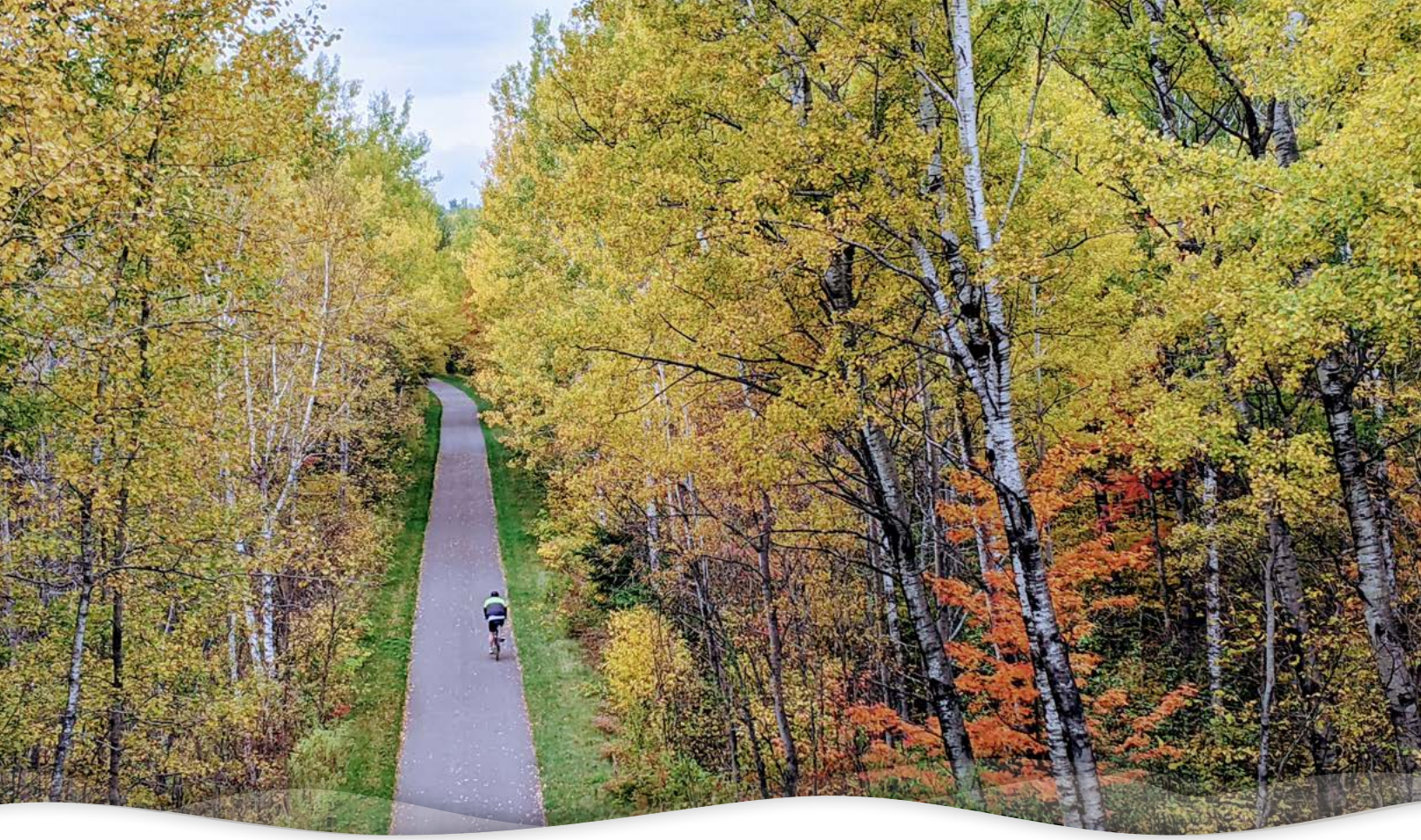


2025

STATE OF THE TRAILS

TRAIL RIDE QUALITY RATINGS, PROJECTIONS AND NEEDS

Featuring data from the researchBike

BY *Andrew Oftedal, Inya Nlenanya, Yazan Alatoom, Zia Zihan, and Abdallah Al-Hamdan*

PARKS & TRAILS COUNCIL OF MINNESOTA

RESEARCH REPORT

January 2026

PARKS & TRAILS
COUNCIL OF MINNESOTA

ABOUT US

Parks & Trails Council of Minnesota is a 501(c)(3) organization dedicated to acquiring, protecting, and enhancing critical land for the public's use and benefit. Founded in 1954, Parks & Trails Council acquires threatened and critical parcels of land, advocates at the Minnesota Capitol, supports volunteers, and produces original research on issues and trends facing Minnesota's parks and trails.

Parks & Trails Council initiated the State of the Trails project in 2016 to provide detailed data on state trail conditions and analyze changes in trail conditions over time. Gathering this information is essential for answering a broad set of policy questions and provides lawmakers, managers, and the public with the information they need to maintain and enjoy Minnesota's state trail system. Parks & Trails Council relies on donations to fund its research program.

Additional information about Parks & Trails Council and opportunities to support our work are available at parksandtrails.org.

CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

This report is a collaborative effort and would not have been possible without the input, guidance, support, patience, and hard work of many people. At the Parks & Trails Council, Brett Feldman, Lisa Filter, Anneliese Tatham, Lauren Mitchell, Delaney Elton, Steve Young, and Phoebe Ward provided thoughtful review and support throughout the project. Zhi Chen and Carl Saxon, both at the Des Moines Area Metropolitan Planning Organization were key collaborators who offered support and insights throughout the project. And a very special thanks to the dedicated staff at the Minnesota Department of Natural Resources for their continued commitment to caring for Minnesota's special places.

The maps in this report were designed with imagery is from Esri, Maxar, Earthstar Geographics, USGS, NGA, NASA, CGIAR, NCEAS, NLS, OS, NMA, Geodatastyrelsen, GSA, GSI, and the GIS user community; and data from the Minnesota Geospatial Information Office, Minnesota DNR, Minnesota DOT, Greater Minnesota Parks and Trails Commission, Metropolitan Council, Iowa DOT, Wisconsin DNR, U.S. Fish and Wildlife Service, Federal Railroad Administration, and OpenStreetMap contributors.

The Research Bike was made possible thanks to generous support from Erik's Bike Shop.

PROJECT TEAM

- Andrew Oftedal, *Parks & Trails Council*
- Chris Oines, *Parks & Trails Council*
- Inya Nlenanya, *Iowa State University*
- Yazan Alatoom, *Iowa State University*
- Zia Zihan, *Iowa State University*
- Abdallah Al-Hamdan, *Iowa State University*

Parks & Trails Council's research program is made possible by generous support from its members.

Cover Photo: Munger State Trail. Photo by Andrew Oftedal.

Published January 2026.

EXECUTIVE SUMMARY

2025 STATE OF THE TRAILS REPORT

OVERVIEW

How smooth are Minnesota's paved state trails to ride? That is the central question of Parks & Trails Council's State of the Trails reports. This 2025 report uses data collected with our Research Bike in 2018 and 2023 to assess the ride quality of the paved state trail system, track changes over time, and project future conditions. These data provide an objective foundation for decisions about maintenance priorities, capital investment, and the long-term stewardship of Minnesota's paved state trail system.

KEY FINDINGS

B-

In 2023, Minnesota's paved state trails scored a B- for overall ride quality

- 67% of trail miles rate as smooth or very smooth to ride. Only 10% of trail miles rate as rough or very rough to ride.
- The average trail mile is smooth to ride but edging close to fair.

Riding conditions declined between 2018 and 2023

- The percentage of trail miles rated smooth or very smooth to ride decreased from 82% in 2018 to 67% in 2023.
- Between 2018 and 2023, the number of trail miles in rough or very rough riding condition more than doubled (from 29 to 66).
- Only one trail received a better grade in 2018 than it did in 2023.

Long-term, trail ride quality is forecast to decline further

- If current rehabilitation trends continue, we estimate only 19-24% of the paved state trail system will be smooth or very smooth to ride by 2035, a year after the Clean Water, Land and Legacy Amendment is set to expire.

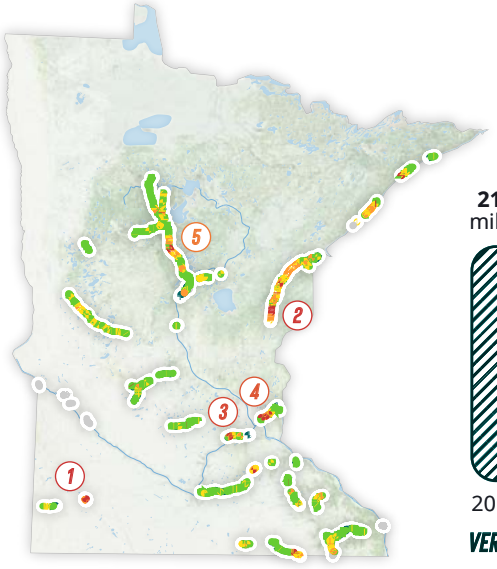
RECOMMENDATIONS

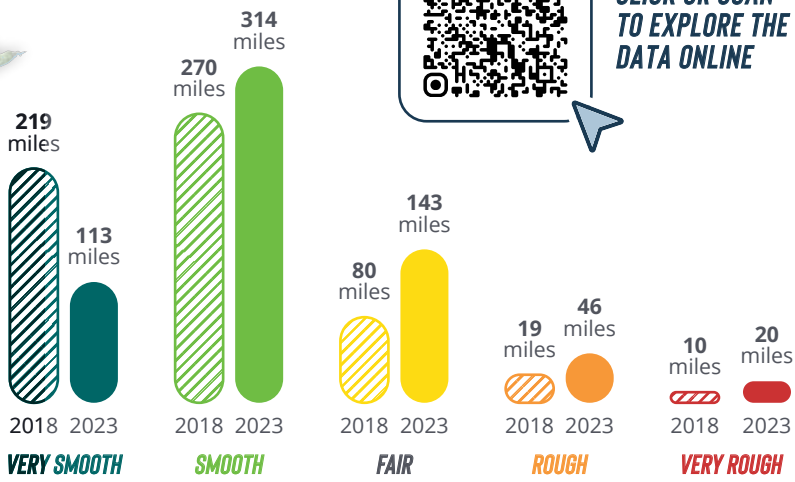
Set a **25-50-25 performance target**

Rehabilitate 30 miles of trail annually

Increase trail **funding and planning**

HOW SMOOTH ARE MINNESOTA'S STATE TRAILS TO RIDE?





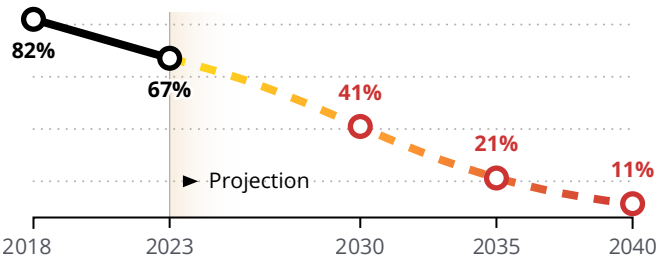
CLICK OR SCAN TO EXPLORE THE DATA ONLINE

ROUGHEST TRAILS (2023 data)

1. **CASEY JONES**
   Currie Loop • 5.6 miles
2. **MUNGER**
   Hinckley to Finlayson Township • 12.8 miles
3. **MINNESOTA VALLEY**
   Minnesota Valley State Rec. Area • 2.5 miles
4. **GATEWAY**
   Saint Paul to Oakdale • 6.9 miles
5. **PAUL BUNYAN**
   Pine River to Pine River Township • 8.2 miles

LONG-TERM RIDE QUALITY FORECAST

*If current trends continue, the percentage of paved state trails in **very smooth** or **smooth** riding condition is projected to decline*



HOW WE CALCULATE OUR RATINGS

Our trail ratings are based on data collected with our Research Bike, an electric-assist bicycle equipped with sensors and cameras to capture the rider experience on paved trails. An iPhone mounted to the handlebars records vibrations felt by the rider, which are combined into a single score (the Trail Roughness Index) indicating how smooth or rough each trail is to ride. Since 2018, we have collected more than 1.1 million roughness data points, documented trails with over 143,000 photos, and published virtual trail tours on Google Maps viewed nearly 10 million times.

PARKS & TRAILS COUNCIL OF MINNESOTA

parksandtrails.org
info@parksandtrails.org
(651) 726-2457

INTRODUCTION

How smooth are Minnesota's paved state trails to ride? That is the central question this report aims to answer.

We think it is an important question. Bike trails are more than just recreational amenities; they are community assets that make Minnesota a better place to live, work, and visit. When trails are well maintained, it is easy to take their benefits for granted: they connect people and communities to the outdoors, improve health by encouraging physical activity, boost tourism and spending at local businesses, enhance safe transportation routes and offer fun recreation for people of all ages, means, and abilities. But as trails age and fall into disrepair, their benefits erode with each new crack in the pavement. Ensuring our trails remain in good condition is not just about safety, comfort, and enjoyment — it is about sustaining the quality of life that Minnesotans value and deserve.

That is why Parks & Trails Council (P&TC) publishes our State of the Trails reports. Our goal is to assess the condition of Minnesota's paved state trail network, track changes over time, and provide trail managers and lawmakers with the data they need to ensure that all Minnesotans, both now and in the future, have access to smooth, safe, and enjoyable trails.

This report is the third installment of our State of the Trails series. Our efforts started small. In 2016, with the help of 24 volunteers, we rode every mile of paved state trail, took notes and photos of conditions, and used a smartphone app to record accelerometer data indicating how bumpy the trail was to ride. That data provided an initial look at trail conditions across the state, which we published in our first *State of the Trails Report* in 2017. A year later, in 2018, we developed a "Research Bike" to refine and standardize our approach. Our second *State of the Trails Report*, published in 2019, documented over 100,000 photos of the state trail system and collected over 530,000 data points on pavement roughness.

The 2019 *State of the Trails Report* helped convince the legislature to allocate an additional $3.2 million for trail maintenance and rehabilitation in 2023. But that amount is just a fraction of what we recommended (and it came too late for its impact to be reflected in this 2025 report). Our new trail grades offer a clear warning: Minnesota is not investing

Munger State Trail • Lisa Filter / P&TC

enough in paved state trail maintenance, and the system is deteriorating.

We are proud to share the latest *State of the Trails Report*, featuring updated data and fresh insights on the condition of Minnesota's paved state trails. We hope this report sparks bold leadership, thoughtful planning, and sustained investments in our state trail system. And we look forward to partnering with communities, agencies, and advocates to keep Minnesota's trail system strong and resilient for years ahead.

PROJECT SCOPE

The State of the Trails project focuses solely on trails that are (1) paved, and (2) authorized as a state trail under Minnesota Statute 85.015. This paved state system is 669 miles, managed by the Minnesota Department of Natural Resources (DNR), used primarily by bicyclists and hikers, and receives over 2 million visits every warm season (April through November). DNR estimates hikers and bicyclists travel more than 13 million miles on the system every year.[1]

This report's analysis is based on data collected between September 7, 2023, and November 4, 2023. Data was collected on 637 paved, off-road miles across 24 different state trails. Missing from our analysis are the Minnesota River State Trail (13.8 paved miles); several short segments and spurs of the Cuyuna Lakes, Gitchi-Gami, Goodhue Pioneer, Luce Line, Preston-Forestville, Root River, and Sakatah Singing Hills State Trails (totaling 4.9 miles); and segments of the Blazing Star, Chester Woods, Gitchi-Gami, Harmony-Preston Valley, Heartland, and Minnesota Valley State Trails that were opened after our data collection period (totaling 13.5 miles). We hope to collect data on all these segments in future editions of the State of the Trails project.

The paved state trail system accounts for only a small portion of state-managed recreational trails in Minnesota. Overall, DNR manages more than 22,000 miles of snowmobile trails, nearly 3,000 miles of ATV trails, and approximately 1,000 miles of state park trails. Assessing the condition of such trails, as well as paved trails owned and maintained by local units of government, is outside the scope of this report.

ABOUT THE RESEARCH BIKE

All the data we have collected for the 2019 and 2025 *State of Trails Reports* were collected using the Research Bike (Figure 1). The Research Bike is a Stromer ST2, electric-assist bicycle outfitted with sensors and cameras to collect data on the user experience of paved bicycle trails. We use the Research Bike to collect three types of data. First, an iPhone mounted to the handlebars records all the vibrations felt by the rider using the iPhone's built-in accelerometer. We use that data to determine how smooth (or rough) each trail segment is to ride. Second, a rear-mounted camera takes a pavement photo every two seconds to visualize pavement conditions. And third, a panoramic camera mounted above the rider's head records 360° video, which we use to create virtual trail tours.

Since 2018, we have used the Research Bike to record over 1.1 million accelerometer data points indicating how smooth Minnesota's state trails are to ride, compiled a comprehensive state trail

1 Robinson, Wascalus, & Gozali-Lee. (2020). *2019 Minnesota State Trail Visitor Study.*

photo database of 143,000 geo-located photos, and published virtual trail tours on Google Street View that have been viewed nearly 10 million times.

HOW WE CALCULATE OUR RIDE QUALITY RATINGS

Our trail ride quality ratings reflect how smooth (or rough) a paved trail is to ride on a bicycle. We measure trail roughness using a statistic we call the Trail Roughness Index (TRI). We created the TRI in 2016 as a method to objectively rate the condition of paved bike trails. Our methodology was updated in 2018, and again in 2025 to improve reliability and validity.

Figure 1

ABOUT THE RESEARCH BIKE

A trail's TRI is calculated by riding a trail with a device called an accelerometer mounted on the bike's handlebars. When the bicyclist hits a crack or bump in the trail, the accelerometer measures the force of the jolt (Figure 2). The TRI is a statistical summary of the accelerometer data that indicates the roughness of the ride. Low TRI scores indicate trails that are very smooth to ride (TRI < 270), and high TRI scores indicate trails that are very rough to ride (TRI ≥ 420).

We use TRI scores to assign a Ride Quality Rating to each trail segment. The Ride Quality Rating is intended to reflect the "seat-in-the-pants" feeling the average rider gets as they ride a paved trail, and ranges from "very smooth" to "very rough" (Figure 3). Additionally, we assigned each trail an overall letter grade using a scale where "very smooth" is equal to an A and "very rough" is equal to a F. The overall letter grade represents the ride quality of the trail's average mile.

A P&TC intern collected all the data. The intern rode 637 miles of state trails — out and back — on the Research Bike during the fall of 2023.

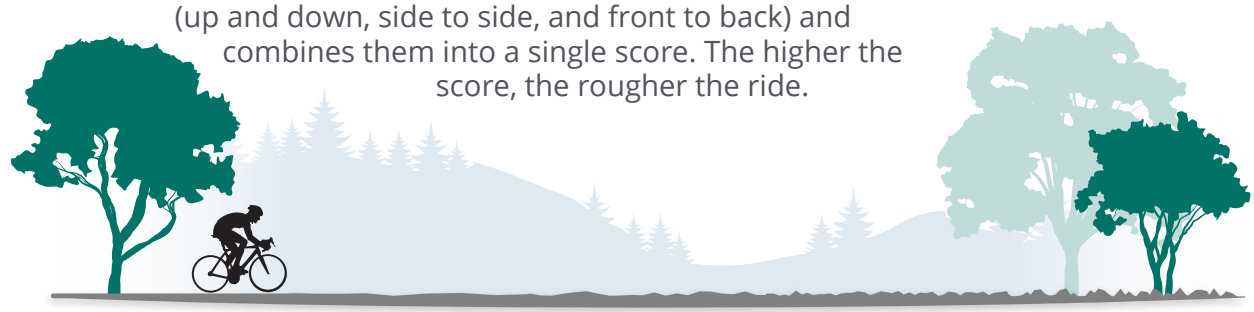
Our TRI scores and Ride Quality Ratings are supplemented with photos taken during the data collection process. Photos were used to verify condition classifications and are helpful to visualize on-the-ground conditions.

Importantly, our ratings *only* describe how smooth a trail is to ride. While trail roughness is a proxy for the trail's overall condition, our ratings do not

Figure 2

HOW THE TRAIL ROUGHNESS INDEX WORKS

The Trail Roughness Index (TRI) measures how bumpy or smooth a trail feels to ride. It's calculated from an accelerometer that records vibrations in three directions (up and down, side to side, and front to back) and combines them into a single score. The higher the score, the rougher the ride.



Three-axis accelerometer sensors

On a new trail, the surface is smooth and uniform. The Research Bike glides easily, and the accelerometer records very few vibrations, indicating a comfortable, steady ride.

As trails age, small cracks and bumps begin to appear in the pavement. When the Research Bike rolls over these defects, the accelerometer picks up more frequent jolts and vibrations, showing that the surface is starting to wear.

Near the end of a trail's life, bumps, cracks, and uneven patches are common. The Research Bike's accelerometer registers strong, frequent jolts, indicating a surface that has become rough and uncomfortable to ride.

Each "spike" on the vibration graph indicates a bump on the trail

identify types of pavement distress, nor do they rate the overall quality of the trail pavement. Further, several components of a safe, well-maintained trail system are not captured by our ratings. Our ratings do not consider the integrity of trail bridges, culverts, or subgrade. Our ratings do not consider the presence or condition of trailhead facilities, interpretive displays, or signage. And our ratings only consider day-to-day upkeep to the extent it impacts the smoothness of the ride (e.g., trails with debris are rougher to ride than freshly swept trails). All those components are integral to a safe, well-maintained trail system.

For more details on our analysis and its limitations, see our methodology.

Figure 3

HOW TO UNDERSTAND OUR RIDE QUALITY RATINGS & LETTER GRADES

A

VERY SMOOTH • TRI < 270

Trail feels like new and provides near-ideal conditions for bicyclists and inline skaters. Small blemishes and crack sealing may be present in isolated areas but do not negatively impact user experience.

B

SMOOTH • 270 ≤ TRI < 320

Trail offers a comfortable ride for bicyclists and inline skaters, with infrequent bumps and depressions. Trail may have some blemishes but still provides a good riding experience.

C

FAIR • 320 ≤ TRI < 370

Trail has intermittent bumps and depressions, but is tolerable to ride for the majority of bicyclists. Some sections may be difficult for inline skaters. While ridable, ride quality is starting to negatively impact user experience.

D

ROUGH • 370 ≤ TRI < 420

Trail has frequent bumps and depressions and is uncomfortable to ride for the majority of bicyclists. Many sections may be difficult for inline skaters. Overall user experience tends to be poor.

