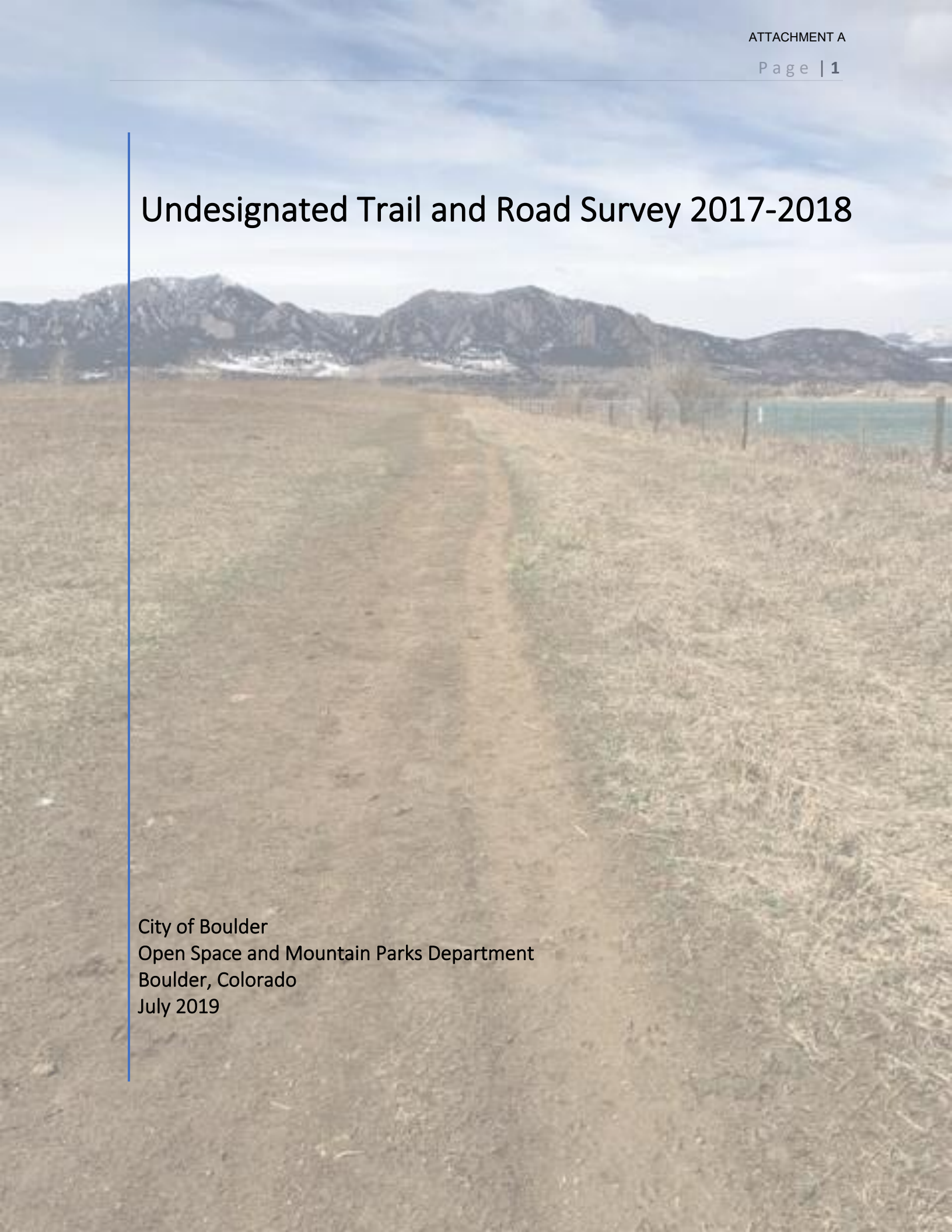

Undesignated Trail and Road Survey 2017-2018

City of Boulder
Open Space and Mountain Parks Department
Boulder, Colorado
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Executive Summary

Undesignated trails are pathways created by repeated visitor use that are sometimes referred to as social, unauthorized, informal or rogue trails. Undesignated roads are pathways created from repeated authorized motorized travel that can sometimes also be used for visitor travel. The 2005 Visitor Master Plan (VMP) suggested a management target of less than 50 system-wide miles of undesignated trails with zero new miles created. City of Boulder Open Space and Mountain Parks (OSMP) staff continue to monitor undesignated trails and roads to detect change over time. This report presents the results of the 2017-2018[1] survey effort and compares with the results from 2012[2]. Data presented in this report is also summarized in an interactive story map: https://arcg.is/0uHaGG .

Undesignated trails and roads were surveyed by recording GPS points at 200ft intervals and when pathway attributes changed. Information collected at each point includes condition, function, pathway type, and a photograph.

Key Findings:

- There were 164 miles of undesignated trails and roads mapped in the 2018 survey. Of the total mileage:
  - 101 miles were classified as undesignated trails,
  - 17 miles were classified as undesignated trails/roads and
  - 45 miles were classified as undesignated roads[3]
- The total linear extent of undesignated trails and roads has decreased by 14 miles since 2012 (178 to 164). This net change is calculated as follows:

45 new miles since 2012	−	59 miles restored, designated, or revegetated	=	-14 miles, a net loss of undesignated trails and roads

- 118 miles have remained in the same corridor through both surveys, though conditions may have changed.
- There were 91 miles of undesignated trails and roads mapped in 2018 classified as high impact, meaning they have no vegetation cover and active erosion.
- Of the 164 miles of undesignated trails and roads mapped in 2018
  - 58 miles were in Natural Areas
  - 39 miles were in Habitat Conservation Areas (HCAs)
  - 47 miles in Passive Recreation Areas
  - 12 miles in Agricultural Areas
- There were 68 miles located in the east where a trail area plan has not yet been completed.

[1] The 2017-2018 survey will be referred to as the 2018 survey throughout this document
[2] The study area has increased from 35,657 acres to 36,954 acres between surveys (Appendix B).
[3] Pathway types are defined in more detail on page 12

- 64 miles have either developed since completion of TSA planning or were not included in the scope of completed TSA plans
- In addition to total undesignated trail mileage, there were 166 “areas of concentrated use” identified, which are heavily impacted sites where significant areas of vegetation have been impacted and erosion observed.
- There are 347 sign structures with at least 460 signs found on undesignated trails and roads; 188 sign structures displayed regulations.

Broader Context and Implications:

Community engagement for the 2019 OSMP Master Plan revealed that managing undesignated trails continues to be important to the community and staff. The Master Plan has three strategies that are aimed at reducing the number of miles of undesignated pathways on OSMP lands:

EHR.4) REDUCE UNDESIGNATED TRAILS: Guided by best practices or area-specific plans, mitigate resource impacts by restoring, designating, re-routing or recategorizing undesignated trails, especially in sensitive habitat areas, while considering appropriate routes to serve desired destinations for visitors.

EHR.5) EXTEND ON-TRAIL REQUIREMENTS: Through future area planning, reduce off-trail travel in targeted locations, especially in sensitive habitat areas.

CCEI.2) ENHANCE COMMUNICATION WITH VISITORS: Foster discovery, enjoyment and stewardship through a coordinated effort to enhance signs, communications and media that incorporate effective design, messaging and languages for a range of audiences as well as increasing ranger and volunteer presence on the system to welcome and inform visitors.

The data provided in this report adds to the knowledge base for implementation of these strategies and the adaptive management of undesignated pathways. The following recommendations should be considered in efforts to improve how undesignated pathways are monitored and managed:

- Collect width measurements to better estimate the overall area of impact of undesignated trails.
- Monitor on a five-year cycle by trail maintenance zone (Appendix E) so that monitoring data can drive effective on-the-ground implementation.
- Develop an adaptive management approach to documenting and managing areas of concentrated use.
- Continue to develop an asset management database to integrate work tracking with monitoring.

- Improve our understanding of the management context for undesignated pathways that form after the approval of a TSA plan or that occur in areas without a TSA plan (i.e., the East TSA).
- Explore ways, such as through physical signage, to inform visitors on-site about which trails are undesignated.
- Create a protocol and develop criteria to evaluate the effectiveness of restoration efforts.

Introduction

Trails are an important infrastructure component of protected areas. Well designed and well-managed trails provide surfaces which can sustain substantial traffic and minimize visitor impact by concentrating traffic onto durable surfaces (Wimpey & Marion, 2011, Soulard 2017). Designated trails are designed and constructed to support recreational use while limiting impacts to natural and cultural resources. Repeated trampling, soil destabilization, loss of vegetation and topsoil from undesignated pathways can impact vegetation, and lead to a further fragmented and impacted land system. The creation of undesignated trails can also contribute to confusion among visitors, leading to further use and impact in areas not designed for visitor travel. On the other hand, undesignated trails and roads can also reveal unserved destination points that could be designed into the designated trail system.

The 2005 Visitor Master Plan (VMP) designated management areas intended to encourage visitor use in the locations that can provide a high-quality visitor experience and ensure compatibility of visitor use with natural, agricultural, and cultural resources. Management Area Designations (MADs) identified by the VMP include Habitat Conservation (HCAs), Passive Recreation, Natural, and Agricultural Areas. Habitat Conservation Areas have the highest priority for managing undesignated trail impacts and require permits for off trail travel[4]. In Passive Recreation, Natural, and Agricultural Areas on-trail travel is encouraged, but not required.

The OSMP department recently passed its first ever Master Plan, which guides future management strategies and aligns work priorities with community values. Engagement for the Master Plan in 2019 included a representative survey of city and county residents within the Boulder Valley Comprehensive Plan area. Two questions focused on undesignated trail management:

> Q1: New trails can be created when visitors try to reach destinations by going off trail or by using trails that are not officially managed by OSMP. In sensitive habitat areas, to what extent would you support or oppose OSMP closing unmanaged trails to better protect natural resources?

- 86% of respondents supported
- 12% opposed
- 3% didn't know

[4] Not all HCAs are activated. "Activated" means the HCA designation made in the VMP has formalized through an City ordinance; these include Eldorado Mountain, the Southern Grasslands, the Western Mountain, and Lower Boulder Creek. Other HCA have been recommended by the VMP but not formally approved by City Council; these include Tall Grass Prairie East, Jewell (note, this close to public access), Sombrero Marsh, and North Foothills. See https://www-static.bouldercolorado.gov/docs/osmp-mgmt-areas-map-1-201806291654.pdf

Q2: In sensitive habitat areas, OSMP currently requires visitors to stay on trail or seek a permit for allowable off-trail uses like educational research. To what extent would you support or oppose OSMP extending these requirements to stay on managed trails into targeted locations to better protect natural resources?

- 83% of respondents supported
- 9% opposed
- 7% didn't know

The recently adopted OSMP Master Plan includes two priority strategies in the Ecosystem Health and Resilience Focus Area aimed at managing undesignated trails:

- REDUCE UNDESIGNATED TRAILS (EHR4): Guided by best practices or area-specific plans, mitigate resource impacts by restoring, designating, re-routing or recategorizing undesignated trails, especially in sensitive habitat areas, while considering appropriate routes to serve desired destinations for visitors.
- EXTEND ON-TRAIL REQUIREMENTS (EHR5): Through future area planning, reduce off-trail travel in targeted locations, especially in sensitive habitat areas.

Guidance from the master plan places an emphasis on managing visitor travel and reducing the overall extent of undesignated trails on the OSMP system. The 2018 undesignated trails and roads survey aims to provide reliable data to inform planning processes and prioritization of restoration efforts as well as to evaluate effectiveness of management techniques.

Methods

The 2018 survey was designed to detect change over time when compared to the 2012 results. Both inventories used the same detailed criteria to define undesignated pathways and reduce inter-observer variability. Some changes were made to the methodology in 2018 to improve management recommendations and implementation of restoration and/or site design actions while not compromising comparability of the total length of pathways in 2012 and 2018.

Data Collection

Undesignated trails were mapped using a Trimble R1 GPS antenna connected by Bluetooth® to a cell phone that used ArcGIS Collector. The R1 provides real-time differential correction using a GNSS application with sub-meter accuracy. For higher levels of accuracy, the 2018 survey used the background GPS application Avenza Maps® to collect line data for digitization from point to line features. Points were taken at any point in a trail where condition or pathway type changed. If these factors were continuous, points were taken every 200 feet. Each point includes a photo of the undesignated road or trail. Photos were stored with the collected points in a related table so that they can be easily referenced. The 2012 undesignated trail survey utilized the Trimble GeoXT GPS units for the collection of data. Data was collected as points that were later digitized into lines using paper hand drawn lines for a reference. Undesignated trails and road like pathways were defined in the 2012 protocol:

- An undesignated trail is defined as a continuous linear or curvilinear pathway on the landscape that:

  1. Is not a designated trail;
  2. Is greater than 20 feet long;
  3. Has a continuous trail boundary on the earth's surface (i.e., width of disturbance stays relatively constant rather than appearing to be a series of foot, paw or hoof prints); and
  4. Has evidence of repeated use.

- An undesignated road is defined as a continuous linear or curvilinear pathway on the landscape that:

  1. Is not a designated trail or designated road;
  2. Is greater than 20 feet long;
  3. Is wide enough to accommodate a vehicle;
  4. Is connected to an access point that accommodates vehicles or to another drivable pathway (includes those off OSMP property);
  5. Is drivable or drivable with "some" maintenance; and
  6. Has evidence of repeated vehicle use.

- An undesignated trail/road pathway type primarily meets the criteria for an undesignated trail but has some evidence of vehicle use.

To more effectively inform management of undesignated pathways, the trail/road pathway type was classified by primary use in the 2018 survey. This differs from the 2012 survey, which determined the trail/road pathway type by presence of continuous boundaries (distinct edges). The change in pathway type definition means that the mileage in each pathway category is not comparable to 2012. The same pathways are captured in both surveys, but the 2018 classification allows for a separate project to begin that will determine which roads should be managed as permanent infrastructure and which roads should remain classified as undesignated pathways. The complexities of the pathway types make any analysis on the changes in specific pathway type's net linear extent challenging. However, the total extent of all pathway types is still comparable to the 2012 survey.

 Classified as an undesignated **trail/road** which is primarily used as a trail but has evidence of repeated vehicle use. Photo from 2018.	 Classified as an undesignated **road** that primarily shows signs of vehicle use. Not mapped in 2012. An example of a temporary access road for forest restoration work that will be closed and restored at the completion of the project. This is an example of an undesignated road that would be mapped in future surveys. Photo from 2018.	 Classified as an undesignated **road** that primarily shows signs of repeated vehicle use. An example of what will most likely be reclassified as a permanent (non-trail) authorized vehicle access road and removed from future undesignated pathway monitoring. Photo from 2018.

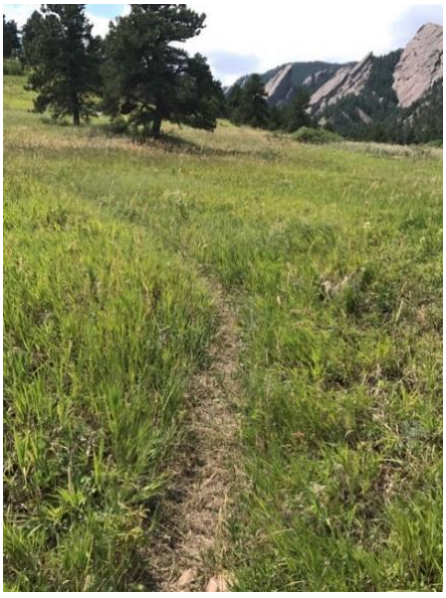
Figure 1: Demonstrates the complexities in comparing pathway categories from the 2012 and 2018 pathway categorization

Other changes to the 2012 methodology included:

- utilizing new technology for data collection to improve accuracy and efficiency

- identifying condition (see Fig. 2)
- photo point monitoring
- standardizing the format for undesignated trail segments which will allow for work prescriptions and tracking with asset management software
- identifying areas of concentrated use
- attempting to determine if trails were created and solely used by cattle

In addition to collecting location information, the 2018 survey collected condition data using condition classes adapted from Jeffery Marion et al. 2009:

	Class N – Recovering or emerging trail that does *N*ot meet mapping criteria (This class will not be used for trend analysis but will be used for trail and visitor management.)
	Class L (Low Impact) – Noticeably impeded vegetation growth; some vegetation cover loss; some organic litter pulverized within tread; some bare soil exposed; tread intact

	Class M (Moderate Impact) – Nearly complete or total loss of vegetation cover; nearly complete or total loss of organic litter within tread; bare soil widespread; tread mostly intact; some rills evident
	Class H (High Impact) – Vegetation and organic litter are rare or nonexistent within the tread; active tread erosion evident (indicated by exposed or undercut roots, loose or undercut rocks, gullying, rutting, widespread rills, incised tread, or sloughing banks)

Figure 2: Visual representation and description of condition classes

Condition class data can be used to further describe use patterns and trends on undesignated trails, but could also be related to unstainable grades, erodibility of soils, or sensitivity of vegetation.

