Comparison with National Results

Recent comparisons of Minnesota's forestry BMP monitoring with national results has cast Minnesota in a less than ideal light (NASF 2015 and 2019, Cristan 2016). In some instances, concerns may be warranted (e.g., implementation of erosion control on roads, approaches to wetlands, and placement of log landings). Other comparisons seem inappropriate (e.g., lumping all wetland crossings in with comparisons against stream crossings in other states, and the exclusion of information related to reforestation, site preparation, pesticide management, and prescribed fire). In some instances, the exclusions likely result from a lack of information provided to researchers compiling the national results. However, other comparisons must be made with consideration of the kinds of information gathered in Minnesota's intensive onsite BMP monitoring effort. Here, we explore and question the methodology used in making broad comparisons.

For example, comparison of a 98% statewide stream crossing compliance rate in Louisiana where compliance is monitored on a Yes/No basis (in conformance with methods used by the Southern Group of State Foresters) with the observation in Minnesota that 28% of NOWW crossings in six watershed units monitored from 2016-2017 were avoidable seems inappropriate on several levels. First, comparing stream crossings to avoidable wetland crossings is not a one-to-one comparison. The average number of wetlands on a site in Minnesota is approximately 7, with 83% of these comprised of NOWWs. Only 10% of hydrologic features found on sites were streams. So, for water related guidelines, we are almost always referencing potential effects on NOWWs, not delivery of sediment to surface waters.

Second, while many crossings of NOWWs are avoidable, some are necessary, especially considering the operational nature of many wooded wetlands in Minnesota. So, keeping equipment out of wetlands entirely may be an unrealistic goal. Instead, minimizing impacts to soils and hydrology may be more realistic, and is in line with the Forestry Exemption to Minnesota's Wetland Conservation Act. Indeed, Minnesota provides strong guidance on how and when wetlands may be accessed for timber harvest, conditions associated with the Forestry Exemption, and strong statutory regulations related to the restoration of hydrologic function (and consequently ecological function) on and around temporary crossings following completion of silvicultural operations.

Third, the text of Minnesota's 2016-2017 Implementation Monitoring Report indicates 95% compliance for stream crossing guidelines (a small subset of what was apparently included in the 2019 national report for Minnesota). For the 2019 NASF report, it appears that results from one biennial report (2016-2017) covering six of fifteen watershed units in Minnesota were used to describe the entire state's level of compliance. It is important to be familiar with the monitoring and reporting cycle used in Minnesota before drawing strong conclusions from one report covering a fraction of the state. Indeed, greater familiarity with the structure and style of reporting provided may have alleviated several of the missteps noted above. Greater clarity and much additional information can be gleaned from reading the text of those reports, which is designed to complement, not replace, data presented in tables and figures.

Additionally, Minnesota uses a robust monitoring protocol to collect substantial additional information about any potential issues observed on site. These details range from measuring the length and slope of approaches to wetlands where erosion control may be needed to sampling of basal area, tree species, super-canopy trees, blowdown, and coarse woody debris remaining in forested portions of riparian management zones. Indeed, the RMZ itself is evaluate according to conditions seen along three representative transects including specific information for non-forested (grass, sedge, and shrub dominated areas), forested (not harvested), partial cut, and clearcut portions of the management zone. In the process of collecting all of this detailed information, we may increase our opportunities to find minor deficiencies in FMG implementation. Whether these minor deficiencies indicate inappropriate implementation of a specific BMP is an open question that does not exist in the more simplistic surveys completed for other states. It is likely that where response option include only "Yes", "No", "Not applicable", and "Insufficient information", any reasonable level of BMP implementation would receive a "Yes" response. This is not the case in Minnesota, where we use a 95% threshold for RMZ width and basal area in gauging compliance. When considering RMZ width, basal area retention, leave tree numbers, and many other factors, this high bar may misrepresent some basically compliant sites as only partially compliant.

Further, we break FMG implementation monitoring into approximately 530 individual questions related to a myriad of potential ways in which various guidelines could be improperly, or only partially implemented. For comparison, the standard implementation survey for the Southern Group of State

Foresters is composed of approximately 117 (Virginia) "Yes"/"No" questions. Only 43 BMPs were evaluated in Tennessee. While the exact number of questions asked in a given state may vary, it is clear that Minnesota takes a quite comprehensive look at FMG implementation.

To facilitate national comparisons, it may behoove Minnesota to provide a simplified reporting format tailored to the kind of "Yes"/"No" analysis performed in other states. This report could either be a simplified representation of our more complex implementation monitoring results, or be embodied in a full revision of how our monitoring program is carried out. While there is great value in the detailed monitoring data collected here, there is also value in providing a more appropriate comparison with other FMG monitoring programs. A first effort towards providing a simplified implementation analysis will be conducted in conjunction with ongoing research focused on examining the accuracy of baseline hydrogeomorphological risk data described earlier in this report. The results of this effort may help to inform the MFRC in any revision process it might pursue.

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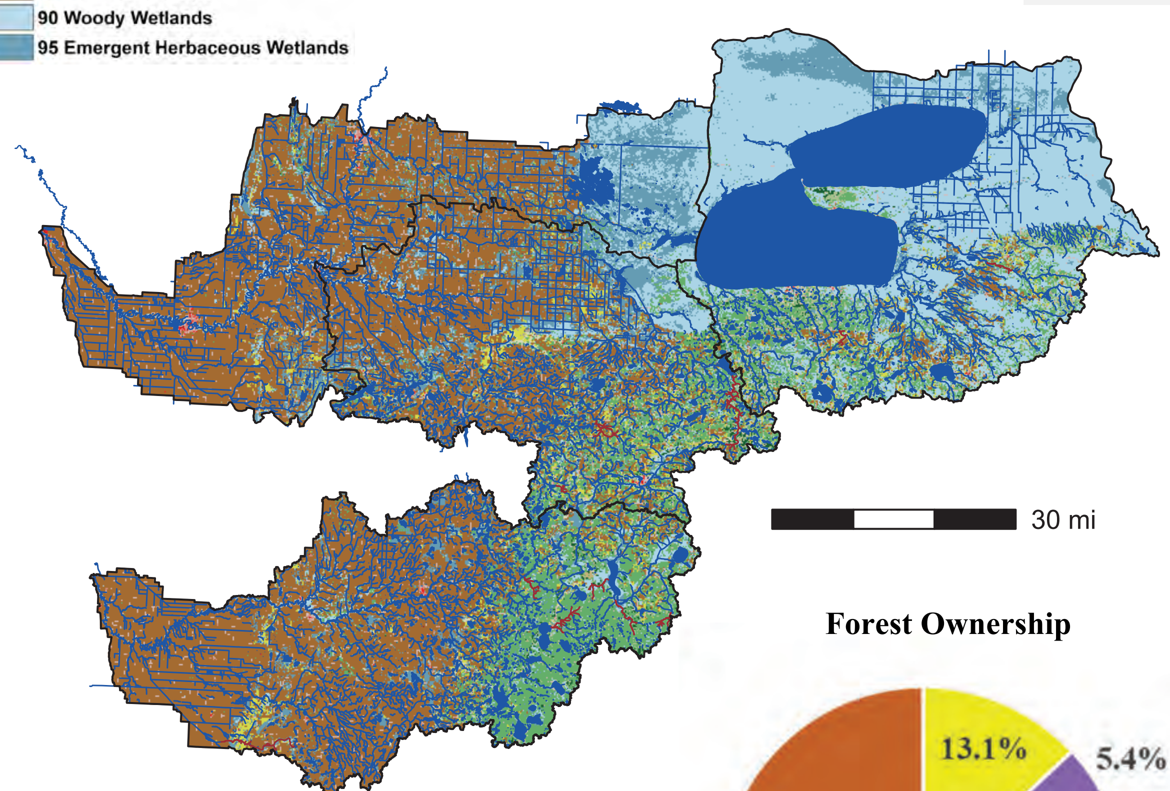
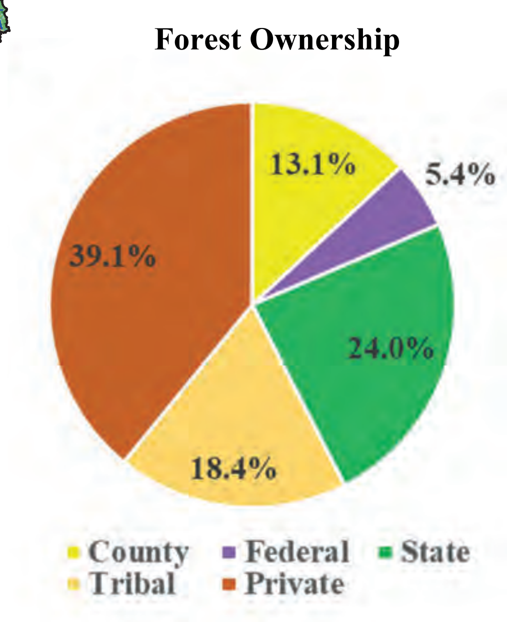
Appendix

Land cover	*Acres*
Agriculture	1,594,042
Barren	3,906
Developed	108,743
Forest	1,321,470
Grassland	135,090
Open water	361,544
Shrub/scrub	7,192
Wetland	483,742
Total	**4,015,729**

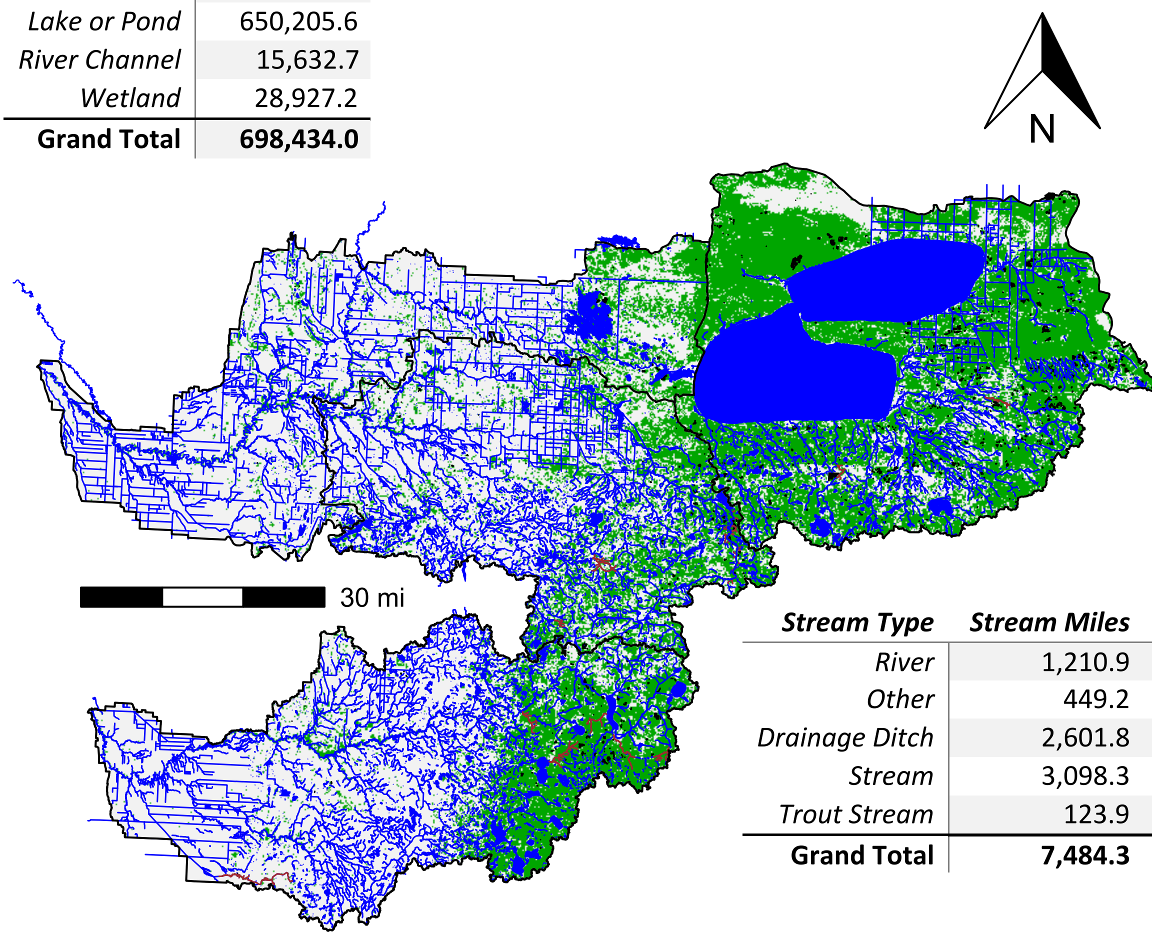


Forest Cover	*Acres*	*Percent*
Aspen	438,108	33.2%
Black ash	131,694	10.0%
Black spruce	82,252	6.2%
Northern hardwoods	87,671	6.6%
Northern white-cedar	109,519	8.3%
Other	179,986	13.6%
Tamarack	185,118	14.0%
Oak - hickory	107,123	8.1%
Total	**1,321,470**	**100.0%**

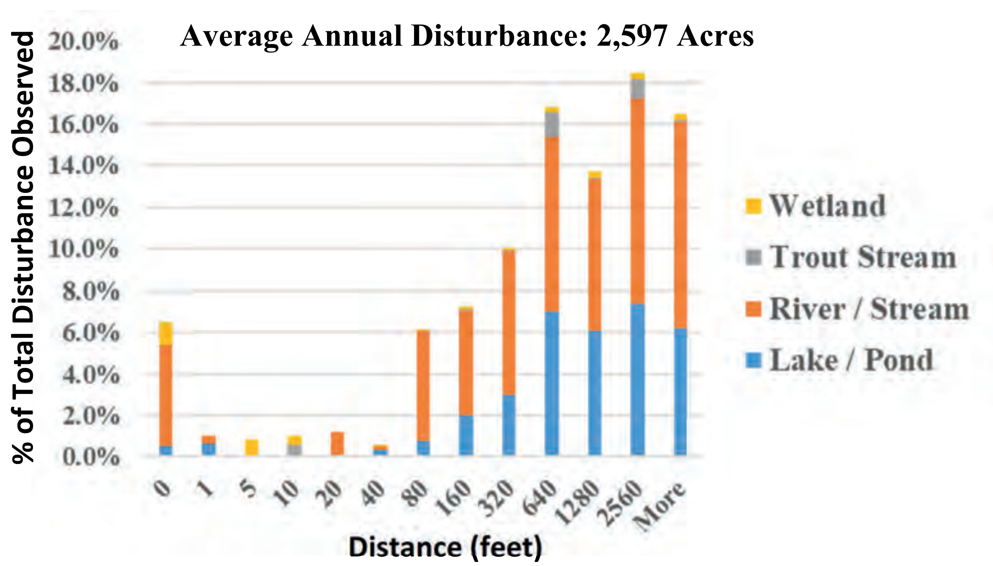


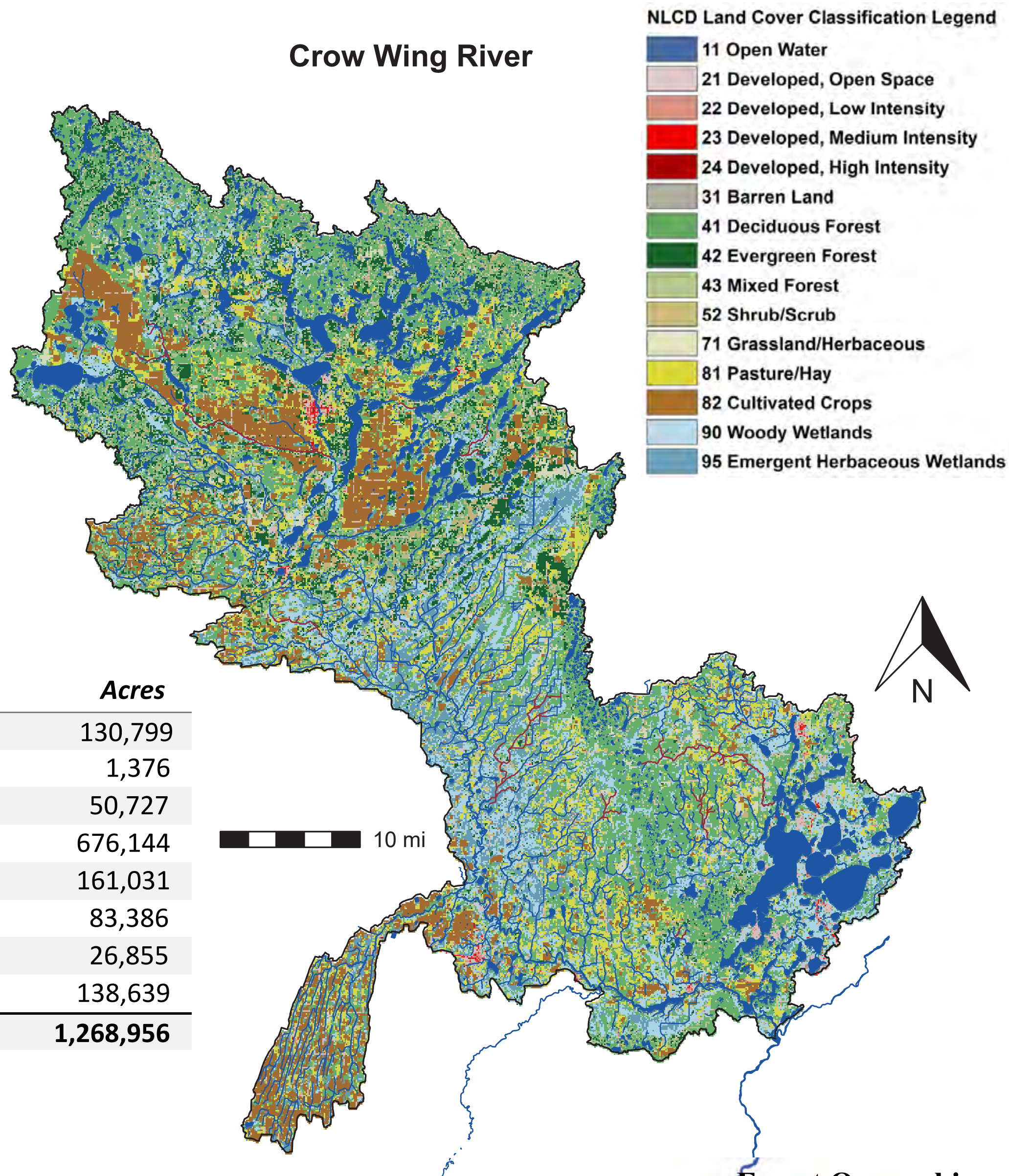
Forest Canopy Change (2012-2017)

Feature	*Acres*
Other	3,668.5
Lake or Pond	650,205.6
River Channel	15,632.7
Wetland	28,927.2
Grand Total	**698,434.0**



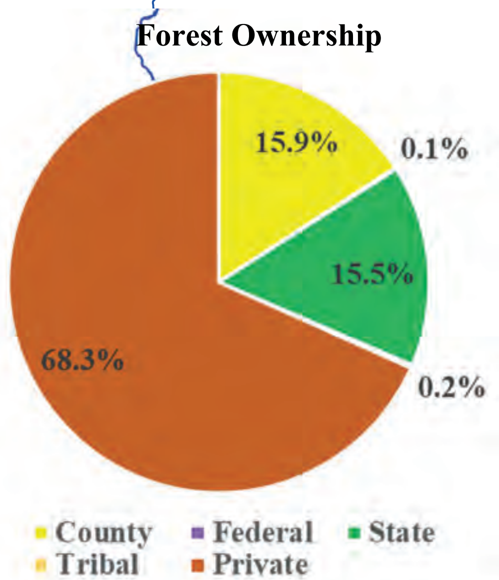
Stream Type	*Stream Miles*	*n*
River	1,210.9	28
Other	449.2	324
Drainage Ditch	2,601.8	626
Stream	3,098.3	978
Trout Stream	123.9	31
Grand Total	**7,484.3**	**180**