F

VERY ROUGH • TRI ≥ 420

Trail is in complete disrepair with very frequent bumps and depressions. Trail is not suitable for inline skaters and may only be suitable for mountain and fat-tire biking. Many bicyclists will avoid the trail entirely.

THE STATE OF THE TRAILS

HOW SMOOTH ARE MINNESOTA'S STATE TRAILS TO RIDE?

Overall, Minnesota's paved state trail system is in good riding condition, with the majority of mileage offering a smooth trail surface (Figure 4). Over two-thirds of the system — 67%, or 427 miles in total — rates as either very smooth or smooth to ride, indicating that most trails provide a high-quality riding surface.

At the same time, 143 miles (23% of the system) are rated fair. On these sections, wear and tear on the pavement surface has begun to affect ride quality. The remaining 10% of the system — 66 miles in total — is rated rough or very rough and requires significant repairs.

Minnesota's paved state trail system, as a whole, received a B- for ride quality (Figure 5). The average mile has a TRI of 310, meaning it is smooth to ride but is edging close to fair. For individual trails, grades varied from an A- (Preston-Forestville) to a C (Gateway, Casey Jones, and Munger).

Letter grades summarize what the average mile of a trail feels like to ride, but they do not always tell the full story. Most state trails include a mix of

Figure 4

HOW SMOOTH ARE MINNESOTA'S STATE TRAILS TO RIDE?

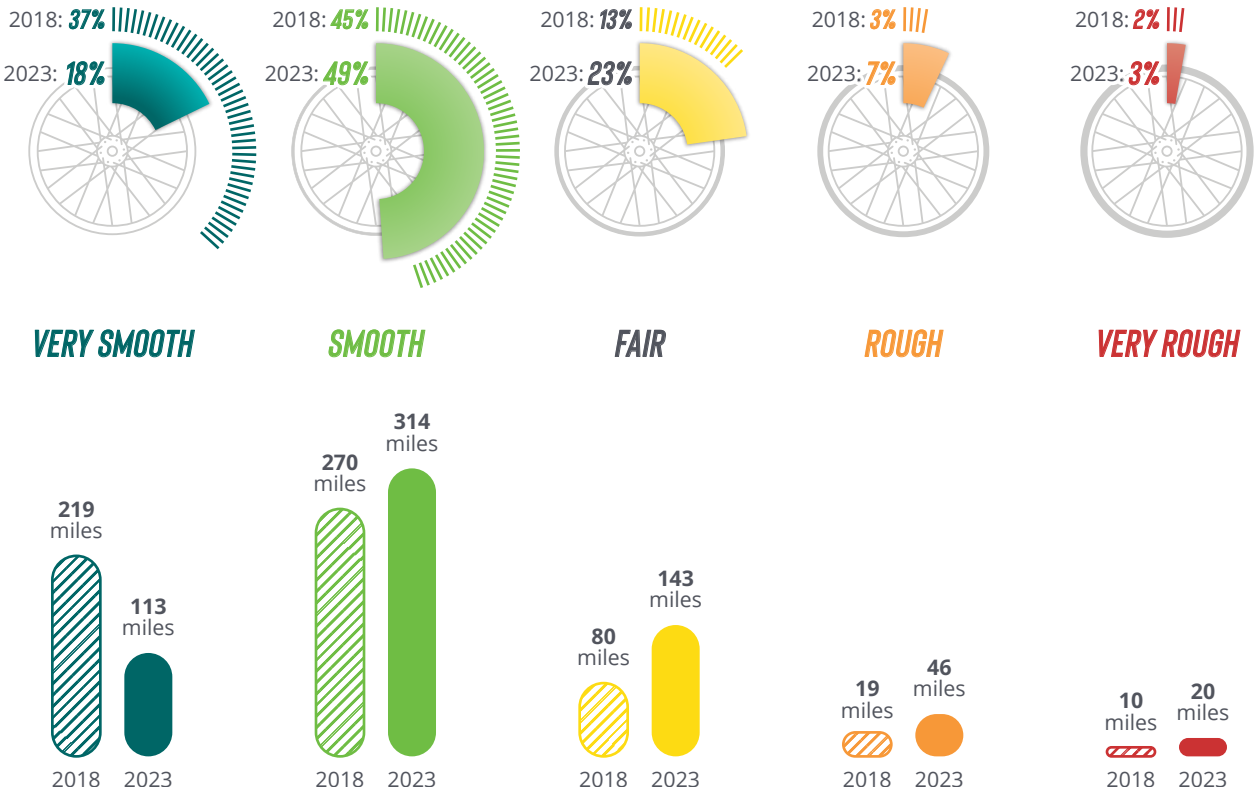
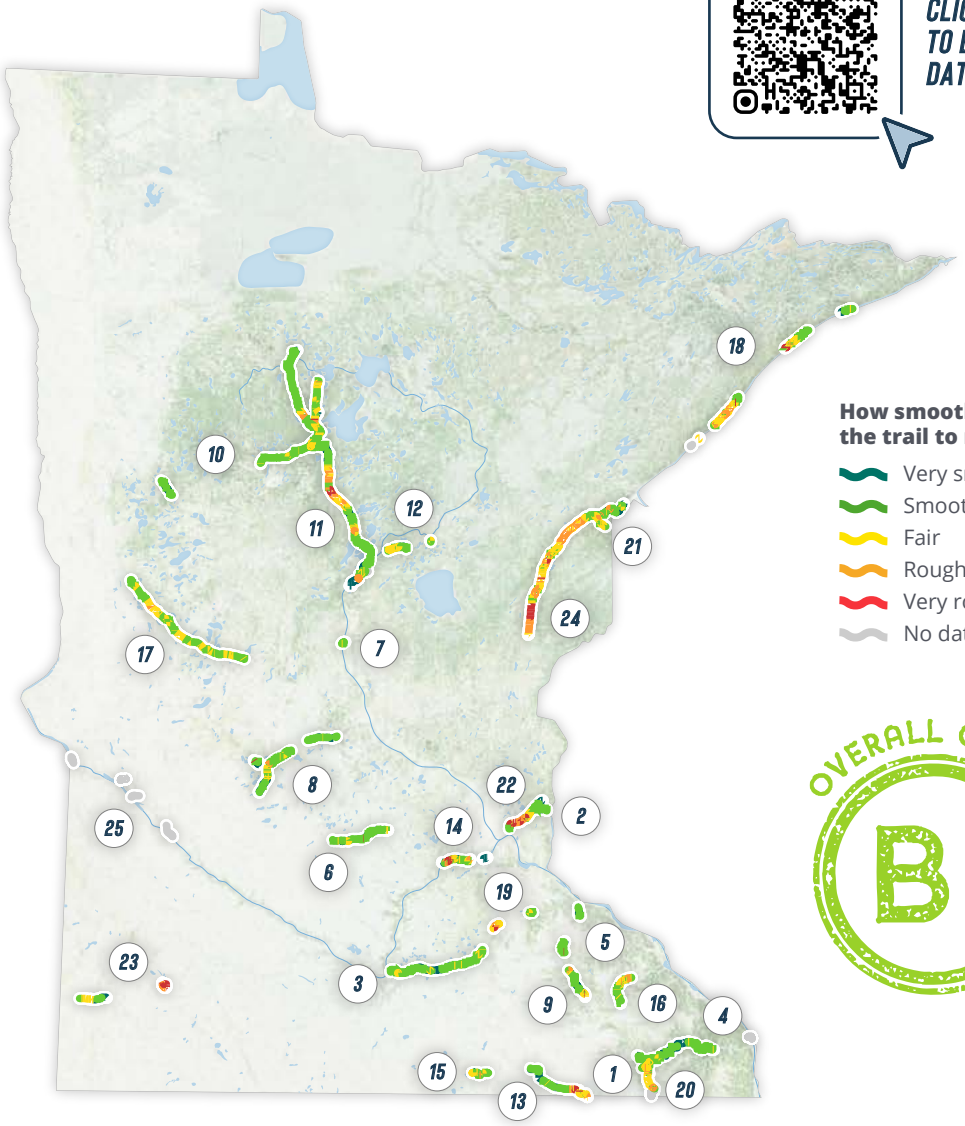


Figure 5

MINNESOTA STATE TRAILS REPORT CARD

CLICK OR SCAN TO EXPLORE THE DATA ONLINE



2023 Trail Grade
Change since 2018

- A- ▼ **1** Preston-Forestville *(pg. 40)*
- B+ ▼ **2** Brown's Creek *(pg. 22)*
- B+ ▲ **3** Sakatah Singing Hills *(pg. 42)*
- B+ ▼ **4** Root River *(pg. 41)*
- B+ ► **5** Goodhue Pioneer *(pg. 31)*
- B+ ▼ **6** Luce Line *(pg. 35)*
- B NA **7** Camp Ripley / Veterans *(pg. 23)*
- B ▼ **8** Glacial Lakes *(pg. 30)*
- B ► **9** Douglas *(pg. 27)*
- B ► **10** Heartland *(pg. 34)*
- B ▼ **11** Paul Bunyan *(pg. 39)*
- B- ▼ **12** Cuyuna Lakes *(pg. 26)*
- B- ▼ **13** Shooting Star *(pg. 43)*
- B- ► **14** Minnesota Valley *(pg. 37)*
- B- ▼ **15** Blazing Star *(pg. 21)*
- B- ▼ **16** Great River Ridge *(pg. 32)*
- B- ▼ **17** Central Lakes *(pg. 25)*
- C+ ▼ **18** Gitchi-Gami *(pg. 29)*
- C+ ► **19** Mill Towns *(pg. 36)*
- C+ ▼ **20** Harmony-Preston Valley *(pg. 33)*
- C+ ► **21** Alex Laveau *(pg. 20)*
- C ▼ **22** Gateway *(pg. 28)*
- C ▼ **23** Casey Jones *(pg. 24)*
- C ▼ **24** Munger *(pg. 38)*
- NO DATA **25** Minnesota River

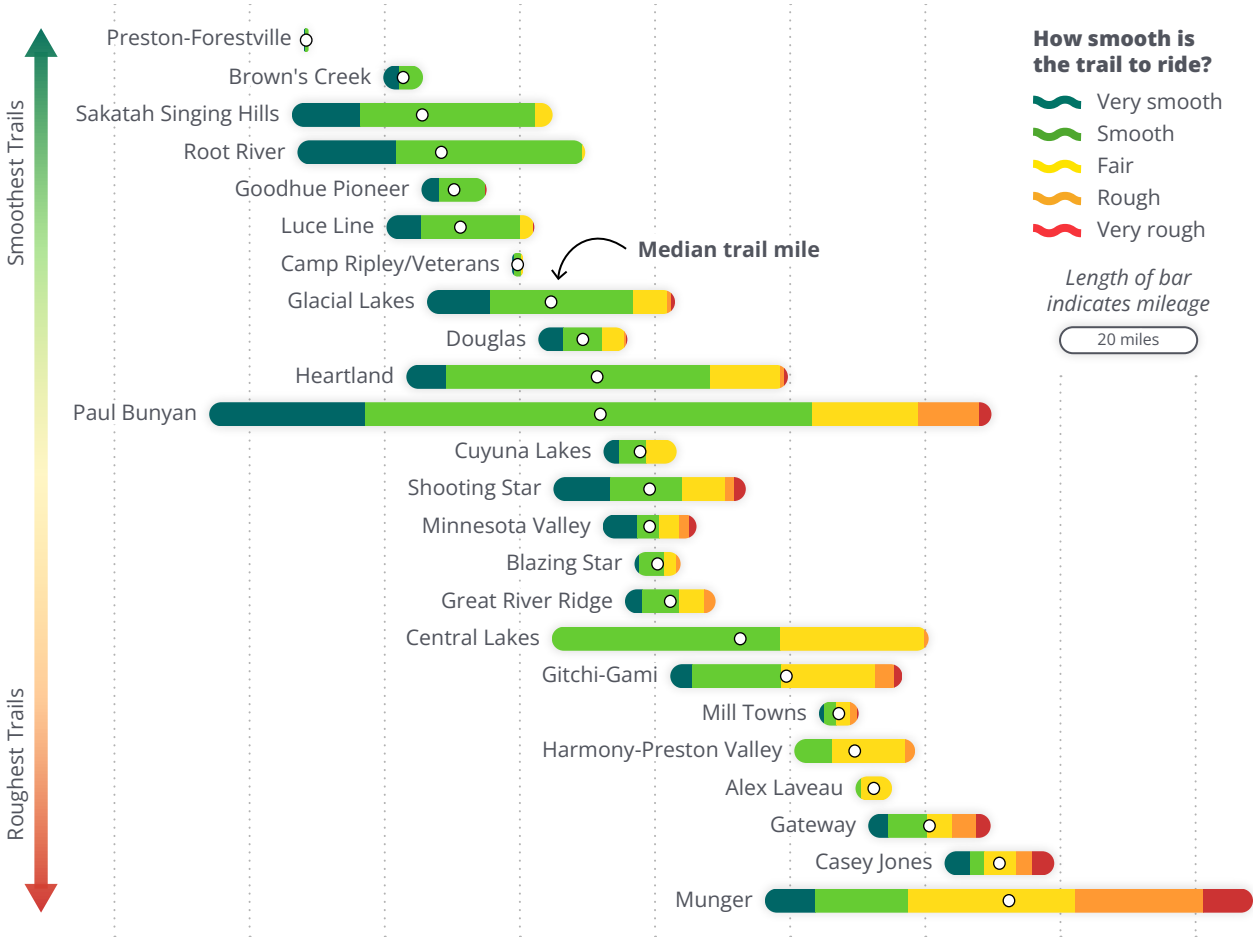
conditions (Figure 6; see individual trail report cards beginning on page 19). For example, even though the Munger State Trail received a C and has the highest average TRI in the state, 29% of its miles are still rated smooth or very smooth (compared to 37% rated rough or very rough). The Munger ranks as the roughest trail on average, but it does not contain the single worst stretch of pavement in the system. That dubious honor belongs to the Casey Jones State Trail; the 5.6-mile loop connecting the City of Currie to Lake Shetek State Park has an average TRI of 434, making it the roughest section in the entire network (Figure 7).[2]

While many trails are showing signs of disrepair, new investments have improved some portions of the system. Between 2018 and 2023, 31 miles of new trails were added and nearly 12 miles of existing trails were rehabilitated (Figure 8). These investments have

Figure 6

MINNESOTA STATE TRAILS RIDE QUALITY RATINGS

2023 data



2 After our 2023 data collection and subsequent analysis, portions of this section of the Casey Jones State Trail were rehabbed in 2024 and 2025.

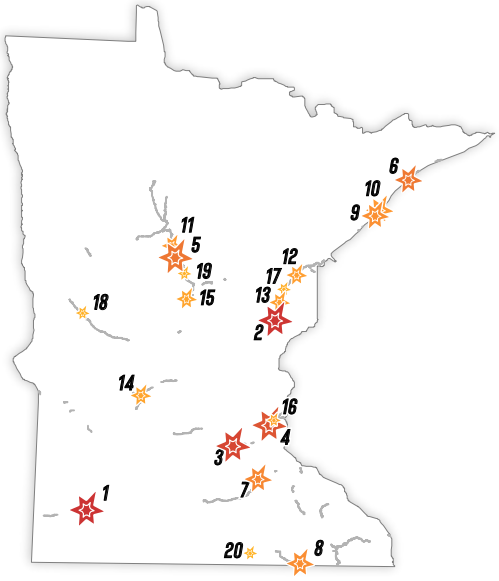
Figure 7

ROUGHEST STRETCHES OF TRAIL IN MINNESOTA'S PAVED STATE TRAIL SYSTEM

2023 data

Avg. TRI

1. 434 — **CASEY JONES** ✓
   Currie Loop • 5.6 miles
2. 419 — **MUNGER**
   Hinckley to Finlayson Township • 12.8 miles
3. 411 — **MINNESOTA VALLEY** ✓
   Minnesota Valley State Recreation Area • 2.5 miles
4. 404 — **GATEWAY**
   Saint Paul to Oakdale • 6.9 miles
5. 387 — **PAUL BUNYAN** ✓
   Pine River to Pine River Township • 8.2 miles
6. 386 — **GITCHI-GAMI**
   Temperance River State Park to Tofte • 2.8 miles
7. 379 — **MILL TOWNS**
   Dundas to Randolph Township • 3.1 miles
8. 376 — **SHOOTING STAR**
   Taopi to Le Roy Township • 9.3 miles
9. 374 — **GITCHI-GAMI**
   Split Rock Lighthouse State Park • 3.1 miles
10. 370 — **GITCHI-GAMI**
    Beaver Bay • 2.6 miles
11. 369 — **PAUL BUNYAN** ✓
    Powers Township to Birch Lake Township • 6.8 miles
12. 366 — **MUNGER**
    Skelton Township to Twin Lakes Township • 13.3 miles
13. 365 — **MUNGER**
    Finlayson Township to Sturgeon Lake Township • 13.8 miles
14. 362 — **GLACIAL LAKES**
    New London Township • 2.4 miles
15. 361 — **PAUL BUNYAN**
    Baxter segment • 1.1 miles
16. 361 — **GATEWAY**
    Lake Elmo to Grant • 2.8 miles
17. 353 — **MUNGER**
    Sturgeon Lake to Moose Lake • 6.2 miles
18. 352 — **CENTRAL LAKES**
    Tumuli Township to Ashby • 7.5 miles
19. 352 — **PAUL BUNYAN**
    Pequot Lakes to Pequot Lakes • 3.1 miles
20. 350 — **BLAZING STAR**
    Myre-Big Island State Park • 1.4 miles



Note: List does not include short (< 1 mile), isolated rough patches of the Goodhue Pioneer State Trail (in Zumbrota), Glacial Lakes State Trail (in Sibley State Park), or Munger State Trail (in Jay Cooke State Park).

✓ Indicates segment was partially or fully rehabbed in 2024 or 2025.

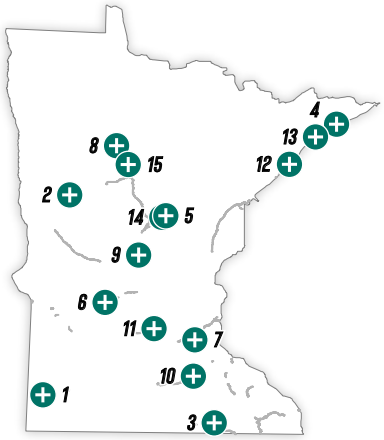
Figure 8

NEW AND RENEWED TRAILS

New trail construction and trail rehabilitation projects completed between 2018 and 2023

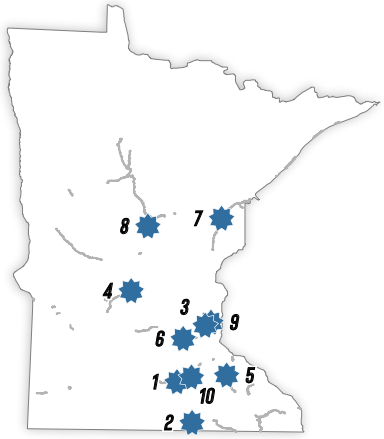
NEW TRAILS (31 MILES)

1. **CASEY JONES**
   130th Ave to Woodstock • 5.3 miles
2. **HEARTLAND**
   Detroit Lakes to Frazee • 5.1 miles
3. **SHOOTING STAR**
   Austin • 3.4 miles
4. **GITCHI-GAMI**
   Grand Marais to Cutface Creek • 3.3 miles
5. **CUYUNA LAKES**
   Deerwood • 2.5 miles
6. **GLACIAL LAKES**
   Sibley State Park • 2.5 miles
7. **MINNESOTA VALLEY**
   Bloomington • 1.7 miles
8. **HEARTLAND**
   Leech Lake Township • 1.5 miles
9. **CAMP RIPLEY / VETERANS**
   Little Falls • 1.4 miles
10. **MILL TOWNS**
    Faribault • 1.1 miles
11. **LUCE LINE**
    Winsted • 1.0 mile
12. **GITCHI-GAMI**
    Shipwreck Spur • 0.8 miles
13. **GITCHI-GAMI**
    Tofte • 0.6 miles
14. **CUYUNA LAKES**
    Portsmouth Spur • 0.5 miles
15. **PAUL BUNYAN**
    Bemidji • 0.5 miles



REHABBED (11.8 MILES)

1. **SAKATAH SINGING HILLS**
   Elysian to Waterville • 5.7 miles
2. **BLAZING STAR**
   Myre-Big Island State Park • 1.4 miles
3. **GATEWAY**
   St. Paul (Maryland to Wheelock) • 1.1 miles
4. **GLACIAL LAKES**
   Richmond • 0.8 miles
5. **GOODHUE PIONEER**
   Zumbrota • 0.6 miles
6. **MINNESOTA VALLEY**
   Shakopee • 0.5 miles
7. **MUNGER**
   Moose Lake • 0.5 miles
8. **PAUL BUNYAN**
   Baxter • 0.5 miles
9. **GATEWAY**
   Oakdale • 0.3 miles
10. **SAKATAH SINGING HILLS**
    Faribault • 0.3 miles



SAKATAH SINGING HILLS

BLAZING STAR

GOODHUE PIONEER

Note: Trails sorted by mileage.

strengthened the paved state trail system. But overall, our findings show the paved state trail system declined significantly between 2018 and 2023.