Function data can provide information to make decisions on the management of undesignated trails. Trail functions included in this inventory:

- Cattle
- Climbing access
- Unserved visitor destination (viewpoint)
- Wildlife/Livestock (Note: When Selected with the addition of “cattle” in comments. There is no evidence of visitor travel)
- Historic (defined by visible bench cuts and grades)
- Community trail to neighborhood

- Shortcut
- Parallel trail to designated trail
- Water Access
- Other / unknown
- Other/ unknown road
- Agricultural road
- Fire road
- Ditch road

Constructed features were also recorded during the inventory. While not on a cyclic maintenance schedule, OSMP undesignated trails can have a wide variety of built features (built features are defined in the glossary of terms). The features collected include:

- Stone Paving
- Culvert
- Ditch – Bar
- Ditch – Side
- Waterbar – Unreinforced
- Waterbar – Stone
- Waterbar – Wood
- Nick
- Grade Reversal
- French Drain
- Check Step – Wood
- Check Step – Stone
- Staircase – Stone
- Staircase – Wood Crib
- Ford
- Stepping Stones
- Causeway – Wood
- Causeway – Stone
- Corduroy
- Puncheon
- Retaining Wall – Stone
- Retaining Wall – Wood
- Backwall – Stone
- Switchback
- Cattle Guard
- Bridge
- Other

In addition to these built features, points were collected for areas of concentrated use. Areas of concentrated use are areas that have trampled vegetation, bare exposed soil, loose or undercut rocks, exposed roots, and rills, but do not have continuous trail boundaries. No attempt was made to record the size of these areas, but future monitoring could include measurements.

Inventory Analysis

This section represents the core analysis of the data collected, and cross tabulates that mapping inventory with TSA plan recommendations.

Mileage of undesignated pathways: Net linear distance was calculated using ArcMap Summary tables. Condition class N trails were not counted in the total distance summary for analysis

since they were not digitally recorded in past monitoring. Net linear distance is an important measure to determine the general system-wide presence of undesignated trails. The same process was used to determine mileage in Trail Study Areas, Management Area Designations, and trail maintenance zones.

Trail Study Area plan undesignated pathways management recommendations: Using the completed TSA plans (Marshall Mesa/Southern Grasslands TSA, Doudy Draw/Eldorado Mountain TSA, North TSA, West TSA) management recommendations were assigned to undesignated pathways based on the management direction in the TSA plan. All trails in the East do not have recommendations assigned to them as a TSA plan hasn't been completed for the East. Additionally, any undesignated pathways that have developed since a TSA was completed were indicated as such.

Signs in proximity to undesignated trails: an inventory of all sign structures on OSMP lands took place in 2015. Using the sign data set created from this inventory, it was possible to select signs along an undesignated trail corridor. Each sign structure had associated sign types which could then be selected to get an approximate number of signs along undesignated trails.

Additional Analyses

Additional analyses were conducted to demonstrate how mapping results can be further extended, integrated, and applied.

Undesignated trails in sensitive areas: Using a City of Boulder Open Space and Mountain Parks GIS layer file that displays areas sensitive to ground disturbance, an analysis was run to determine how many miles of undesignated trails were located in areas sensitive to ground disturbance. Areas sensitive to ground disturbance was a layer created to determine response to wildfires, but also serves as a comprehensive layer of sensitive areas. The GIS tool "intersect" pulled segments of undesignated trails that were in sensitive areas. These areas include raptor closures, Preble's jumping mouse habitat, New Zealand mud snail closures, burrowing owl habitat, northern leopard frog breeding sites, prairie dog colonies, wetlands, rare plant species and communities, and cultural resources.

Undesignated trails in critical wildlife habitat: Using a GIS layer file that displays critical wildlife areas developed in the Boulder County Comprehensive Plan, an analysis was run that identified undesignated trails and roads that fell within the areas identified as critical wildlife habitat. The GIS tool "identify" pulled segments of undesignated trails that were in critical wildlife habitat. Critical wildlife habitat is a subset of the data used in the sensitive area's analysis.

Undesignated trails in rare and sensitive plan communities: Using a GIS layer file that displays rare and sensitive plant communities, an analysis was run that identified undesignated trails

and roads that fell within the areas identified as rare and sensitive plant communities. The GIS tool "identify" pulled segments of undesignated trails that were in rare and sensitive plant communities. Rare and sensitive plant communities is a subset of the data used in the sensitive area's analysis.

Grid Cell Density: The Identity tool was used in ArcMap with 300 x 300 meter grid cells. Cell size is based off cell sizes used in 2012 so that results from 2018 and 2012 could be compared. The tool breaks undesignated trails and roads at grid lines and adds a unique ID to each segment of trail that matches with the grid cell. Density is then calculated on a cell by cell basis where the length of undesignated trails and roads divided by cell area gives a grid cell density. Cell density can identify areas where undesignated trails are prevalent.

Kernel Density: The Kernel Density ArcGIS tool was used to determine the relative density of undesignated trails and roads and spatial variability of density across OSMP lands. Following the 2012 undesignated trail report as a guideline, the density was calculated using a search radius of 750 feet emanating from any undesignated trail or road segment. Results were then displayed in a grid of 50-foot cells. Cell size and search radius were based off cell sizes used in 2012 so that results from 2018 and 2012 could be compared. Kernel density is an analysis that can identify areas where undesignated trail density is relatively higher. Kernel density is a good visual representation of undesignated trail and road density, but the results are hard to qualify. A map can be found in the appendix (Appendix J).

Project Area Fragmentation: To determine how undesignated trails fragment continuous land blocks on OSMP lands, a GIS analysis was conducted. The analysis used designated trails, roads, and undesignated trails and roads along with OSMP property data. A "dissolve" tool was utilized on the properties to eliminate internal property boundaries creating larger land blocks. The trails and roads were then buffered by 40 feet on either side and erased from the project area. Buffers were based on 2012 parameters so that results from 2018 and 2012 could be compared. Species or habitat specific buffers could be changed depending on site-specific conditions. Using the explode tool the singular properties polygon was split up into smaller pieces by the buffered line features. The resulting map could then be compared visually and statistically to determine how much the undesignated trails fragment the project area.

Euclidean distance from trails or roads: A GIS analysis was run to measure the distance from a grid of points on OSMP lands are from the nearest designated trails, roads, and undesignated trails and roads. The Euclidean distance tool with 100 x 100 foot grid cells was used. Grid cells size was based on 2012 analysis so that results from 2018 and 2012 could be compared. The Euclidean distance tool determines the straight-line distance from the nearest trail or road.

Strava® heatmap comparison to undesignated trails data: Strava® is a fitness app that people use to track their fitness activities. Strava® collects users' miles, elevation, dates and times and

spatial location. Strava® then uses this data to produce a heatmap that displays the pathways people take in doing their fitness activities. The heatmap is updated monthly and displays a collection period of two years. A visual comparison between the undesignated trails displayed by condition class to Strava's heatmap shows that there could be some correlation to Strava® user patterns and the presence of social trails (Appendix P).

Trail work and undesignated trail connections: Using GIS, an analysis determined the number of trail connections per mile on OSMP designated trails. The analysis involved capturing all the undesignated trails that connect to designated trails and then calculating a ratio of undesignated pathway connection points and designated trail segment length. The analysis will be examined later in the discussion section.

Results

Inventory Analyses

Mileage of undesignated pathways

The total mileage of undesignated pathways from the 2018 mapping is 163.6 miles. The table below shows the breakdown of the mileage into the different pathway categories. Undesignated trail pathways make up much of the mileage (100.9 miles), with undesignated roads (45.4 miles) and undesignated trail/roads[5] making up the rest (17.3 miles) (Table 1).

Pathway	Mileage	Percent of Total
Trail	100.9	59.9%
Road	45.4	29.6%
Trail/Road	17.3	10.5%
Total	163.6	100%

Table 1: The table shows the total linear mileage of all pathway types of undesignated trails

An additional 9.3 miles of condition class N pathways were mapped during the survey that are not included in Table 1 because they do not have continuous trail boundaries and cannot be included in trend comparisons. However, Class N pathways help identify developing use patterns, recovering trail scars, or dispersed connection corridors between trails. The location and extent of Class N trails are relevant and integrated into information guiding ongoing management efforts.

Undesignated Pathways by Condition Class

Undesignated pathways were assigned a condition class during the inventory. The total mileage of undesignated trail mileage by condition classification can be found in Table 2.

Condition Class	Trail	Road	Trail/Road	Total
Class L (Low Impact)	17.1	10	5.5	32.6 (19.9%)
Class M (Medium Impact)	27.1	9	4.1	40.2 (24.6%)
Class H (High Impact)	56.7	26.3	7.7	90.8 (55.5%)
Total	100.9	45.4	17.3	163.6 (100%)

Table 2: Mileage by condition class

Additionally, of the 45 new miles of undesignated trails and roads mapped, the distribution of mileage by condition class was a very even split: Of new mileage, 35% of the trails and roads were recorded as condition class H, 30% were recorded as class M, and 35% were recorded as class L.

[5] Trails/Roads are trails that have evidence of visitor and vehicle travel or could accommodate a vehicle if accessible by a vehicle.

Undesignated Pathways by Function

Functions were ascribed to undesignated trails in the monitoring process. Table 3 displays the total mileage associated with each trail or road's primary function. Agricultural roads were the most common function of undesignated roads, unserved visitor destinations were the most common known function for undesignated trails. It should also be noted that 10.5 miles of undesignated trails were classified as being created and used by cattle and are listed under the wildlife/livestock trail function.

Trail Function	Mileage	Percent of Mileage
Other/Unknown	25.0	15.3%
Other/Unknown Road	21.4	13.1%
Agricultural Road	21.1	12.9%
Unserved Visitor Destination	19.0	11.6%
Parallel Trail	16.6	10.1%
Community Trail	15.9	9.8%
Shortcut	11.6	7.1%
Wildlife/Livestock	10.8	6.6%
Climbing Access	6.4	3.9%
Ditch Road	5.6	3.4%
Other/Unknown (View)	5.0	3.1%
Water Access	4.0	2.4%
Fire Road	0.9	0.5%
Historic	0.3	0.2%

Table 3: Total linear extent of Undesignated trails by trail function

Undesignated Pathways and Trail Study Areas

Trail Study Areas (TSAs) divide OSMP into four geographic planning regions: North, West, South, and East (Appendix F). Of these regions the West and East have the most total mileage of undesignated pathways (Table 4). The West has the most mileage of undesignated trails while the East has the most mileage of undesignated roads.

Year	Mileage 2012	Mileage 2018	Change
North	30.2	21.9	-8.3
West	56.1	53.9	-2.2
South	24.4	23.8	-0.6
East	66.6	63.6	-3.0
Not in TSA	0.5	0.5	0

Table 4: Total mileage by TSA

Undesignated Pathways and Trail Study Area Plan Recommendations

Thirty-eight miles of recently surveyed undesignated trails and roads have specific management direction from a TSA plan. This includes almost 27 miles of undesignated trails

and roads to be closed and restored. Another 13 miles of undesignated trails and roads are recommended to be designated and on-the-ground management actions have yet to occur so they can be designated. There are an additional 63.8 miles of undesignated pathways that do not have management guidance from a TSA plan either because of emergence of the pathway after TSA plan completion, the trail was not included in the inventoried data for the TSA plan or the plan did not include a management recommendation for the undesignated pathway. The East TSA area where a plan has not been completed contains 67.2 miles of undesignated pathways. Condition Class N pathways are included in this table because some have recommendations assigned to them.

TSA Plan Management Recommendation	Mileage
Designate	13.0
Restore/Close	27.3
Retain	1.7
Undesignated pathways in areas with no TSA Plan guidance (East Area) *Labeled in map as Not in Plan	67.2
Undesignated pathways within completed TSA plans that do not have specific management direction or have emerged since plan completion. *Labeled in map as Not in Plan	63.8

Table 5: Undesignated Trail and Road Mileage and TSA Plan Management Recommendations

Mileage by Management Area Designation

The Visitor Master Plan (2005) provides guidance on the Management Area Designations for OSMP properties (Appendix A & D). Each management designation has recommended strategies for guiding the management of undesignated trails. It should be noted that not all HCAs are active and require on-trail travel[4] (see pg. 9). Natural Areas contain the highest mileage of the four management areas (Table 7) while Passive Recreation Areas contain the highest ratio of miles per acre.

	Year	Mileage	Percent of Total Mileage	Percent of Total OSMP Acres	Miles/Acre
Agricultural Areas	2012 Total	15.6	8.8	10.2	0.9
	2018 Total	12.3	8.0	10.0	0.8
Habitat Conservation Areas	2012 Total	39.8	22.4	38.7	0.6
	2018 Total	38.7	23.8	40.1	0.6

Natural Areas	2012 Total	60.7	34.2	36.3	0.9
	2018 Total	58.1	35.5	35.6	1.0
Passive Recreation Areas	2012 Total	50.7	28.5	12.4	2.3
	2018 Total	47.3	28.5	12.0	2.4
OSMP Properties that don't yet have a management area designation	2012 Total	10.9	6.1	2.3	2.7
	2018 Total	7.3	4.2	2.3	1.8

Table 6: Total mileage of undesignated trails by management area designation

Undesignated Pathways Built Features

Some undesignated trails and roads have had infrastructure built on them. Table 8 displays the total numbers of each type of built feature found on undesignated trails (Appendix G). The most common features found on the system are wood check steps.

Feature	Count
Check Step – Wood	208
Check Step – Stone	127
Culvert	90
Retaining Wall – Stone	55
Staircase – Stone	31
Bridge	29
Waterbar - Wood	29
Waterbar – Stone	19
Other	19
Drain Dip (Waterbar – Unreinforced)	17
Staircase – Wood Crib	8
Backwall – Stone	7
Grade Reversal	4
Nick	4
Retaining Wall – Wood	4
Ditch – Side	3
Stone Paving	2
Switchback	2
Cattle Guard	1
Ditch – Bar	1
French Drain	1
Stepping Stones	1
Total	662

Table 7: Total counts of built features occurring on undesignated trails

Signs in Proximity to Undesignated Pathway

Currently there are 347 sign structures with at least 460 signs[6] within 10 feet of undesignated trails and roads. Of these signs, 188 structures include regulatory signs.

Sign Type	Count	Percent of Total
Regulatory - Dog	82	17.8
Wayfinding/Directional	59	12.8
Regulatory – Limited Access/Closure	51	11
Restoration	46	10
Regulatory - Bike	40	8.7
Informational	34	7.4
Property Boundary	25	5.4
HCA Boundary	23	5.0
Other	17	3.7
Interpretive	15	3.3
Parking	15	3.3
Regulatory – Rules and Regs	15	3.3
Livestock	13	2.8
Maps	13	2.8
Regulatory - Horse	5	1.1
Fee	4	0.8
Ditches	2	0.4
Compost	1	0.2
Trailhead ID	1	0.2
Total	460	100

Table 8: Numbers of sign types along undesignated trails and roads

Areas of Concentrated Use

The survey found 166 areas of concentrated use which vary in size but are areas that have been heavily impacted. (Appendix H)

Additional Analyses

Undesignated Pathways in Sensitive Areas

Almost half, 46.5%, of undesignated trails and roads are in sensitive areas[7] (Appendix O). Also 17.6% of undesignated trails and roads are in critical wildlife habitat using Open Space and Mountain Parks GIS layers. Another 18.7% of undesignated trails and roads are in rare and

[6] The sign inventory provides information on types of signs found on sign structures but not the total number of individual signs. For example, if there are 3 regulatory signs on a structure the inventory records that there are regulatory signs, not how many.

[7] Sensitive Areas defined in methods section on Pg. 16

sensitive plant communities. An additional 8.7% of undesignated trails and roads are located in wetlands. Critical wildlife habitat, rare and sensitive plant communities, and wetlands are subsets of the sensitive area's dataset.

