# Colorado Department of Transportation Roadside Fen Inventory

May 2018

*CNHP's mission is to advance the conservation of Colorado's native species and ecosystems through science, planning, and education for the benefit of current and future generations.*

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# EXECUTIVE SUMMARY

State and federal highways in Colorado stretch from the eastern plains to the Continental divide and the canyons and plateaus of western Colorado, and range in elevation from 3,369 ft (1,027 m) to 14,130 ft (4,307 m). As highways cross Colorado's many mountain passes, they intersect watersheds rich in fen wetlands. Fens are wetlands with organics soil, which have formed over thousands of years. These wetlands are an irreplaceable resource that support high biodiversity, sequester carbon, and support regional hydrology.

The Colorado Department of Transportation (CDOT) has determined that road construction and maintenance should avoid fen wetlands whenever practicable. Efficient implementation of this policy, however, has been hindered by a lack of comprehensive information on fens surrounding the Colorado highway network. In order to aid transportation planning, CDOT identified a need to better understand the distribution and extent of fens near Colorado highways. To this end, CDOT contracted Colorado State University and the Colorado Natural Heritage Program (CNHP) to map all potential fens near Colorado highways.

Potential fens within a 500-m buffer of Colorado highways were identified from digital aerial photography and topographic maps. Each potential fen polygon was hand-drawn in ArcGIS based on the best estimation of fen boundaries and attributed with a confidence value of 1 (low confidence), 3 (possible fen), or 5 (likely fen). After field verification, additional confidence values of 7 (confirmed fen) and 0 (confirmed non-fen) were added. The final map contained 1,795 potential fen locations of all confidence levels, including 241 confirmed fens and 155 likely fens. The average fen polygon was 3.8 acres, though polygon size varied greatly, from < 0.1 to 336.7 acres. In total, there were a combined 396 polygons of confirmed and likely roadside fens, covering 2,414 acres (0.07% of the total highway buffer acreage).

Fen distribution was analyzed by watershed, highway segment, land ownership, proximity to road, elevation, geology, and ecoregion. The vast majority of confirmed and likely fens occurred between 9,000 to 11,000 ft. This elevation range contained 79% of all confirmed and likely fen locations and 89% of all confirmed and likely fen acres. The majority of confirmed and likely fen locations occurred on public lands (73%). Eight primary hot-spots of fen formation were identified across the state.

This report and associated dataset provide CDOT with a critical tool for conservation planning at a statewide scale. These data will be useful for guiding individual management actions, such as planning for road expansion activities. Wherever possible, CDOT should avoid direct disturbance to the fens mapped through this project, and should also strive to protect the watersheds surrounding high concentrations of fens, thereby protecting their water sources.

# ACKNOWLEDGMENTS

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# 1.0 INTRODUCTION

Organic soil wetlands, known as fens, are an irreplaceable resource. Fens are groundwater-fed wetlands with organic soils that typically support sedges and low stature shrubs (Rydin et al. 2017; Mitsch & Gosselink 2015). The strict definition of an organic soil (peat) is one with 40 cm (16 in) or more of organic soil material in the upper 80 cm (31 in) of the soil profile (Soil Survey Staff 2014). Accumulation of organic material to this depth requires constant soil saturation and cold temperatures, which create anaerobic conditions that slow the decomposition of organic matter. In Colorado's mountains, peat accumulation occurs very slowly, as little as 20 cm (8 in) per 1,000 years (Chimner 2000; Chimner and Cooper 2002). By storing organic matter in their soils, fens act as carbon sinks. Fens also help to regulate local and regional hydrology by stabilizing base flow through the slow release of groundwater. In addition, fens throughout the Southern Rockies support numerous rare plant species that are often disjunct from their main populations (Cooper 1996; Cooper et al. 2002; Johnson & Stiengraeber 2003; Lemly et al. 2007). The long-term maintenance of fens requires protection of both the hydrology and the plant communities that enable fen formation.

Human land use activities can have detrimental impacts on fen wetlands, often altering their hydrology to the extent that water levels and associated plant community composition is significantly changed or eliminated (Charman 2002). Fens in Colorado are impacted by a variety of land uses, including ditching, draining, grazing, recreation, excavation and flooding to form reservoirs, excavation for peat harvesting, discharge of sediment and waste water from historic mining activity, and road building (Austin & Cooper 2016; Johnston et al. 2012; Chimner et al. 2010; Cooper & McDonald 2000). While road impacts have not been studied explicitly in Colorado, research in Canada clearly demonstrates the impact that road construction and maintenance can have on fen hydrology, water chemistry, vegetation, and soil carbon dynamics (Brockring et al. 2017; Strack et al. 2017; Wood 2010; Pomeroy 1985).

Interest in and concern for Colorado's fen wetlands began in the 1990s, when early botanical studies of Colorado fens discovered a number of rare plant species and plant communities (Cooper et al. 2002; Cooper 1996; Sanderson & March 1996;). As a result, several federal and state agencies developed policies to protect fen wetlands. Region 6 of the U.S. Fish and Wildlife Service (USFWS) instituted a policy on the protection of fens in 1998 (amended in 1999).[1] Current policy of the Rocky Mountain Region (Region 2) of the U.S. Forest Service (USFS) considers fens a sensitive plant habitat that should be managed for conservation and restoration (USFS 2011). The U.S. Army Corps of Engineers (USACOE), which regulates impacts to wetlands under the federal Clean Water Act, also applies stricter standards for permitting impacts to fens.[2]

[1] The USFWS Region 6 Regional Policy on the Protection of Fens can be found here: https://www.fws.gov/mountain-prairie/es/fen/FWSRegion6FenPolicy1999.pdf.

[2] See the 2017 USACOE Regional Conditions to Nationwide Permits in the State of Colorado. http://www.nwo.usace.army.mil/Portals/23/docs/regulatory/CO/jds/Final%202017%20Regional%20Conditions%20in%20Colorado.pdf?ver=2017-04-20-134328-567.

Like other agencies, the Colorado Department of Transportation (CDOT) recognizes the importance of fen wetlands. Under current CDOT policy, road construction and maintenance should avoid fen wetlands whenever practicable. Efficient implementation of this policy, however, has been hindered by a lack of comprehensive information on fens surrounding the Colorado highway network. In order to aid transportation planning, CDOT contracted with the Colorado Natural Heritage Program (CNHP) to create an inventory of all fen wetlands within and surrounding CDOT's right-of-way (ROW) statewide. The project included compiling all past research efforts to inventory fens in Colorado, mapping potential fens within a 500-m buffer of all federal and state highways in GIS, and visiting as many of the potential fen polygons as possible within two field seasons. The information developed through this project will be highly valuable for future planning of CDOT road construction and maintenance activities.

# 2.0 Study Area

State and federal highways in Colorado stretch from the eastern plains to the Continental divide and the canyons and plateaus of western Colorado. The highway network traverses a diverse array of ecosystems and land use types. Highways in Colorado range from elevations of 3,369 ft (1,027 m) on the eastern border with Kansas to 14,130 ft (4,307 m) at the top of Mount Evans. Total length of state and federal highways is 9,103 miles (14,649 km). Highways pass through each of the major river basins in the state and cross land in both public and private ownership. Because right-of-way and easement widths vary by land ownership and management, we defined the study area for this project as a 500-m buffer on either side of every state and federal highway segment in Colorado. The total area within this buffer was 3,448,761 acres or 5,388 square miles (Figure 1).

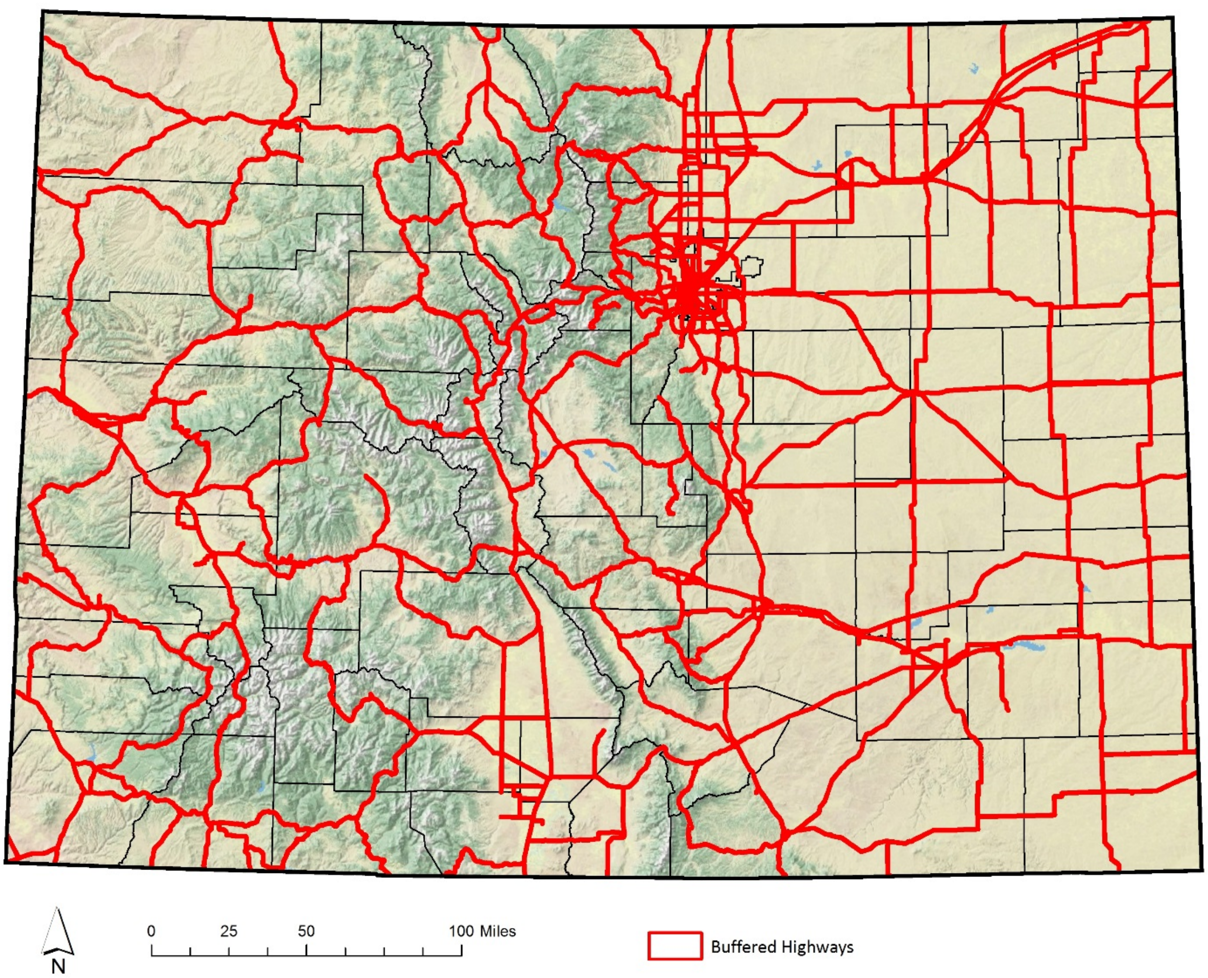


**Figure 1. State and federal highway network with 500-m buffer.**

# 3.0 METHODS

Mapping and verification of fens along the state and federal highway network was conducted in two phases: 1) a ***preliminary mapping phase*** and 2) a ***field verification phase***. Preliminary mapping took place in the office in ArcGIS 10.3/10.4 in advance of summer field seasons, using aerial imagery and ancillary data sources. Field verification took place during the summers of 2016 and 2017. Field crews visited as many potential fen polygons as was practical.

## 3.1 Preliminary Fen Mapping Methods

During the preliminary mapping phase, all potential fens within a 500-m (1640-ft) buffer around state and federal highways were delineated, regardless of their adjacency or proximity to the highways. A buffer width of 500 m from all highways was used because right-of-way (ROW) widths are not standard across Colorado and they are not available as a digital spatial layer. Many ROWs on private lands are only 50 m from the road, which is substantially smaller than 500 m. However, there is not a true ROW on public lands (e.g., U.S. Forest Service [USFS] or Bureau of Land Management [BLM]). Where highways pass through public lands, CDOT has established easements for road maintenance and these are often much wider than the standard ROW. In addition, CDOT is interested in fen-containing wetland complexes that may be up or downstream of the ROW and may be impacted by road maintenance activities. The 500-m buffer was intentionally large to capture any potential fens of interest.

To map potential fens in ArcGIS 10.3/10.4, true color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2004, 2009, 2011, 2013, and 2015 were used in conjunction with color-infrared imagery from 2013 and 2015. High (but variable) resolution World Imagery from Environmental Systems Research Institute (ESRI) was also used. To focus the initial search, all wetland polygons mapped by the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) program located within the 500-m buffer and mapped with a "B" (saturated) hydrologic regime were isolated from the full NWI dataset and examined.[3] Wetlands mapped as "Palustrine Emergent Saturated" (PEMB) and "Palustrine Scrub-Shrub Saturated" (PSSB) were specifically targeted, as they are the best indication of fen formation, and every PEMB and PSSB polygon in the study area was checked. However, photo-interpreters were not limited to the original NWI polygons and also mapped any potential fen observed outside of B regime NWI polygons. In addition to the NWI polygons, CNHP compiled data from several previous projects that involved either GIS or in-field mapping of fen polygons or field surveys within fen and potential fen wetlands. A list of these studies is provided in Table 1. We also looked at CNHP's documented records (Element Occurrences) of fen-dependent species and plant communities.

Using all available imagery and data, potential fen polygons were hand-drawn based on the best estimation of fen boundaries. Each potential fen polygon was attributed with a confidence value of 1, 3, or 5 (Table 2). In addition to the confidence rating, any justifications of the rating or interesting

[3] For more information about the National Wetland Inventory and the coding system, please visit: http://www.fws.gov/wetlands/

observations were noted, including iron fens, beaver influence, floating mats, and springs. Once all potential fens were mapped, each polygon was assigned a code for tracking throughout the verification process. The code was a combination of the closest highway segment and a running sequential four-digit number (e.g., 082A-0278).

**Table 1. Studies and datasets compiled to assist with fen mapping.**

| ***Title*** | ***Authors*** | ***Year*** |
|---|---|---|
| Survey of Critical Biological Resources in Lake County | D. Culver and P. Smith | In Progress |
| Fen mapping for the Rio Grande National Forest | G. Smith, J. Lemly, P. Smith, and B. Kuhn | 2016 |
| Inventory of fens in a large landscape of west-central Colorado | B.C Johnston, B.T Stratton, W.R. Young, L.L. Mattson, J.M. Almy, and G.T Austin | 2012 |
| Wetland mapping and fen survey in the White River National Forest | D. Malone, E. Carlson, G. Smith, D. Culver, and J. Lemly | 2011 |
| Wetland surveys and findings assessment within and near the maximum footprint for the proposed Colorado I-70 corridor improvement project, Tier I: milepost 130 to milepost 259 | J.R. Jones, K.M. Driver and D.J. Cooper | 2009 |
| Final Report: Regional assessment of fen distribution, condition, and restoration needs, San Juan Mountains | R.A, Chimner, D.J. Cooper, K. Nydick and J. Lemly | 2008 |
| Fens of Grand Mesa, Colorado: characterization, impacts from human activities, and restoration | G. Austin | 2008 |
| Fen mapping of the San Juan National Forest (dataset but no published report) | U.S. Forest Service, San Juan National Forest staff | 2006 |
| Mapping and characterization of mires and fens in North Park, Jackson County, Colorado | J.B. Johnson and T.D. Gerhardt | 2004 |
| Mapping and characterization of mires and fens in South Park, Park County, Colorado | J.B. Johnson and T.D. Gerhardt | 2002 |
| Extreme rich fens of South Park, Colorado: their distribution, identification, and natural heritage significance | J. Sanderson and M. March | 1996 |

**Table 2. Potential fen confidence levels.**

| ***Confidence*** | ***Description*** |
|---|---|
| **5** | ***Likely fen.*** Strong photo signature of fen vegetation, fen hydrology, and good landscape position. |
| **3** | ***Possible fen.*** Some fen indicators present (vegetation signature, topographic position, ponding, or visibly saturated substrate), but not all indicators present. Some may be weak or missing. |
| **1** | ***Low confidence fen.*** At least one fen indicator present, but weak. |

## 3.2 Field Verification Methods

To verify fens in the field, technicians visited or observed as many potential fen polygons as possible during the summers of 2016 and 2017. The preference was to visit potential fen polygons in person, however, many polygons were remotely observed due to lack of access to private lands. The field crew tracked which polygons were visited onsite and which were remotely observed.

Within each potential fen visited onsite, soil cores were examined to confirm if the site had organic soil at a depth consistent with the definition of a fen. Our working definition of a fen was based on the Natural Resources Conservation Service (NRCS) definition of organic soil (Soil Survey Staff 2014):

> *"It is a general rule that a soil is classified as an organic soil (Histosol or Histel) if more than half of the upper 80 cm (32 in) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials."*

If organic soil was confirmed, data were collected for the confirmed fen including: dominant plant species, proximity to the closest highway, and general comments about the fen. Photos were also taken. Presence of rare plants were also noted, if observed. Comments on changes to the fen polygons boundary were made in the field for the final GIS dataset.