RIDE QUALITY RATINGS ON MINNESOTA'S PAVED STATE TRAILS DECLINED SIGNIFICANTLY BETWEEN 2018 AND 2023

In 2018, 82% of Minnesota's paved state trails were in smooth or very smooth riding condition. But the system is aging faster than it is being renewed, and by 2023, only 67% of the system was smooth or very smooth to ride. During the same period, the number of miles in rough or very rough riding condition more than doubled. Overall, nearly half (48.6%) of paved state trail miles saw their Ride Quality Rating decline between 2018 and 2023 (e.g., from very smooth to smooth, or smooth to fair, etc.; Figure 9). During the same period, Ride Quality Ratings

Figure 9

HOW MINNESOTA'S PAVED STATE TRAIL SYSTEM CHANGED BETWEEN 2018 AND 2023

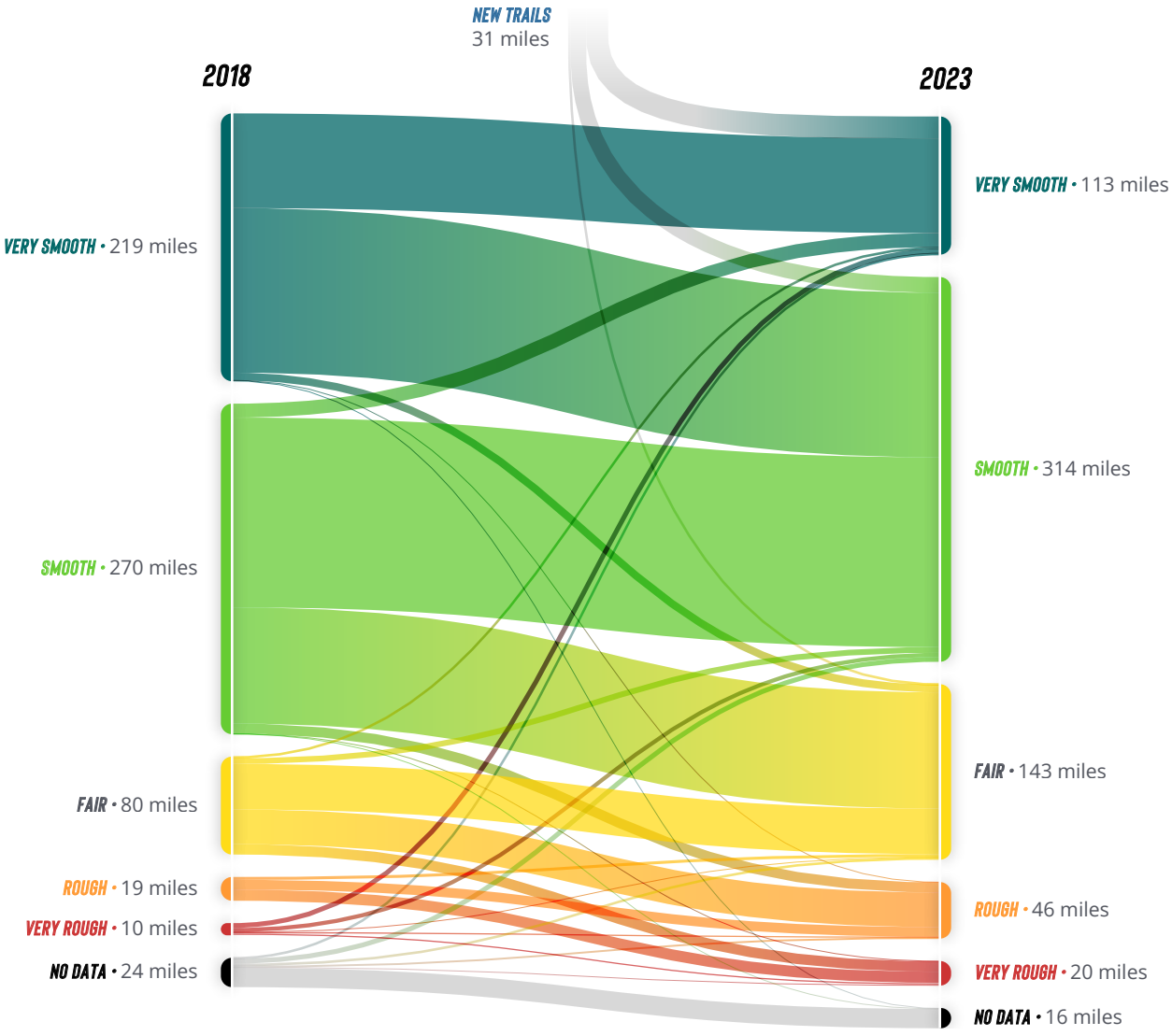
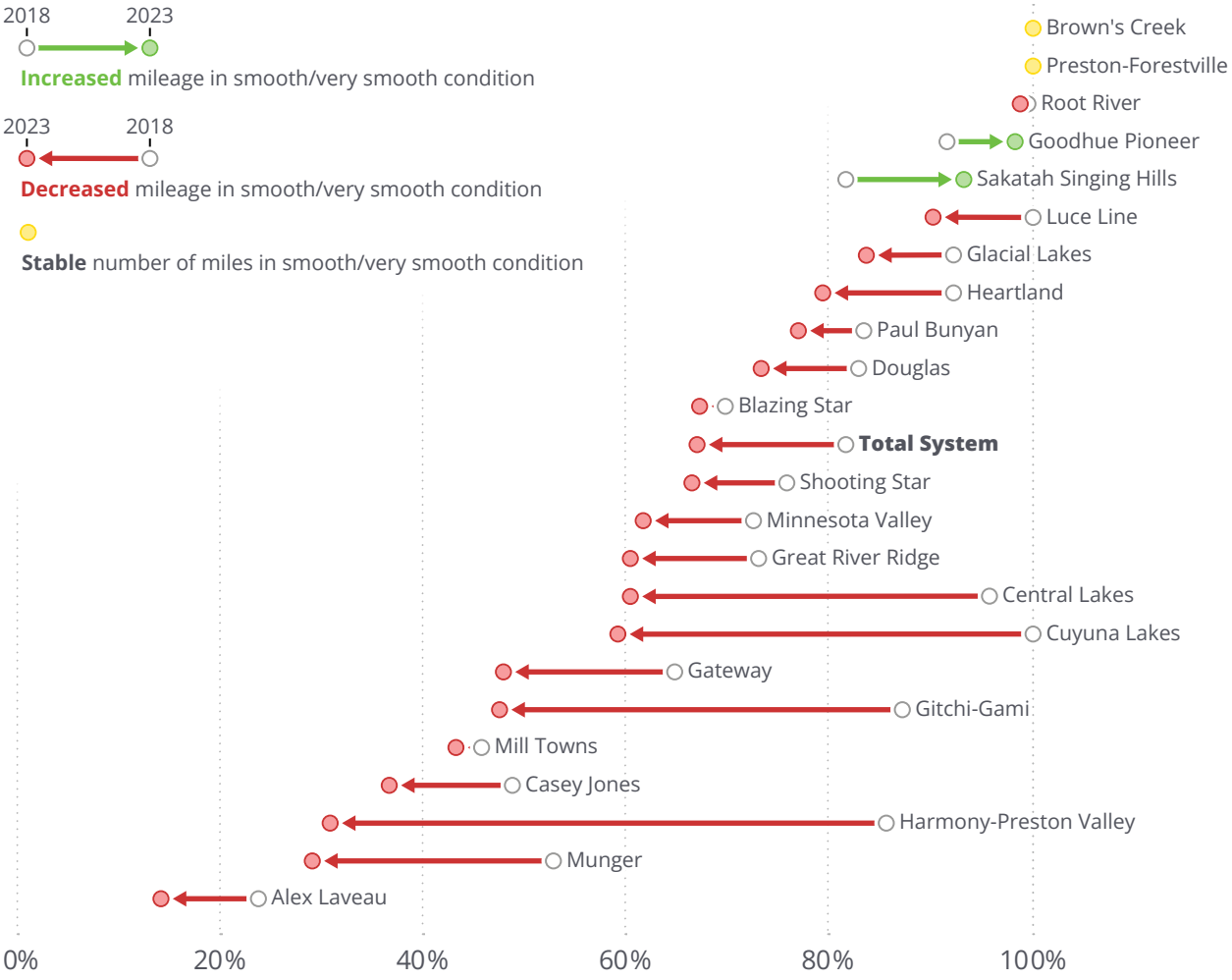


Figure 10

SMOOTH TRAILS ARE GETTING HARDER TO FIND

*Percentage of trail that is **smooth** or **very smooth** ro ride*



remained stable on 46.7% of the system and improved on just 4.7%.

For trail users, the takeaway is clear: smooth trails are getting harder to find. Of the 23 trails where we have comparable data, 19 have fewer miles rated smooth or very smooth in 2023 than they did in 2018. Only the Goodhue Pioneer and Sakatah Singing Hills State State Trails improved in this regard, while the Brown's Creek and Preston-Forestville State Trails remained stable (Figure 10).

Letter grades tell a similar story. Of the 23 trails where we have comparable data, 16 received a lower grade in 2023 than in 2018. Only the Sakatah Singing Hills State Trail earned a higher grade in 2023 than in 2018 (refer back to Figure 5 on page 7).

Taken together, these trends point to a growing maintenance gap. Even as new miles are added and select segments are resurfaced, the pace of renewal is not keeping up with the natural aging of the system.

MAINTAINING THE STATE TRAIL SYSTEM

Minnesota's paved state trail system is entering a critical phase. Ride Quality Ratings across the system declined significantly between 2018 and 2023, and for the first time since we started our State of the Trails project, less than 75% of the system is smooth or very smooth to ride. Many trails were built decades ago and are nearing the end of their service life.

By examining changes in TRI scores from 2018 to 2023, we can quantify how paved trail conditions have evolved over time. Our findings provide insight into how Minnesota's paved trails are aging, how many may require renewal in the near future, and what the system's long-term trajectory could look like if current rehabilitation patterns continue. Together, these findings offer an evidence-based view of the system's current health and its future maintenance needs.

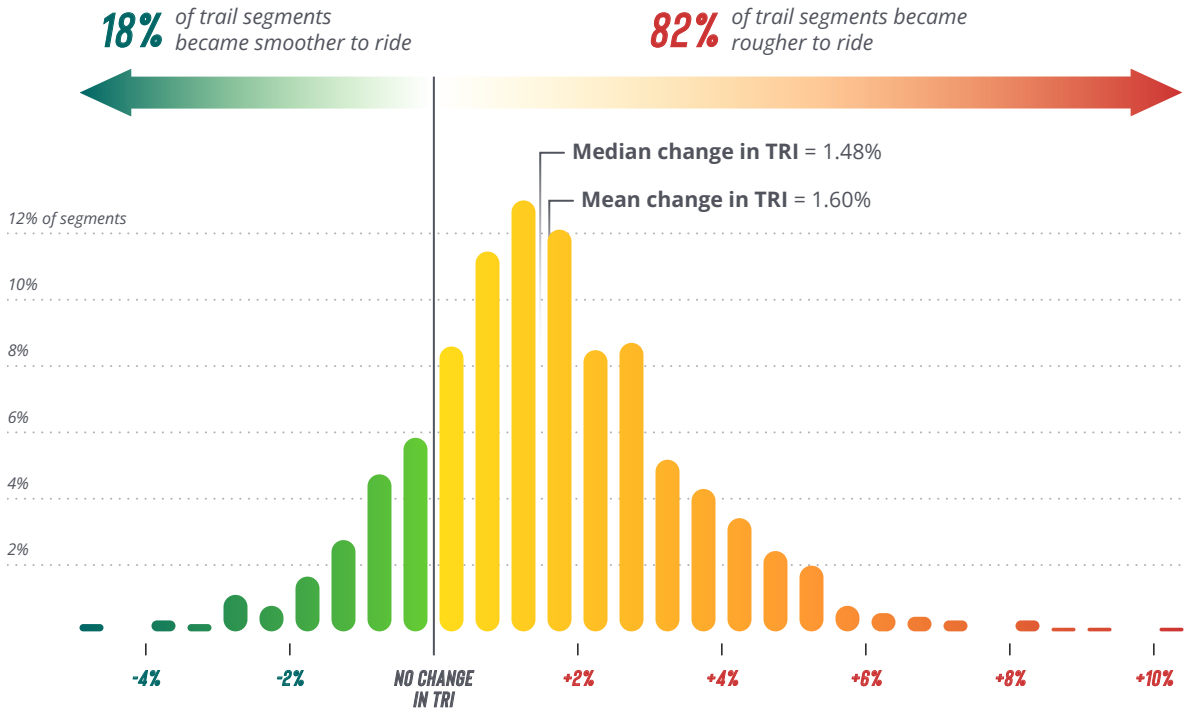
THE AVERAGE LIFE CYCLE OF A PAVED TRAIL IS 25 YEARS

On average, a trail's TRI increases at an annualized rate of 1.6% each year (Figure 11). There is a lot of variation in how TRI changes year-to-year, however, and more work needs to be done to

Figure 11

ANNUAL CHANGE IN TRAIL ROUGHNESS INDEX

Annualized percentage change in Trail Roughness Index (TRI) between 2018 and 2023

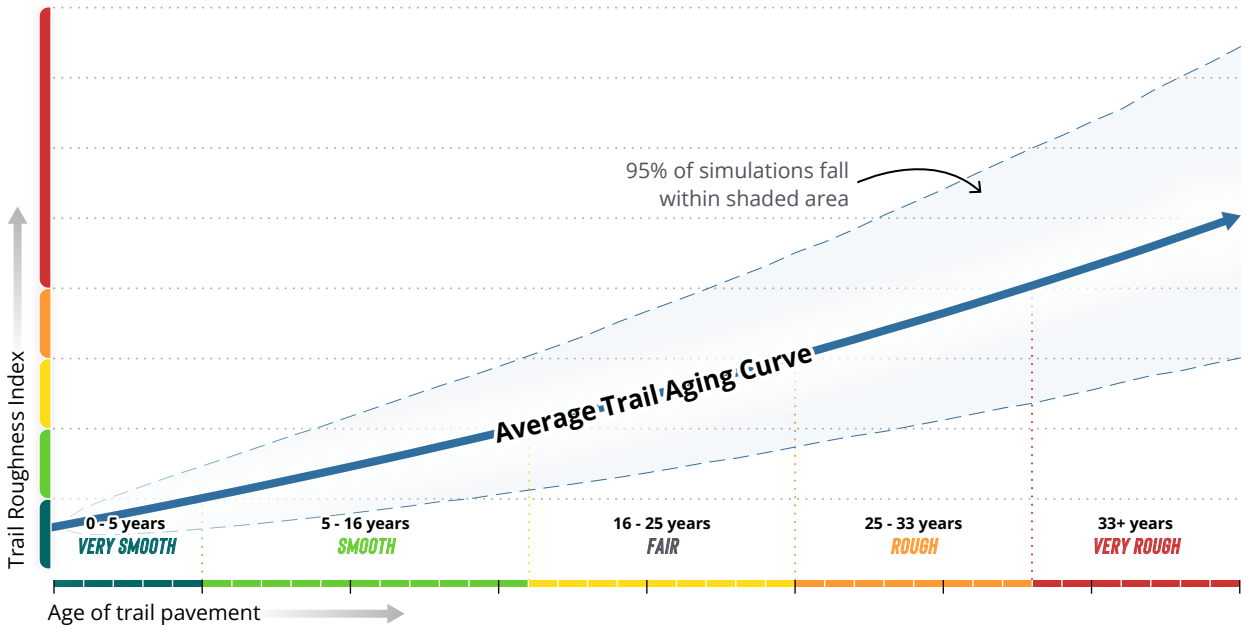


Note: Excludes segments that were rehabbed between 2018 and 2023

Figure 12

TRAIL AGING CURVE

Projected TRI for an average paved trail



Note: Based on 10,000 simulations of a hypothetical trail's TRI over 40-year period

understand the influencing factors. On approximately a quarter of trail segments, TRI was relatively stable between 2018 and 2023 (i.e., annualized change between -0.5% and 0.5%). TRI increased by more than 3% on approximately 20% of segments. And surprisingly, even when excluding trails where major rehabilitation was completed, TRI improved on approximately 18% of trail segments. These improvements may reflect limitations in the data — such as random variation from bicycle vibrations, differences in how bumps or debris were encountered, or other measurement inconsistencies — or they may indicate that minor maintenance activities, like crack sealing or localized surface repairs, helped smooth out isolated rough areas.

Year-to-year changes in TRI provide a basis for estimating both the average rate of deterioration and the uncertainty surrounding it. We ran 10,000 simulations to model how riding conditions evolve and found that, on average, it takes about 25 years for a newly built trail to become rough to ride (Figure 12). The pace of aging varies considerably, however, presumably influenced by factors such as maintenance frequency, pavement type, soil and drainage conditions, surrounding vegetation, and weather events. For example, our analysis suggests that at 25 years of age, a trail has roughly a 6% chance of being smooth, a 43% chance of being fair, a 41% chance of being rough, and a 9% chance of being very rough (Figure 13).

126 STATE TRAIL MILES WILL REQUIRE MAJOR REHABILITATION OR REPLACEMENT WITHIN 5 YEARS

Based on our simulations, we expect an additional 60 miles of trail (±8 miles, 95%

Figure 13

RIDE QUALITY ACTUARIAL TABLE

Likelihood of Ride Quality Rating at different trail ages

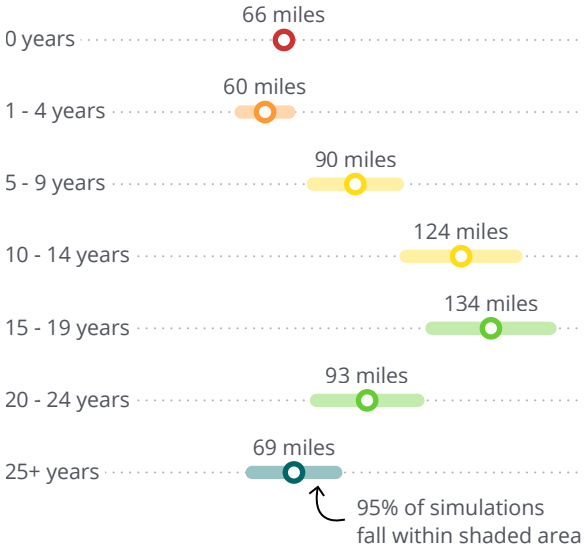
Trail Age (years)	VERY SMOOTH	SMOOTH	FAIR	ROUGH	VERY ROUGH
5	48%	52%	—	—	—
10	9%	84%	7%	—	—
15	2%	53%	43%	2%	—
20	—	21%	60%	17%	1%
25	—	6%	43%	41%	9%
30	—	2%	20%	46%	33%
35	—	—	7%	31%	61%
40	—	—	2%	15%	83%

Note: Based on 10,000 simulations

Figure 14

SERVICE LIFE REMAINING

Projected number of years until major rehabilitation or replacement is needed on Minnesota's paved state trails



Note: Based on 10,000 simulations

confidence interval) to reach the end of their service life within the next five years. That is in addition to the 66 miles of trail we have identified as already being in rough or very rough riding condition, meaning nearly one-fifth of the entire paved state trail system will soon need resurfacing or reconstruction.

Longer term, we project that approximately 90 miles will likely need rehabilitation in five to nine years, and another 124 miles within 10 to 14 years (Figure 14). By 15 to 19 years, an additional 134 miles are projected to reach the end of their service life. Cumulatively, this suggests that nearly 480 miles — over half of the system — will need rehabilitation within the next two decades.

These findings illustrate a clear and growing rehabilitation challenge. Without increased funding and a stronger focus on rehabilitation, ride quality on Minnesota's paved state trail system will continue to decline. The following recommendations outline goals and policies to meet the challenge moving forward.

RECOMMENDATIONS

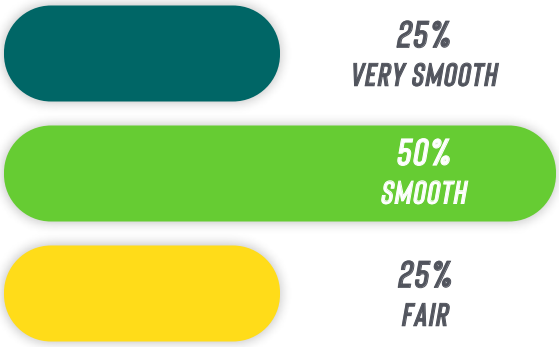
Set a performance target

Clear performance targets are critical for effective asset management. Targets define acceptable conditions, enable consistent evaluation, and guide long-term planning and funding decisions. In our 2019 *State of the Trails Report*, we proposed a "25-50-25" performance standard for the Minnesota paved state trail system (Figure 15). At any given time, the goal should be to keep 25% of the system's miles in very smooth riding condition, 50% in smooth riding condition, and 25% in fair riding condition. When we first proposed the standard, it seemed within reach: 54% of the system was

Figure 15

HOW SMOOTH SHOULD THE STATE TRAIL SYSTEM BE TO RIDE?

We suggest "25-50-25" as a performance target for Minnesota's paved state trail system



in smooth riding condition, and 21% was very smooth.

Today, that target is further out of reach, but we believe it remains an ambitious yet achievable goal. The question of "how good is good enough" is never an easy one to answer, and some will view our goal as too ambitious while others think it is not ambitious enough. We are open to revisiting performance targets in the future, especially as new trails are built, priorities evolve, data improve, and new voices join the conversation. But for now, we believe a "25-50-25" is a useful target to guide rehabilitation needs.

Rehabilitate 30 miles annually

Maintaining a "25-50-25" performance target across Minnesota's paved state trail system will require rehabilitating an estimated 30 miles of trail each year. This need has increased since our 2019 report, where we recommended that 24 miles needed to be rehabilitated each year. The increased need is primarily a reflection that our 2019 recommendation was not fulfilled and highlights the reality that the longer we wait to rehabilitate the system, the more difficult (and expensive) the undertaking becomes.

Between 2018 and 2023, only 12 miles of the system were rehabilitated. If that trend continues, and approximately 2.5 miles are rehabilitated each year, we estimate only 39-43% of the system will be in smooth or very smooth riding condition by 2030 (Figure 16). That number would fall to 19-24% by 2035. Paradoxically, that is a year after the Clean Water, Land and Legacy Amendment — which was passed in part to make transformational investments in our parks and trails system — is set to expire.

Ensuring Minnesota's paved state trails have a better legacy in 2035 will require significantly boosting the rate of trail rehabilitation. Our analysis finds that, even if trail rehabilitation were to increase to 10 miles each year, only 33-38% of the system would be in smooth riding condition by 2035. Boosting rehabilitation further, to 20 miles each year, would be sufficient to keep 50-55% of the system in smooth riding condition for perpetuity. To meet a "25-50-25" performance target, our analysis finds rehabilitating 30 miles a year (on average) is necessary.

