

# Trail Condition Monitoring Report

2019-2023 Survey



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City of Boulder Open Space and Mountain Parks  
August 2024

## Suggested Citation:

Engelman, J. 2019-2023 Designated Trail Monitoring Report. The City of Boulder, Department of Open Space and Mountain Parks. Boulder, Colorado.

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## Acknowledgments

This report is the collective work of many OSMP staff over many years. We'd like to thank Jake Engelman for project management, leading data collection, analysis, and report writing; Jeff Haley for project sponsorship; Frances Boulding, Hilary Dees, and Adam Gaylord for project oversight; and numerous other internal contributors and reviewers. We'd also like to thank all the staff and volunteers who take care of our trails.

Individually, and collectively, we thank you.

# Executive Summary

This report presents findings from the City of Boulder’s Open Space and Mountain Parks (OSMP) condition monitoring of over 150 miles of designated trails, emphasizing sustainable management amid high levels of visitation. Conducted from 2019-2023, the five-year monitoring cycle assessed infrastructure and identified trends as outlined in the 2005 Visitor Master Plan (VMP). This report summarizes data collection methodologies, condition metrics, and recommendations for future management based on trail classifications and observed conditions.

## Key Context

- **Visitor Use Management:** OSMP’s charter purposes include providing passive recreation opportunities as well as preserving and protecting natural resources. This is accomplished by building and maintaining trail infrastructure to support the estimated 6 million annual visits (Leslie, 2024) across the OSMP system while protecting other, more sensitive habitats.
- **Trail Condition Monitoring:** Conducted every five years, the 2019-2023 survey is the fourth round of monitoring called for by the Visitor Master Plan to assess infrastructure and trail conditions for informing trail design and maintenance priorities.
- **Trail Management Objectives (TMOs):** TMOs classify trails by type, class, and intended use (e.g., hiking, biking, accessible) and guide management practices. Monitoring compares actual conditions with TMO standards, generating a Trail Condition Index (TCI), where a higher score indicates better conditions.
- **Data Collection Tools:** OSMP utilized the High-Efficiency Trail Assessment Process (HETAP) and GPS technology to gather comprehensive condition data at 59,628 stations across 157 miles of trail.

## Important Takeaways

- **Condition Index Results:** The overall average TCI for OSMP designated trails rose from 56.8 (2015-17) to 58.9, with 39% of trails in a routine maintenance state, 44% needing preventative repair, and 16% requiring critical repairs.
  - **Routine maintenance** indicates the trail meets assigned standards and has functioning infrastructure.
  - **Preventative repair** indicates the trail does not meet assigned standards but is within a reasonable threshold to meet the standard.
  - **Critical repair** indicates that the trail does not meet assigned standards, that infrastructure is in a state of disrepair, that severe problem features are present, or a combination of those factors.
- **Infrastructure Overview:** OSMP surveyed a total of 15,900 structures (e.g., steps, retaining walls, and drainage features), with over 81% of structures falling in the routine maintenance category. The total number of managed structures has increased significantly, and the percentage of structures in a routine maintenance phase has increased since the first survey in 2007.
- **Soil Loss and Braiding Issues:** The survey found soil loss across 54.4 miles (35%) of the trails and an upward trend in trail braiding.
- **Trail Design:** Steep trail grades were commonly associated with failing infrastructure and the presence of issues such as erosion, affirming the importance of sustainable trail grades in trail design.

- **Recent Work:** Trail work projects completed by staff and volunteers have resulted in considerable improvements in trail conditions; however, in other areas, aging infrastructure has continued to deteriorate. Recently designed trails had significantly higher condition index scores. Repair work on legacy trails such as Mt. Sanitas trail and the 1<sup>st</sup>/2<sup>nd</sup> Flatirons trail also improved condition index scores considerably.
- **Cost Estimates:** Systemwide deferred maintenance, and total replacement costs decreased slightly between surveys, despite an additional 4 miles of trail being built between surveys.
- **Applications for Future Management:** Continued focus on building and repairing trails to sustainable standards is paramount to improving current and future conditions especially since trail grade appears to be the most determinant design factor for trail condition over time. Where reroutes of trails are not feasible and grades cannot be lowered on existing trails, preventative maintenance and installation of structures can be effective at mitigating development of problem features. However, trails with more structures require more time, effort, and cost to maintain.

## Background

The City of Boulder’s Open Space and Mountain Parks (OSMP) manages over 150 miles of designated trails with an estimated 6 million visits annually (Leslie, 2024). Achieving conservation objectives on OSMP-managed lands requires the ability to sustain visitation while avoiding or minimizing adverse impacts on natural, cultural, and scenic resources. Designated trails play a crucial role in protecting resources and creating opportunities for passive recreation (Marion et al., 2018).

To assess the condition of the designated trail system and associated infrastructure, OSMP staff conducts monitoring surveys on five-year cycles. The goals of trail condition monitoring are to:

- Inventory existing infrastructure and current conditions.
- Provide trail access information (trail nutrition labels) for visitors.
- Evaluate change over time to assess the effectiveness of trail management and design.
- Prioritize and fund future work.

## Plan Guidance and Past Trail Condition Monitoring

The 2005 Visitor Master Plan (VMP) outlines strategies to assess and manage designated trails. A goal stated in the VMP is to construct and maintain trails to sustainable standards, resulting in a designated trail system that provides a high-quality visitor experience while protecting and preserving physical and environmental resources (OSMP 2005: 40). The VMP also proposes that the condition of designated trails is monitored annually to assess the compliance of our trail system with trail sustainability standards (OSMP 2005:61). The VMP established standards for several key community initiatives and services that support and enhance the experiences of visitors and protect the natural values of the Open Space and Mountain Parks lands. Trail condition monitoring projects over the last 20 years have specifically evaluated monitoring measures in the VMP’s Trails and Facilities initiative:

Monitoring Measure	Frequency and Timing of Monitoring	Current Status	Proposed Standard
<u>Maintenance Condition: Trails</u> An aggregate measure which includes: grade, clearance, % change in width, compaction, erosion, undesignated trails, and braiding.	Annual On-going	Vary by trail segment	Trails kept in acceptable condition by regularly scheduled maintenance

Figure 1: VMP trail condition monitoring direction with frequency and proposed standards

OSMP conducted the first complete round of designated trail condition monitoring in 2007-2008. In 2012-2013, a second round of trail condition monitoring was conducted for the north, south, and east trail study areas. The West Trail Study Area (WTSA) was not assessed because of time limitations and intensive changes from trail reroutes guided by the WTSA implementation.

The 2007 and 2012 trail condition monitoring used problem assessment methodology to record data on the linear extent of predetermined condition indicators. This approach is helpful to characterize the frequency and extent of trail impact problems when infrequent, as well as document locations to guide maintenance. However, this approach is hard to use for characterizing average tread conditions, has low precision, and did not allow for integrating updates to trail standards. For these reasons, monitoring protocols were updated for the 2015-2017 survey to use an inventory assessment approach based on the U.S. Forest Service Trail Inventory and Condition Assessment (TRACS) methodology. This approach records census information based on accuracy tolerances. Inventory assessments provide accurate, precise, and versatile data but are often more time intensive.

This report focuses on the most recent 2019-2023 survey of system-wide trail condition monitoring, the fourth round of monitoring since the adoption of the VMP. This report also summarizes trail condition trends from previous surveys.

This work is also in support of the OSMP Master Plan strategy for Responsible Recreation, Stewardship, and Enjoyment (RRSE) tier 1 strategy of reducing the trail maintenance backlog by using a prioritized, life-cycle approach to improve the condition of OSMP’s diverse portfolio of historic and modern trails.

### Trail Management Objectives (TMOs)

To assess trail condition, it is essential to know a trail’s designed or ideal condition. OSMP manages 18 types of trails with unique design standards to allow for a diverse range of recreation opportunities. OSMP design standards are determined by Trail Management Objectives (TMOs). TMOs document the management intention for the trail and provide essential reference information for subsequent trail management, design and construction, maintenance, condition assessment, prescriptions, and reporting. TMOs are the fundamental building blocks for trail management. OSMP utilizes TMOs adapted from the U.S. Forest Service Trail Fundamentals and Trail Management Objectives Framework. Effectively managing a trail and determining what is necessary to meet standards first requires answering the following questions:

- What is the purpose of the trail (Desired Experiences, Resource Protection)?
- What is the intended level of development of the trail (Trail Class)?
- What is the intended type or types of uses for the trail (Managed Uses)?

The TMO framework defined below provides an integrated means to consistently record and communicate the intended design and management guidelines for trail design, construction, maintenance, and use (Appendices B-F):

**Trail Type** is the predominant trail surface and general mode of travel accommodated by a trail. OSMP primarily manages standard terra trails. Other trail types are snow or water.

**Trail Class** is a trail's prescribed scale of development, representing its intended design and management standards. There is five Trail Classes:

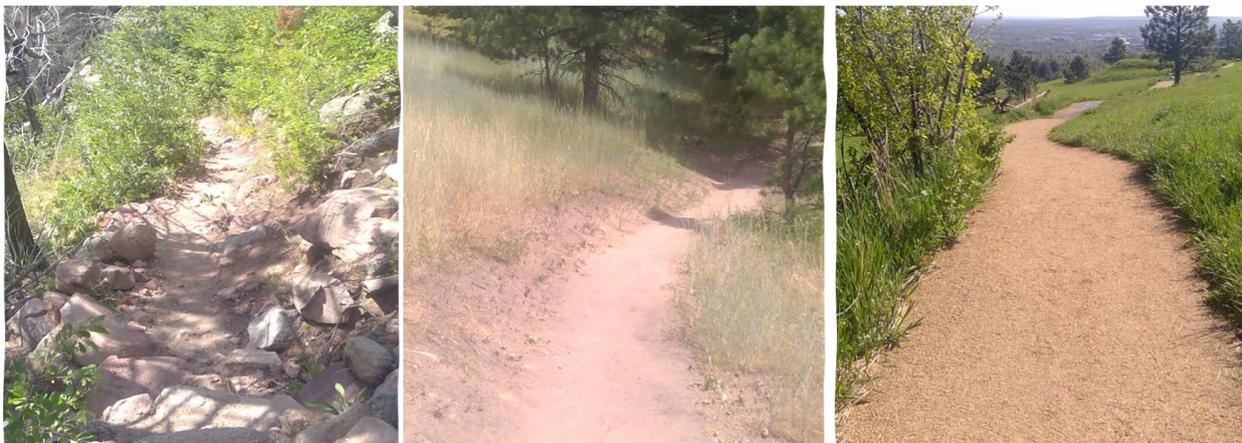
- Trail Class 1—Minimally Developed
- Trail Class 2—Moderately Developed
- Trail Class 3—Developed
- Trail Class 4—Highly Developed
- Trail Class 5—Fully Developed

**Managed Use** is a mode of travel that is actively managed and appropriate on a trail based on its design and management. There can be more than one managed use per trail or trail segment. Managed uses can be a subset of all the allowed uses on the trail. OSMP managed uses include hiking, biking, equestrian, authorized motor vehicle, and accessible.

**Designed Use** is the single managed use of a trail that requires the most demanding design, construction, and maintenance parameters and that, in conjunction with the applicable trail class, determines which design parameters will apply to a trail (Appendices B-F).

**Design Parameters** are technical guidelines for the survey, design, construction, maintenance, and assessment of a trail based on its designed use and trail class. Design parameters reflect the design objectives for OSMP trails and determine the dominant physical criteria that most define their geometric shape. These criteria include tread width, surface, grade, outslope, clearing, and turn radius.

Below are examples of three classes of trails with a hiking designed use from least (left) to most developed (right).



Class 2 Hiking

Class 3 Hiking

Class 5 Hiking

Figure 2: Examples of Hiking trail designed use classes

# Methods

## Data Collection

This report focuses on the most recent 2019-2023 system-wide trail condition monitoring survey. This report also summarizes trail condition trends from previous surveys. The most recent two rounds of systemwide monitoring, starting in 2015 through 2023, used an inventory assessment approach based on the U.S. Forest Service Trail Inventory and Condition Assessment (TRACS) methodology, which is described in more detail below. The first two monitoring rounds, starting in 2007 through 2013, used a problem assessment methodology. A comparison of results over time across methodologies is possible, with some limitations.

Additionally, before 2019, both designated and undesignated trail monitoring were conducted as two-year projects intended to alternate and be repeated every 5 years. In 2019, the monitoring rhythm was updated to survey a fifth of OSMP lands for both designated and undesignated trails each year while still on 5-year cycles. This change allows staff to better apply monitoring results to management decisions.

## Equipment

Data Collection was conducted using the High-Efficiency Trail Assessment Process (HETAP) software produced by Beneficial Designs. The HETAP software uses a Wheeled Instrument Sensor Package (WISP). The WISP is comprised of a measuring wheel with an attached sensor box, mounted computer, and camera.

Trail alignments are collected utilizing an EOS Arrow 100 GPS unit connected to a Microsoft Surface laptop by Bluetooth. Alignments are collected as points using ArcMap. Those points are then turned into lines utilizing a data analysis tool created using the ArcPy Python site package.