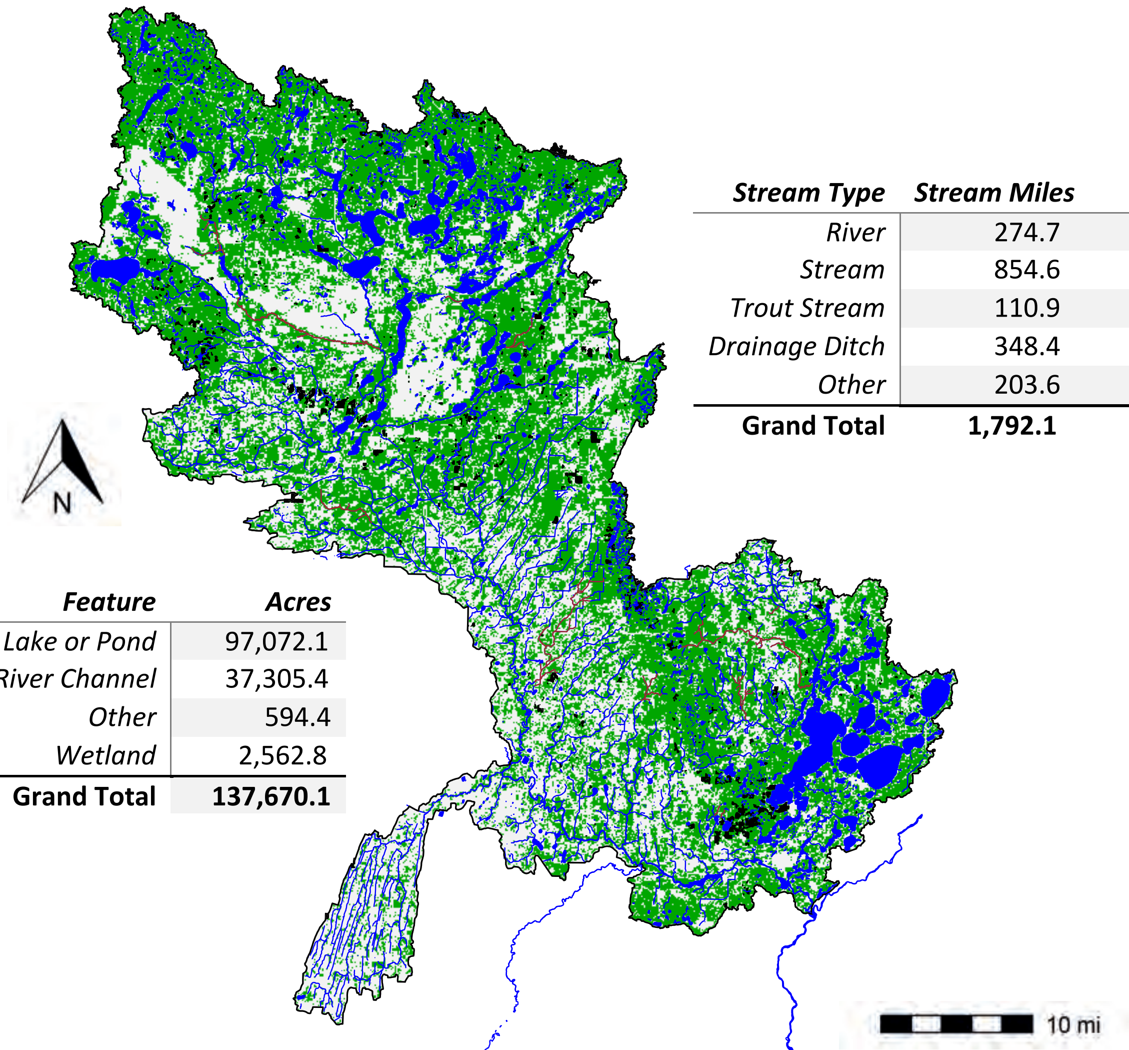


Land cover	*Acres*
Agriculture	130,799
Barren	1,376
Developed	50,727
Forest	676,144
Grassland	161,031
Open water	83,386
Shrub/scrub	26,855
Wetland	138,639
Total	**1,268,956**

Forest Cover	*Acres*	*Percent*
Aspen	276,771	40.9%
Oak - pine	68,653	10.2%
Other	164,115	24.3%
Paper birch	40,656	6.0%
Red pine	59,581	8.8%
Oak - hickory	66,369	9.8%
Total	**676,144**	**100.0%**

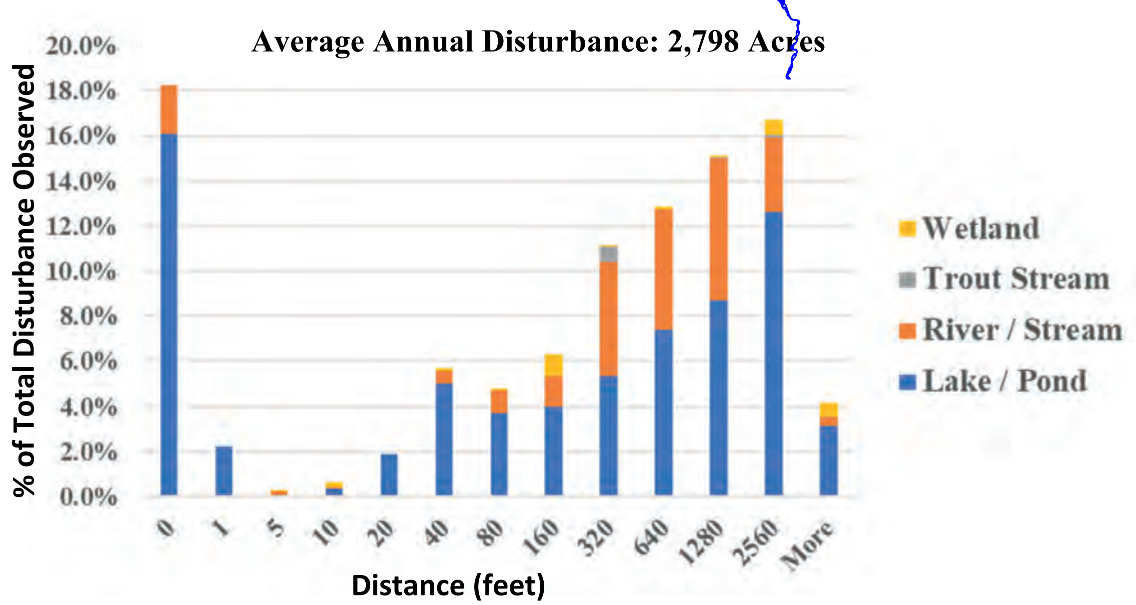


Forest Canopy Change (2012-2017)



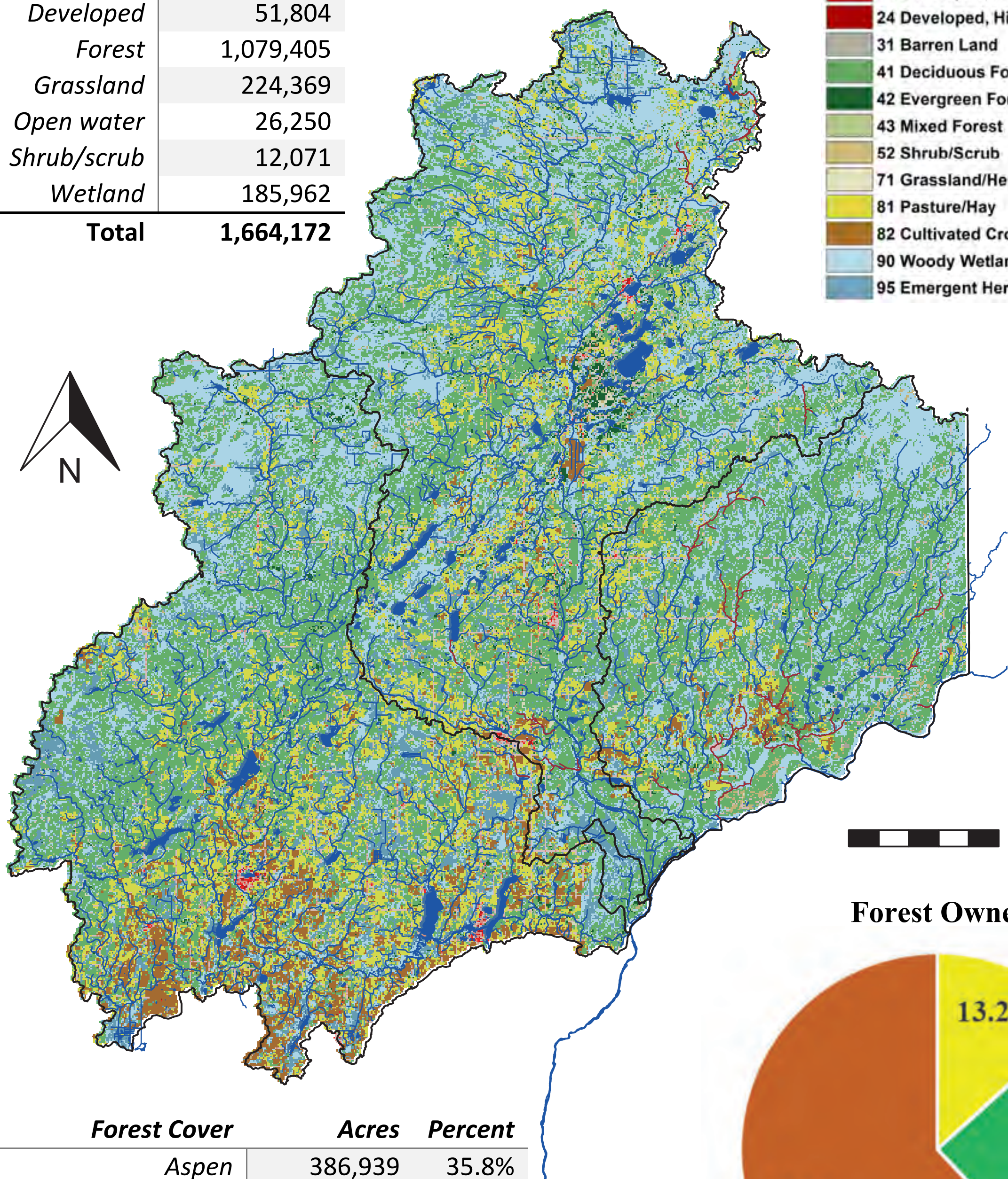
Stream Type	Stream Miles	n
River	274.7	79
Stream	854.6	1,002
Trout Stream	110.9	58
Drainage Ditch	348.4	279
Other	203.6	446
Grand Total	**1,792.1**	**1,864**

Feature	Acres
Lake or Pond	97,072.1
River Channel	37,305.4
Other	594.4
Wetland	2,562.8
Grand Total	**137,670.1**



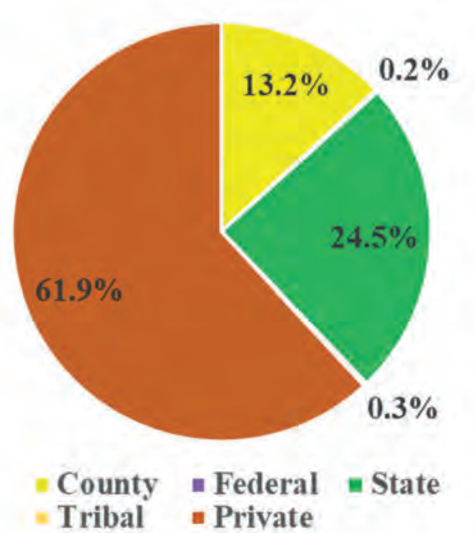
Kettle River
Snake River
Upper St. Croix River

Land cover	*Acres*
Agriculture	83,030
Barren	1,281
Developed	51,804
Forest	1,079,405
Grassland	224,369
Open water	26,250
Shrub/scrub	12,071
Wetland	185,962
Total	**1,664,172**

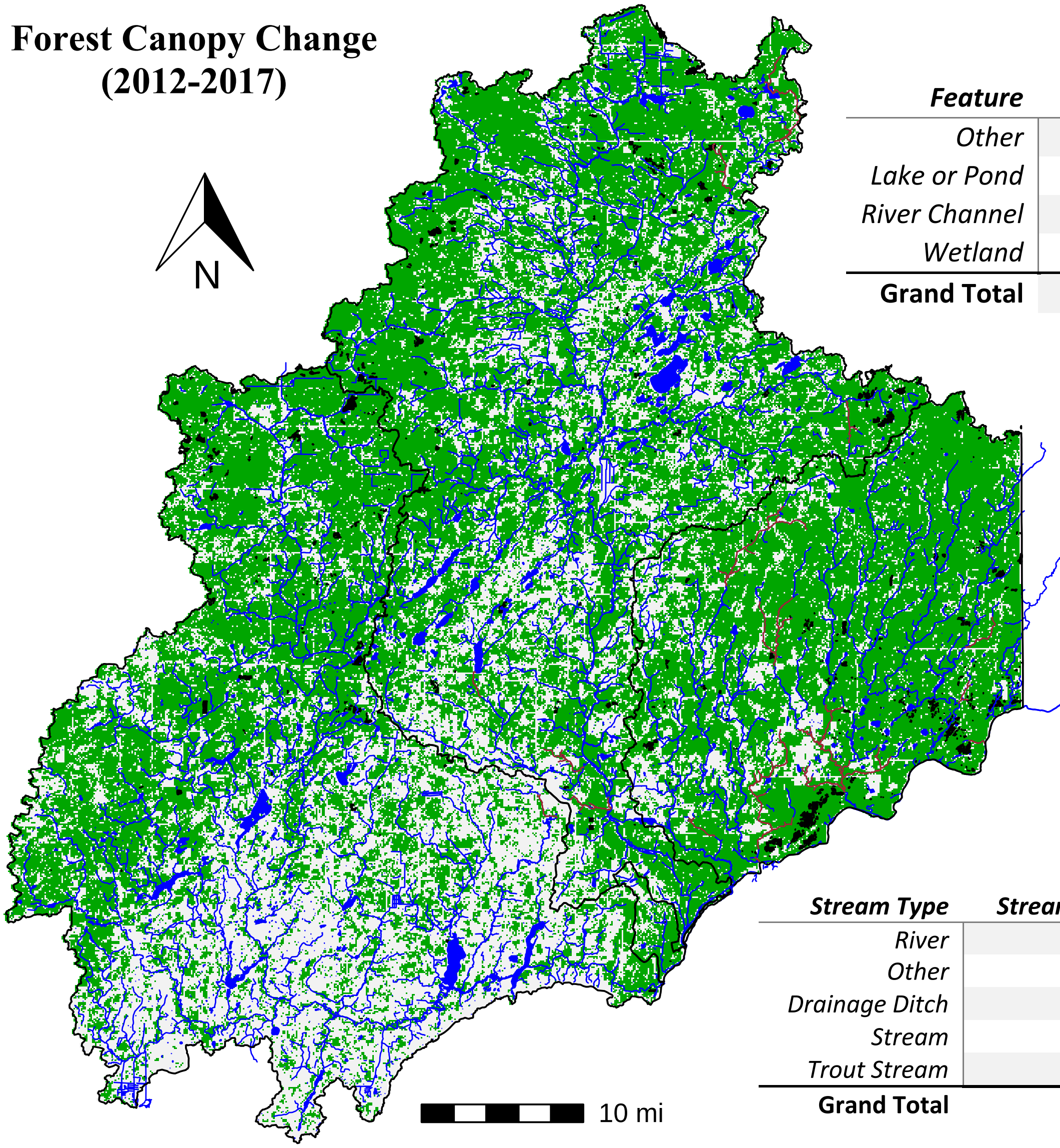


Forest Cover	*Acres*	*Percent*
Aspen	386,939	35.8%
Black ash	100,242	9.3%
Central hardwoods	80,394	7.4%
Northern hardwoods	122,642	11.4%
Other	104,475	9.7%
Paper birch	58,149	5.4%
Tamarack	63,103	5.8%
Oak - hickory	163,461	15.1%
Total	**998,925**	**100.0%**

Forest Ownership

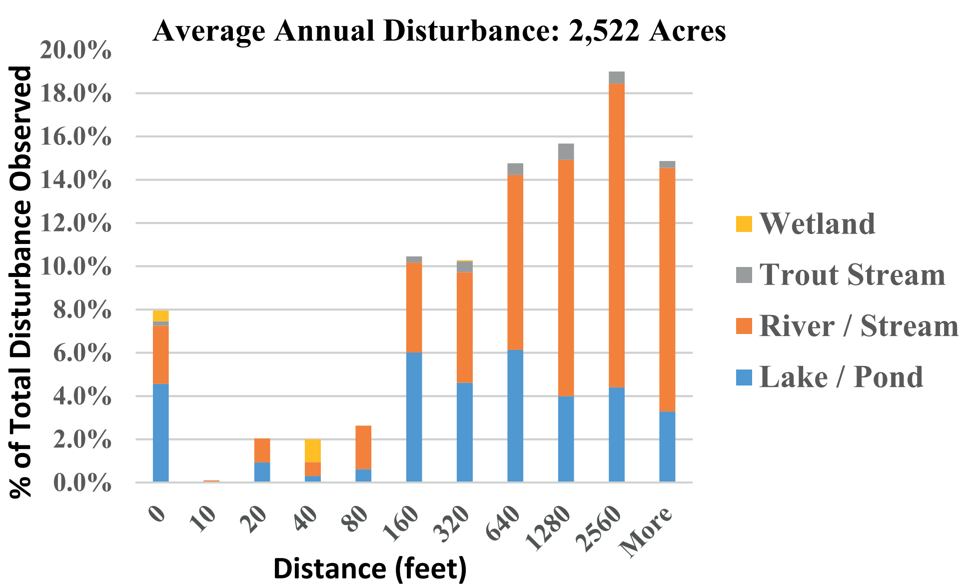


Forest Canopy Change (2012-2017)

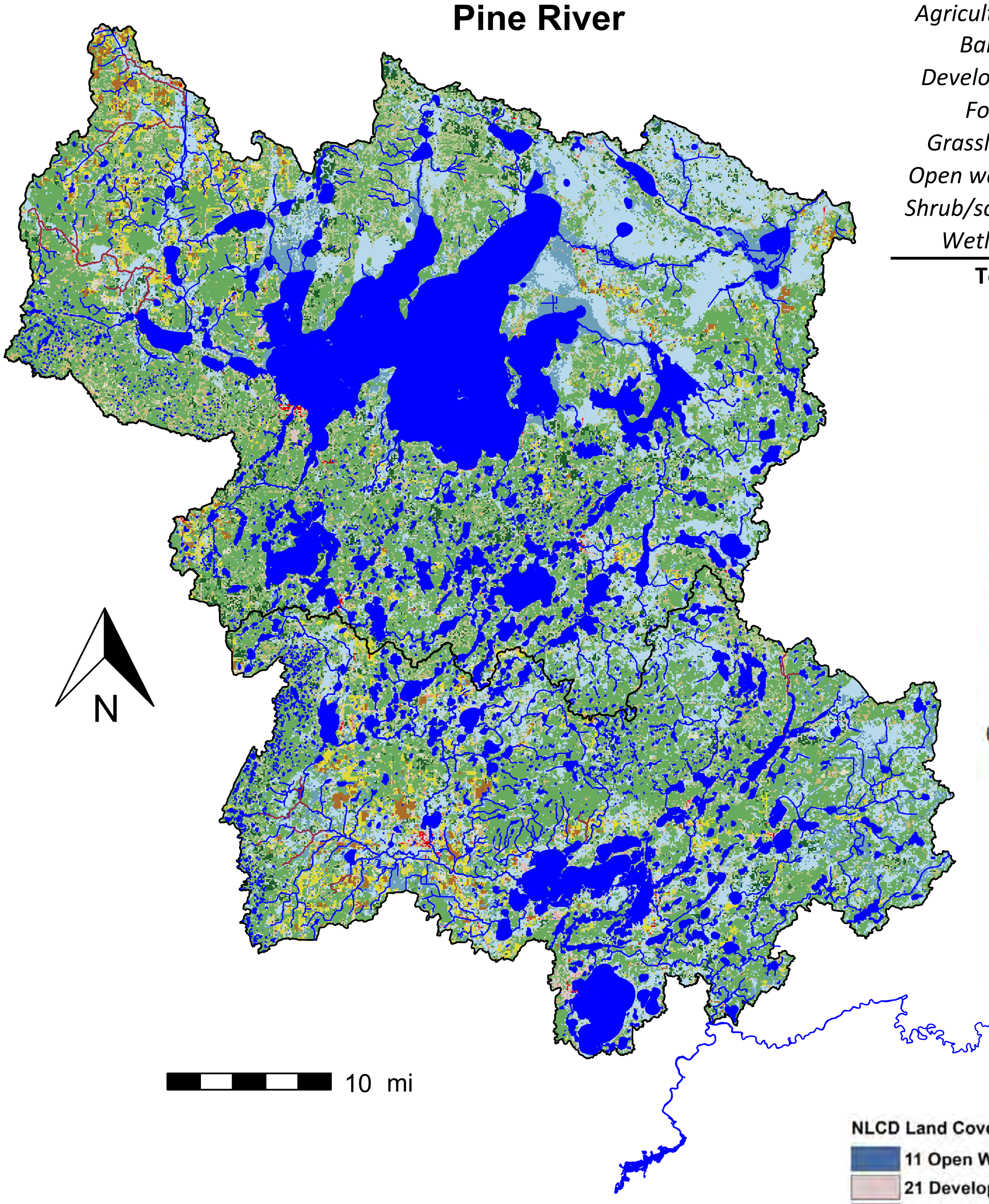


Feature	*Acres*
Other	558.6
Lake or Pond	25,068.2
River Channel	9,641.2
Wetland	1,841.8
Grand Total	**37,109.8**