Capital improvement funding and planning

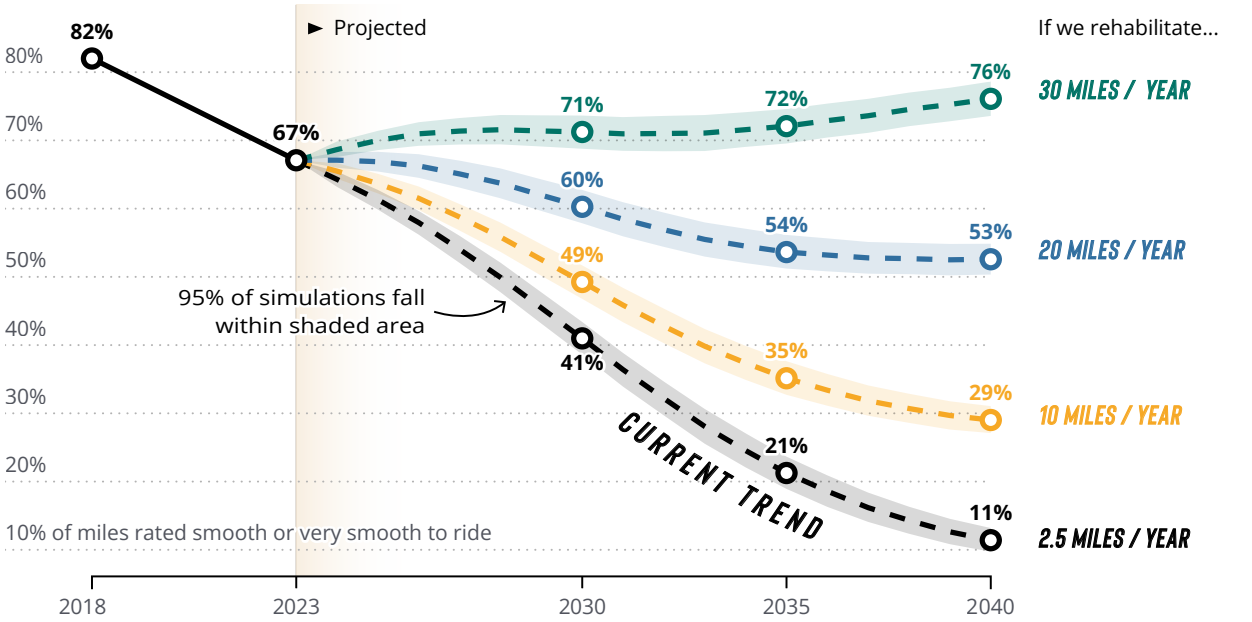
Rehabilitating 30 miles of paved state trails annually — and maintaining a 25-50-25 standard — will require significant investment and planning.

Although project-level cost estimates are beyond the scope of this report, providing a general estimate of costs is still helpful in understanding the need and informing long-term planning. Paved trail rehabilitation costs vary widely

Figure 16

DIFFERENT SCENARIOS FOR THE FUTURE OF MINNESOTA'S STATE TRAILS

*Projected % of Minnesota's paved state trail miles rated **very smooth** or **smooth** to ride under different rehabilitation scenarios*



Note: Each scenario is based on 10,000 simulations. Current trend is based on average annual trail rehabilitation completed between 2018 and 2023.

from project to project and depend on a myriad of project-specific factors (e.g., the trail's condition, level of rehabilitation necessary, materials, drainage issues, accessibility requirements, and culvert or bridge repair) and market fluctuations (e.g., inflation, regional construction markets, and material availability). Depending on those factors, per-mile rehabilitation costs can range from $150,000 on the low end to over $1 million on the high end, with an average of approximately $300,000 per mile (in 2025 dollars).[3] Based on that program-wide planning average, maintaining a 25-50-25 standard (through rehabilitating 30 miles each year) would cost roughly $9 million annually. This figure is solely intended to illustrate the general scale of investment needed and is not a prediction of actual costs; costs for specific projects can only be determined through engineering and predesign work.

State trail rehabilitation projects are primarily funded through a combination of state bonding appropriations and dedicated funds. In recent years, however, state bonding appropriations (which historically were the primary funding source for capital improvements, including trail rehabilitation) have become less reliable. As a result, trail rehabilitation has become more reliant on the Legacy Parks & Trails Fund (funded through a constitutional sales tax) and the Environment and Natural Resources Trust Fund (funded by the state lottery), even though both were only designed

3 Minnesota DNR. (2025). 10-Year Capital Asset Need: Taking care of what we have.

to *supplement* rather than replace traditional funding sources.[4] Further, the DNR has shifted to submitting bonding requests for "Natural Resources Asset Preservation" rather than for specific programs or projects. As a result, bonding appropriations for trail rehabilitation are not clearly distinguished from other capital priorities, limiting transparency into how much is requested and spent on maintaining existing state trail infrastructure.

Reestablishing trail rehabilitation as a distinct line item in bonding appropriations (as it was from 2008–2012, and again in 2023) would offer increased funding and improved transparency. Legislators would be able to exercise oversight and evaluate requested funding levels in relation to documented needs. By normalizing trail maintenance as an ongoing responsibility, this approach would help preserve existing assets over the long-term and avoid the higher costs associated with deferred maintenance.

Consistent funding for trail rehabilitation also requires a planning framework to guide how funds are allocated over time. Detailed, public-facing capital improvement plans are critical because they provide clarity and allow lawmakers to make informed decisions. Effective capital improvement plans are transparent and include prioritized project lists, estimated costs, and implementation timelines. The list of the 20 roughest trail sections shown in Figure 7 (see page 9) is intended to offer a useful starting point for a state trails capital improvement plan; however, additional factors beyond TRI should also be considered when establishing priorities (e.g., visual inspections, system plan classification, trail use, geographic distribution, etc.).

The benefits of such a priority-based approach are clear. Lawmakers can see precisely what projects are being funded (or deferred) and how individual investments fit within a long-term rehabilitation program. For the public, capital improvement plans improve transparency and set clearer expectations about when local trails are likely to be repaired.

Parks & Trails Council is committed to working with lawmakers, trail managers, and the public to follow through on these recommendations and ensure Minnesota has a trail system we can all be proud of. Our 2025 *State of the Trails Report* finds a trail system facing many challenges. The good news is most of the paved state trail system remains in smooth riding condition, and increased trail maintenance funding passed in 2023, coupled with other funding sources, is starting to pay dividends.[5] But the work is far from over. Continued and increased funding will be essential to keep pace with aging infrastructure, rising costs, and growing demand. The insights from this report can help ensure that every dollar invested moves Minnesota's trail system closer to the standard our communities deserve.

4 Minn. Const. art. XI, sec. 15 and Minnesota Statutes 2025, section 116P.03

5 DNR rehabilitated sections of the Casey Jones, Paul Bunyan, Minnesota Valley, and Great River Ridge State Trails after data was collected for this report.

STATE TRAIL REPORT CARDS

The following pages provide trail-by-trail summaries and maps for each Minnesota paved state trail where we have roughness data. Each overview includes key trail statistics, a map showing segment ride quality, changes since 2018, and contextual information about the trail's location and connections.

Together, these maps and trail summaries translate thousands of data points into an accessible, one-page format. They are designed to help trail managers, planners, and users quickly identify where maintenance may be needed, which sections provide the smoothest ride, and how conditions vary along each trail.

An interactive version of these maps, including links to all of our photos and directions, is available on our website.

CLICK OR SCAN TO EXPLORE THE DATA ONLINE

Figure 17

HOW TO UNDERSTAND OUR TRAIL MAPS

For use with trail maps on pages 20 - 43

Trail Summary

- B- Overall 2023 trail grade
- IMPROVED / STABLE / DECLINED — Grade comparison to 2018
- Paved miles, including road segments
- Year(s) trail was constructed

State Trail Ride Quality

- Very smooth
- Smooth
- Fair
- Rough
- Very rough
- No data
- On-street segment

Other

- Hiking trail
- Other paved state / regional trail
- Unpaved state / regional trail
- P — Trail parking / Trailheads

Transportation

- Railroad
- 35 — Interstate highway
- 65 — U.S. highway
- 61 — State highway
- 46 — County highway

Outdoor Recreation Areas & Park Amenities

- State Park, State Recreation Area, & Regional Parks
- State Scientific & Natural Areas
- State Forests
- State Wildlife Management Areas
- State Aquatic Managemenet Areas
- Ranger station
- Picnic area
- Campground
- Restrooms
- Amphitheater
- Playground
- Vollyball court
- Gift shop
- Swimming
- Fishing access

ALEX LAVEAU STATE TRAIL

C+ Trend since 2018: STABLE

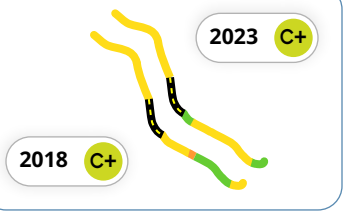
6.6 Miles

Constructed in 1994

How smooth is the trail to ride?

Very Smooth	
Smooth	0.8 miles
Fair	4.6 miles
Rough	
Very Rough	

5-Year Change



BLAZING STAR STATE TRAIL

B- Trend since 2018: DECLINED

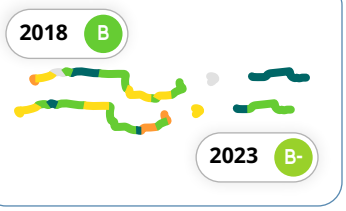
6.7 Miles

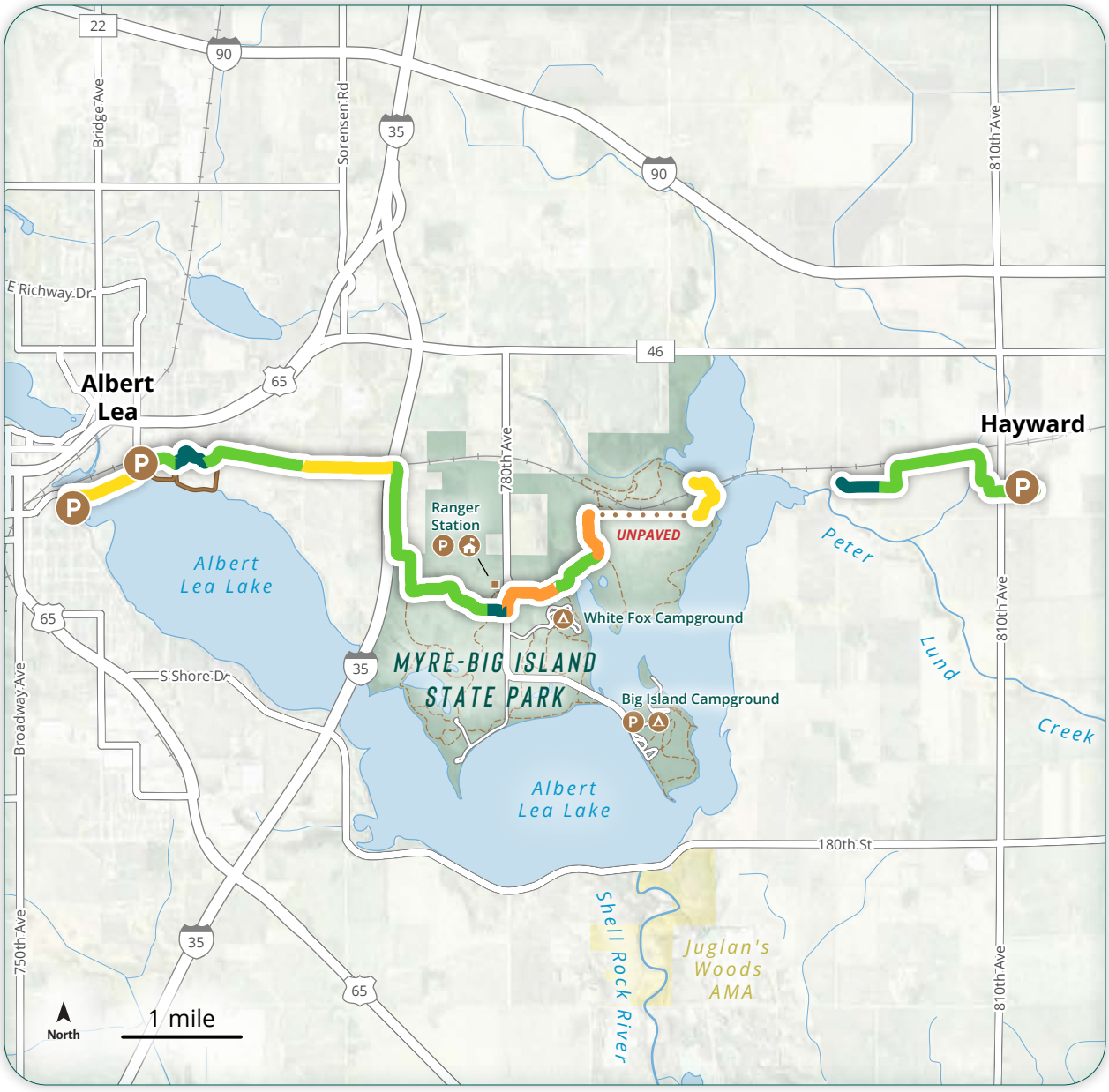
Constructed in 2004, 2005, 2015, 2022, & 2023

How smooth is the trail to ride?

Very Smooth	0.6 miles
Smooth	3.9 miles
Fair	1.5 miles
Rough	0.7 miles
Very Rough	

5-Year Change





BROWN'S CREEK STATE TRAIL

B+ Trend since 2018: DECLINED

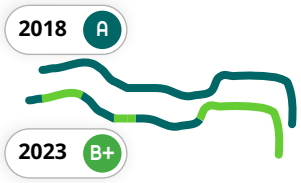
5.8 Miles

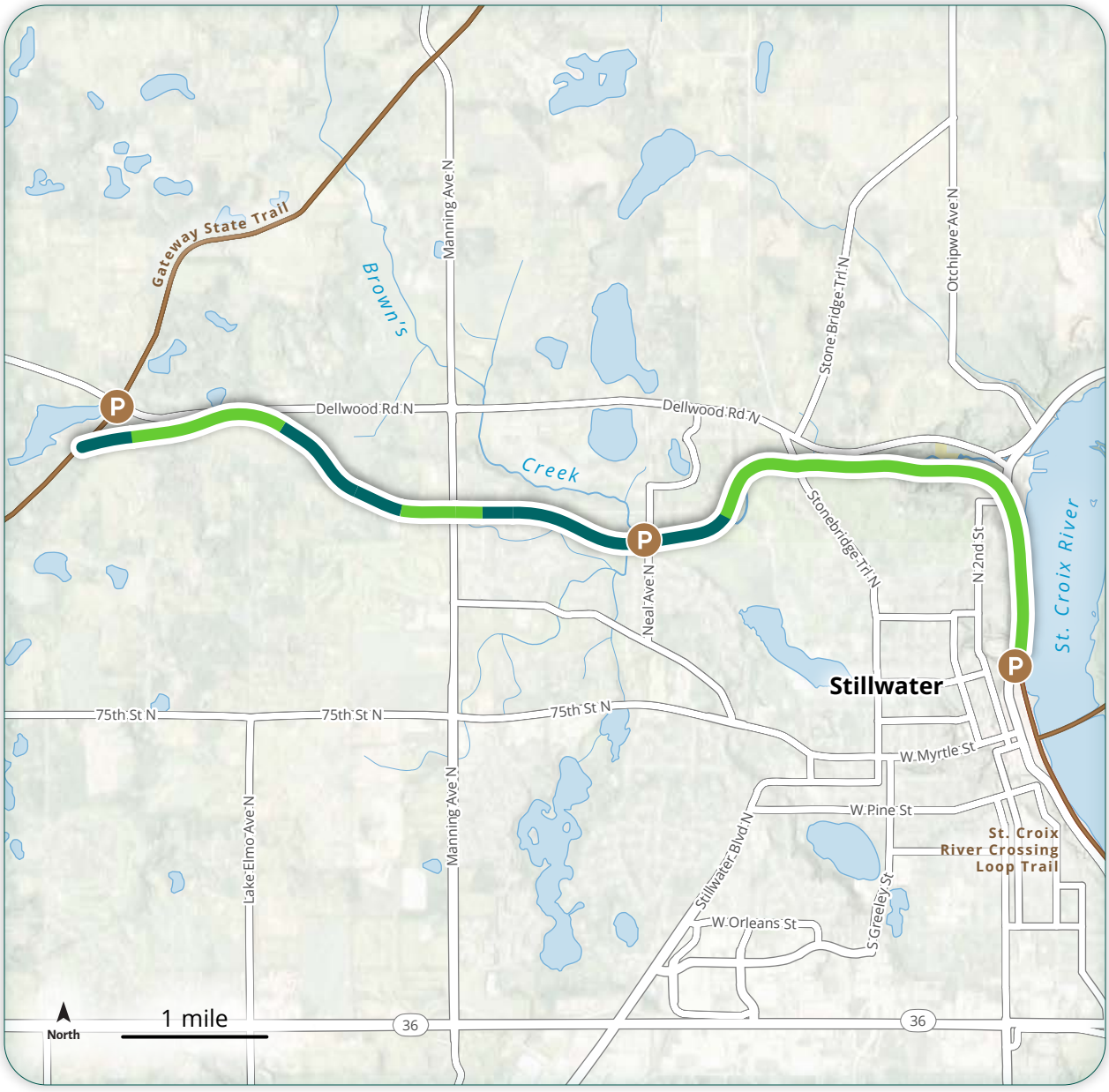
Constructed in 2014

How smooth is the trail to ride?

Very Smooth	2.2 miles
Smooth	3.5 miles
Fair	
Rough	
Very Rough	

5-Year Change





CAMP RIPLEY / VETERANS STATE TRAIL

B

Trend since 2018: N.A.

1.4 Miles

Constructed in 2019

How smooth is the trail to ride?

Very Smooth	0.2 miles
Smooth	1.1 miles
Fair	0.1 miles
Rough	
Very Rough	

5-Year Change

Trail was new construction in 2019.

CASEY JONES STATE TRAIL

C Trend since 2018: DECLINED

16 Miles

Constructed in 1999, 2007, 2023

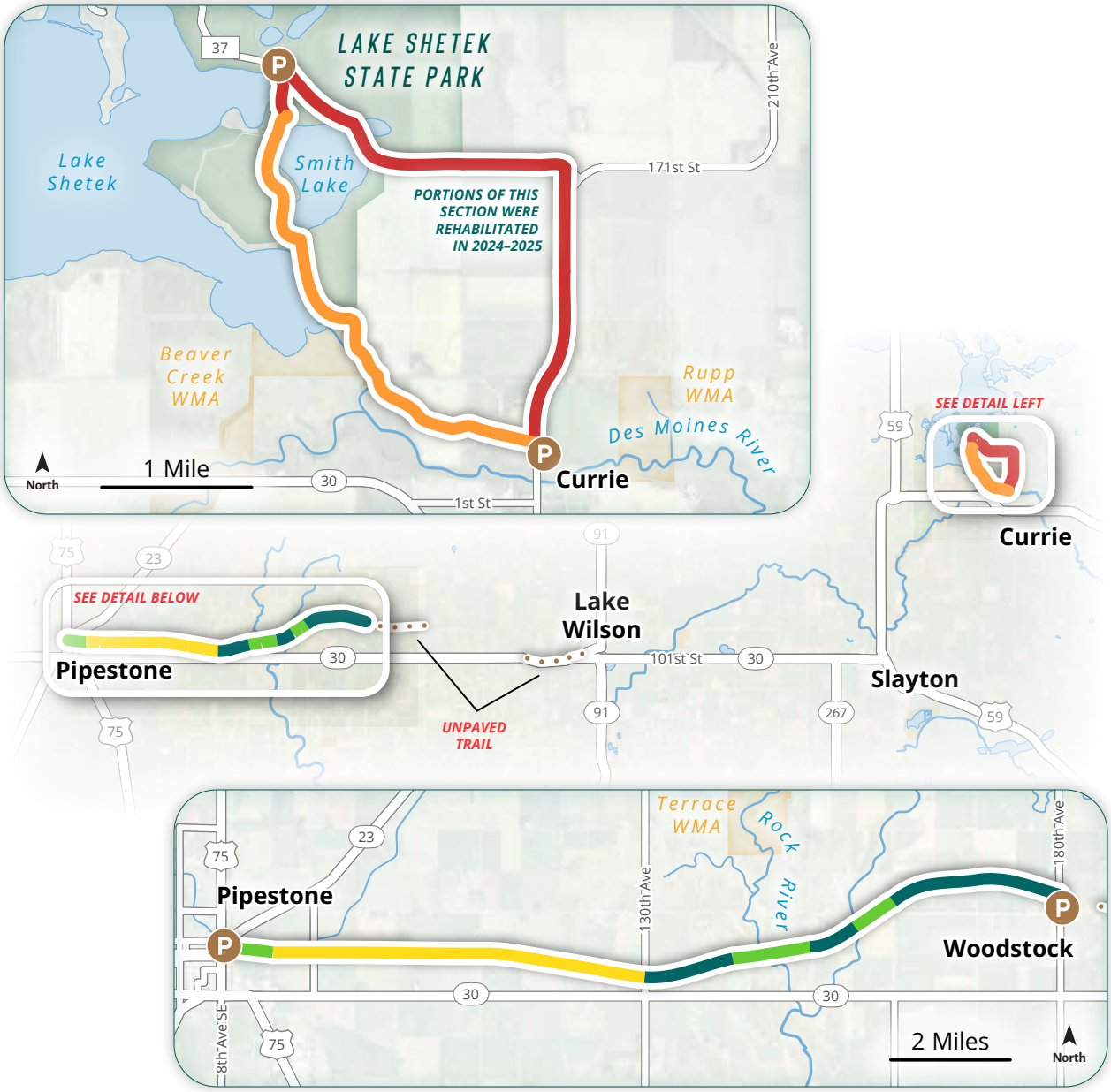
How smooth is the trail to ride?