In 2016, all field data were collected using paper maps of potential fens, paper field forms, and a standalone GPS unit and camera. In 2017, field data were primarily collected using a 9.7-inch Samsung Galaxy S2 tablet with 32GB storage capacity. The tablet allowed the field crew to view several data layers simultaneously along the highway network including: aerial imagery, topographic maps, highway maps and mileposts, the 500-m buffer around the highways, and land ownership. In addition, the crew was able to collect all data electronically, including photos.

### *Prioritization for Site Visits*

Due to the large number of mapped potential fen polygons and the fact that the 500-m buffer often extended well past the CDOT ROW, not every mapped polygon could be visited. A priority ranking system was followed in the field, as follows:

- Proximity to the highway was the most important consideration. The closer a polygon was to the highway, the more important it was to visit. However, differing levels of access on private vs. public lands meant this priority was treated differently depending on location.
- On private land where the ROW was defined by a fence, an attempt was made to visit all polygons within the ROW. All polygons immediately adjacent to the ROW were remotely observed, if possible. However, permission to access private land beyond the ROW was not requested and polygons that were not visible from the ROW or other public roads were not assessed.
- On USFS or BLM land where the easement boundary was not defined on the ground, the closer a polygon was to the road, the more important it was to visit.

- Fen confidence was also a strong consideration for ranking field visits. High confidence polygons were a higher priority to visit than low confidence polygons.

- A direct connection between the highway and the wetland containing the polygon gave the polygon a higher priority. If there was expansive upland between the highway and the polygon, it was a lower priority. In instances where there was a major break (e.g., river, cliff, etc.) between the polygon and the highway, the crew did not visit the polygon.

### *Soil Cores*

At every polygon visited onsite, crews excavated and examined at least one soil core to verify areas containing organic soil. For larger polygons, two or more soil cores were often examined to fully characterize the polygon. A GPS waypoint was taken at every soil core to associate the data with the precise spatial location of the core. In addition to the GPS waypoint, a photo was taken of every soil core for reference.

Soil cores were either dug with a 40-cm sharpshooter shovel or sampled with a 100-cm gouge auger (Figure 2). The auger provided quick access to deep in the soil profile with little ground surface disturbance, but in some circumstances the auger could not adequately break though the soil and the sharpshooter shovel was used instead. Pits dug with a sharp sharpshooter shovel were slightly larger than the width of the shovel on all sides to minimize disturbance to the ground surface. Pits were dug to the depth of one shovel length, when possible. The core was removed and set down next to the pit, and care was taken to keep all horizons intact and in order. Pits were always back filled after data were recorded to avoid leaving a tripping hazard for wildlife or people. Because it was difficult to dig soil pits in areas with deep standing water, crews concentrated on areas with no or shallow standing water.

**Figure 2. Soil cores taken with a sharpshooter shovel and a gouge auger.**

For each soil core, the depth of organic material observed, if any, was recorded. The gouge auger allowed for observations deeper in the soil profile (up to 100 cm) than the sharpshooter shovel (up to 40 cm). If the core was dug with a sharpshooter shovel, only the top 40 cm of the soil profile was visible, but this was typically enough to confirm whether the polygon was a fen (Figure 3).

**Figure 3. Examples of organic soil. Note the presence of roots and fibric organic material throughout the soil core. Color may be dark brown to reddish brown depending on source material. Soil holds together.**

### *Vegetation Data Collection*

If a polygon was confirmed to be a fen, a list of dominant and readily observable vascular plant species was recorded. The search for species was limited to no more than 30 minutes to minimize the amount of time spent at each site. When all species were identified, or 30 minutes of time was spent searching, the overall cover of each species within the polygon was visually estimated using the following cover classes (Peet et al. 1998):

1 = trace (one or two individuals)
2 = 0–1%
3 = >1–2%
4 = >2–5%
5 = >5–10%
6 = >10–25%
7 = >25–50%
8 = >50–75%
9 = >75–95%
10 = >95%

Nomenclature for all plant species followed Weber and Wittmann (2012a, 2012b) and all species were recorded using the fully spelled out scientific name. Any unknown species were recorded with a unique descriptive name and given a collection number for later identification. Unknown species were collected by the field crew if the species represented >10% cover over the entire polygon, even if the species appeared to be unidentifiable. This was in case the same species was encountered in a further developed state at a later site and could be compared with the earlier voucher. While collecting dominant unknown species was mandatory, collecting species with lower cover was optional. The crew never collected specimens identified as or suspected to be federally or state listed species. All crew members were aware of listed species and documented occurrences with photographs. Photo numbers were recorded on the field form for any species documented with photographs.

### *Confirmed Fen Photos*

At least one representative photo was taken for each confirmed fen and these photos were taken with a photo placard whenever possible (Figure 4). Photo placards were placed in the very corner of the photo, taking up only a small portion of the frame, with as little arm or body visible as possible. The fen polygons ID was written in full on the first line of the placard (e.g., 285A-2347). The second line of the placard contained the date, and the third line contained the direction of the photo.

**Figure 4. Example photos. Note placement of photo placard in corner and information written on placard.**

All photos taken during the two field season were organized and re-named for easy reference. Photos were re-named with three to four pieces of information: 1) the fen polygon ID, 2) "Site" or "Soil" for either site overview photos or soil core photos, 3) a sequential number to account for multiple photos from each site, and 4) names of soil core photos also include the GPS waypoint number to connect the photos with a precise location. In total over 3,300 photos were taken during the two field seasons.

## 3.3 Data Analysis

### *Post-Field Mapping Revisions and Final Fen Polygons*

After all field data were collected, image analysts revisited all potential fen polygons and revised confidence ratings and fen boundaries based on the field data. These revisions expanded the original fen confidence rating by adding a 7 for confirmed fens and a 0 for sites that were determined to not be a fen (Table 3). The *"confirmed fen"* rating was based on both field verification visits supported by this study and results from previous fen studies. All polygons were retained in the dataset to clearly show areas that had been considered and were determined to not be fen, as negative data can be as valuable as the confirmation of fens.

**Table 3. Final fen confidence levels.**

| *Confidence* | *Description* |
|---|---|
| 7 | ***Confirmed fen.*** Site was visited in the field either through this sampling effort or another highly reputable sampling effort. Site is confirmed to be a fen. |
| 5 | ***Likely fen.*** Strong photo signature of fen vegetation, fen hydrology, and good landscape position. |
| 3 | ***Possible fen.*** Some fen indicators present (vegetation signature, topographic position, ponding, or visibly saturated substrate), but not all indicators present. Some may be weak or missing. |
| 1 | ***Low confidence fen.*** At least one fen indicator present, but weak. |
| 0 | ***Not a fen.*** Site was either visited in the field and or observed from the roadside and was determined to not be a fen wetland. |

### *GIS Analysis of Confirmed and Likely Fens*

To interpret and provide context to the data, several analyses were conducted in GIS using the confirmed and likely fens and ancillary data sources. We examined geographic distribution of confirmed and likely fens by watershed, highway segment, land ownership, proximity to highway, elevation, geology, and ecoregions. Most analyses were carried out as simple intersects in GIS using the centroids of all confirmed and likely fen and statewide data layers. However, for land ownership, if a polygon was partially on both private and public land, it was classified as private due to the more stringent limitations on access associated with private lands. In addition, polygons on land owned by the State Land Board or Denver Water were treated like private land because they were bound by ROW fences. For all other public lands, we presumed the fen polygons existed on a public easement with CDOT, though easement distances vary by land management agency and are not demarcated on the landscape. In a handful of cases, a fen polygon was located on public land, but a swath of private land separated the highway and the public land containing the fen.

Determining proximity to highway was a more complicated process. CDOT's interest in fens is primarily motivated by agency policy to avoid road construction and maintenance activities in fens wherever practicable. CDOT policy also advises avoiding activities within wetlands that are contiguous with fens to limit impacts on adjacent fen hydrology. For this reason, all confirmed and likely fens were categorized into several bins based on their relationship to the ROW and their contiguity to roadside wetlands.

For private lands, it was straightforward to distinguish between fens that extended into the ROW, fens contiguous with wetlands that extended into the ROW, and fens that were completely beyond the ROW fence. For all fen polygons on private lands, we walked the ROW fence line to determine whether fens or larger wetlands complexes containing fens actually extended into the fenced ROW zone.

For public lands, where there is no defined ROW, we could not rely on a ROW fence line to determine contiguity. Instead, we intersected the potential fen mapping with the most current National Wetland Inventory (NWI) mapping for Colorado and identified all confirmed and likely fen polygons within or adjacent to wetland complexes that extended into a 40-m (130-ft) buffer from the highway centerline. This resulted in six categories to encompass all possible scenarios.

If occurring on private property, a fen polygon may:

1) extend into the fenced highway ROW (***In ROW***);
2) occur outside the fenced highway ROW, but exist within or contiguous to a wetland complex that extends into the ROW, making the fen polygon contiguous to the ROW (***ROW Contiguous***); or
3) occur fully outside the highway ROW, with no contiguous wetland extending into the ROW (***ROW Non-Contiguous***).

If occurring on public property, a polygon may:

4) occur in a public easement and within 40 m of the highway centerline or within in a wetland complex that occurs within 40 m of the highway centerline, making the fen polygon contiguous to the highway (***Easement Contiguous***);

5) occur in a public easement but beyond 40 m of the highway centerline with no contiguous wetland area connecting it to the 40 m buffer (***Easement Non-Contiguous***); or
6) occur beyond the public easement because private land separated the highway and the public land containing the fen (***Non-Easement***).

Within each of the six categories, fens were also grouped into classes by distance to the highway, measured as the distance from the closest margin of the fen polygon to the closest visible pavement edge, which may have been the highway itself or a highway pull-out. Distance to highway classes can be viewed along with contiguity as a measure of likelihood that road construction and maintenance activities would disrupt the fen. Measurements were made in GIS using high resolution aerial imagery after fen polygon boundaries were adjusted post-field verification. For most highways segments, gravel roadbed extends beyond the pavement edge into the ROW or easement, often sloping from the raised pavement to the natural vegetation below. The influence of this sloping roadbed can be difficult to measure precisely, as vegetation often colonizes the gravel surface. For this reason, measurements were based on the visible pavement edge in GIS and distances were binned into variable distance classes that increased in size with greater distance to the road.

Along with GIS analyses, the results section also includes summaries of observations made by the fen mappers during the mapping process and an analysis of vegetation data collected onsite in confirmed fens. A separate standalone **Appendix B** includes species lists and photographs of each confirmed fen.

# 4.0 RESULTS

## 4.1 Final Map of Confirmed and Potential Roadside Fens

The preliminary mapping phase resulted in 1,795 potential fen polygons delineated within the 500-m buffer surrounding state and federal highways. During field verification, crews assessed 707 polygons (40%). Of those, data were collected onsite within 443 polygons and the remaining 264 were observed remotely. Crews prioritized polygons closer to the road, those with a direct connection to the ROW, and those with high confidence. Most of the 1088 unassessed polygons were far from the highway or were mapped with a low confidence.

Of the total potential fen polygons, 241 were confirmed to be fens (confidence level =7) based on field verification supported by this study or through previous fen studies (Table 4; Figure 5). Confirmed fens covered 1,719 acres within the 500-m buffer. The average size of confirmed fens (7.1 acres) was significantly larger than other confidence levels, primarily driven by a handful of very large fens along U.S. Route 285D in South Park. Another 155 polygons were considered likely fens (confidence level = 5) due to their landscape position, aerial photo signature, and remote field observations. Likely fens covered 695 acres. In the following analyses, we grouped confirmed and likely fens as the wetlands of greatest management interest to CDOT. These 396 wetlands should be avoided whenever practicable.

In addition, another 1,054 polygons were considered possible or low confidence fens (confidence levels = 3 or 1). These polygons could not be ruled out by remote observation or through aerial image interpretation, but are not as likely to be fens as the 396 confirmed and likely fens. In addition, 345 polygons were confirmed as non-fens (confidence level = 0), either through onsite evaluation or clear indication from remote observation.

**Table 4. Potential fen counts and acreage, by confidence levels.**

| *Confidence* | *Number* | *Acres* | *Average size (acres)* |
|---|---|---|---|
| **7 – Confirmed Fen** | 241 | 1,719 | 7.1 |
| **5 – Likely Fen** | 155 | 695 | 4.5 |
| ***Confirmed and Likely Fens*** | ***396*** | ***2,414*** | ***6.1*** |
| **3 – Possible Fens** | 401 | 1,436 | 3.6 |
| **1 – Low Confidence Fens** | 653 | 2,094 | 3.2 |
| ***Possible and Low Confidence Fens*** | ***1054*** | ***3530*** | ***3.3*** |
| ***All Potential and Confirmed Fens*** | ***1450*** | ***5944*** | ***4.1*** |
| **0 – Confirmed Non-Fens** | 345 | 956 | 2.8 |
| ***Total Polygons*** | ***1795*** | ***6,599*** | ***3.8*** |

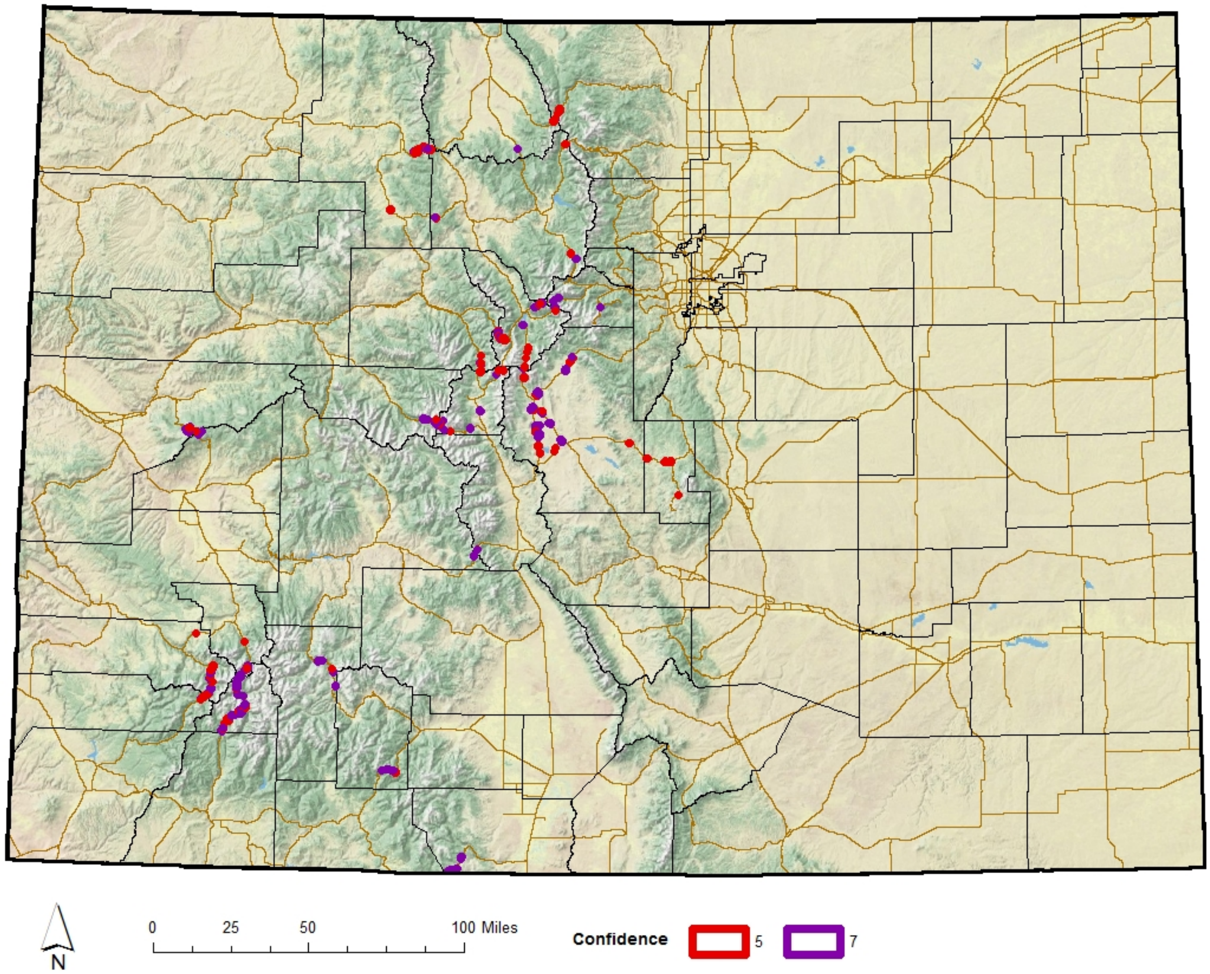


**Figure 5. Confirmed and likely fens along Colorado state and federal highways. Fen area exaggerated to visually highlight the locations.**

## 4.2 Mapped Likely Fens by Watershed and Highway Segment

Fen distribution along state and federal highways was not uniform. Certain mountainous, high-elevation watersheds and associated highway segments had particularly high numbers, or particularly large acreage, of confirmed and likely fens (Figure 6). Four watersheds stood out due to high numbers of confirmed and likely fens. Mineral Creek (HUC12: 140500010405) had 28 confirmed and likely fens within the 500-m buffer; Walton Creek (HUC12: 140500010405) and Red Mountain Creek (HUC12: 140200060201) both had 27; and Tenmile Creek-Animas River (HUC12: 140801040302) had 23. Mineral Creek, Tenmile Creek-Animas River, and Red Mountain Creek watersheds are adjacent and all intersect U.S. Route 550B in the San Juan Mountain range. Walton Creek watershed is in the northern part of the state, near Rabbit Ears Pass on U.S. Route 40A.

