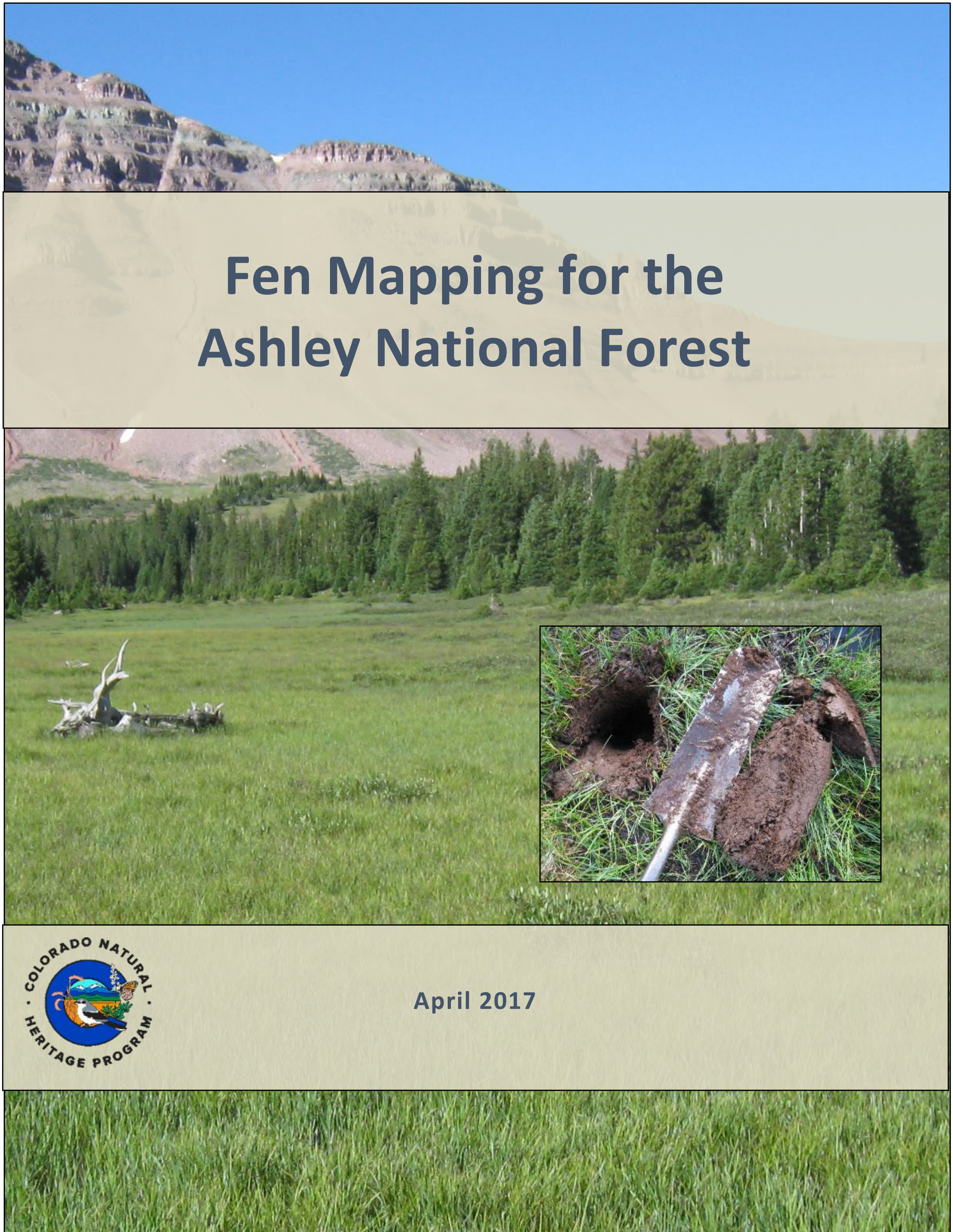
Fen Mapping for the Ashley National Forest



April 2017

CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

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EXECUTIVE SUMMARY

The Ashley National Forest (ANF) covers 1.3 million acres within the Upper and Lower Green River Basin in northeast Utah. The diverse geography of the ANF creates an equally diverse set of wetlands that provide important ecological services to both ANF and lands downstream. Organic soil wetlands known as fens are an irreplaceable resource that the U.S. Forest Service has determined should be managed for conservation and restoration. Fens are defined as groundwater-fed wetlands with organic soils that typically support sedges and low stature shrubs. In the arid west, organic soil formation can take thousands of years. Long-term maintenance of fens requires maintenance of both the hydrology and the plant communities that enable fen formation.

In 2012, the U.S. Forest Service released a new planning rule to guide all National Forests through the process of updating their Land Management Plans (also known as Forest Plans). A component of the new planning rule is that each National Forest must conduct an assessment of important biological resources within its boundaries. Through the biological assessment, biologists at the ANF identified a need to better understand the distribution and extent of fen wetlands under their management. To this end, U.S. Forest Service contracted Colorado State University and the Colorado Natural Heritage Program (CNHP) to map all potential fens within the ANF.

Potential fens in the ANF 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). The final map contained 8,614 potential fen locations (all confidence levels), covering 13,869 acres or 1% of the total land area. This total included 4,019 ***likely fens***, 2,765 ***possible fens***, and 1,830 ***low confidence fens.*** The average fen polygon was just 1.61 acres, but the largest polygon was over 175 acres.

Fen distribution was analyzed by elevation, bedrock geology, Land Type Association, and watershed. The vast majority of mapped potential fens occurred between 9,000 to 12,000 feet. This elevation range contained 94% of all potential fen locations and 99% of likely fen locations. Four watersheds in particular have very high numbers of likely fens. South Fork Ashley Creek had 375 likely fens, Upper Sheep Creek had 267 likely fens, Middle Sheep Creek had 266 likely fens and Fall Creek-Rock Creek had 251 likely fens.

The Ashley National Forest contains a rich resource of fen wetlands. This report and associated dataset provides the ANF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing ANF biological assessment required by the 2012 Forest Planning Rule, but can also be used for individual management actions, such as planning for timber sales, grazing allotments, and trail maintenance. Wherever possible, the Forest 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

The authors at Colorado Natural Heritage Program (CNHP) would like to acknowledge the U.S. Forest Service for their financial support of this project. Special thanks to John Proctor, Regional Botanist for U.S. Forest Service Region 4, for supporting this project.

Thanks to Kate Dwire with Rocky Mountain Research Station for sharing the location of known fens sites on the ANF as well as the known locations of plants associated with fens. Those data were very helpful in refining our search image for fens in Ashley National Forest.

We also thank colleagues at CNHP who have worked on previous projects mapping and surveying fen wetlands in the field, specifically Erick Carlson, Denise Culver, Laurie Gilligan, Lexine Long, Peggy Lyon, and Dee Malone. Thanks to Sarah Marshall, CNHP Wetland Ecologist, for conducting a review of mapped fens for consistency in our application of confidence ratings. Special thanks David Cooper, Rod Chimner, and Brad Johnson, each of whom has shared with us their great knowledge of fens over the years.

Finally, we would like to thank Tracey Trujillo and Carmen Morales with Colorado State University for logistical support and grant administration.

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1.0 INTRODUCTION

The Ashley National Forest (ANF) covers 1.3 million acres within the Upper and Lower Green River Basins in northeast Utah and spans a broad elevation range from 5,471 to 13,534 ft. The diverse geography of the ANF creates a template for an equally diverse set of wetlands. Heavy snowfall in the mountains percolates through shallow mountain soils and creates extensive areas of wet meadows, riparian shrublands, and organic soil wetlands known as fens. These wetland habitats provide important ecological services to both ANF and lands downstream (Mitsch & Gosselink 2007; Millennium Ecosystem Assessment 2005). Wetlands act as natural filters, helping to protect water quality by retaining sediments and removing excess. Wetlands help to regulate local and regional hydrology by stabilizing base flow, attenuating floods, and replenishing belowground aquifers. Wetlands also support habitat for numerous plant and animals species that depend on aquatic habitats for some portion of their life cycle (Redelfs 1980 as cited in McKinstry et al. 2004).

Organic soil wetlands known as fens are an irreplaceable resource. Fens are defined as groundwater-fed wetlands with organic soils that typically support sedges and low stature shrubs (Mitch & Gosselink 2007). 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. By storing organic matter deep in their soils, fens act as a carbon sink. In the arid west, peat accumulation occurs very slowly; estimates are 20 cm (8 in) per 1,000 years in Colorado (Chimner 2000; Chimner and Cooper 2002). Long-term maintenance of fens requires maintenance of both the hydrology and the plant communities that enable fen formation.

In 2012, the U.S Forest Service released a new planning rule that will guide all National Forests through the process of updating their Land Management Plans (also known as Forest Plans).[1] A component of the new planning rule is that each National Forest must conduct an assessment of important biological resources within its boundaries. Through the process of conducting the biological assessment, biologists at the ANF identified a need to better understand the distribution and extent of fen wetlands under their management. To this end, U.S. Forest Service contracted Colorado State University and the Colorado Natural Heritage Program (CNHP) to map all potential fens within the ANF. This project builds upon CNHP's previous projects mapping fens on the White River National Forest (Malone et al. 2011) and the Rio Grande National Forest (Smith et al. 2016).

[1] For more information on the 2012 Forest Planning Rule, visit the following website: http://www.fs.usda.gov/main/planningrule/home.

2.0 STUDY AREA

2.1 Geography

The fen mapping study area was the entire Ashley National Forest (ANF), which straddles the Utah/Wyoming border (Figure 1). The ANF includes portions Daggett, Uintah, Duchesne, Wasatch and Utah counties in Utah, as well as a small portion of Sweetwater County in Wyoming. The only sizeable municipalities near the study area are Vernal and Naples, Utah, located southeast of the study area; Manila, Utah, near the Utah/Wyoming border; and Green River City, Wyoming, to the north. Much of the ANF is located in the high Uinta Mountains and includes King's Peak, the highest mountain in Utah. Elevation in the study area ranges from 5,471 ft. (1,668 m) to 13,469 ft. (4,105 m) and the mean elevation is 8,984 ft. (2,738 m). The floodplains of the major rivers and the Flaming Gorge Reservoir are the lowest elevation areas.

The ANF is located within the Upper Green Basin (HUC 6: 140401) in southwest Wyoming and the Lower Green Basin (HUC 6: 140600) in northeast Utah (Figure 2). The Green River flows into the study area at the north portion near Green River City, Wyoming. The Green River is impounded on the Utah side near the Utah/Wyoming border which forms the Flaming Gorge Reservoir. The Green River then flows east, leaving the study area on eastern border dipping into Colorado before it joins the Yampa River and returns to Utah east of Vernal.

2.2 Land Type Associations

The U.S. Forest Service has developed Land Type Associations for each National Forest to describe the major geomorphic landforms within the Forest. The most common Land Type Association in the ANF is the Alpine Moraine (19% of study area) (Figure 3). The next most common Land Type Associations are the Uinta Bollie (13%) and Trout Slope (10%). See Table 1 for the map concepts of these Land Type Associations.

2.3 Geology

The most common surficial geology in the fen mapping study area is sandstone, which covers 37% of the study area (Figure 4). The next most common geology is quaternary alluvium, which covers alluvial fans originating in the high mountains and also the floodplains of major rivers and streams (27% of study area). Shale (10%) and carbonate dominated formations of limestone or dolomite (9%) are also common. The majority of surficial geologic formations are sedimentary or depositional.