Very Smooth	3.8 miles
Smooth	2.1 miles
Fair	4.5 miles
Rough	2.5 miles
Very Rough	3.2 miles

5-Year Change

2018 C+

2023 C



CENTRAL LAKES STATE TRAIL

B- Trend since 2018: DECLINED

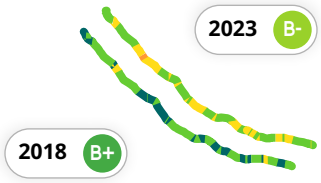
55.4 Miles

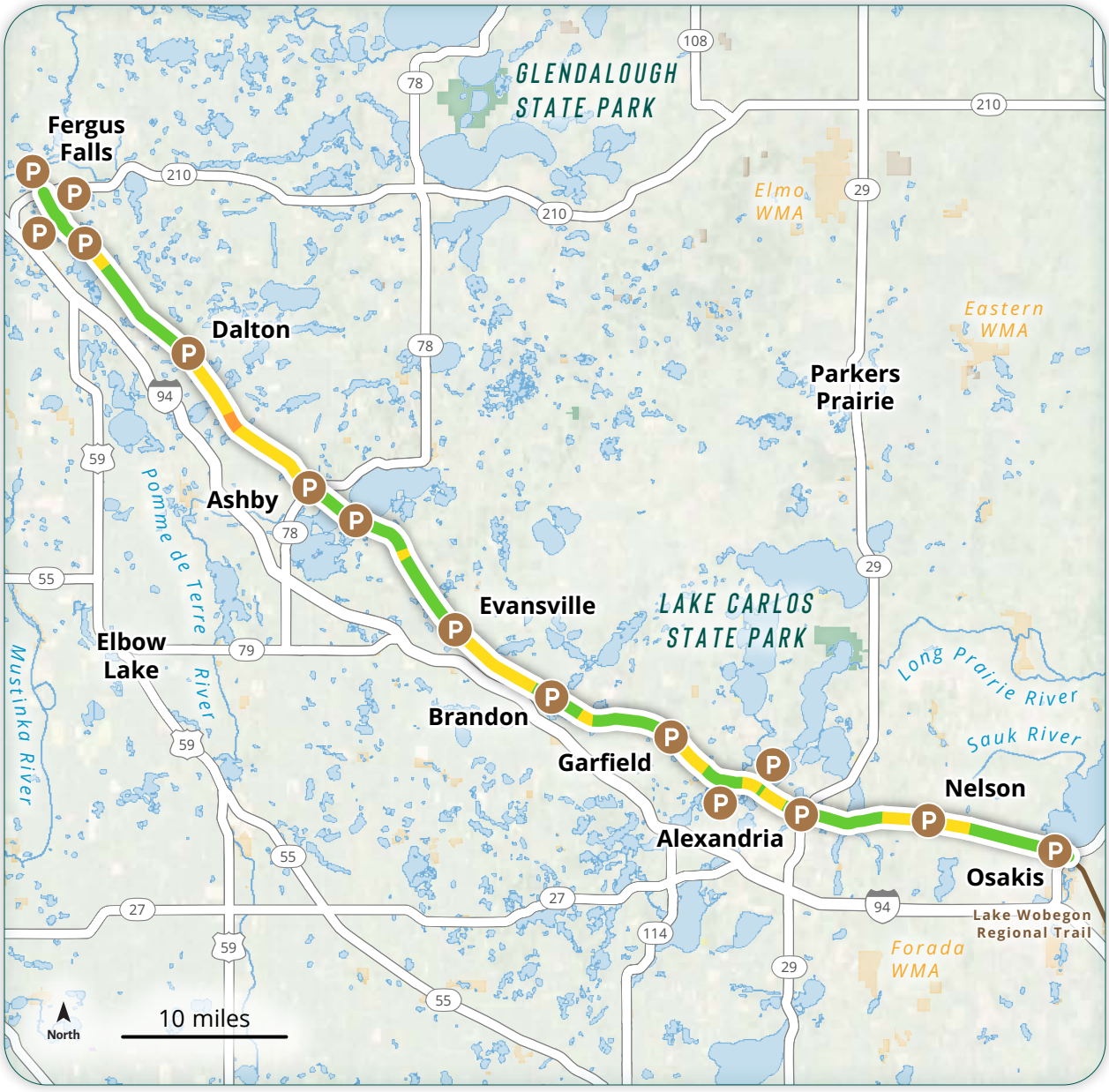
Constructed in 2003, 2019

How smooth is the trail to ride?

Very Smooth	
Smooth	33.5 miles
Fair	21.1 miles
Rough	0.8 miles
Very Rough	

5-Year Change





CUYUNA LAKES STATE TRAIL

B- Trend since 2018: DECLINED

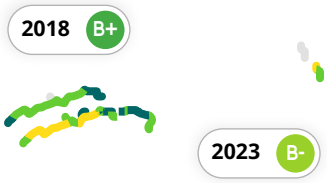
12.3 Miles

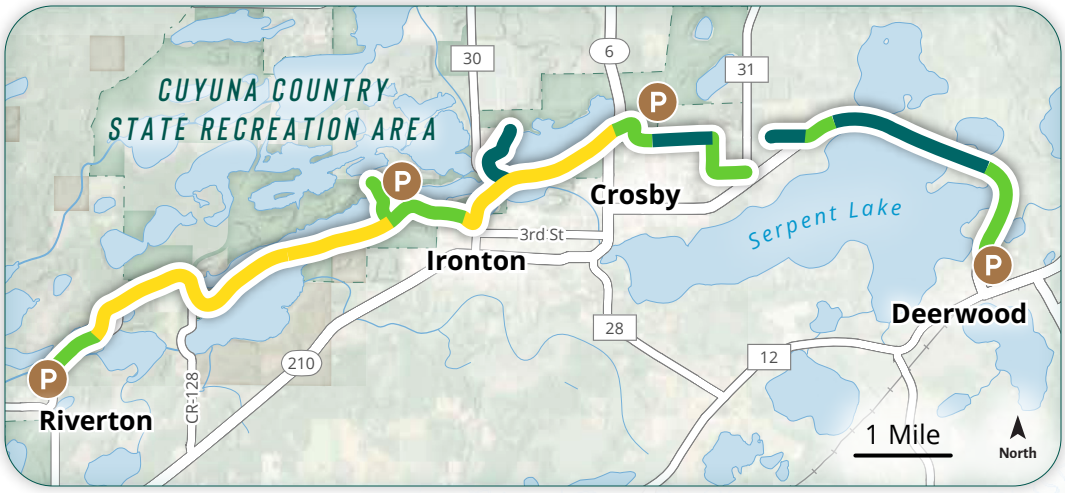
Constructed in 2005, 2011, 2012, 2014, 2021 & 2023

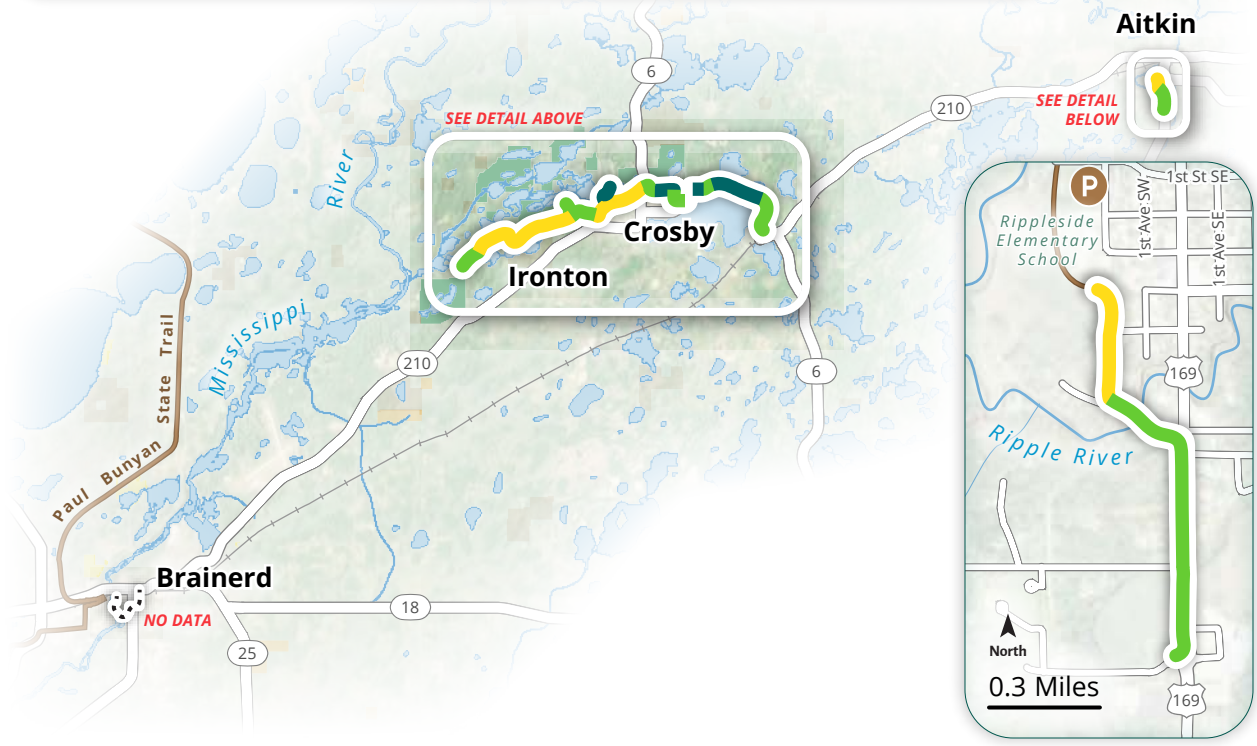
How smooth is the trail to ride?

Very Smooth	2.4 miles
Smooth	4 miles
Fair	4.3 miles
Rough	
Very Rough	

5-Year Change







DOUGLAS STATE TRAIL

B Trend since 2018: STABLE

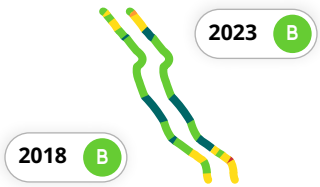
12.8 Miles

Constructed in 2006 & 2016

How smooth is the trail to ride?

Very Smooth	3.7 miles
Smooth	5.7 miles
Fair	3.1 miles
Rough	0.2 miles
Very Rough	0.1 miles

5-Year Change



GATEWAY STATE TRAIL

C Trend since 2018: DECLINED

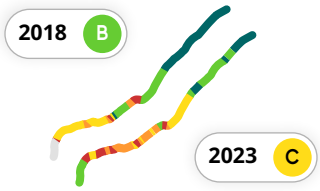
17.9 Miles

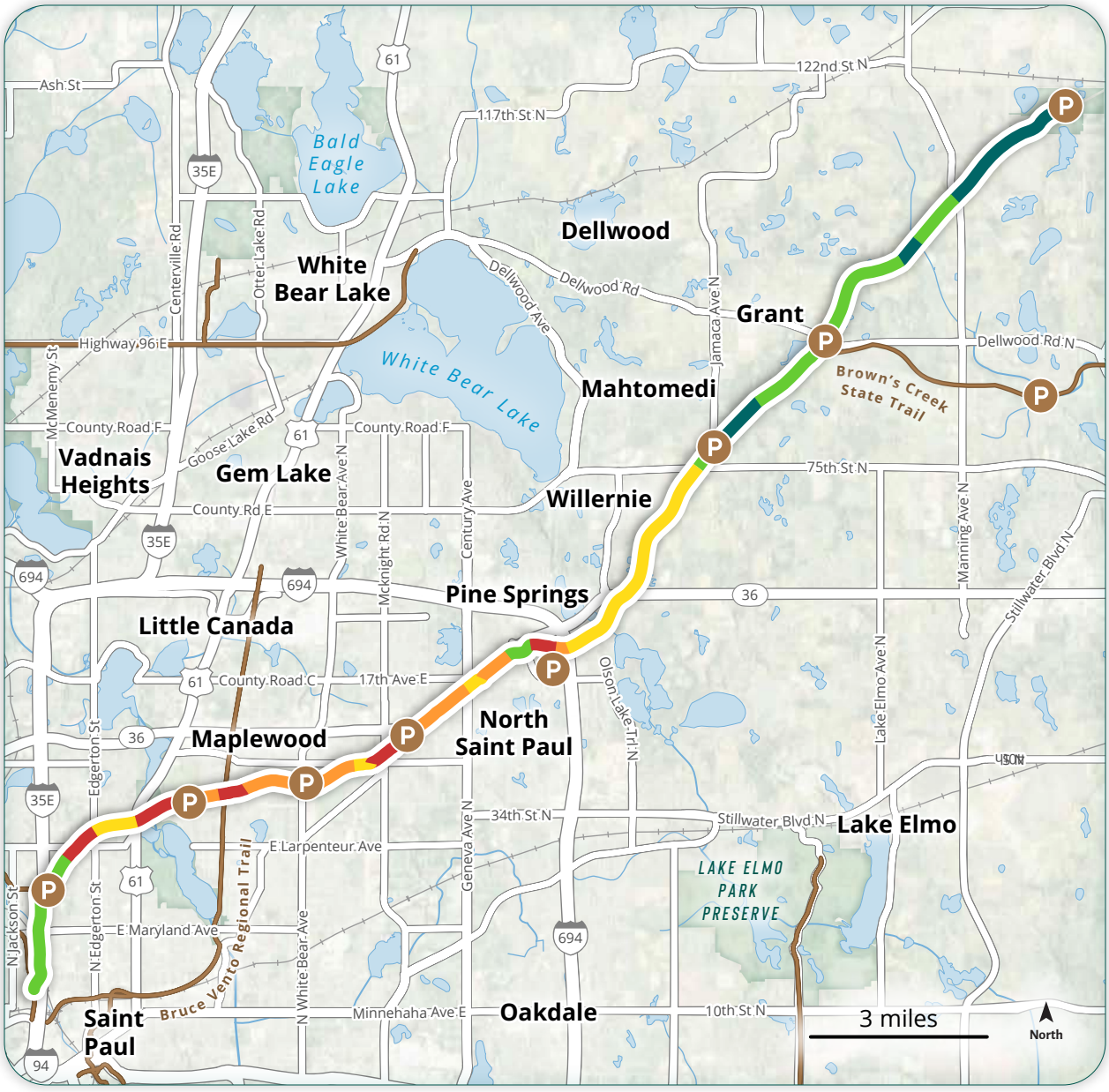
Constructed in 1991, 2000, 2002, 2006, 2007, 2010, 2016, 2019, & 2023

How smooth is the trail to ride?

Very Smooth	2.9 miles
Smooth	5.7 miles
Fair	3.9 miles
Rough	3.3 miles
Very Rough	2.2 miles

5-Year Change





GITCHI-GAMI STATE TRAIL

C+ Trend since 2018: DECLINED

34.8 Miles

Constructed in 2002, 2004, 2006, 2008, 2010, 2012, 2013, 2021, & 2022 *
*Some segments have unknown construction dates

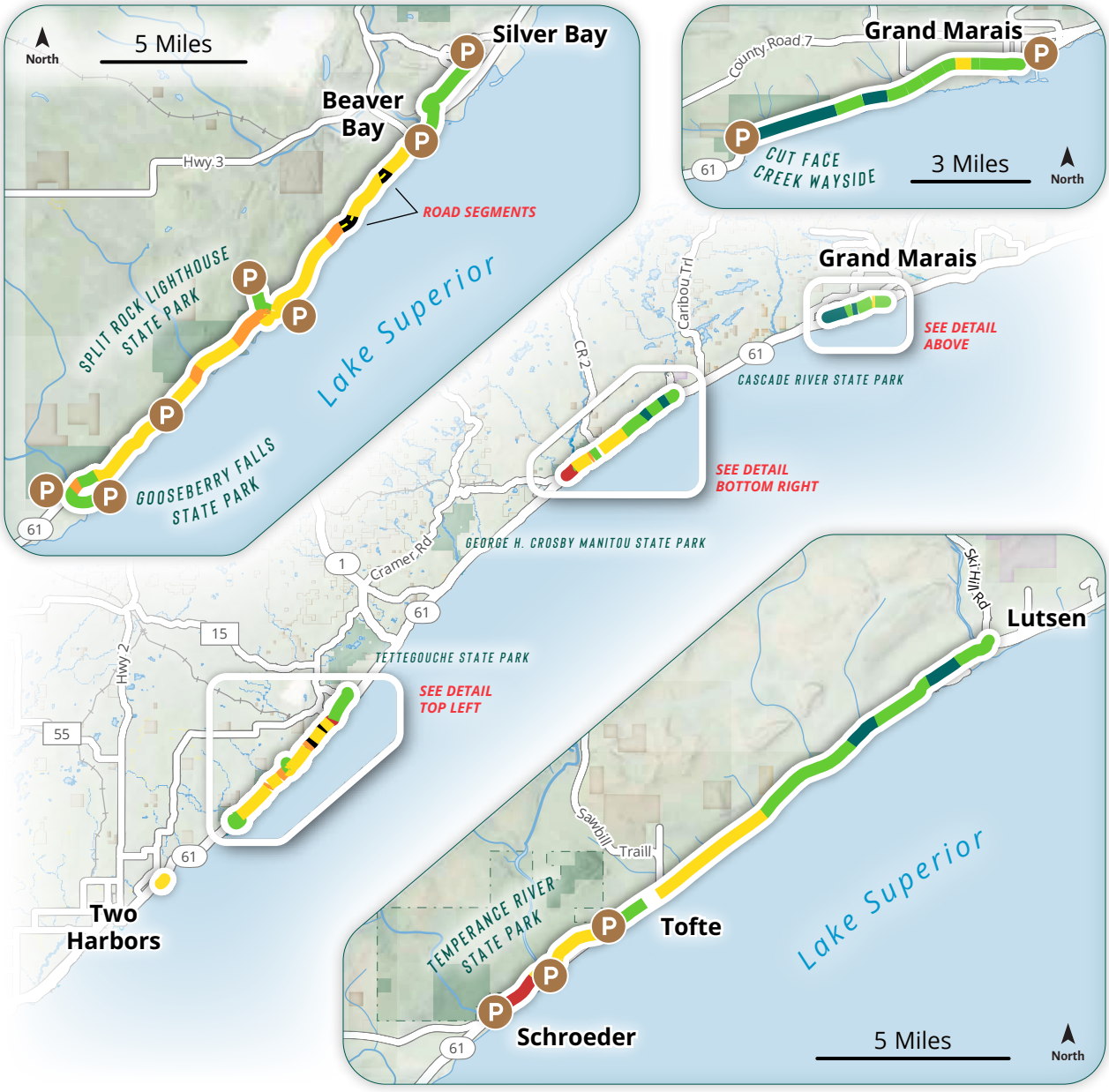
How smooth is the trail to ride?

Very Smooth	3.3 miles
Smooth	12.9 miles
Fair	14 miles
Rough	2.6 miles
Very Rough	1.2 miles

5-Year Change

2018 B

2023 C+



GLACIAL LAKES STATE TRAIL

B Trend since 2018: DECLINED

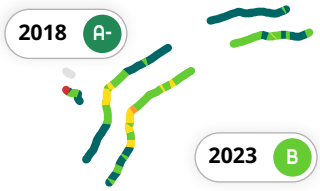
36.6 Miles

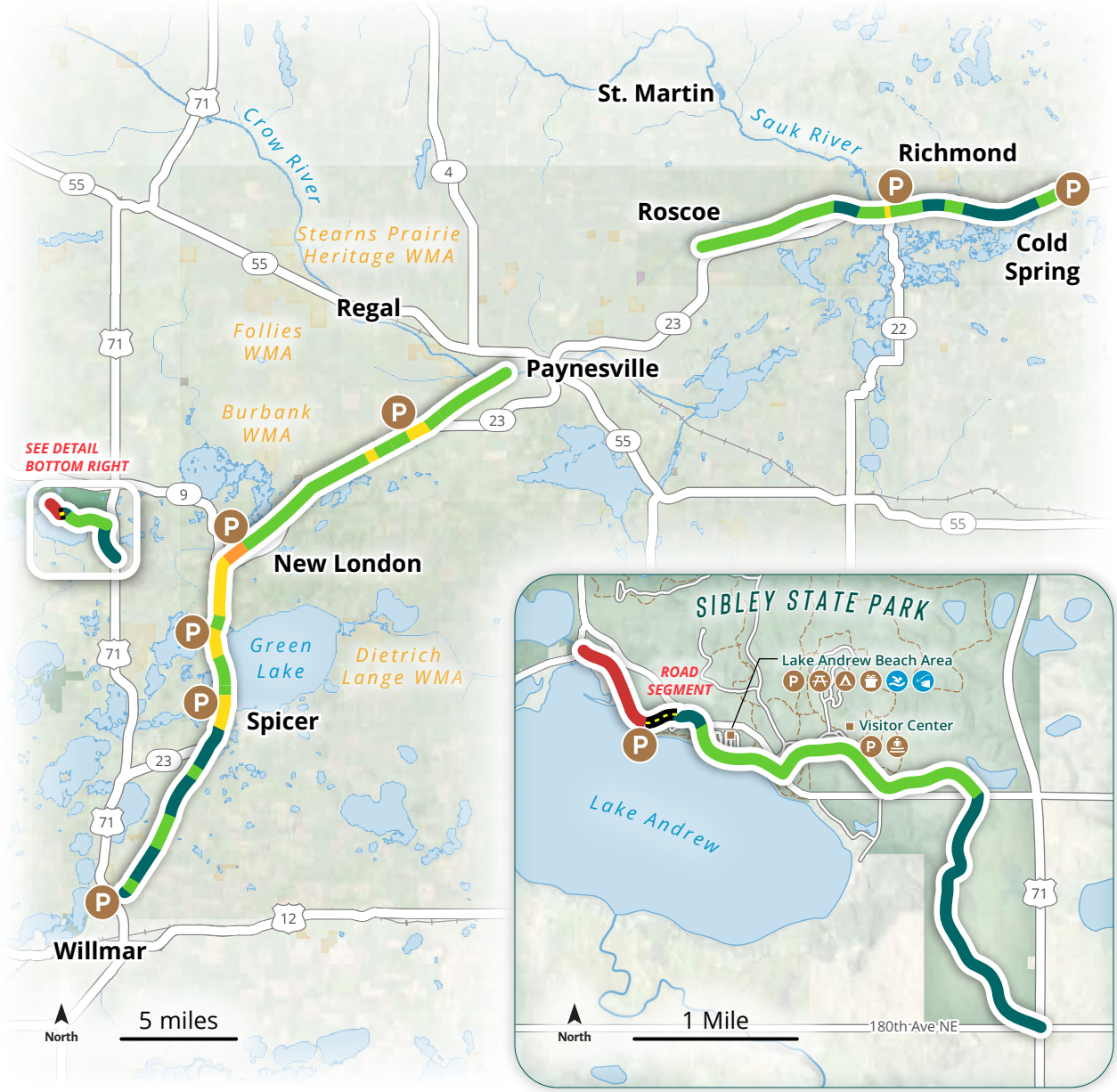
Constructed in 1998, 2008, 2011, 2012, 2014, 2017, 2021, & 2022 *
*Some segments have unknown construction dates

How smooth is the trail to ride?