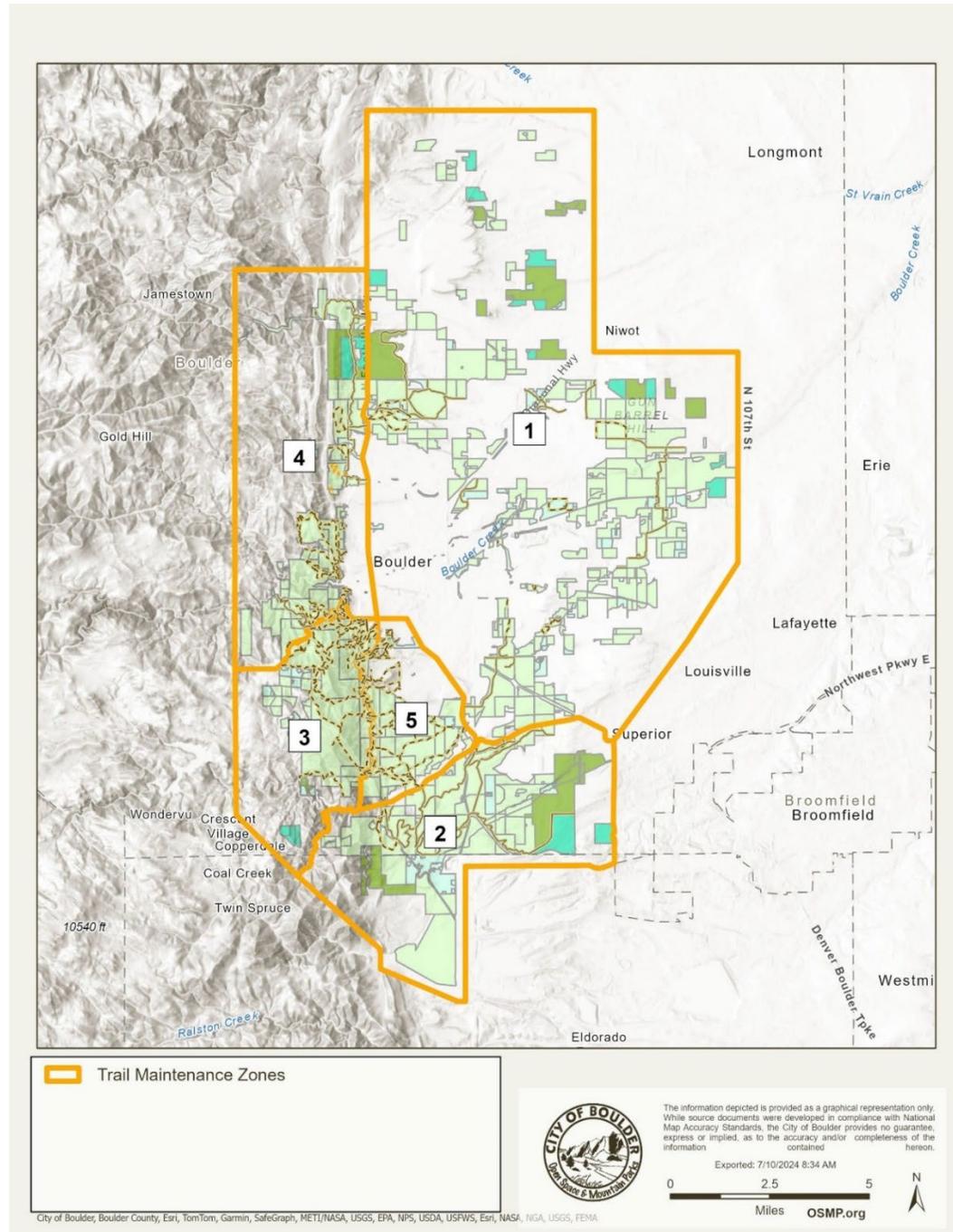


Figure 3: Photos of an example of what data collection looks like as well as the equipment used in collection

## Study Area

Monitoring was conducted on OSMP-managed designated trails. The study area consists of nearly 160 miles of trails ranging in character from steep, remote, and rugged to wide, surfaced roads designed for authorized vehicle access. Some Class 1 trails, which are primarily low use climbing access, were not surveyed. The study area was broken into five sub-areas that OSMP manages as separate trail maintenance zones (Figure 4). Each zone has approximately 30 miles of trail.

Figure 4: Trail maintenance zones used by OSMP



## High Efficiency Trail Assessment Process (HETAP)

Trails were broken up into trail segments with beginning and ends defined by junctions with other trails (Figure 5). Data is collected as stations of trail segments. Each station is defined by the distance along a trail segment where measured indicators are consistent. A new station is recorded whenever measured indicators change (Figure 5). Station data includes measurements of Grade, Outslope, Width, Surface Type, and Surface Firmness, as well as a photo of the trail.

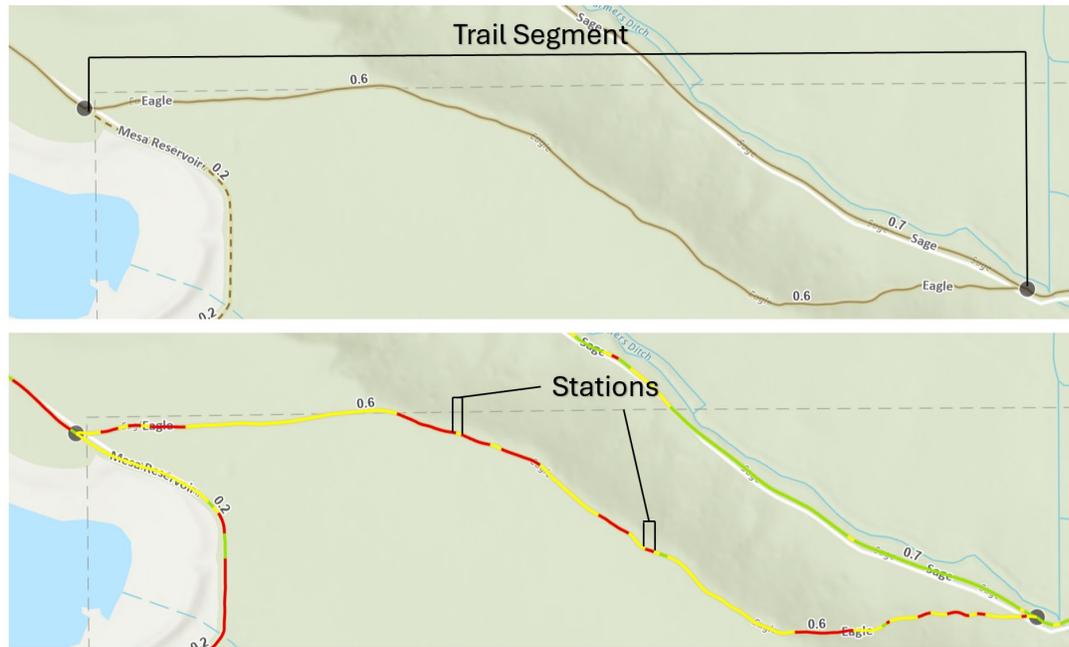


Figure 5: An example of a trail segment (defined by trail junctions) and stations along that segment (defined by changes in measured indicators).

The HETAP software is also used to record structure features (built infrastructure, such as staircases and cattleguards) and problem features (such as soil loss, braiding, and obstructions). These features are recorded as points or lines in addition to being recorded by the distance along the trail that they start at, measured from the closest junction. Line features have a start and end distance, while point features only have a start distance. 28 types of structure features and 6 types of problem features are recorded. Most features have associated conditions that are recorded along with a photo at the time of the survey (Tables 1 & 2).

Structure Features (Built Infrastructure)	Possible Condition States
Backwall - Stone	Routine Maintenance, Repair
Backwall - Wood	Routine Maintenance, Repair
Boardwalk	Routine Maintenance, Repair
Causeway - Stone	Routine Maintenance, Repair
Causeway - Wood	Routine Maintenance, Repair
Check Step - Stone	Routine Maintenance, Repair
Check Step - Wood	Routine Maintenance, Repair
Ditch - Bar	Routine Maintenance, Repair
Ditch - Side	Routine Maintenance, Repair
Puncheon	Routine Maintenance, Repair
Retaining Wall - Stone	Routine Maintenance, Repair
Retaining Wall - Wood	Routine Maintenance, Repair
Staircase - Stone	Routine Maintenance, Repair
Staircase - Wood	Routine Maintenance, Repair
Stepping Stones	Routine Maintenance, Repair
Stone Paving	Routine Maintenance, Repair
Built Water Access	Routine Maintenance, Repair
Cattleguard	Routine Maintenance, Repair
Climbing Turn	Routine Maintenance, Repair
Culvert	Routine Maintenance, Repair
Drain dip	Routine Maintenance, Repair
Ford	Routine Maintenance, Repair
French Drain	Routine Maintenance, Repair
Grade Reversal	Routine Maintenance, Repair
Switchback	Routine Maintenance, Repair
Viewpoint	Routine Maintenance, Repair
Waterbar - Stone	Routine Maintenance, Repair
Waterbar - Wood	Routine Maintenance, Repair

Table 1: Types of infrastructure surveyed and whether they were surveyed as point or line features.

Problem Features	Possible Condition States
Drainage Issue	None
Multiple Treads (Braiding)	Mild Damage, Moderate Damage, Severe Damage, Recovering Damage
Soil Loss	Mild Damage, Moderate Damage, Severe Damage
Obstruction – Tread	None
Obstruction - Vertical	None
Undesignated Trail Connection	None

Table 2: Problem features surveyed and whether they are surveyed as point or line features

To reduce interobserver variability, definitions were developed for the condition states that could be assigned to problem features. Table 3 shows typical photos of the condition state of soil

loss as a problem feature. Table 4 shows typical photos of the condition state of multiple treads (braiding) as a problem feature.

Soil Loss Condition State	Representative Photos
<p>Mild Damage: Trail tread shows minor erosion rills or less soil than adjacent topography but is functional for the managed uses of the trail, and eroded soils do not appear to be significantly impacting adjacent vegetation or water.</p>	
<p>Moderate Damage: Trail tread is gullied, often with exposed roots or loose rocks, and starting to affect travel for managed uses. AND/OR, eroded soils appear to be moderately impacting adjacent vegetation or water.</p>	
<p>Severe Damage: Trail tread is gullied, often with exposed roots or loose rocks, and preventing travel for managed uses. Original trail tread is not functional and trail impacts such as tread widening or braiding are visible. AND/OR, eroded soils appear to be significantly impacting adjacent vegetation or water.</p>	

Table 3: Soil loss condition states

Multiple Tread Condition State	Representative Photo
<p>Mild Damage: Noticeably impeded vegetation growth; some vegetation cover loss; some organic litter pulverized within the tread; some bare soil exposed; tread intact.</p>	
<p>Moderately Damaged: Nearly complete or total loss of vegetation cover; nearly complete or total loss of organic litter within the tread; bare soil widespread; tread mostly intact; some rills evident.</p>	
<p>Severely Damaged: Vegetation and organic litter are rare or nonexistent within the tread; active tread erosion evident.</p>	
<p>Recovering Damage: Past tread erosion evident; vegetation is reestablishing because tread is no longer usable.</p>	

Table 4: Possible multiple tread condition states (adapted from Marion et al. 2008).

## Data Processing and Analysis

Station-level data and features (structure and problem) are imported and processed using a custom data processing application developed by OSMP staff. The application imports the data into OSMP's production database, where it is linear referenced to trail alignment data.

The station-level data is then evaluated for compliance with OSMP's Trail Management Objectives (TMOs) and associated design parameters, as discussed above. Station-level data is also linked to structure and problem feature data so that station condition data represents compliance with design standards, the condition of structures, and the presence of problem features such as erosion or braiding. Each station is assigned a condition class representing a maintenance category and associated color code:

- **Routine maintenance** indicates the trail meets assigned standards and has functioning infrastructure.
- **Preventative repair** indicates the trail does not meet assigned standards but is within a reasonable threshold to meet the standard.
- **Critical repair** indicates that the trail does not meet assigned standards, that infrastructure is in a state of disrepair, that severe problem features are present, or a combination of those factors.

Station-level condition classes are then weighted using SQL script and ArcGIS Pro to produce a Trail Condition Index (TCI) from 0 to 100 for each trail segment. The TCI represents how closely a trail meets its TMO (Appendices B-F). Table 5 demonstrates how a trail's TCI is generated.

Condition Class	Weight*	% of trail length in each condition class			
		Sample Trail 1	Sample Trail 2	Sample Trail 3	Sample Trail 4
Routine Maintenance	1	100%	0%	0%	50%
Preventative Repairs	0.5	0%	100%	0%	30%
Critical Repairs	0	0%	0%	100%	20%
	Index Score:	100	50	0	65

\* Weight multiplied by % length for each class then summed = Index Score

Table 5: Example of how the percent of trail length in each condition class is weighted and summed to produce the TCI.

The TCI was modeled after similar tools used by transportation departments to assess road conditions. TCI scores place trails into maintenance classes, as discussed above:

- A TCI of 0-33 needs **Critical repair**
- A TCI of 33-66 needs **Preventative repair**
- A TCI of 66-100 needs **Routine maintenance**

# Results & Discussion

**Monitoring Goal: Maintain inventory of existing infrastructure and current conditions. What is the state of our trail system almost 20 years post-VMP adoption?**

During the 2019-2023 survey, a total of 59,628 stations were recorded, averaging 14 feet in length for a total of 156.6 miles. Station-level measurements are the lowest unit of measurement and represent the most detailed findings of the survey. The average grade, outslope, and width across all stations were 9.5%, 3.2%, and 4.7 feet, respectively (Table 6).

Total Stations	Mean Grade	Mean Outslope	Mean Width	Max Grade	Min Grade	Max Outslope	Min Outslope	Max Width	Min Width
59,628	9.5%	3.2%	4.7 ft	76.2%	0%	36.5%	0%	30 ft	1 ft

Table 6: Average, minimum, and maximum grade, outslope, and width of station data.