Resource Type		Mileage	Percent of total Study Area Acreage
Undesignated Pathways in Sensitive Areas		74.7	49.9
Subset of sensitive areas dataset	Critical Wildlife Habitat	28.2	22.7
	Rare and Sensitive Plant Communities	30.7	22.8
	Wetlands	14.3	10.7

Table 9: Total Mileage of undesignated trails and roads in sensitive areas *(Sensitive Areas include raptor closures, Preble's jumping mouse habitat, New Zealand mud snail closures, burrowing owl habitat, northern leopard frog breeding sites, prairie dog colonies, wetlands, rare plant species and communities, and cultural resources.)*

Undesignated Pathways Grid Cell Density

The density of undesignated pathways ranges from 0 to 2733 feet per acre, as analyzed in 300 x 300 meter grid cells across the OSMP system (Appendix I). The average density of undesignated trails was 32.9 ft/acre. A majority, 1,471, of grid cells had a density of zero feet per acre, and 581 (24%) grid cells have a density of 37 feet per acre or more. Of the 2,436 grid cells, 1,519 (62%) were partial cells (≤ 22.23 acres), partial cells could skew results in showing higher densities. The average cell size was 15.17 acres. A better visual tool for viewing undesignated trail density is the kernel density map (Appendix J).

The following areas had the highest densities of undesignated trails and roads: Saddle Rock, Crown Rock, Red Rocks, NIST, NCAR, the Richardson I property, Sawhill Ponds, Dry Creek trail, and the Steinbach property.

Euclidean (straight line) Distance

Undesignated trails further fragment land that contains designated trails or roads. Euclidean distance is the straight-line distance between two points in space. When only designated trails and roads are used in determining unfragmented areas, the average distance any point is from a trail or road is 749 feet (Figure 3) and the distance any point is from a trail or road ranged from zero to 4,500 feet. When adding undesignated trails and roads into the analysis, the average distance any point is from a trail or road drops to 506 feet (Figure 3) and the distance any point is from all trails or roads ranges from zero to 3,585 feet.

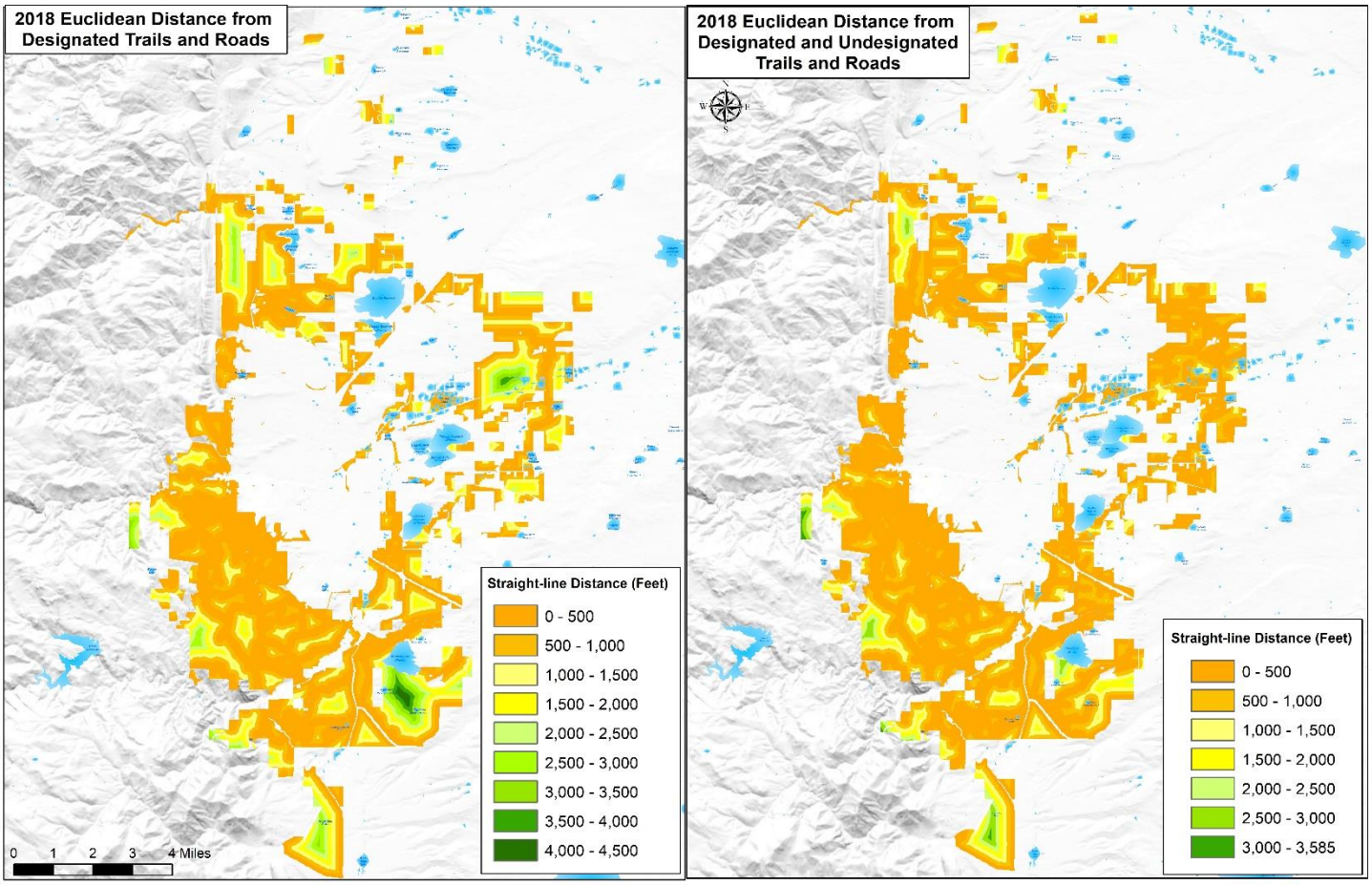


Figure 3: A comparison of Euclidean distance analysis with (right) and without (left) undesignated trails included

Project Area Fragmentation

Including only designated trails and roads

When only including designated trails and roads in the fragmentation analysis, the average area of continuous land is 74 acres. A total of 85.5% of the OSMP system has a total area less than 100 acres before being interrupted by a trail or road. An additional 14.5% (69 of

476 polygons) have a total area of 100 acres or more. Only 3.8% (18 of 476 polygons) have a total area greater than 500 acres (Appendix L).

Including designated and undesignated trails and roads

The largest remaining trail free area, without trails or roads of any designation, is 2,326 acres. The average area of land block is 26.13 acres. Only 1% (13 of 1,321 total polygons) have an area greater than 500 acres. Only 5.6% (74 of 1,321 polygons) have an area greater than 100 acres. Most, 94.4% (1,247 of 1,321 polygons), of the OSMP system has a total area less than 100 acres before being interrupted by a trail or road. (Appendix K)

Strava® Heatmap

A comparison of the pathways evident from Strava heatmap shows some similarity to the pathways mapped in this study (Appendix P).

Discussion

Changes in Mileage

The mileage of undesignated pathways is 163.7 miles, a reduction of 14 miles from 2012. This reduction in undesignated pathway mileage could reflect the efforts to increase focus on undesignated trail management. While the mileage of undesignated trails and roads has decreased since 2012, there are still many new trails developing on OSMP land.

There were 45.3 miles of 2018 mapped undesignated pathways that do not fall within the corridor of a 2012 undesignated pathway and are considered new. Another 59.3 miles mapped in 2012 do not fall within the corridors of pathways mapped in 2018 and this could indicate either successful closure and restoration of a trail or the designation or construction and rerouting of trails that were formerly considered undesignated. More trails have disappeared than have been created since 2012. Of the 45 miles of new trails, condition classes are evenly split between class H, M, and L indicating that there may not be a direct link between the impact levels and the length of time a trail has existed. An additional 118.4 miles has remained within the same corridor since 2012. OSMP staff are currently developing an asset management system to track work and evaluate success of future management actions related to undesignated trails.

Undesignated pathways can ecologically fragment the landscape and have the potential to negatively impact the natural, cultural and recreational resources that OSMP strives to protect under direction of the City charter. Undesignated trails also have the potential to detract from, or enhance, the quality of visitor experiences. The extent of undesignated trails also speaks to visitor travel patterns not met by the designated trail system and the need for ongoing community involved planning processes to develop well designed infrastructure to unserved destinations. The dynamic nature of undesignated trails makes it difficult to capture management recommendations in static snapshot planning efforts. Developing criteria to define when public engagement is needed prior to closure and restoration of undesignated trails, could be helpful.

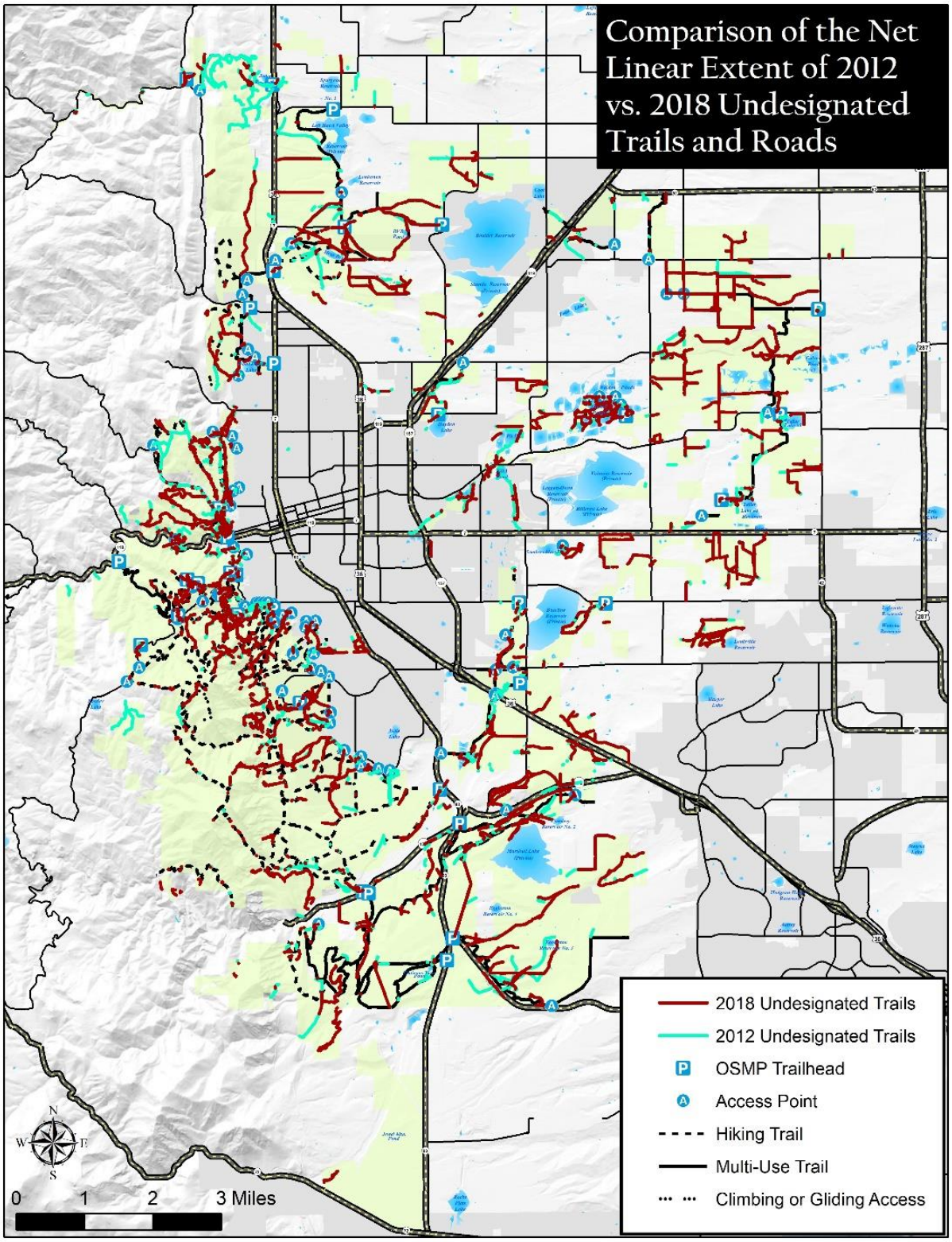


Figure 4: Map of the comparison of 2012 and 2018 undesignated trails and roads

Condition Class of Undesignated Pathways

The 2012 survey did not include the condition classes of undesignated pathways, so no change in condition can be interpreted. In 2018, the largest proportion of undesignated trails and roads are condition class H (High Impact). Trails and roads classified as condition class H could show that undesignated pathways could have established long-term use patterns or that trails are in unsustainable alignments vulnerable to erosion impacts. There are many factors that could play into condition class. Trails with slopes above 12%, generally have more soil loss (Marion, Hocket 2008), so undesignated trails on steep slopes could be categorized as class H with relatively low levels of use. Additionally, trails under forest canopy could appear to have higher levels of impact because the shading, soils and sparse vegetation cover under canopy may show impact with lower levels of trampling (Marion, Cole 1996).

Undesignated trails and roads classified as class L (Low Impact) and M (Medium Impact) have similar mileage in the 2018 inventory. It's difficult to infer change from condition class L and M trails and roads without prior condition class information. These condition classes could represent developing use patterns, or they could inversely show declining use patterns. Trend information from future studies will inform level of change and where impacts are increasing versus declining.

Undesignated Trails in Trail Study Areas

Most of the 2018 surveyed undesignated trails and roads (76%) were not included in TSA plans. Perhaps this is because TSA plans represent a snapshot in time when some of the undesignated pathways had not yet developed or they were not included in the inventory for the TSA plan. For the entire eastern part of the OSMP system, the East TSA plan has not been completed, explaining roughly half of the trails that have no recommendation assigned to them in a TSA. A total of 45 miles of undesignated trails have developed since the 2012 survey, representing their dynamic nature. After a TSA plan's completion, emergent trails are intended to be restored and closed unless staff determine restoration will not be successful without additional community engagement. Possible reasons to recommend further community engagement include unserved visitor destinations like climbing areas or viewpoints that may benefit from designated trail access. Another example would be undesignated trails where staff consider restoration work would not be successful without regulatory change to restrict or permit off-trail travel.

It should also be noted that 13 miles of undesignated pathways are slated to be designated in completed TSA plans. This mileage represents pathways that have been identified as future designated trail corridors but have yet to have site-design or construction to establish a sustainable alignment.

Undesignated Pathways by Management Area Designation

OSMP has differing management strategies for each Management Area outlined in the 2005 VMP. Passive Recreation Areas, Natural Areas, and Agricultural Areas all have very similar language as to the goals of undesignated trail management; to eliminate undesignated trails

when they are redundant or damaging resources. The strategy for HCAs is to eliminate all undesignated trails, unless they are made a part of the designated trail system or provide access to appropriate low use destinations. HCAs have the highest priority for managing undesignated trails and have the lowest ratio of miles to acres of the management areas. Most HCAs are regulated to have no unpermitted off-trail travel which may account for the lower ratio of miles to acres. However, HCAs are also often further from access points which could also be an explanation for the lower ratio. As OSMP staff continue to develop the undesignated trail stewardship program, Management Area Designations will continue to be an important tool to prioritize restoration efforts along with a suit of additional considerations.

Areas of Concentrated Use

Figure 5: An example of an area of concentrated use

A common impact found on the OSMP system are areas of concentrated use. 166 areas of concentrated use were recorded during the 2018 undesignated trail and road survey (Appendix H). These areas meet some definitions of a trail, (trampled vegetation, bare exposed soil, loose or undercut rocks, exposed roots, etc.) but do not have continuous trail boundaries. Areas of concentrated use tend to cluster around high visitation areas with most occurring in the larger Chautauqua area and on Mount Sanitas trail.

These areas do not count toward total undesignated trail mileage, but they do indicate heavy visitor use and impact. Many of these areas are also viewpoints or rest areas indicating a potential visitor desire for formalized and managed viewpoint destinations to mitigate impacts.

Signs on Undesignated Pathways

The 2012 OSMP Undesignated Trail Survey found 449 signs on undesignated trails. Sign inventory data in GIS shows that currently there are 347 sign structures with at least 460 signs[8] within 10 feet of undesignated trails. The 2012 study collected signs as a feature during the

[8] The sign inventory provides information on types of signs found on sign structures but not the total number of individual signs. For example, if there are 3 regulatory signs on a structure the inventory records that there are regulatory signs, not how many.

undesignated trail survey, while the 2018 survey relied on a separate sign survey and an updated live signs dataset. Of these signs, 188 are regulatory signs compared to 190 in 2012. Regulation signs on undesignated trails can create the perception that an undesignated trail is a designated trail.