Stream Type	*Stream Miles*	*n*
River	622.9	139
Other	108.0	493
Drainage Ditch	417.1	459
Stream	1,663.1	1,556
Trout Stream	130.3	79
Grand Total	**2,941.4**	**227**

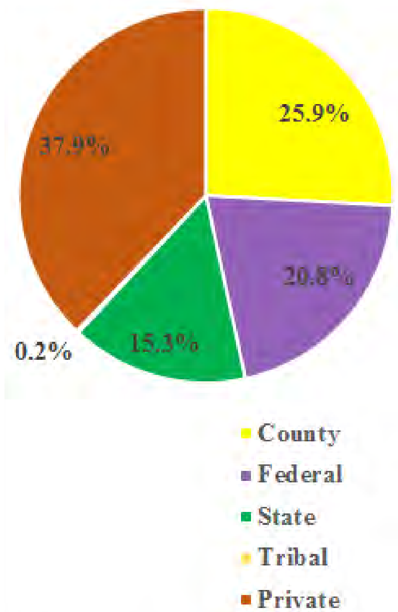


Leech Lake River
Pine River



Land cover	*Acres*
Agriculture	14,449
Barren	1,031
Developed	40,379
Forest	899,554
Grassland	59,114
Open water	221,801
Shrub/scrub	20,539
Wetland	101,980
Total	**1,358,846**

Forest Ownership

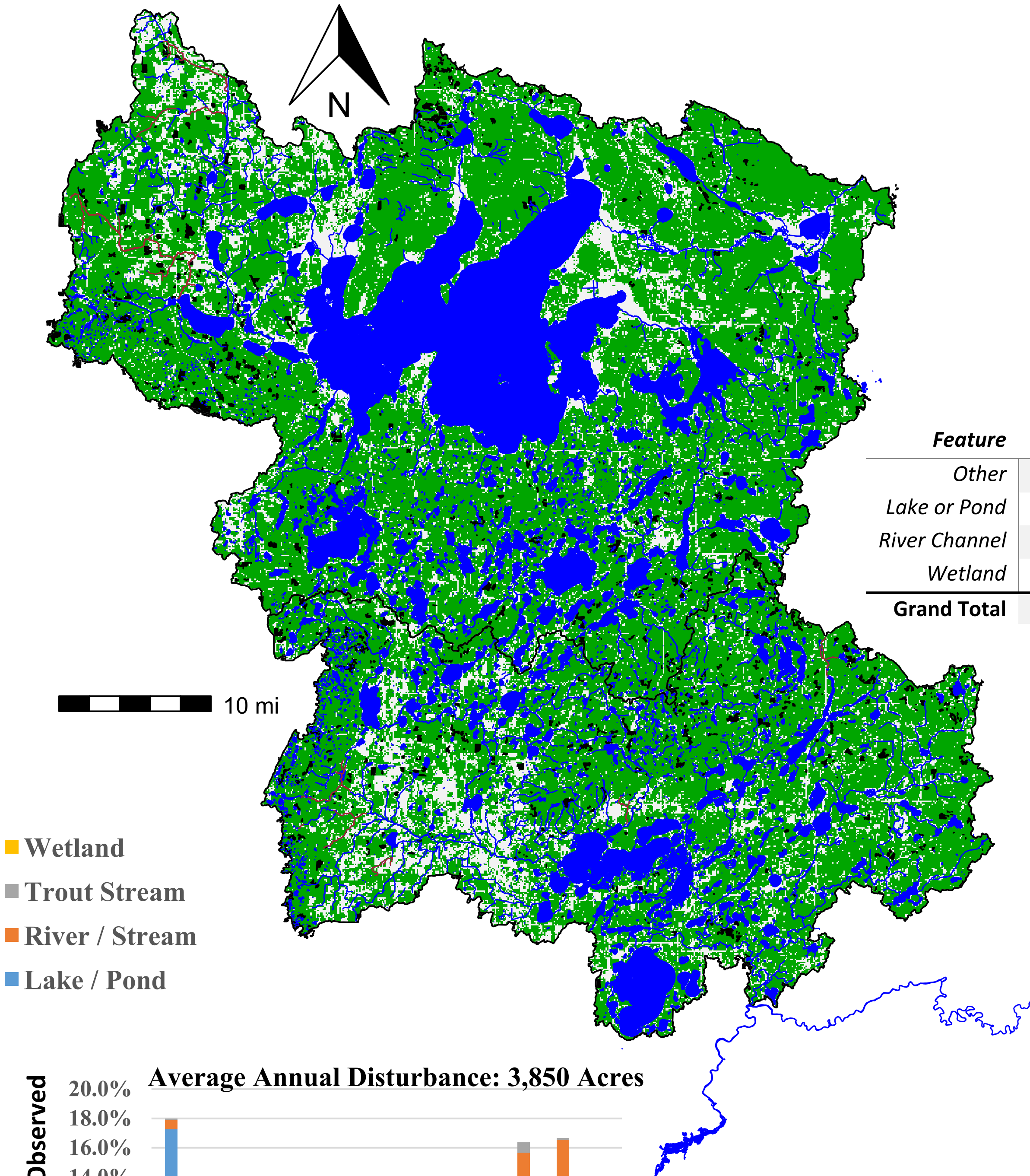


Forest Cover	*Acres*	*Percent*
Aspen	321,447	35.7%
Black ash	52,329	5.8%
Northern hardwoods	69,772	7.8%
Other	236,725	26.3%
Paper birch	59,804	6.6%
Tamarack	52,329	5.8%
Oak - hickory	107,149	11.9%
Total	**899,554**	**100.0%**

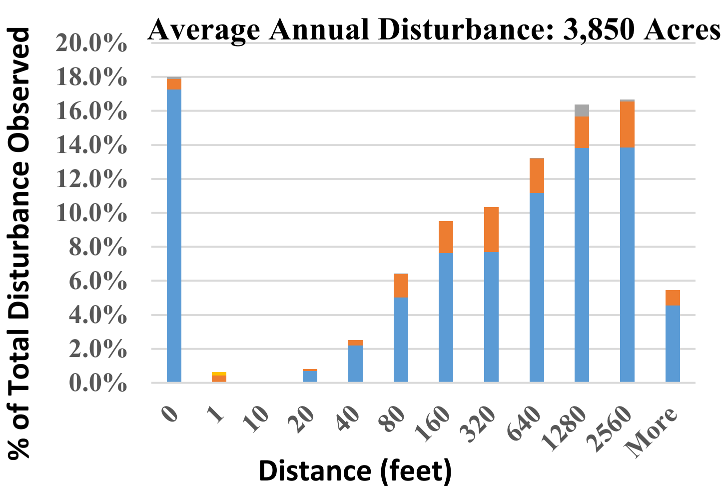
NLCD Land Cover Classification Legend

- 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 Canopy Change (2012-2017)



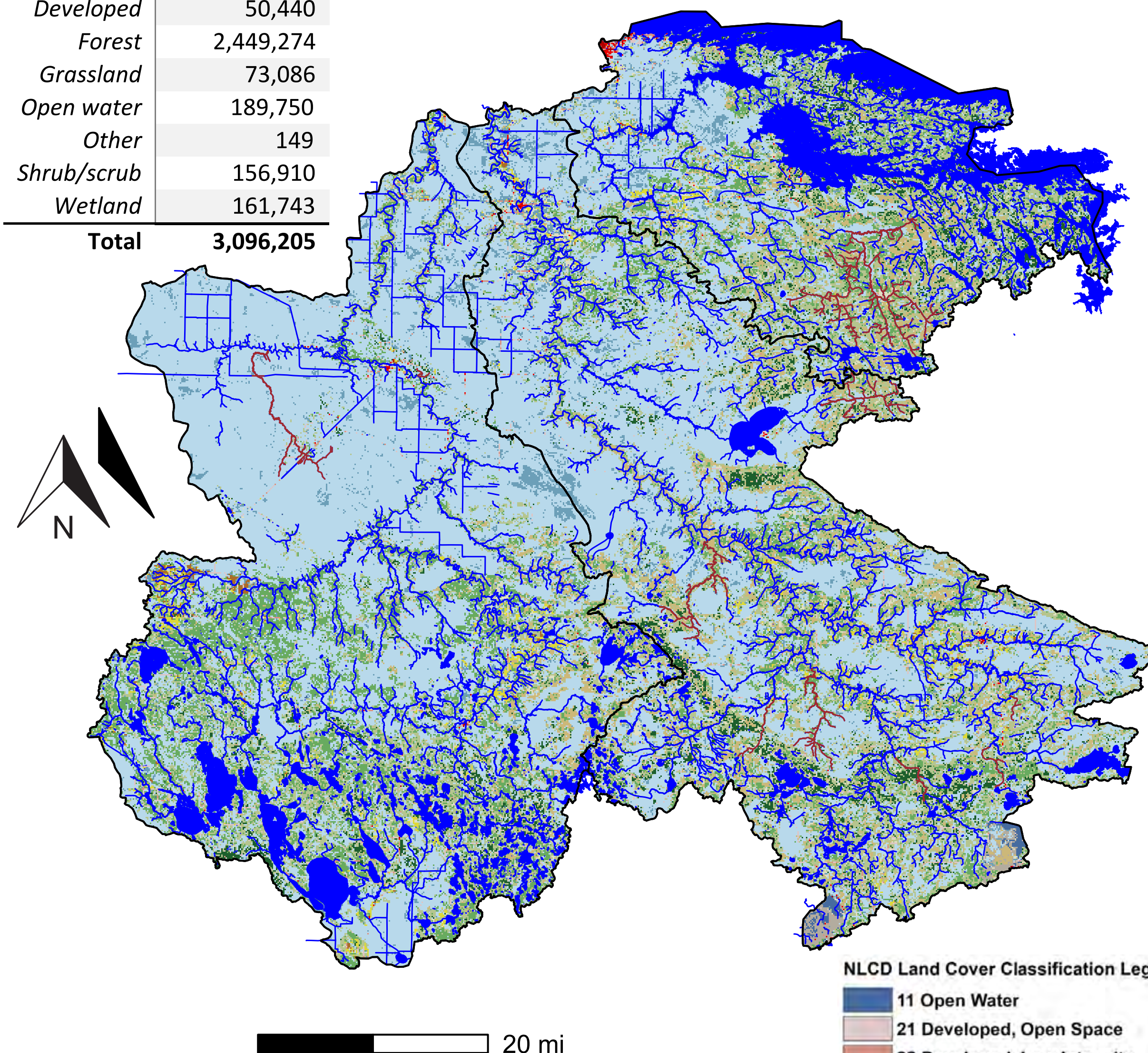
Feature	Acres
Other	5,477.5
Lake or Pond	361,488.7
River Channel	18,359.6
Wetland	5,140.3
Grand Total	**394,644.2**



Stream Type	Stream Miles	n
River	226.7	80
Other	514.5	920
Drainage ditch	75.7	146
Stream	796.1	1359
Trout Stream	77.6	41
Grand Total	**1,690.6**	**2546**

Land cover	Acres
Agriculture	6,061
Barren	8,791
Developed	50,440
Forest	2,449,274
Grassland	73,086
Open water	189,750
Other	149
Shrub/scrub	156,910
Wetland	161,743
Total	**3,096,205**

Little Fork River
Big Fork River
Rainy River – Rainy Lake

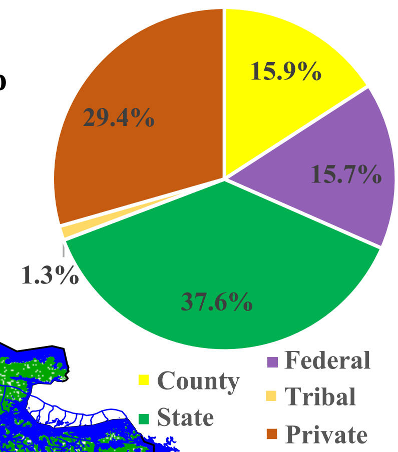


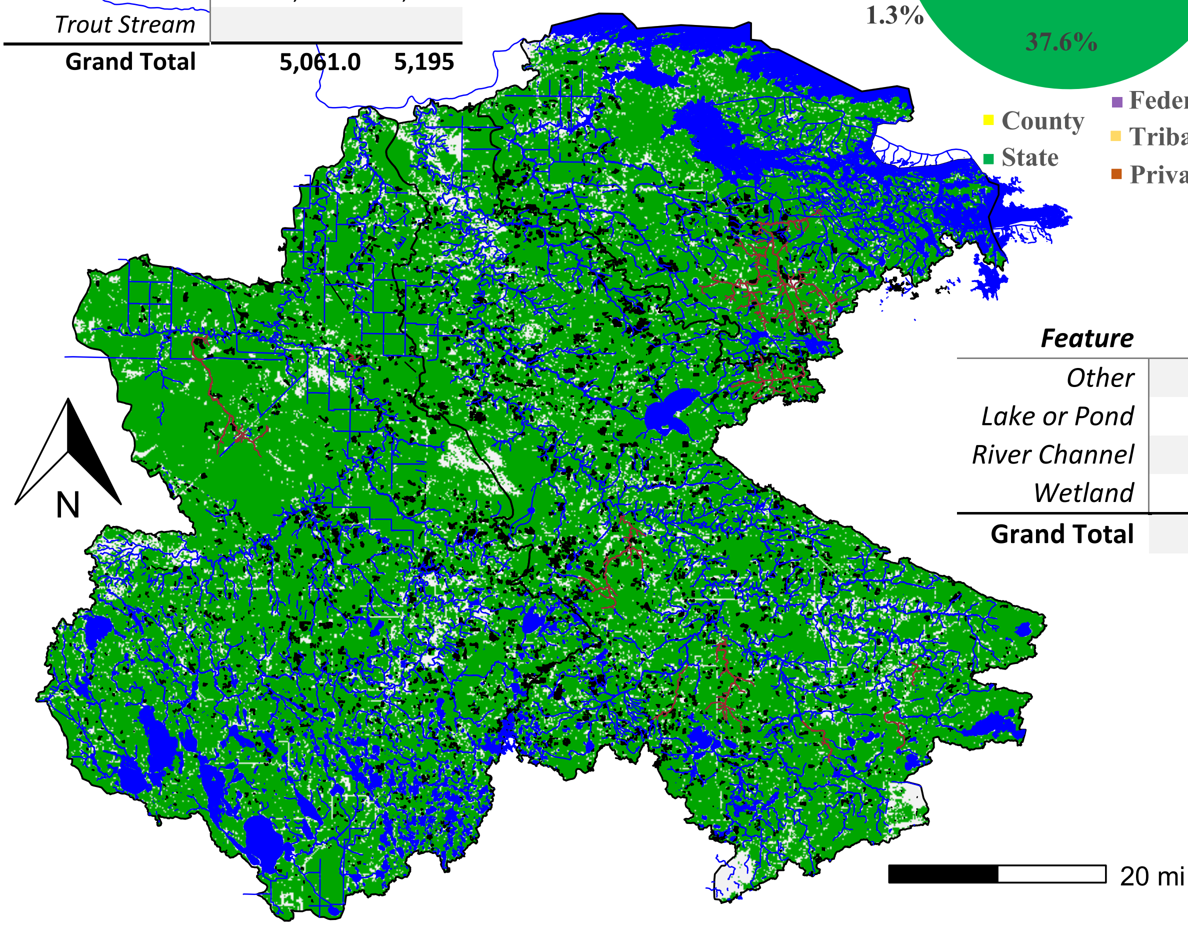
Forest Cover	Acres	Percent
Aspen	880,368	35.9%
Black ash	184,241	7.5%
Black spruce	447,325	18.3%
Northern white-cedar	187,265	7.6%
Other	490,932	20.0%
Tamarack	259,144	10.6%
Total	**2,449,274**	**100.0%**

Forest Canopy Change (2012-2017)

Stream Type	Stream Miles	n
River		
Other	531.0	929
Drainage Ditch		
Stream	2,790.0	3,287
Trout Stream		
Grand Total	**5,061.0**	**5,195**

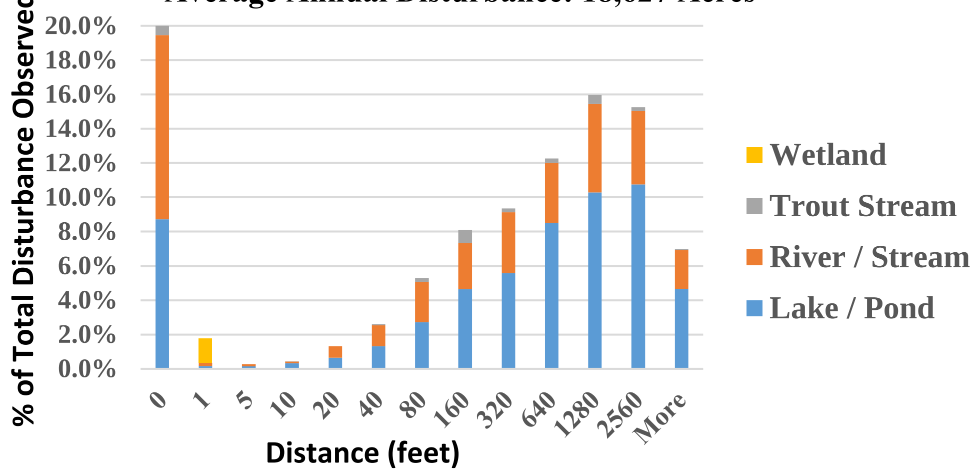
Forest Ownership

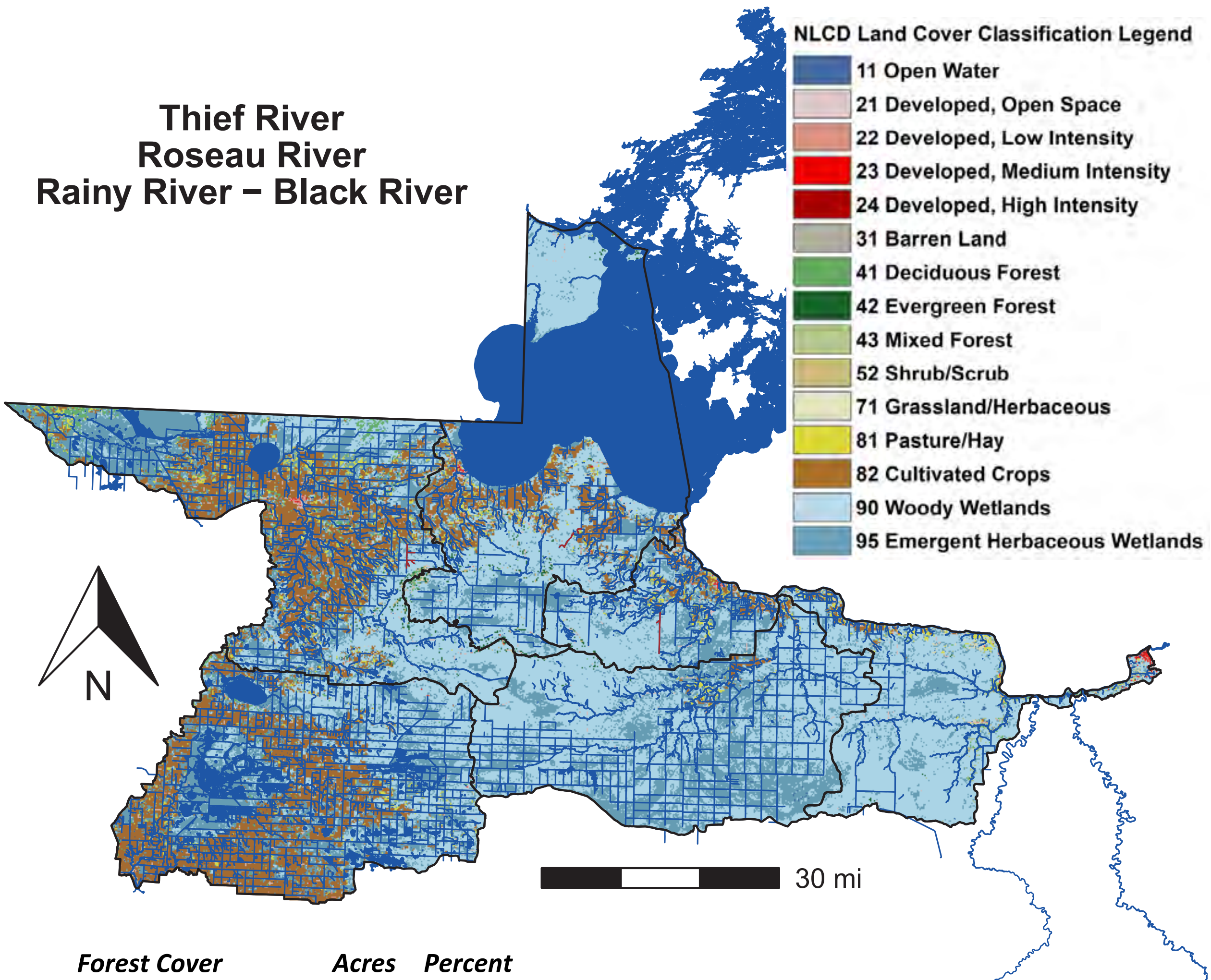




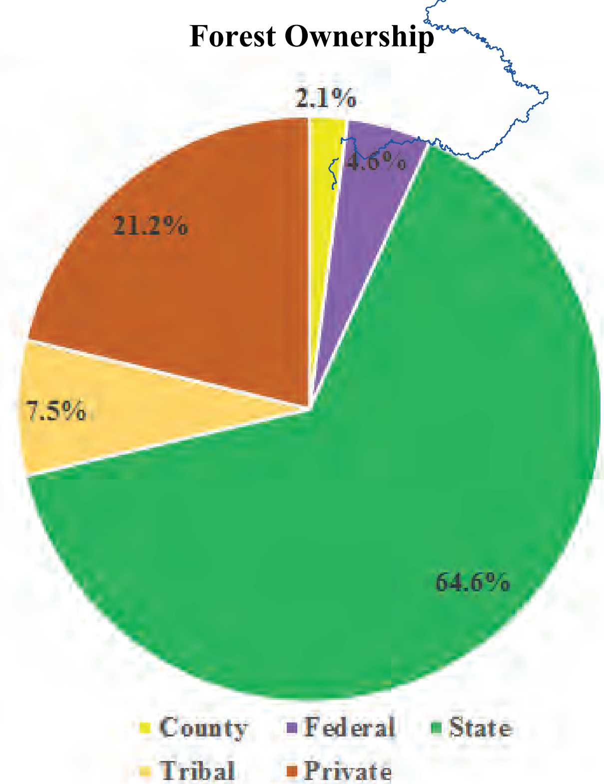
Feature	Acres
Other	1,414.0
Lake or Pond	372,728.3
River Channel	21,605.4
Wetland	17,613.5
Grand Total	**413,371.2**