## Results by Trail Management Objective and Station Level Condition

OSMP builds and maintains trails based on the designed and managed uses. Appendices B-F show the trail design standards. Condition data can show general condition patterns within those trail classes when broken down to a station level. Figure 6 shows that the largest amount of mileage falls into Class 3 hiking trails, and most of that mileage is in routine maintenance or preventative repairs condition. Class 2 hiking and biking trails are the only trails with zero miles within the routine maintenance category. Conversely, Class 4 and 5 biking trails are the only class of trails with zero miles of stations that needed critical repairs

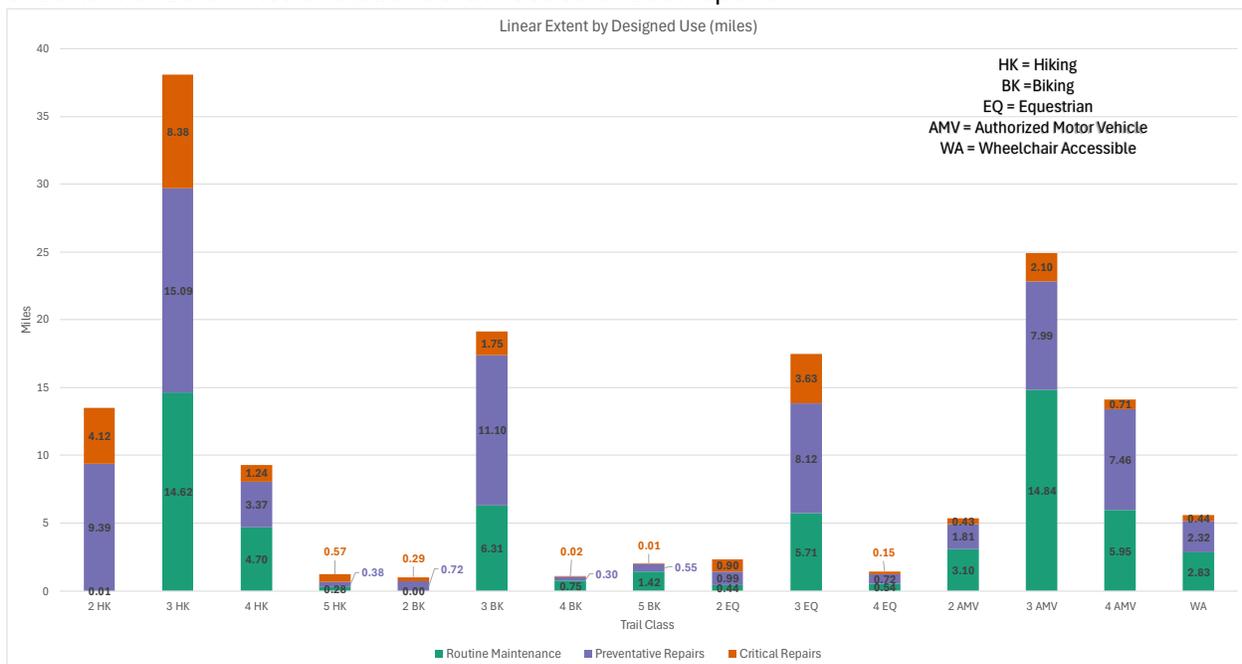


Figure 6: Linear extent of condition states of stations categorized by trail management objective and condition state grouped by use and ordered from least developed (left) to most developed (right).

Averages of station data evaluated by TMO show the range of trail types and experiences on OSMP land. Average grade, width, and outslope are within or close to desired design parameters for most TMOs. Nearly 40% of the stations surveyed meet assigned standards and are in a routine maintenance condition phase. Another 45% have minor compliance issues or minor damage from problem features and are in a preventative repairs condition phase. The final 16% are out of compliance with standards, have major damage from problem features, and are in a critical repair condition phase (Table 7). At a station level, as the average grade increases, the condition of stations decreases. The average tread width remains constant with the condition. The average outslope increases slightly as the condition decreases among stations. In other words, the grade of a station appears to have the most significant effect on condition, followed by outslope and width, with the latter appearing to have relatively little to no impact on condition (Table 7). This holds true for the 2015-17 and 2019-23 surveys.

<b>Condition Index</b>	<b>Total Stations</b>	<b>Total Distance (miles)</b>	<b>% of total distance</b>	<b>Mean Station Length (Ft)</b>	<b>Mean Grade (%)</b>	<b>Mean Tread Width (Ft)</b>	<b>Mean Outslope (%)</b>
<b>Routine Maintenance</b>	22277	61.5	39.3%	14.6	6.0	4.8	2.4
<b>Preventative Repairs</b>	26646	70.3	44.9%	13.9	8.7	4.7	3.2
<b>Critical Repairs</b>	10705	24.8	15.8%	12.2	19.0	4.4	4.7

Table 7: Data collected at a station level, and the averages of that data when categorized by condition state.

The trail types with the lowest average Trail Condition Index were Class 2 equestrian and Class 5 hiking trails. Both trail types had average TCIs in a condition state of critical repair. Class 2 hiking trails also had a low average TCI, although the average is still within the preventative repairs condition state. Class 4 hiking trails, Class 4 and 5 biking trails, Class 2 and 3 authorized motor vehicle trails, and wheelchair-accessible trails all had average TCIs within the routine maintenance condition state (Table 8). Low condition scores are not necessarily an indication that trail standards are failing but rather that a designated alignment may not be able to meet standards because of exceptions for topography, resource protection, or management of legacy trails that were not designed to sustainable standards.

	TMO	Total Segments	Mean Condition Index	Condition Category	Mean Grade (%)	Grade Target Range (%)	Mean Tread Width (Ft)	Mean Target Range (ft)	Mean Outslope (%)	Mean Target Range (%)
<b>Hiking Trails</b>	2HK	48	36.8	Critical Repair	17.9	0-18	3.5	1-2	3.8	3-20
	3HK	161	49.0	Preventative Repair	11.9	0-12	3.9	1-3	3.2	3-5
	4HK	33	75.6	Routine Maintenance	7.5	0-10	3.7	2-5	3.8	3-5
	5HK	17	31.8	Critical Repair	10.2	0-5	4.8	3-6	3.3	2-5
<b>Biking Trails</b>	3BK	40	57.9	Preventative Repair	5.6	0-10	4.3	1-3	2.7	3-5
	4BK	8	87.3	Routine Maintenance	5.4	0-8	4.0	2-5	1.8	3-5
	5BK	4	85.5	Routine Maintenance	2.8	0-5	7.5	3-6	1.9	2-5
<b>Equestrian Trails</b>	2EQ	4	29.5	Critical Repair	10.8	0-20	2.4	2-5	3.2	3-5
	3EQ	45	56.2	Preventative Maintenance	8.8	0-12	4.2	2-5	3.2	3-5
	4EQ	13	69.4	Routine Maintenance	6.5	0-10	6.9	2-8	3.4	3-5
<b>Authorized Motor Vehicle Trails</b>	2AMV	21	71.6	Routine Maintenance	5.9	0-12	7.9	6-10	2.7	3+
	3AMV	72	70.3	Routine Maintenance	6.3	0-12	9.4	8-10	2.9	3-5
	4AMV	50	66.1	Routine Maintenance	6.2	0-12	9.9	10-12	2.6	3-5
<b>Accessible Trails</b>	WA	45	67.5	Routine Maintenance	3.9	0-5	6.1	3+	2.2	2

Table 8: Segment data summarized by trail management objective

Compliance issues represent areas of a trail that do not meet the assigned TMOs. Compliance issues for width and problem features account for most compliance issues on the trail system (Table 9). Grade compliance issues represent 13% of the total mileage surveyed despite grade having the most considerable impact on and contributing to problem features such as erosion and infrastructure in a repair condition state (Table 9).

<b>Compliance Issue</b>	<b>Linear Extent (Feet, Miles)</b>	<b>Percentage of Total Survey</b>
Width	306,964' (58.1 miles)	37%
Grade	67,722' (12.8 miles)	13%
Outslope	157,707 (29.9 miles)	19%
Problem Feature	246,213' (46.6 miles)	39%

*Table 9: Total extent of compliance issues on the OSMP trail system.*

## Results by Trail Maintenance Zone and Trail Condition Index

OSMP utilizes trail maintenance zones to organize and prioritize management (Figure 2). Each trail maintenance zone contains around 30 miles of trails. Each zone’s trails generally have common physical landscape characteristics, soil types, topography, and managed uses. When looking at station-level data, trail maintenance Zone 3 contains the highest number of trails needing preventative or critical repairs (Figure 7). Zones 1 and 4 contain the greatest extent of mileage in routine maintenance.

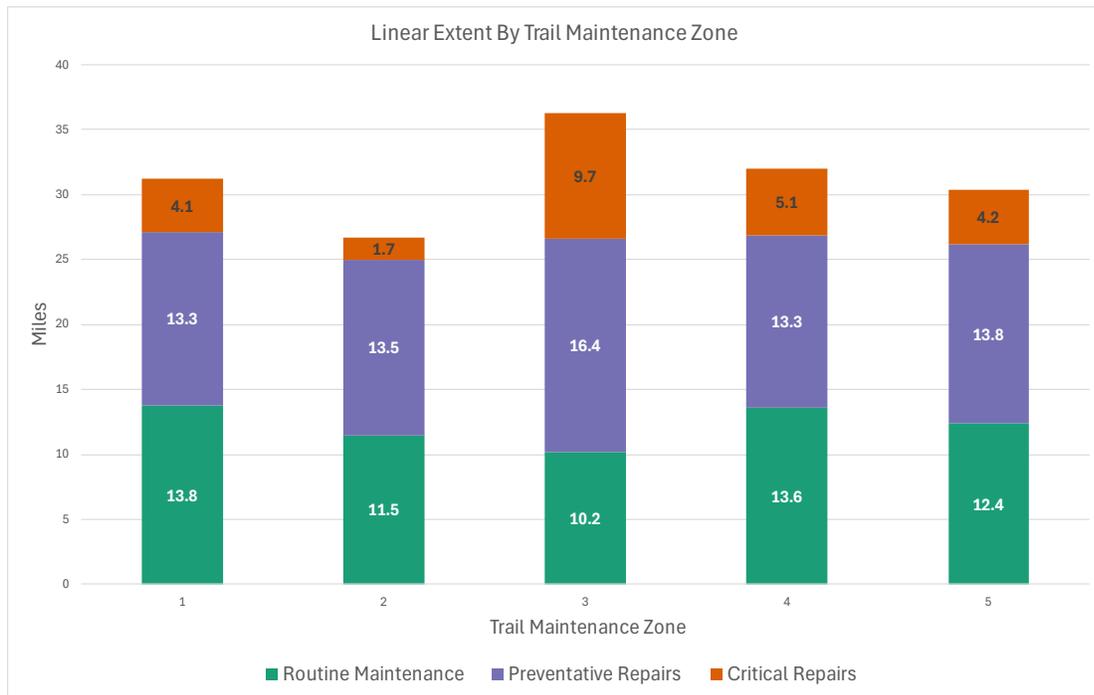


Figure 7: Trail condition extent by trail maintenance zone

Overall, the average TCI across the entirety of OSMP-managed lands was 59. Figure 8 shows that average condition varied among trail maintenance zones. Zone 3 had the lowest average trail condition (48). Zone 3 covers the mountain backdrop of OSMP land and contains many trails that were never designed but rather were adopted into the trail system. These trails are known internally to the department as Legacy Trails. Some examples of Legacy Trails include Fern Canyon, the 1<sup>st</sup>/2<sup>nd</sup> flatiron, Saddle Rock, and Shadow Canyon. Zone 2 has the highest condition index and consists of the highest concentration of trails designed, built, or repaired using industry-standard sustainable trail practices. Zones 1 and 2 had an average condition index that fell into the routine maintenance condition. All other zones fell into the preventative repairs category.

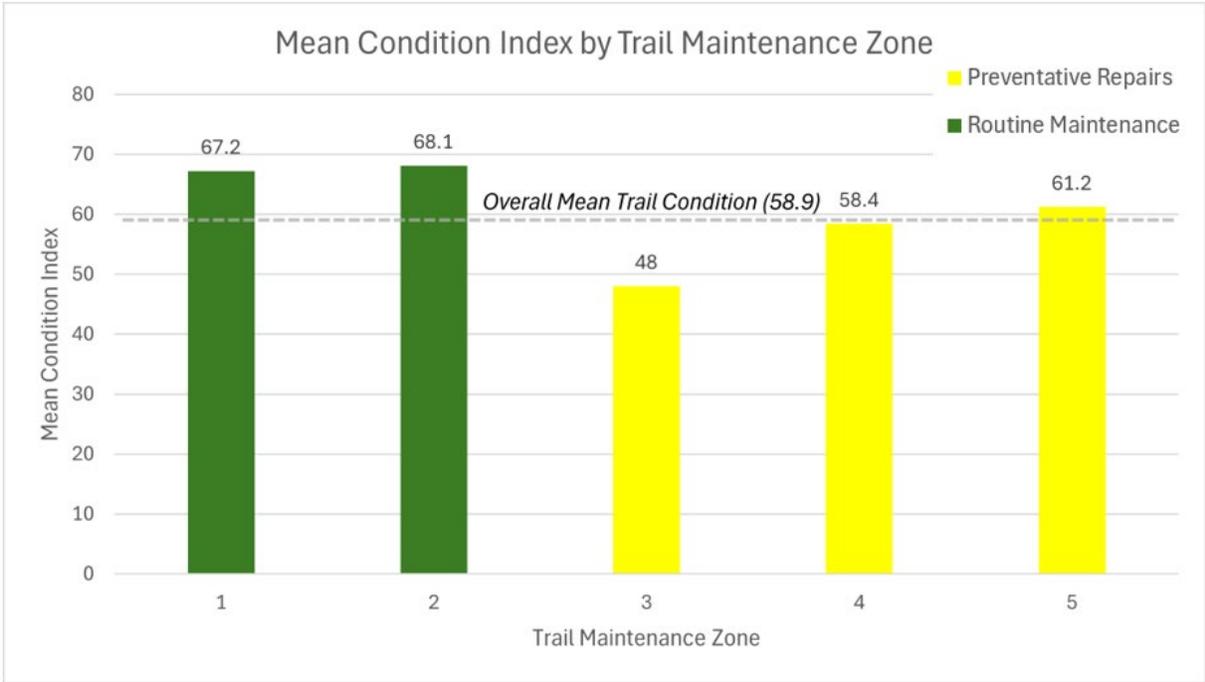


Figure 8: Mean condition index of trails categorized by trail maintenance zone

Figure 9 below shows a map of the OSMP trail system overlaid with trail condition data.