Very Smooth	9.4 miles
Smooth	21.1 miles
Fair	4.8 miles
Rough	0.7 miles
Very Rough	0.4 miles

5-Year Change





GOODHUE PIONEER STATE TRAIL

B+ Trend since 2018: STABLE

9.5 Miles

Constructed in 1997, 2007, 2010, & 2022

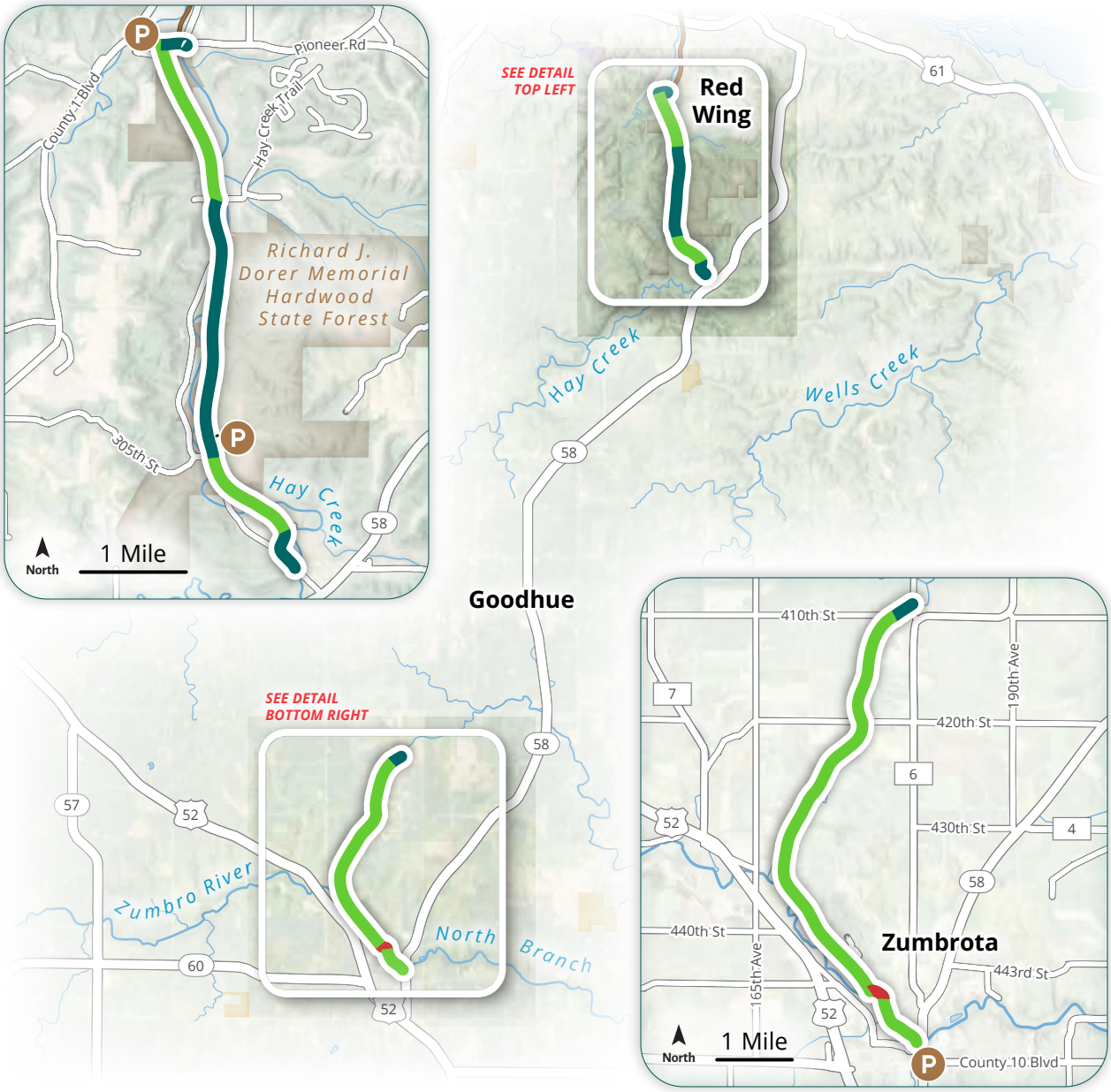
How smooth is the trail to ride?

Very Smooth	2.5 miles
Smooth	6.7 miles
Fair	
Rough	
Very Rough	0.2 miles

5-Year Change

2018 B+

2023 B+



GREAT RIVER RIDGE STATE TRAIL

B- Trend since 2018: DECLINED

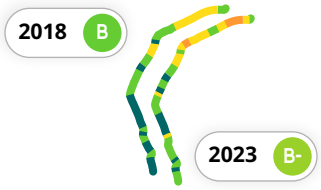
13.2 Miles

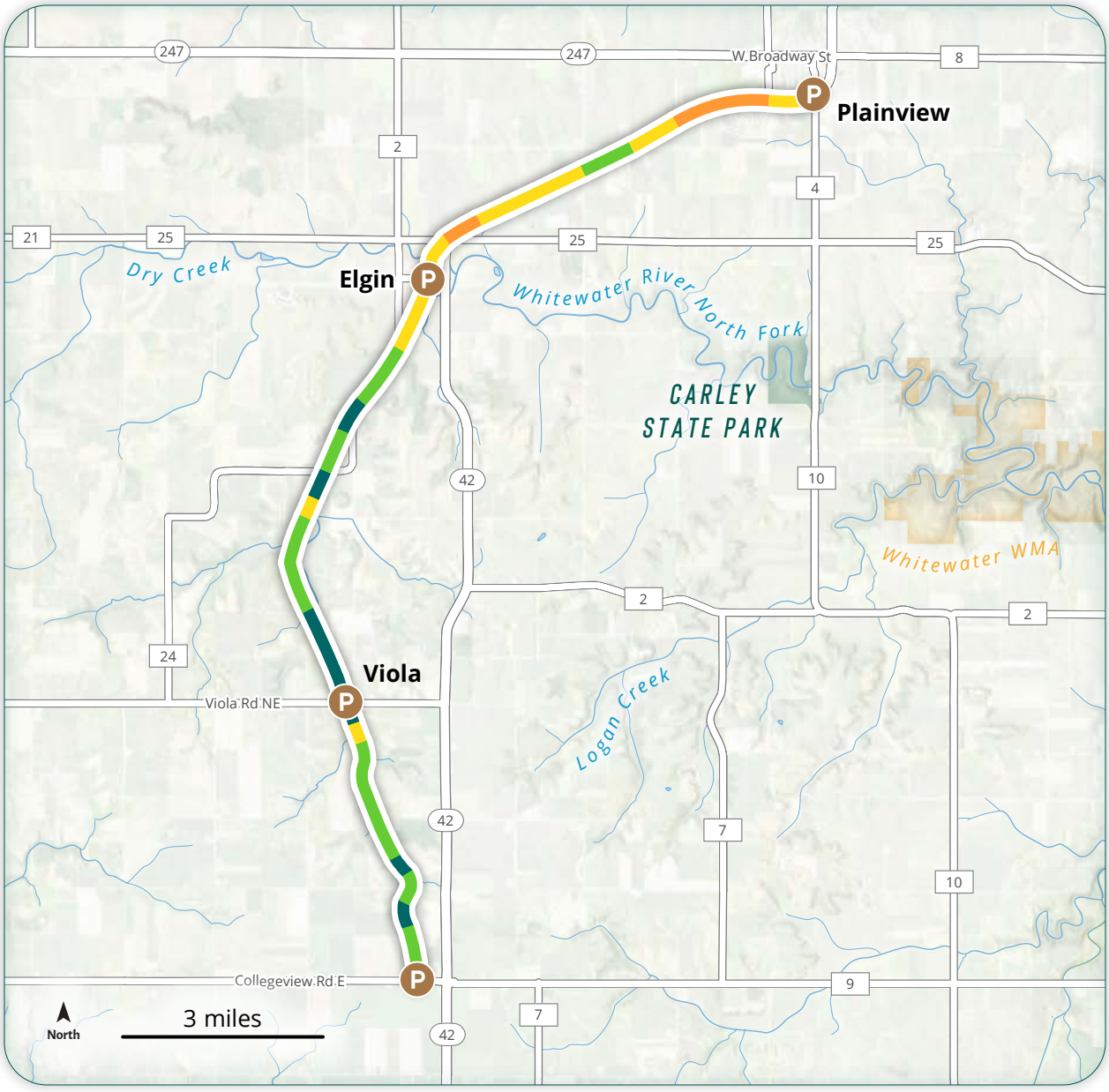
Constructed in 2007 & 2009

How smooth is the trail to ride?

Very Smooth	2.5 miles
Smooth	5.5 miles
Fair	3.7 miles
Rough	1.5 miles
Very Rough	

5-Year Change





HARMONY-PRESTON VALLEY STATE TRAIL

C+ Trend since 2018: DECLINED

22 Miles

Constructed in 1997, 1999, & 2024

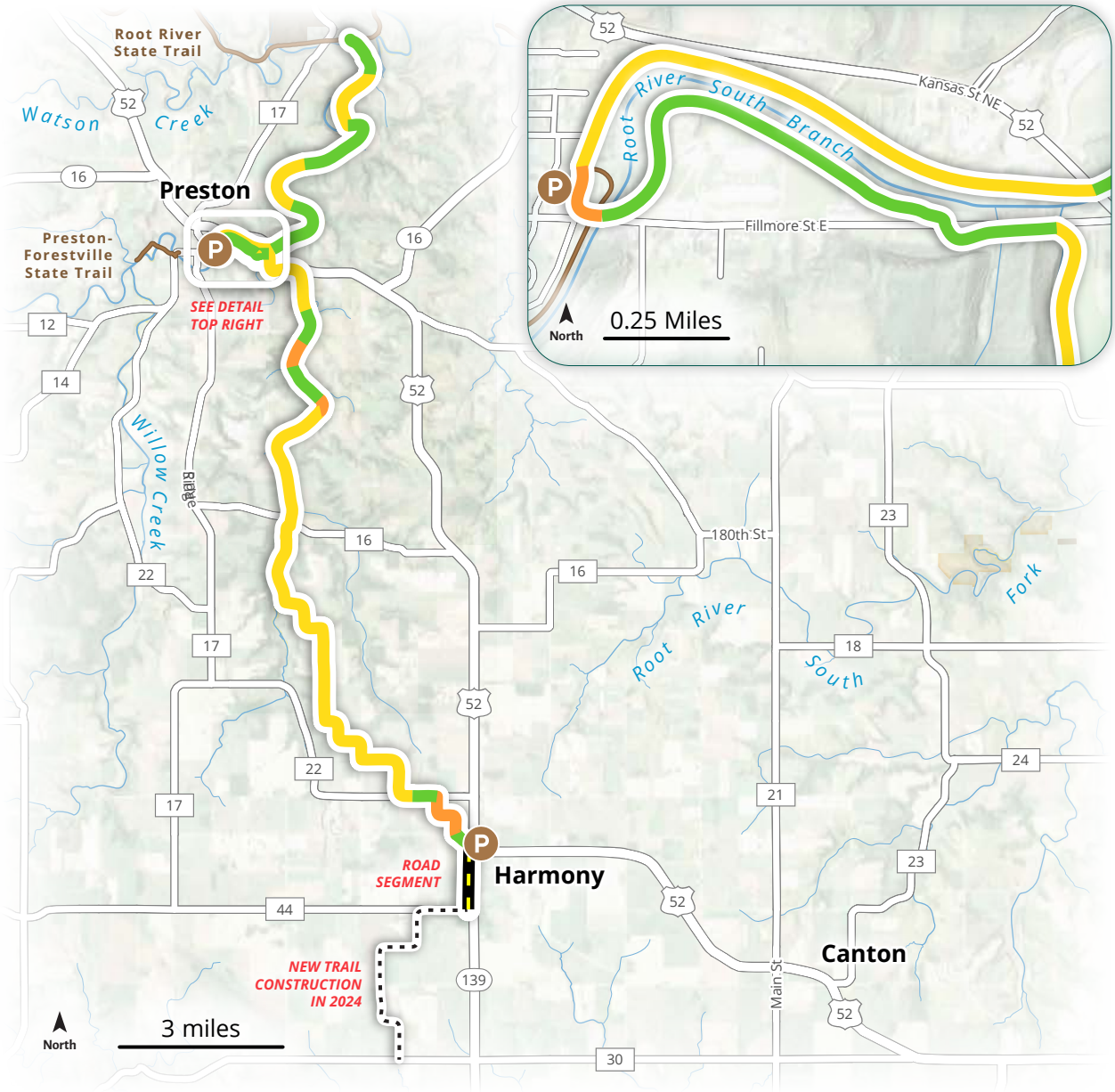
How smooth is the trail to ride?

Very Smooth	
Smooth	5.5 miles
Fair	10.9 miles
Rough	1.4 miles
Very Rough	

5-Year Change

2023 C+

2018 B



HEARTLAND STATE TRAIL

B Trend since 2018: STABLE

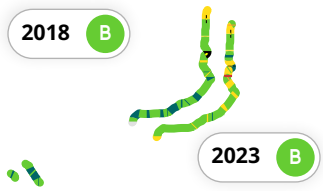
56.4 Miles

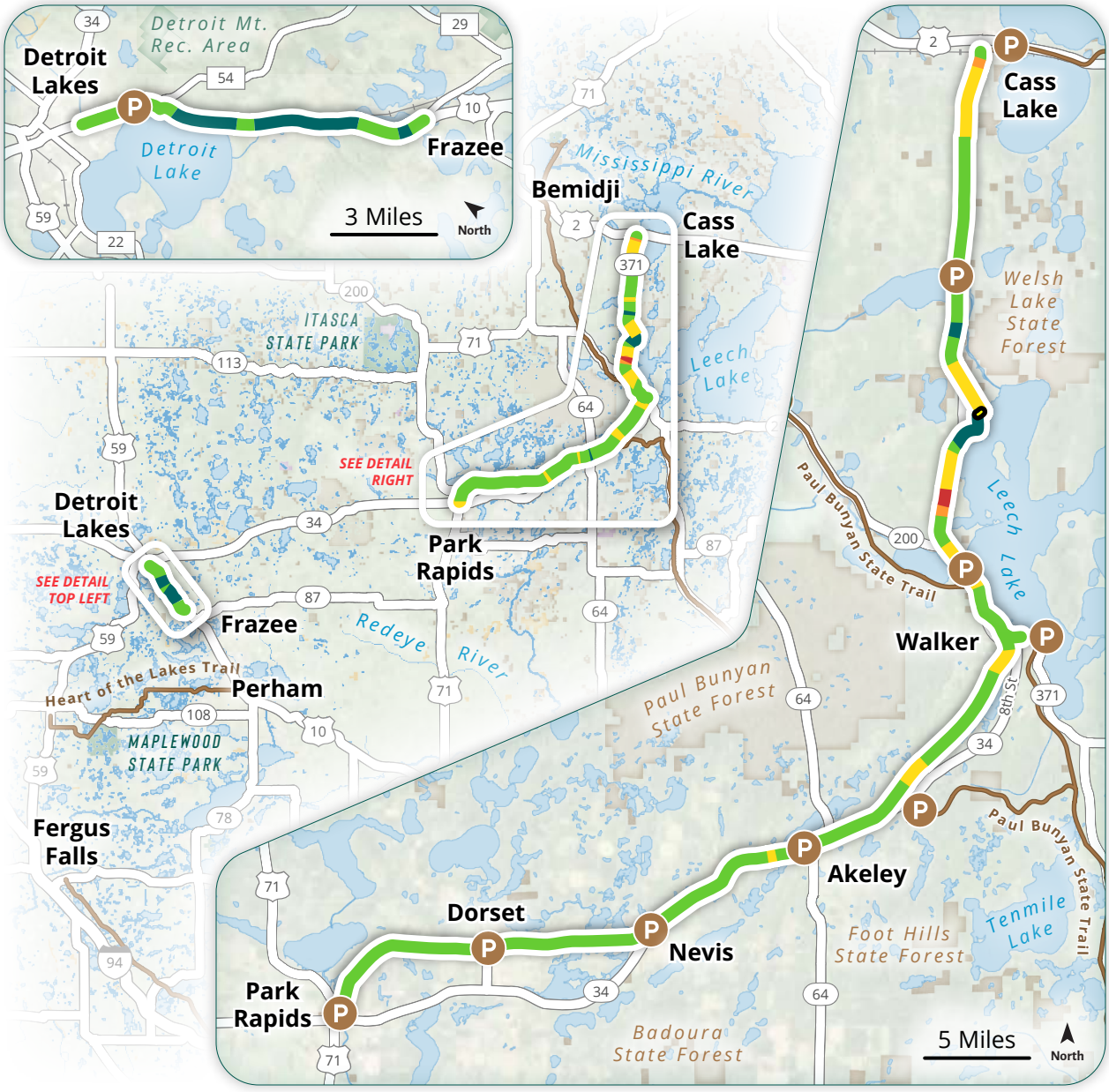
Constructed in 2002, 2015, & 2021 *
*Some segments have unknown construction dates

How smooth is the trail to ride?

Very Smooth	5.7 miles
Smooth	38.9 miles
Fair	10.4 miles
Rough	0.7 miles
Very Rough	0.5 miles

5-Year Change





LUCE LINE STATE TRAIL

B+ Trend since 2018: DECLINED

23.2 Miles *

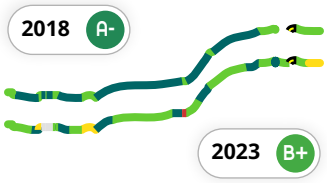
Constructed in 2015 & 2021 *

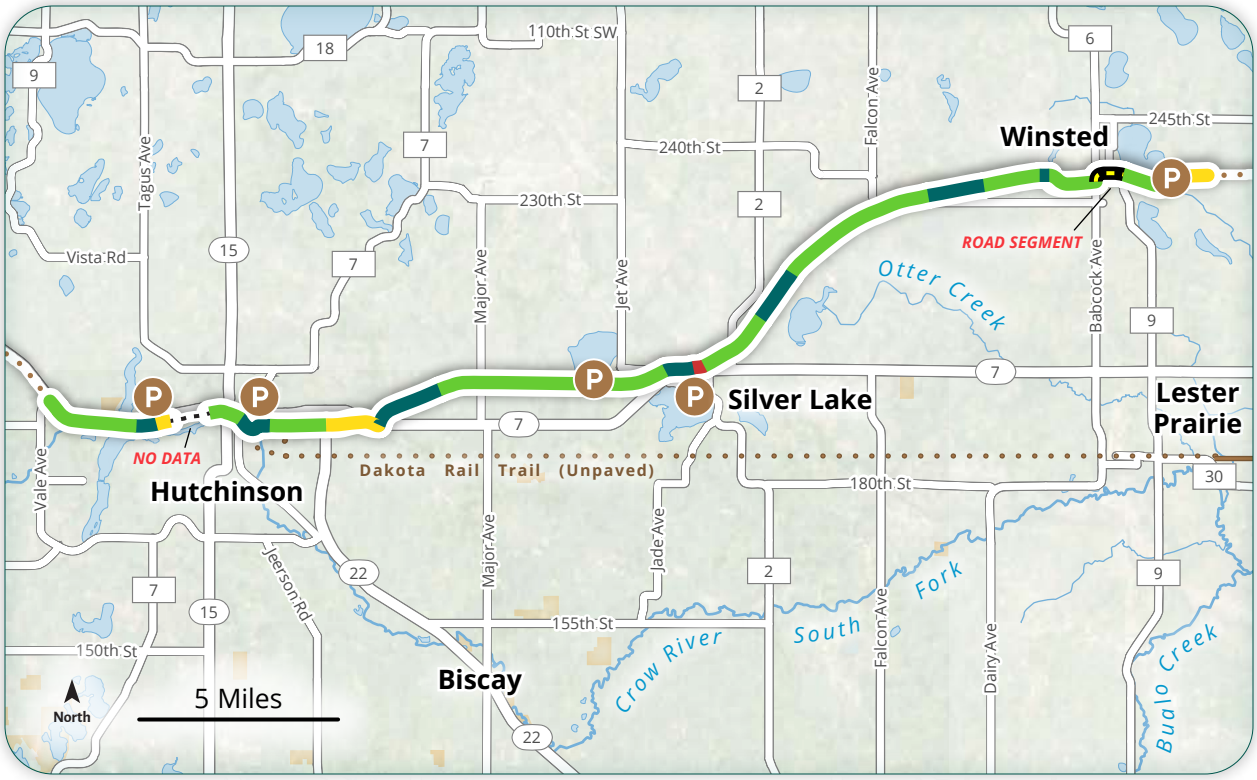
*Paved segments

How smooth is the trail to ride?

Very Smooth	5 miles
Smooth	14.6 miles
Fair	1.9 miles
Rough	
Very Rough	0.2 miles

5-Year Change





MILL TOWNS STATE TRAIL

C+ Trend since 2018: STABLE

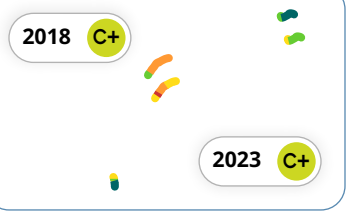
6.1 Miles

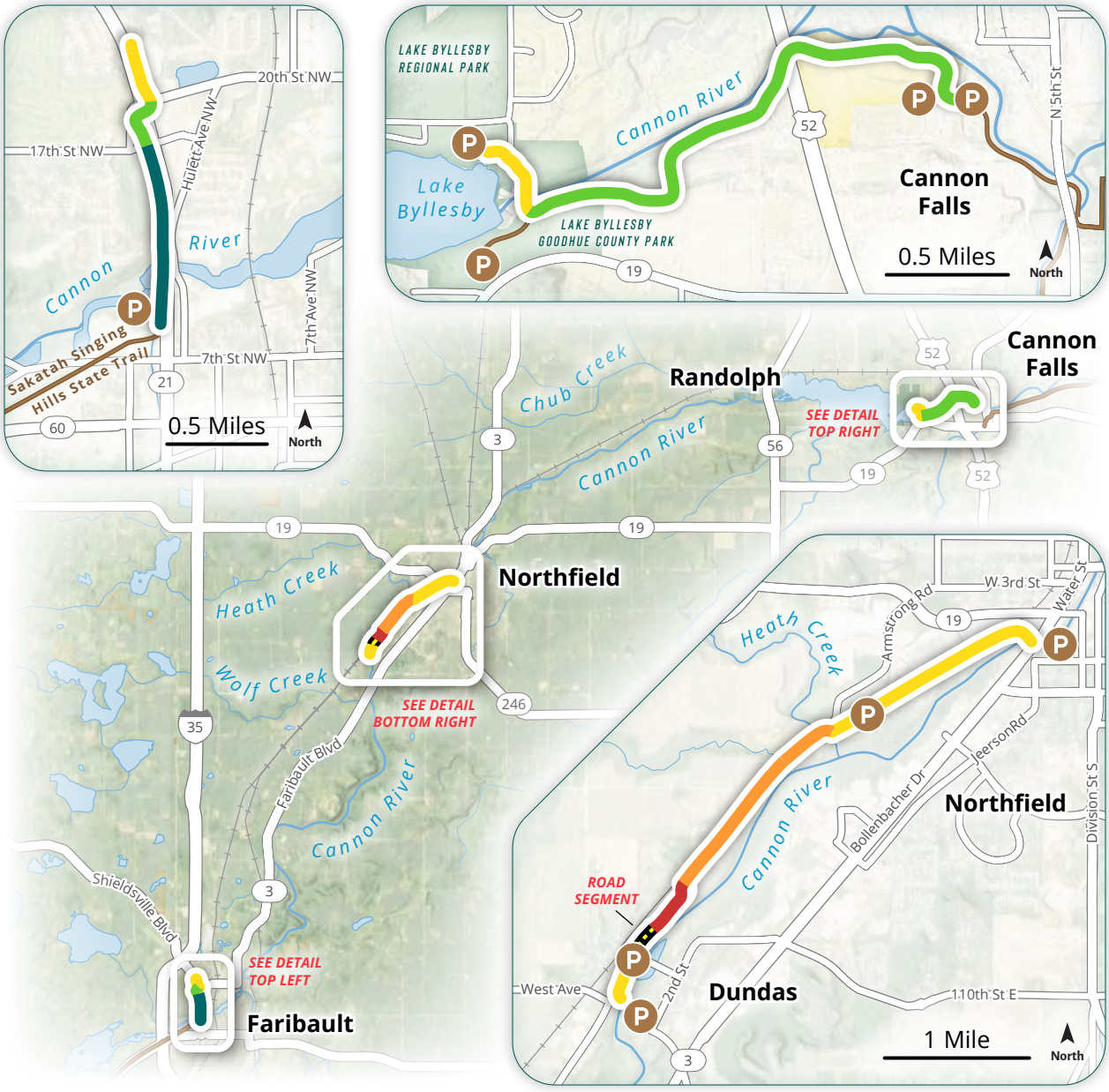
Constructed in 1998, 2008, 2016, & 2019

How smooth is the trail to ride?