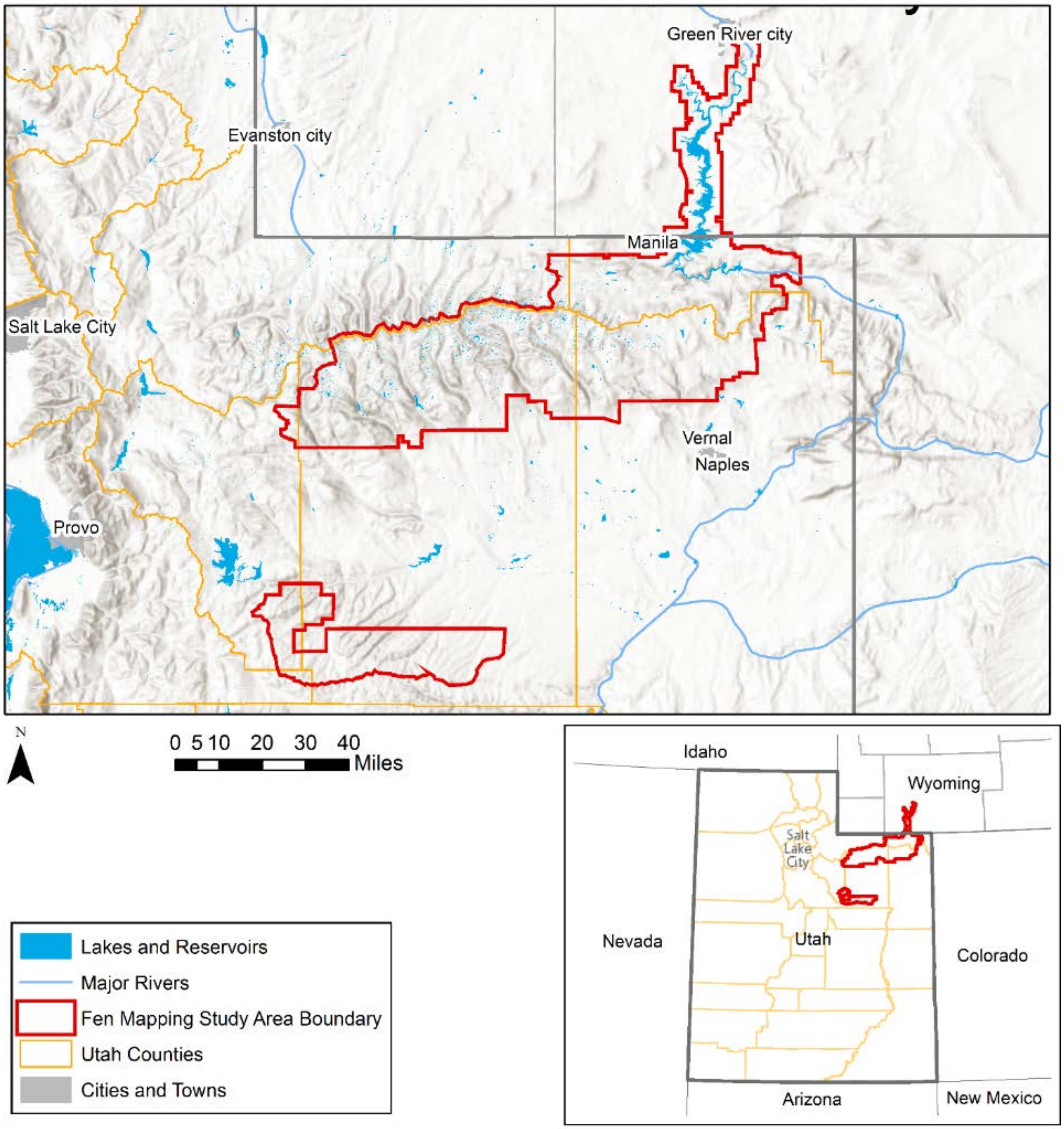

Figure 1. Location of the Ashley National Forest (fen mapping study area) within the states of Utah and Wyoming.

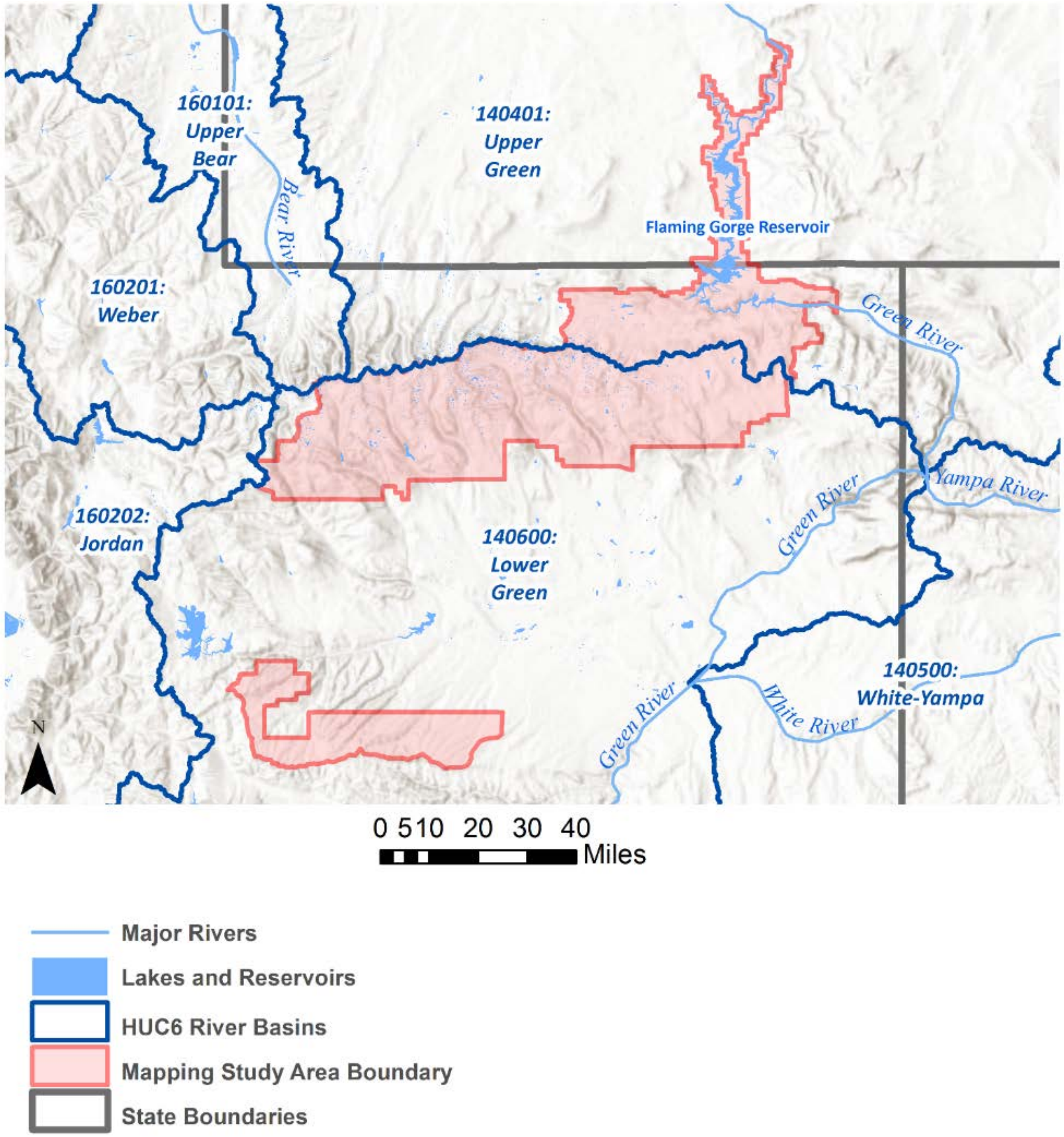

Figure 2. HUC6 river basins and major waterways in the fen mapping study area.

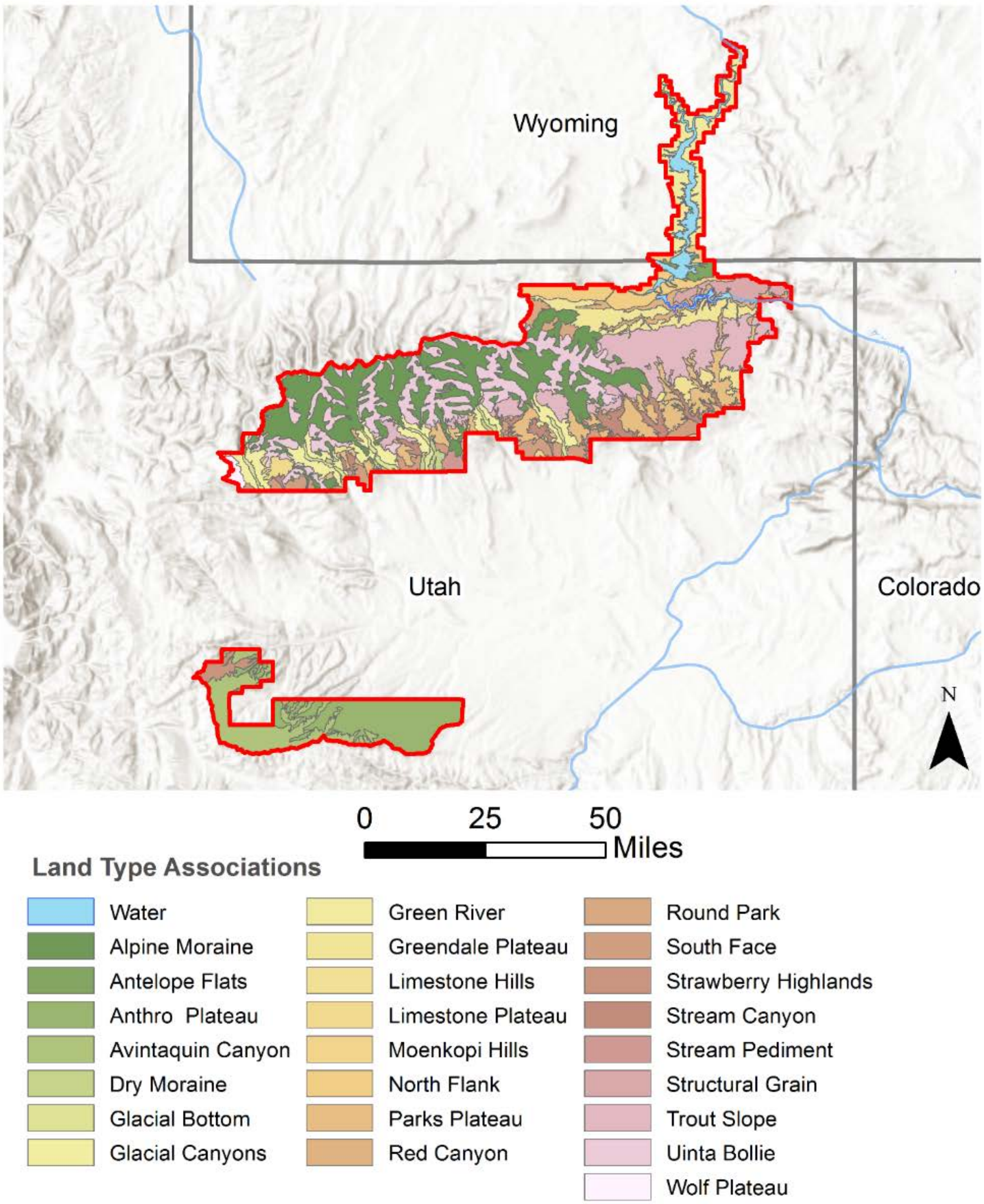

Figure 3. Land Type Associations of the fen mapping study area.