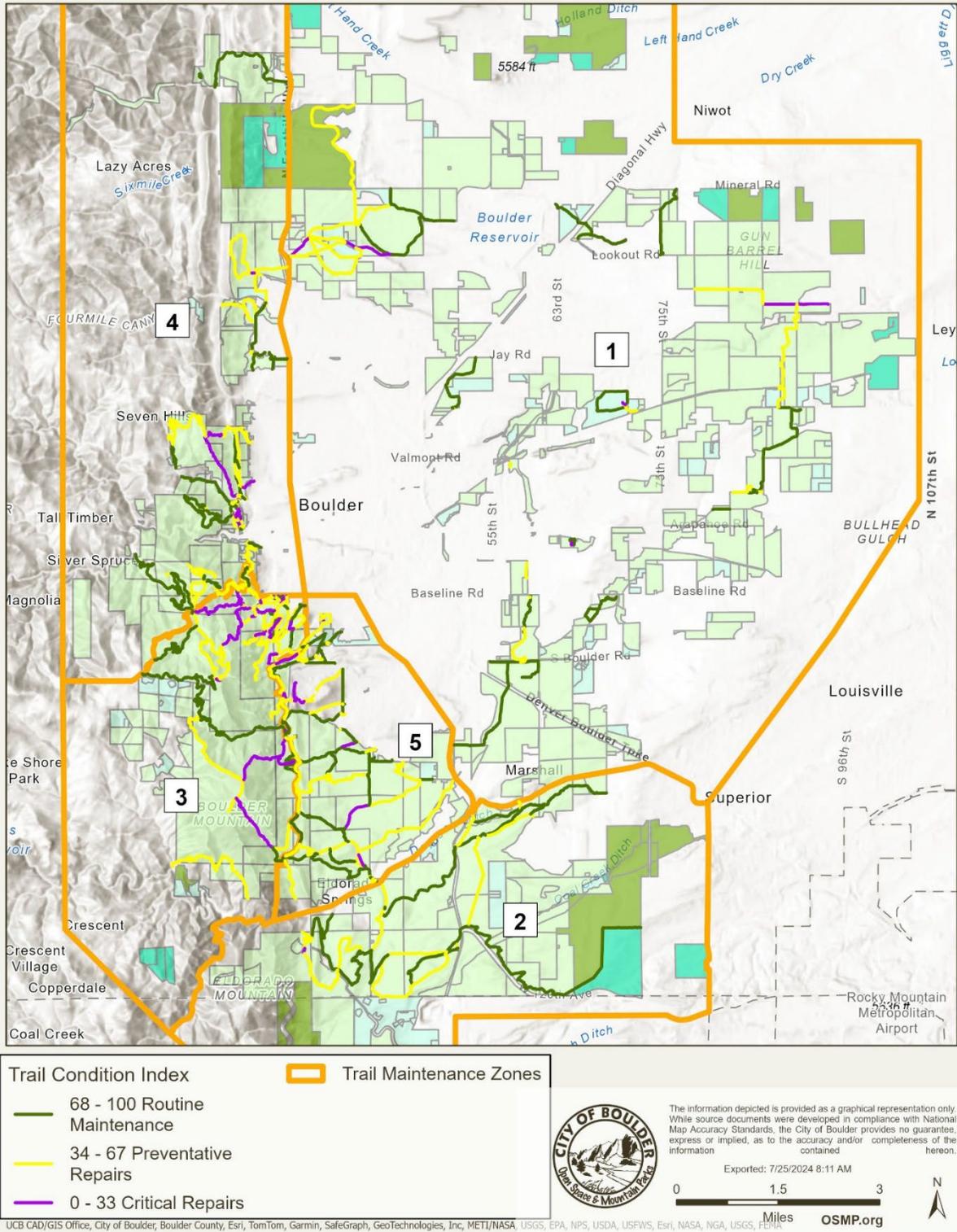


Figure 9: Map of Trail condition with maintenance zones displayed

## Inventory of Structures

Structures (feature data) are recorded as points or lines. Discrete structures used to manage water on the trail tread or to gain elevation are recorded as points. Structures that run parallel to or within the trail tread and support the tread surface through retaining materials or elevating the trail tread surface are recorded as line features. 5,041 point structures and 10,859 line structures were recorded during the survey, totaling 15,900 structures managed by OSMP (Tables 10 & 11). Drain dips and grade reversals were the most common point structures on the system, while drainage ditches adjacent to the trail were the most common line structures. The line structures surveyed spanned 30 miles of the OSMP trail system.

Structure	Routine Maintenance	Repair	Total	% of total structures
Built water access	8	0	8	<1%
Cattle guard	5	0	5	<1%
Climbing turn	50	0	50	1%
Culvert	330	12	342	7%
Drain dip	1329	165	1494	30%
Ford	45	0	45	1%
Grade reversal	2386	12	2398	48%
Ladder	1	0	1	<1%
Switchback	129	1	130	3%
Waterbar - stone	277	78	355	7%
Waterbar - wood	160	53	213	4%
<b>Total</b>	<b>4,720</b>	<b>321</b>	<b>5,041</b>	

Table 10: Point Structures collected during the inventory and the total structures in a routine maintenance or repair condition

<b>Structure</b>	<b>Routine Maintenance</b>	<b>Repair</b>	<b>Total</b>	<b>% of total trail mileage</b>
Backwall - stone	55 (1,353.6')	8 (254.4')	63 (1608')	1%
Backwall - wood	1 (10.5')	1 (28.9')	2 (39.4')	<1%
Boardwalk	0 (0')	4 (480.7')	4 (480.7')	<1%
Causeway - stone	14 (340.0')	0 (0')	14 (340')	<1%
Causeway - wood	26 (2,390.5')	0(0')	26 (2390.5')	2%
Check step - stone	1,945 (7,795.5)	819 (3,897')	2,764 (11,692.5')	7%
Check step -wood	1,670 (7,927.4')	1,080 (5,328.6')	2,750 (13,256')	8%
Ditch	339 (95,729.6')	18 (2,801.3')	357 (98,530')	62%
Puncheon	14 (897.8')	2 (28.3')	16 (926.1')	<1%
Retaining wall - stone	615 (15,221.9')	9 (198.1')	624 (15,420')	10%
Retaining wall - wood	21 (757.1')	0 (0')	21 (757.1')	<1%
Staircase - stone	383 w/ 3,049 steps (7,301.2')	83 w/ 678 steps (1,715.6')	466 w/ 3,727 steps (9,016.8')	6%
Staircase - wood	42 w/ 385 steps (1,358.7')	4 w/ 29 steps (116.9')	46 w/ 414 steps (1,475.6')	1%
Stepping stones	1 w/ 12 steps (29.3')	0 (0')	1 (29.3')	>1%
Stone Paving	62 (2,548.1')	3 (88.8')	65 (2,636.2')	2%
<b>Total</b>	<b>8,208 (143,661.2' or 27.2 Miles)</b>	<b>2,651 (14,979.6' or 2.8 Miles)</b>	<b>10,859 (158,580.8' or 30 miles)</b>	

Table 11: Line structures collected during the inventory with the length of those structures and the total structures in a routine maintenance or repair condition

## Problem Features

### Soil Loss (Erosion)

Soil loss was recorded on 54.4 miles of trails throughout the OSMP trail system, accounting for approximately 35% of the total mileage surveyed. Of those 54 miles, 68% of the mileage exhibited mild soil loss, 27% moderate soil loss, and 5% severe soil loss (Figure 10).

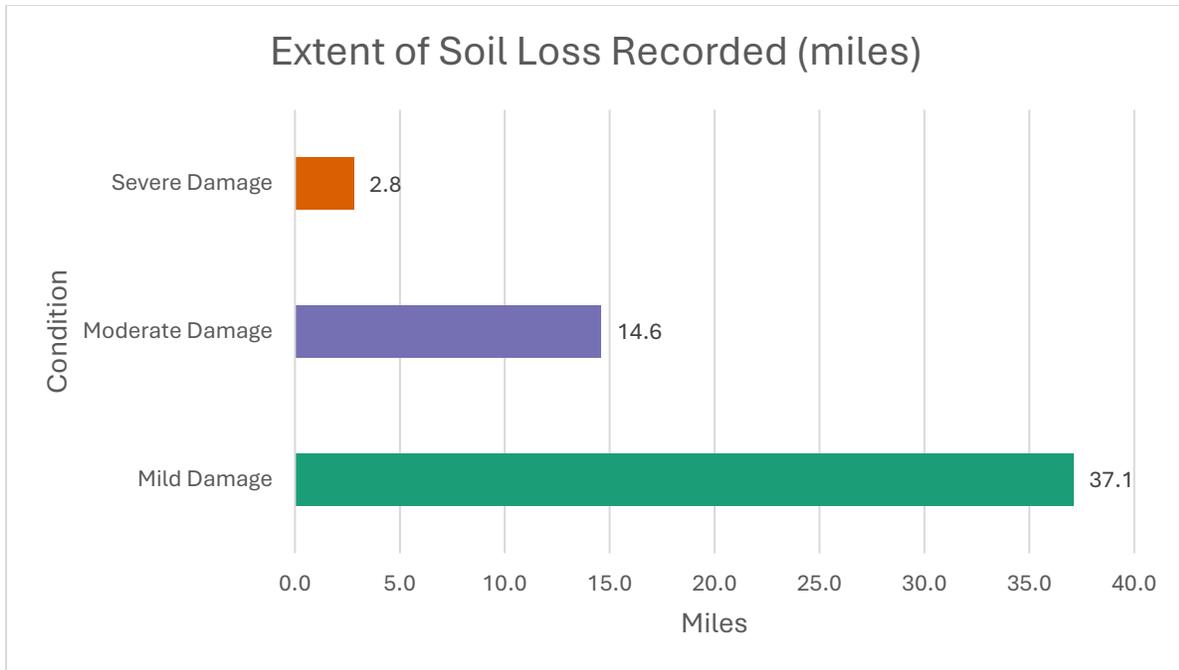


Figure 10: The linear extent of soil loss (erosion) measured during the 2019-23 condition monitoring.

#### Multiple Treads (Braiding)

Braiding was recorded on 16.3 miles of trails throughout the OSMP trail system. Of those, 16 miles (31% of the mileage) exhibited mild damage, 32% moderate damage, and 37% severe damage (Figure 11).

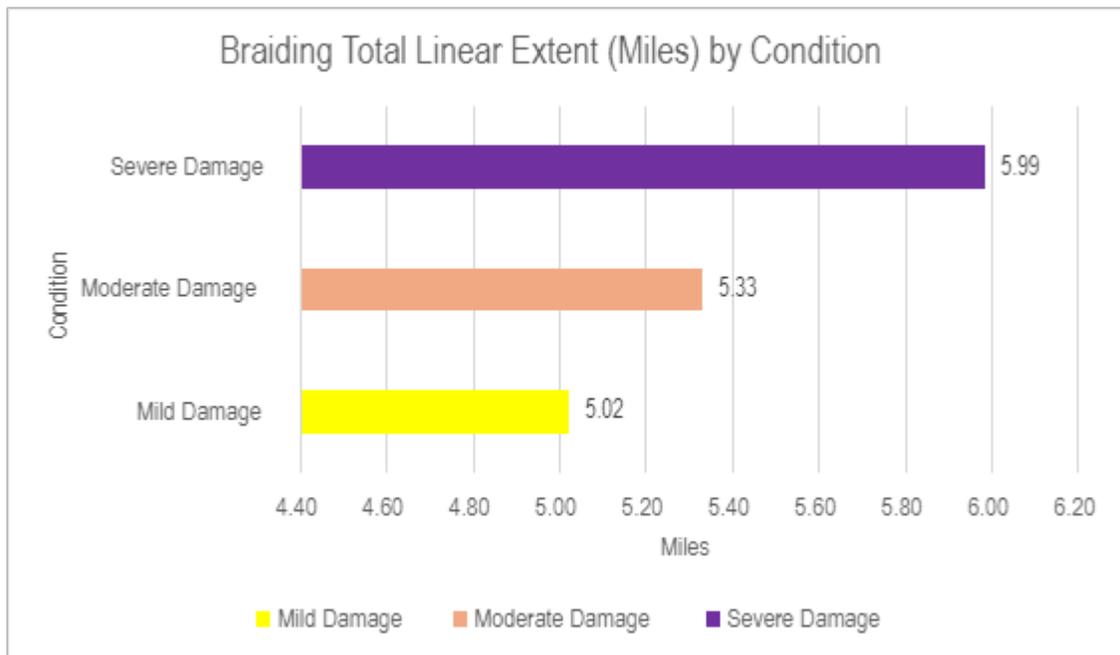


Figure 11: The linear extent of braiding surveyed categorized by condition.

## Monitoring Goal: Provide trail access information (trail nutrition labels) for visitors

All trail users need trail information to make informed decisions. For example, hikers want to know which trail is most appropriate for the time they have available, the people in their group, and the type of hike that best suits their needs or desires. Information about the accessibility of a trail enables people with disabilities to decide whether the characteristics of the trail are suited to their abilities. The Architectural Barriers Act for Outdoor Developed Areas (F216.13 and 1017.10) directs land management agencies to provide the following information:

- Length of the trail or trail segment
- Type of trail surface
- Typical and minimum trail tread width
- Typical and maximum trail grade
- Typical and maximum trail outslope

Providing this information on the OSMP website or on signage at trailheads allows people the opportunity to understand the possible challenges of the trail before selecting destinations. The HETAP equipment used for condition monitoring was specifically developed to provide the above information. To view trail access information for OSMP visit:

<https://maps.bouldercolorado.gov/websites/osmp/UniversalAccess/>

## Monitoring Goal: Evaluate change over time to assess effectiveness of trail management and design. How has our trail system changed?