Sorted by confirmed and likely fen acreage, Antero Reservoir (HUC12: 101900010205) and High Creek (HUC12: 101900010208) were significant. These watersheds lie adjacent each other in the South Park valley, and are crossed by U.S. Route 285D. Though they do not have a high number of individual fens (6 and 1, respectively), together they represent 28% of the total confirmed and likely fen acreage. See Appendix A for a full accounting of confirmed and likely fens by HUC12 watershed.

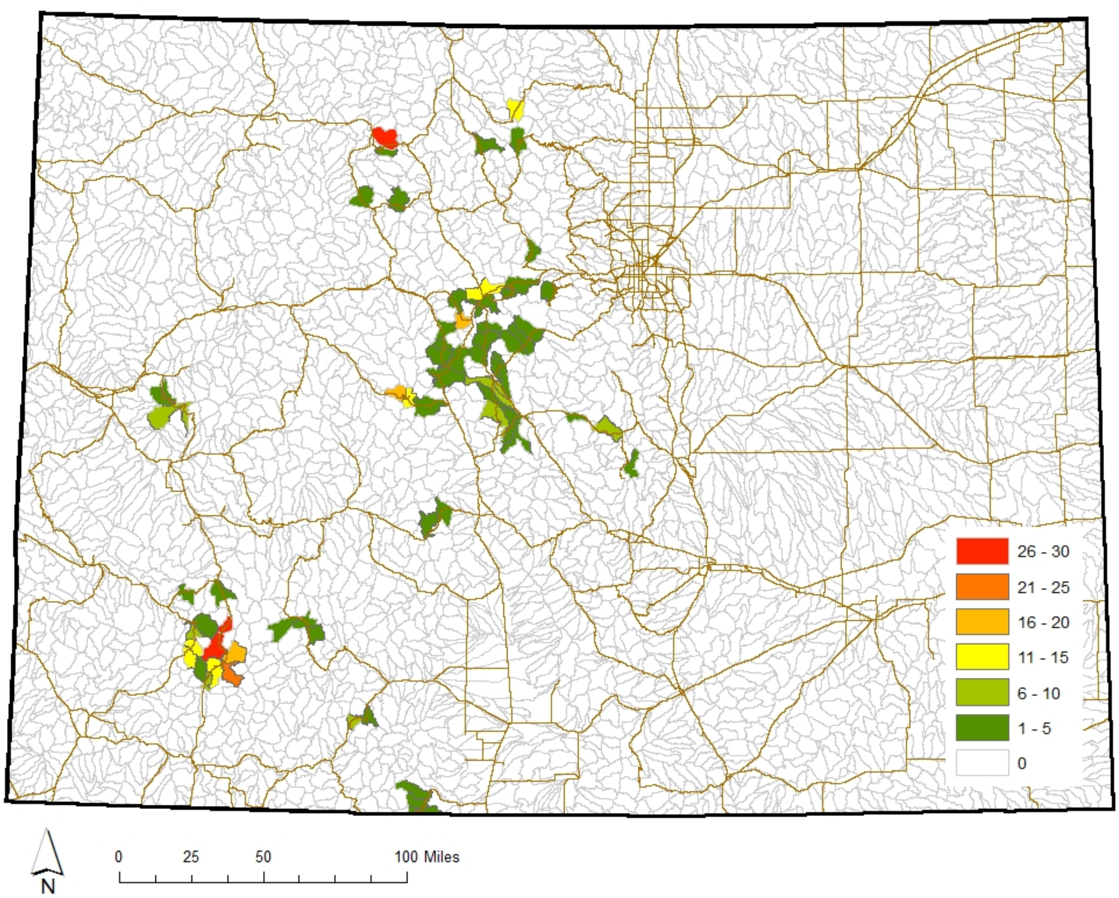


**Figure 6. Count of confirmed and likely fens by HUC12 watershed along Colorado state and federal highways.**

Fen density was also analyzed by highway segment. Two highway segments were especially dense in confirmed and likely fens: U.S. Route 550B and U.S. Route 285D. The U.S. Route 550B segment was singular in its number of individual confirmed and likely fens. From its southern terminus in Durango, this highway segment runs north along the Animas River through the San Juan and Uncompahgre National Forest in the San Juan Mountain range. Fens were particularly abundant near the highway's high mountain passes, including Molas Pass (10,900 ft), as well as along Mineral Creek south of Red Mountain Pass (10,250 ft) and the historic mining town of Ironton (9,500 ft). From Ironton, U.S. Route 550B continues north through Ouray, then drops in elevation to its northern terminus in Montrose. Throughout this segment, 117 confirmed and likely fens were mapped within the 500-m buffer.

The U.S. Route 285D segment stretches north from its junction with U.S. Route 24 (near U.S. Route 24 mile marker 226, south of Antero Reservoir), and extends through the South Park valley. It continues northeast from Fairplay, climbs out of South Park over Kenosha pass, and then descends in elevation toward Conifer, reaching its terminus in the foothills of Indian Hills. Though only 19 fens were mapped along this segment, this stretch of highway has a disproportionately large acreage of confirmed and likely fens (1,025 acres) due to the unique hydrogeology of South Park. It is an area particularly known for large and significant fens.

**Table 5. Confirmed and likely fen number and acreage by highway segment.**

| Highway Segment | Confirmed & Likely Fens | |
|---|---|---|
| | Number | Acres |
| US 550B | 117 | 341 |
| I-70A | 39 | 62 |
| CO 145A | 36 | 106 |
| CO 82A | 36 | 68 |
| US 40A | 30 | 246 |
| CO 65A | 23 | 84 |
| US 285D | 19 | 1,025 |
| US 24A | 19 | 150 |
| CO 14B | 14 | 23 |
| CO 17A | 11 | 40 |
| CO 149A | 11 | 35 |
| CO 9B | 8 | 154 |
| US 160A | 8 | 18 |

| Highway Segment | Confirmed & Likely Fens | |
|---|---|---|
| | Number | Acres |
| CO 9C | 7 | 27 |
| CO 91A | 4 | 13 |
| US 6F | 3 | 1 |
| US 50A | 2 | 5 |
| CO 67F | 2 | 4 |
| CO 134A | 2 | 3 |
| CO 103A | 1 | 6 |
| US 34A | 1 | 2 |
| CO 131B | 1 | 2 |
| CO 62A | 1 | <1 |
| CO 125A | 1 | <1 |
| **Total** | **396** | **2,414** |

On a more localized scale, certain sections of highway (smaller units than segments) had a particularly high density or acreage of fens. Below are the most notable hot-spots of confirmed and likely fen formation.

- US 550B: Molas Pass (51 fens in 8 miles) (Figures 7-9)
- US 550B: Near Red Mountain Pass (53 fens in 12 miles) (Figures 10-12)
- CO 145A: Near Lizard Head Pass (22 fens in 4 miles) (Figures 13-14)
- CO 82A: Independence Pass (26 fens in 8 miles) (Figure 15-16)
- US 285D: South Park (15 fens, many large, in 24 miles) (Figure 17-19)
- US 40A: Near Rabbit Ears pass (28 fens in 7 miles) (Figure 20-21)
- CO 65A: Grand Mesa (23 fens in 11 miles) (Figure 22-23)
- I-70A: West of Copper Mountain Ski Resort (22 fens in 5 miles) (Figure 24-26)

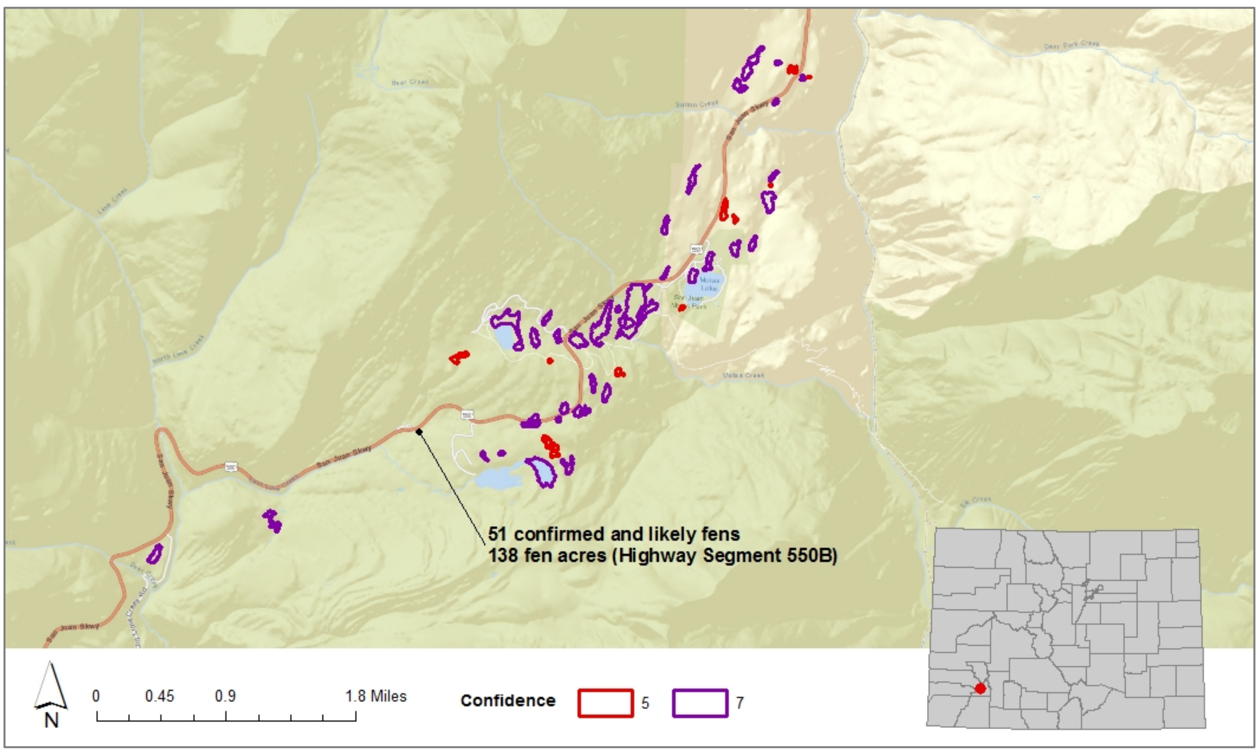


**Figure 7. U.S. Route 550, Molas Pass, Colorado**


**Figure 8. Polygon 550B-0378 in the Molas Pass area.**


**Figure 9. Polygon 550B-0363 in the Molas Pass area. This fen was immediately adjacent to the highway and was likely bisected when the road was built.**

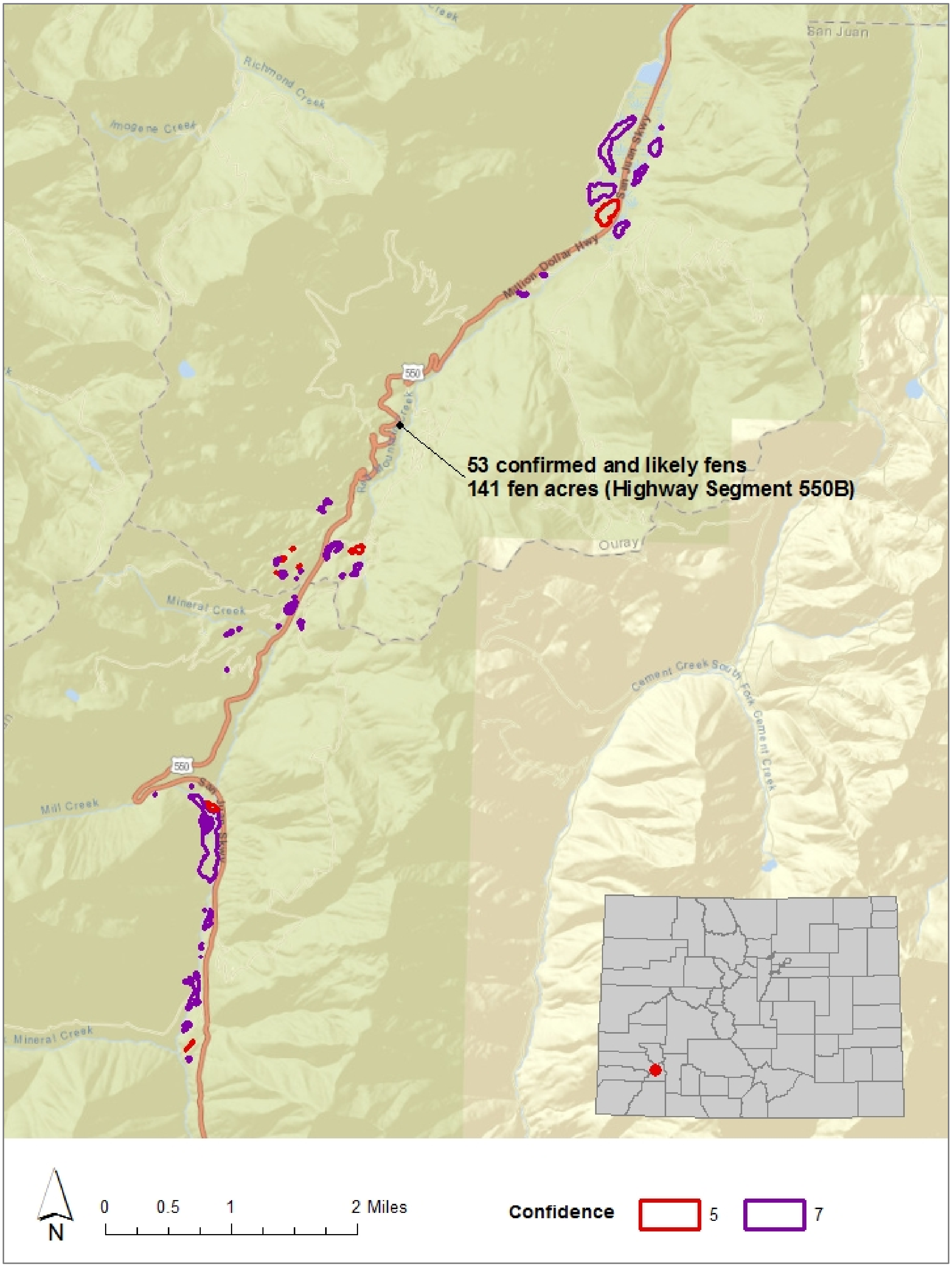


**Figure 10. U.S. Route 550, Red Mountain Pass, Colorado**

**Figure 11. Polygon 550B-0583, Chattanooga Iron Fen along Mineral Creek outside of Silverton. Photo taken in 2007 as part of the Chimner et al. (2008) study.**

**Figure 12. Polygon 550B-0871 in Ironton Park. Note pools of iron-rich water. Photo taken in 2006 as part of the Chimner et al. (2008) study.**