Figure 6: Picture of a regulatory sign on an undesignated trail

In order to curtail the use of undesignated pathways, the 2019 OSMP Master Plan includes an increased effort by staff to improve practices on signage informing visitors on the difference between an undesignated and designated trail. A 2015 survey partnering with Leave No Trace revealed that 40% of respondents indicated that they always stay on a designated trail despite being observed using an undesignated trail (Lawhon et al. 2016). Signing regulations on undesignated trails likely contributes to visitor confusion.

Undesignated Pathways in Sensitive Resource Areas

As undesignated pathways are not planned or formally established, they are poorly located with respect to resource protection needs and that off-trail users will not recognize or attempt to avoid sensitive flora and fauna (Wimpey & Marion, 2011, Soulard 2017). It was found that nearly half of all undesignated trails and roads are in sensitive areas, highlighting the impact undesignated trails and roads have on sensitive resource areas. Sensitive areas are defined by a GIS layer including raptor nests, Preble's meadow jumping mouse habitat, prairie dogs, New Zealand mud snail closures, wetlands, rare plants, rare plant communities, cultural resources, and historic structures. The layer that includes all these sensitive areas encompasses 50% of the study area, so the high percentage of undesignated pathways in sensitive areas is also a result of sensitive areas comprising a large portion of the system, rather than an overabundance of undesignated trails and roads in sensitive areas.

Further looking into undesignated pathways in sensitive resource areas, 17.6% of undesignated trails and roads occur in critical wildlife habitat and rare and sensitive plant

species. These areas are subsets of the larger sensitive areas data. Some research has been done looking into wildlife reactions to off-trail travel. Many studies have indicated that wildlife species have more intense reactions to spatially unpredictable activities, such as undesignated trail use (Hamr, 1988; MacArthur et al., 1982; Miller et al., 2001; Schultz & Bailey, 1978; Soulard, 2017; Taylor & Knight, 2003). While true of all undesignated pathways, the unpredictable human presence in critical wildlife habitat is particularly concerning. Additionally, 18.7% of undesignated trails and roads fall in rare and sensitive plant communities. Trails in critical habitat and rare and sensitive plant communities could be prioritized for management action. OSMP ecological staff have also identified riparian and wetland areas as being priority areas for closure and restoration of undesignated trails.

Density of Undesignated Pathways

Visually the density of undesignated trails and roads looks very similar from 2012 to 2018. The density of undesignated trails and roads is generally higher the closer you are to a trailhead or access point (Appendix J). The cell densities suggest that undesignated trails and roads are more localized to certain problem areas, rather than an evenly distributed problem throughout the study area. There are large areas of the OSMP land system which have very low densities of undesignated trails. It should also be noted that the study area increased from 35,657 acres to 36,954 acres, a 6% increase, which is proportionate to the decreased average cell density, a 5% decrease.

The majority of OSMP land has less than one foot of undesignated pathways per acre. This indicates is that the 163 miles of trails are clustered in less than half of the actual land. Sites can be identified, using the grid cell density analysis, where restoration work could have the largest impact such as the Saddle Rock/Amphitheater area near Chautauqua.

Euclidean Distance and Undesignated Pathways

The areas of the system where the distance from trails or roads is the greatest remains mostly unchanged from 2012 to 2018 (Figure 7). The greatest distance from a road or trail remained similar from 3,609 feet in 2012 to 3,585 feet in 2018. Additionally, the average straight-line distance remained similar from 493 feet in 2012 to 506 feet in 2018 (Figure 7). Finding similar analyses for urban open space park systems proved difficult. It is possible that the OSMP land system does provide more areas with a high distance from trails and roads compared to other urban proximity land conservation agencies. OSMP staff can use this data to help identify and protect the areas that have less disturbance from human presence.

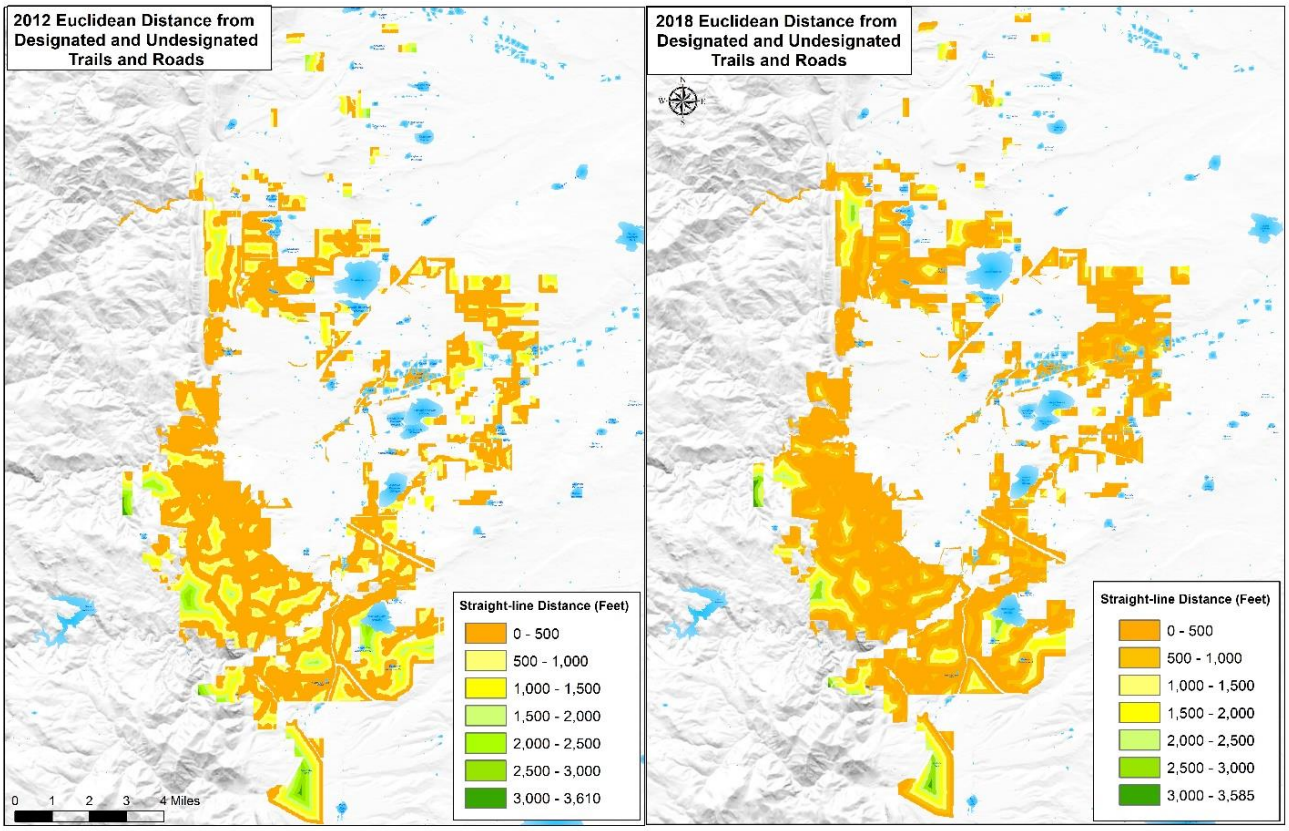


Figure 7: A comparison of 2012 (left) and 2018 (right) Euclidean distance analyses

Undesignated Pathways Land Fragmentation

There is increasing evidence that seemingly non-consumptive, low-impact activities such as hiking, cross-country skiing and bird watching along recreational trails could negatively affect wildlife (Soulard 2017; Taylor and Knight, 2003). The degree to which trails act as ecological edges, reducing the suitable habitat for some wildlife, is contingent upon the arrangement of trails in a network and the use level and use type on the trails. Moreover, not all wildlife species respond to trails and trail use in the same way; response types include attraction, aversion, and habituation. Undesignated trails and roads can further fragment an already fragmented land system by designated trails and roads. A GIS analysis split OSMP lands into fragments based on trail and road locations. When using only designated trails and roads in the analysis there were 476 polygons that had an average area of 74 acres. When inputting undesignated along with designated trails and roads as fragmenting lines, OSMP land was fragmented into 1,321 polygons with an average size of 26.13 acres (Figure 8). Visitor use patterns can greatly reduce the size connected land, leaving smaller and smaller congruous areas of open space. When considering undesignated roads and trails, there are almost three times the number of polygons indicating a more fragmented landscape. It should be noted that not all trails and roads have the same use patterns. Trails and roads that have much higher volumes of use are likely to provide greater barriers to land connectivity while low volume trails may have a lesser

effect. The OSMP land system does provide five connected land areas with a size of over 1,000 acres despite the high amount of visitation and proximity to an urban area.

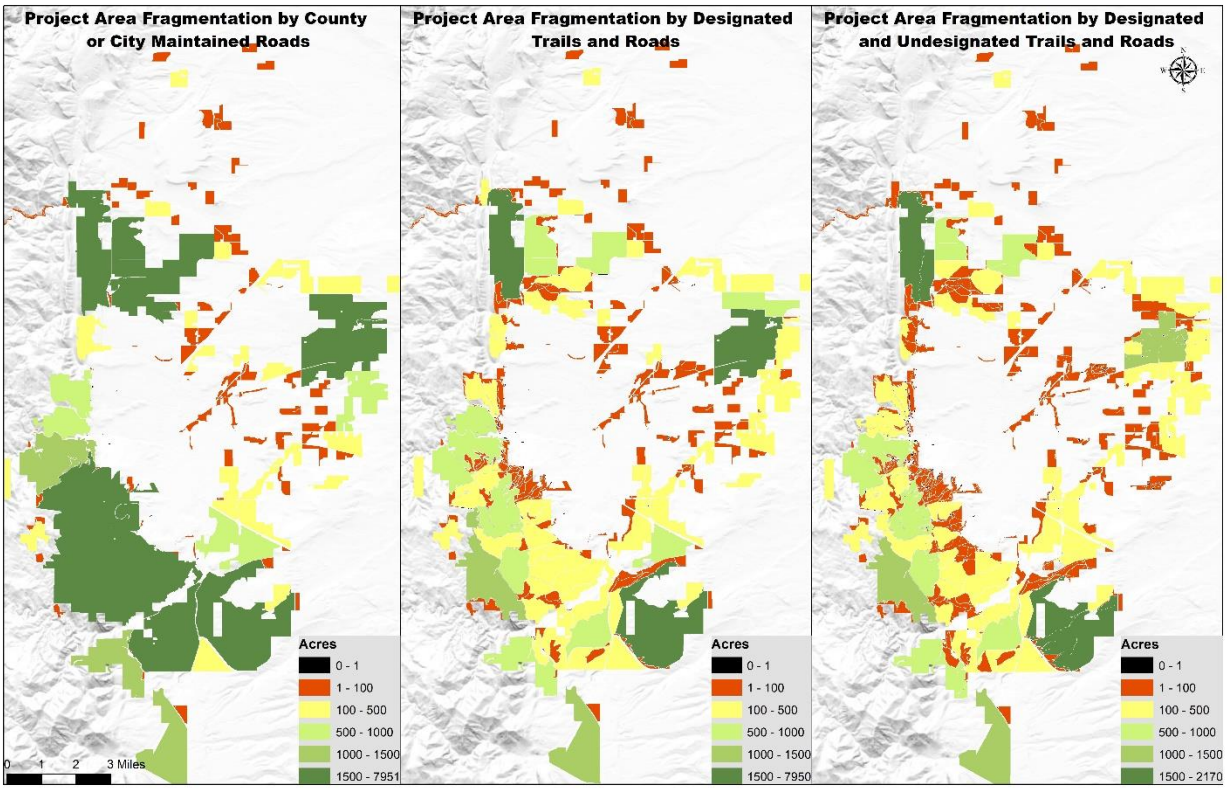


Figure 8: A comparison of land fragmentation when including trails and roads

Project area fragmentation was also analyzed in 2012. The survey found that OSMP lands were split into 1,101 unfragmented polygons with an average size of 29.58 acres. So, although there is an observed decrease in mileage of undesignated trails and roads between 2012 and 2018, there is an increase in land fragmentation. Decreased mileage with increased fragmentation could indicate some “hot spot” areas of fragmentation. Further research could provide insight into this change in conditions.

Further analyses with different parameters based on species habitat and avoidance or non-avoidance to trails, could provide further insight into the affect trails have on species specific habitat fragmentation.

Undesignated Roads

Figure 9: An example of an undesignated road that will likely be reclassified as a permanent service road

Close to 30% of undesignated pathways are undesignated roads. Some of these roads are caused by temporary operational access and should be restored or managed as undesignated roads. Other undesignated roads (driveways, utility access, ditch maintenance, farm access roads, etc) are not managed for visitor access and are currently classified as undesignated roads but should instead be designated as service roads when there is a permanent need for vehicle access. Figure 1 is a common example of a permanent undesignated road. OSMP staff are currently identifying these permanent non-recreation roads in order to assign management objectives and maintenance cycles. These permanent service roads will not be included in future undesignated trail monitoring which will reduce the reported systemwide mileage. Not all the roads mapped in the survey will be classified as permanent. Some roads mapped in the survey are undesignated and will continue to be classified and managed as undesignated.

Strava® Heatmap

Strava® is a fitness app that people use to track their fitness activities. Strava® collects users' miles, elevation, times and spatial location. Strava® then uses this data to produce a heatmap that displays the pathways people take in doing their fitness activities. Strava® is updated monthly and displays a collection period of two years so recent use patterns are shown. A visual comparison between the undesignated trails displayed by condition class to the Strava® heatmap shows that there could be some correlation to Strava® user patterns and the presence of social trails (Appendix P). Generally, the greater the impact on an undesignated trail, the higher density of use there is in the Strava® heatmap.

There are limitations to using the Strava® data. First, Strava® users are likely only a subset of OSMP visitors. Another limitation is that Strava® does not explain the specific numbers behind the density of the lines in the heatmap. It is difficult to say how much more use a thick line in the heatmap sees versus a thin line in the heatmap; however, partnering with Strava® may allow access to this information.

Despite these limitations, Strava® could be used as a predictive management tool to see what new trails might be developing. If a trail is restored, it would also be expected that the trail sees less use and the "heat" of the line would greatly diminish over time. A study using

similar methods to the ones used in this analysis suggests using Strava® as a first step in the process of deciding where monitoring efforts should be employed (Rice et al. 2019). Additionally, Strava® could help during the next survey when determining what trails are cattle created with no human use, and what trails sustain visitor travel. While the Strava® maps cannot be used quantitatively, unless more information is acquired from Strava® through a partnership, they can be used qualitatively as a management tool.

Trail Work and Undesignated Pathway Connections

The trails stewardship group at OSMP has begun to incorporate and prioritize undesignated trail closure and restoration around trail projects. Some projects have undesignated trail closure and restoration in the scope of the project, and some do not. To try and understand the effect of having undesignated trail closures in the scope of a trail project an analysis was run measuring the number of undesignated trail connections on trails. Understanding the relative number of undesignated trail connection points could help in site design.

Trail projects that used a holistic site design approach included the Lion's Lair trails, Long canyon trail, and the Chautauqua meadows trail. These trails had very low numbers of undesignated trail connections with four, zero, and one respectively. As a comparison there are several trails that had work done on them with minor restoration of undesignated trails in the scope of the project including the Shanahan trails. The south fork of the Shanahan trail has 11 connections the North Fork has 13 and the connector has seven.

While connection points do not tell the whole story of undesignated trails as they relate to trail work, they do show the potential progress that can be made towards the restoration of undesignated trails. When trails are being reconstructed or re-routed, the closure and restoration of undesignated trails could help to resolve some of the impacts of undesignated trails seen on OSMP lands. Additionally, monitoring the number of undesignated trail connections can help evaluate long term effectiveness of site designs so future trail work can be informed by previous effective management strategies.

The connections analysis map could highlight trails that are "hot spots" for undesignated trails and can help prioritize trail work (Appendix Q).