### Trend Results by Trail Maintenance Zone and Trail Condition Index

Overall, the average condition index score for trail segments managed by OSMP slightly improved since the last round of monitoring. The average condition index increased from 57 in the 2015-17 survey to 59 in the 2019-2023 survey. Every trail maintenance zone saw improvements except Zone 1, which saw a slight decrease in condition index from 70.7 in 2015-17 to 67.2 in 2019-23 (Figure 12). Trail maintenance Zone 5 saw the most significant increase in the average condition index from 51.2 in 2015-17 to 61.2 in 2019-23 (Figure 12).

Trail maintenance Zone 1 saw a slight decrease in the average condition index. Still, major project work completed after Zone 1 was surveyed, including work in the Gunbarrel Hill area, Sawhill Ponds, and Boulder Valley Ranch, should improve the average condition index in the next round of condition monitoring.

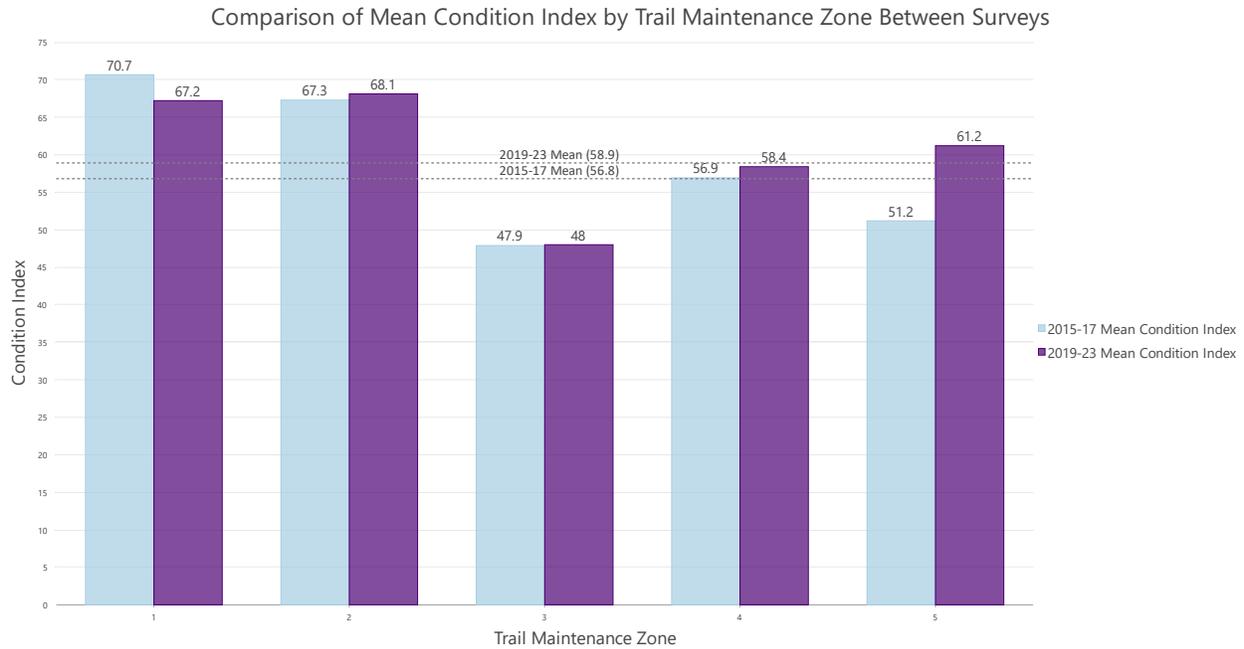


Figure 12: Comparison of mean condition index by Trail maintenance Zones by survey period

Major repair work and trail reroutes contributed to the significant improvements in trail maintenance Zone 5. Trail maintenance Zone 5 had several major repair projects that occurred between surveys repairing trails that were severely damaged in the 2013 flood. Trails that saw flood repairs in maintenance Zone 5 include Mesa trail, Shadow Canyon South trail, North and South Shanahan trails, and NCAR/Bear trail. Major re-routes that contributed to a higher zone score included three Mesa trail segments and portions of the Towhee and Homestead trails.

Examining the 2015-17 and 2019-23 survey data, OSMP analyzed the change in condition indexes for individual trail segments. On average, segments improved slightly, but there was considerable variability in the extent of change among segments (Figure 13), with the standard deviation of the change of 23.6. Changes outside that range are considered outliers and can be the most telling when looking for trails that had dramatic improvements or declines in condition.

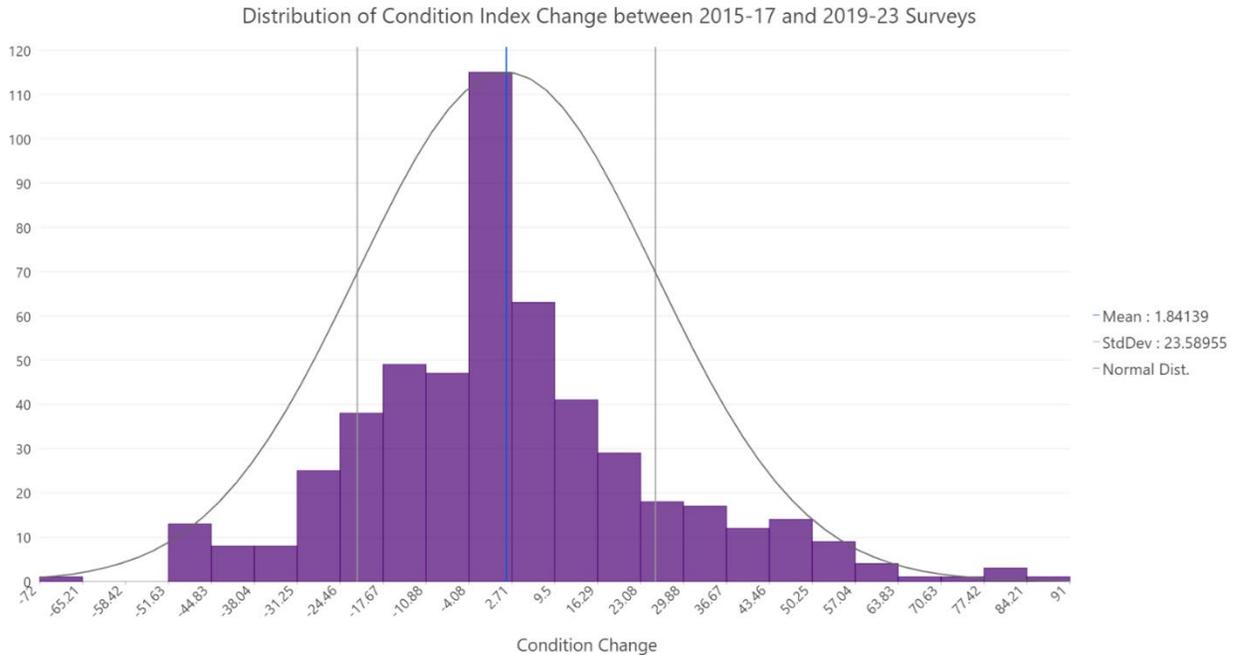


Figure 13: Distribution of condition index change of trail segments between the 2015-17 and 2019-23 surveys.

Figure 14 shows changes in the condition index on a segment level across the trails managed by OSMP. The trends in trail condition demonstrate the dynamic nature of managing a complex trail system. Trail work projects have made considerable improvements in systemwide trail conditions, while in some areas, aging infrastructure has continued to deteriorate; this demonstrates why a slight increase in the systemwide TCI is hard to achieve and reflects a significant amount of trail work. Trails that saw major improvements were those that had major repair or redesign work completed since the 2015-17 survey. Some examples of these trails are Green Mountain West Ridge, Bear Canyon, Chautauqua, Community Ditch (biking trail segments), and Foothills South. Trails that saw a significant decline in condition are found in the mountain backdrop or in the northern portion of the trail system. Some trails that saw substantial decreases in condition include Cobalt, Fern Canyon, and Flatirons Vista North. Several legacy trails, such as Saddle Rock Trail or Fern Canyon Trail, continued to have declining condition scores; however, the legacy trails that had major repair work done on them, such as the 1<sup>st</sup>/2<sup>nd</sup> Flatiron Trail and Sanitas, saw marked improvements in condition index.

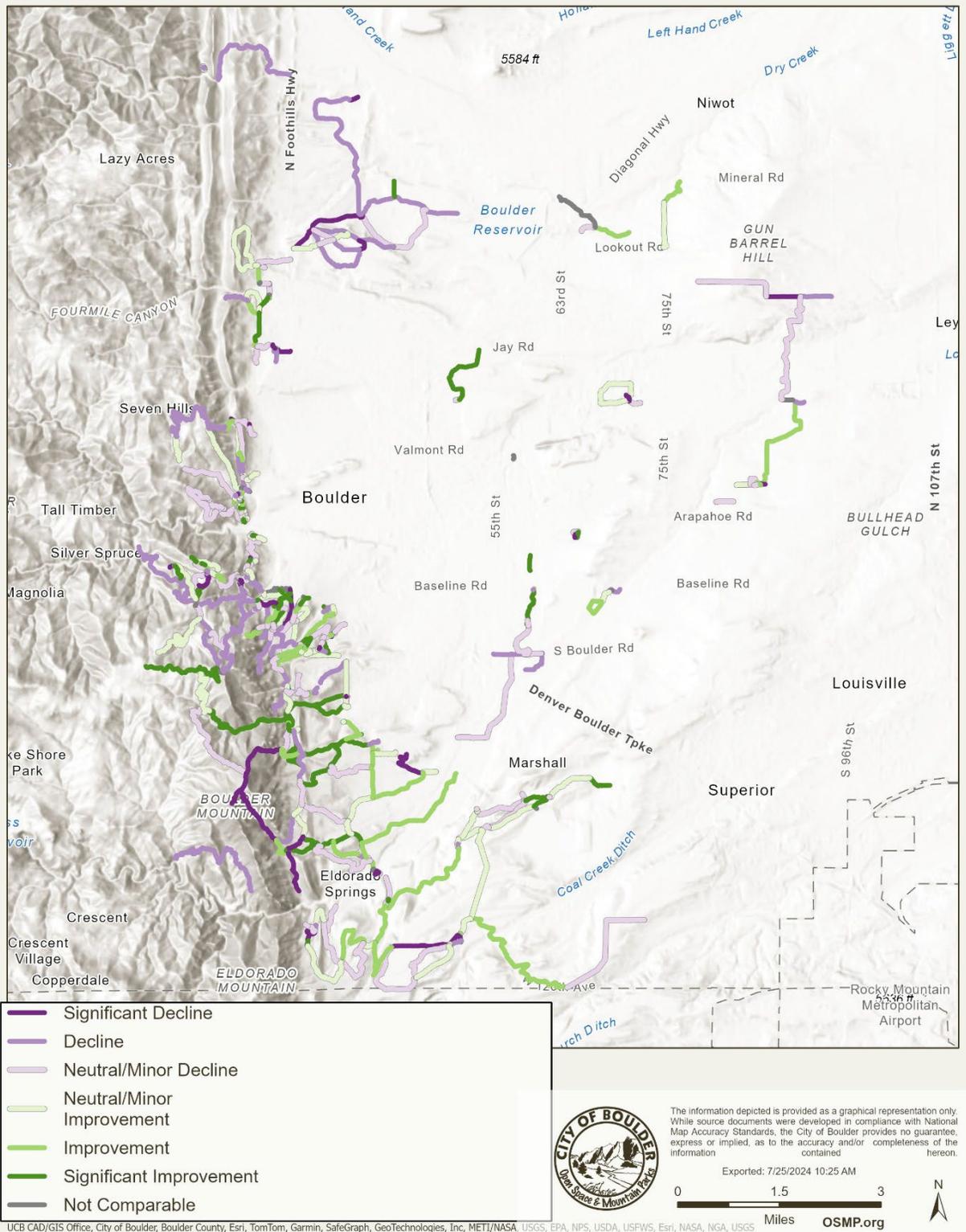


Figure 14: Condition segment changes by trail segment.

## Changes By Trail Management Objective

Even though there are 5 trail classes and associated levels of development, most of OSMP's trail mileage, 100 miles, falls within Class 3 regardless of designed use type (hiking, biking, etc). Class 2 and Class 4 make up the next largest mileage, and OSMP manages very little Class 1 or 5 miles of trail. The most common designed use is hiking followed by authorized motor vehicle, biking, equestrian, and accessible. Comparing station-level condition data by TMO from the 2015-17 and 2019-23 surveys provides insight into the effectiveness of different design techniques as well as maintenance needs for different managed uses. Across all condition categories and TMOs, a focus on annual routine maintenance of structures will help prevent stations and segments from deteriorating into a state of preventative repair.

Hiking trails had the largest variance between classes in trends but also accounted for the most mileage across the system. Hiking Class 2 trails experienced the most significant decline, with the average condition index indicating a need for critical repairs. In contrast, Class 3 trails showed improvement, but still require attention as their average condition index remains in the preventative repair category. Class 4 trails remained stable, with a slight shift toward preventative repairs. In contrast, Class 5 trails improved overall but still face concerns due to the high proportion of stations needing critical repair, particularly on trails with crusher fine surfaces.

Biking trails showed a general decrease in the percentage of stations requiring critical repairs, with Class 2 bike trails showing the most improvement. However, Classes 2 and 3 saw decreased routine maintenance stations, suggesting a need for targeted repairs.

Equestrian trails remained consistent between surveys, with Class 4 trails showing significant improvement.

Authorized motor vehicle trails showed a decrease in out-of-compliance stations and a decline in compliant stations, indicating a need for more routine maintenance after significant reconstruction efforts following the 2013 flood.

Accessible trails saw a concerning increase in stations with minor compliance issues and a decrease in compliant stations, highlighting the need for more frequent maintenance to meet stringent standards.

## Photo-Point Monitoring

The HETAP survey equipment used for trail condition monitoring automatically records a photo at each station (approximately every 14ft). Photo points demonstrate the dynamic nature of trails and surrounding vegetation and are a powerful tool to help evaluate the effectiveness of trail design techniques over time. Table 12 shows examples of how photo points can be used to further understand changes in condition at specific locations around the trail system.