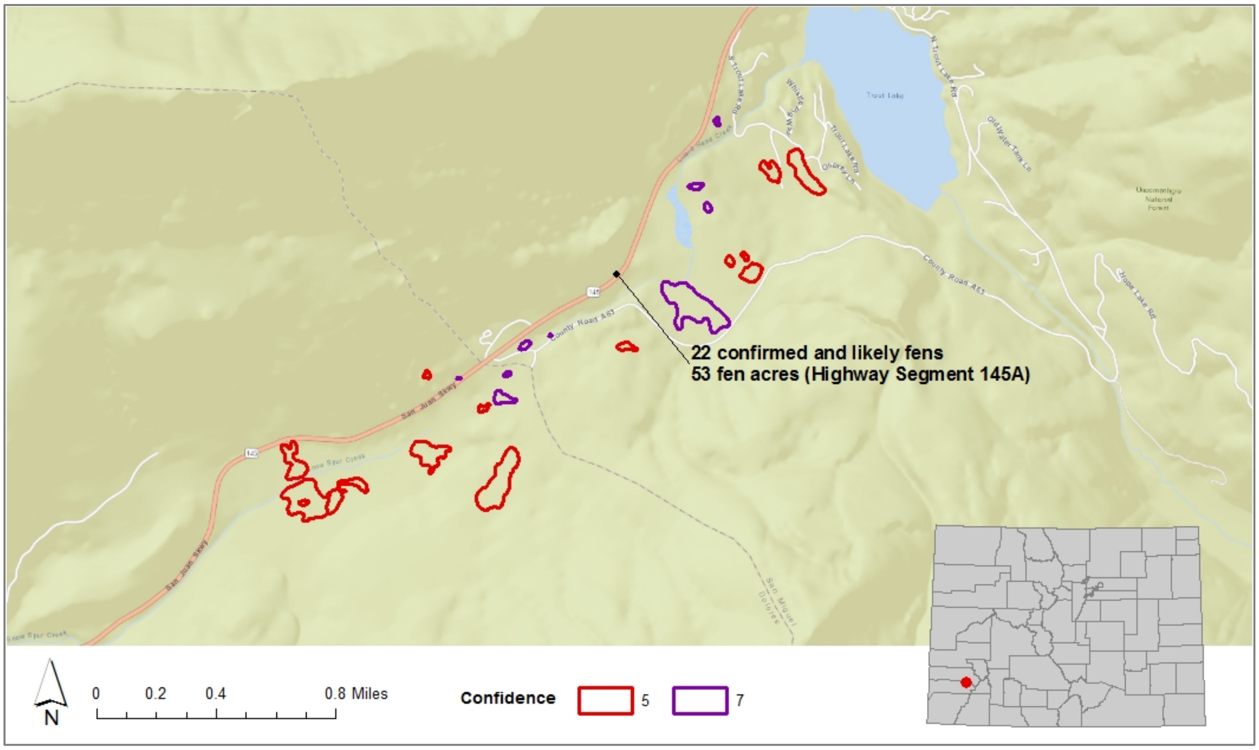


**Figure 13. CO State Highway 145, Lizard Head Pass, Colorado**


**Figure 14. Polygon 145A-0675 in the Lizard Head Pass area.**

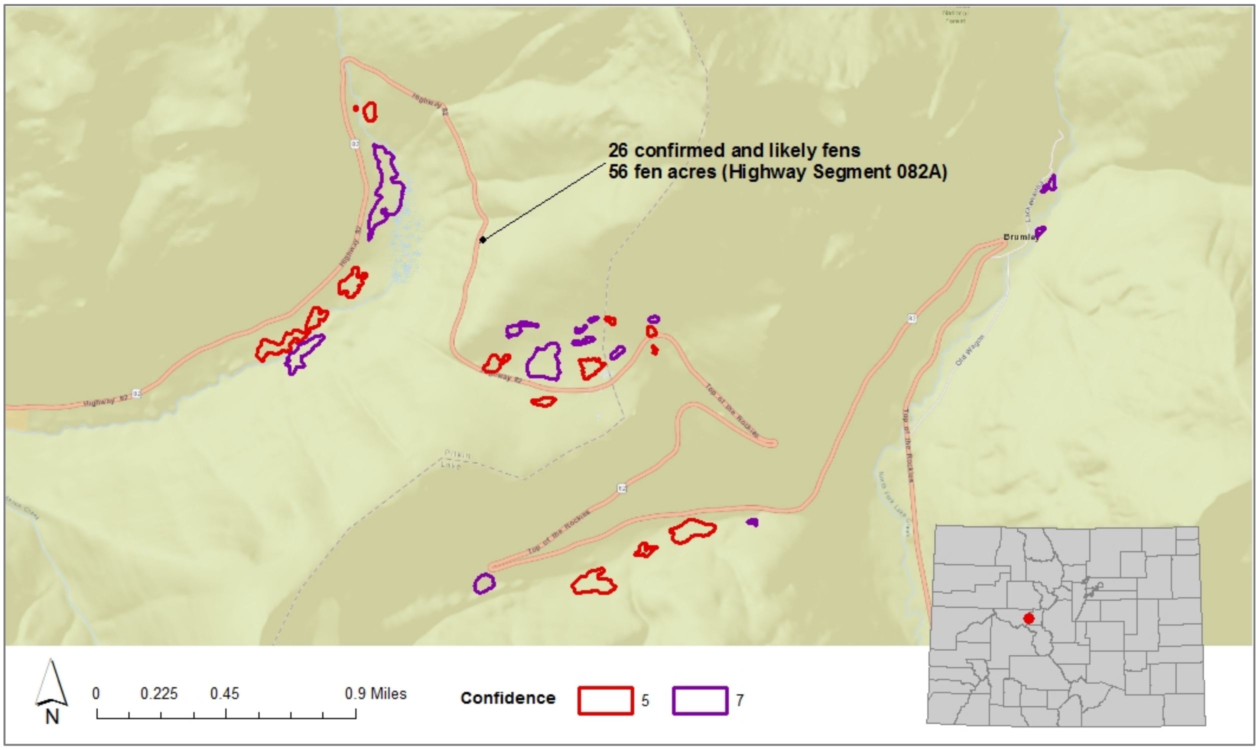


**Figure 15. CO State Highway 82, Independence Pass, Colorado**

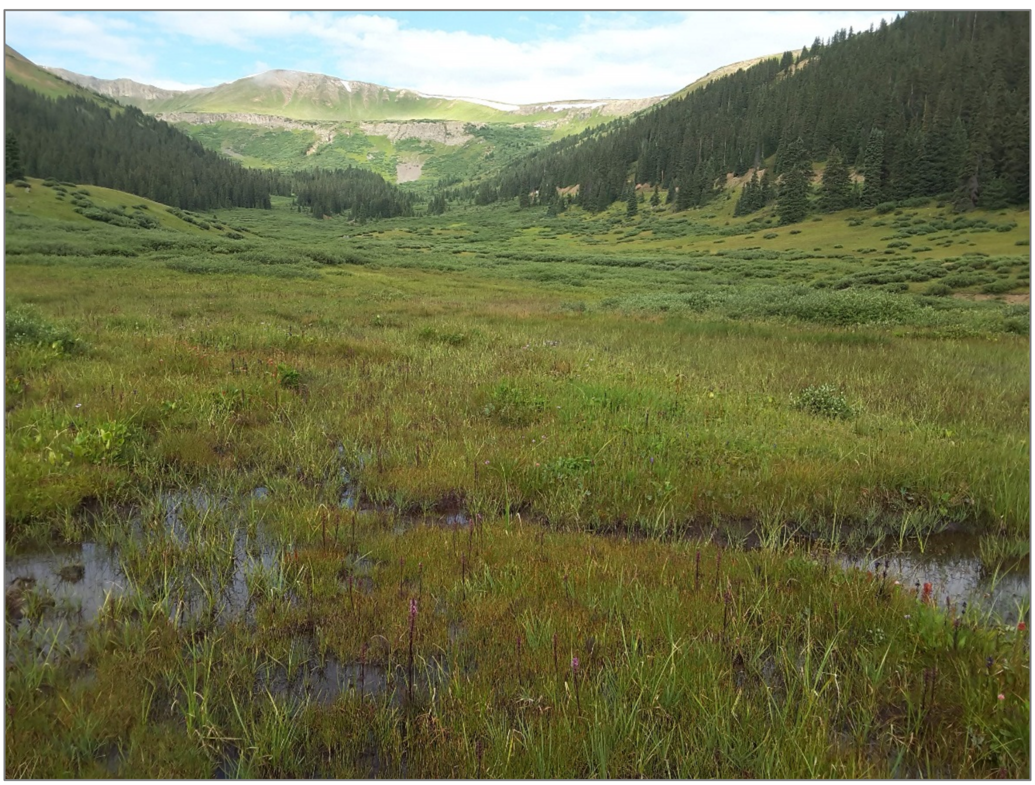

**Figure 16. Polygon 082-3240 near Independence Pass.**

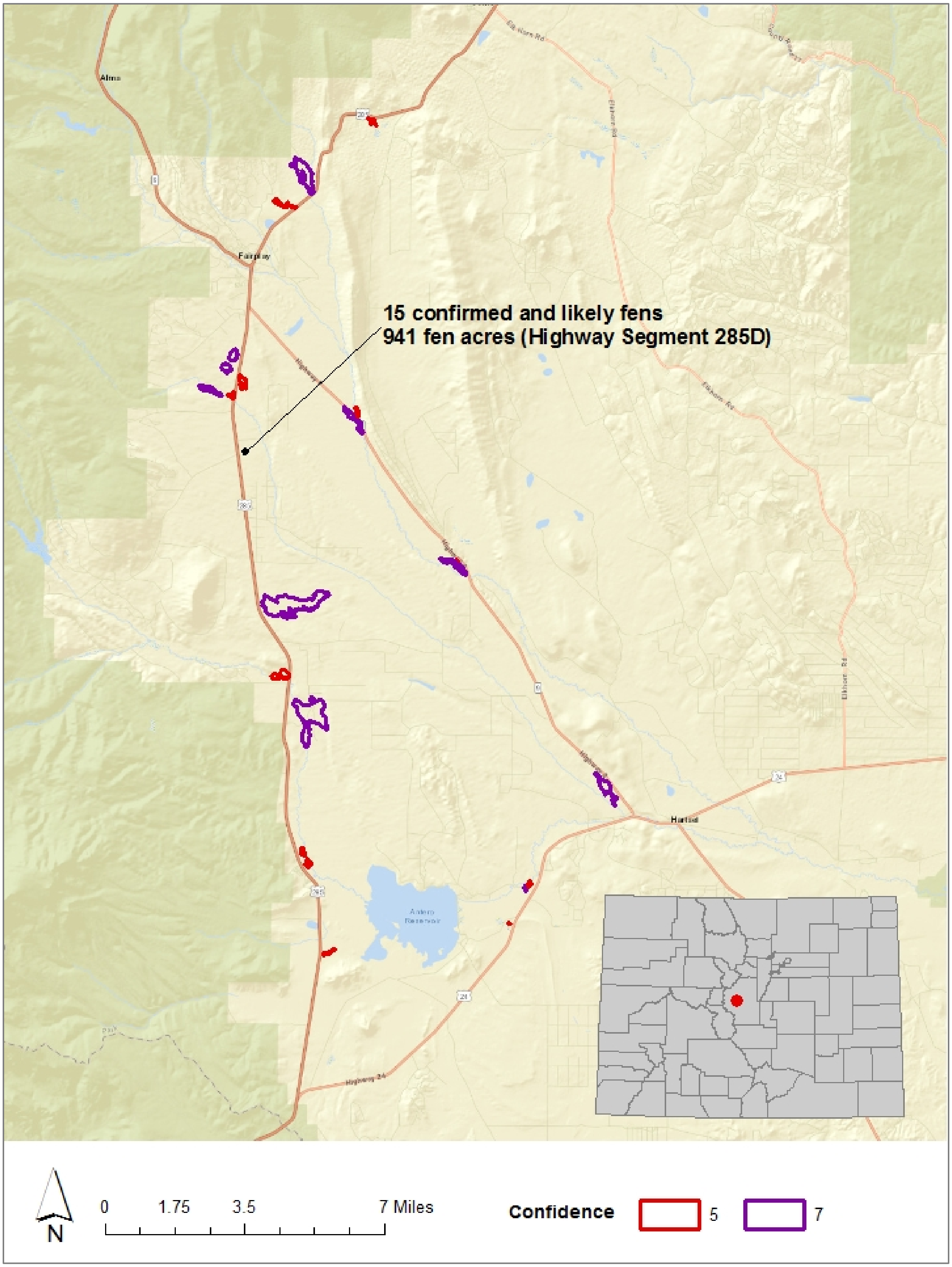


**Figure 17. U.S. Route 285, South Park, Colorado**

**Figure 18. Polygon 285D-3052, High Creek Fen in South Park.**

**Figure 19. Polygon 285D-3071 along the South Fork of the South Platte River.**

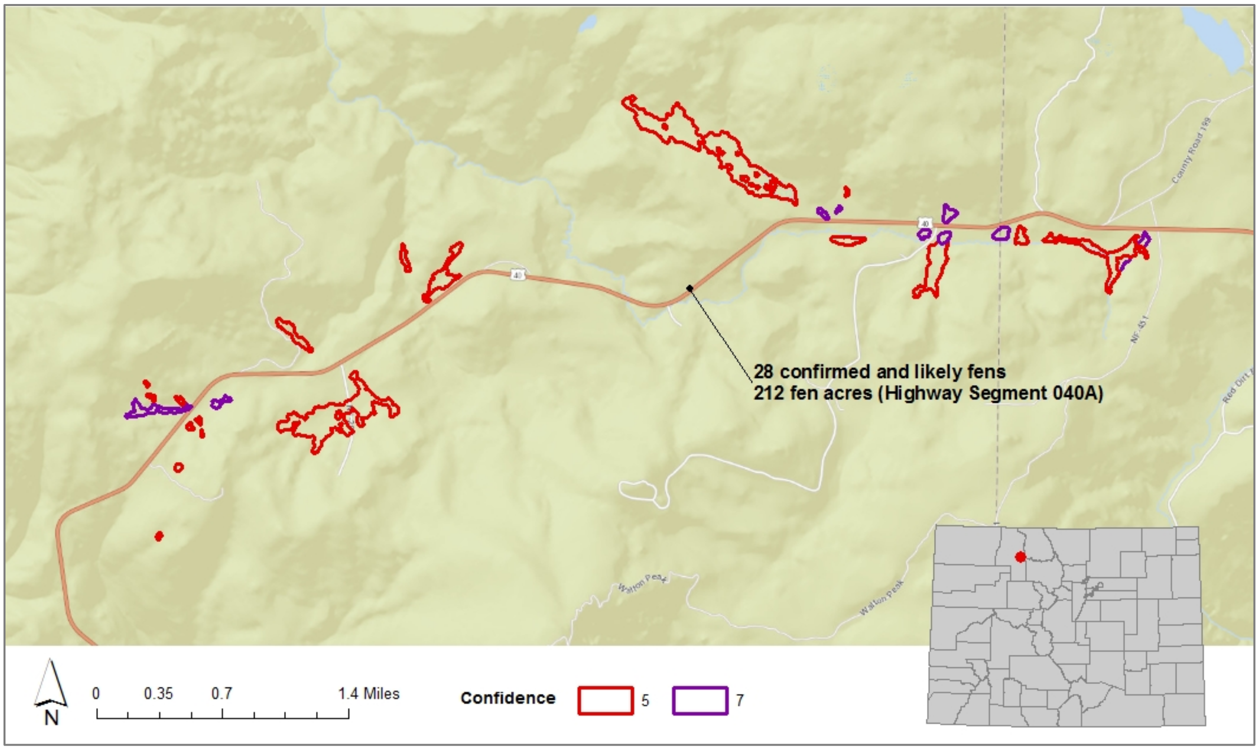


**Figure 20. U.S. Route 40, Near Rabbit Ears Pass, Colorado**

**Figure 21. Polygon 040A-0259 near Rabbit Ears Pass.**

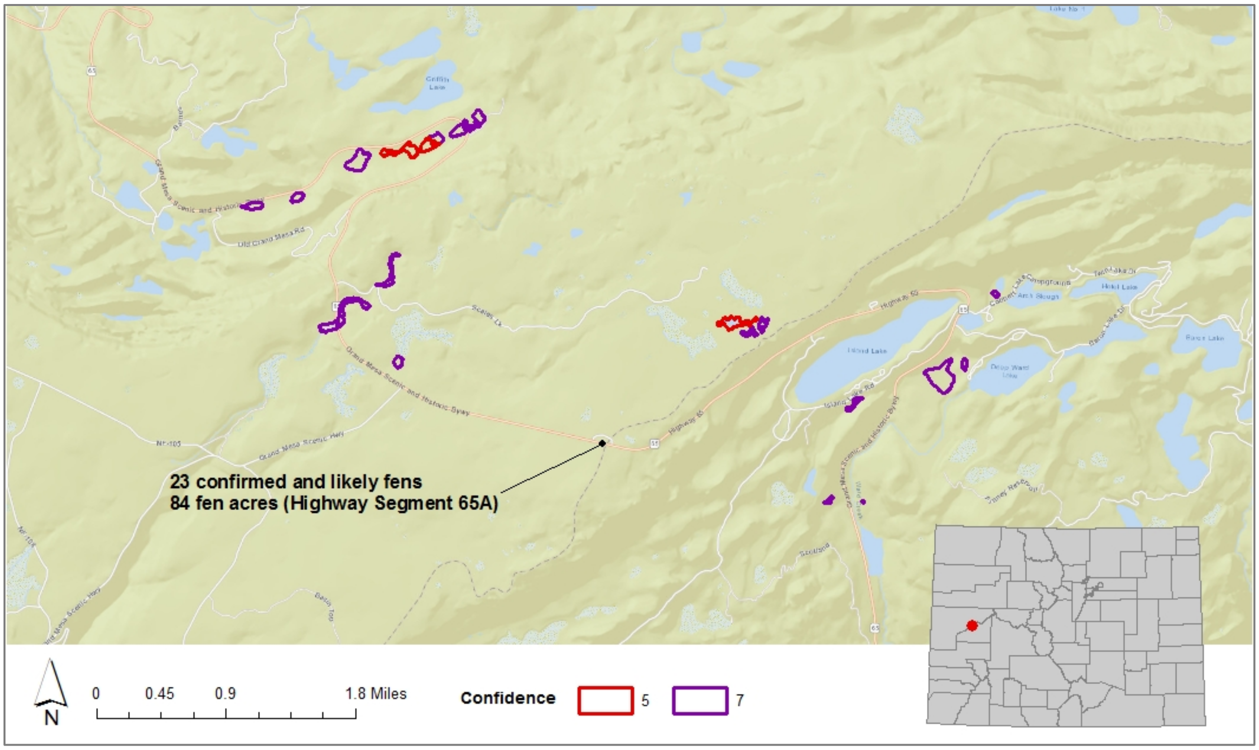


**Figure 22. CO State Highway 65, Grand Mesa, Colorado**

**Figure 23. Polygon 065A-3405 on Grand Mesa.**

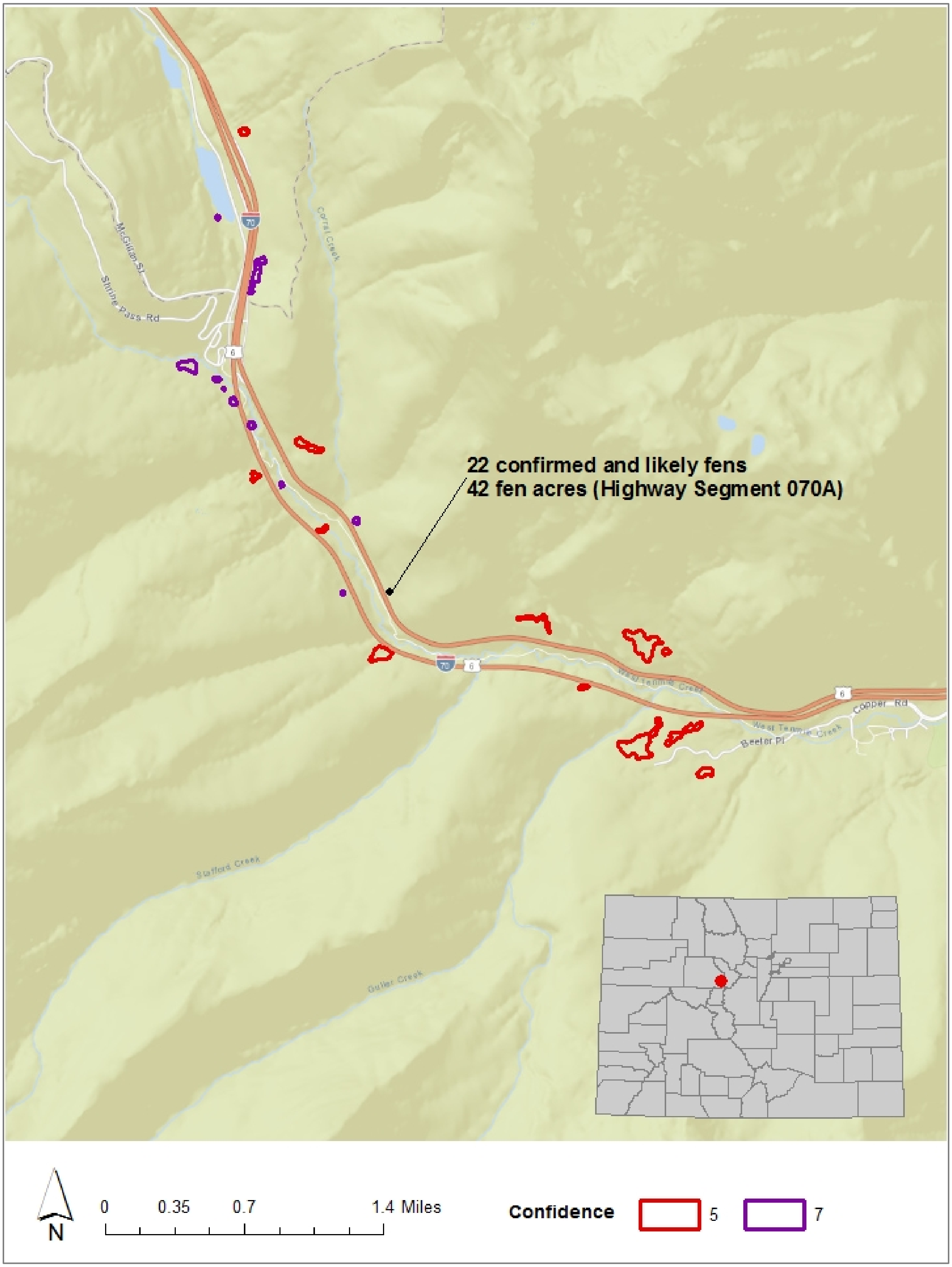


**Figure 24. Interstate 70, West of Copper Mountain Ski Resort, Colorado**

**Figure 25. Polygon 070A-0474 along Interstate 70 near Vail Pass.**

**Figure 26. Polygon 070A-2965 along Interstate 70 near Vail Pass.**

## 4.3 Mapped Potential Fens by Land Ownership and Proximity to Road

The majority of confirmed and likely fens were located on public lands (Table 6). Fens primarily occur in Colorado at an elevation band from roughly 9,000 to 11,000 ft (see Section 4.4 for more information on elevation), and these elevations are typically less developed than lowland and foothill areas, and thus more likely to be incorporated into U.S. Forest Service or other public lands. Nearly three-quarters (73%) of all confirmed and likely fens occurred on U.S. Forest Service (USFS) land, accounting for 37% of confirmed and likely fen acreage. Another 6% of confirmed and likely fens and 2% of fen acres occurred on Bureau of Land Management (BLM) lands, mostly in the San Juan Mountains where BLM administers high elevation lands adjacent to USFS land. These areas are somewhat atypical of most BLM lands in Colorado, which are more commonly found at lower elevations. Remaining public land owners with mapped fens include local governments (Denver Water and Denver Mountain Parks), state land (Colorado Parks and Wildlife and State Land Board), and the National Park Service (Rocky Mountain National Park), who each own land containing 10 or fewer of the mapped confirmed and likely fens. The remaining 18% of fens and 45% of fen acres occurred on private lands. These include several of the large fens in South Park.

Of those polygons on private land (or land owned by the State Land Board or Denver Water), where a fence demarcated the ROW, only four fens were found to extend into the actual ROW (Table 7). All four of these fens were much larger than the portion within the ROW. Polygons 550B-0566 and 550B-0850 both crossed multiple land ownerships, including private property, BLM, and USFS land, in the San Juan Mountains. In both cases, a sliver of the fen polygon was within the private ROW. Polygon 024A-3246 was one of several confirmed or likely fens found within vegetated drainages near the town of Divide. Of the polygons near Divide, only 024A-3246 extended all the way into the ROW; the others ended before reaching the ROW. Finally, polygon 067F-3793 was an interesting case. This polygon was drawn around the margin of an artificially excavated lake near Cripple Creek. The peat soil dug within the ROW was dried, indicating a historic fen that was no longer functioning. Farther out from the ROW, however, there was indication that the margins of the lake were, indeed, still fen.

While very few fens extended into the ROW, 34 confirmed or likely fens on private land were part of wetland complexes that did extend into the ROW. More than a dozen of these were relatively close to the highway (< 25 m from the pavement edge). Another 45 confirmed or likely fens were on private lands, but upland vegetation separated the ROW from the fens and/or their encompassing wetland complexes, even if they were 10 m or less from the pavement. We observed that in many areas of the state, the gravel road base underneath the actual road pavement often extended nearly to the margin of the ROW or even past the ROW, isolating the highways and ROW from wetlands immediately adjacent.