Table 1. Descriptions of Land Type Associations within the fen mapping study area.

NAME	*MAP CONCEPT*
Alpine Moraine	Glaciated lands including cirque basins and side slopes at the heads of the glacial canyons of the Uinta Mountains and pot hole or knob and kettle landforms. This includes scoured basins and drift basins above treeline with alpine plant communities.
Antelope Flats	This association includes sandy and gravelly quaternary pediments associated with the Green River and gypsiferous and alkaline or saline sediments of Mancos Shale.
Dry Moraine	Older glaciated landforms associated with the major glacial conyons of central Uinta Mountains. Vegetation is variable and includes mountain big sagebrush/needle-and-thread grass, mountain brush, ponderosa pine and aspen communities.
Glacial Bottom	Current flood plains and terraces along the bottoms of lower reaches of the major canyons of the south slope of the Uinta Mountains. Vegetation structure is the most complex in the Uinta Mountains. Coniferous trees including ponderosa pine and limber pine.
Glacial Canyons	This association consists of the steep canyon walls of the glaciated canyons of the south slope of the Uinta Mountains. It includes small to large areas of boulder fields with little vegetation or sometimes with scattered coniferous trees and aspen.
Green River	Flats, hills and canyons underlain by the Green River Formation. This association flanks the Flaming Gorge Reservoir in the Wyoming portion of the Ashley National Forest. Vegetation is generally dominated by cold desert shrub species of sagebrush.
Greendale Plateau	Flats, hills and canyons underlain by the Green River Formation. This association flanks the Flaming Gorge Reservoir in the Wyoming portion of the Ashley National Forest. Vegetation is generally dominated by cold desert shrub species of sagebrush.
Limestone Hills	Scarp and dip slopes of Mississippian Limestone of the south slope of the Uinta Mountains. This is part of the limestone donut that interruptedly surfaces around the Uinta Mountains. Douglas-fir generally dominates the scarp slopes.
Limestone Plateau	Plateau lands underlain by Mississippian Limestone of the south slope of the Uinta Mountains. Karst topography including depressions of internal drainage is included in the association. In general the association is of higher elevations than the Limestone Hills.
Moenkopi Hills	Foothills of the Uinta Mountains underlain by the Moenkopi Formation. This includes vegetated slopes and slopes eroding to badlands. Pinyon-juniper and mountain brush communities dominated by alderleaf mountain are common to this association.
North Flank	The North Flank Association is comprised of some of the youngest deposits and oldest rocks in Utah. This association contains the classic faults and folds of Laramide orogeny that uplifted the Uinta Mountains about 70 to 40 million years ago.
Parks Plateau	Plateau lands of Bishop Conglomerate and possibly Browns Park Formation of the eastern Uinta Mountains. Vegetation includes large stands of lodgepole pine with an obvious history of stand replacement fire. Stands of stable or persistent aspen.
Red Canyon	Precipitous walls of Red Canyon are the central theme of this association. It also includes some tributary canyons that feed into Red Canyon. Vegetation varies with aspect, depth to bedrock, and other features.
Round Park	Vegetation is dominated by large stands of lodgepole pine at lower elevations and by mixed coniferous stands at higher elevations. Meadows including Round Park are included.

NAME	***MAP CONCEPT***
South Face	Slopes of the south face of the Uinta Mountains. Gravel and cobble debris washed from Parks Plateau covers large areas of this association. It also includes dip slopes of the Park City Formation. Mountain big sagebrush/grass communities cover much of this association.
Stream Canyon	Stream formed canyons of the south slope of the Uinta Mountains including Dry Fork and Brownie canyons, and Ashley Creek and Brush Creek gorges. Geologic strata is variable and includes Mississippian limestone and Weber Sandstone.
Stream Pediment	Gravel, cobble, and boulder pediments associated with streams at lower elevations on the south slope of the Uinta Mountains. Coarse fragments are mostly quartzitic sandstone. Mountain big sagebrush/grass and mountain brush communities with alderleaf.
Structural Grain	The Structural Grain Association is composed of land types of the Uinta Mountain Group located on the North Flank of the Uinta Arch that are high angle north dipping against Paleozoic through Mesozioc rocks to the north.
Trout Slope	Large, continuous subalpine forests of lodgepole pine, engelmann spruce, and some subalpine fir dominate the association. Meadows or "parks" including Trout Creek Park, Big Park (of North Fork Ashley Creek), and Summit Park are included.
Uinta Bollie	Alpine summits and slopes above glaciation including Matterhorn type peaks, rounded bollies, low gradient benches, talus of cirque headwalls and side slopes with underlying or exposed Precambrian quartzitic sandstones and shales of the Uinta Mountain Group.

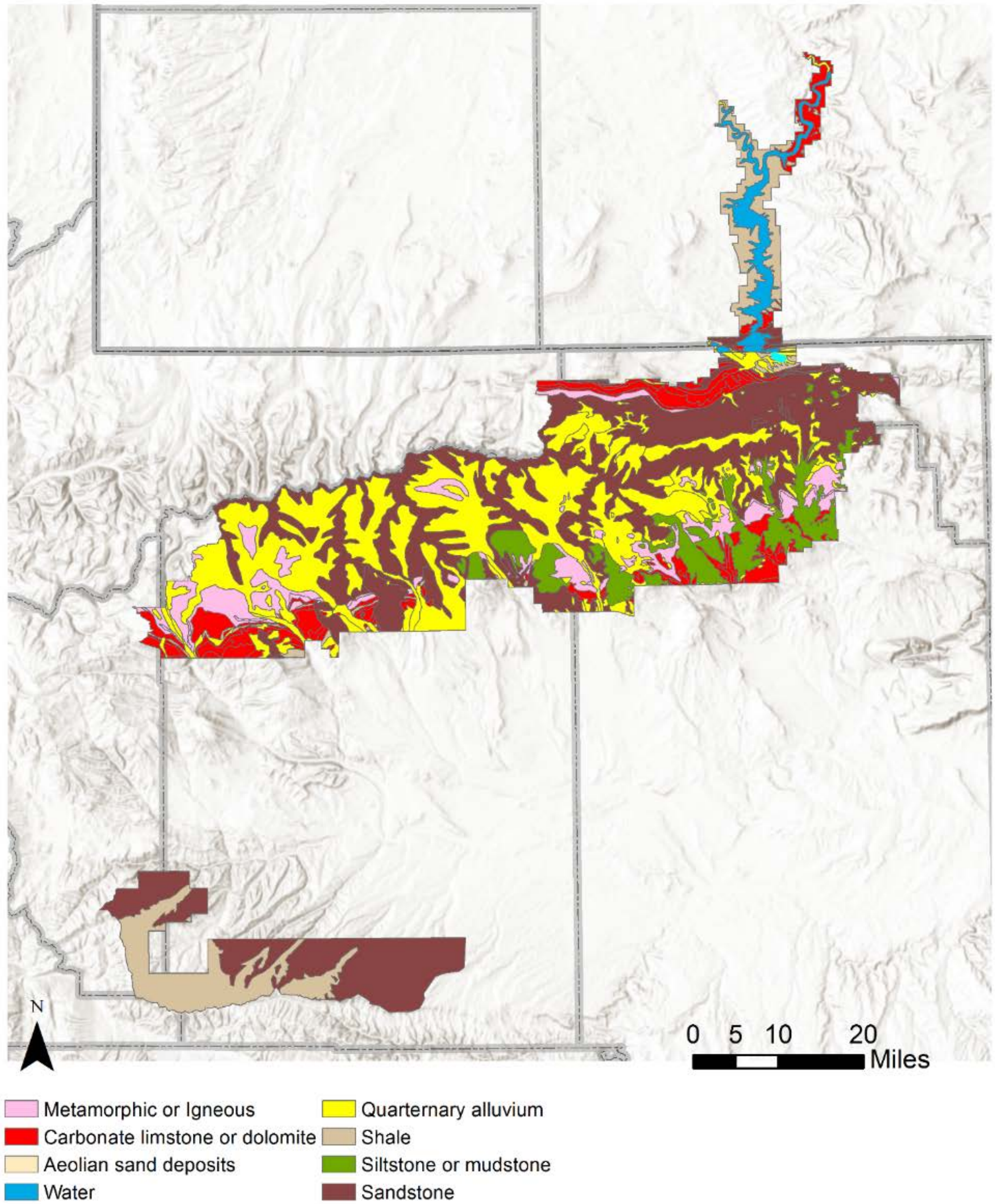

Figure 4. Geology within the fen mapping study area.

3.0 Fen Mapping Methods

Potential fens in the ANF were identified by analyzing digital aerial photography and topographic maps. True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2005, 2009 and 2011 were used in conjunction with color-infrared imagery from 2014. 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 in the 1970s and early 80s with a "B" (saturated) hydrologic regime were isolated from the full NWI dataset and examined.[2] 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 fens they observed outside of B regime NWI polygons (Figure 5).

Potential fen polygons were hand-drawn in ArcGIS 10.3 based on the best estimation of fen boundaries. In most cases, this did not match the exact boundaries of the original NWI polygons because the resolution of current imagery is far higher than was available in the 1980s. The fen polygons were often a portion of the NWI polygon or were drawn with different, but overlapping boundaries. This will provide ANF the most accurate and precise representation of fens in the Forest, as opposed to estimates based on the NWI polygons themselves. 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 observations were noted, including impoundments, beaver influence, floating mats and springs.

Table 2. Description of 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.

In addition to the fen mapping described above, the Forest Service will also receive an enhanced version of the 1980s original NWI mapping with a "Fen Potential" attribute. This attribute will highlight NWI polygons that contain or have significant overlaps with Likely or Possible fen mapping polygons (Figures 5, 6 and 7).