Table 12: Representative photos of how photo point monitoring can provide insight into trail condition changes

## Condition of Structures

Structures (feature data) are recorded as lines or points with associated condition and photographs (See Table 1). This survey recorded 5,041 point structures and 10,859 line structures spanning nearly 30 miles (Tables 13&14). Over 91.5% of point structures were in a routine maintenance state (Table 13), and 75.8% of line structures were in a routine maintenance state (Table 14). The 2,651-line structures in a state of disrepair cover approximately 2.8 miles across the system, leaving 7,809 line structures spanning 27.2 miles in a routine maintenance condition state (Table 14).

The 2019-23 survey identified 94 more point structures than the 2015-17 survey (Table 13). The most recent survey also identified fewer point features in a state of disrepair and more structures in a state of routine maintenance. Improvements to overall infrastructure are likely the result of several factors. An increased focus on maintenance sweeps likely resulted in more infrastructure remaining in routine maintenance rather than falling into disrepair. Trail staff have prioritized maintenance sweeps in the past 5 years following the 2015-17 survey, so every trail receives routine maintenance work twice yearly. The effectiveness and lifespan of infrastructure, mainly features like drain dips and culverts, benefit significantly from the biannual maintenance sweeps. Additionally, reroutes and major trail redesigns contributed to the increased number of

features in a routine maintenance state. For example, the number of grade reversals increased in the most recent survey by 425 structures, and the number of drain dips increased by 362. As trail design best practices have evolved over time, grade reversals have proven more effective than drain dips in shedding water from trails and preventing erosion. The point structure that needs the most focus by the OSMP trails department is drain dips, contributing to nearly half of the point features in a state of disrepair.

	Routine Maintenance	Repair	Total structures
2015-17 Point Features	4,326 structures	621 structures	4,947 structures
2019-23 Point Features	4,720 structures	321 structures	5,041 structures

Table 13: Comparison of point features between surveys categorized by condition state.

The 2019-23 survey identified 1,196 more line structures than the 2015-17 survey, which spanned 5.6 miles more than the 2015-17 survey (Table 14). The survey also found an increase in line structures in the routine maintenance condition phase and a decrease in line structures in a state of disrepair. The most concerning finding among line structures in the most recent survey is a significant increase of wooden check steps in a state of disrepair. The 2019-23 survey found 1,014 check steps in a state of disrepair spanning nearly a mile. Most of the wooden check steps are found in trail maintenance Zones 3 and 4 (the mountain backdrop) and are nearing the end of their lifecycle.

	Routine Maintenance	Repair	Total structures
2015-17 Line Features	6,810 structures 20.5 miles	2,299 structures 3.5 miles	9,109 structures 24 miles
2019-23 Line Features	8,208 structures 27.2 Miles	2,651 2.8 Miles	10,859 structures 30 miles

Table 14: Comparison of line features between surveys categorized by condition state.

The first survey of systemwide trail condition monitoring, called for by the 2005 VMP, was conducted in 2007-2008. The 2007-08 trail condition monitoring recorded infrastructure using condition metrics like those in the 2015-17 and 2019-23 surveys and can be used for longer trend comparisons. The 2007-08 survey did not separate point and line features, so overall numbers must be used for comparison. Total built infrastructure has increased significantly since the 2007-08 survey (Table 15). Because the overall numbers increased, the percentage of structures in a routine maintenance phase can provide insight into the condition trends of built infrastructure. The percentage of infrastructure in a routine maintenance condition phase has increased since 2007 (Table 15). As infrastructure is added to the trail system, new infrastructure should, in theory, remain in a routine maintenance phase over most of its life cycle. New infrastructure could account for many of the improved features in a routine maintenance condition phase. Aging infrastructure should be systematically prioritized to continue to increase the amount of infrastructure in a routine maintenance cycle. An example of aging infrastructure is aging wooden

check steps (1,014 steps), which account for nearly 35% of the infrastructure in the 2019-23 repair condition phase.

Survey Year(s)	Total Features Recorded	Routine Maintenance Condition Phase	Repair Condition Phase	Percent of Features in Compliance
2007	5,228	3,956	1,272	76%
2015-17	14,056	11,136	2,920	79%
2019-23	15,900	12,928	2,972	81%

Table 15: Comparison of total infrastructure surveyed in 2007, 2015-17, and 2019-23.

In the 2019-23 survey, there was also a correlation between failing structures and steeper grades. Stations with failed infrastructure had an average grade eight percent higher than stations without significant differences in average outslope or width measurements (Table 16). Since structures are often a treatment for steeper grades, this indicates that steeper trails require more maintenance over the lifecycle of trail structures.

	Mean Grade (%)	Mean Width (Ft.)	Mean Outslope (%)
<b>No Infrastructure issues</b>	9.5	4.7	3.2
<b>Failing infrastructure</b>	17.4	5.1	3.4

Table 16: A comparison of measurements where infrastructure is failing or where infrastructure is in working condition.

## Problem Features

A comparison of problem features with station data averages for measures of trail design parameters helps to understand how trail design relates to the development of maintenance issues. Steep grades alone do not always result in compliance issues. However, soil loss due to steep grades can increase the rate at which obstructions, such as rocks and tree roots, in the tread are exposed, which can, in turn, lead to braiding and contribute to poor overall condition. In the 2019-23 data, stations with major problem features had an average grade of ten percent higher than stations without problem features (Table 17). In those same stations, outslope and width remained consistent among stations with failing infrastructure or problem features and stations without any compliance issues (Table 17).

	Mean Grade (%)	Mean Width (Ft.)	Mean Outslope (%)
<b>No problem features</b>	7.9	4.7	3.1
<b>Minor problem feature issues</b>	10.4	4.6	2.9
<b>Major problem feature issues</b>	17.7	4.4	3.7

Table 17: A comparison of average measurements categorized by the occurrence or absence of problem features.

### Soil Loss (Erosion)

The 2019-23 survey found a decrease in severe and moderate soil loss problems (Figure 15). Some of that decrease can be attributed to significant trail repair projects and trail re-routes. Many trails severely damaged in the 2013 flood were repaired between the 2015-17 survey and the most recent survey. The 2019-23 survey did find a significant increase in mild soil loss damage problems. These areas of mild damage should be considered in routine maintenance sweeps, so they do not develop into moderate or severe damage areas.

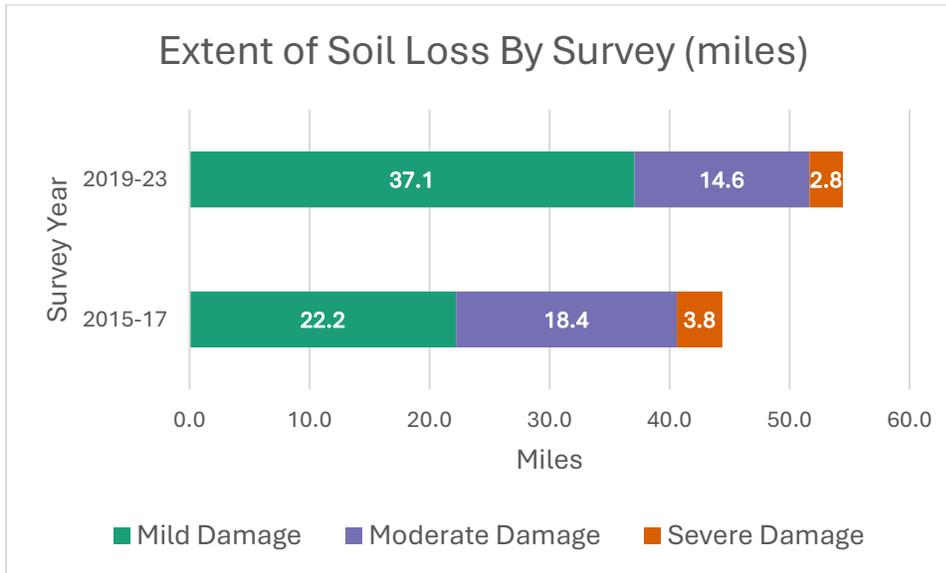


Figure 15: A comparison of soil loss between surveys.

The 2007-08 trail condition monitoring also captured erosion but did not include the condition category classified in the 2015-17 and 2019-23 surveys as mild damage. As such, comparing erosion numbers can only include the moderate and severe damage categories. Despite the decrease from 2015-17, the 2019-23 survey recorded increased erosion compared to the 2007-08 survey (Table 18). The 2007-08 survey also only recorded problems greater than 30 feet in length.

Survey Year	Erosion (Miles)	% of Total Surveyed Trail Mileage
2007	10.7	7.6%
2015-17	22.2	14.7%
2019-23	17.4	11.2%

Table 18: Comparison of the total moderate and severe erosion mileage, including the 2007, 2015-17, and 2019-23 surveys

### Multiple Treads (Braiding)

The 2019-23 survey recorded more instances of severe, moderate, and mild braiding along trails than the 2015-17 survey (Figure 16). Braiding can indicate other issues, such as drainage issues or erosion, that make the original trail alignment undesirable to travel upon.

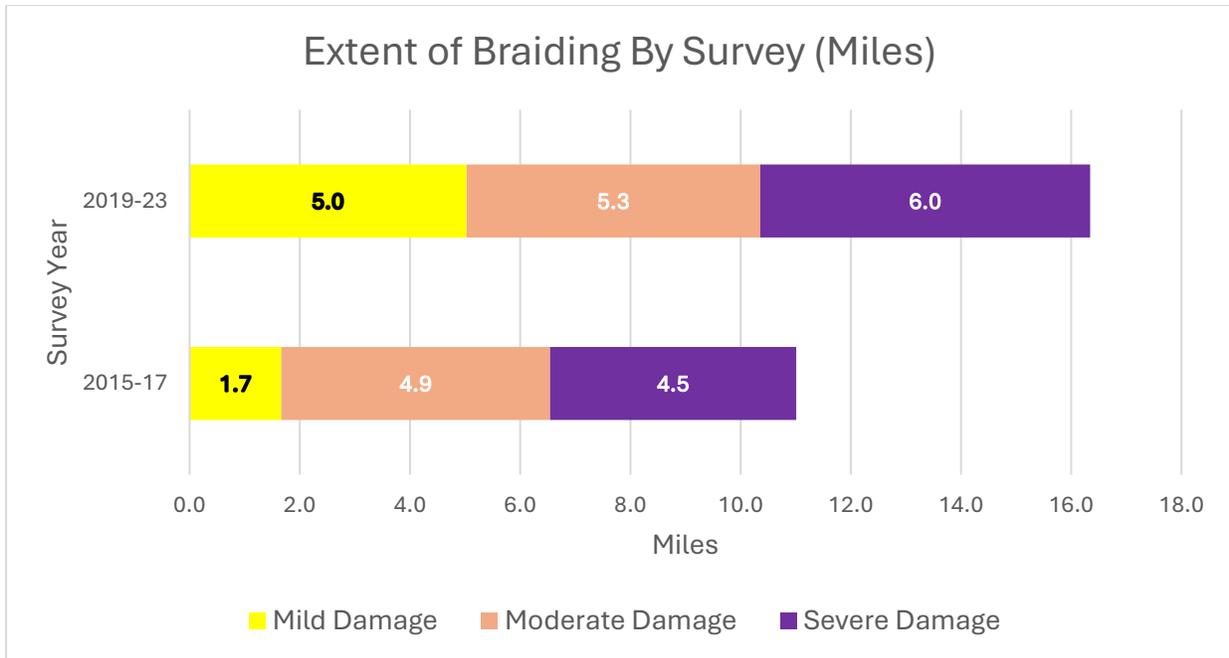


Figure 16: A comparison of the linear extent of braiding between surveys categorized by condition.

The 2007 trail condition monitoring also captured braiding. Despite overall improved conditions from 2015-17 to 2019-23, the 2015-23 surveys saw a significant increase in braiding since 2007. (Table 19). The 2007 survey only recorded problems greater than 30 feet in length, which could account for some of the difference.

Survey Year	Braiding (Miles)	% of distance
2007	3.0	2.1%
2015-17	12.7	8.4%
2019-23	16.3	10.5%

Table 19: Comparison of the mileage of braiding between the 2007, 2015-17, and 2019-23 surveys.

## Monitoring Goal: Prioritize and fund future work. Where are we going?

### Cost Estimating

OSMP staff use trail condition monitoring data to estimate the cost to maintain, repair, and replace visitor infrastructure around the system.

#### *Deferred Maintenance Estimates*

This estimate is based on the average linear foot (LF) repair and construction costs applied by condition categories and TMOs. This estimate includes a wide range of project costs depending on location, materials, terrain, and type of work. On the high end of the cost spectrum, projects with extensive rock work like Boulder Falls cost \$615/LF while use of volunteers or youth corps and simple logistics on projects like the South Boulder Creek Trail can be as low as \$9.72/LF. The estimates presented below (Table 20) include the total cost estimated by linear foot to define the low end of the range and a 30% inflation adjustment to define the high end of the range. 2018 cost estimates were based on 2015-17 condition monitoring and were initially presented to the Open Space Board of Trustees (OSBT) in October 2018. The estimate of deferred maintenance across all TMOs by condition class was \$39 – 50 million (Table 20). The same methodology and cost per linear foot was applied to the 2019-2023 conditions and produced an estimated deferred maintenance backlog of \$38-\$50 million. There is a slight decrease despite adding 4 miles of trails to the system between surveys.

Condition Category	Estimated Cost (USD)	
	2015-17	2019-23
Routine Maintenance (Green)	\$1.3-\$1.7 million	\$1.4-\$1.8 million
Preventative Repairs (Yellow)	\$23-\$30 million	\$22.8-\$29.6 million
Major Repairs and Rebuilds (Red)	\$14.3-\$18.6 million	\$13.8-\$17.9 million
<b>Total</b>	<b>\$39 - 50 million</b>	<b>\$38-50 million</b>

Table 20: Estimated deferred maintenance costs by condition category and monitoring cycle.