On public lands, fens ranged in distance from the pavement. Fourteen confirmed and likely fens occurred less than 5 m from the pavement edge. Another 23 occurred between 5–10 m from the pavement edge and 36 occurred between 10–25 m. These and other fens very close to the highways should be closely monitored by CDOT. Across all confirmed and likely fens, nearly a third (30%) were located over 200 m from the highway. As distance from highway increased, the likelihood that fens were contiguous to the highway decreased, but even with great distances, many fens were hydrologically connected to roadside wetlands or streams.

**Table 6. Confirmed and likely fens by major land ownership class.**

| Ownership | Confirmed & Likely Fens | |
|---|---|---|
| | Number | Acres |
| USFS | 288 | 895 |
| Private | 74 | 1,079 |
| BLM | 23 | 58 |
| Local Gov't | 7 | 30 |
| State Land | 2 | 13 |
| Land Trust | 1 | 337 |
| NPS | 1 | 2 |
| **TOTAL** | **396** | **2415** |

**Table 7. Confirmed and likely fens by distance from road and ROW status.**

| Distance from Road (m) | Private | | | Public | | | Grand Total |
|---|---|---|---|---|---|---|---|
| | In ROW | ROW Contiguous | ROW Non-Contiguous | Easement Contiguous | Easement Non-Contiguous | Non-Easement | |
| <5 m (16 ft) | 2 | -- | -- | 14 | -- | -- | 16 |
| 5-10 m (16-33 ft) | 2 | 3 | 1 | 20 | 3 | -- | 29 |
| 10-25 m (33-82 ft) | -- | 11 | 7 | 16 | 2 | -- | 36 |
| 25-50 m (82-164 ft) | -- | 1 | 2 | 28 | 8 | 1 | 40 |
| 50-75 (164-246 ft) | -- | 6 | 5 | 12 | 10 | 1 | 34 |
| 75-100 m (246-328 ft) | -- | 2 | 2 | 15 | 14 | -- | 33 |
| 100-150 m (328-492 ft) | -- | -- | 6 | 15 | 26 | 2 | 49 |
| 150-200 m (492-656 ft) | -- | 3 | 3 | 16 | 16 | 1 | 39 |
| >200 m (656 ft) | -- | 8 | 19 | 15 | 71 | 7 | 120 |
| **Total** | **4** | **34** | **45** | **151** | **150** | **12** | **396** |

## 4.4 Mapped Potential Fens by Elevation, Geology, and Ecoregion

### *Elevation*

Elevation is an important factor in the location of fens. Fen formation occurs where there is sufficient groundwater discharge to maintain permanent saturation. This is most often at higher elevations, where slow melting snowpack can percolate into subsurface groundwater.

Of the 396 confirmed and likely fens, the majority (314 polygons or 2,159 acres) occurred between 9,000 to 11,000 ft, which represents 79% of confirmed and likely fen locations and 89% of confirmed and likely fen acres (Table 8; Figure 27). The 500-ft elevation band of 10,000 to 10,500 ft stood out as one zone of peak fen formation (Figure 28). This elevation band supported the greatest number of confirmed and likely fens (35% of all confirmed fens and 26% of all likely fens). However, a different picture emerged when examining fen acreage. The 500-ft elevation band of 9,000 to 9,500 ft supported the greatest acreage of confirmed and likely fens within the buffer of state and federal highways (Figure 29). Fifty-one percent of confirmed fen acres and 33% of likely fen acres occurred between 9,000 and 9,500 ft elevation. The presence of these two distinct peaks of fen formation is due to the influence of large fens that occur in South Park along U.S. Route 285D, which lies between 9,000–9,500 ft, thus skewing the acreage data lower than the count data. These fens are fewer in number, but several are very large in acreage (average of 43.8 acres per confirmed and likely fen in South Park, versus average of 6.1 acres across all confirmed and likely fens). Most other hot-spots of fen formation (see Section 4.2), are high-mountain passes in the 10,000 to 10,500 ft range, where fens more commonly form in clusters of small-acreage polygons.

**Table 8. Confirmed and likely fens by elevation.**

| *Elevation Range (ft)* | *Confirmed & Likely Fens* | |
|---|---|---|
| | *Number* | *Acres* |
| > 7,000 - 7,500 | -- | -- |
| > 7,500 - 8,000 | 1 | 1 |
| > 8,000 - 8,500 | 4 | 32 |
| > 8,500 - 9,000 | 23 | 142 |
| > 9,000 - 9,500 | 50 | 1,100 |
| > 9,500 - 10,000 | 62 | 489 |
| > 10,000 - 10,500 | 124 | 366 |
| > 10,500 - 11,000 | 78 | 205 |
| > 11,000 - 11,500 | 39 | 61 |
| > 11,500 - 12,000 | 2 | 2 |
| > 12,000 - 12,500 | 13 | 16 |
| > 12,500 - 13,000 | -- | -- |
| **Total** | **396** | **2,414** |

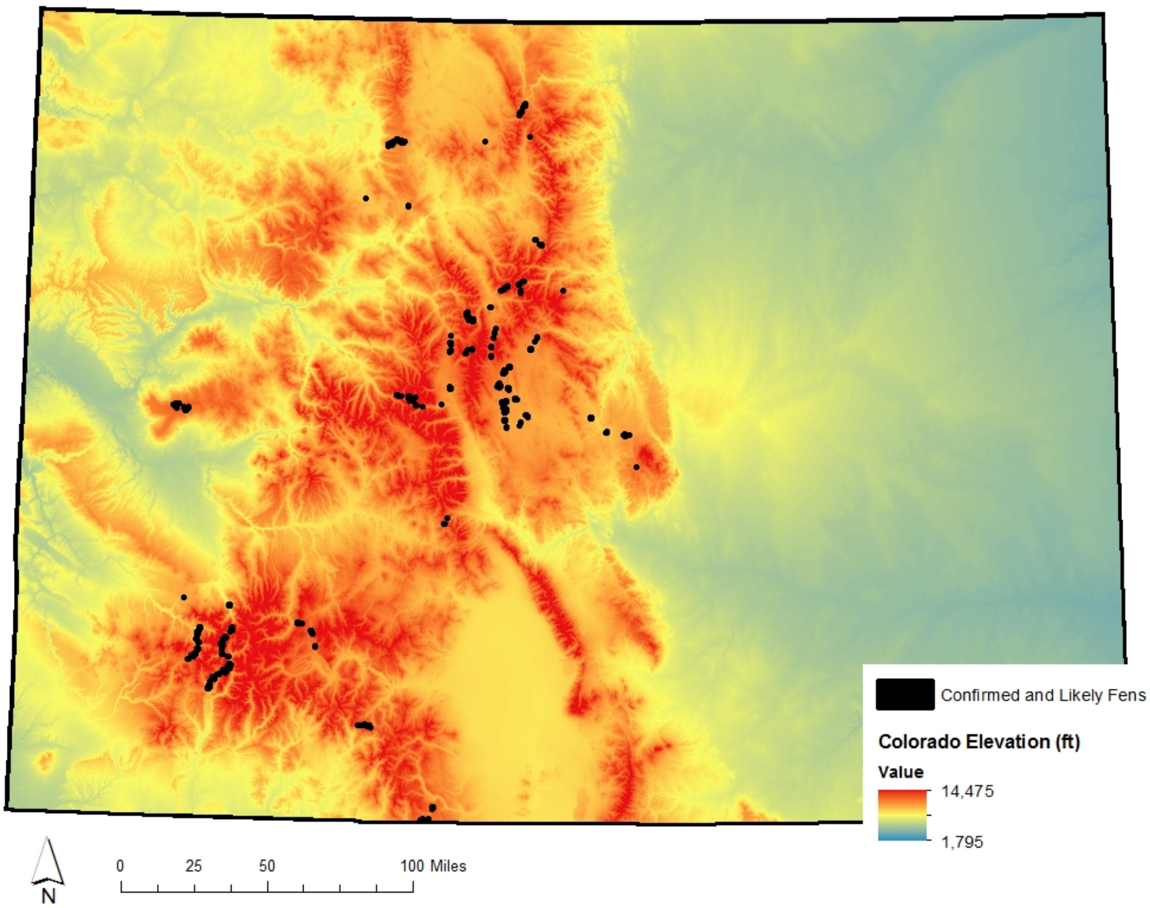


**Figure 27. Confirmed and likely fens along Colorado state and federal highways by elevation. Fen area exaggerated to visually highlight the locations.**