Average Annual Disturbance: 18,627 Acres





Forest Cover	Acres	Percent
Aspen	497,090	35.6%
Black spruce	239,974	17.2%
Northern white-cedar	92,133	6.6%
Other	304,253	21.8%
Tamarack	261,401	18.7%
Total	**1,394,851**	**100.0%**

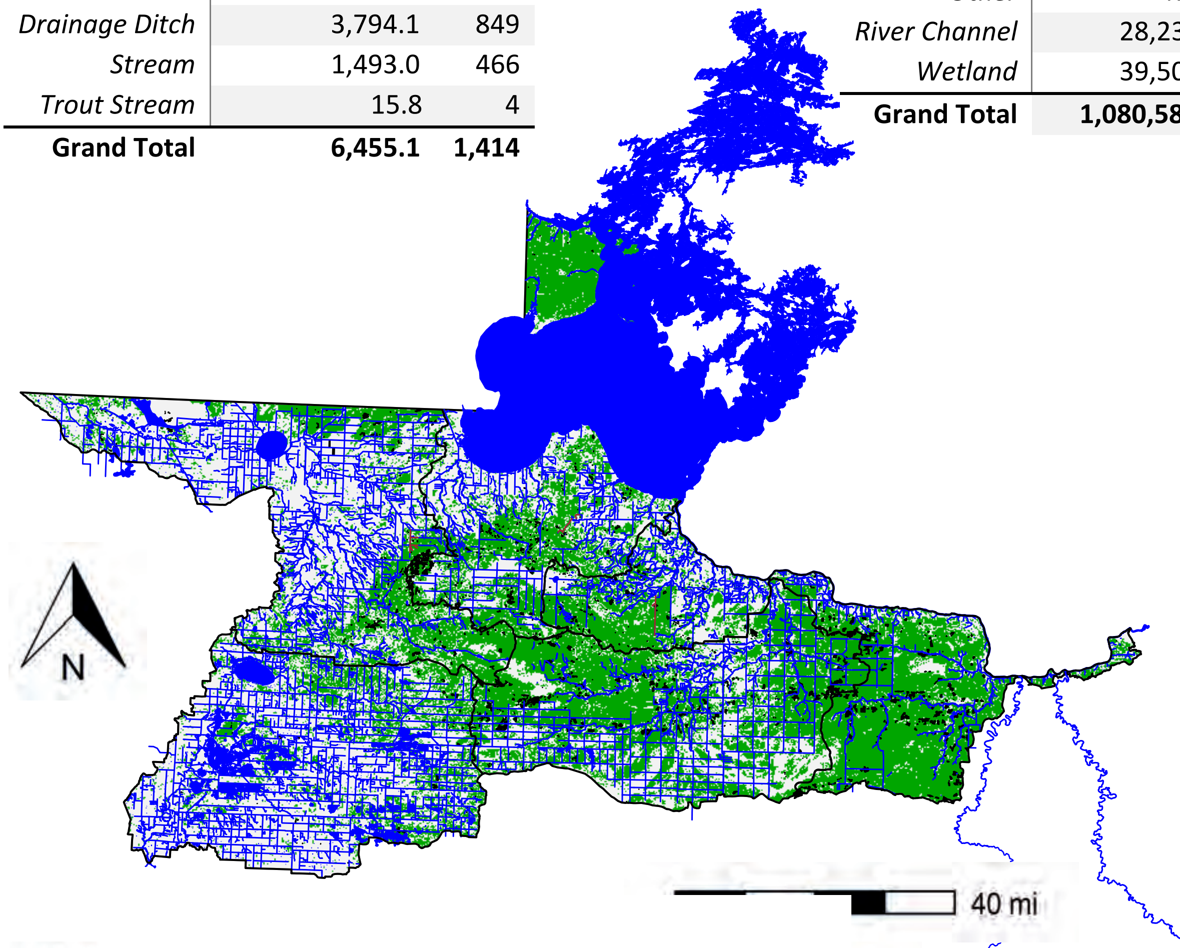


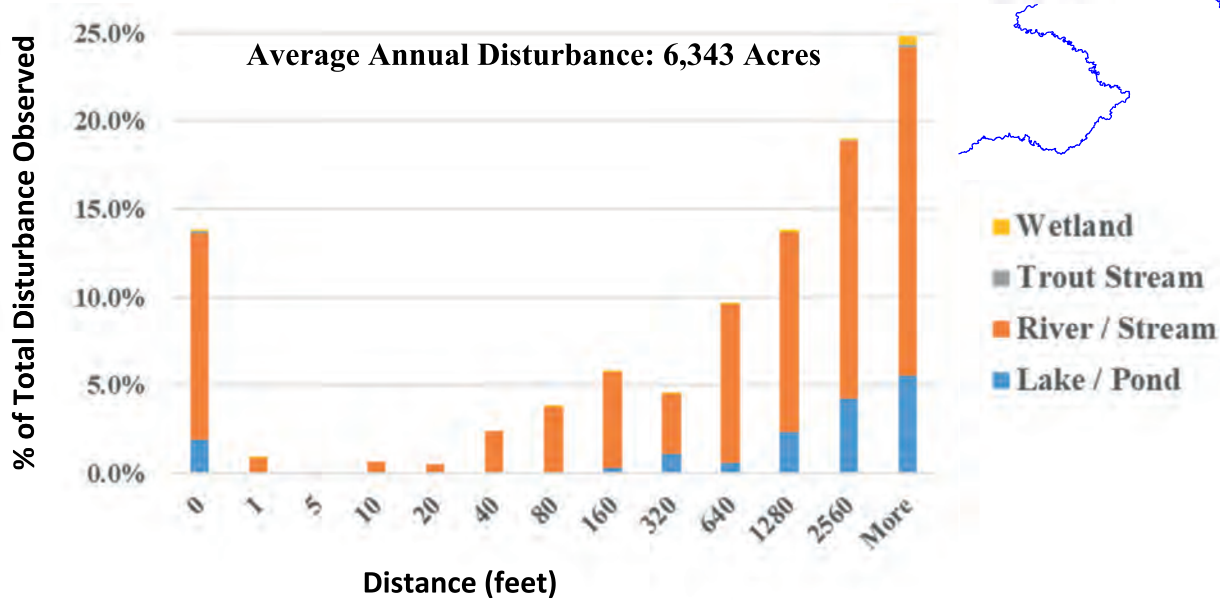
Land cover	Acres
Agriculture	513,754
Barren	977
Developed	54,475
Forest	1,394,851
Grassland	76,767
Open water	329,848
Other	544
Shrub/scrub	4,859
Wetland	841,129
Total	**3,217,204**

Forest Canopy Change (2012-2017)

Stream Type	*Stream Miles*	*n*
River	901.5	15
Other	250.7	81
Drainage Ditch	3,794.1	849
Stream	1,493.0	466
Trout Stream	15.8	4
Grand Total	**6,455.1**	**1,414**

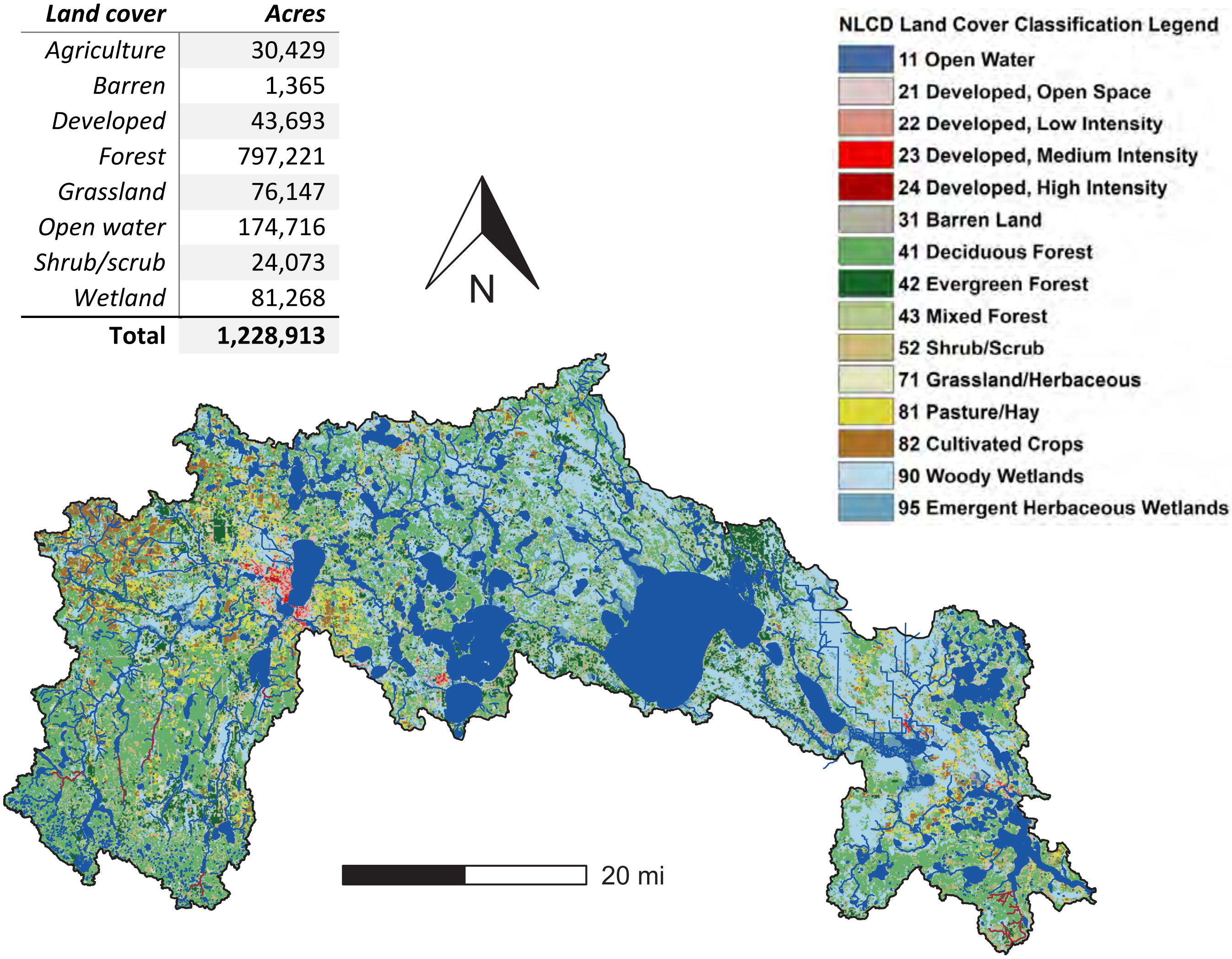
Feature	*Acres*
Lake or Pond	1,012,375.4
Other	471.9
River Channel	28,233.1
Wetland	39,505.5
Grand Total	**1,080,585.8**



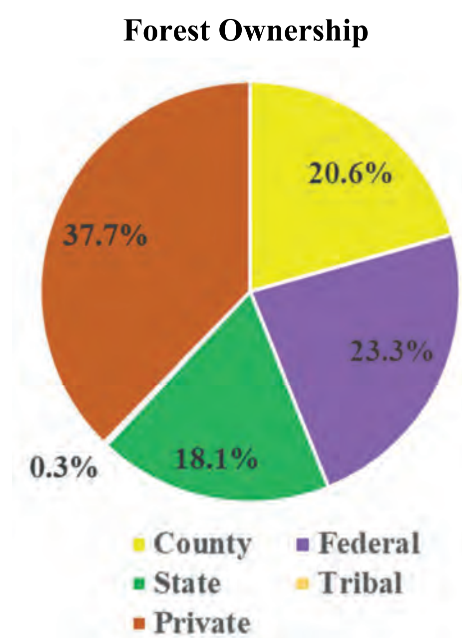


Mississippi Headwaters

Land cover	*Acres*
Agriculture	30,429
Barren	1,365
Developed	43,693
Forest	797,221
Grassland	76,147
Open water	174,716
Shrub/scrub	24,073
Wetland	81,268
Total	**1,228,913**



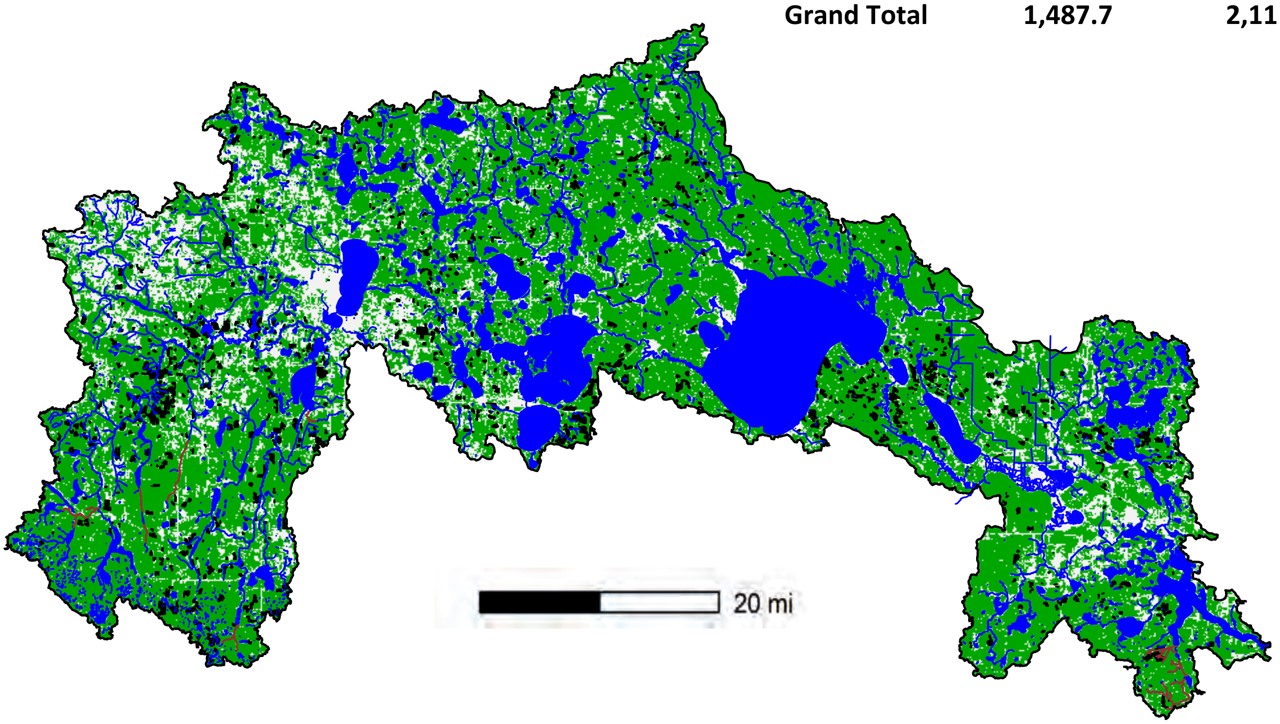
Forest Cover	*Acres*	*Percent*
Aspen	267,464	34.0%
Black ash	55,421	7.1%
Northern hardwoods	57,830	7.4%
Other	183,129	23.3%
Paper birch	48,192	6.1%
Red pine	62,649	8.0%
Tamarack	53,011	6.7%
Oak - hickory	57,830	7.4%
Total	**785,526**	**100.0%**

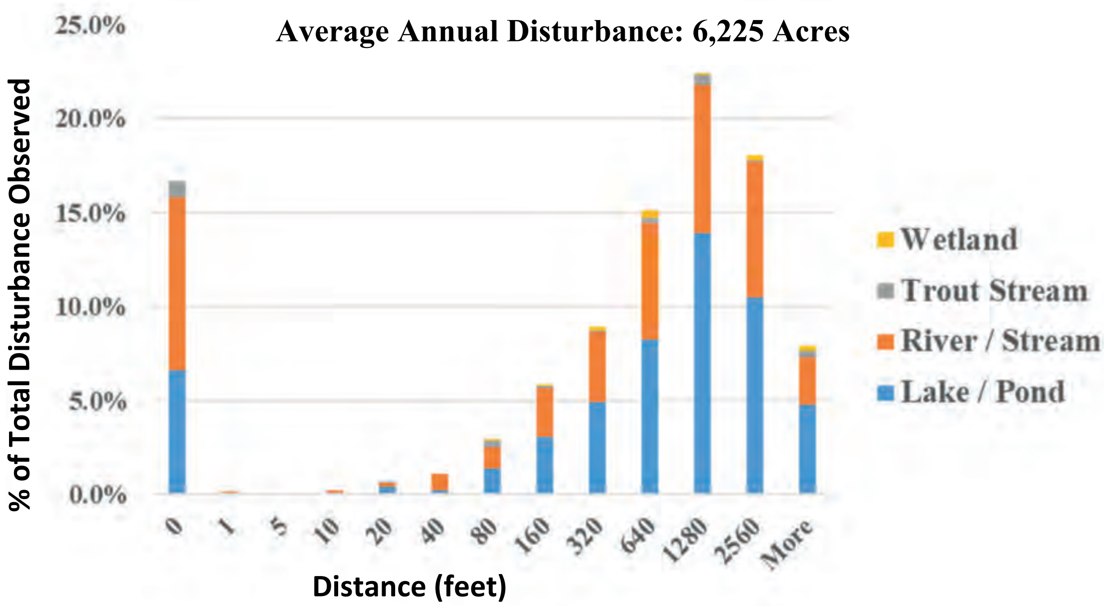


Forest Canopy Change (2012-2017)