Figure 17 shows the change in the extent of mileage in different condition states. 2019-23 saw a decrease in the percent of mileage in a critical repair state with an increase in the percent of mileage in a preventative repair condition state.

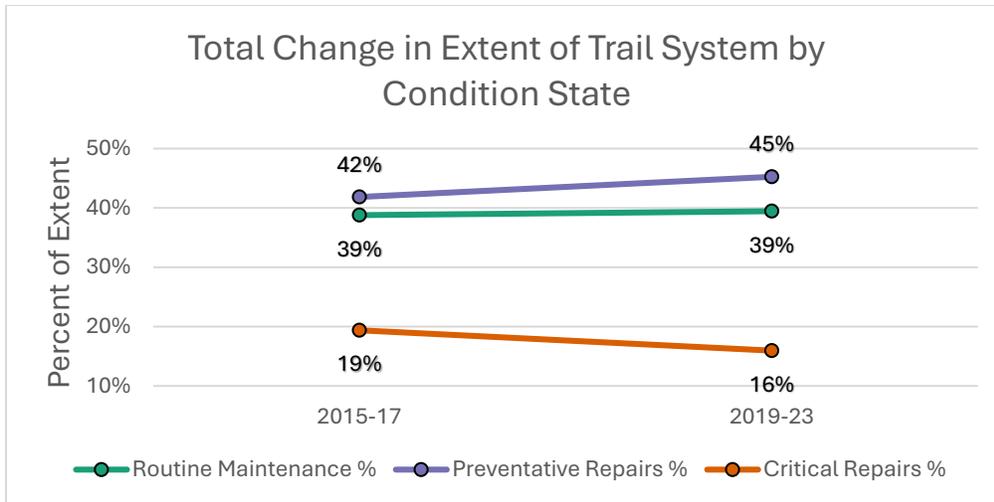


Figure 17: Total change in linear extent by condition state between the surveys

Table 21 shows that the deferred maintenance costs decreased in all of the trail maintenance zones except for zone 4. The increase in zone 4 is due to additional trail mileage such as Anemone Trail being added to the zone.

Maintenance Zone	Estimated Cost (USD)	
	2015-17 Survey	2019-23 Survey
1	\$3.4-4.5 million	\$3.4-4.5 million
2	\$3.6-4.6 million	\$3.0-3.8 million
3	\$14.2-18.5 million	\$13.5-17.6 million
4	\$8.7-11.3 million	\$9.9-12.9 million
5	\$8.7-11.3 million	\$8.0-10.4 million

Table 21: Deferred maintenance cost by maintenance zone with both surveys included

### Total System Replacement Costs

OSMP used trail condition data and the average cost per linear foot to construct different trail types to estimate the total cost to replace all trails on the system. While these estimates are useful to understand the value of trail infrastructure on the system, it's worth keeping in mind that it can be difficult to calculate standard costs for such a wide variety of trail assets. Also, these estimates do not include time for design, projected construction costs for new trails, or overhead costs (vehicles, OSMP buildings, etc.). It is considered industry standard for the annual operating budget for trail maintenance and repair to total approximately 3% of the total system replacement cost (Table 22).

Year of Estimate	Total Estimated System Replacement Cost	Annual Operating Budget	Percent Annual Operating Budget of Total Estimated Replacement Cost
2022	\$70 - 80 million	\$2.2 million	2.8 - 3.1%
2024	\$70 - 90 million	\$3.3 million	3.7 - 4.7%

Table 22: Estimated total system replacement costs for 2022 vs 2024 compared to annual operating budget.

The estimates presented here use the same cost per linear feet averages to allow trend comparison over time. However, concurrently with condition monitoring, staff have been using an asset management enterprise software called Beehive to improve work tracking and tracking of project costs. Future updates to trail cost estimates will use updated averages of linear feet project cost across condition categories and TMOs.

## Conclusion and Management Applications

This report highlights findings regarding trail conditions, emphasizing the need for ongoing monitoring, maintenance, and strategic management of infrastructure to meet visitor demands while ensuring environmental conservation. Future efforts should prioritize repairs and upgrades to the trail system, particularly focusing on high-use areas and areas with sensitive resources to inspire valuable experiences on OSMP lands and to foster accessibility.

Overall, trail work (reroutes and repairs) by staff and volunteers over the last twenty years has resulted in considerable improvements in systemwide trail conditions. However, OSMP manages a complex trail system with legacy trails that were not designed for long term sustainability along with aging trail infrastructure that has continued to deteriorate. Maintaining and repairing legacy trails inherently means diverting resources away from other work across the trail system which demonstrates why the improvement in the systemwide Trail Condition Index score between 2015 and 2023 is hard to achieve and is the result of significant trail work efforts. Additionally, the amount of designated trail infrastructure has increased meaningfully since the first condition survey in 2007 as past trail planning efforts are implemented and new planning efforts are adopted. Condition monitoring results have been helpful to better understand long term maintenance commitments when adding new trail and visitor infrastructure opportunities.

Continued focus on building new trails to sustainable standards is paramount to improving current and future conditions especially since trail grade appears to be the most determinant design factor for trail condition over time. Where reroutes of trails are not feasible and grades cannot be lowered on existing trails, preventative maintenance and installation of structures can be effective at mitigating development of problem features. However, trails with more structures require more time, effort, and cost to maintain. Additionally, some structures such as wood check steps require less time effort and cost to install but have shorter life-cycles, as is being realized in the WTSA. Stone structures often require more time, effort, and cost to install but also have much longer life-cycles and require significantly less maintenance over time.

Of the different types of trails managed by OSMP, Authorized Motor Vehicle (AMV) trails could benefit from expanded focus on routine maintenance. AMV trails are important for both management and emergency services, and many have index values in good condition due to rebuilds following the 2013 flood. However, many AMV trails experienced a notable decline in condition index between the 2015-17 and 2019-23 surveys and have high replacement costs justifying additional investment in routine maintenance to avoid large capital expenses.

Understanding long-term trends in overall condition and the specific condition of infrastructure helps us understand the cost of maintaining a wide and varied trail system in an urban-proximate environment that receives high visitation. Repairing and maintaining trails is incredibly labor intensive and therefore as labor costs increase, so too does the cost of doing business. Adding additional mileage also increases the overall maintenance and total system replacement costs but if sustainably designed, these new miles of trail will require less lifetime maintenance.

The results in this report represent an evaluation of trail condition from a management perspective specifically regarding trail sustainability and levels of maintenance and investment that trail infrastructure will need over time. Staff recognize that this evaluation may be surprising to many OSMP visitors because the experience of a trail is not always related to the condition of a trail. OSMP visitors have consistently rated OSMP trails as very good quality and extremely important over time. Additionally, most OSMP visitors reported their overall trip satisfaction as excellent or good in the 2021-2023 OSMP Public Opinion and Visitor Experience Survey.

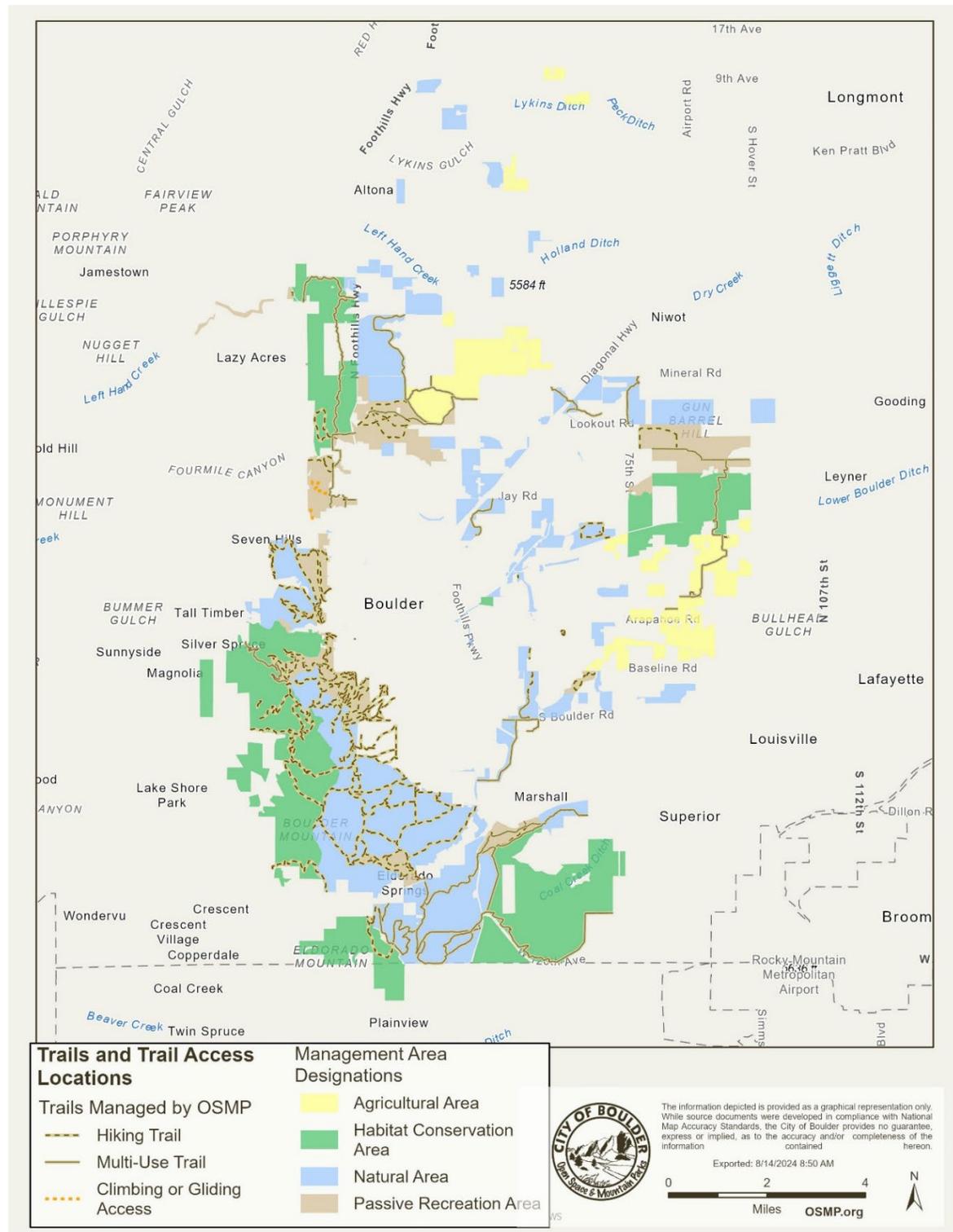
Designated trail condition monitoring will continue a five-year cycle to allow OSMP to track changes in trail condition over time, prioritize maintenance, and inform trail design and construction. The next trail condition report will be published in 2030.

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# Appendices

## Appendix A: Management Area Designations



Appendix A: A map showing the Management Area Designations as assigned by OSMP

## Appendix B: Hiker Trail Design Standards (TMOs)

Hiker/Pedestrian		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width		0-24"	12-24"	18-36"	24-60"	36-72"
Design Surface	Type	Native, ungraded, may be continuously rough	Native, limited grading, may be continuously rough	Native with some onsite borrow or imported material where needed for stabilization, occasional grading, intermittently rough	Native with improved sections of borrow or imported material, routine grading, minor roughness	Likely imported material, routine grading, uniform, firm, and stable
	Protrusions	≤24" Common and continuous	≤6" Common and continuous	≤6" Common, not continuous	≤3" Uncommon, not continuous	No protrusions
Design Grade	Target	0-25%	0-18%	0-12%	0-10%	0-5%
	Short Pitch Max	40%	35%	25%	15%	5%
	Max Pitch Density	0-40% of trail	0-30% of trail	0-20% of trail	0-20% of trail	0-5% of trail
Design Outslope	Target	3% - natural cross slope	3-20%	3-5% (or crowned)	3-5% (or crowned)	2-5% (or crowned)
	Max	3% - natural cross slope	25%	10%	10%	5%
Design Clearing (for woody vegetation, not for grasses / forbs)	Height	6'	6-7'	7-8'	8-10'	8-10'
	Width	≥ 24" Some vegetation may encroach into clearing area	24-48" Some light vegetation may encroach into clearing area	36-60" Some light vegetation may encroach into clearing area	48-72"	60-72"
Design Turn	Radius	No minimum	2-3'	3-6'	4-8'	6-8'

\* Determination of trail specific Design Grade, Design Surface, and other Design Parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall trail sustainability.

### Appendix B: Hiking Trail Class Designed Use Standards

## Appendix C: Biking Trail Design Standards (TMOs)

Bicycle		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width		6-12"	12-24"	18-36"	24-60"	36-72"
Design Surface	Type	Native, un-graded May be continuously rough Sections of soft or unstable tread on grades < 5% may be common and continuous	Native, limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common	Native with some onsite borrow or imported material where needed for stabilization, occasional grading Intermittently rough Sections of soft or unstable tread on grades < 5% may be present, but not common	Native, routine grading with improved sections of borrow or imported materials Stable with minor roughness	Likely imported material, routine grading Uniform, firm, and stable
	Protrusions	≤24" Common and continuous	≤6" Common and continuous	≤6" Common, not continuous	≤3" Uncommon, not continuous	No protrusions
Design Grade	Target	0-20%	0-12%	0-10%	0-8%	0-5%
	Short Pitch Max	30% 50% on downhill-only segments	25% 35% on downhill-only segments	15%	10%	8%
	Max Pitch Density	0-30% of trail	0-30% of trail	0-20% of trail	0-10% of trail	0-5% of trail
Outslope	Target	3-10%	3-5%	3-5% (or crowned)	3-5% (or crowned)	2-5% (or crowned)
	Max	10%	10%	10%	5%	5%
Design Clearing (for woody vegetation, not for grasses / forbs)	Height	6'	6-8'	8'	8-9'	8-9'
	Width	24 – 36" Some vegetation may encroach into clearing area	24 - 48" Some light vegetation may encroach into clearing area	36-60" Some light vegetation may encroach into clearing area	48-72"	60-72"
Design Turn	Radius	2-3'	3-6'	4-8'	8-10'	8-12'

\* Determination of trail specific Design Grade, Design Surface, and other Design Parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall trail sustainability.