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

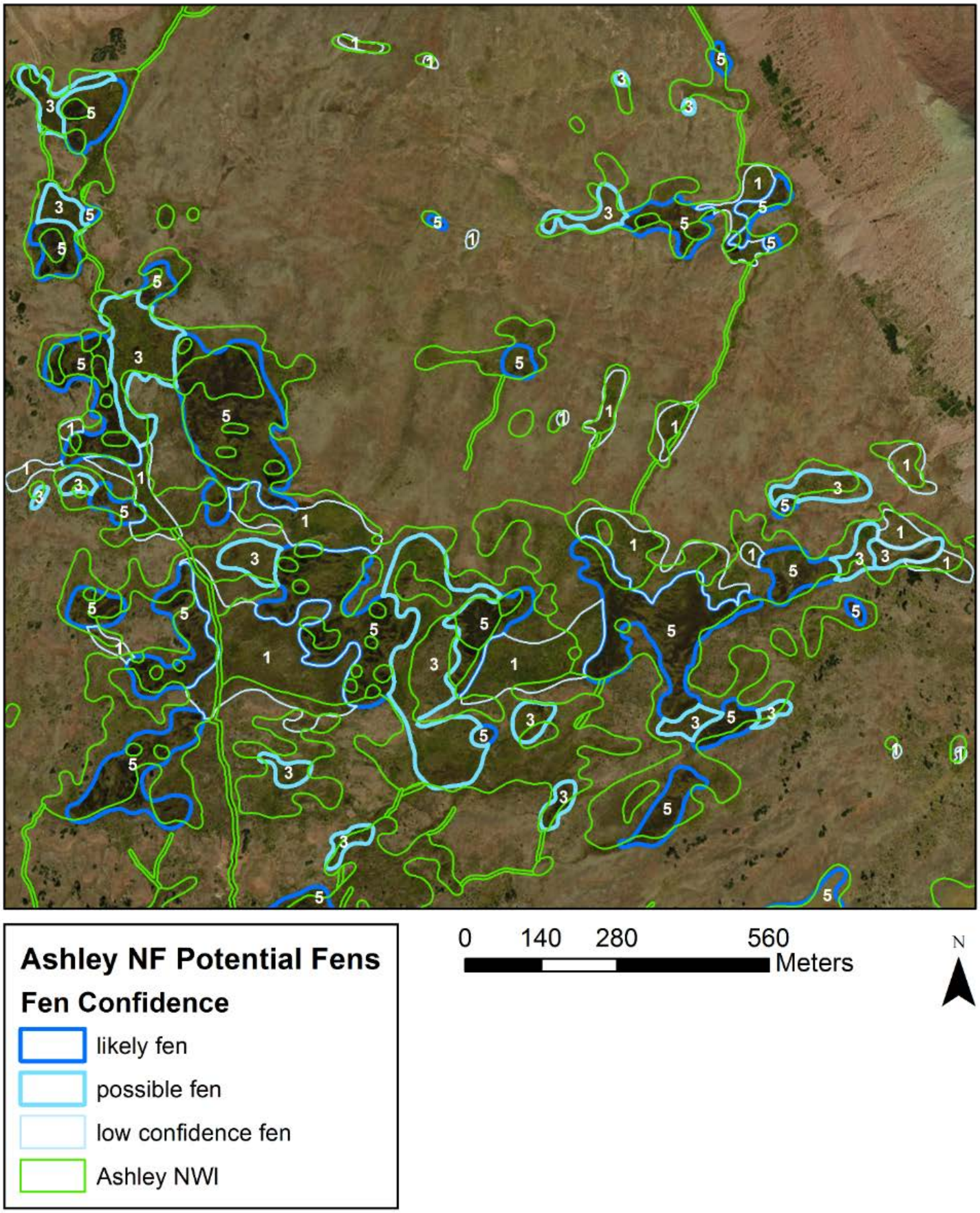

Figure 5. Example of potential fen mapping (blue) over NWI polygons (green). Note areas of overlap and areas where the fen mapping is either more extensive or more restricted than the NWI saturated polygons.

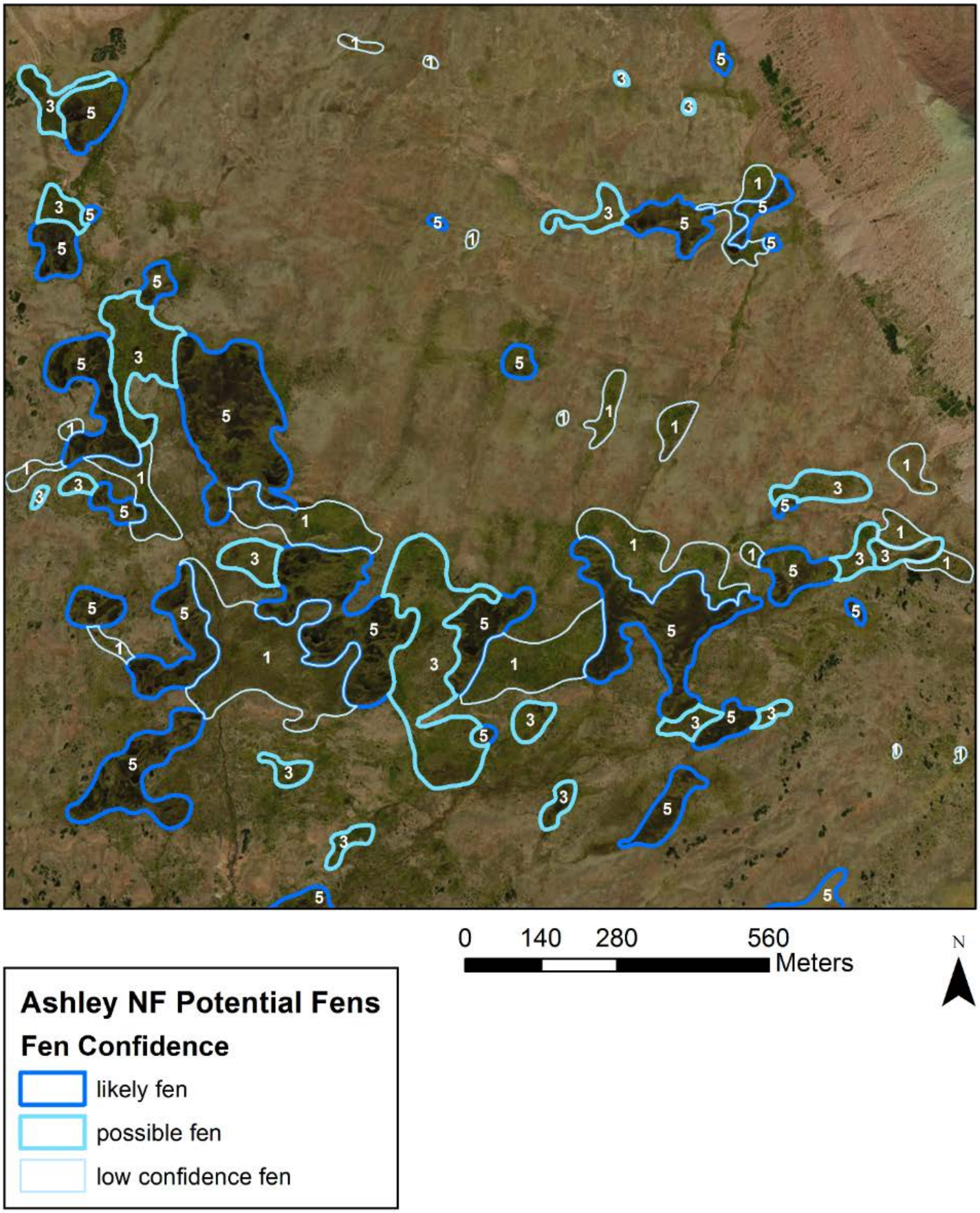

Figure 6. An example of potential fen mapping on Ashley National Forest.

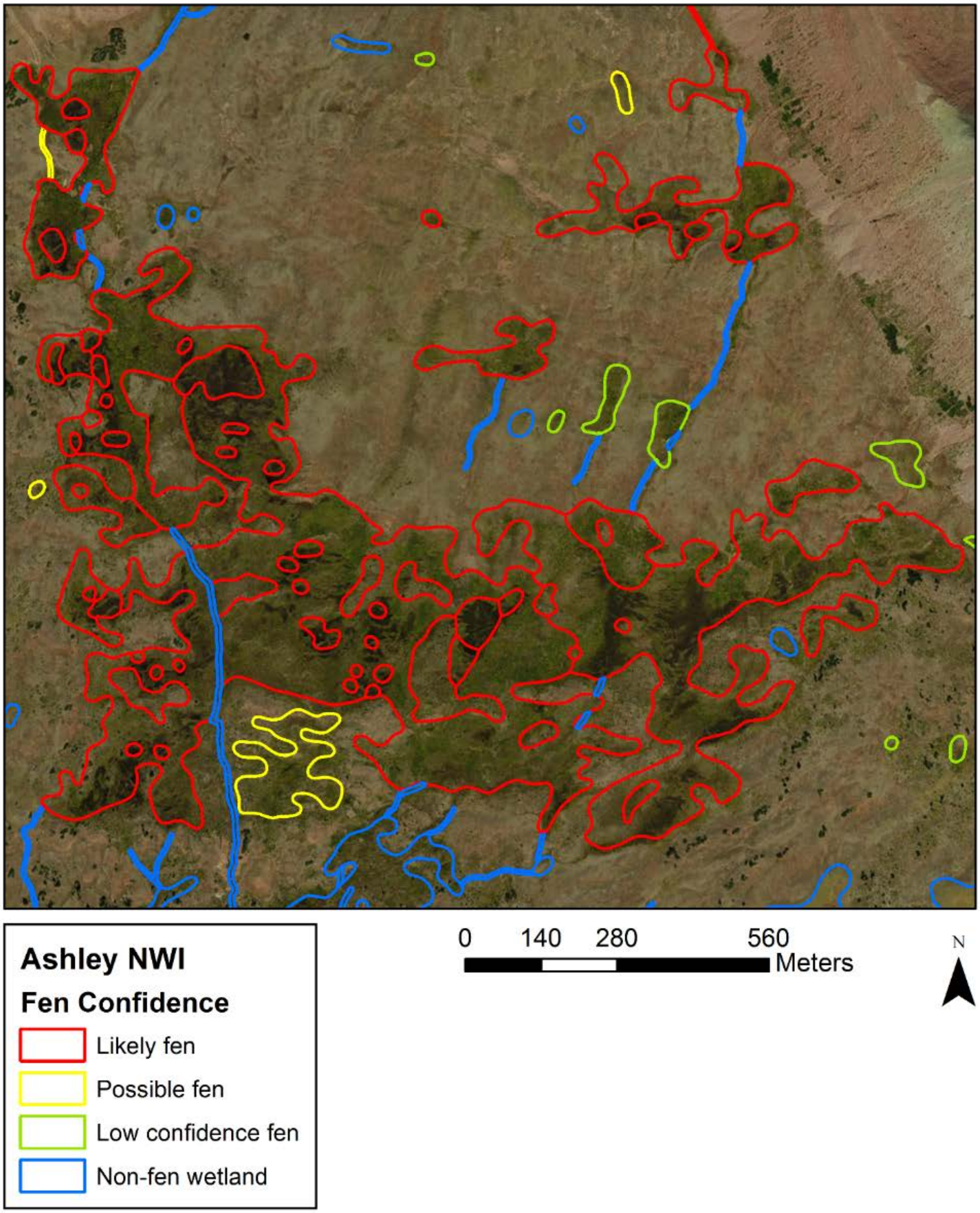

Figure 7. Example area of "Fen Potential" attribution of original 1970s/80s NWI data

4.0 RESULTS

4.1 Potential Fen Mapping Acreage

The final map of potential fens contained 8,614 potential fen locations (all confidence levels), covering 13,869 acres or 1% of the total land area (Table 3; Figures 8 and 9). This total included 4,019 ***likely fens*** (confidence level = 5), 2,765 ***possible fens***, and 1,830 ***low confidence fens.*** The count of likely fens was slightly higher than the count of possible fens, and on average the likely fens were considerably larger (2.24 acres vs. 1.06 acres), resulting in 9,007 acres of likely fens, 2,929 acres of possible fens, and 1,830 acres of low confidence fens. The size of individual potential fens ranged from over 180 acres to 0.10 acres. The two largest mapped fens are shown in Figures 10 and 11.