Broader Context and Implications

Community engagement for the 2019 OSMP Master Plan has revealed that managing undesignated trails continues to be important to the community and staff. The Master Plan has three strategies that are aimed at reducing the number of miles of undesignated pathways on OSMP lands:

> EHR.4) REDUCE UNDESIGNATED TRAILS: Guided by best practices or area-specific plans, mitigate resource impacts by restoring, designating, re-routing or recategorizing undesignated trails, especially in sensitive habitat areas, while considering appropriate routes to serve desired destinations for visitors.
>
> EHR.5) EXTEND ON-TRAIL REQUIREMENTS: Through future area planning, reduce off-trail travel in targeted locations, especially in sensitive habitat areas.
>
> CCEI.2) ENHANCE COMMUNICATION WITH VISITORS: Foster discovery, enjoyment and stewardship through a coordinated effort to enhance signs, communications and media that incorporate effective design, messaging and languages for a range of audiences as well as increasing ranger and volunteer presence on the system to welcome and inform visitors.

The data provided in this report adds to the knowledge base for implementation of these strategies and the adaptive management of undesignated pathways. The following recommendations should be considered in efforts to improve how undesignated pathways are monitored and managed:

- Collect width measurements to better estimate the overall area of impact of undesignated trails.
- Monitor on a five-year cycle by trail maintenance zone (Appendix E) so that monitoring data can drive effective on-the-ground implementation.
- Develop an adaptive management approach to documenting and managing areas of concentrated use.
- Continue to develop an asset management database to integrate work tracking with monitoring.
- Improve the understanding of the management context for undesignated pathways that form after the approval of a TSA plan or that occur in areas without a TSA plan (i.e., the East TSA).
- Explore ways, such as through physical signage, to inform visitors on-site about which trails are undesignated.
- Create a protocol and develop criteria to evaluate the effectiveness of restoration efforts.

Appendices

Appendix A : *Management Strategies for Undesignated Trails from 2005 Visitor Master*

Management Strategies for Undesignated Trails by Management area designation in Visitor Master Plan (2005)			
Passive Recreation Strategies	Natural Area Strategies	Agricultural Area Strategies	Habitat Conservation Area Strategies
Lower priority for management of undesignated trails. Minimize new undesignated trails. Management actions for existing undesignated trails include: - Evaluate best management actions - Designate - Re-route - Close and reclaim - Retain undesignated trails - Monitor newly established or developing undesignated trails	Variable priority for management of undesignated trails. Minimize new undesignated trails. Management actions for existing undesignated trails include: - Evaluate best management actions - Designate - Re-route - Close and reclaim - Retain undesignated trails - Monitor newly established or developing undesignated trails	Variable priority for management of undesignated trails. Minimize new undesignated trails. Management actions for existing undesignated trails include: - Evaluate best management actions - Designate - Re-route - Close and reclaim - Retain undesignated trails	High priority for management of undesignated trails. Minimize new undesignated trails. Management actions for existing undesignated trails include: - Evaluate best management actions - Designate - Re-route - Close and reclaim

Table 11: Management Strategies for Undesignated Trails from 2005 Visitor Master plan