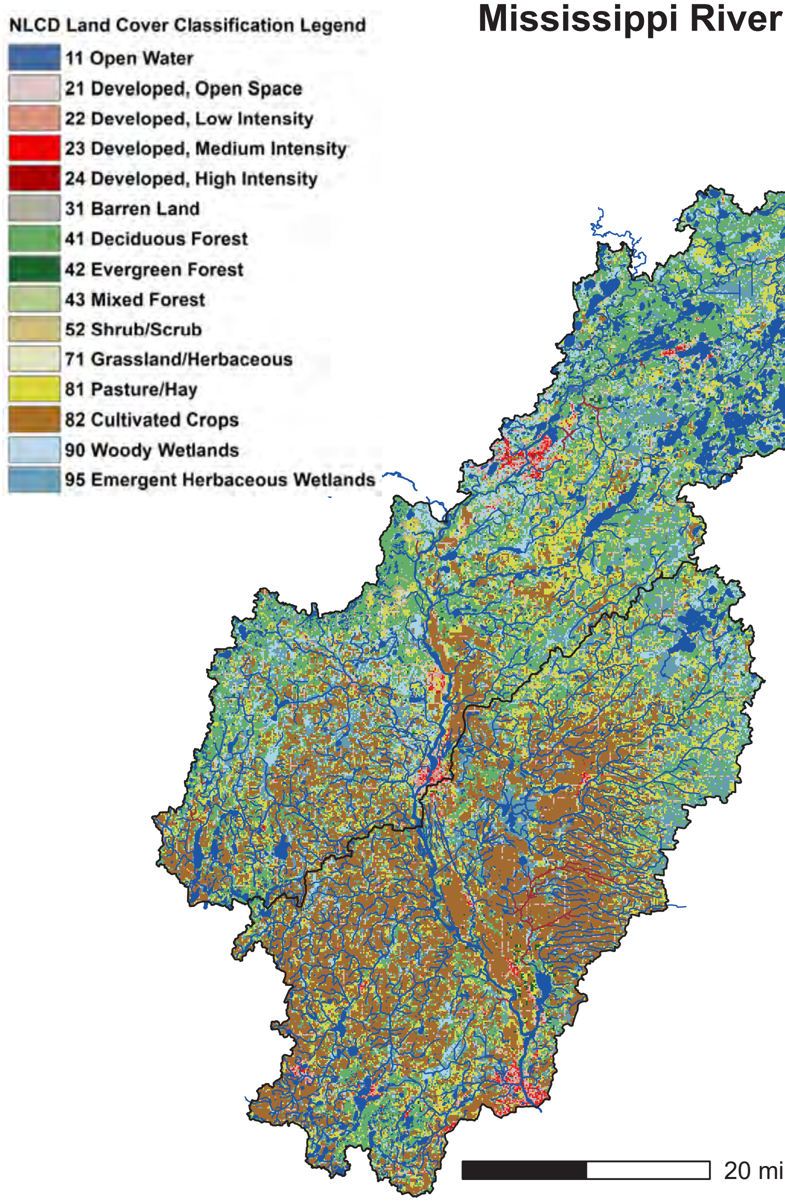
	202,558.6
	2,681.8

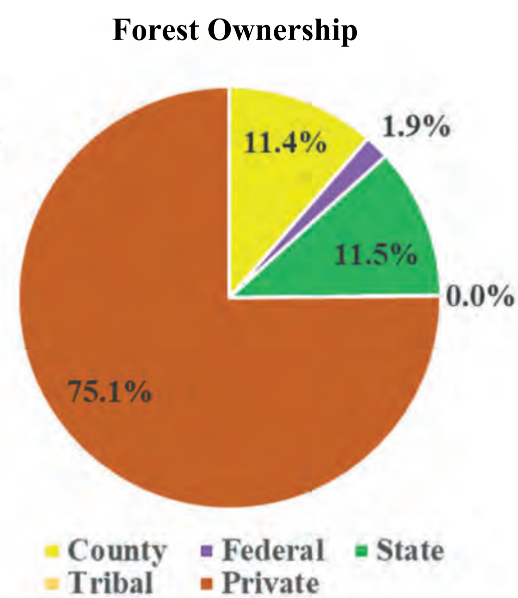
Stream Type	*Stream Miles*	*n*
River	228.8	74
Other	579.8	739
Drainage Ditch	80.3	108
Stream	779.5	1,161
Trout Stream	48.1	29
Grand Total	**1,487.7**	**2,111**





Mississippi River – Brainerd
Mississippi River – Sartell

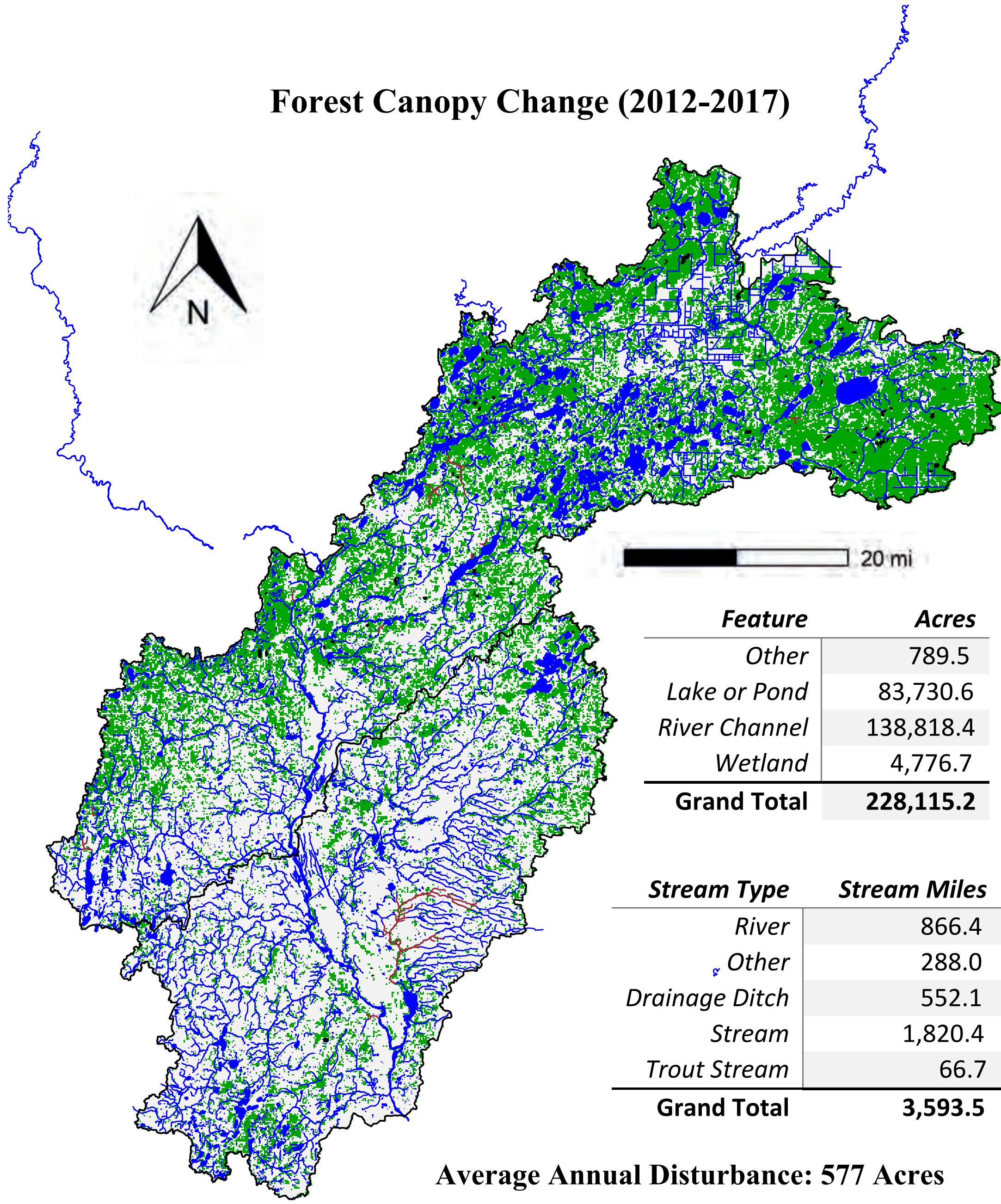




Forest Cover	*Acres*	*Percent*
Aspen	135,904	20.2%
Black ash	59,607	8.9%
Central hardwoods	57,223	8.5%
Lowland hardwoods	40,533	6.0%
Northern hardwoods	84,834	12.8%
Other	95,371	14.2%
Tamarack	35,764	5.3%
Oak - hickory	162,131	24.1%
Total	**672,368**	**100.0%**

Land cover	*Acres*
Agriculture	368,024
Barren	1,251
Developed	87,047
Forest	672,368
Grassland	255,403
Open water	81,173
Shrub/scrub	6,181
Wetland	260,949
Grand Total	**1,732,397**

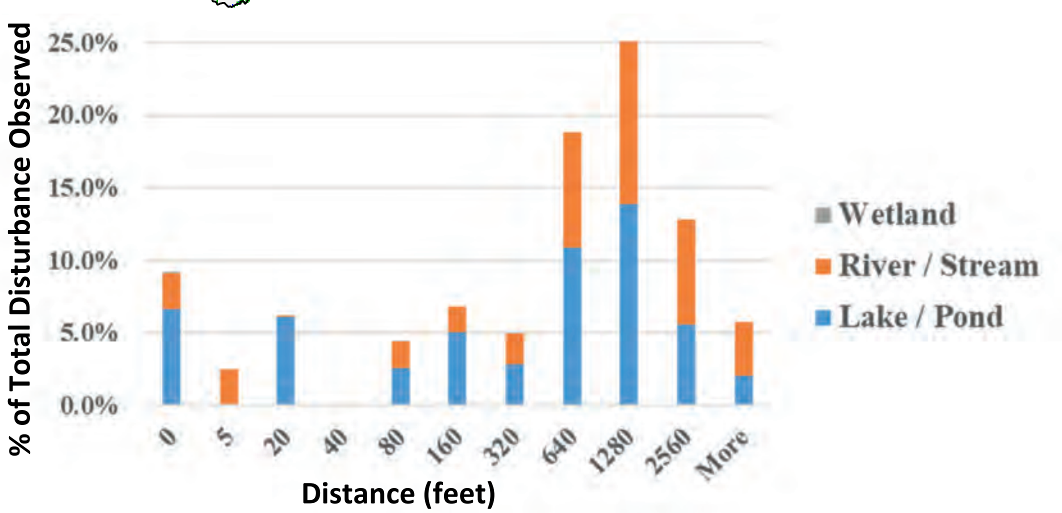
Forest Canopy Change (2012-2017)



Feature	Acres
Other	789.5
Lake or Pond	83,730.6
River Channel	138,818.4
Wetland	4,776.7
Grand Total	**228,115.2**

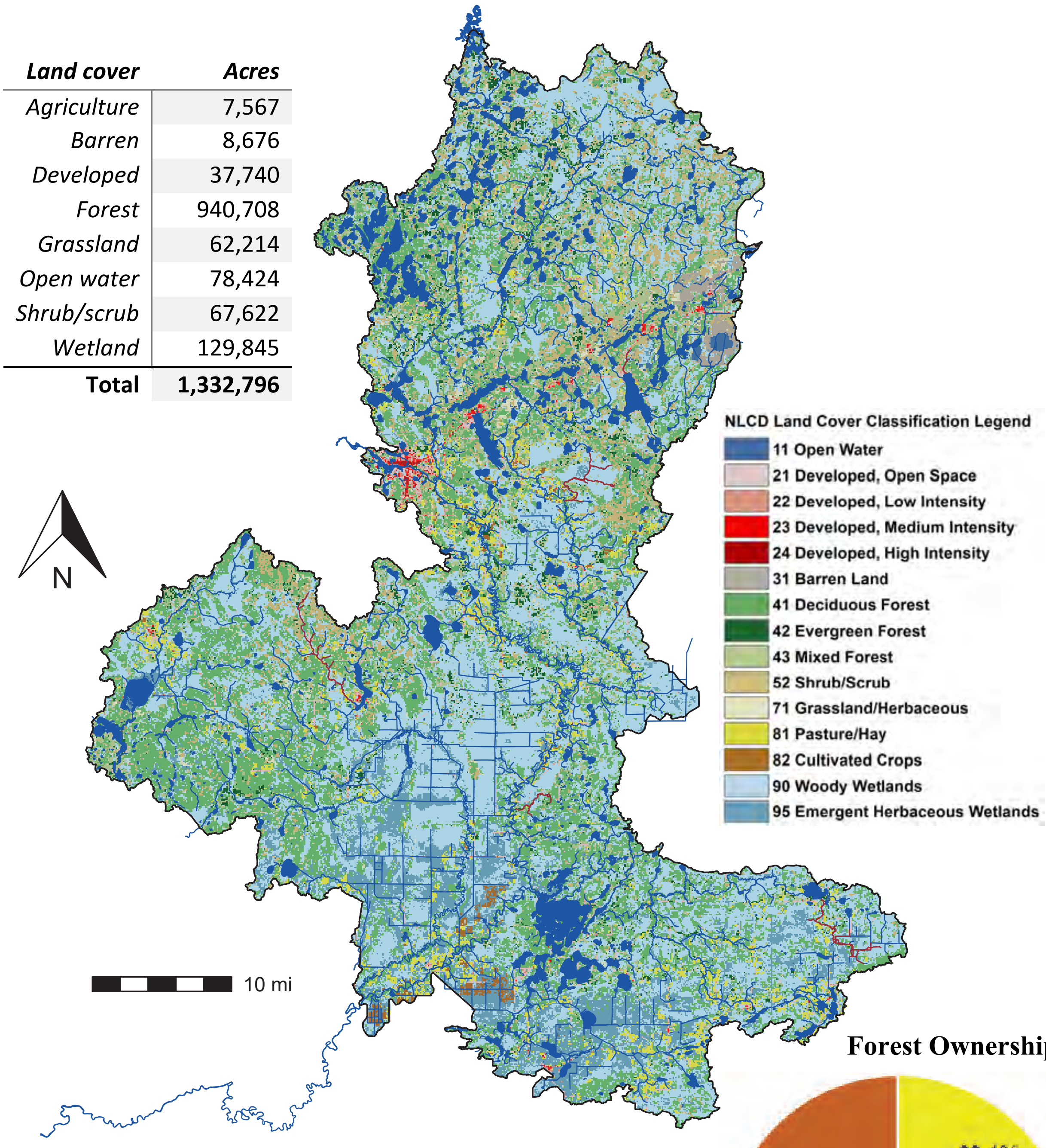
Stream Type	Stream Miles	n
River	866.4	47
Other	288.0	424
Drainage Ditch	552.1	335
Stream	1,820.4	1,242
Trout Stream	66.7	23
Grand Total	**3,593.5**	**2,070**

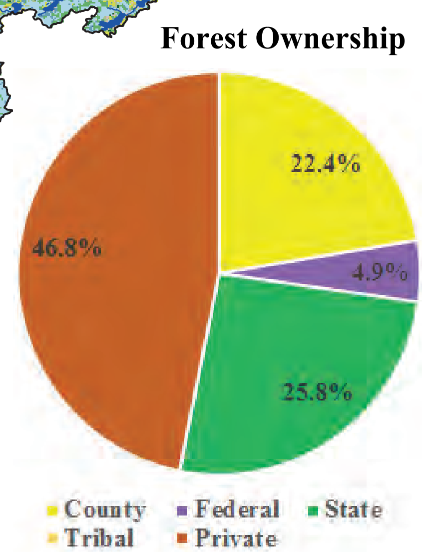
Average Annual Disturbance: 577 Acres



Mississippi River – Grand Rapids

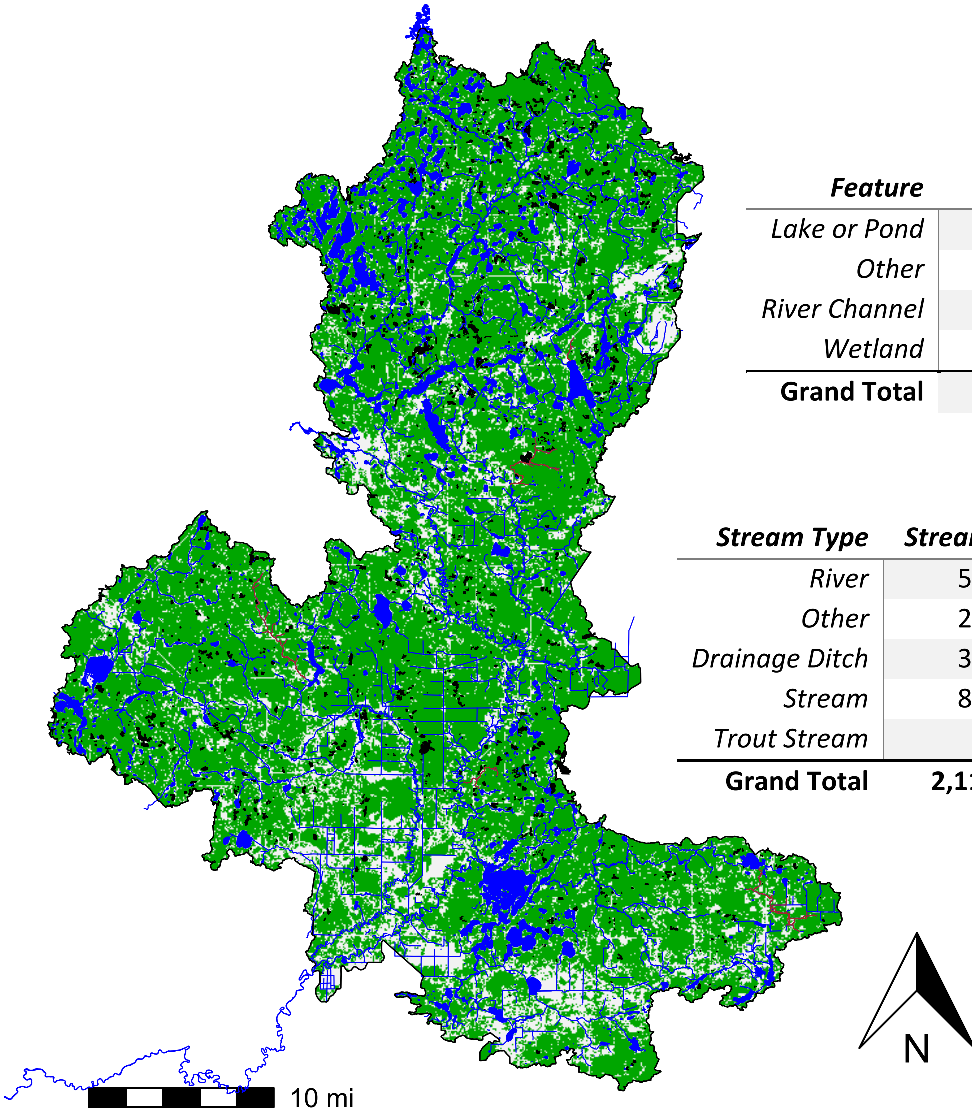
Land cover	Acres
Agriculture	7,567
Barren	8,676
Developed	37,740
Forest	940,708
Grassland	62,214
Open water	78,424
Shrub/scrub	67,622
Wetland	129,845
Total	**1,332,796**





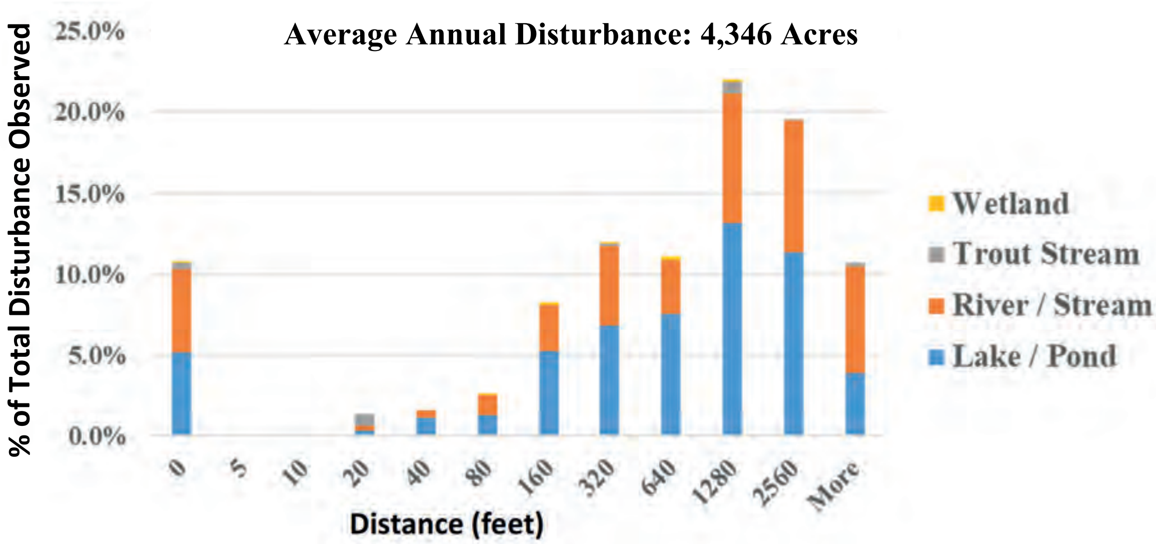
Forest Cover	Acres	Percent
Aspen	388,229	41.3%
Black ash	91,724	9.8%
Black spruce	74,659	7.9%
Northern hardwoods	104,523	11.1%
Other	194,114	20.6%
Tamarack	87,458	9.3%
Grand Total	**940,708**	**100.0%**

Forest Canopy Change (2012-2017)