Table 3. Potential fen counts and acreage, by confidence levels.

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	4,019	9,007	2.24
3 – Possible Fen	2,765	2,929	1.06
1 – Low Confidence Fen	1,830	1,932	1.06
TOTAL	**8,614**	**13,869**	1.61

Original NWI mapping for the ANF contained 20,220 acres with a "B" (saturated) hydrologic regime, including 17,794 acres of herbaceous wetlands (PEMB and PEMBb) and 2,422 acres of shrub wetlands (PSSB and PSSBb) (Table 4). These polygons were the starting point for potential fen mapping. After examining each polygon with a saturated hydrologic regime and the landscape surrounding them, fen polygons were drawn covering 53% of those acres (10,790 acres), while the remaining 47% were determined to not be potential fens. In addition, once photo-interpretation was underway, it was apparent that the NWI code of semi-permanently flooded aquatic bed (PABF) also overlapped with many fen polygons, particularly floating mat fens. Once that was discovered, all PABF polygons were also examined. Of the 1,841 acres mapped as PABF, 491 acres (27%) were mapped as potential fens. Finally, 2,589 acres not mapped as saturated or aquatic bed by NWI were mapped as potential fens.

Polygons mapped as saturated herbaceous in NWI made up a far greater share of the potential fens (90% of the fen/NWI overlap) than polygons mapped as saturated shrubs (10%). This ratio was relatively similar to the ratio of all saturated herbaceus vs. shrub acres in NWI and indicates that the fens in ANF are far more likely to be herbaceus dominated. However, this should be confirmed in the field, as many fen shrubs are short statured and may have been missed by NWI.

Table 4. Acres mapped by NWI as saturated and the overlap with mapped potential fens.

NWI Code	Not Mapped as Fen	Mapped as Fen, by Confidence			Total Mapped as Fen	Grand Total by NWI Code
		1	3	5		
PEM1B	8,078	960	1,891	6,808	9,659	17,737
PEM1Bb	33	10	9	5	23	57
PSSB	953	220	274	410	905	1,858
PSSBb	363	183	14	4	202	564
PFOB	3	--	--	1	1	4
Total Saturated NWI Acres	**9,430**	**1,373**	**2,188**	**7,228**	**10,790**	**20,220**
PABF	1,350	21	78	392	491	1,841
Total NWI Acres	**10,781**	**1,395**	**2,267**	**7,619**	**11,280**	**22,061**
Other or No NWI Code	--	538	663	1,388	2,589	2,589
Grand Total	**10,781**	**1,933**	**2,929**	**9,007**	**13,869**	**24,650**

The following sections break down the fen mapping by elevation range, bedrock geology, ecoregion and HUC12 watershed. The last section summarizes observations made by the fen mappers during the mapping process, including potential floating mat fens.

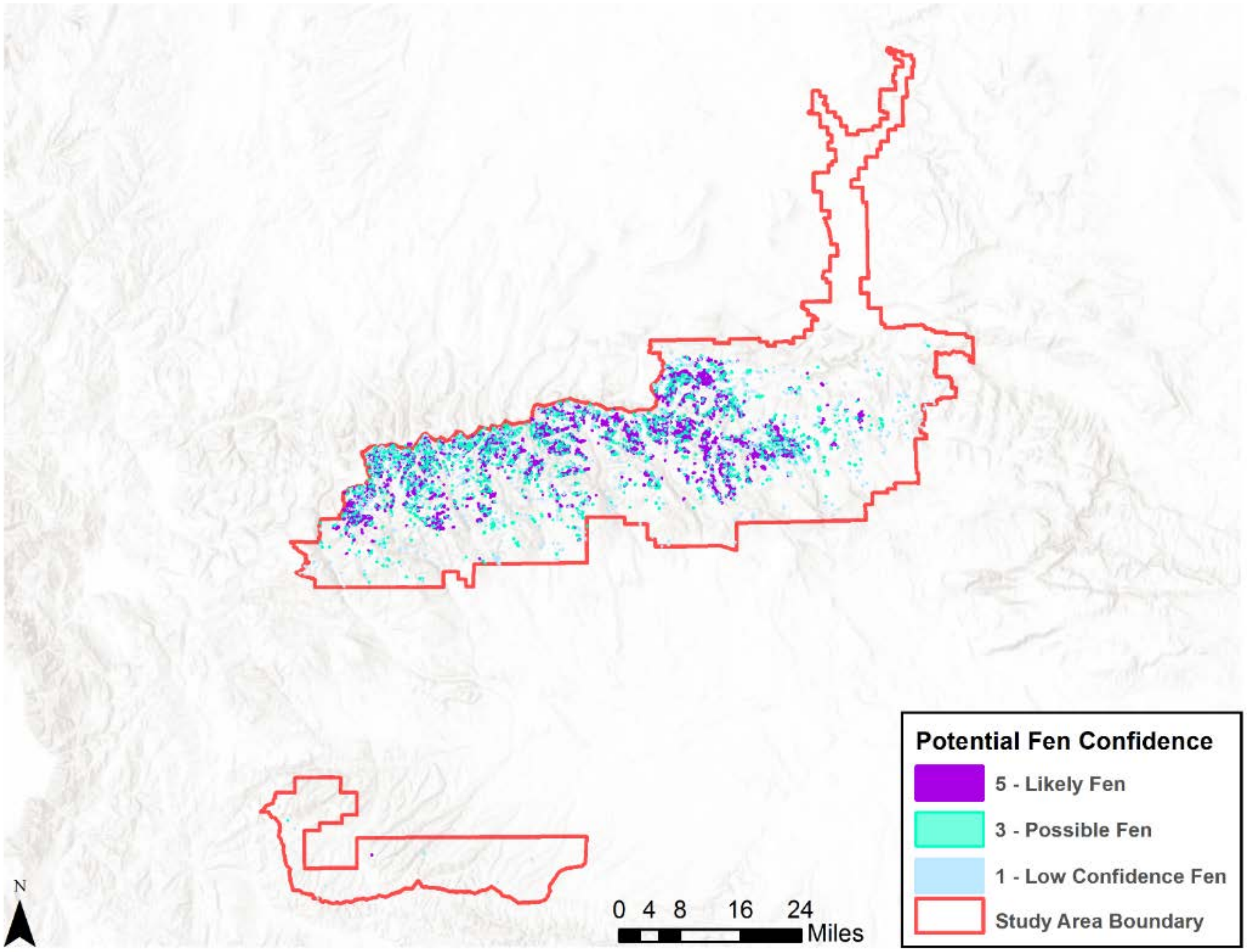

Figure 8. All potential fens within the fen mapping study area.

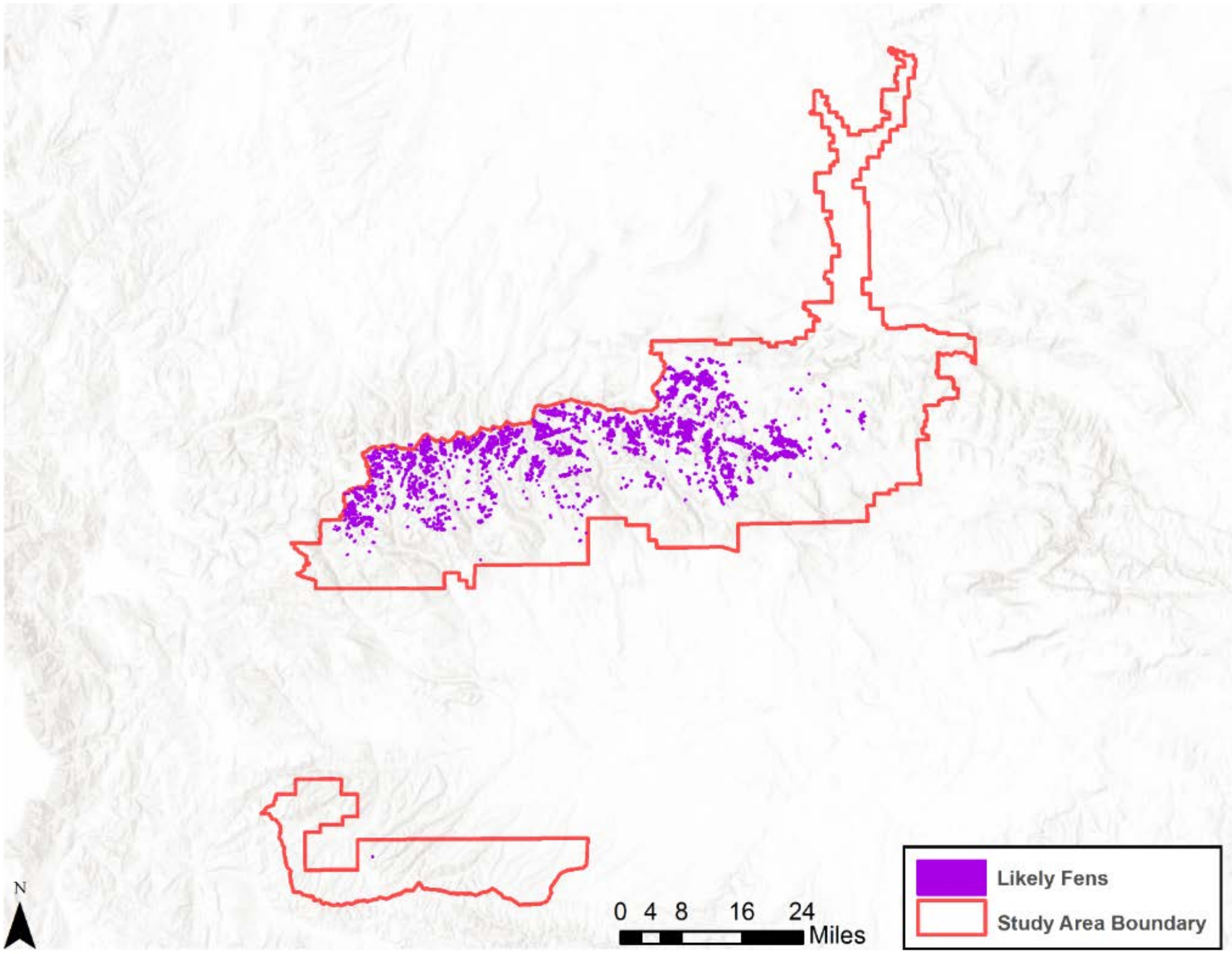

Figure 9. Likely fens (confidence rating = 5) within the fen mapping study area.