Very Smooth	0.6 miles
Smooth	1.9 miles
Fair	2 miles
Rough	1.1 miles
Very Rough	0.3 miles

5-Year Change





MINNESOTA VALLEY STATE TRAIL

B- Trend since 2018: STABLE

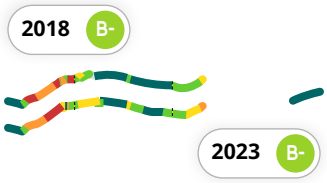
13.8 Miles

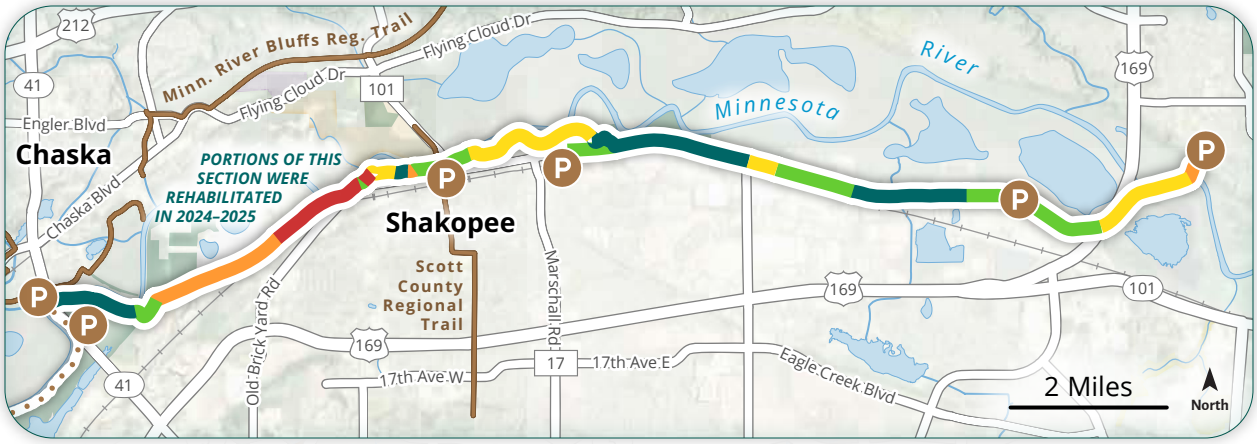
Constructed in 1985, 1998, 2010, 2012, 2014, 2016, 2020, 2021, & 2022 *
*Some segments have unknown construction dates

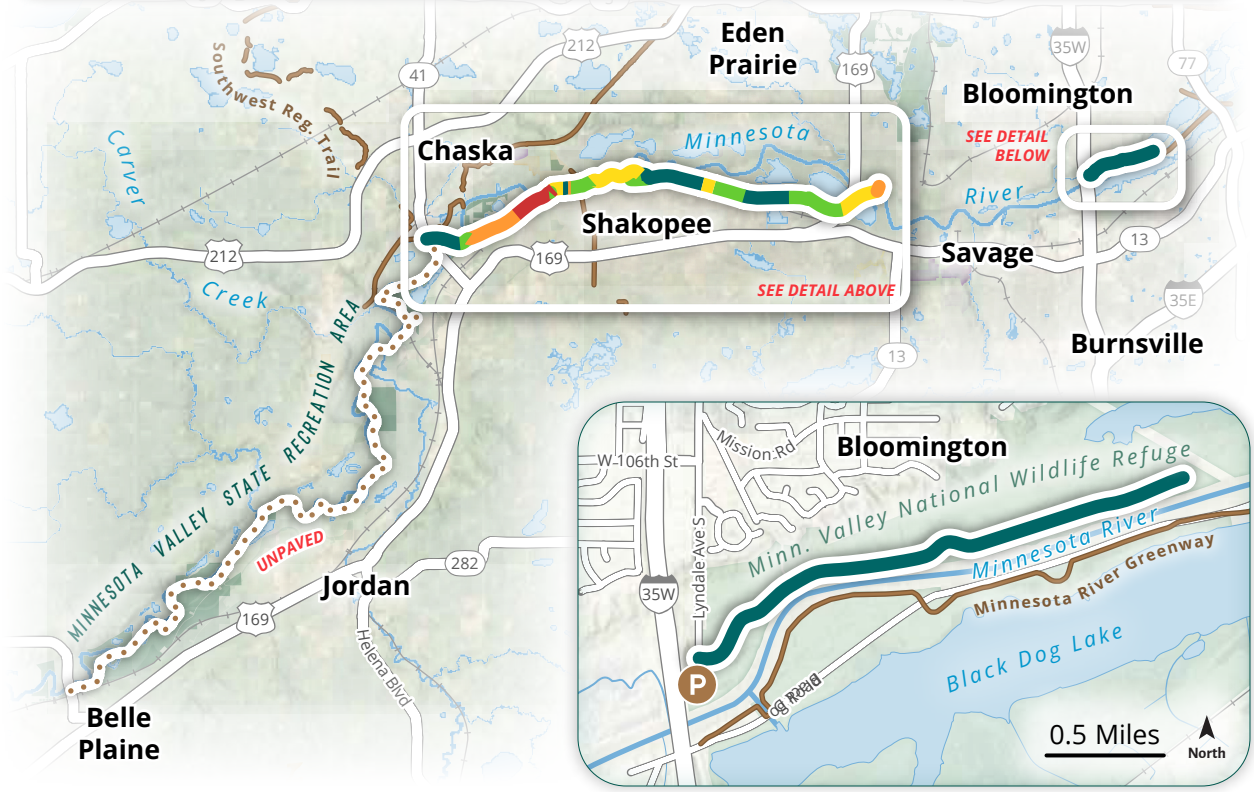
How smooth is the trail to ride?

Very Smooth	5.1 miles
Smooth	3.3 miles
Fair	2.8 miles
Rough	1.4 miles
Very Rough	1 miles

5-Year Change







MUNGER STATE TRAIL

C Trend since 2018: DECLINED

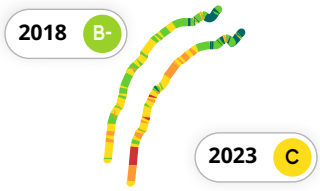
71.8 Miles

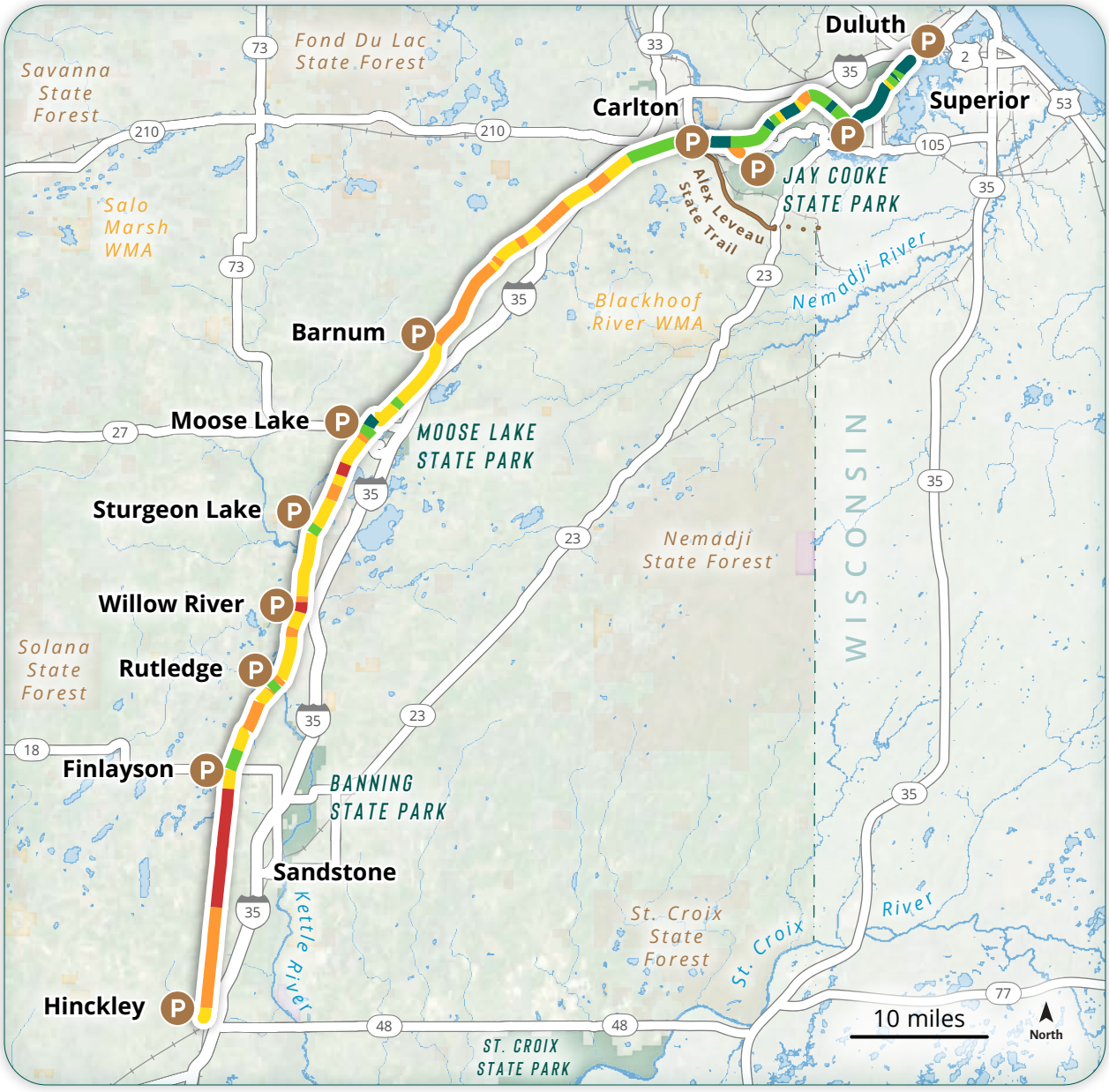
Constructed in 1988, 1994, 2000, 2013, 2018, & 2021 *
*Some segments have unknown construction dates

How smooth is the trail to ride?

Very Smooth	7.4 miles
Smooth	13.6 miles
Fair	24.5 miles
Rough	19.1 miles
Very Rough	7.2 miles

5-Year Change





PAUL BUNYAN STATE TRAIL

B Trend since 2018: DECLINED

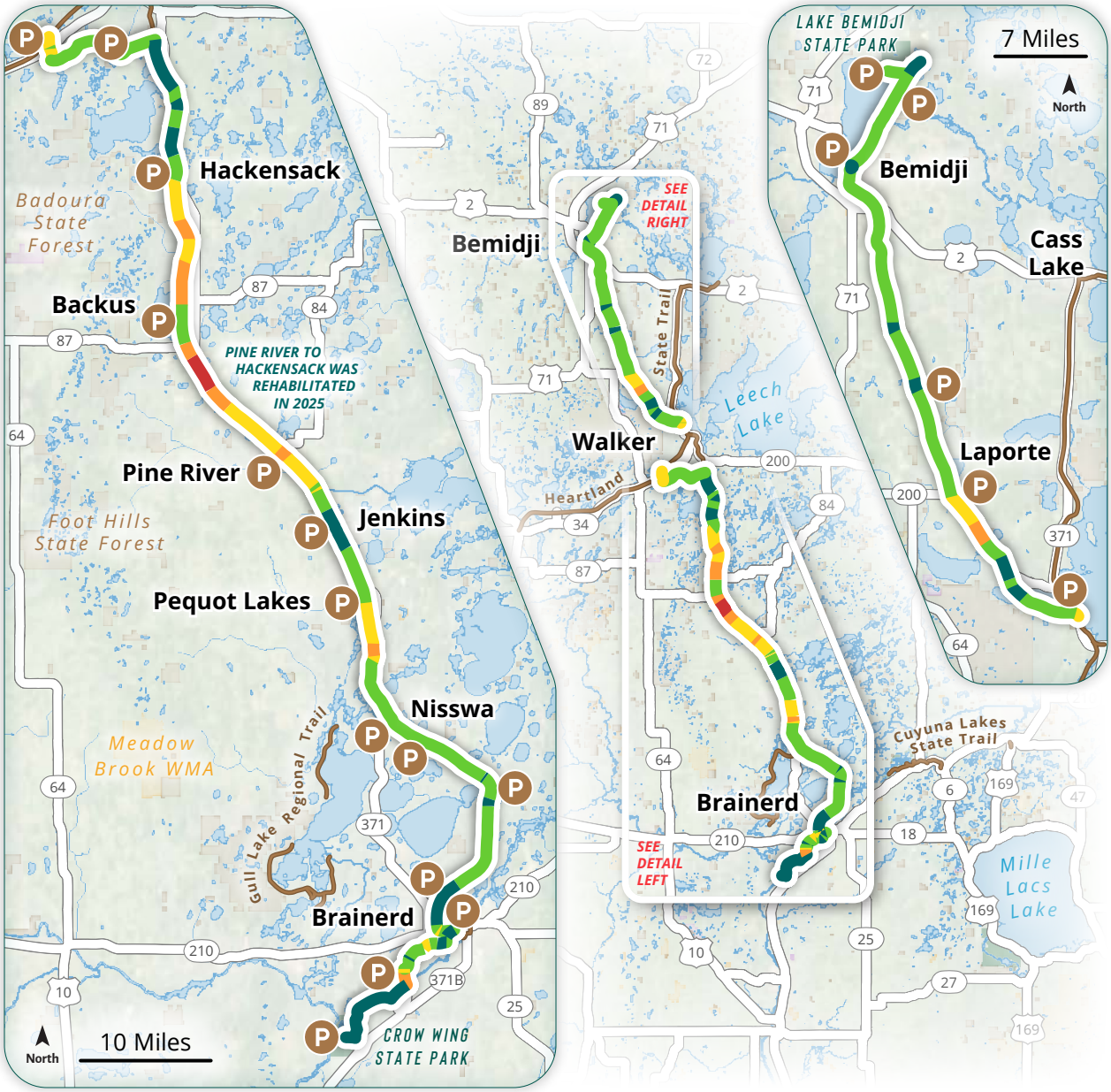
115.1 Miles

Constructed in 1997, 1999, 2003, 2008, 2010, 2011, 2013, 2014, 2021, & 2022

How smooth is the trail to ride?

Very Smooth	22.8 miles
Smooth	65.8 miles
Fair	15.8 miles
Rough	8.8 miles
Very Rough	1.9 miles

5-Year Change



PRESTON-FORESTVILLE STATE TRAIL

A- Trend since 2018: DECLINED

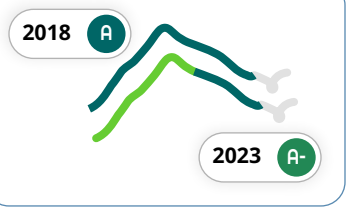
0.8 Miles

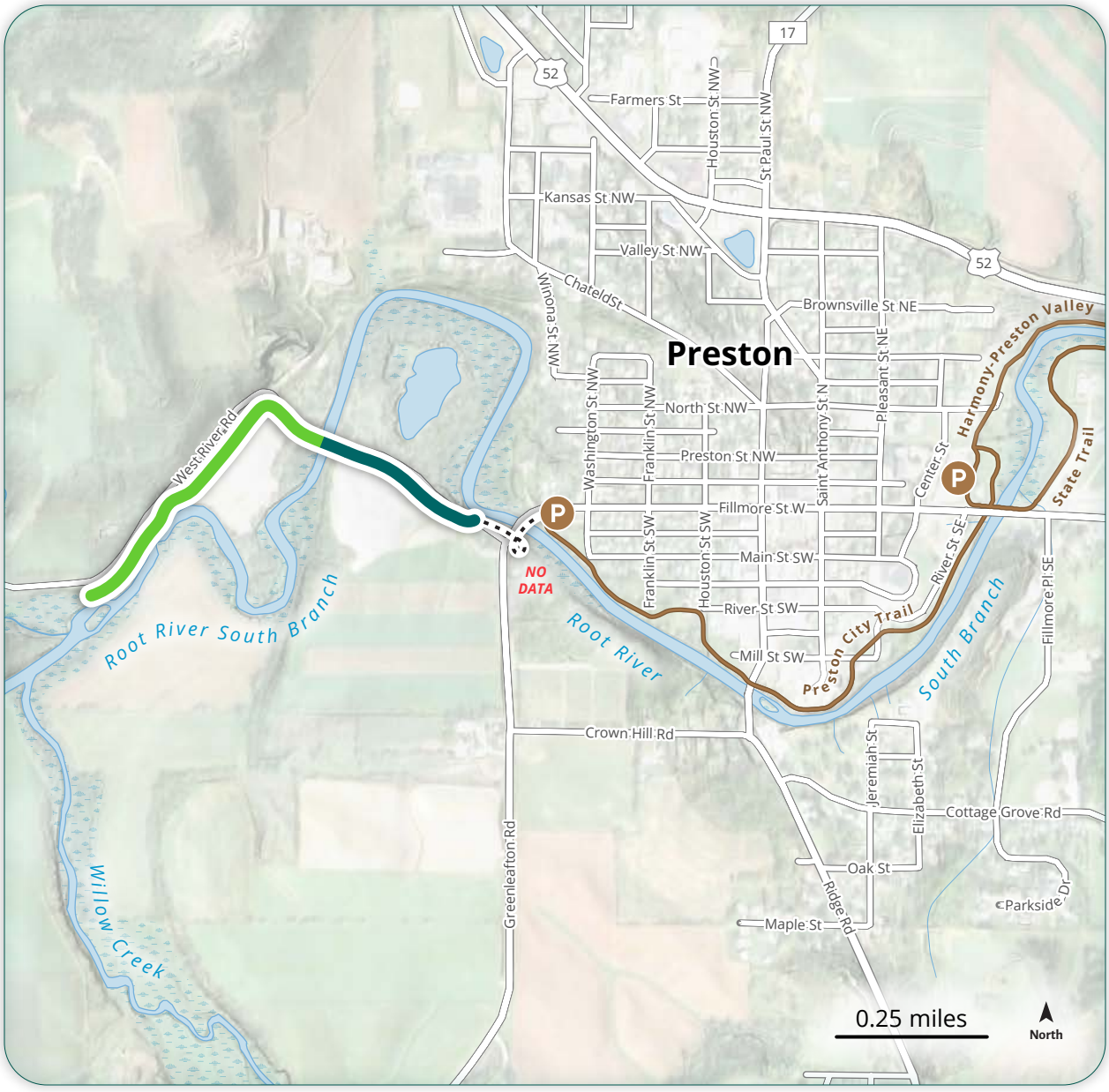
Constructed in 2010

How smooth is the trail to ride?

Very Smooth	0.2 miles
Smooth	0.4 miles
Fair	
Rough	
Very Rough	

5-Year Change





ROOT RIVER STATE TRAIL

B+ Trend since 2018: DECLINED

42.3 Miles

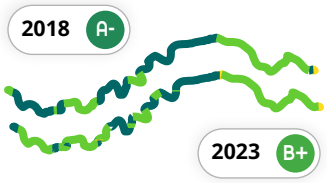
Constructed in 2010, 2012, 2015, & 2017 *

*Some segments have unknown construction dates

How smooth is the trail to ride?