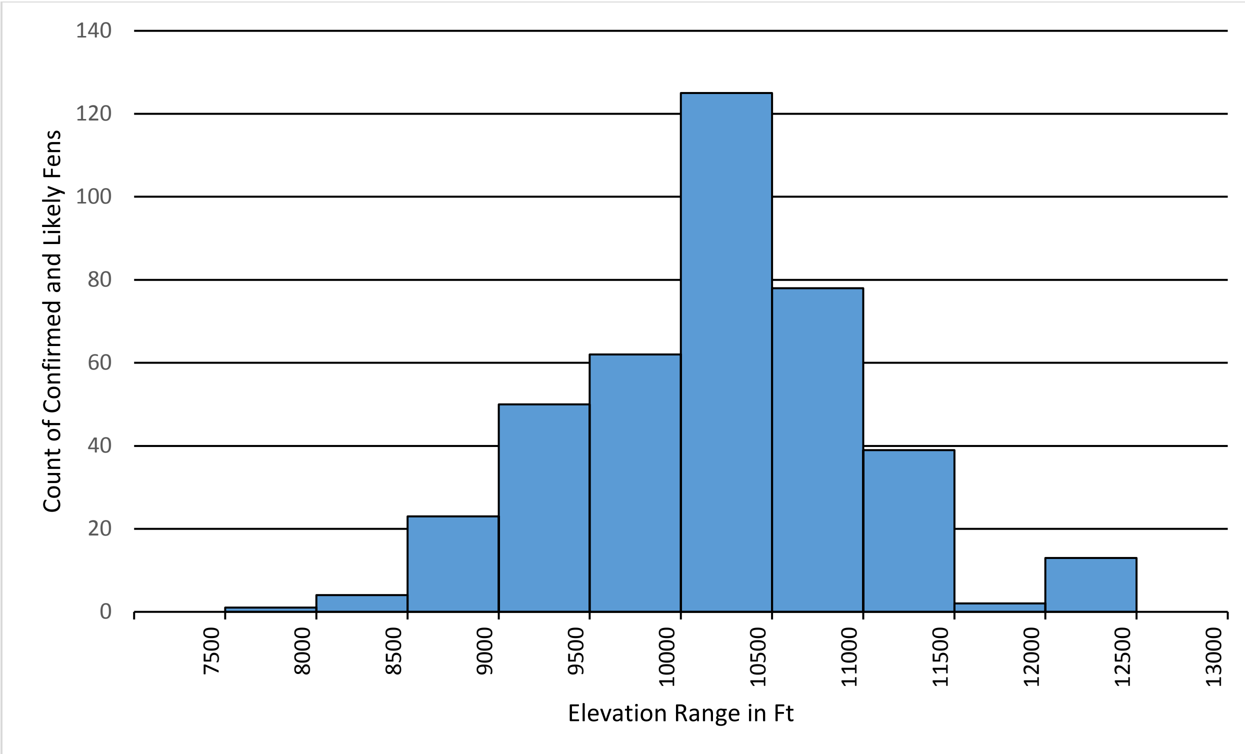


**Figure 28. Histogram of confirmed and likely fens by elevation within 500-m buffer of Colorado highways.**

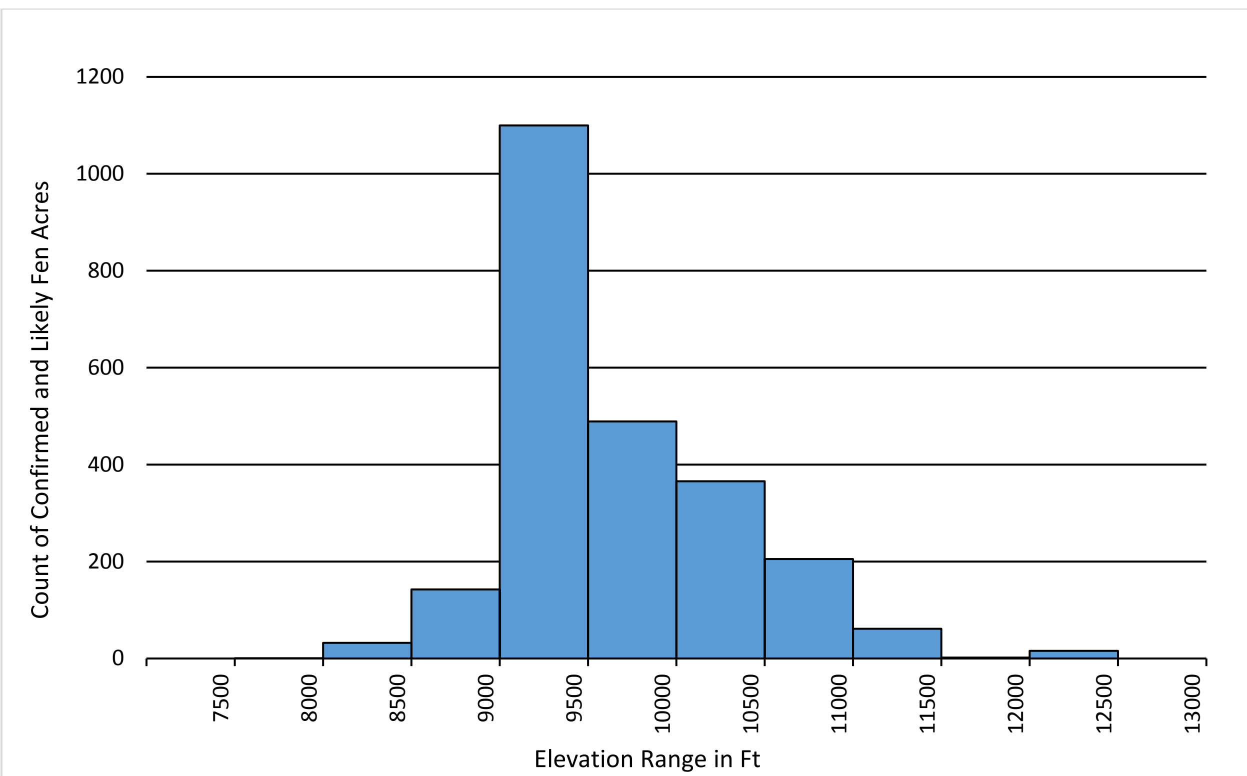


**Figure 29. Histogram of confirmed and likely fen acres by elevation within 500-m buffer of Colorado highways.**

### *Geology*

The most common geologic substrate type under both confirmed and likely fens was metamorphic or igneous units with a dominantly silicic composition. This substrate occurs in a large swath of central Colorado along the continental divide and covers 17% of the state as a whole. Forty percent of all confirmed and likely fens and 18% of all confirmed and likely fen acres have formed over this bedrock type (Table 9).

In contrast, quaternary age younger alluvium and surficial deposits underlies 10% of the state, but represents the greatest acreage of both confirmed and likely fens. This geologic substrate represents 50% of combined confirmed and likely fen acres. Quaternary age younger alluvium and surficial deposits occur in scattered fragments across the state, but are relatively common in the South Park valley. This disproportionate acreage of fens that formed over quaternary age younger alluvium and surficial deposits is, again, influenced by the large-acre fens in South Park.

Sandstone dominated formations of all ages is also a prominent geologic substrate, underlying 17% of all confirmed and likely fens and 20% of confirmed and likely fen acres. Sandstone dominated formations of all ages is the most common geologic substrate occurring in Colorado, covering 30% of the state, though most of this is at lower elevations. The fens that did occur on sandstone were mostly located on sedimentary outcrops in the San Juan Mountains and in South Park.

**Table 9. Confirmed and likely fens by geologic substrate within a 500-m buffer of Colorado highways.**

| Geology | Confirmed & Likely Fens | |
|---|---|---|
| | Number | Fen Acres |
| Metamorphic or igneous units with a dominantly silicic composition all ages | 160 | 431 |
| Quaternary age younger alluvium and surficial deposits | 111 | 1,202 |
| Sandstone dominated formations of all ages | 68 | 487 |
| Carbonate dominated formations either limestone or dolomites of all ages | 19 | 38 |
| Shale dominated formations of all ages | 18 | 55 |
| Metamorphic or igneous units with dominantly mafic composition all ages | 10 | 43 |
| Quaternary age older alluvium and surficial deposits | 5 | 114 |
| Siltstone and or mudstone dominated formations of all ages | 3 | 4 |
| Evaporite units either halite, gypsum, or other saline mineral dominated formations | 1 | 36 |
| Water | 1 | 3 |
| **Total** | **396** | **2,414** |

### *Ecoregions*

Ecoregions are relatively homogenous patches of the landscape that share biotic and abiotic characteristics. Ecoregion classifications are based on patterns of geology, landforms, soils, vegetation, climate, land use, wildlife, and hydrology. Therefore, ecoregions integrate the elevation and geology data presented earlier. The ecoregion framework used for this analysis was derived from Omernik (1987) and is used by several federal agencies.[4] The framework was developed as a four-tiered hierarchy with the most detailed landscape information within Level IV ecoregions; each higher level is progressively more generalized.

Every one of the confirmed and likely fens occurred within the Southern Rockies Level III ecoregion. Eighty percent of all confirmed and likely fens occur within three Level IV ecoregions: Crystalline, Volcanic, or Sedimentary Subalpine Forests (Table 10). Crystalline Subalpine Forests are more common in the high country of north-central Colorado. This ecoregion covers 5% of Colorado, but contained 33% of all confirmed and likely fen locations. Volcanic Subalpine Forests primarily occur in southern Colorado in Gunnison, Saguache, Hinsdale, Mineral, Rio Grande, and Conejos counties, where large volcanic calderas formed over 20 million years ago. This ecoregion covers only 4% of Colorado, but contained 26% of all confirmed and likely fen locations. Sedimentary Subalpine Forests occur in the western San Juan Mountains and on either side of the Gore Range north of South Park. This ecoregion covers 6% of Colorado and contained 21% of all confirmed and likely fens.

The Grassland Parks ecoregion stands out as supporting the greatest total acreage for both confirmed and likely fens (48% of confirmed and likely fen acres), though it only covers 1% of Colorado. Grassland Parks are found in relatively few locations in Colorado, the largest of these being South Park. As previously mentioned, this reflects the size of the fens in the South Park valley. In contrast, the fens that form in the Volcanic Subalpine Forest and Crystalline Subalpine Forest ecoregions tend to be numerous but small in acreage.

**Table 10. Confirmed and likely fens by Level IV Ecoregion.**

| *Level IV Ecoregions* | *Confirmed & Likely Fens* | |
|---|---|---|
| | *Number* | *Fen Acres* |
| Crystalline Subalpine Forests | 130 | 500 |
| Volcanic Subalpine Forests | 103 | 314 |
| Sedimentary Subalpine Forests | 83 | 223 |
| Grassland Parks | 26 | 1,169 |
| Alpine Zone | 26 | 39 |
| Crystalline Mid-Elevation Forests and Shrublands | 15 | 69 |
| Sagebrush Parks | 2 | 56 |
| Volcanic Mid-Elevation Forests and Shrublands | 5 | 28 |
| Sedimentary Mid-Elevation Forests and Shrublands | 5 | 15 |
| Foothills and Shrublands | 1 | 2 |
| **TOTAL** | **396** | **2,414** |

[4] For more information on Omernik ecoregions, see https://www.epa.gov/eco-research/ecoregions.

## 4.5 Notable Mapped Fens

The largest mapped fen within the 500-m buffer of state and federal highways was High Creek fen (Figure 30), located along U.S. Route 285D in South Park. The ecology and hydrology of this and other significant fens in South Park is well-documented (Legg 2011; Johnson & Steingraeber 2003; Johnson & Gerhardt 2002; Johnson 2000; Cooper & Sanderson 1997; Cooper 1996; Sanderson & March 1996) and it is now managed by the Nature Conservancy as an established conservation area. High Creek fen covers 337 acres, and extends well beyond the highway buffer. This fen is 130 m from the highway at its closest point, and is not connected to the highway via any contiguous wetlands.

Several specific fen characteristics were noted by photo-interpreters, as well as by technicians during field verification (Table 11). Thirteen confirmed fens were noted as being confirmed or probable iron fens (Figure 31). All but one of these locations are located in the San Juan Mountains, along U.S. Route 550B. Iron fens are notable because of their highly acidic groundwater (pH as low as 4.0) and their potential to support rare Sphagnum moss species (Chimner et al. 2008; Cooper et al. 2002).

Beaver influence is a potentially confounding variable in fen mapping because longstanding beaver complexes can cause persistent saturation that appears very similar to fen vegetation signatures, but often do not accumulate organic soil. However, beavers can build dams in fens, so areas influenced by beavers cannot be excluded from mapping. Ten confirmed fens (55 acres) and 2 likely fens (23 acres) showed some evidence of beaver influence.

Floating mat fens (Figure 32) can also be of interest for conservation. They are a unique kind of fen, where at least 40 cm of peat forms above standing water, and they can support several state rare plant species. Three confirmed fens were documented to contain at least some areas of floating mats.

Springs and fens are both important components of groundwater-dependent ecosystems (GDEs). Springs were noted when observed on either the topographic map, aerial imagery, or if observed during field verification. Four confirmed fens were observed in proximity to visible springs (Figure 33). This survey was not an exhaustive examination of springs within fens, as many springs are not visible from aerial imagery, though they can be implicated in fen formation.

**Table 11. Confirmed and likely fens with distinctive characteristics within a 500-m buffer of Colorado highways.**

| *Observation* | *Confirmed & Likely Fens* | |
|---|---|---|
| | *Number* | *Fen Acres* |
| Iron Fen | 13 | 106 |
| Beaver Influence | 12 | 78 |
| Floating Mat | 3 | 25 |
| Spring | 4 | 9 |