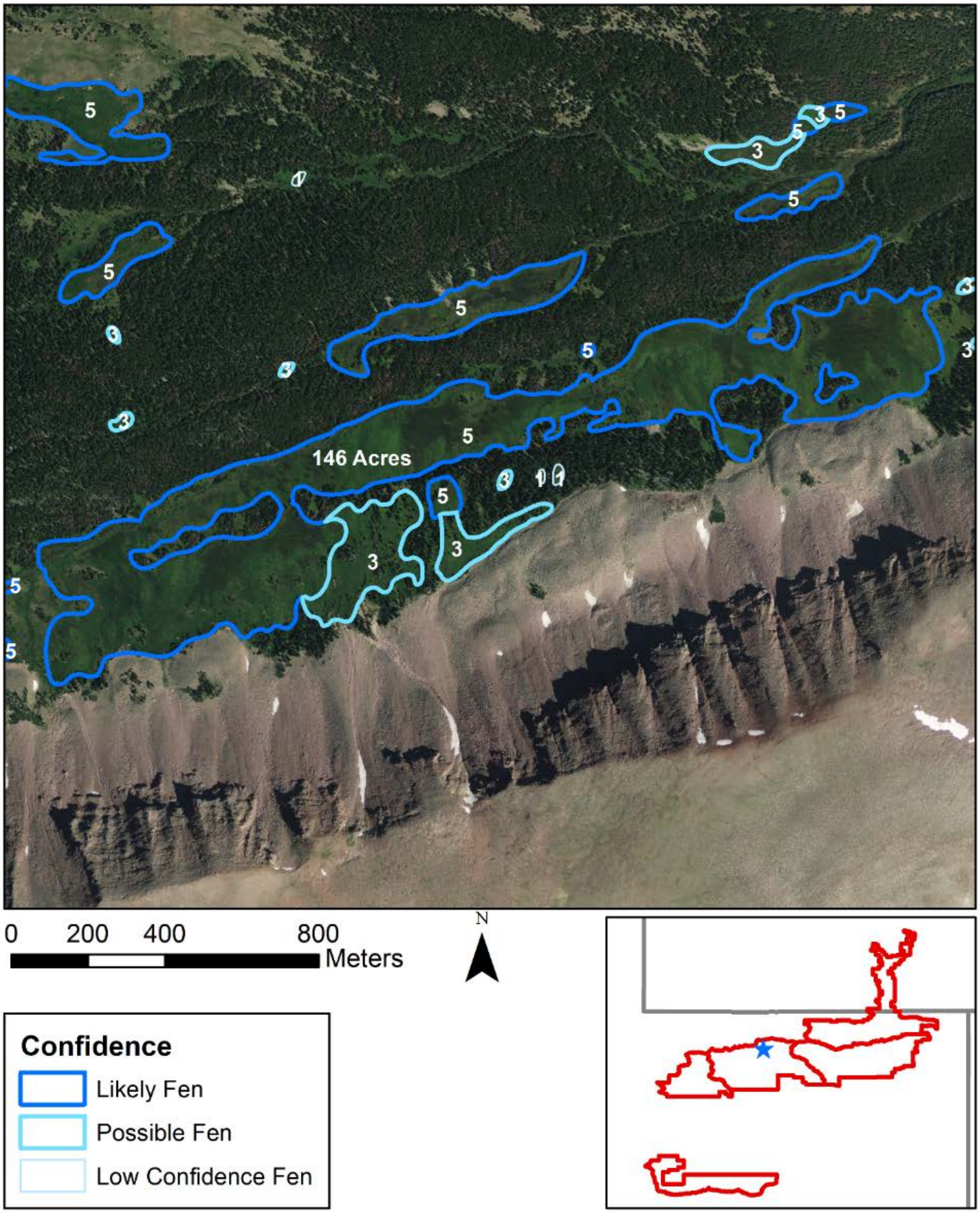

Figure 10. Largest mapped likely fen, 146 acres within one polygon. This fen is located in the Painter's Basin and the Uinta Rivers headwaters, just east of King Peak in Duchesne County.

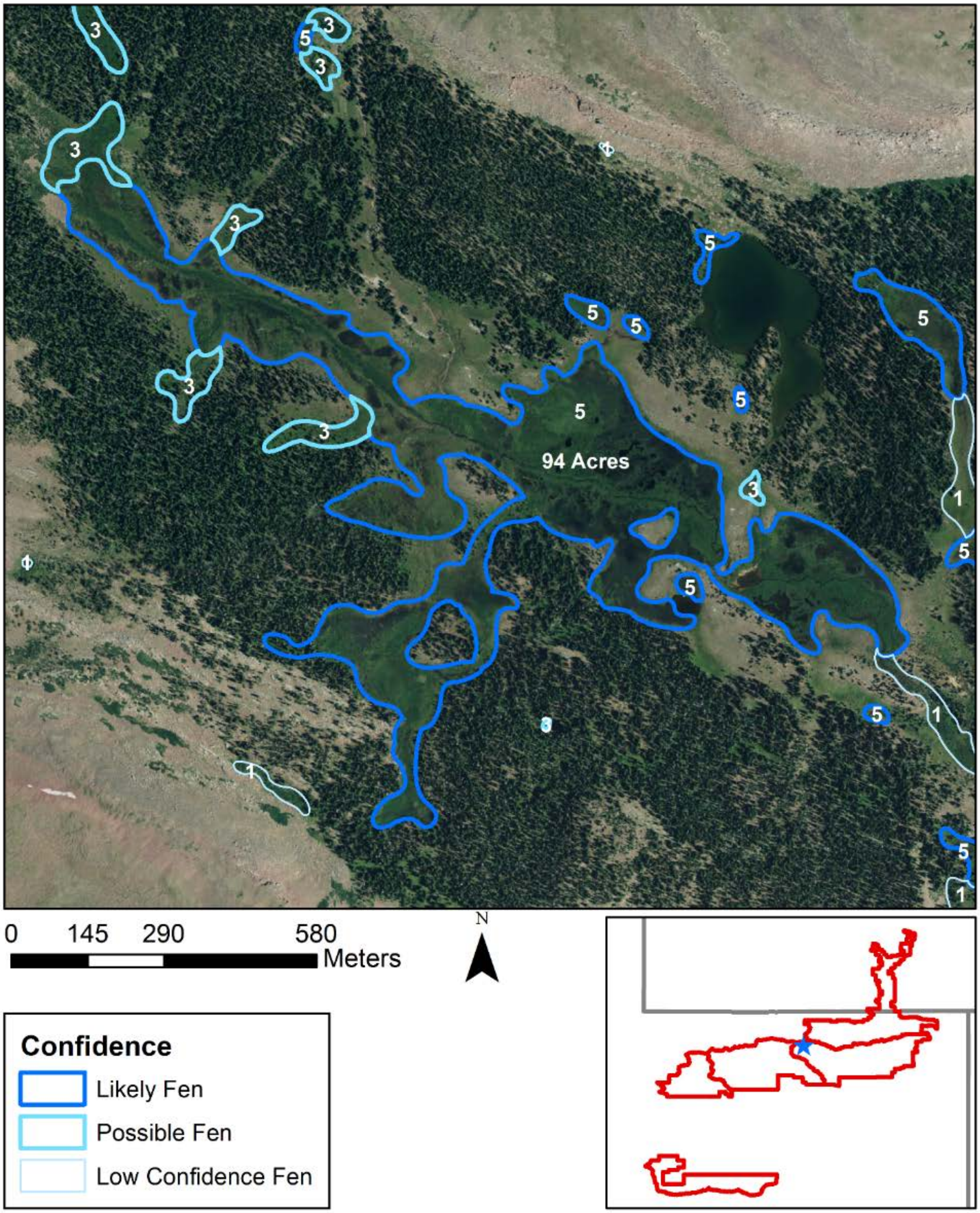

Figure 11. Second largest mapped likely fen, 94 acres within one polygon. This fen is located in the Reader Lakes area, west of Chepeta Lake in Duchesne County.

4.2 Mapped Potential Fens by Elevation

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

Of all potential fens, 3,992 polygons (7,074 acres) were mapped between 10,000 and 11,000 feet, which represents 46% of potential fen locations and 51% of potential fen acres (Table 5; Figure 13). Of the 4,019 total likely fens mapped, 1,996 polygons (50%) and 5,345 acres (59%) were located between 10,000 and 11,000 feet (Table 5; Figures 12 and 14). This is clearly the zone of maximum fen formation for the ANF.

The elevation bands of 9,000 to 10,000 feet and 11,000 to 12,000 feet were relatively similar in terms of potential and likely fens. Between 9,000 to 10,000 feet, there were 2,522 mapped potential fens (2,740 acres), which represent 29% of potential fen locations and 19% of potential fen acres. In addition, there were 1,361 likely fens (1,562 acres), which represent 34% of likely fen locations and 17% of likely fen acres. Between 11,000 to 12,000 feet, there were 1,622 mapped potential fens (2,769 acres), which represent 19% of potential fen locations and 20% of potential fen acres, and 629 likely fens (1,804 acres), which represent 16% of likely fen locations and 20% of likely fen acres. The likely fens mapped between 11,000 to 12,000 feet were much larger on average (2.9 acres) than the likely fens mapped between 9,000 to 10,000 feet (1.15).

These three elevation bands combined (9,000 to 12,000 feet) contain 94% of potential fen locations (91% of acres) and 99% of likely fen locations (97% of acres).

Table 5. Potential and likely fens by elevation within the fen mapping study area.

Elevation Range (ft)	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
< 9,000	452	1,270	58	289
> 9,000 – 10,000	2,522	2,740	1,361	1,562
> 10,000 – 11,000	3,992	7,074	1,996	5,345
> 11,000 – 12,000	1,622	2,769	629	1,804
> 12,000	26	15	5	7
Total	**8,614**	**13,869**	**4,019**	**9,007**