Appendix B: *Map of Project Area*

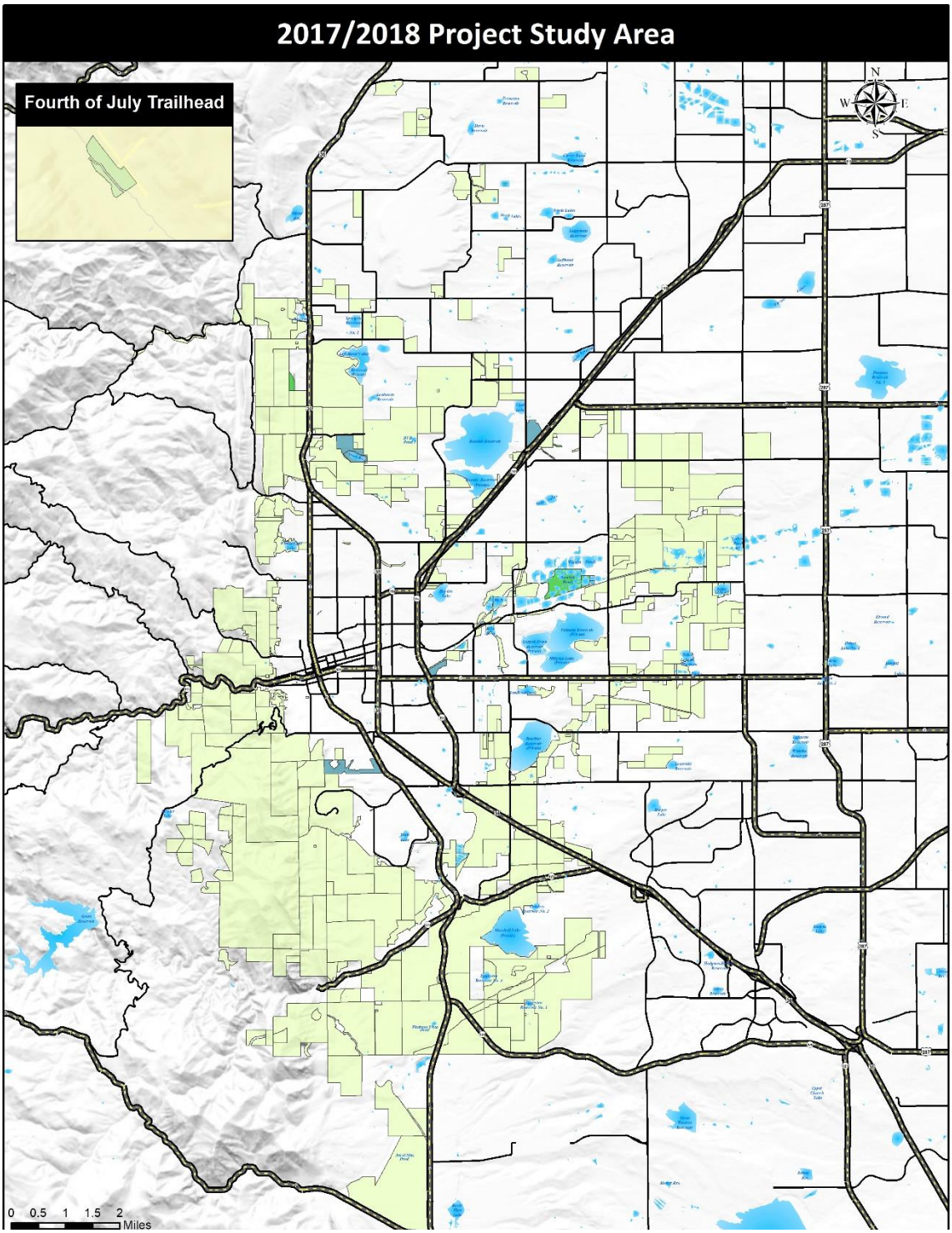


Figure 8: Map of Project Area

Appendix C: *Map of Pathway Types*

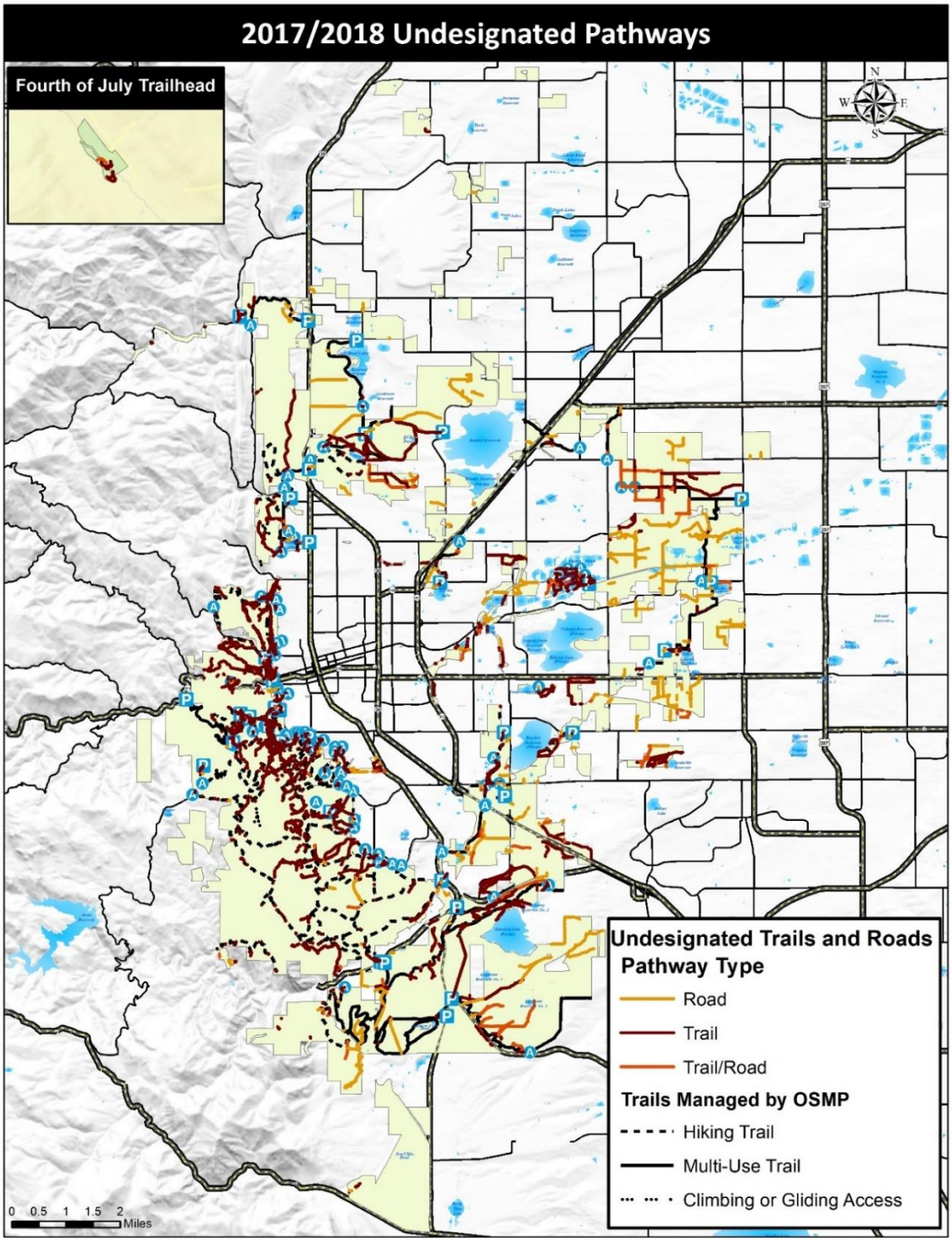


Figure 9: Map of Pathway Types

Appendix D: *Map of OSMP Management Area Designations*

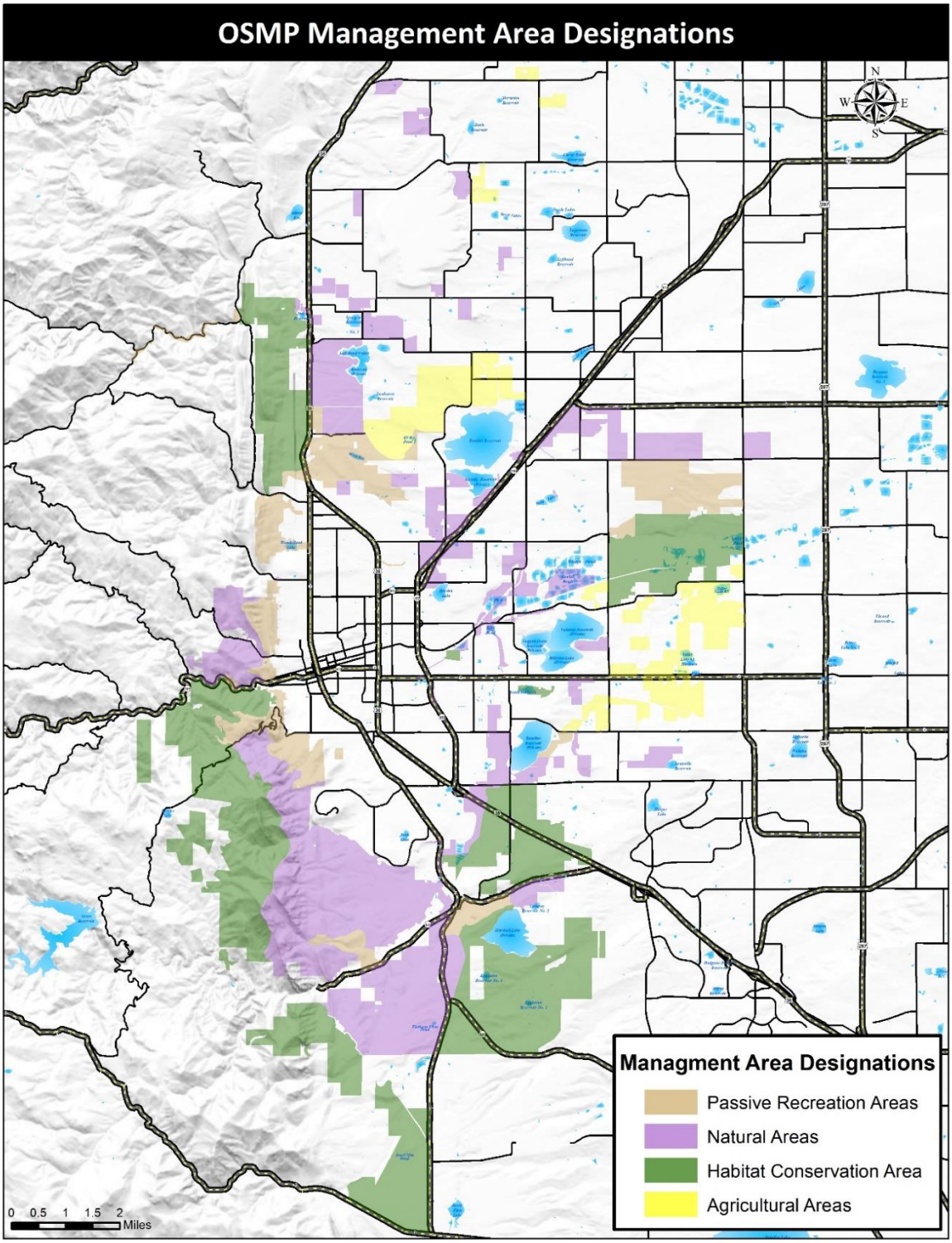


Figure 10: Map of OSMP Management Area Designations

Appendix E: *Map of Trail Maintenance Zones*

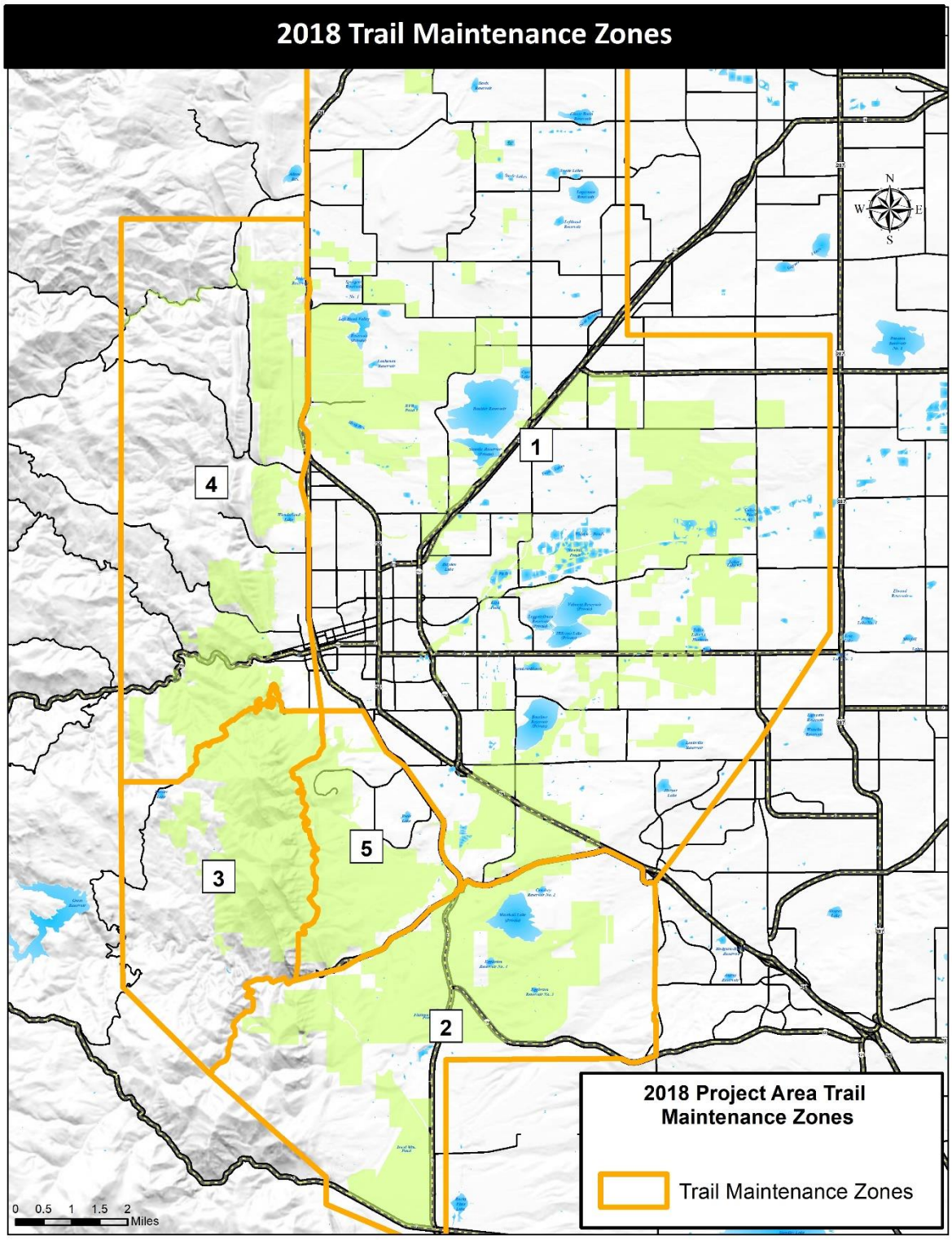


Figure 11: Map of Trail Maintenance Zones

Appendix F : *Map of TSAs*

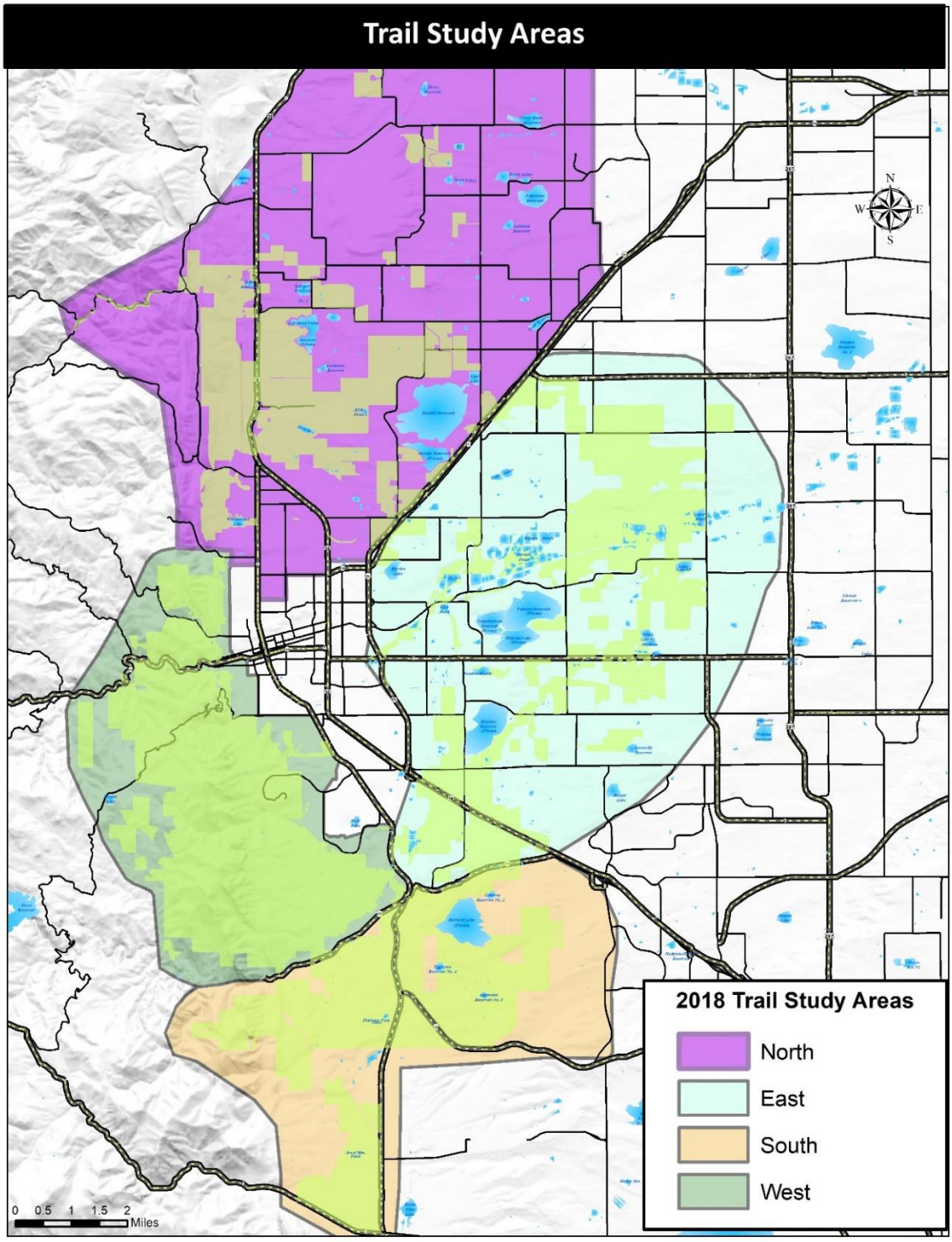


Figure 12: Map of TSAs

Appendix G: *Map of built features on Undesignated Trails and Roads*

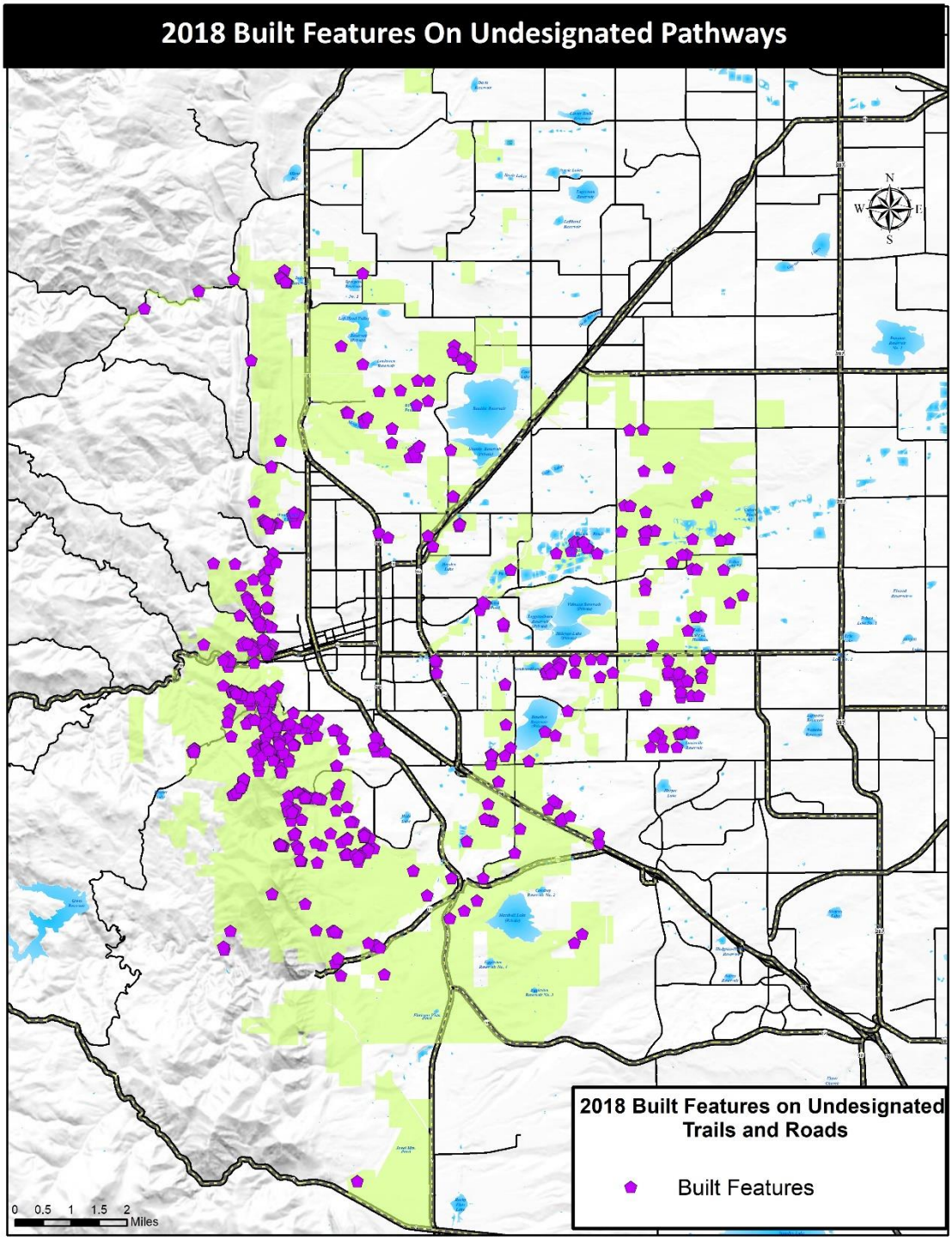


Figure 13: Map of built features on Undesignated Trails and Roads

Appendix H: *Map of Areas of Concentrated Use*

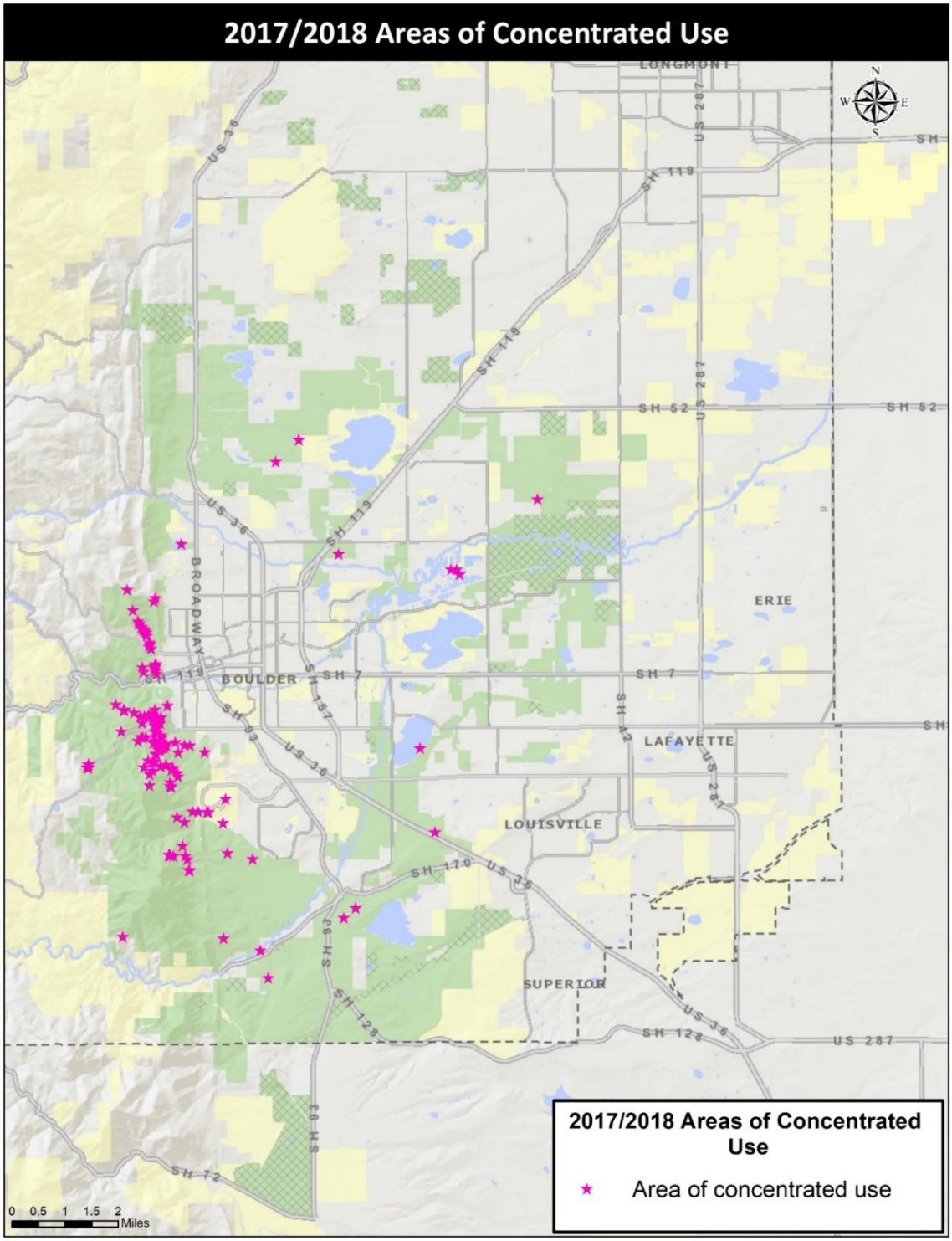


Figure 14: Map of Areas of Concentrated Use

Appendix I: *Map of grid-cell density of undesignated trails and roads*

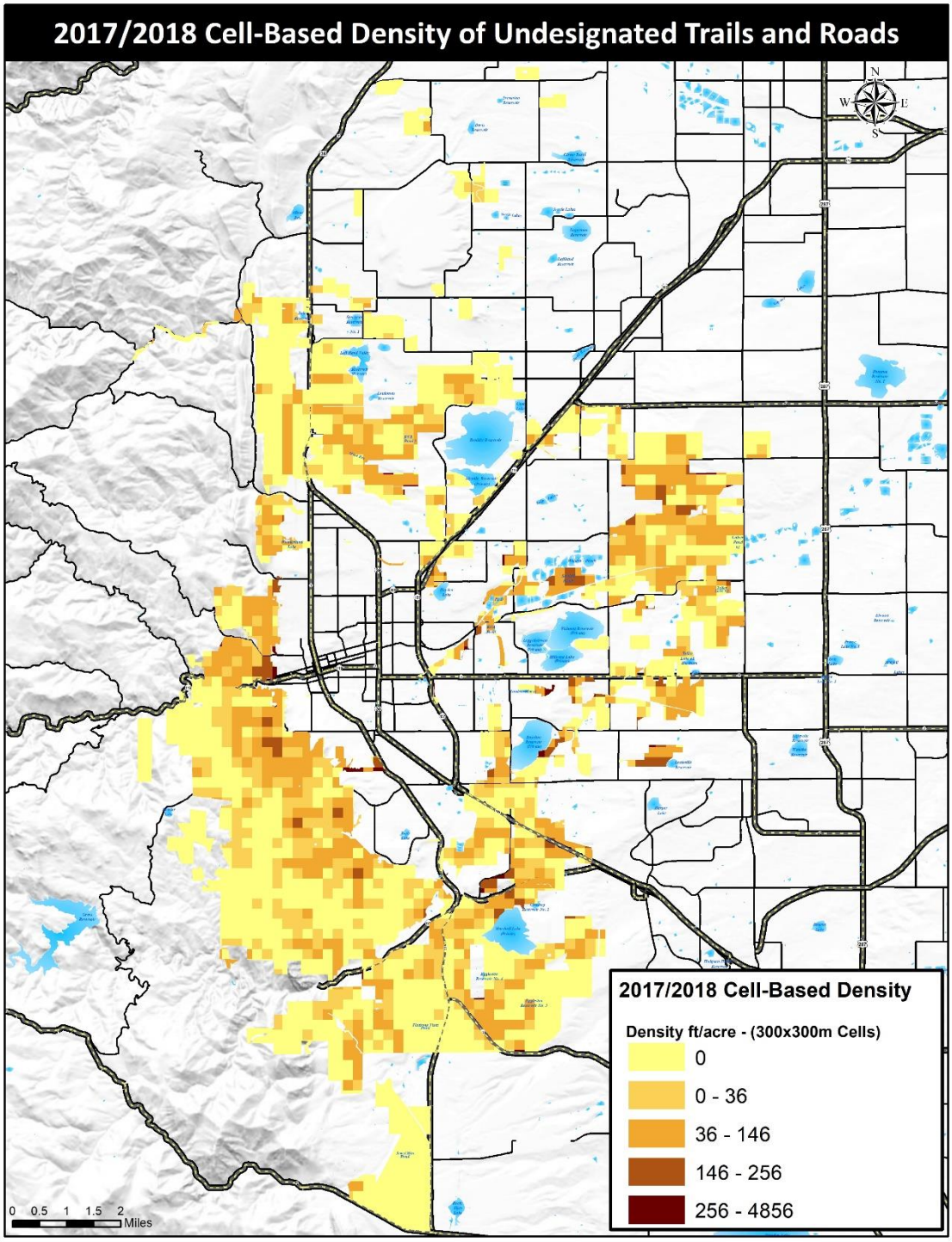