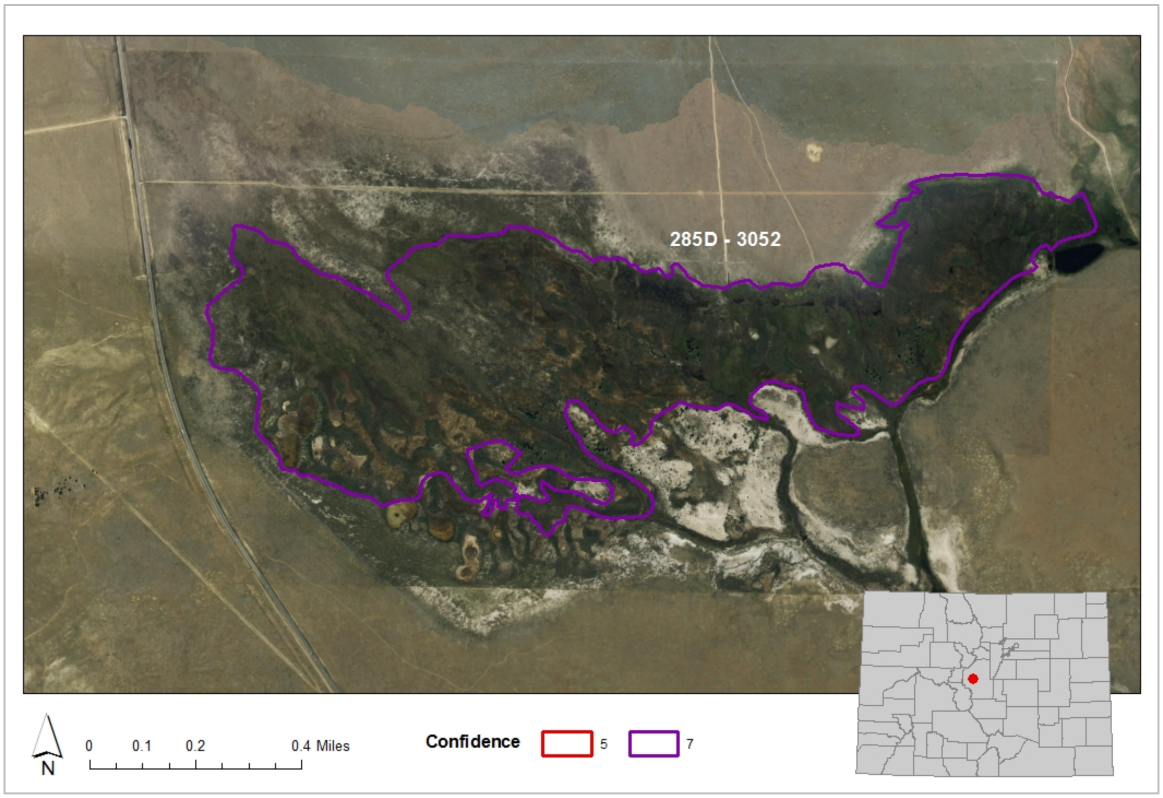


**Figure 30. The largest fen in our survey (337 acres), High Creek fen lies in the South Park valley.**

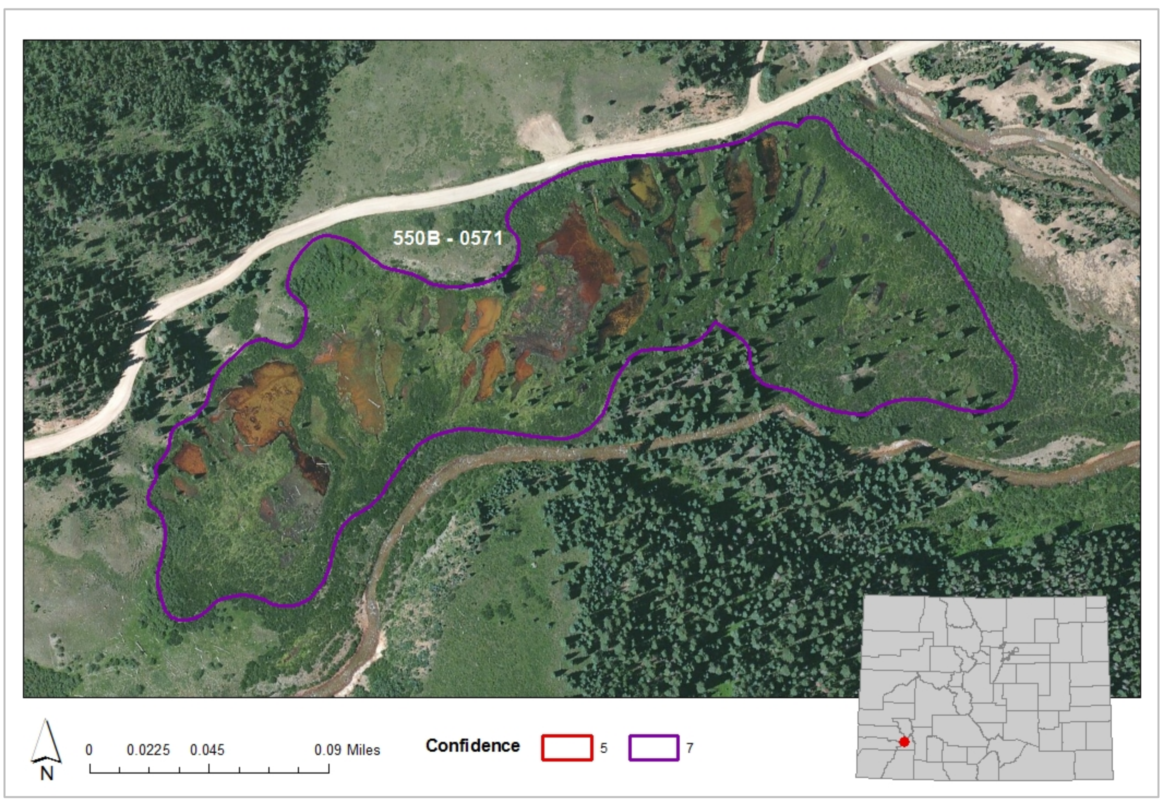


**Figure 31. A clear example of an iron fen that is also impacted by beaver activity.**

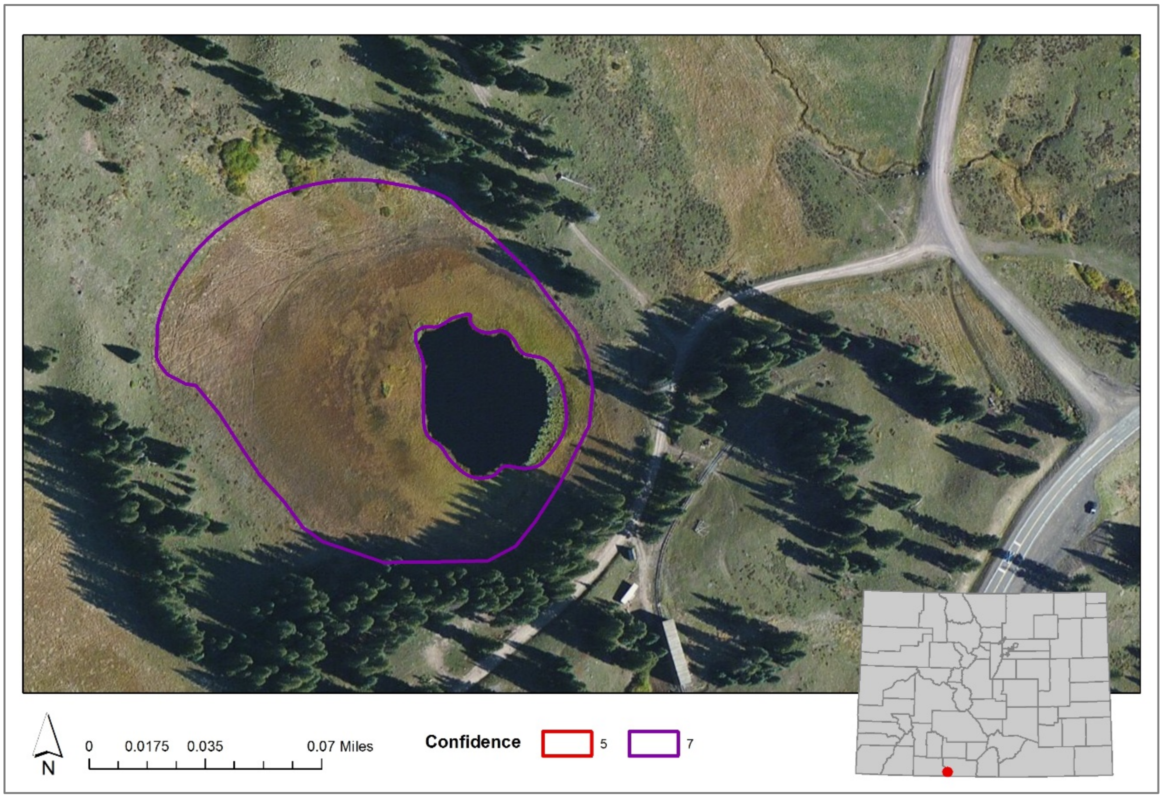


**Figure 32. A fen that was documented as containing floating mats.**

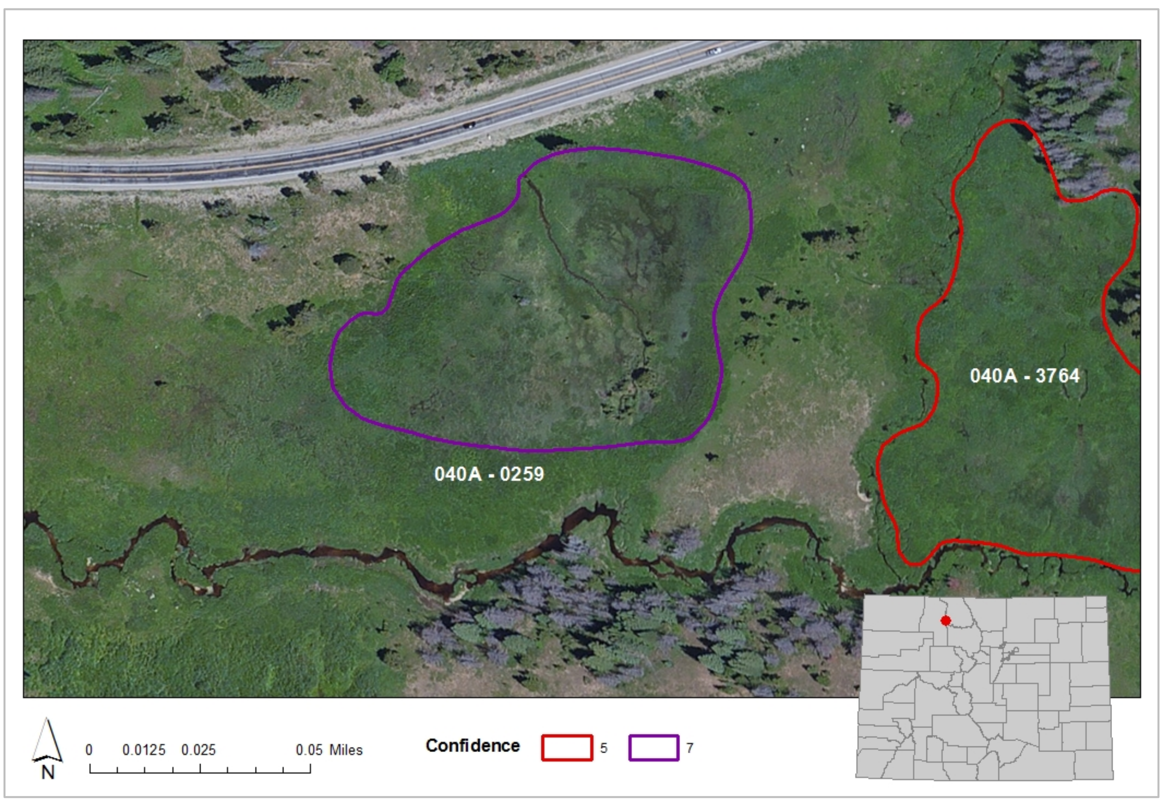


**Figure 33. A fen influenced by a spring originating just below the highway.**

## 4.6 Common and Rare Plant Species

The primary goal of this project was to map and field verify fen polygons, and not to conduct a full vegetation analysis within the fens. However, dominant plant species were documented in 182 of the 241 confirmed fen polygons. From those surveys, 240 unique taxa were identified, and 183 to the species level. The average number of species per site was 14. The least diverse sites were generally graminoid-dominated, most frequently with high area cover of water sedge (*Carex aquatilis*) and Northwest Territory sedge (*Carex utriculata*), sometimes with scattered diamondleaf willow (*Salix planifolia*). The most diverse sites were those with spatial heterogeneity, with islands of upland species interspersed with areas of peat accumulation. The number of plant species identified also depended on the timing of the survey and the ability to fully access the site. Several confirmed fens were visited in early to mid-June in both 2016 and 2017, before most high elevation fen species were fully flowering. Full species inventories were not conducted on confirmed fens located on private lands beyond the ROW fence. Several previous studies of fens in Colorado provide greater detail on species composition within fens (Bultema 2015; Johnston et al. 2012; Malone et al. 2011; Chimner et al. 2008; Austin 2008; Johnson 2000; Sanderson & March 1996).

### *Common Plant Species Observed*

Of the twenty most common plant species observed in fen sites within the highway buffer (Table 12), all were native. The majority of these species are well-suited to areas with lower disturbance or relatively unaltered landscapes, as indicated by their coefficients of conservatism (C-values), which ranged from 4 to 9. The most common species observed were largely adapted to wetland environments, and included eight true wetland obligates (OBL), six facultative wetland species (FACW), and three facultative species (typically occurring in both wetlands and non-wetlands; FAC). Of all 240 species recorded, only 22 are listed as Facultative Upland (usually occurring in non-wetlands; FACU), and none are listed as true upland obligates (UPL).

No non-native species were among our most commonly observed species; however four non-native species were recorded within surveyed fens. Common dandelion (*Taraxacum officinale*) was observed at 15 sites, timothy grass (*Phleum pratense*) was observed at five sites, Canada thistle (*Breea arvensis*) was observed at four sites, and meadow foxtail (*Alopecurus pratensis*) was observed at one site. Canada thistle is a list B noxious weed; the rest of these species are introduced, but are not included on noxious weed lists. All non-native species occurred with low area cover within fens (all four species had an average cover less than 1%).

Many of the most common species observed occurred in low cover. This includes many ubiquitous forbs, such as Rocky Mountain hemlockparsley (*Conioselinum scopulorum*) (44% of sites, 2% average cover), redpod stonecrop (*Clementsia rhodantha*) (42% of sites, 1% average cover), and felwort (*Swertia perennis*) (38% of sites, 1% average cover). To focus on the species that best represent the sites surveyed, a unitless 'importance value' was calculated by adding relative frequency and relative abundance of each species.[5] The resulting twenty most important species (Table 13) best characterize the species composition of Colorado fens within a 500-m buffer of state and federal highways. Together, these species comprised approximately 85% of the total plant cover recorded in all site visits.

[5] Relative frequency for each species = number of times the species was observed / total number of species observations across all sites. Relative abundance for each species = sum of cover for that species wherever it occurred / sum of cover of all species across all sites.

**Table 12. Twenty most common plant species observed in surveyed fens.**

| *Scientific Name (Weber) USDA synonym in parentheses* | *Common Name* | *# of Obs* | *Average Cover* | *Wetland Status[1]* | *C-Value* | *Native Status* |
|---|---|---|---|---|---|---|
| *Carex aquatilis* | water sedge | 145 | 32.3 | OBL | 6 | Native |
| *Salix planifolia* | diamondleaf willow | 136 | 23.2 | OBL | 7 | Native |
| *Carex utriculata* | Northwest Territory sedge | 110 | 30.8 | OBL | 5 | Native |
| *Psychrophila leptosepala (Caltha leptosepala)* | white marsh marigold | 106 | 9.8 | OBL | 7 | Native |
| *Pedicularis groenlandica* | elephanthead lousewort | 92 | 3.0 | OBL | 8 | Native |
| *Deschampsia cespitosa* | tufted hairgrass | 85 | 7.5 | -- | 4 | Native |
| *Conioselinum scopulorum* | Rocky Mountain hemlockparsley | 80 | 1.7 | FACW | 7 | Native |
| *Clementsia rhodantha (Rhodiola rhodantha)* | redpod stonecrop | 76 | 1.4 | FACW | 8 | Native |
| *Swertia perennis* | felwort | 69 | 1.3 | FACW | 8 | Native |
| *Betula glandulosa* | resin birch | 50 | 22.8 | OBL | 9 | Native |
| *Pentaphylloides floribunda (Dasiphora fruticosa)* | shrubby cinquefoil | 50 | 5.6 | FAC | 4 | Native |
| *Epilobium* sp. | willowherb | 47 | 0.7 | -- | -- | Native |
| *Geum macrophyllum* | largeleaf avens | 47 | 1.0 | FAC | 6 | Native |
| *Salix wolfii* | Wolf's willow | 43 | 20.1 | OBL | 8 | Native |
| *Senecio triangularis* | arrowleaf ragwort | 43 | 2.3 | FACW | 7 | Native |
| *Calamagrostis canadensis* | bluejoint | 39 | 18.4 | FACW | 6 | Native |
| *Viola* sp. | violet | 33 | 1.5 | -- | -- | Native |
| *Viola macloskeyi* | smooth white violet | 31 | 1.6 | OBL | -- | Native |
| *Picea engelmannii* | Engelmann spruce | 30 | 3.2 | FAC | 5 | Native |
| *Mertensia ciliata* | tall fringed bluebells | 29 | 1.5 | FACW | 7 | Native |

[1] Wetland Indicator Status based on the 2016 National Wetland Plant List for the Western Mountains region. OBL = obligate wetland species, found in wetlands 99% of the time; FACW = facultative wetland species, found in wetlands 67–99% of the time; FAC = facultative species, found in wetlands 34–66% of the time; FACU = facultative upland species, found in uplands 67–99% of the time; UPL = obligate upland species, found in uplands 99% of the time.

**Table 13. Twenty most important plant species observed in surveyed fens.**

| *Scientific Name (Weber) USDA synonym in parentheses* | *Common Name* | *Import. Value[1]* | *# of Obs* | *Avg Cover* | *Wetland Status* | *C-Value* | *Native Status* |
|---|---|---|---|---|---|---|---|
| *Carex aquatilis* | water sedge | 28.3 | 145 | 32.3 | OBL | 6 | Native |
| *Carex utriculata* | Northwest Territory sedge | 20.7 | 110 | 30.8 | OBL | 5 | Native |
| *Salix planifolia* | diamondleaf willow | 20.6 | 136 | 23.2 | OBL | 7 | Native |
| *Psychrophila leptosepala (Caltha leptosepala)* | white marsh marigold | 9.3 | 106 | 9.8 | OBL | 7 | Native |
| *Betula glandulosa* | resin birch | 7.5 | 50 | 22.8 | OBL | 9 | Native |
| *Deschampsia cespitosa* | tufted hairgrass | 6.5 | 85 | 7.5 | -- | 4 | Native |
| *Salix wolfii* | Wolf's willow | 5.9 | 43 | 20.1 | OBL | 8 | Native |
| *Pedicularis groenlandica* | elephanthead lousewort | 5.0 | 92 | 3.0 | OBL | 8 | Native |
| *Calamagrostis canadensis* | bluejoint | 5.0 | 39 | 18.4 | FACW | 6 | Native |
| *Eleocharis quinqueflora* | fewflower spikerush | 4.2 | 26 | 25.5 | OBL | 8 | Native |
| *Conioselinum scopulorum* | Rocky Mountain hemlockparsley | 3.9 | 80 | 1.7 | FACW | 7 | Native |
| *Clementsia rhodantha (Rhodiola rhodantha)* | redpod stonecrop | 3.6 | 76 | 1.4 | FACW | 8 | Native |
| *Pentaphylloides floribunda (Dasiphora fruticosa)* | shrubby cinquefoil | 3.4 | 50 | 5.6 | FAC | 4 | Native |
| *Swertia perennis* | felwort | 3.2 | 69 | 1.3 | FACW | 8 | Native |
| *Senecio triangularis* | arrowleaf ragwort | 2.2 | 43 | 2.3 | FACW | 7 | Native |
| *Geum macrophyllum* | largeleaf avens | 2.1 | 47 | 1.0 | FAC | 6 | Native |
| *Epilobium* sp. | willowherb | 2.1 | 47 | 0.7 | -- | -- | Native |
| *Picea engelmannii* | Engelmann spruce | 1.7 | 30 | 3.2 | FAC | 5 | Native |
| *Viola* sp. | violet | 1.6 | 33 | 1.5 | -- | -- | Native |
| *Carex* sp. | sedge | 1.5 | 25 | 4.3 | OBL | -- | Native |

[1] Importance value is a unitless number derived as the sum of relative frequency and relative cover across all species and all sites.

The four most important species were also the most frequently occurring, and were each present at over half of the surveyed fens: water sedge (*Carex aquatilis*), Northwest Territory sedge (*Carex utriculata*), diamondleaf willow (*Salix planifolia*), and white marsh marigold (*Psychrophila leptosepala*). Other important species include several woody species: resin birch (*Betula glandulosa*), Wolf's willow (*Salix wolfii*), shrubby cinquefoil (*Pentaphylloides floribunda*), and Engelmann spruce (*Picea engelmannii*).

The list also includes graminoids, such as tufted hairgrass (*Deschampsia cespitosa*), bluejoint (*Calamagrostis canadensis*), and fewflower spikerush (*Eleocharis quinqueflora*). While fewflowered spikerush occurred in only 14% of sites, it was the 10th most important species; in the sites where it occurred, it covered a high percentage of the site (average cover of 25.5%).

### *Rare Plant Species Observed in this Study and Documented from Previous Studies*

Four rare plant species[6] were observed in fens surveyed within the 500-m buffer (Table 14). These species are all considered globally secure (G5 or G4) but imperiled within the state (S1 or S2). Many rare fen plant species are common in northern latitudes, but are found in their far southern extent in Colorado within fens, which serve as glacial relicts. Three of the four rare plant observations were of previously documented populations that were revisited during this study. One new rare plant population was located during this study (*Carex diandra*) and this population will be added to the CNHP Biotics database.

Several additional rare plant populations have been previously documented within the 500-m buffer. Not all were observed during this study because rare plant populations were not the focus. That does not imply, however, that those populations no longer exist. Our crews did not seek out rare fen plant populations, especially those on private land, during the course of this study. It is important for CDOT to be aware of previously documented populations of rare fen plant species close to the highway, in case these species are encountered during planning for road construction and maintenance. Table 15 is a list of all rare fen plant species previously documented within CNHP's Biotics database within the 500-m buffer of Colorado highways. The number of element occurrences (EOs) indicates how many populations have been documented within roadside wetlands.