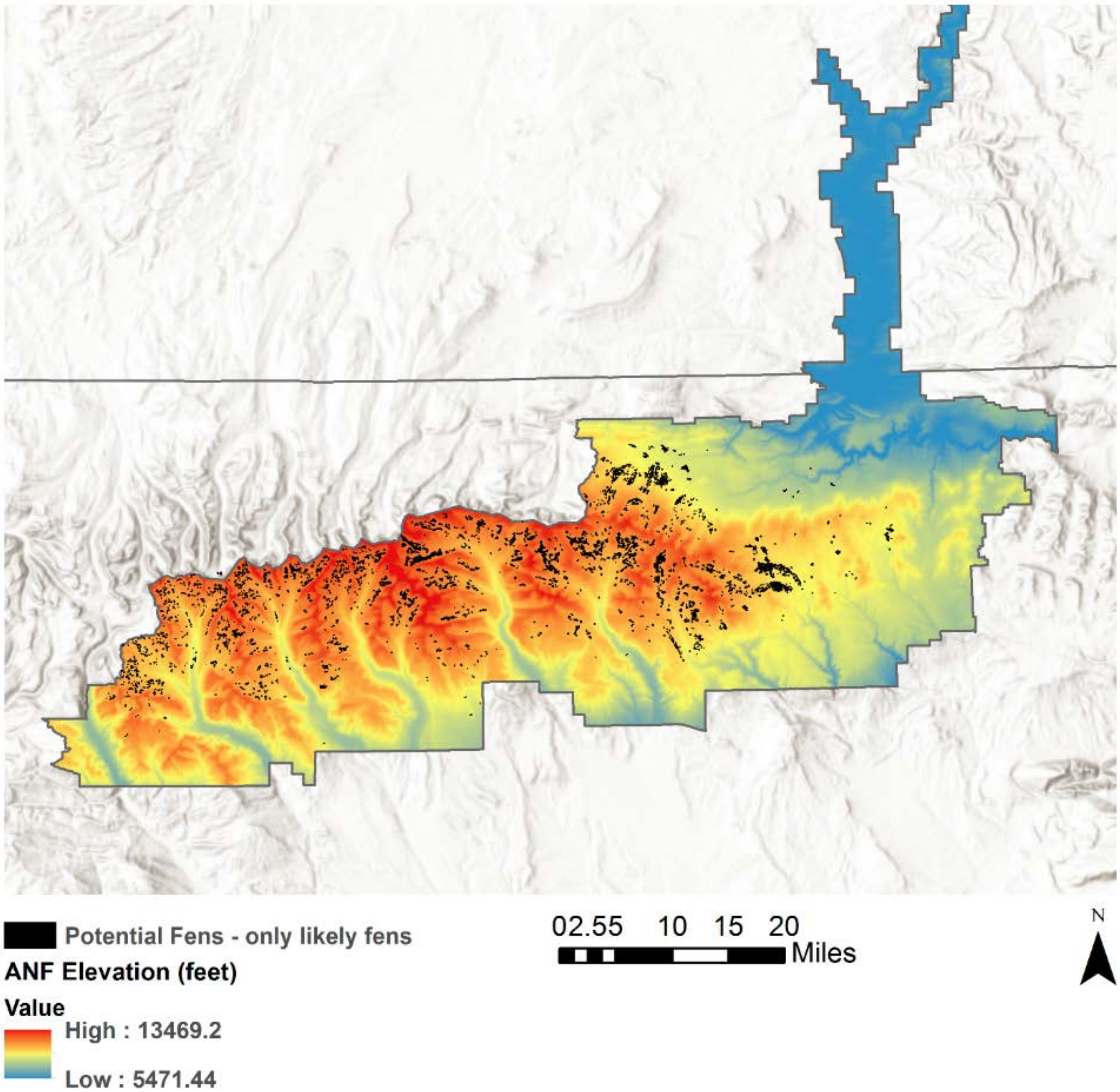

Figure 12. Likely fens (confidence rating = 5) and elevation within the fen mapping study area.

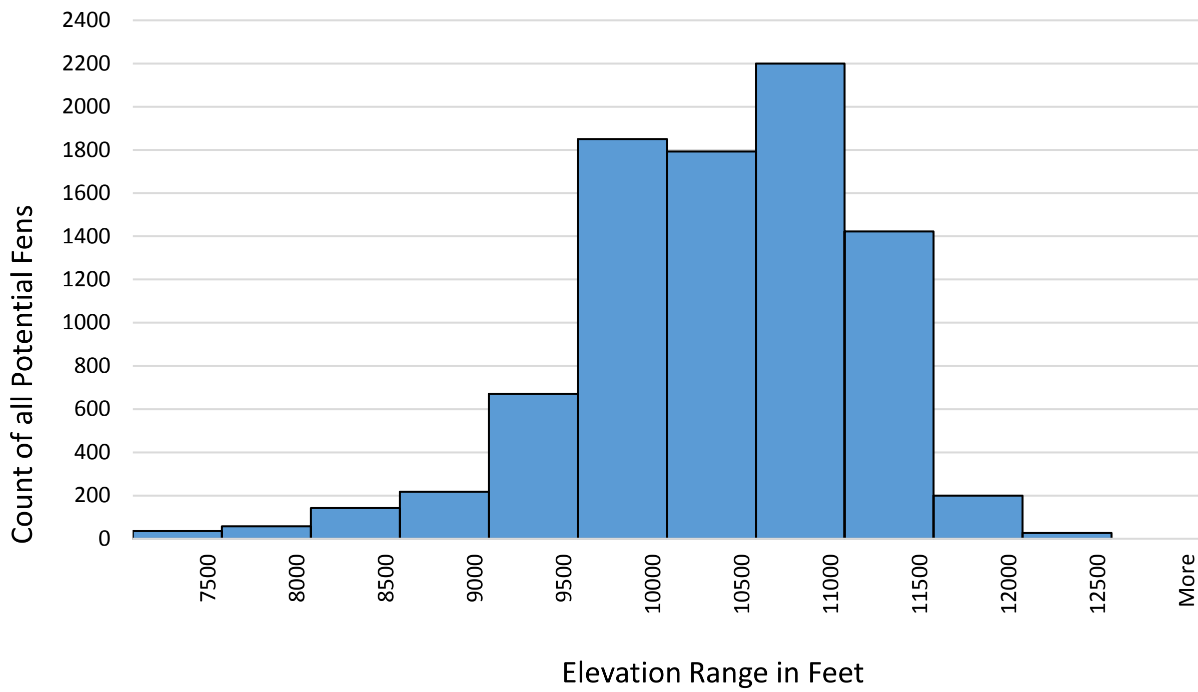

Figure 13. Histogram of all potential fens by elevation within the fen mapping study area.

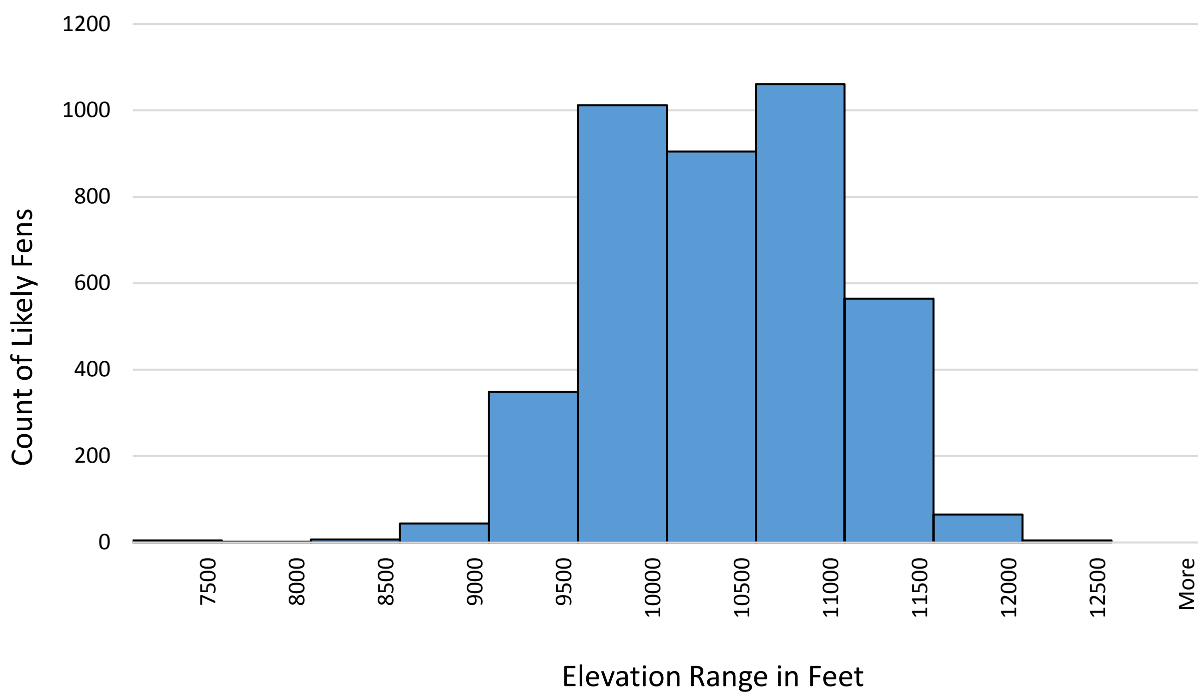

Figure 14. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

The most common geologic substrate under both potential and likely fens in ANF was quaternary age or younger alluvium, which underlies 6,803 mapped potential fens (10,508 acres) and 3,489 likely fens (7,518 acres) (Table 6). While alluvium represents the dominant substrate in only 27% of the Forest, 79% of all potential fens and 87% of likely fens occurred in these areas. Alluvium typically occurs at the toe of slopes as alluvial fans or within the floodplains of rivers and other low-lying areas that can accumulate alluvial material over time. Similarly, fens often form at the toe of slopes or the edges of floodplain valleys where there is a distinct break in slope, locations that are likely to contain alluvium. The next most common substrate containing potential or likely fens was sandstone, which underlies 37% of the ANF and 15% of all potential fens (1,360 locations) and 11% of likely fens (445 locations).

Table 6. Potential and likely fens by geologic substrate within the fen mapping study area

Geology	*Acres of Geologic Substrate Within ANF[1]*	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Sandstone	514,695	1,360	2,392	445	1,220
Quaternary age younger alluvium	374,867	6,803	10,508	3,489	7,518
Shale	136,552	22	21	--	--
Carbonate dominated formations either limestone or dolomites	126,234	50	219	4	<1
Siltstone or mudstone	103,556	205	504	27	154
Metamorphic or igneous with dominantly mafic composition	97,302	163	194	49	101
Metamorphic or igneous with dominantly silicic composition	5,868	1	<1	---	---
		8,614	**13,869**	**4,019**	**9,007**

[1] Acres of geologic substrate shown are only for those substrates where fens were mapped. The total acreage is not shown because it does not equal the total acreage of the ANF.

4.4 Mapped Potential Fens by Land Type Association

Land Type Associations combine location, geology, and dominant vegetation and are defined by each Forest. Alpine Moraines covers a third of the ANF (33%), and this LTA contains the vast majority of both potential and likely fen locations in ANF. Alpine Moraines contain 7,236 mapped potential fens (10,584 acres) and 3,766 likely fens (3,883 acres) (Table 7). This represents 84% of potential fen locations and 93% of likely fen locations.

Trout Slope, which covers 18% of the Forest, contains 411 mapped potential fens (1,329 acres) and 94 likely fens (600 acres). This represents 5% of potential fen locations and 2% of likely fen locations. Uinta Bollie, Greendale Plateau, Parks Plateau, and Round Park also contain more than ten likely fen locations.

Table 7. Potential and likely fens by Land Type Association within the fen mapping study area.

Land Type Association Map Unit Name	*Acres within ANF[1]*	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Alpine Moraine	451,801	7,236	10,584	3,766	3,883
Trout Slope	250,522	441	1,329	94	600
Uinta Bollie	304,822	392	353	84	122
Greendale Plateau	93,225	153	617	23	251
Parks Plateau	169,601	111	204	10	7
Round Park	18,327	78	237	24	141
Glacial Bottom	28,391	46	354	--	--
Glacial Canyons	124,915	35	47	5	7
Stream Canyon	76,592	21	24	1	2
South Face	85,359	19	9	1	1
Limestone Plateau	12,817	19	8	4	1
Avintaquin Canyon	140,755	13	2	1	1
Wolf Plateau	10,492	11	8	--	--
Limestone Hills	32,905	8	11	1	<1
Stream Pediment	14,106	7	23	--	--
North Flank	88,716	6	3	--	--
Dry Moraine	17,199	5	9	--	--
Anthro Plateau	186,467	5	5	--	--
Structural Grain	42,795	4	3	--	--
Red Canyon	50,191	3	8	--	--
Strawberry Highlands	21,205	1	<1	--	--
		8,614	**13,859**	**4,019**	**9,007**

[1] Acres of Land Type Associations shown are only for those ecoregions where fens were mapped. The total acreage is not shown because it does not equal the total acreage of the ANF.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC 12 watersheds revealed interesting patterns. Four watersheds in particular had very high numbers of likely fens (Figure 15). South Fork Ashley Creek (HUC12: 140600020201) had 375 likely fens, which covered 3.22% of the landscape in this watershed. Upper Sheep Creek (HUC12: 140401060601) had 267 likely fens, covering 1.84% of the landscape. Middle Sheep Creek (HUC12: 140401060603) had 266 likely fens, representing 1.56% of the landscape. Fall Creek-Rock Creek (HUC12: 140600030301) had 251 likely fens representing 1.73% of the basin. See Appendix A for the full HUC12 watershed and likely fens table.