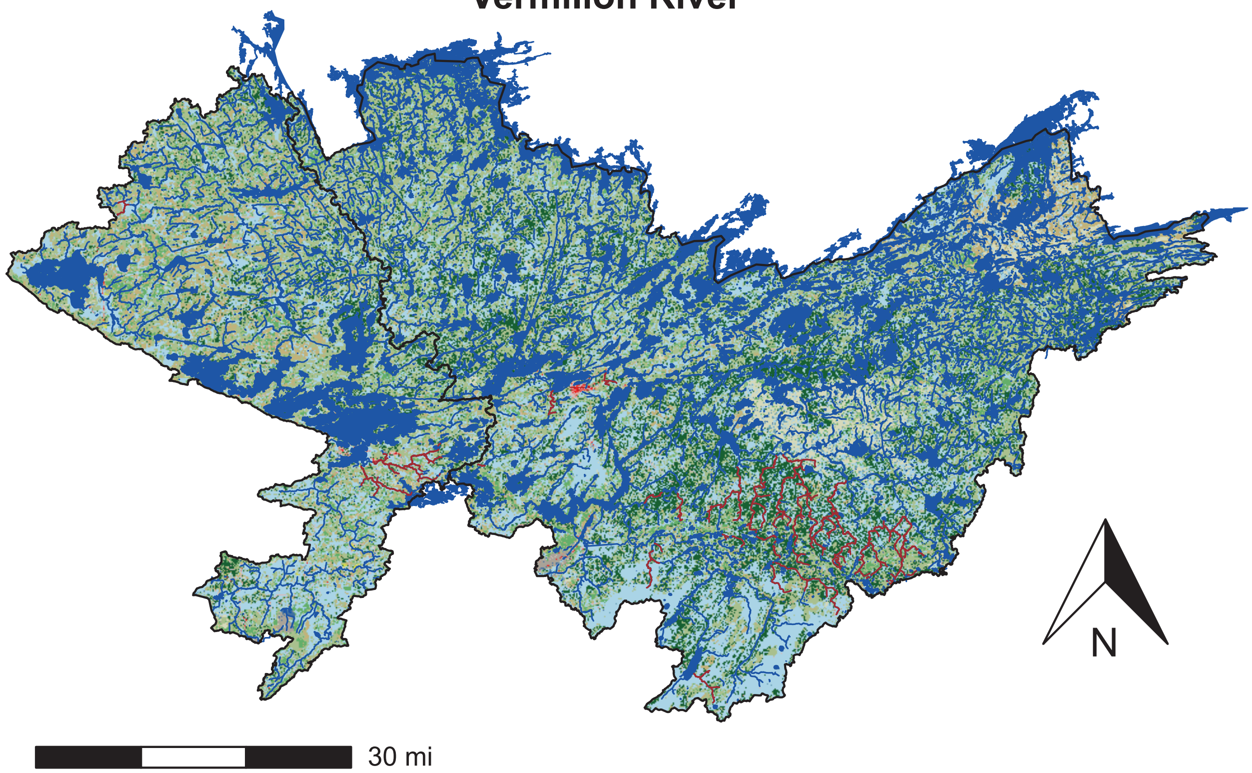


Feature	Acres
Lake or Pond	85,144.6
Other	595.0
River Channel	33,867.3
Wetland	2,064.8
Grand Total	**121,875.3**

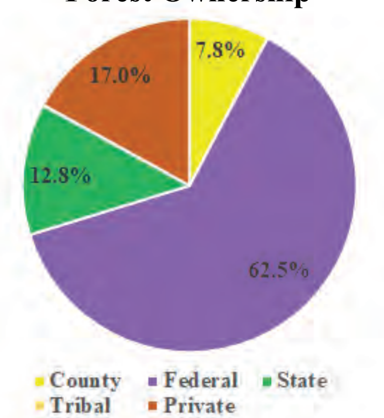
Stream Type	Stream Miles	n
River	584.9	86
Other	221.9	611
Drainage Ditch	387.1	330
Stream	856.9	1,228
Trout Stream	62.4	51
Grand Total	**2,113.2**	**2,306**



Rainy River – Headwaters Vermilion River



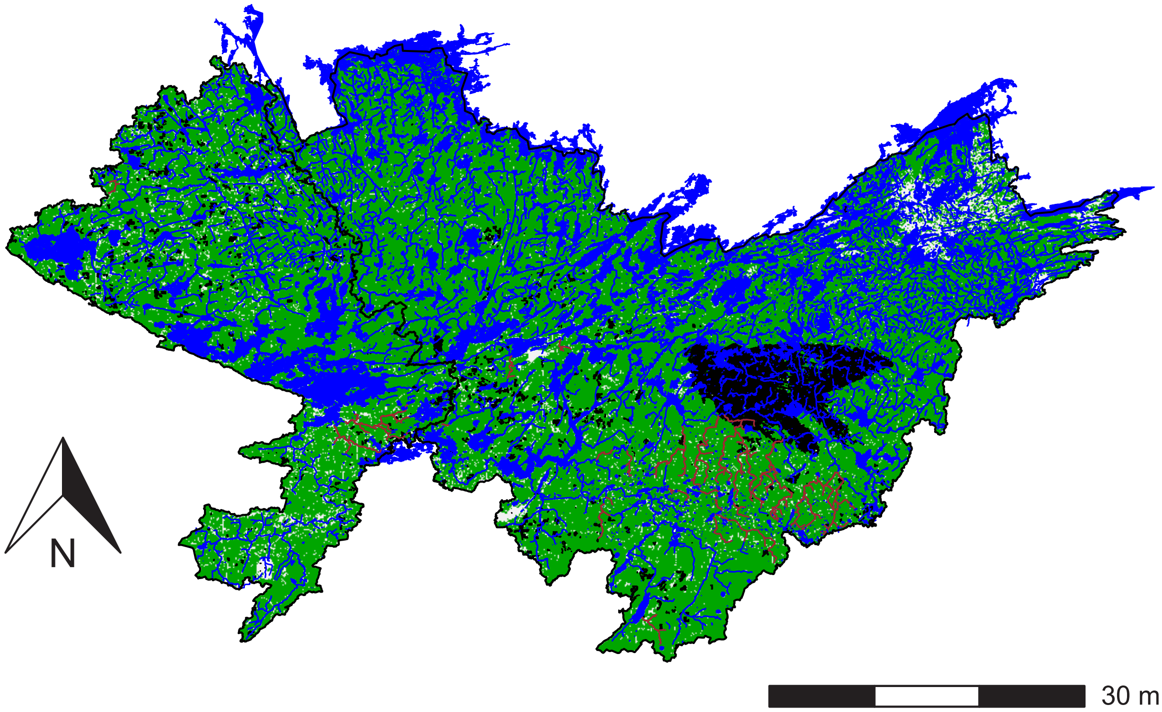
Forest Ownership



Forest Cover	Acres	Percent
Aspen	462,185	30.0%
Balsam fir	172,202	9.0%
Black spruce	246,561	14.5%
Jack pine	164,153	8.5%
Northern hardwoods	84,782	4.9%
Other	320,893	19.6%
Paper birch	166,160	8.7%
Red pine	101,024	4.8%
Total	**1,717,960**	**100.0%**

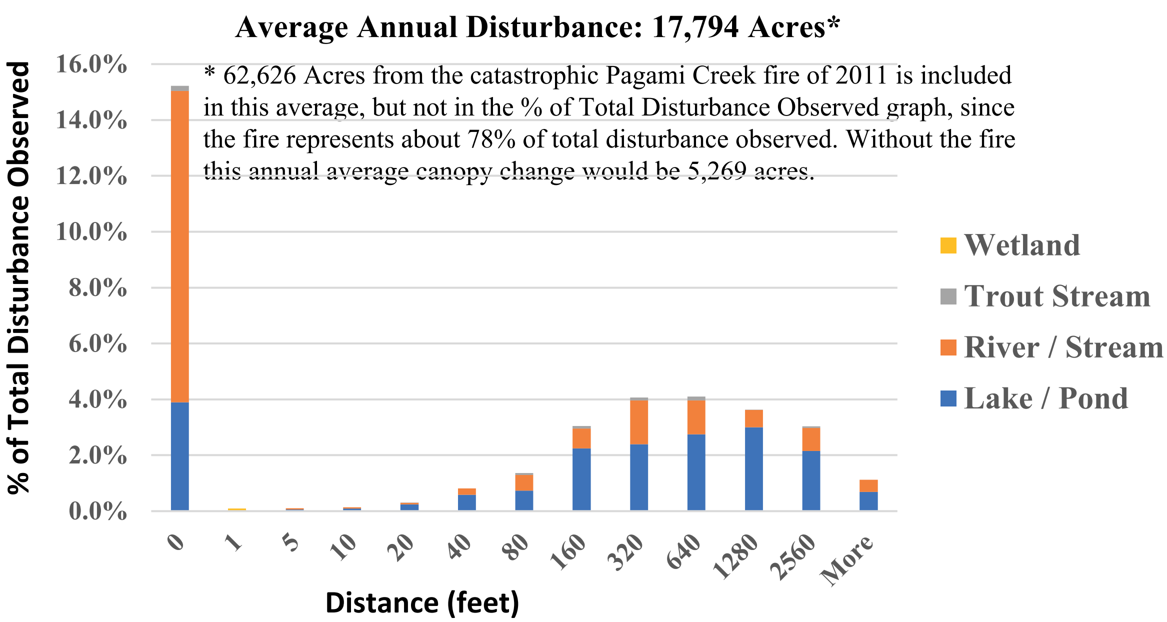
Land cover	Acres
Agriculture	28
Barren	4,986
Developed	28,110
Forest	1,717,960
Grassland	68,232
Open water	308,964
Other	392
Shrub/scrub	109,013
Wetland	31,474
Total	**2,269,158**

Forest Canopy Change
(2012-2017)

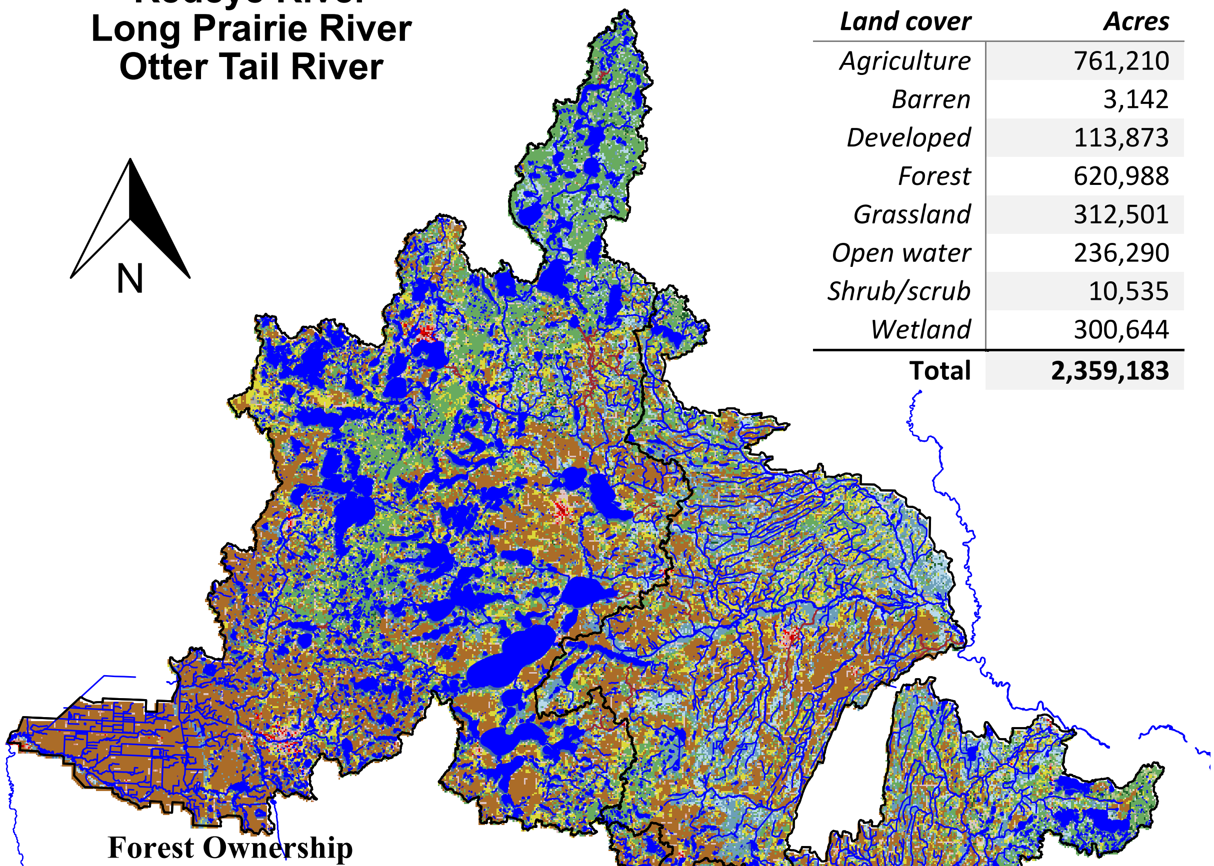
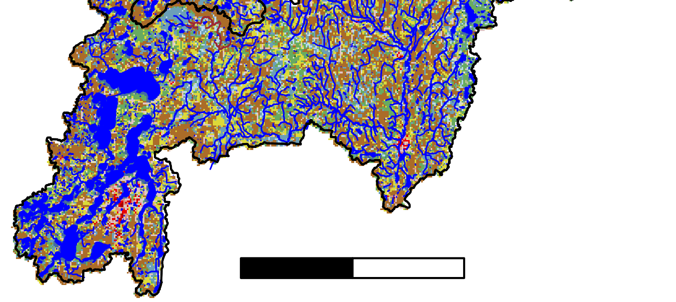


Stream Type	Stream Miles	n
River	580.1	553
Other	1,343.1	3,174
Drainage Ditch	27.0	53
Stream	2,253.0	4,255
Trout Stream	277.2	127
Grand Total	**4,480.4**	**8,162**

Feature	Acres
Other	5.4
Lake or Pond	420,982.8
River Channel	33,458.9
Wetland	10,420.5
Grand Total	**464,867.7**

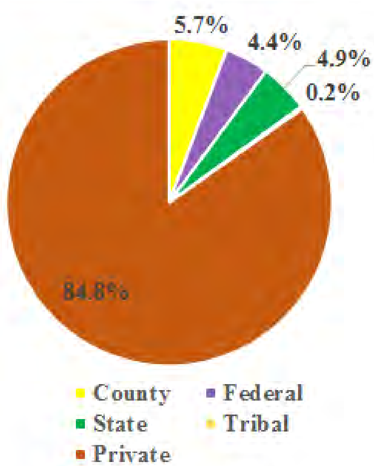


Redeye River
Long Prairie River
Otter Tail River

Land cover	Acres
Agriculture	761,210
Barren	3,142
Developed	113,873
Forest	620,988
Grassland	312,501
Open water	236,290
Shrub/scrub	10,535
Wetland	300,644
Total	**2,359,183**

Forest Ownership

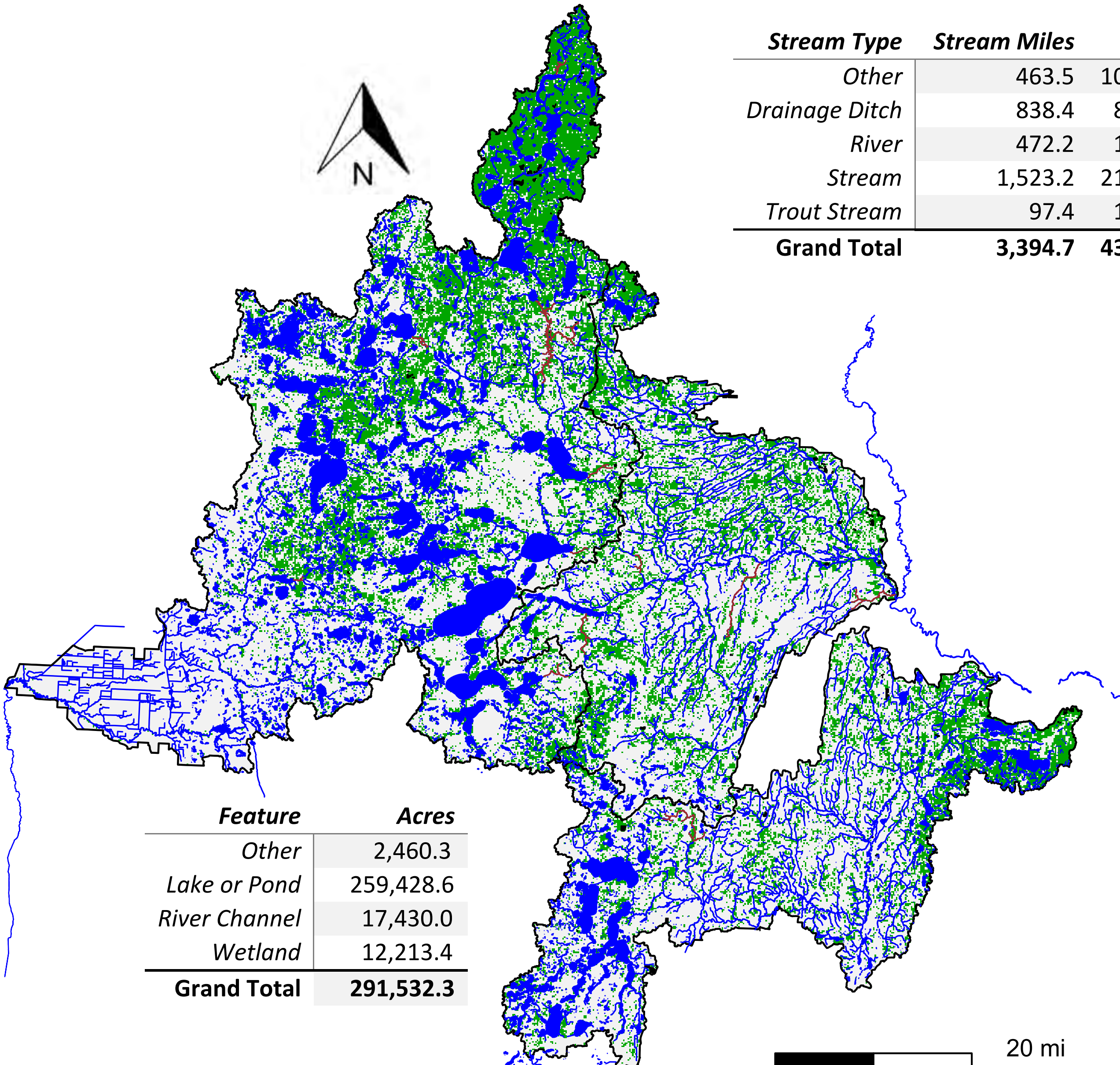


Forest Cover	Acres	Percent
Aspen	117,996	19.0%
Black ash	36,035	5.8%
Central hardwoods	58,060	9.3%
Northern hardwoods	93,022	15.0%
Other	144,079	23.2%
Oak - hickory	171,795	27.7%
Total	**620,988**	**100.0%**

NLCD Land Cover Classification Legend

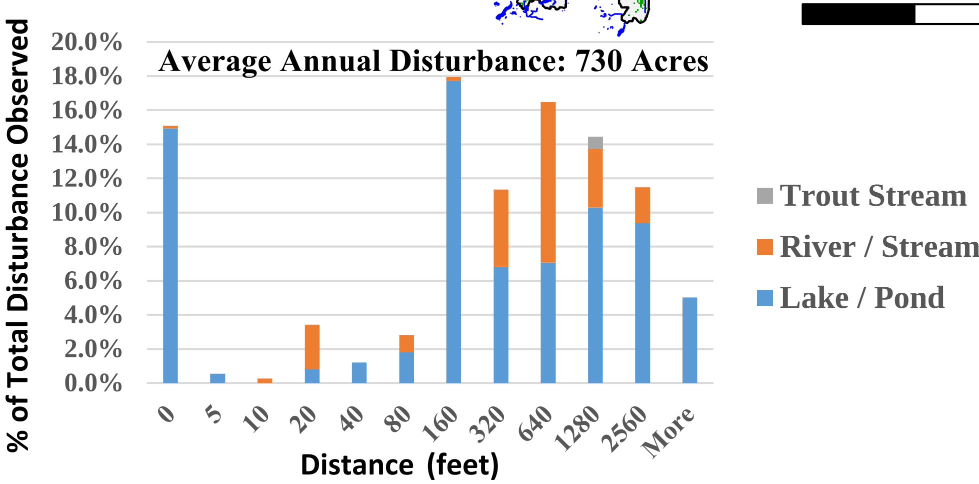
- 11 Open Water
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90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

Forest Canopy Change (2012-2017)