Figure 17: Map of grid-cell density of undesignated trails and roads

Appendix J: *Map of kernel density of undesignated trials and roads*

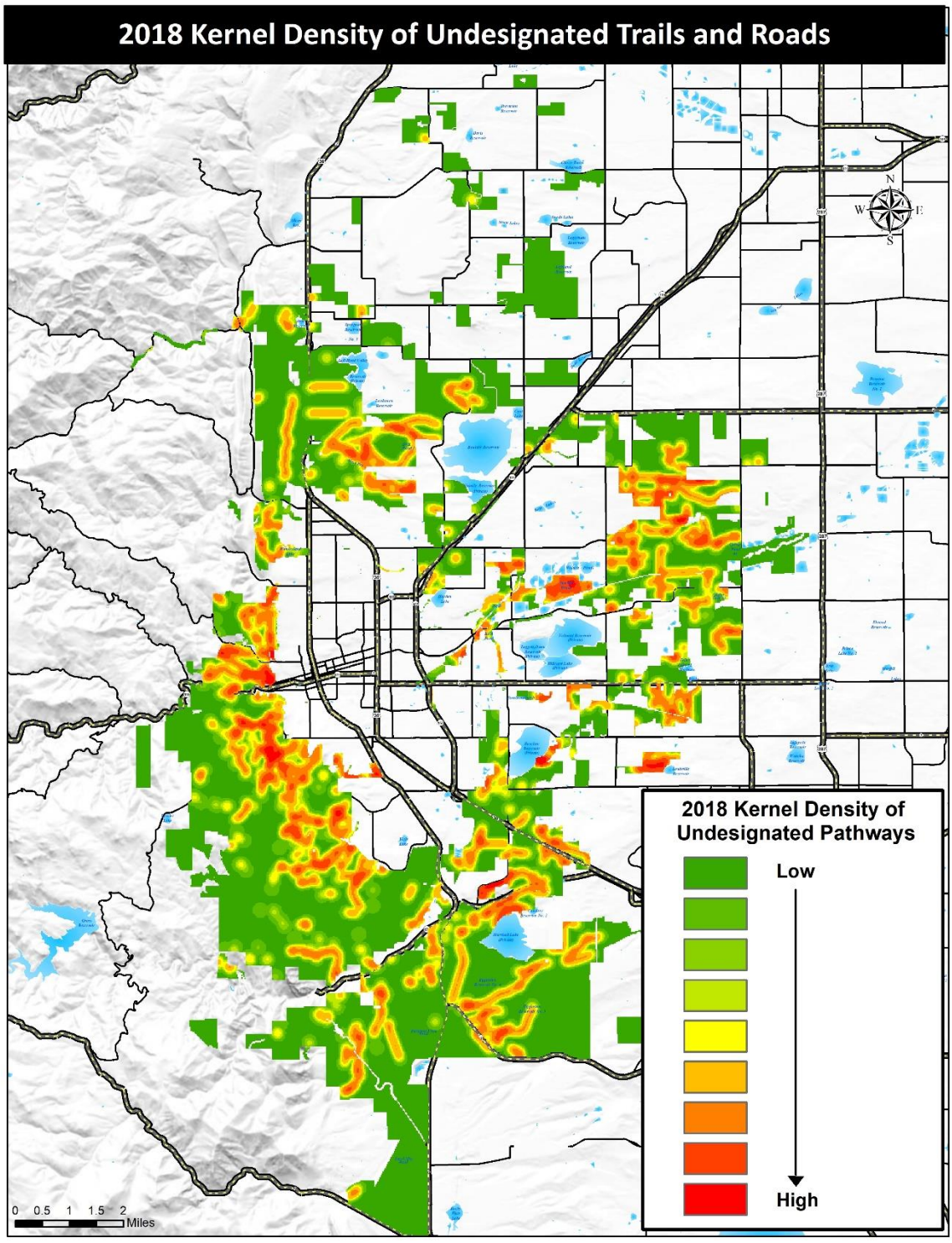


Figure 18: Map of kernel density of undesignated trials and roads

Appendix K: Maps comparing land fragmentation by roads and trails both designated and undesignated

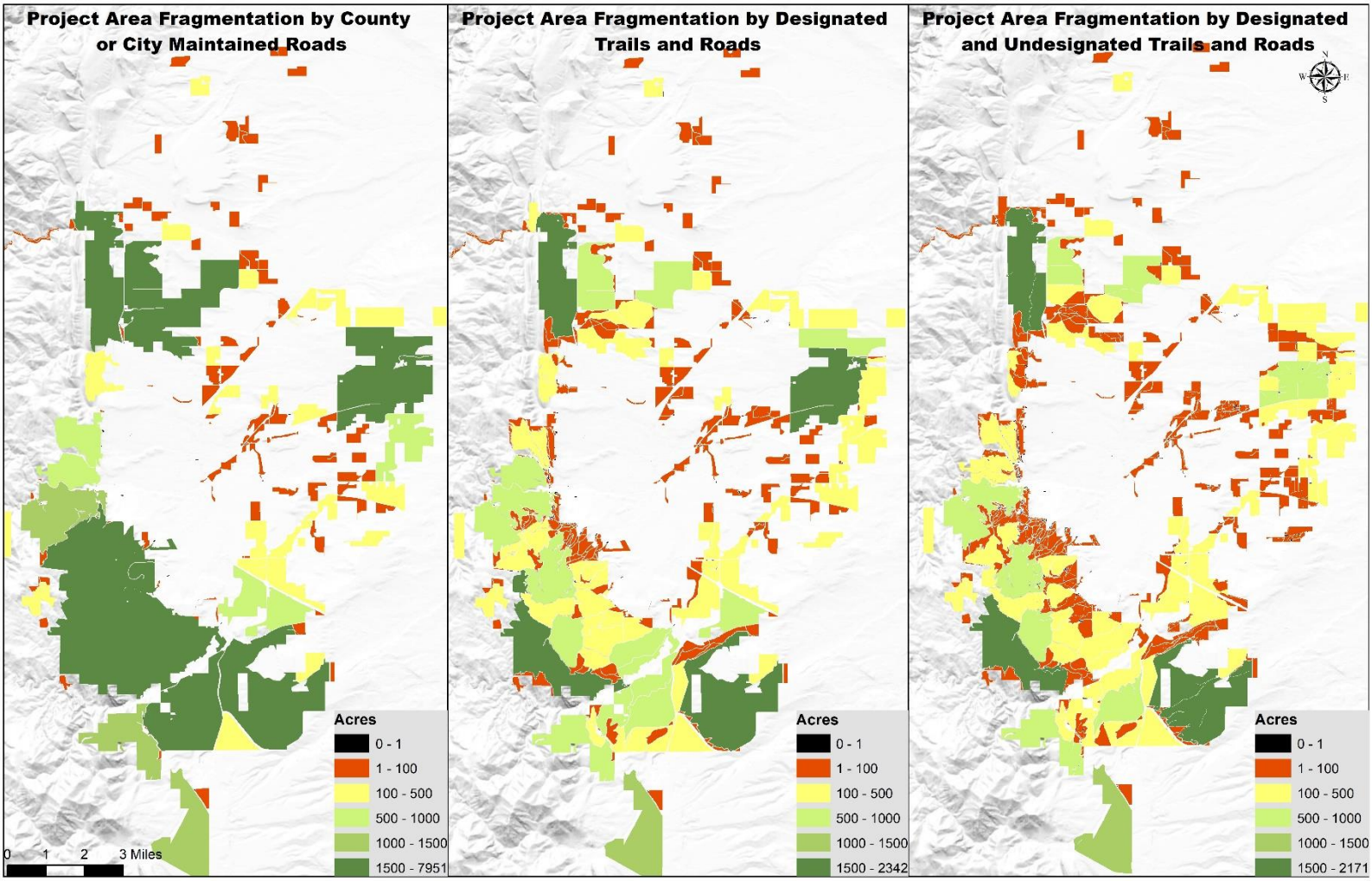


Figure 19: Maps comparing land fragmentation by roads and trails both designated and undesignated

Appendix L: *Map of land fragmentation by designated trails and roads*

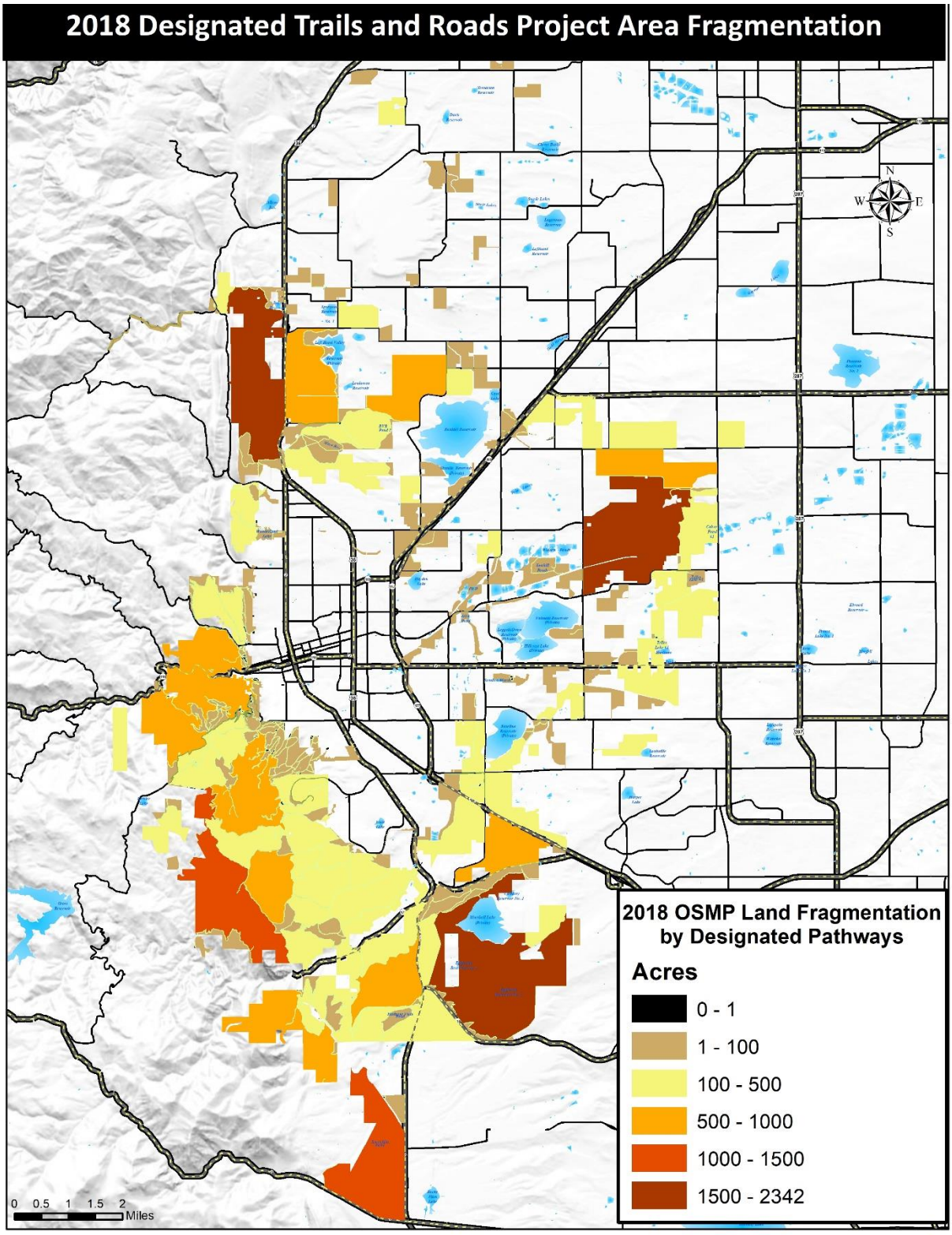


Figure 20: Map of land fragmentation by designated trails and roads

Appendix M: *Map of euclidean (straight-line) distance from designated trails and roads*

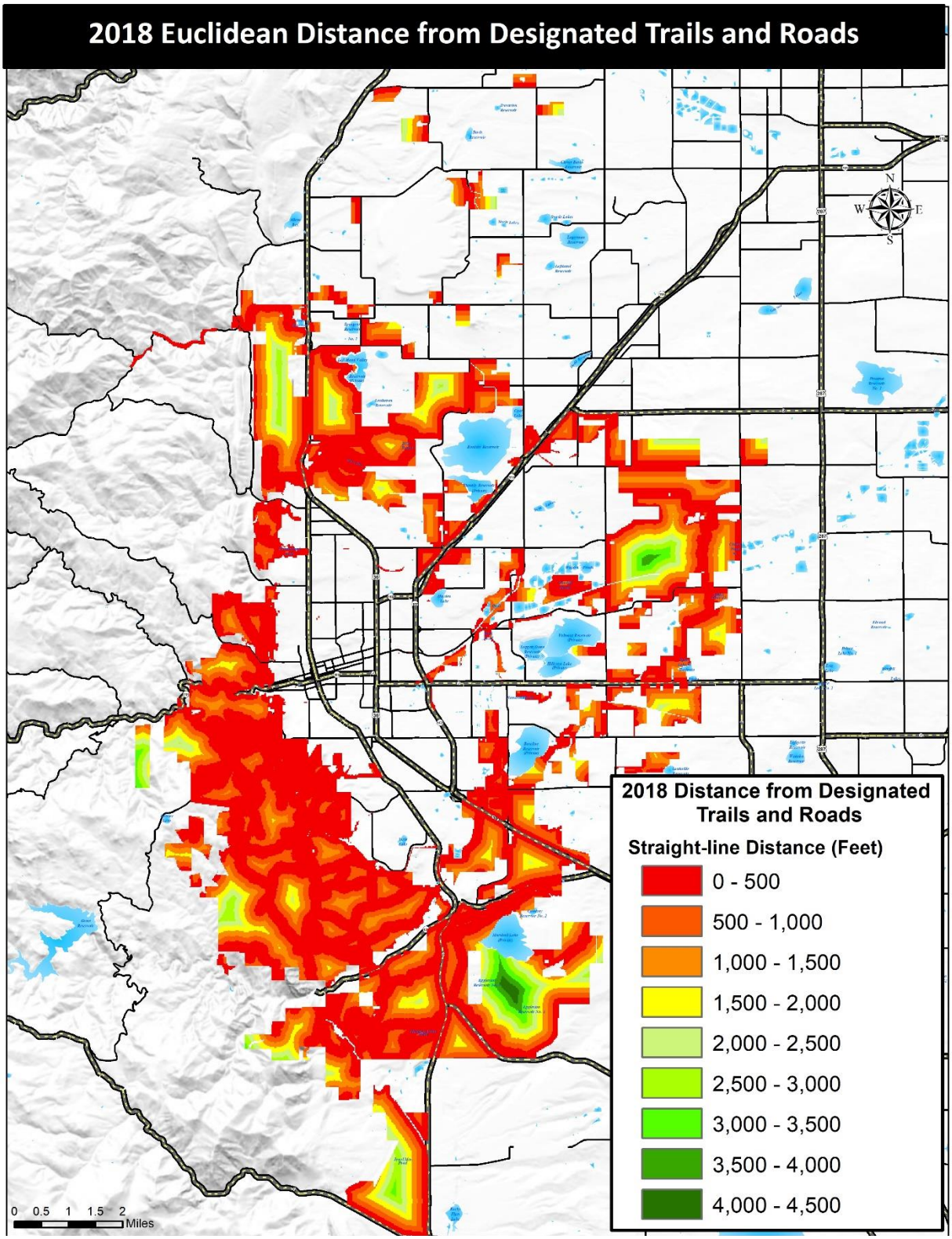


Figure 21: Map of euclidean (straight-line) distance from designated trails and roads

Appendix N*: Map of euclidean (straight-line) distance from designated and undesignated trails and roads*