### Appendix C: Biking Trail Class Designed Use Standards

## Appendix D: Equestrian Trail Design Standards (TMOs)

Equestrian		Trail Class 1	Trail Class 2	Trail Class 3	Trail Class 4	Trail Class 5
Design Tread Width			12 – 24" 48 – 60" or greater along precipices	18 – 48" 48 – 60" or greater along precipices	24 – 96" 48 – 60" or greater along precipices	
Design Surface	Type	Typically not designed or actively managed for equestrians, although use may be accepted	Native, limited grading, may be continuously rough	Native with some onsite borrow or imported material where needed for stabilization, occasional grading, intermittently rough	Native with improved sections of borrow or imported material, routine grading, minor roughness	Typically not designed or actively managed for equestrians, although use may be accepted
	Protrusions		≤6" Common and continuous	≤6" Common, not continuous	≤3" Uncommon, not continuous	
Design Grade	Target		0-20%	0-12%	0-10%	
	Short Pitch Max		30%	20%	15%	
	Max Pitch Density		0-20% of trail	0-20% of trail	0-10% of trail	
Design Outslope	Target		3-5%	3-5% (or crowned)	3-5% (or crowned)	
	Max		10%	10%	5%	
	Height		8-10'	8-10'	8-10'	
Design Clearing <small>(for woody vegetation, not for grasses / forbs)</small>	Width		48 - 72" Some light vegetation may encroach into clearing area	48 - 72" Some light vegetation may encroach into clearing area	48 - 96"	
	Radius		4-5'	5-8'	6-10'	
Structures	Bridge	Bridges without handrails: 48" Bridges with handrails: 60" minimum width	Bridges without handrails: 48" Bridges with handrails: 60" minimum width	Bridges without handrails: 48" Bridges with handrails: 60" minimum width		
	Steps	72" minimum length 8" maximum height	72" minimum length 8" maximum height	72" minimum length 8" maximum height		

\* Determination of trail specific Design Grade, Design Surface, and other Design Parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall trail sustainability.

### Appendix D: Equestrian Trail Class Designed Use Standard

## Appendix E: Authorized Motor Vehicle Trail Design Standards (TMOs)

Authorized Motor Vehicle		Class 1	Class 2 - Low development 4x4 routes / 2 tracks	Class 3 - Surfaced, graded, single lane, intended to accommodate 5 ton vehicles, equipment, and trailers	Class 4 - Surfaced, graded, two way traffic, intended to accommodate 10 ton vehicles, equipment, and trailers. Based on County private driveway standards.	Class 5
Design Tread Width	Single Lane	Typically not designed or actively managed for authorized vehicle, although use may be accepted.	6-10'	8-10'	10-12'	Typically not designed or actively managed for authorized vehicle, although use may be accepted.
	WITH Turn Out Areas		NA	Turn outs 8' wide, 60' long, located no further than 2000' apart. Dead ends must have turn around loop or hammerhead.	Turn outs 8' wide, 60' long, located no further than 2000' apart. Dead ends must have turn around loop or hammerhead.	
	OR Double Lane		NA	NA	16 -20'	
Design Surface	Type		Native, limited grading May be continuously rough Sections of soft or unstable tread on grades < 5% may be common	Imported materials for tread stabilization common, routine grading Minor roughness Sections of soft tread not common	Imported materials for tread stabilization with minimum 4" aggregate base course Class 6, routine grading Minor roughness Sections of soft tread not common	
	Protrusions		≤6" Common and continuous	≤6" Common, not continuous	≤2" Uncommon, not continuous	
Design Grade	Target		0-12%	0-12%	0-12%	
	Short Pitch Max		20%	14% for 200' max	14% for 200' max	
	Max Pitch Density		0-30% of trail	0-20% of trail	0-10% of trail	
Design Outslope / Inslope	Target		3% - natural cross slope	3-5% (or crowned)	3-5% (or crowned)	
	Max		natural cross slope	10%	10%	
Design Clearing (for woody vegetation, not for grasses / forbs)	Height	6-8'	8-10'	10-12'		
	Width	Tread width	Tread width plus ditch	Tread width plus ditch		
	Shoulder	NA	NA	2' on both sides of tread		
Design Turn	Radius	10'	20'	80'		
Structures (Bridges)	Structures (Minimum Width)	NA	10'	10'		
	Load (Tons)	NA	5	10		

\* Determination of trail specific design parameters should be based upon soils, hydrological conditions, use levels, erosion potential, and other factors contributing to surface stability and overall trail sustainability.

### Appendix E: Authorized Motor Vehicle Use Trail Class Designed Use Standard

## Appendix F: Accessible Trail Design Standards (TMOs)

Accessible*		FSORAG Outdoor Recreation Access Routes (ORAR)	FSTAG Wheelchair Accessible (WA)	Adaptive Mountain Bike (aMTB)	
Design Tread Width	Minimum	3ft	3ft	4ft	
	Passing Spaces	Trails less than 5ft will have passing spaces at intervals of 200ft maximum. Space must be 5ft x 5ft minimum (can be intersection of two trails if flat). Exception where a vehicular way serves as ORAR.	Trails less than 5ft will have passing spaces at intervals of 1000 ft maximum. Space must be 5ft x 5ft minimum (can be intersection of two trails if flat).	Trails less than 8ft will have passing spaces at intervals of 1000 ft maximum. Space must be 8'W by 12'L minimum (can be intersection of two trails if flat).	
Design Surface	Type	Firm and stable.	Firm and stable.	Compact and mostly stable, with some variability. Where soils permit, natural surface is preferable. Crusher fines are preferable to road-base.	
	Openings	Gaps in tread surface such as bridge decking must be small enough to prevent passage of a 1/2" diameter sphere. Elongated openings should be placed perpendicular to the dominant direction of travel.			
	Protrusions	1/2" maximum if paved or elevated. 1" maximum if natural surface, crusher fines or roadbase.	1/2" maximum if asphalt, concrete, or boards. 2" maximum if natural surface, crusher fines or roadbase.	4" maximum	
Design Grade	Target	0 - 5%	0 - 5%	0-8%	
	Short Pitch Max	10%	12%	15%	
	Maximum Pitch Density	Grades between 5 - 8.33% can run for 50' maximum.		Not more than 30% of trail length shall have grades steeper than 8.33%.	Not more than 20% of trail length shall have grades steeper than 8.33%.
		Grades between 8.33 - 10% can run for 30' maximum.		Grades between 5 - 8.33% can run for 200' maximum.	
				Grades between 8.33 - 10% can run for 30' maximum.	
			Grades between 10 - 12% can run for 10' maximum.		
Rest Intervals	Frequency	Where the grade is steeper than 5% the segment should have rest intervals at the top and bottom.			
	Length and Width	Rest intervals must be 5ft minimum length and be as wide as widest part of trail leading to the rest interval (or if adjacent to trail must be 3ft minimum width).	Rest intervals must be 5ft minimum length and be as wide as widest part of trail leading to the rest interval (or if adjacent to trail must be 3ft minimum width).	Rest intervals must be 12ft minimum length and be as wide as widest part of trail leading to the rest interval (or if adjacent to trail must be 4ft minimum width).	
	Grade	Resting intervals shall not be steeper than 3% in any direction. Where the surface is paved or is elevated above the natural ground, the slope shall not be steeper than 2% in any direction.	Rest intervals must have a 2% maximum grade and outslope (5% if necessary for drainage and if surface is other than concrete, asphalt, or boards).	Rest intervals must have a 2% maximum grade and outslope (5% if necessary for drainage and if surface is other than concrete, asphalt, or boards).	
Outslope	Target	2%	2%	2%	
	Max	3% if surface is not paved or elevated above the natural ground	5% if necessary for drainage and if surface is other than concrete, asphalt, or boards.	10% if surface is not paved or elevated above the natural ground.	
Clearing	Height	Constructed features, including signs, etc. shall not extend into the space above an ORAR more than 4 inches if they are between 27" and 80" above the surface.	NA	NA	
	Width	Gate openings and openings in barriers for pedestrian passage shall provide a clear width of 36 inches.	Gate openings and openings in barriers for pedestrian passage shall provide a clear width of 36 inches.	Gate openings and openings in barriers for pedestrian passage shall provide a clear width of 48 inches. Corridor clearing should maintain 8ft including tread and shoulder.	
Design Turn	Radius	NA	NA	20 - 25' see diagram	

\*Forest Service Outdoor Recreation Accessibility Guidelines (FSORAG) and Forest Service Trail Accessibility Guidelines (FSTAG) are based on the Outdoor Developed Area Accessibility Guidelines (ODAAG), supplement of the Architectural Barriers Act Accessibility Standards (ABAAS) developed by the Architectural and Transportation Barriers Compliance Board (U.S. Access Board). The aMTB design parameters were compiled by OSMF staff in 2022 based on a review of standards and best practices from other agencies.

### Appendix F: Accessible Trail Class Designed Use Standard

## Glossary of Terms

**Back wall:** Wall built to reinforce hillside above trail tread.

**Braiding (multiple-treads):** multiple treads separated by ground cover.

**Cattle Guard:** a metal grid shaped guard that runs over a ditch and prevents cattle and other animals from crossing but allows pedestrians or vehicles to pass over the ditch

**Causeway:** Retaining structure on trail edges to hold raised tread material.

**Check step- stone:** Individual step placed perpendicular to trail to prevent erosion.

**Check step- wood:** Individual step placed perpendicular to trail to prevent erosion.

**Climbing turn:** Change of direction on hillside without a platform.

**Corduroy:** Several logs buried or half-buried in tread perpendicular to trail through a low-lying area.

**Culvert:** A structure that allows water to flow under the trail

**Design Parameters:** Design Parameters: Technical guidelines for the survey, design, construction, maintenance, and assessment of a trail, based on its Designed Use and Trail Class.

**Designed Use:** The Managed Use of a trail that requires the most demanding design, construction, and maintenance parameters and that, in conjunction with the applicable Trail Class, determines which Design Parameters will apply to a trail.

**Designated Trail:** Trails which have a way-finding sign with a trail name and are maintained (City of Boulder, 2019).

**Ditch- bar:** Excavated channel running parallel to trail on both sides of trail

**Ditch-side:** Excavated channel running parallel to trail on one side of trail only.

**Drain dip (waterbar-unreinforced):** An excavated triangular area in the tread at a 45 degree angle to trail.

**Drainage Issue:** A feature recorded as a problem feature. Indicates pooling of water, or the presence of excessive mud leading to damage or other associated drainage issues.

**Ford:** Armored stream crossing

**French drain:** An excavated ditch alongside and across rail filled with rocks.

**Grade:** The rise of a trail over the length of a trail expressed as a percentage (Rise / Run).

**Grade Reversal:** Points along the trail where the trail grade descends from both directions.

**Legacy Trail:** A use pattern adopted by OSMP as a designated trail that was never built or designed.

**Managed Use:** A mode of travel that is actively managed and appropriate on a trail, based on its design and management.

**Obstruction - Tread:** A barrier such as a rock or log that impedes travel along a trail and exceeds design standards.

**Obstruction – Vertical:** A barrier such as a tree branch that is present with in the vertical clearing space assigned to each TMO.

**Outslope:** The percentage of rise to length when measuring the trail tread from edge to edge perpendicular to the direction of travel.

**Passive Recreation:** non-motorized activities that:

- Offer constructive, restorative, and pleasurable human benefits that foster an appreciation and understanding of Open Space [and Mountain Parks] and its purposes

- Do not significantly impact natural, cultural, scientific, or agricultural values
  - Occur in an Open Space and Mountain Parks setting, which is an integral part of the experience
  - Require only minimal facilities and services directly related to safety and minimizing passive recreational impacts
  - Are compatible with other passive recreational activities
- (City of Boulder, 2005)

**Puncheon:** Timber planks running parallel to trail set on mud sills to elevate tread. Puncheon is distinguished from bridges by low ground clearance.

**Problem Feature:** Problems such as erosion, trail braiding, drainage issues, or obstructions. Tracked and recorded in monitoring.

**Retaining wall- stone:** Stacked rocks built to reinforce trail tread

**Retaining wall- wood:** Tiered timber built to reinforce trail tread

**Soil Loss (Erosion):** A problem feature that indicates the evidence of damage to the trail tread from loss of soil.

**Staircase- stone:** Multiple stone steps structurally connected.

**Staircase- wood:** Multiple wood steps structurally connected.

**Stepping Stones:** Individual rocks placed in a low-lying area or stream for stepping across.

**Stone Paving:** Tread surface made up of set stones

**Structure:** Infrastructure built and maintained by OSMP

**Surface Firmness:** The firmness of the trail tread ( Paved, Hard, Firm, Soft, Very Soft)

**Surface Type:** The material that composes the tread of a trail

**Switchback:** Built structure to create a platform for a trail to switch directions on a hillside.

**Trail Class:** The prescribed scale of development for a trail, representing its intended design and management standards.

**Trail Condition Index:** A score from 0-100 indicating how closely a trail segment meets its assigned TMO.

**Trail Corridor:** The area on both sides of the centerline of a trail that includes the trail tread. Typically includes a vegetation clearing zone.

**Trail Grade:** The rise of a trail over the length of a trail expressed as a percentage.

**Trail Management Objective (TMO):** Documentation of the intended purpose and management of a trail based on management direction, including access objectives.

**Undesignated Trail Connection:** The point at which an undesignated trail leaves a designated trail

**Waterbar- stone:** An excavated triangular area in the tread reinforced by rocks at a 45 degree angle to the tread.

**Waterbar- wood:** An excavated triangular area in the tread reinforced by rocks at a 45 degree angle to the tread.

**Width:** The width of the trail surface on which visitors travel.