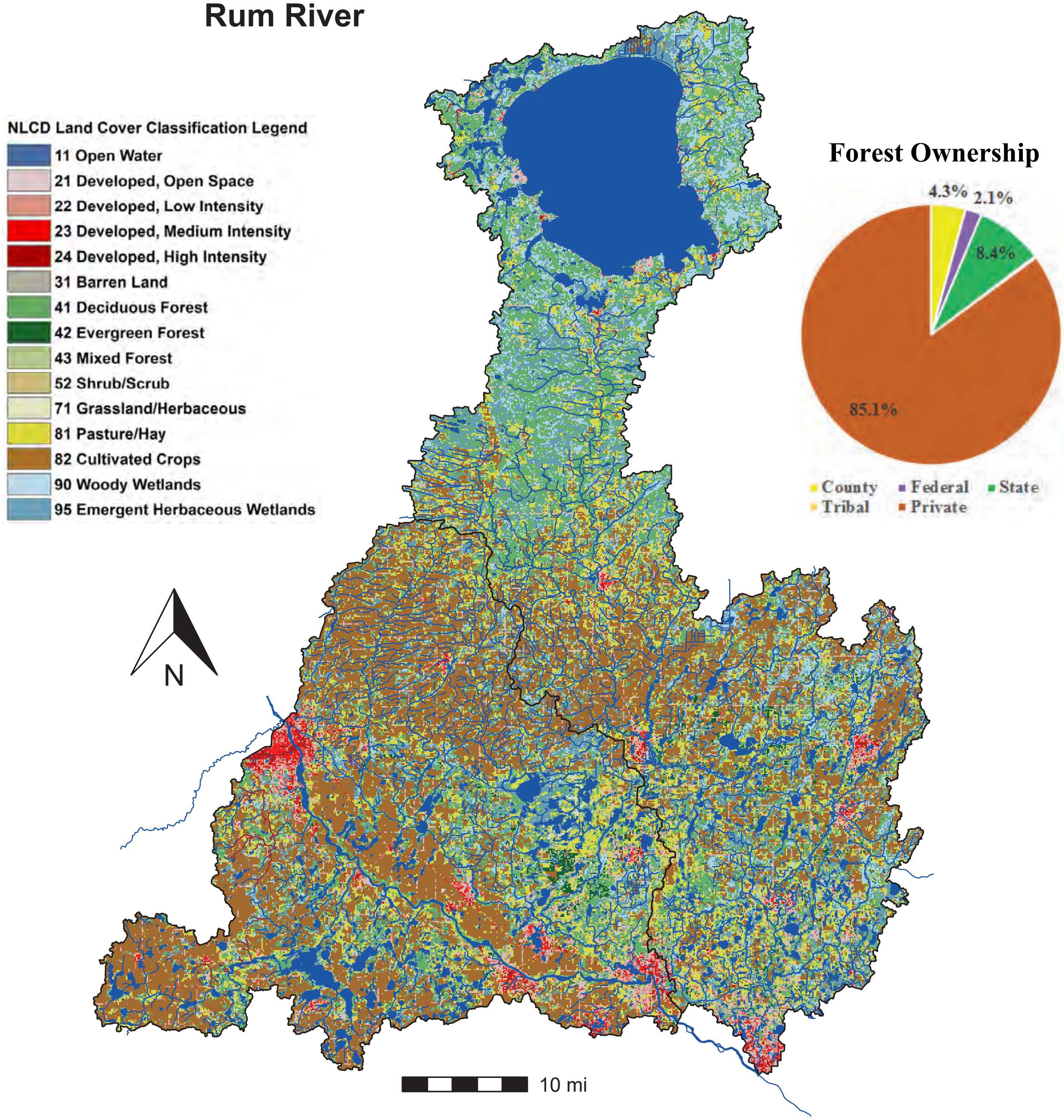


Stream Type	*Stream Miles*	*n*
Other	463.5	1016
Drainage Ditch	838.4	889
River	472.2	184
Stream	1,523.2	2129
Trout Stream	97.4	139
Grand Total	**3,394.7**	**4357**

Feature	*Acres*
Other	2,460.3
Lake or Pond	259,428.6
River Channel	17,430.0
Wetland	12,213.4
Grand Total	**291,532.3**



Mississippi River – St. Cloud
Rum River

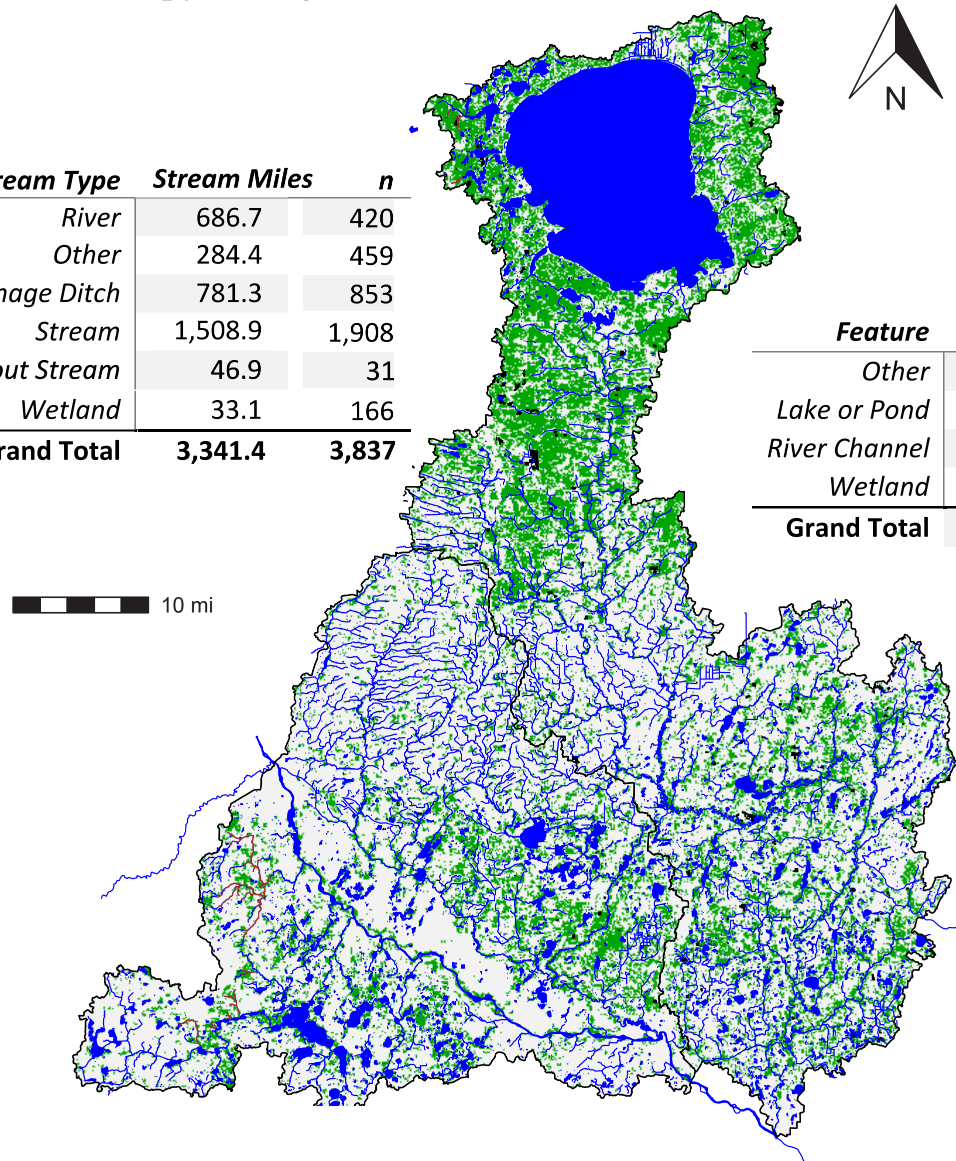


Land cover	*Acres*
Agriculture	466,539
Barren	1,539
Developed	137,649
Forest	447,295
Grassland	260,951
Open water	178,773
Shrub/scrub	3,019
Wetland	235,416
Total	**1,731,178**

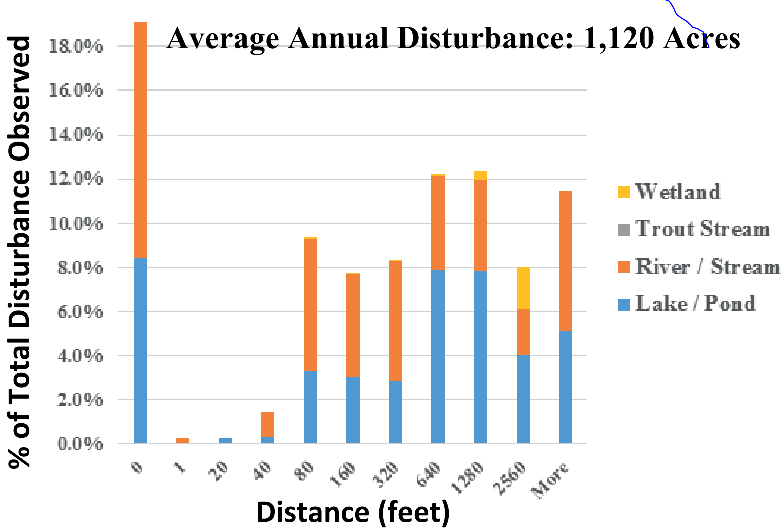
Forest Cover	*Acres*	*Percent*
Aspen	54,225	12.1%
Black ash	49,208	11.0%
Central hardwoods	53,213	11.9%
Lowland hardwoods	55,091	12.3%
Northern hardwoods	36,309	8.1%
Other	54,345	12.1%
Oak - hickory	144,904	32.4%
Total	**447,295**	**100.0%**

Forest Canopy Change (2012-2017)

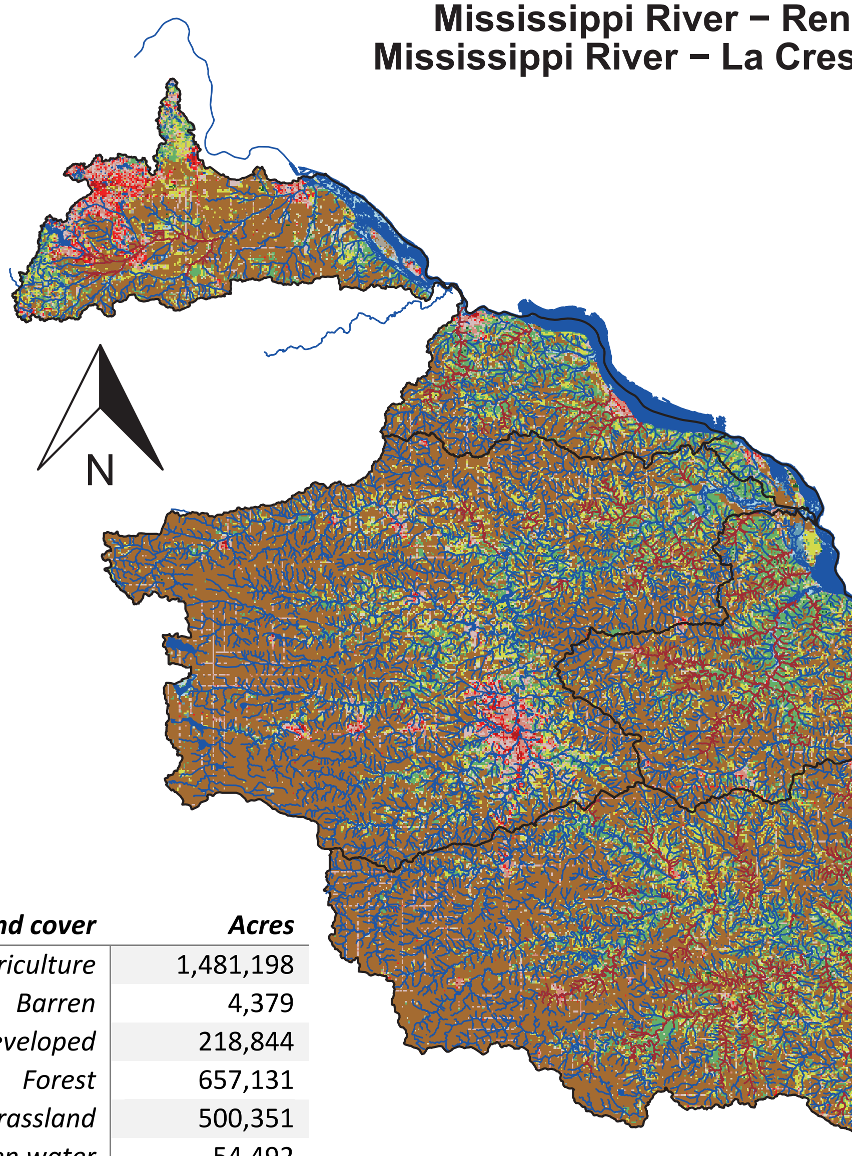
Stream Type	*Stream Miles*	*n*
River	686.7	420
Other	284.4	459
Drainage Ditch	781.3	853
Stream	1,508.9	1,908
Trout Stream	46.9	31
Wetland	33.1	166
Grand Total	**3,341.4**	**3,837**

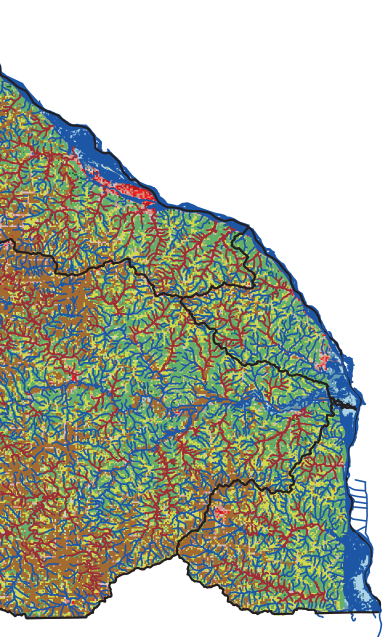


Feature	*Acres*
Other	255.9
Lake or Pond	181,877.0
River Channel	35,970.6
Wetland	17,853.4
Grand Total	**235,957.0**

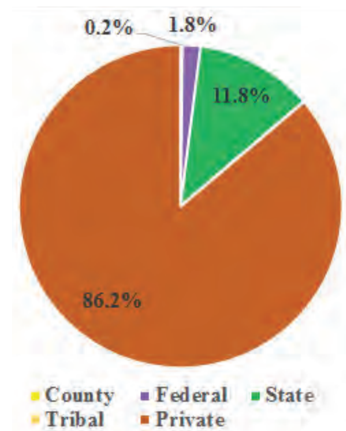


Mississippi River – Lake Pepin
Mississippi River – Winona
Zumbro River
Root River
Mississippi River – Reno
Mississippi River – La Crescent

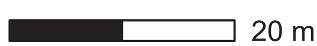




Forest Ownership

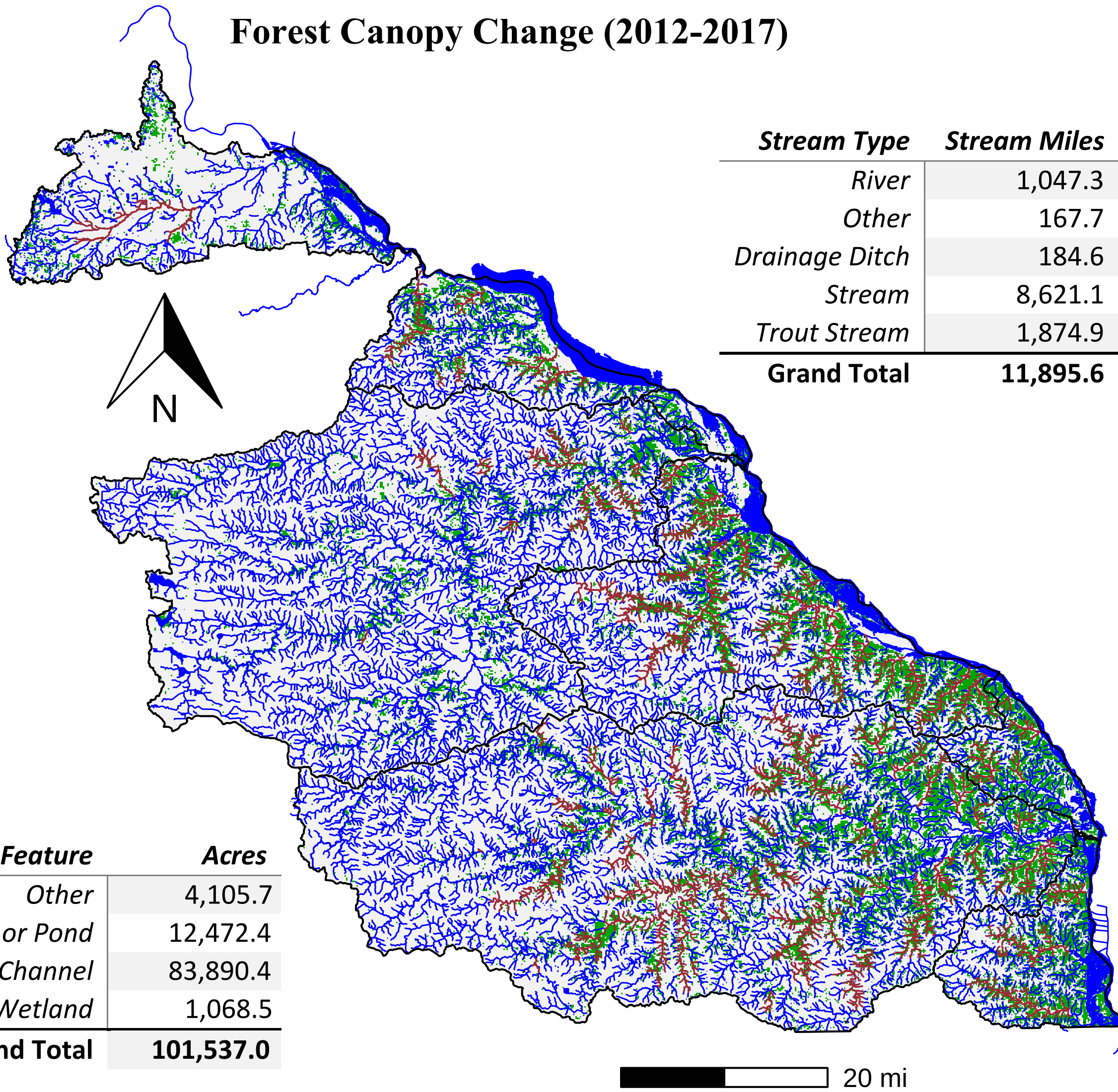


Land cover	*Acres*
Agriculture	1,481,198
Barren	4,379
Developed	218,844
Forest	657,131
Grassland	500,351
Open water	54,492
Shrub/scrub	1,299
Wetland	37,147
Total	**2,950,842**



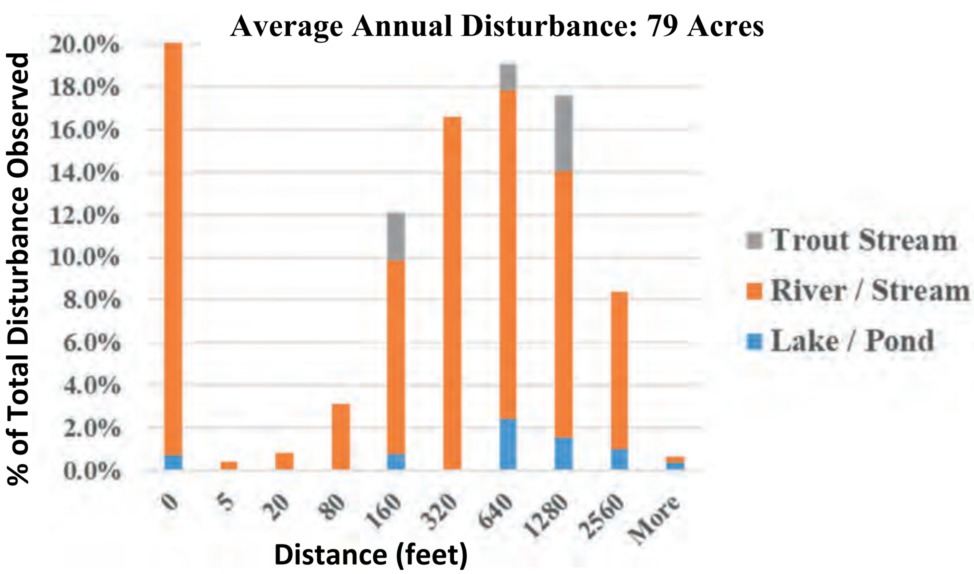
Forest Cover	*Acres*	*Percent*
Central hardwoods	54,193	8.2%
Lowland hardwoods	86,516	13.2%
Northern hardwoods	85,142	13.0%
Other	80,733	12.3%
Oak - hickory	350,548	53.3%
Total	**657,131**	**100.0%**