**Table 14. Rare plant species observed in fens within the 500-m buffer of Colorado highways.**

| *Scientific Name (Weber)* | *Common Name* | *G Rank* | *S Rank* | *# of Obs* | *Average Cover* |
|---|---|---|---|---|---|
| *Carex diandra* | lesser panicled sedge | G5 | S1 | 1 | 37.5% |
| *Eriophorum gracile* | slender cottongrass | G5 | S1S2 | 1 | 2.0% |
| *Primula egaliksensis* | Greenland primrose | G4 | S2 | 1 | 0.1% |
| *Salix candida* | sageleaf willow | G5 | S2 | 1 | 1.5% |

[6] Rarity was based on the Colorado Natural Heritage ranking system. For more information, please see: https://cnhp.colostate.edu/ourdata/help/heritage/.

**Table 15. Rare fen plant species previously documented within the 500-m buffer of Colorado highways.**

| ***Scientific Name (Weber)*** <br> ***USDA synonym in parentheses*** | ***Common Name*** | ***G Rank*** | ***S Rank*** | ***# of EOs*** |
|---|---|---|---|---|
| *Carex diandra* | lesser panicled sedge | G5 | S1 | 1 |
| *Carex leptalea* | bristly-stalked sedge | G5 | S1 | 3 |
| *Carex limosa* | mud sedge | G5 | S2 | 1 |
| *Carex livida* | livid sedge | G5 | S1 | 1 |
| *Carex viridula* | little green sedge | G5 | S1 | 6 |
| *Cylactis arctica* ssp. *acaulis* <br> *(Rubus arcticus* ssp. *acaulis)* | dwarf raspberry | G5T5 | S1 | 2 |
| *Eriophorum gracile* | slender cottongrass | G5 | S1S2 | 3 |
| *Primula egaliksensis* | Greenland primrose | G4 | S2 | 10 |
| *Ptilagrostis porteri* | Porter's feathergrass | G2 | S2 | 1 |
| *Salix candida* | sageleaf willow | G5 | S2 | 5 |
| *Salix myrtillifolia* | low blueberry willow | G5 | S1 | 1 |
| *Salix serissima* | autumn willow | G4 | S1 | 4 |
| *Sisyrinchium pallidum* | pale blue-eyed grass | G3 | S2 | 17 |
| *Trichophorum pumilum* | little bulrush | G5 | S2 | 4 |
| *Utricularia minor* | lesser bladderwort | G5 | S2 | 1 |

# 5.0 DISCUSSION

Colorado's fen wetlands are relatively rare. Along Colorado highways, confirmed and likely fens covered 2,413 acres, or just 0.07% of the total highway buffer. This percentage is consistent with estimates of fens throughout the entire state, which likely cover <100,000 acres, or 0.15% of the Colorado landscape (analysis based on CNHP datasets). Much of the state is not conducive to fen formation, especially the lower elevations on either side of the Continental Divide. Fens are generally restricted to an elevation band between 9,000 and 11,000 ft, where the climate is dominated by winter snowfall. Within the 500-m buffer of Colorado highways, there was a significant spike in number of fens between 10,000 and 10,500 ft. However, 9,000 to 9,500 ft contained the most fen acres, due to the large acreage of fens in South Park. The majority of fens formed over metamorphic or igneous bedrock in the mountains, or in valley bottoms covered by more recent alluvium.

Several significant hot-spots of fen formation were observed along the highway network, many of which have been the focus of previous research. Areas of especially high fen density or acreage included Molas Pass and Red Mountain Pass on U.S. Route 550 and Lizard Head Pass on Colorado State Highway 145. These passes cross through the San Juan Mountains, which are known for abundant and significant fens, including iron fens (Harbert & Cooper 2017; Johnston et al. 2012; Chimner et al. 2010; Cooper et al. 2002). U.S. Route 285 and Colorado State Highway 9 through South Park contained the highest density of fen acres, including several large fens that support rare plant populations and have been identified as priorities for conservation (Johnson & Steingraeber 2003; Cooper & Sanderson 1997; Cooper 1996; Sanderson & March 1996). Indeed, many of the fens in South Park are conserved via land trusts, managed by Colorado Open Lands and The Nature Conservancy, including High Creek fen. Across the state, the San Juan Mountains and South Park stood out as the two most important concentrations of fen resources along the highway network.

In addition, the highway network crossed other documented fen hotspots, such as Colorado State Highway 65 through Grand Mesa (Austin & Cooper 2015; Austin 2008); Interstate 70 west of Copper Mountain Ski Resort (Jones et al. 2009); and Colorado State Highway 82 across Independence Pass (Malone et al. 2011). In addition, fens were concentrated along U.S. Route 40 just west of Rabbit Ears Pass, but fens in this areas have not been as well-documented. Lastly, individual fens or smaller groups of fens occur along several other highway segments. All areas where fens occur are important to consider in transportation planning.

Several fens surveyed occurred close to the highway or, in more limited cases, within the actual highway ROW. In many cases, fen soils were not found within the ROW, but confirmed or likely fens existed just beyond the ROW fence. There were several examples of fens that were likely bisected or truncated by the original highway construction. For example, along Colorado Highway 14 near Cameron Pass and also along U.S. Route 550 near Molas Pass, several fens occur immediately adjacent to the road and end abruptly at the edge of the pavement. These fens were clearly impacted by road construction and likely continue to be impacted by the highway. Disrupting the hydrology of fens can lead to drying of the peat body and loss of characteristic fen

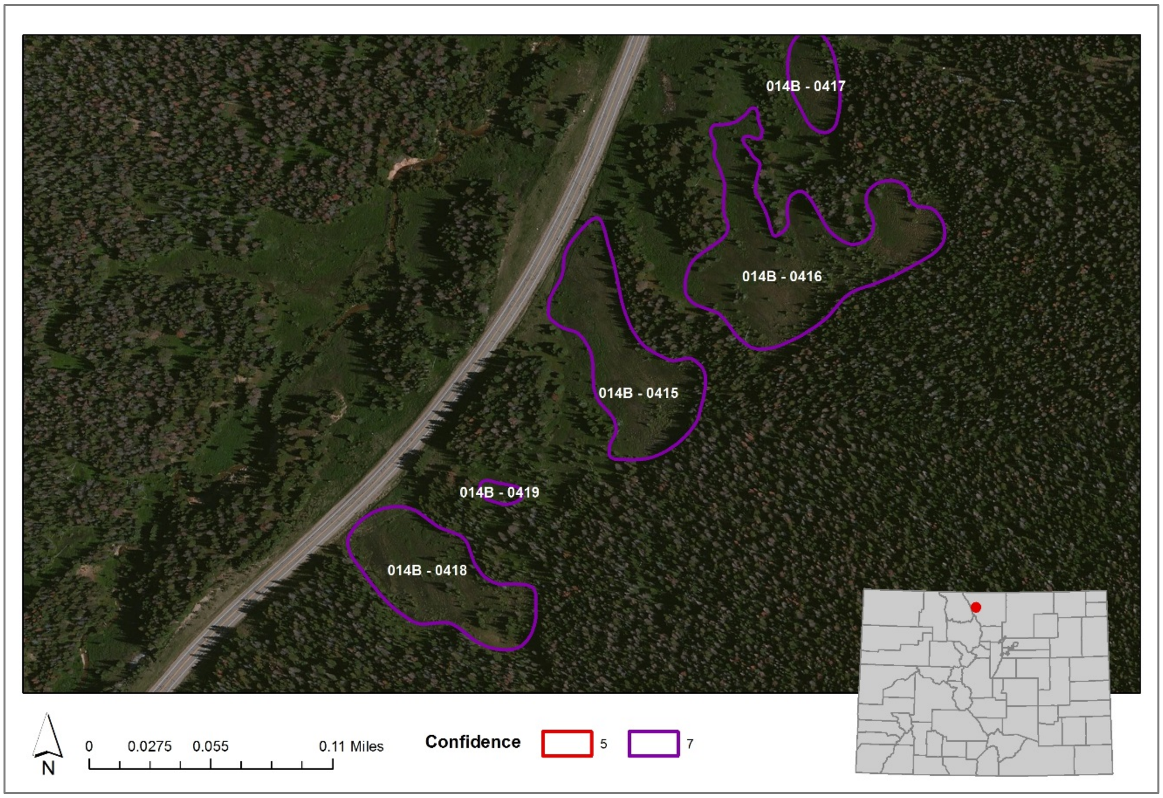


**Figure 34. Fens likely bisected by CO Hwy 14 near Cameron Pass.**

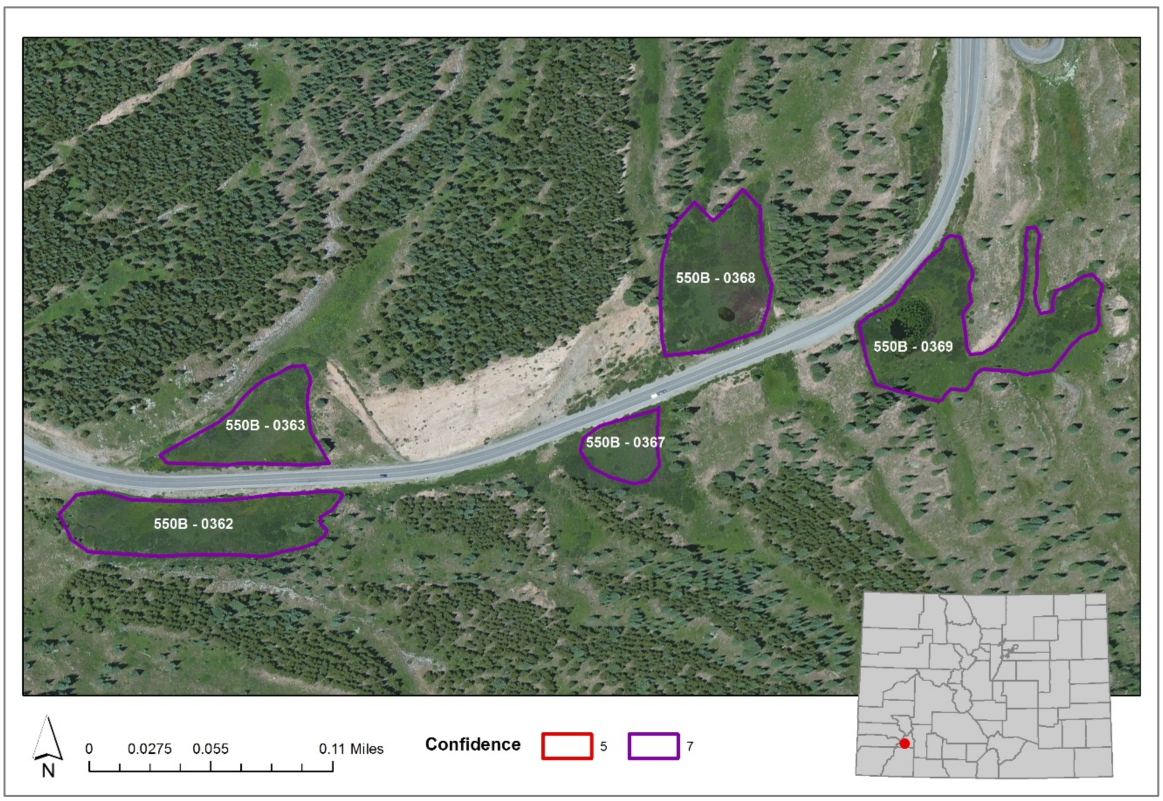


**Figure 35. Fens likely bisected by U.S. Route 550 near Molas Pass.**

plant communities (Schumelpfenig et al 2013; Patterson & Cooper 2007). Care should be taken to limit further impact to these and other roadside fens.

This report and associated dataset provide CDOT with a critical tool for conservation planning at both a local and statewide scale. The 396 confirmed and likely fen locations should be flagged early on in planning for road construction and maintenance. Their locations should be made known to road crews working in these areas and best management practices should be established for working near these wetlands. Wherever possible, CDOT should avoid direct disturbance to the fens mapped through this project, and should also strive to protect the watersheds surrounding high concentrations of fens, thereby protecting their water sources. With these data in-hand, CDOT will be able to provide stronger environmental stewardship to the fen wetlands surrounding the Colorado highway network.

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# APPENDIX A: CONFIRMED AND LIKELY FENS BY HUC12 WATERSHED

| HUC 12 Code | HUC 12 Name | Confirmed & Likely Fens | |
|---|---|---|---|
| | | Number | Fen Acres |
| 101900010205 | Antero Reservoir | 6 | 340 |
| 101900010208 | High Creek | 1 | 337 |
| 140500010405 | Walton Creek | 27 | 212 |
| 101900010209 | Fourmile Creek | 7 | 173 |
| 101900010103 | Crooked Creek | 2 | 143 |
| 101900010106 | 101900010106 | 6 | 95 |
| 140801040103 | Mineral Creek | 28 | 88 |
| 140801040302 | Tenmile Creek-Animas River | 23 | 85 |
| 140200060201 | Red Mountain Creek | 27 | 76 |
| 101900010404 | Michigan Creek | 1 | 69 |
| 110200010206 | City of Leadville-Arkansas River | 1 | 53 |
| 140100040102 | Headwaters Roaring Fork River | 19 | 43 |
| 140100020302 | West Tenmile Creek | 19 | 38 |
| 140300020201 | Headwaters Dolores River | 12 | 37 |
| 140801040202 | Lime Creek | 13 | 36 |
| 140100010202 | Upper Fraser River | 2 | 34 |
| 110200010201 | Tennessee Creeks | 1 | 32 |
| 140300030102 | Lake Fork | 13 | 28 |
| 140801040203 | Outlet Cascade Creek | 6 | 28 |
| 140200020602 | Lake Sanc Cristobal-Lake Fork | 5 | 28 |
| 140200050702 | Headwaters Kannah Creek | 9 | 26 |
| 140801040104 | Cunningham Creek-Animas River | 17 | 25 |
| 101900010603 | Twin Creek | 9 | 25 |
| 101900070204 | Joe Wright Creek | 14 | 23 |
| 140100051307 | Coon Creek | 5 | 22 |
| 110200010101 | North Fork Lake Creek | 15 | 22 |
| 101900010604 | Pulver Gulch | 1 | 22 |
| 140200050108 | Ward Creek | 6 | 21 |
| 140300030106 | Headwaters San Miguel River | 4 | 21 |
| 140300030103 | South Fork San Miguel River | 7 | 21 |
| 130100050402 | Elk Creek | 2 | 19 |
| 140801010203 | Wolf Creek | 9 | 17 |
| 140100020501 | Straight Creek-Blue River | 13 | 15 |
| 140100051308 | Mesa Creek | 3 | 15 |
| 110200010202 | East Fork Arkansas River | 4 | 13 |
| 101900010403 | Jefferson Creek | 1 | 12 |
| 140100020101 | Headwaters Blue River | 4 | 10 |
| 130100011101 | Pass Creek | 2 | 10 |
| 130100050203 | Toltec Creek-Rio de Los Pinos | 4 | 9 |

| | | | |
|---|---|---|---|
| 101900010102 | Headwaters Middle Fork South Platte River | 1 | 8 |
| 101900010105 | Trout Creek | 1 | 7 |
| 140200020502 | Headwaters Cebolla Creek | 1 | 6 |
| 140100020102 | French Gulch-Blue River | 1 | 6 |
| 140100030206 | Resolution Creek-Eagle River | 1 | 6 |
| 101900040203 | Headwaters West Chicago Creek | 1 | 6 |
| 101900010210 | 101900010210 | 2 | 5 |
| 140100030201 | South Fork Eagle River | 3 | 5 |
| 101900040102 | Headwaters Clear Creek | 4 | 5 |
| 140100030101 | Upper Gore Creek | 3 | 4 |
| 110200020502 | Headwaters West Beaver Creek | 2 | 4 |
| 140200030105 | Porphyry Creek-Tomichi Creek | 1 | 4 |
| 130100050201 | Headwaters Rio de Los Pinos | 2 | 3 |
| 101900010207 | Outlet Agate Creek | 1 | 3 |
| 110200010103 | Lake Creek | 2 | 3 |
| 140100011001 | Headwaters Rock Creek | 2 | 3 |
| 101900020202 | Headwaters North Fork South Platte River | 2 | 3 |
| 140100020401 | Dillon Reservoir | 1 | 2 |
| 140801040201 | Headwaters Cascade Creek | 2 | 2 |
| 140500010103 | Headwaters Yampa River | 1 | 2 |
| 140100010302 | Headwaters Colorado River | 1 | 2 |
| 130100010303 | Spring Creek | 5 | 1 |
| 140100020201 | North Fork Snake River | 3 | 1 |
| 110200010601 | Middle Fork South Arkansas River | 1 | 1 |
| 140200060205 | Coal Creek-Uncompahgre River | 1 | 1 |
| 140500010402 | Harrison Creek | 1 | <1 |
| 140300030109 | Hay Creek-Leopard Creek | 1 | <1 |
| 101800010402 | Headwaters Illinois River | 1 | <1 |

Only watersheds containing confirmed and likely fens are shown.