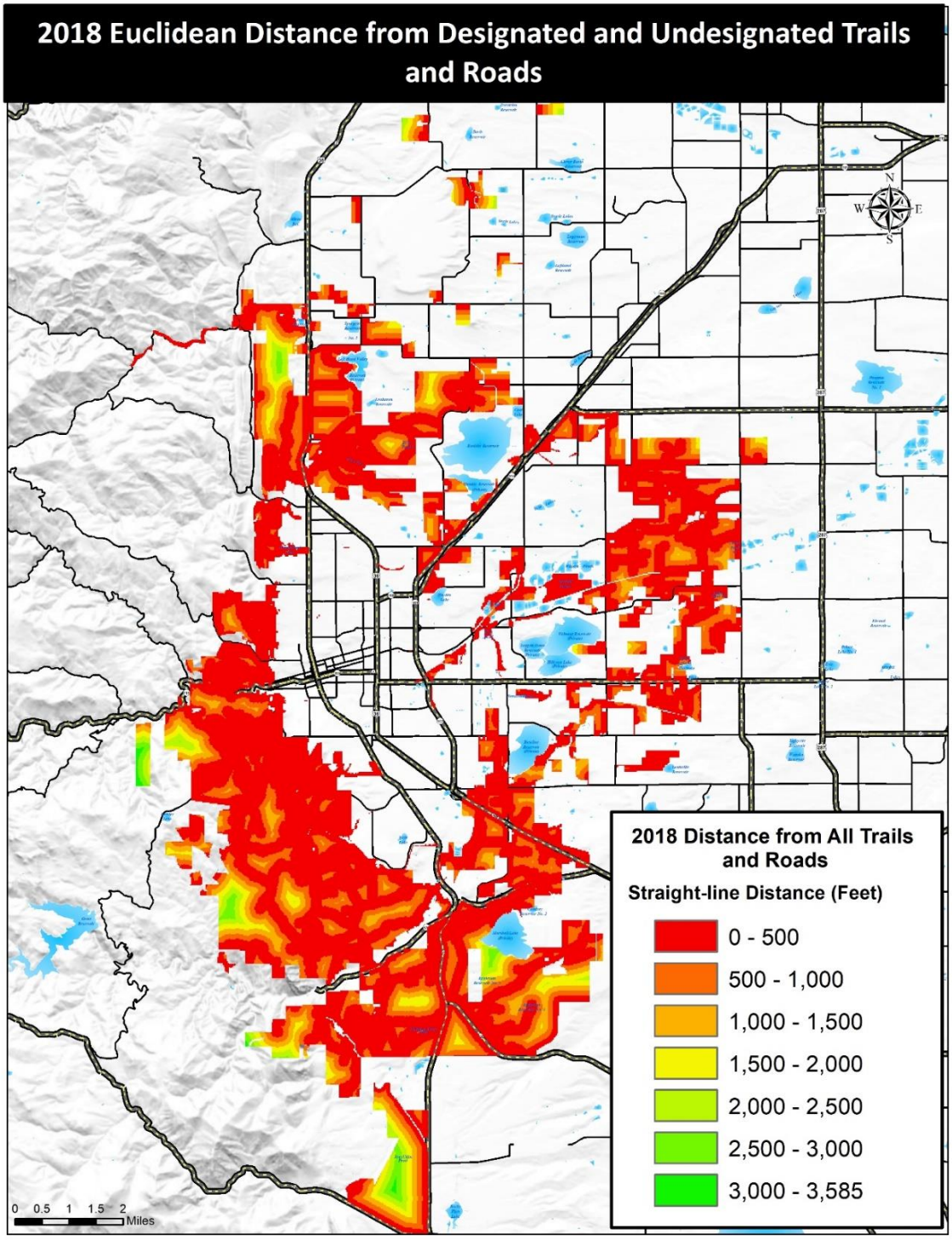


Figure 22 : Map of euclidean (straight-line) distance from designated and undesignated trails and roads

Appendix O: *Map of undesignated trails in sensitive areas*

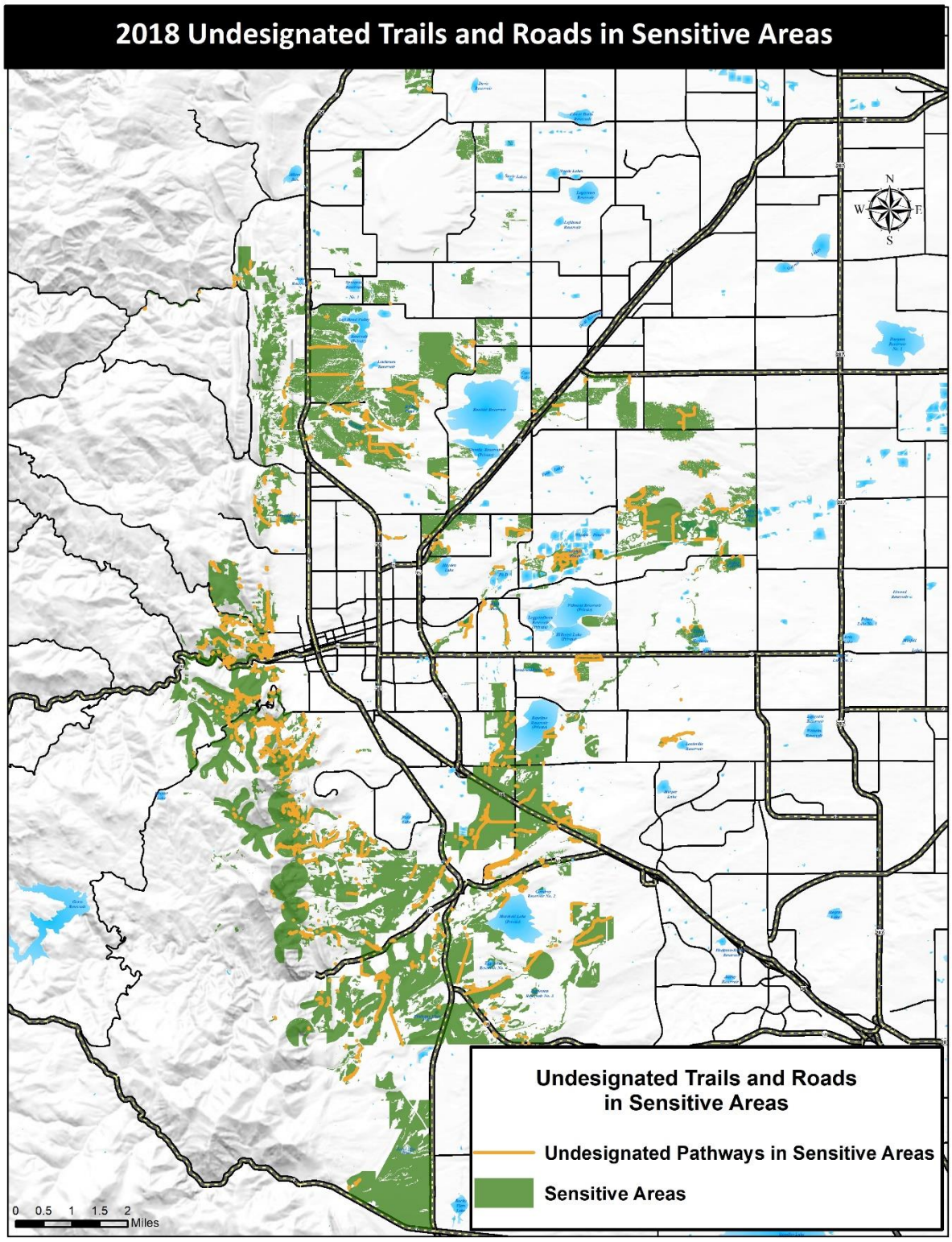


Figure 23: Map of undesignated trails in sensitive areas

Appendix P: *Comparison of Strava and undesignated trail data comparison*

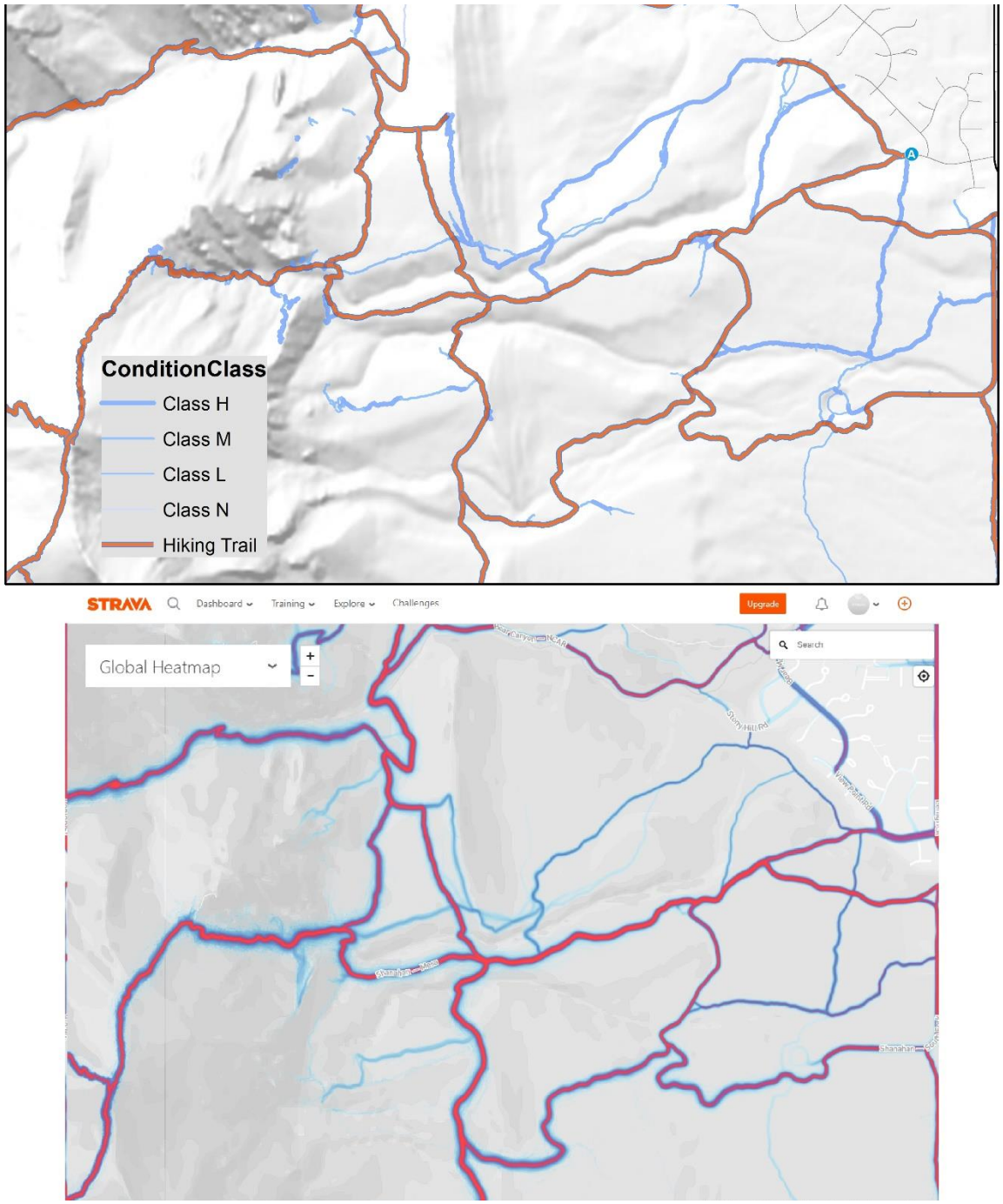


Figure 24: Comparison of Strava and undesignated trail data comparison

Appendix Q: *Map of undesignated pathway connections to designated trails*

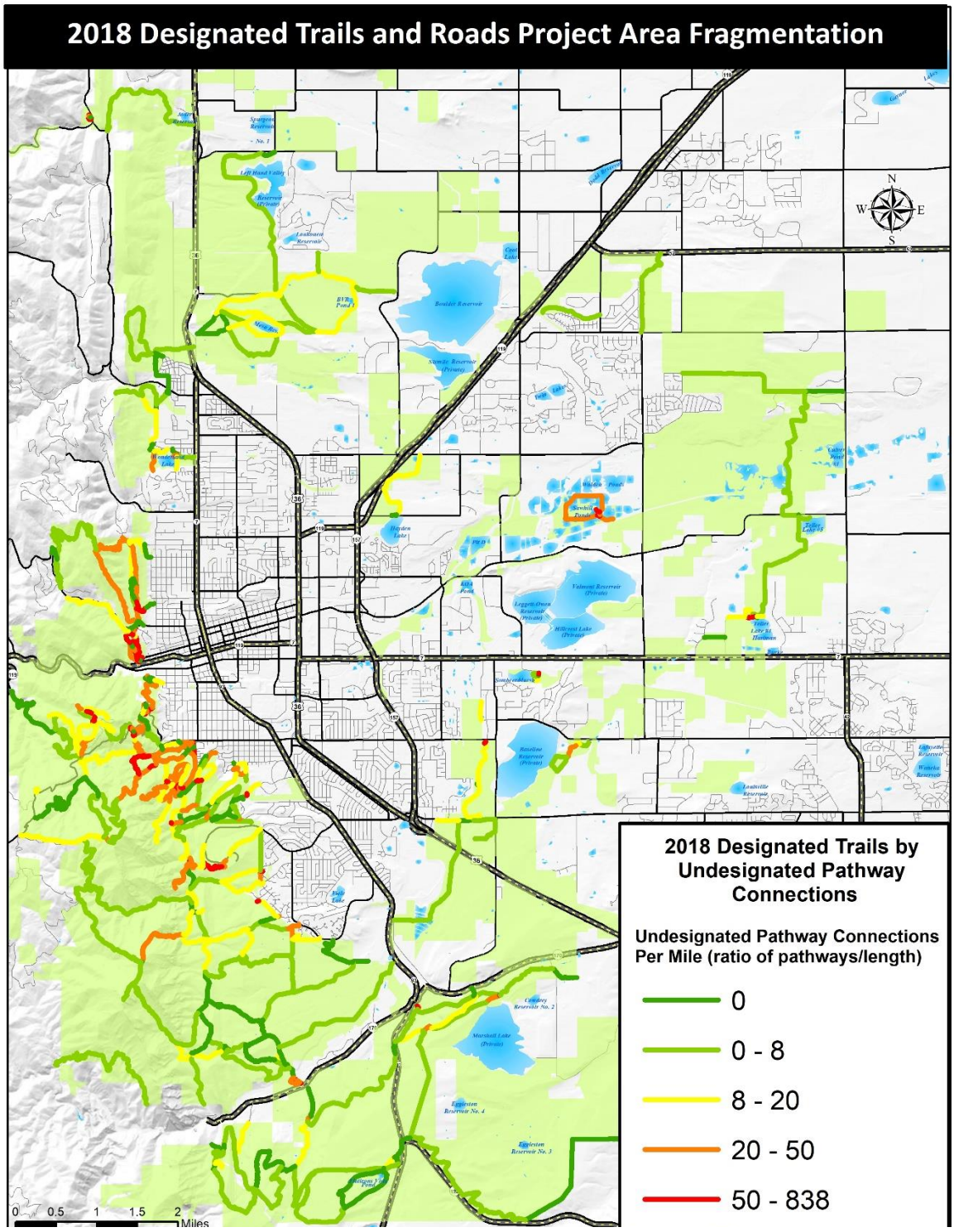


Figure 25: Map of undesignated pathway connections to designated trails

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Glossary of terms

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

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

Designated Trail: A trail built and maintained by City of Boulder Open Space and Mountain Parks

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.

Ford: Armored stream crossing

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

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

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

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

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

Sensitive Areas - A GIS layer representing the combination of raptor closures, Preble's jumping mouse habitat, New Zealand mud snail closures, burrowing owl habitat, northern leopard frog breeding sites, prairie dog colonies, wetlands, rare plant species and communities, and cultural resources.

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 in made up of set stones

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

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

Undesignated Pathway: A term used to describe the combination if undesignated roads, trails, and trail/roads.

Undesignated Road: A road that is not represented in OSMP roads GIS data. Could represent access roads for ditches, oil and gas, agriculture, or emergencies. Could also represent temporary access roads that are not permanent infrastructure.

Undesignated Trail: A trail not built or maintained by OSMP. Represents a use pattern by OSMP visitors, staff or cattle.

Undesignated Trail/Road: An undesignated trail that has some evidence of use by vehicles and is connected to an area accessible by vehicles.

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.