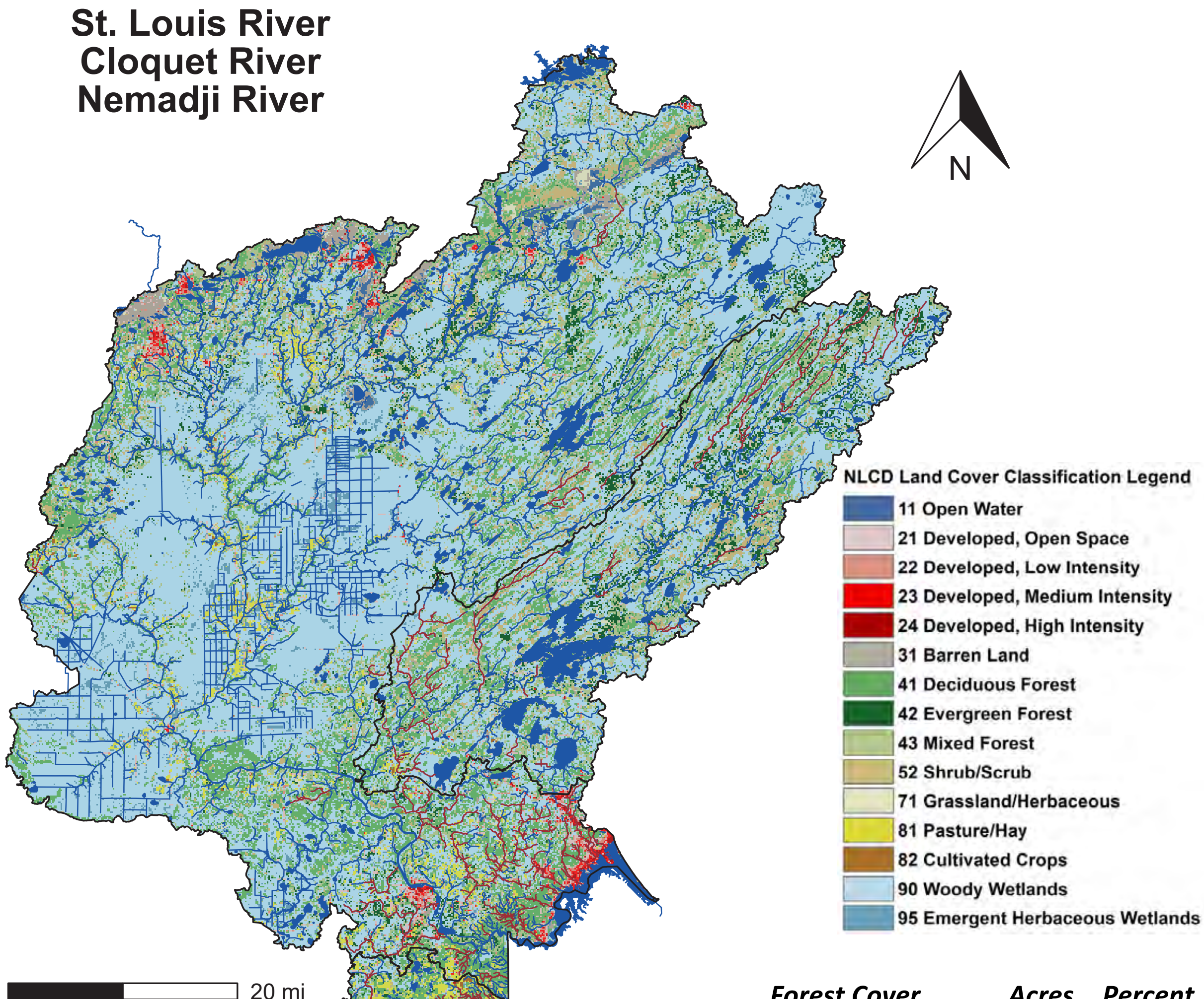
Forest Canopy Change (2012-2017)



Stream Type	Stream Miles	n
River	1,047.3	117
Other	167.7	1,006
Drainage Ditch	184.6	197
Stream	8,621.1	10,410
Trout Stream	1,874.9	2813
Grand Total	**11,895.6**	**14,543**

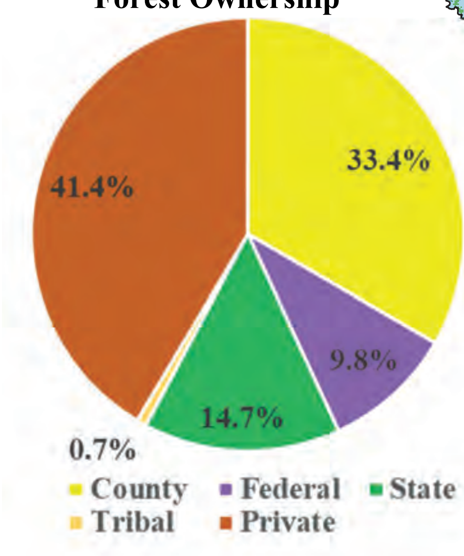
Feature	Acres
Other	4,105.7
Lake or Pond	12,472.4
River Channel	83,890.4
Wetland	1,068.5
Grand Total	**101,537.0**





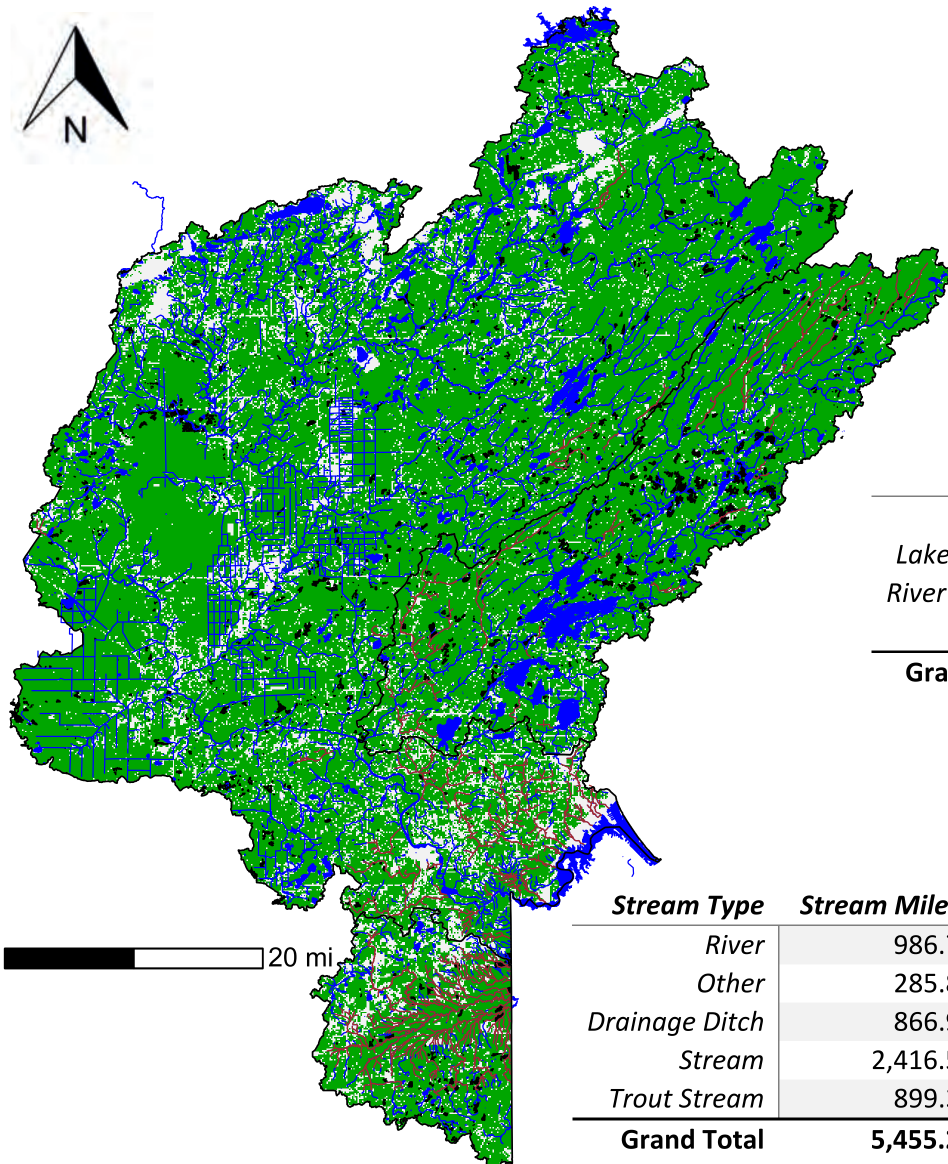
Forest Cover	*Acres*	*Percent*
Aspen	718,214	35.1%
Black ash	102,48	5.0%
Black spruce	375,9927	18.4%
Northern hardwoods	127,097	6.2%
Other	343,097	16.8%
Paper birch	121,321	5.9%
Tamarack	258,408	12.6%
Total	**2,046,615**	**100.0%**

Forest Ownership



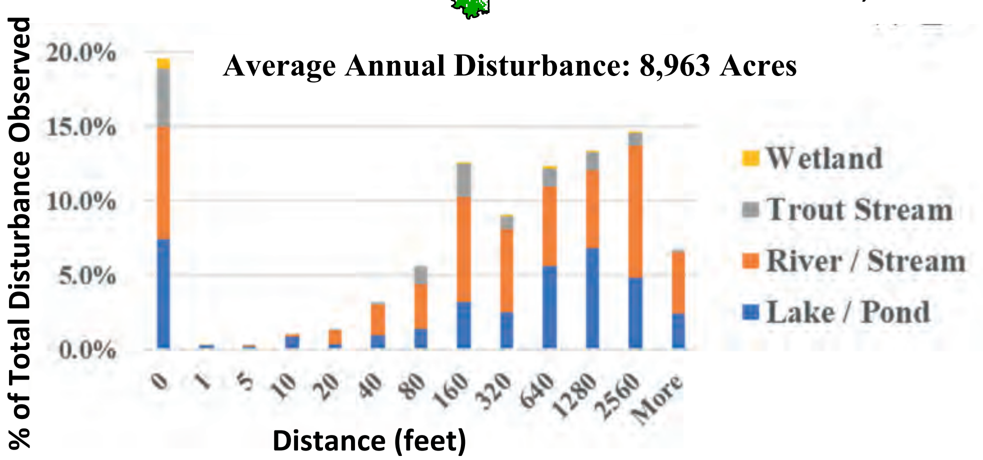
Land cover	*Acres*
Agriculture	3,650
Barren	26,989
Developed	91,203
Forest	2,046,615
Grassland	92,155
Open water	90,125
Shrub/scrub	87,346
Wetland	77,793
Total	**2,515,876**

Forest Canopy Change (2012-2017)

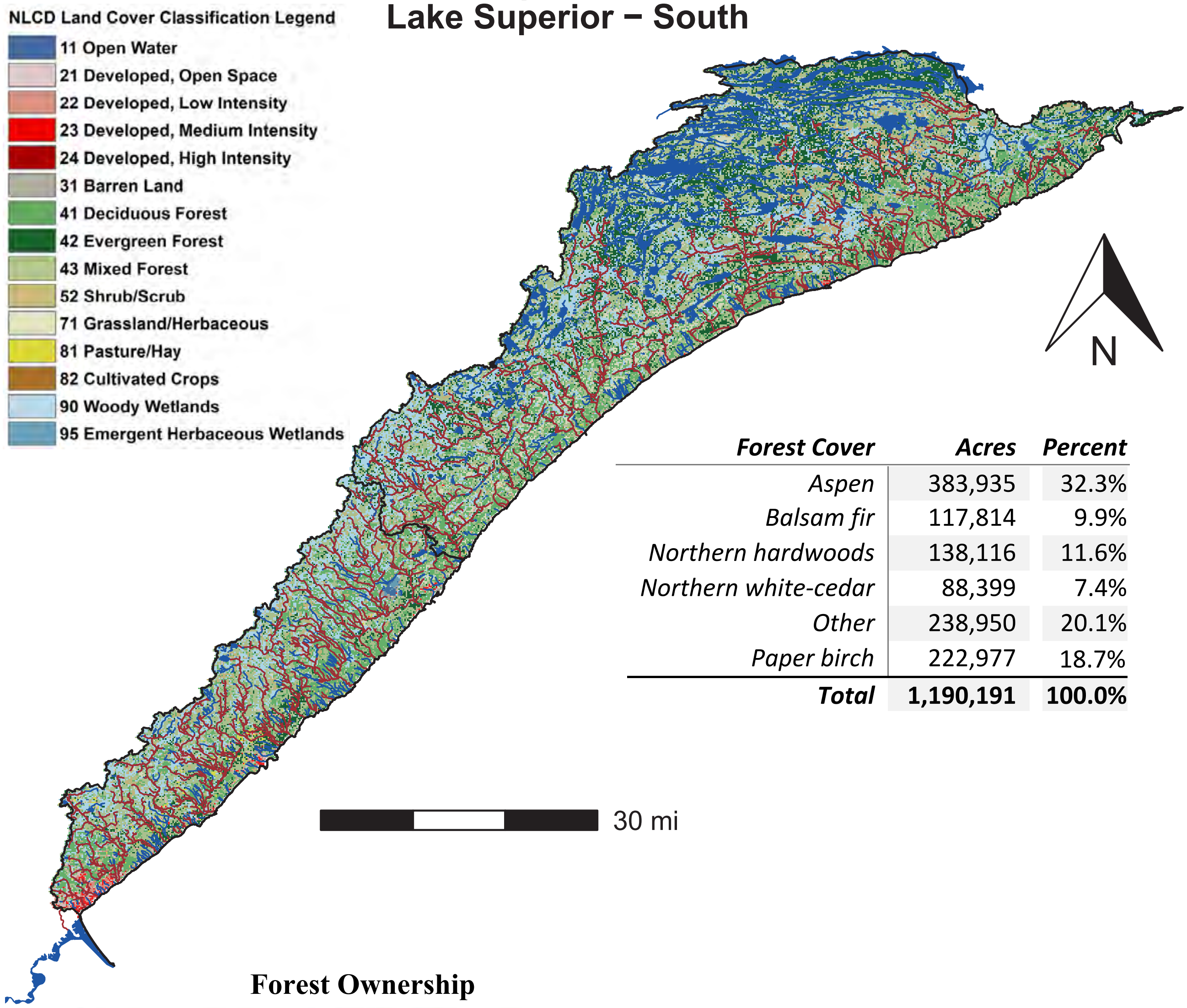


Feature	*Acres*
Other	859.3
Lake or Pond	98,151.3
River Channel	36,483.6
Wetland	6,656.1
Grand Total	**142,150.2**

Stream Type	*Stream Miles*	*n*
River	986.7	59
Other	285.8	337
Drainage Ditch	866.9	412
Stream	2,416.5	947
Trout Stream	899.3	221
Grand Total	**5,455.2**	**156**

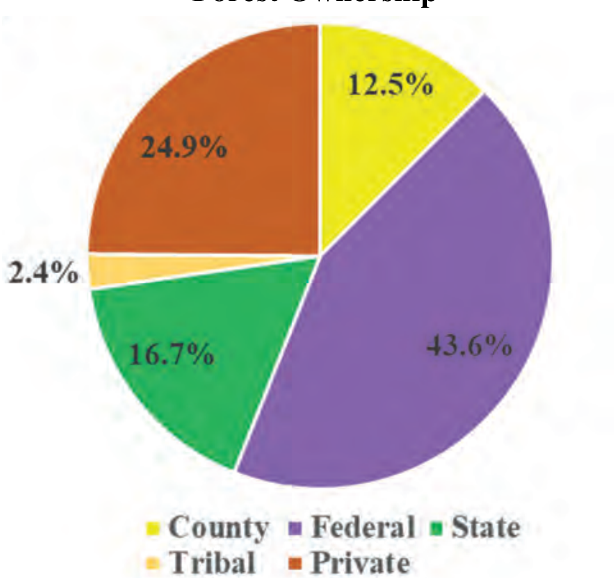


Lake Superior – North
Lake Superior – South



Forest Cover	*Acres*	*Percent*
Aspen	383,935	32.3%
Balsam fir	117,814	9.9%
Northern hardwoods	138,116	11.6%
Northern white-cedar	88,399	7.4%
Other	238,950	20.1%
Paper birch	222,977	18.7%
Total	**1,190,191**	**100.0%**

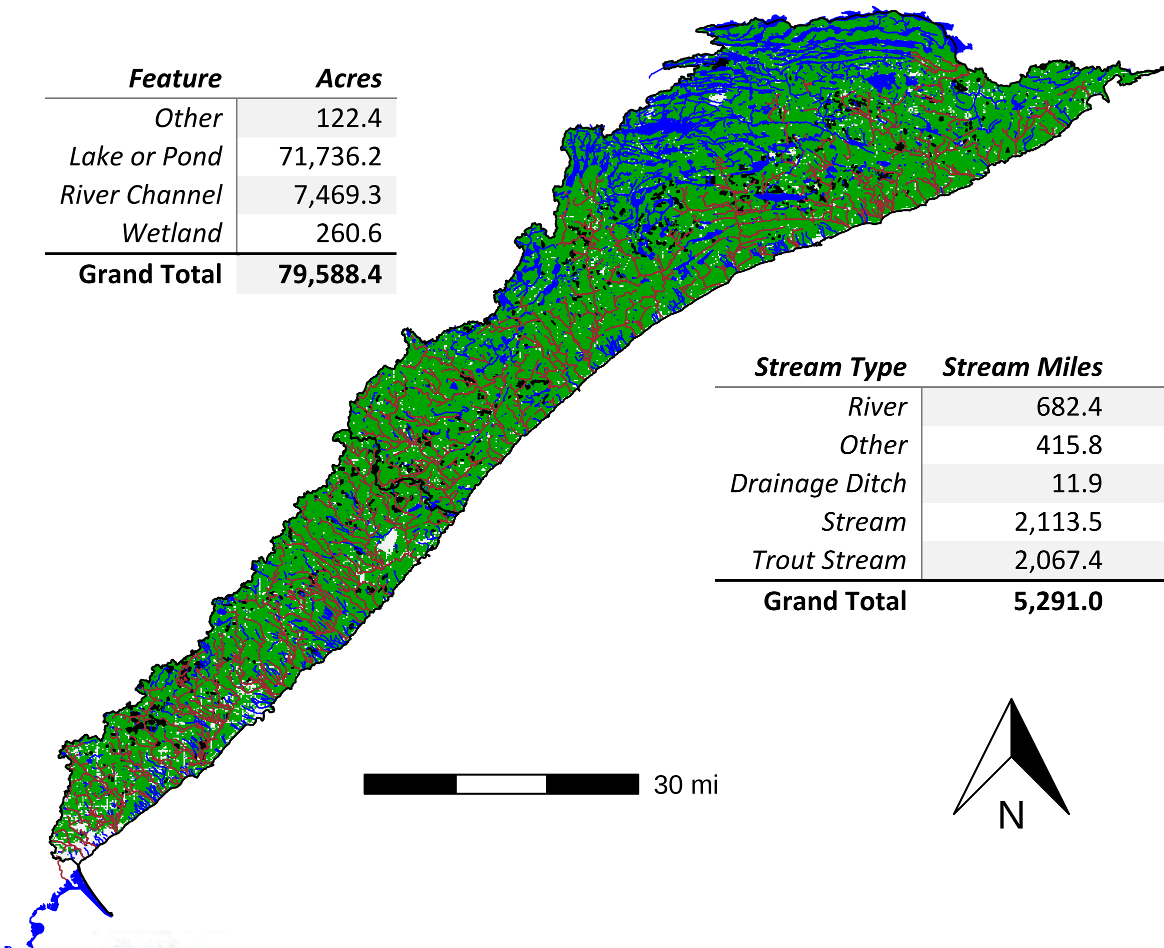
Forest Ownership



Land cover	*Acres*
Agriculture	558
Barren	2,279
Developed	40,187
Forest	1,190,191
Grassland	43,142
Open water	67,807
Other	84
Shrub/scrub	59,912
Wetland	11,084
Total	**1,404,160**

Forest Canopy Change (2012-2017)

Feature	*Acres*
Other	122.4
Lake or Pond	71,736.2
River Channel	7,469.3
Wetland	260.6
Grand Total	**79,588.4**



Stream Type	*Stream Miles*	*n*
River	682.4	243
Other	415.8	1,163
Drainage Ditch	11.9	10
Stream	2,113.5	2,541
Trout Stream	2,067.4	1,219
Grand Total	**5,291.0**	**5,176**