Very Smooth	14.4 miles
Smooth	27.4 miles
Fair	0.5 miles
Rough	
Very Rough	

5-Year Change



SAKATAH SINGING HILLS STATE TRAIL

B+ Trend since 2018: IMPROVED

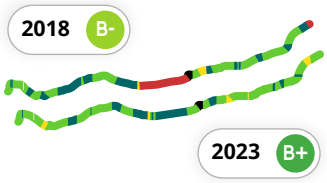
39.4 Miles

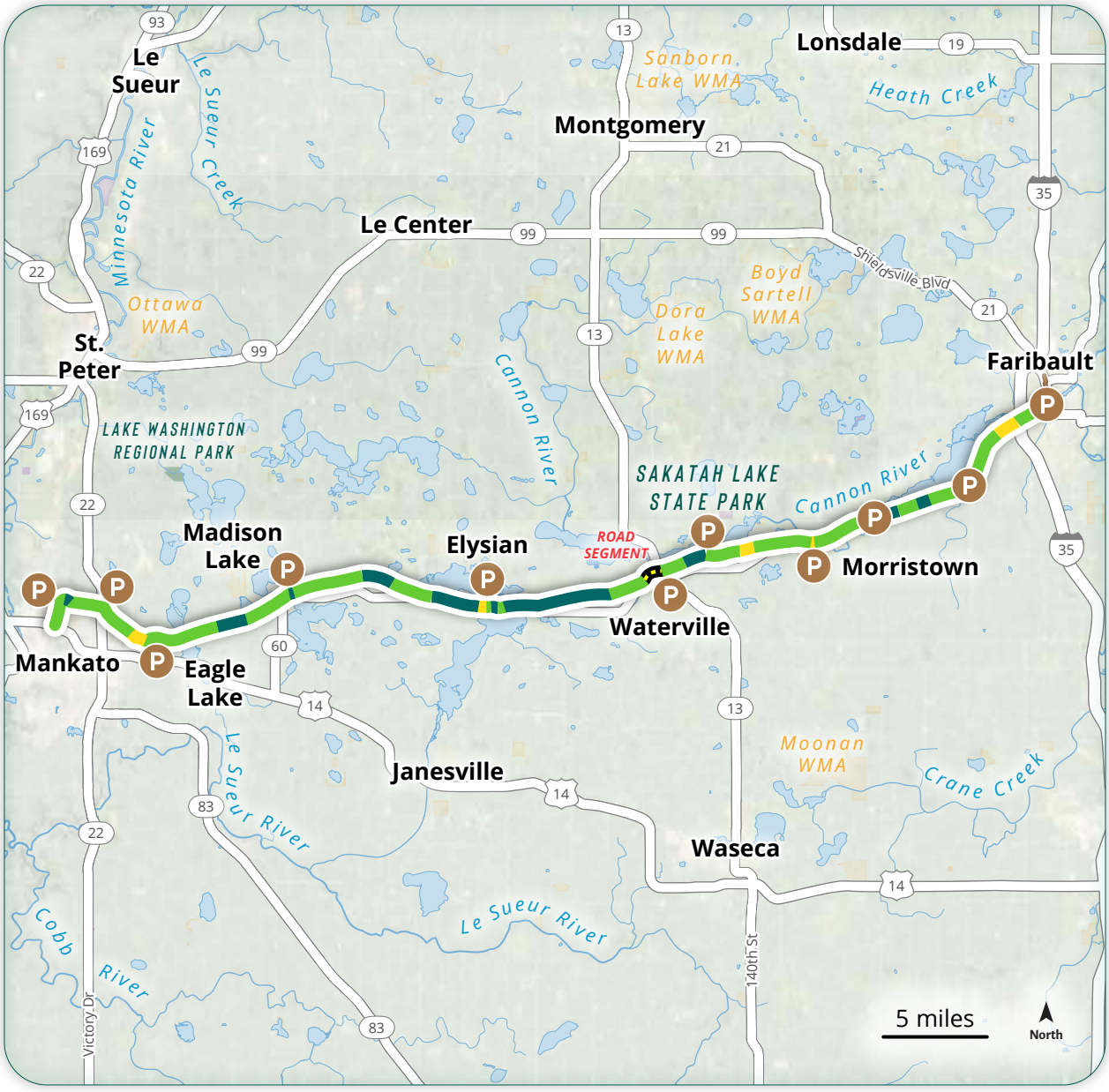
Constructed in 2009, 2012, 2015, 2018, 2020, & 2022

How smooth is the trail to ride?

Very Smooth	9.9 miles
Smooth	25.9 miles
Fair	2.5 miles
Rough	
Very Rough	

5-Year Change





SHOOTING STAR STATE TRAIL

B- Trend since 2018: DECLINED

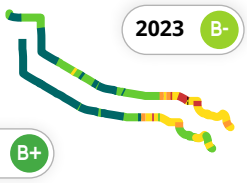
28.8 Miles

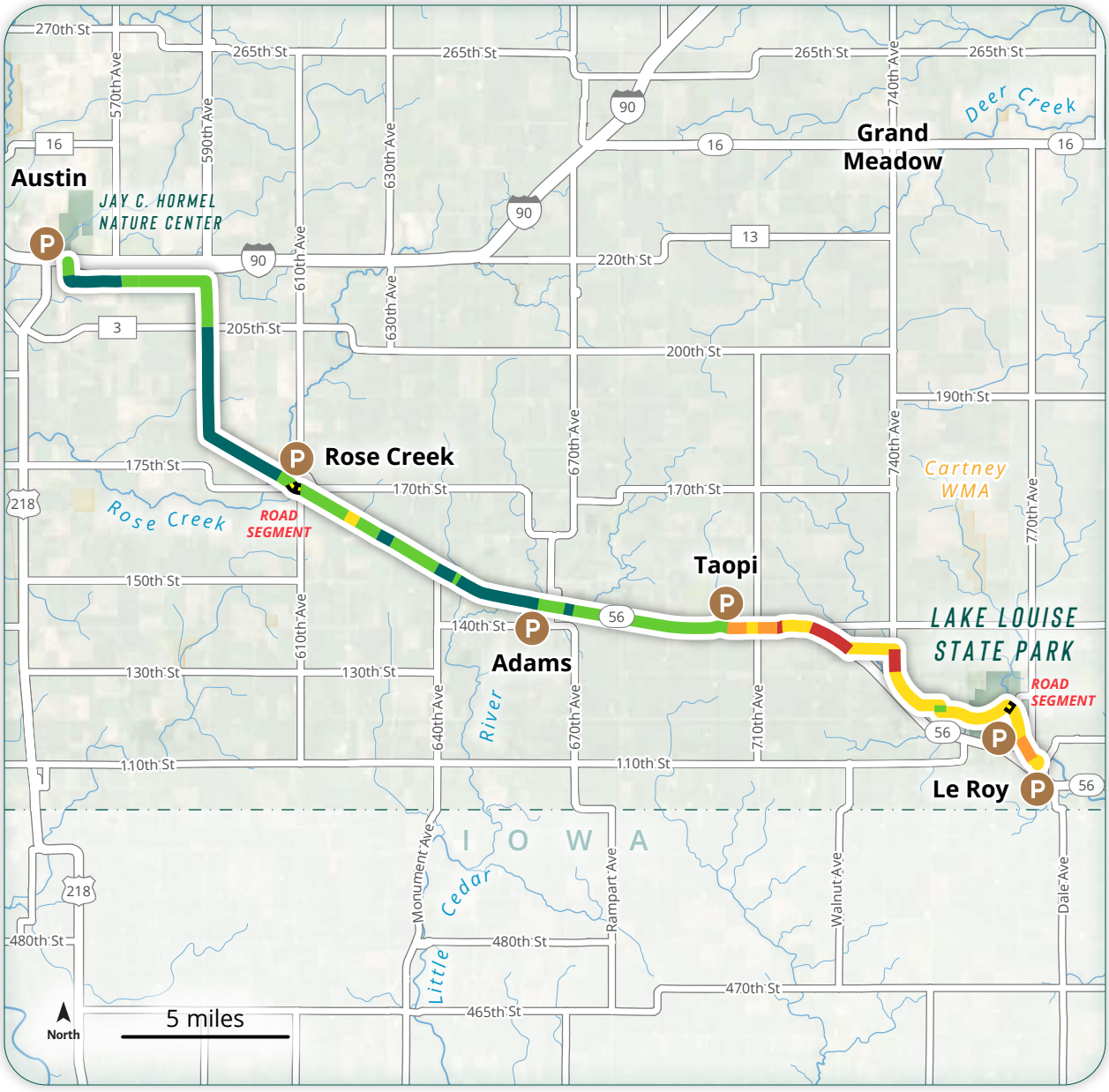
Constructed in 2005, 2008, 2011, 2015, 2017, & 2021

How smooth is the trail to ride?

Very Smooth	8.3 miles
Smooth	10.6 miles
Fair	6.4 miles
Rough	1.4 miles
Very Rough	1.6 miles

5-Year Change





METHODOLOGY

Our State of the Trails project uses a smartphone-based approach to measure trail smoothness through bicycle-mounted data collection. This method leverages the three-axis accelerometer sensors built into standard smartphones to record vibration data as the bicycle travels over trail surfaces. Our methodology was designed to produce an objective, replicable measure of how smooth or rough a trail feels to ride using widely available technology.

Trail roughness scores presented in this report are based on data collected with an iPhone mounted to the handlebars of P&TC's Research Bike (see Figure 1 on page 3). All data were collected by a trained intern following a consistent protocol to ensure comparability across trails and later processed and summarized to generate an overall Trail Roughness Index (TRI) and Ride Quality Rating for each trail segment. We also took pavement photos and trail videos during the data collection process to supplement our ratings and visualize on-the-ground conditions.

DATA COLLECTION

Our 2023 data was collected on 637 paved state trail miles between September 7, 2023, and November 4, 2023. A P&TC intern, riding the Research Bike, traversed each trail segment out-and-back to ensure our ratings reflect both directions of travel (Figure 18). During data collection, we aimed to ride each trail as naturally as possible (e.g., primarily riding in the right lane; yielding to, and passing other users as needed; and steering around easily avoidable pavement cracks and bumps as possible). This approach helps our ratings reflect a typical "everyday" trail experience as much as possible.

Bicycle speed was kept as consistent as possible throughout the process, with an average speed of 15.1 mph (*Mdn* = 15.3, *SD* = 2.68).

An iPhone SE was securely mounted to the handlebars of the Research Bike to record three-axis accelerometer data (x, y, z) while riding each trail. The smartphone's internal sensors continuously captured acceleration measurements at a consistent sampling rate of twice per second. Data were recorded using the SensorLog app

Figure 18

DATA COLLECTION

Chris Oines / P&TC

($2.99 on Apple's App Store). In total, we collected 597,622 accelerometer data points for analysis.

In addition to accelerometer data, a rear-mounted GoPro Hero 5 camera captured still photos every two seconds (approximately every 45 feet). A total of 77,740 photos were taken to help validate our ratings and provide visual documentation of on-the-ground trail conditions.

DATA PROCESSING AND ANALYSIS

To accurately measure the vibrations caused by trail roughness, the constant effect of gravity was removed from the raw acceleration data. This was accomplished by calculating the linear acceleration across all three axes (x, y, z), isolating only the vibration components relevant to trail surface conditions.[6]

A response-based methodology was then applied to quantify the whole-body vibration experienced by the cyclist. For every 0.01 miles traveled, the Root Mean Square (RMS) of acceleration was calculated using the following equation: [7]

$$RMS = \sqrt{(1/n)\sum\left(x_i^2 + y_i^2 + z_i^2\right)}$$

Where:

- *RMS* is the Root Mean Square of acceleration,
- *n* is the total number of acceleration values in the segment, and
- x_i, y_i, and z_i are individual acceleration values along each axis.

To calibrate our roughness measure, we collected test data on six test pavement segments using both the Research Bike and a walking profiler. A walking profiler is a portable device widely used in pavement management to measure vertical displacements caused by surface irregularities (Figure 19). These measurements are processed to calculate the International Roughness Index (IRI), a globally standardized metric that quantifies surface smoothness, correlates

Figure 19

WALKING PROFILER

Data from a walking profiler was used to calibrate our trail roughness data

Photo courtesy of the Institute of Transportation at Iowa State University

6 Alatoom et al. (2024), " A Sequence-Based Hybrid Ensemble Approach for Estimating Trail Pavement Roughness Using Smartphone and Bicycle Data," *Infrastructures*.

7 International Organization for Standardization. (1997). *ISO 2631-1: Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements* (2nd ed.).

strongly with perceived ride quality, and serves as an industry benchmark for pavement roughness.

Calibration proceeded in two steps. First, because vibration intensity is influenced by cycling speed, RMS values were normalized to account for speed variability. Each 0.01-mile trail segment's RMS was adjusted using the equation: [6-8]

$$RMS_{normalized} = RMS \times V^{a}$$

Where:

- V is the bicycle speed, and
- a is a coefficient estimated through optimization methods to minimize the Mean Square Error between the reference IRI values and the RMS measurements.

Second, a regression analysis was performed between the normalized RMS values from the smartphone-based bike system and the reference IRI values from the walking profiler. The regression provided a calibration model, defining the mathematical relationship between the smartphone-derived vibration data and standardized IRI measurements (R^2 = 0.866, F = 26.06, p = 0.007). The high R^2 value indicates that the model explains about 87% of the variation in the reference IRI, while the large F-statistic and low p-value confirm that this relationship is statistically significant. Overall, the results demonstrate that the smartphone-based system provides a strong and reliable estimate of trail roughness using a cost-effective alternative to specialized profiling equipment.

All data processing and calibration was completed by research scientists at the Institute for Transportation at Iowa State University.

DATA AGGREGATION AND CLASSIFICATION

Following normalization and calibration, RMS values from each 0.01-mile interval were aggregated by trail segment. The TRI for each segment represents the average of all normalized, calibrated RMS values within that segment. Because the focus of TRI is trail pavement roughness, data collected from wood-decked bridges and road intersections was removed prior to calculating TRI scores.

Trail segments were delineated in three phases. First, initial start and end points were defined using every road junction, trail junction, trailhead, bridge, tunnel, railroad crossing, underpass, water crossing, and known construction point. Second, segments longer than two miles were reviewed manually and, when possible, divided at logical wayfinding locations such as restaurants, private drives, 90-degree turns, public water accesses, or jurisdictional boundaries. Finally, segments shorter than 0.1 mile were merged with the shortest adjoining segment, unless construction dates were known to differ. This process resulted in 1,020 paved, off-road shared use trail segments ranging in length from

8 Ahlin & Granlund (2002), "Relating road roughness and vehicle speeds to human whole body vibration and exposure limits," *International Journal of Pavement Engineering*.

9 Sun et al. (2001), "Modeling indirect statistics of surface roughness," *Journal of Transportation Engineering*.

10 Múčka (2017), "International roughness index specifications around the world," *Road Materials and Pavement Design*.

0.03 miles to 3.8 miles (*M* = 0.62, *Mdn* = 0.48, *SD* = 0.49).

TRI scores were then converted to Ride Quality Ratings using a scale developed internally by P&TC staff. TRI scores were compared across segments with known ride qualities, analyzed alongside photos and video captured during data collection, and cross-referenced with ratings from prior State of the Trails reports. Through this iterative process, threshold TRI values of 270, 320, 370, and 420 were established to delineate very smooth, smooth, fair, rough, and very rough trails.

COMPARISON TO 2018 DATA

The TRI methodology used in this report is different than the one used in our 2019 *State of the Trails Report* and uses a completely different scale. TRI scores from the two reports are not comparable to one another. To enable meaningful trend analysis, we reprocessed data from 2018 using the updated 2023 methodology and revised trail segmentation. As a result, some 2018 findings based on the new methodology differ slightly from those published in 2019, though the overall patterns and conclusions remain consistent. We recognize this may cause some confusion, but updating the 2018 analysis was essential to ensure accurate, consistent, and comparable results over time. We remain proud of our original 2019 analysis but are confident that the updated methodology provides a more robust and precise measure of trail roughness.

FUTURE TRAIL PROJECTIONS

To forecast how trail riding conditions are likely to change over time, we used Monte Carlo simulations to model changes in TRI scores across Minnesota's paved state trail system. Three related simulations were conducted: one to estimate TRI of a hypothetical trail over a 40-year period, one to estimate the remaining service life of each segment, and one to evaluate alternative rehabilitation scenarios. Each simulation began with the segment's current TRI value and applied random annual changes drawn from a normal distribution defined by the observed mean and standard deviation of observed TRI changes between 2018 and 2023. This approach captures both the average deterioration trend and the natural variability in trail aging. For each simulation, 10,000 iterations were run, generating a probabilistic distribution of future TRI outcomes. The resulting forecasts provide insight into expected trail conditions, uncertainty ranges, and the likely timing of maintenance or resurfacing needs under different management strategies.

LIMITATIONS

The TRI measures the smoothness of the path taken by the bicycle, and as such may underestimate the roughness of trails where bumps or cracks are easily avoided (for example, those along pavement edges or longitudinal seams). Conversely, the TRI may overestimate trail roughness where debris is present due to factors such as seasonality, storm activity, or infrequent sweeping.

TRI scores summarize the roughness experienced by the Research Bike as it traveled each trail segment out and back. In most cases, this provides a reliable representation of ride quality, though it cannot fully capture every nuance of a trail's surface. TRI is also subject to sources of measurement error — such as random vibrations from the bicycle frame, pedaling motion, or rider movement

— as well as calibration uncertainty. To help quantify this uncertainty, our online interactive map includes 95% confidence intervals for each trail segment's TRI. Across all 1,020 segments, the average margin of error was ±17.1 points. Overall, we are confident that each estimate falls within one rating category, providing a dependable basis for classification.

It is also important to note that the TRI represents an average roughness for an entire trail segment. Within any given segment, conditions may vary considerably: smooth pavement in one stretch, rough in another. This is especially true for longer segments, where the likelihood of variation is greater.

Finally, while the TRI is an objective measure of surface vibration, translating TRI scores into Ride Quality Ratings involves more subjectivity and interpretation. Perceptions of "smooth" or "rough" depend on factors such as bicycle type, riding experience, and personal comfort thresholds. To support transparency, all 143,000 trail photos collected since 2018 are available through our online interactive map, allowing users to explore the data and form their own assessments. Although we believe our TRI thresholds accurately represent the experience of most users, we recognize that our internally derived scale would benefit from broader testing and refinement.

Despite these limitations, the TRI provides an objective, replicable, and cost-effective measure of trail smoothness that centers on the user experience and is supported by photographic evidence. Our TRI scores provide an additional, data-driven perspective to Minnesota's paved state trails, and are only intended to complement visual inspections and maintenance assessments conducted by trained professionals.

REFERENCES

Ahlin, K., & Granlund, N. O. J. (2002). Relating Road Roughness and Vehicle Speeds to Human Whole Body Vibration and Exposure Limits. *International Journal of Pavement Engineering*, 3(4), 207–216. https://doi.org/10.1080/10298430210001701

Alatoom, Y. I., Zihan, Z. U., Nlenanya, I., Al-Hamdan, A. B., & Smadi, O. (2024). A Sequence-Based Hybrid Ensemble Approach for Estimating Trail Pavement Roughness Using Smartphone and Bicycle Data. *Infrastructures*, 9(10), 179. https://doi.org/10.3390/infrastructures9100179

International Organization for Standardization. (1997). *ISO 2631-1: Mechanical vibration and shock—Evaluation of human exposure to whole-body vibration—Part 1: General requirements* (2nd ed.). International Organization for Standardization. https://www.iso.org/obp/ui/es/#iso:std:iso:2631:-1:ed-2:v2:en

Minnesota DNR. (2025). *10-Year Capital Asset Need: Taking care of what we have*. Minnesota Department of Natural Resources. https://files.dnr.state.mn.us/aboutdnr/legislativeinfo/10yr-capital-asset-need.pdf

Múčka, P. (2017). International Roughness Index specifications around the world. *Road Materials and Pavement Design*, 18(4), 929–965. https://doi.org/10.1080/14680629.2016.1197144

Robinson, M., Wascalus, J., & Gozali-Lee, E. (2020). *2019 Minnesota State Trail Visitor Study*. Minnesota Department of Natural Resources. https://files.dnr.state.mn.us/aboutdnr/reports/recreation/dnr_state_trail_visitor_study_2019_final_report.pdf

Sun, L., Zhang, Z., & Ruth, J. (2001). Modeling Indirect Statistics of Surface Roughness. *Journal of Transportation Engineering*, 127(2), 105–111. https://doi.org/10.1061/(ASCE)0733-947X(2001)127:2(105)

LINKS TO OTHER DATA BIKE PROJECTS:

Des Moines Area Metropolitan Planning Organization • Iowa Data Bike

MassTrails • Data Bike

Arvada, CO • Data Bike

Rockford, IL • State of the Trails Report

Community Planning Association of Southwest Idaho • COMPASS Data Bike

National Park Service • Trailblazer

Trekview • Trail Quality Index

ABOUT THE AUTHORS

Andrew Oftedal is the Research and Policy Manager at Parks & Trails Council, where he leads research on the issues, trends, and attitudes shaping Minnesota's parks and trails. He has more than 10 years of experience conducting research on parks, trails, and tourism in Minnesota and has authored more than 30 technical reports and peer-reviewed articles. His work focuses on visitor experience, trail use monitoring, outdoor recreation policy and the State of the Trails project. He holds a master's degree in Natural Resources Science and Management from the University of Minnesota.

Dr. Inya Nlenanya is a Senior Research Scientist at the Institute for Transportation (InTrans) at Iowa State University, where he manages the Iowa Pavement Management Program and leads research in infrastructure asset management. His recent projects include research for the Minnesota Department of Transportation (MnDOT) on the deterioration and lifecycle management of pedestrian assets, and for the Des Moines Area Metropolitan Planning Organization (MPO) on the development of a regional trail management program.

Yazan Alatoom is a Predoctoral Research Associate at Iowa State University's Institute for Transportation (InTrans). His research focuses on developing low-cost sensing systems and AI-driven frameworks for pavement evaluation and transportation asset management. His expertise includes computer vision, data analytics, and intelligent sensing technologies aimed at advancing affordable and practical infrastructure monitoring solutions.

Dr. Zia Zihan is a Postdoctoral Research Associate at Iowa State University's Institute for Transportation. His research focuses on leveraging remote sensing data and AI-driven analysis for transportation infrastructure monitoring and management. His expertise spans pavement condition assessment, UAV photogrammetry, LiDAR, computer vision, and geospatial data analytics to support proactive asset management strategies.

Dr. Abdallah Al-Hamdan is a Doctoral Researcher at Iowa State University's Institute for Transportation. His research focuses on advancing data-driven and AI-enabled solutions for transportation asset management, integrating geospatial analytics, statistical modeling, and intelligent infrastructure systems. His expertise includes pavement, pedestrian, and ancillary asset management; asset performance modeling; and the development of GIS-based asset management systems to support data-informed decision-making for transportation agencies.

STATEMENT OF VALUES

Parks & Trails Council's research program exists to collect, analyze, and communicate data on Minnesota's parks and trails in order to improve visitor experiences, inform policy discussions, and support data-driven decision-making. Our research complements the work of our public partners and together brings clarity and confidence to our public policy advocacy. We are nonprofit and nonpartisan, and strive to be an independent, honest and forthright voice for parks and trails at the State Capitol where critical decisions are made.

Parks & Trails Council values:

- Openness and inclusivity in our organization, programs and advocacy.
- Sustainable, long-term statewide land stewardship and conservation.
- Outdoor recreation for all Minnesotans for its educational, health and community benefits.
- Collaboration and volunteerism.
- Service as an independent, honest and forthright voice for parks and trails.
- Decisions informed by the best available science and data.

PARKS & TRAILS
COUNCIL OF MINNESOTA

275 East 4th Street, Suite #250
St. Paul, MN 55101
651.726.2457
parksandtrails.org