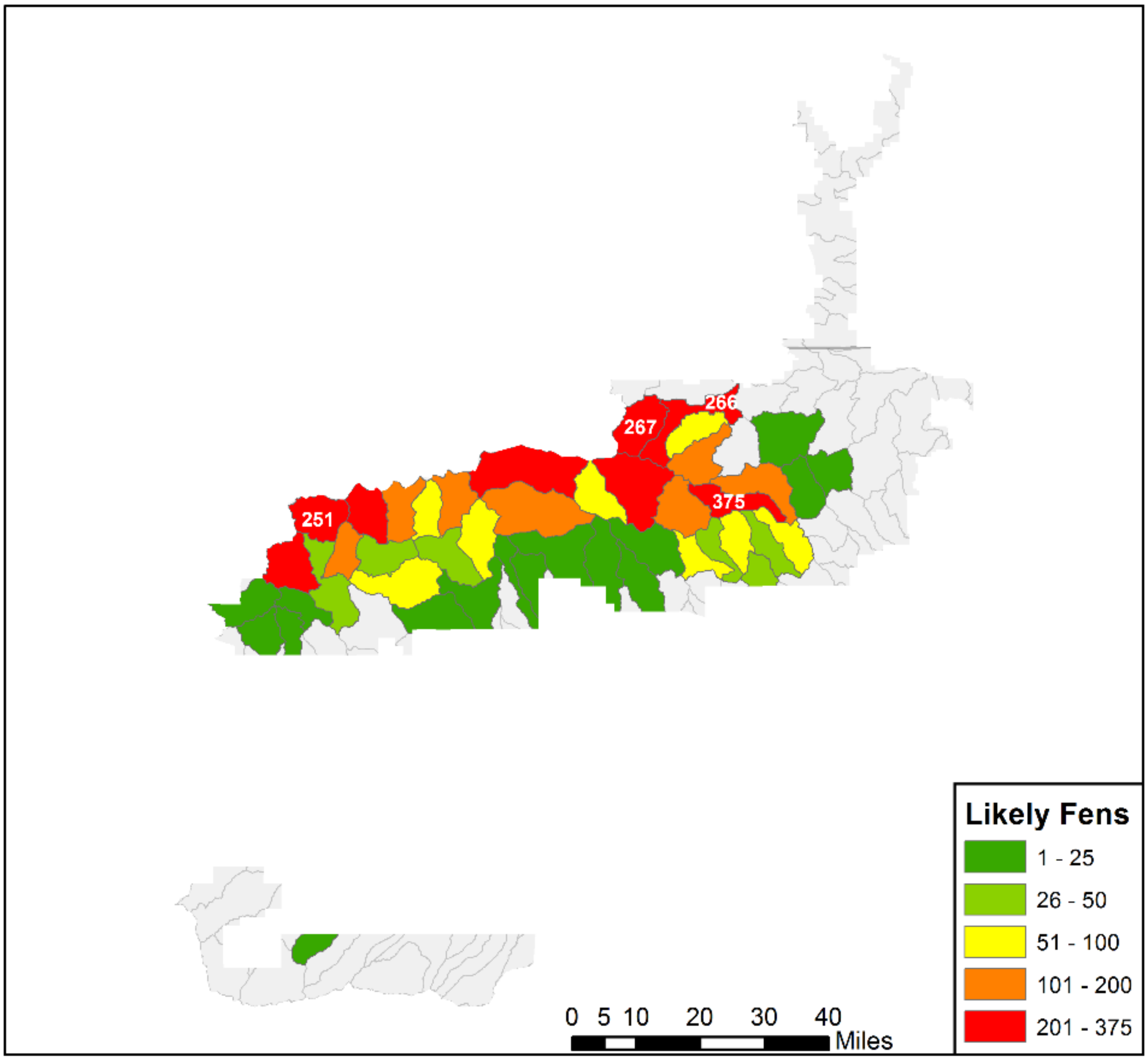

Figure 15. Likely fens by HUC12 watershed within the fen mapping study area.

4.6 Mapped Potential Fens with Distinctive Characteristics

Several characteristics related to fens were noted by photo-interpreters when observed throughout the fen mapping process (Table 8), though this was not an original objective of the project and was not consistently applied.

Of particular interest was identifying markers for potential floating mat fens, a rare type of fen that is known to occur in Ashley National Forest (Kate Dwire, *personal communications*) (Figure 14). Forty-eight potential fens (89 acres) and thirteen likely fens (48 acres) were identified as potential floating mat fens.

Springs and fens are both important components of groundwater-dependent ecosystems (GDEs) and are of particular interest to the U.S. Forest Service (USDA 2012). Springs were noted when observed on either the topographic map or aerial imagery. However, this was not a comprehensive investigation of springs or even springs within fens. Sixty potential fens were observed in proximity to springs.

Beaver influence is a potentially confounding variable in fen mapping because longstanding beaver complexes can cause persistent saturation that looks very similar to fen vegetation signatures. Beavers also build dams in fens, so areas influenced by beavers cannot be excluded from the mapping. Sixty-three potential fens (471 acres) and three likely fens (81 acres) showed some evidence of beaver influence.

Table 8. Potential and likely fens with distinctive characteristics within the fen mapping study area.

Observation	*# of Potential Fens*	*Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Beaver Influence	63	471	3	81
Possible Floating Mat	48	89	13	48
Spring	60	94	3	40
Total	**171**	**654**	**19**	**169**

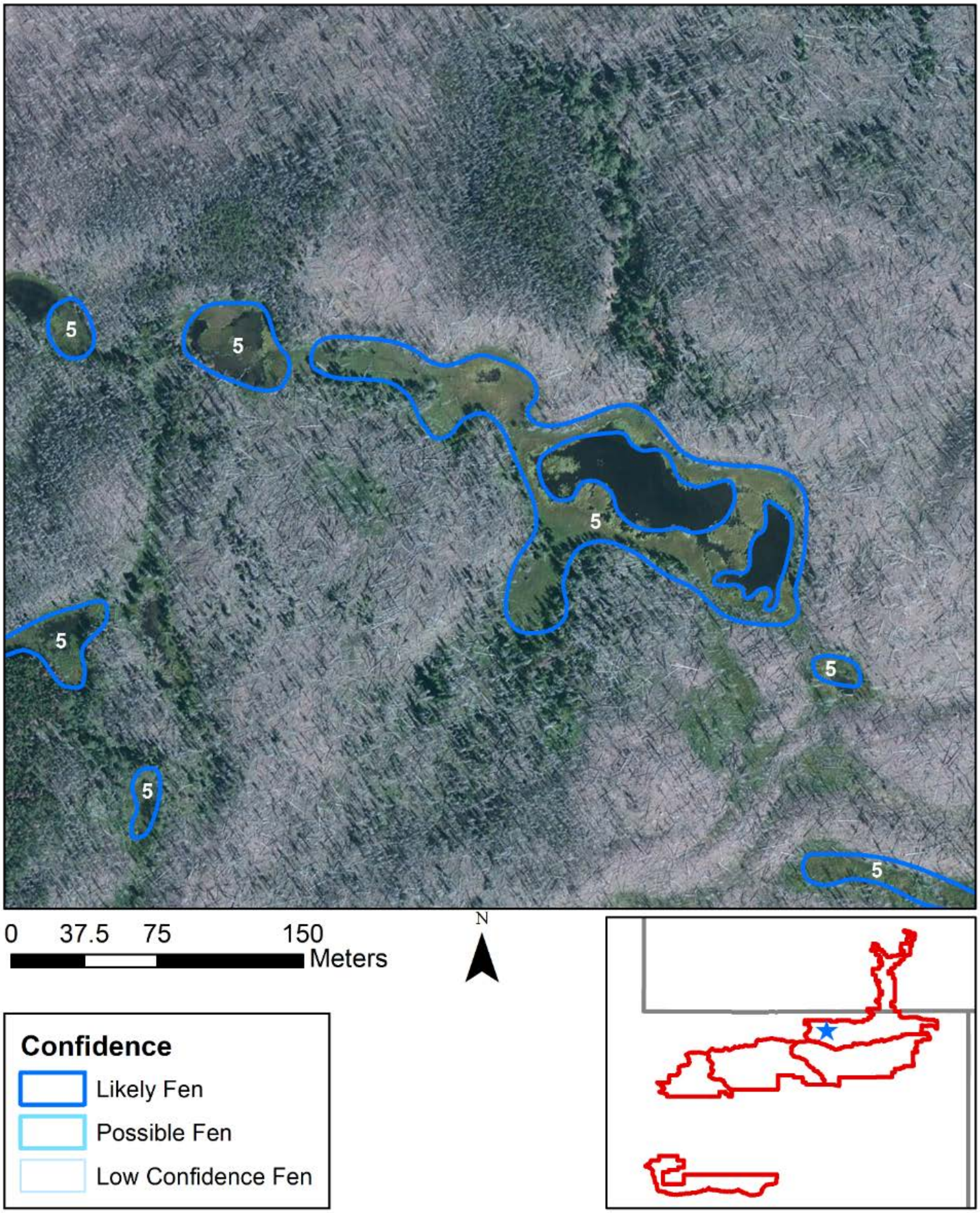

Figure 16. Possible floating mat fens near Sheep Creek Park.

5.0 Discussion

The Ashley National Forest contains a rich resource of fen wetlands, covering up to 13,869 acres across its jurisdiction. While that represents only 1% of the entire landscape, these fen wetlands are an irreplaceable resource for the Forest and the citizens of Utah and Wyoming. Fens throughout the Rocky Mountains 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). Along with habitat for rare plant species, fens also play a pivotal role in regional hydrologic processes. By slowly releasing groundwater, they help maintain stream flows throughout the growing season. With a predicted warmer future climate, in which snow pack may be less and spring melt may occur sooner, maintaining groundwater storage high in the mountains is imperative. Intact fens also sequester carbon in their deep organic soils, however, disturbing fen hydrology can lead to rapid decomposition of peat and associated carbon emissions (Chimner 2000).

Analysis of the potential fen data showed clear patterns in fen distribution within the ANF. There was a strong elevation gradient, with 94% of potential fens falling between 9,000 and 12,000 feet. High snowfall and slow snowmelt at these elevations allows for ample groundwater discharge for fen wetlands. There were also clear hotspots for fens in the ANF, including the South Fork of Ashley Creek, Upper and Middle Sheep Creek and Fall Creek-Rock Creek. These areas should be actively conserved.

Bedrock geology can exert a strong influence on species composition within fens (Chimner et al. 2010; Lemly & Cooper 2011). The ANF is dominated by sedimentary geologic formations and quaternary alluvium. Because much of the surrounding subsurface geology is sedimentary, it is reasonable to assume that even the alluvium in ANF is sedimentary in origin. Groundwater flowing through sedimentary bedrocks can contain a high concentration of calcium and magnesium ions and groundwater fens formed on these substrates may support a distinct suite of plants. The most calcium rich fens are often found associated with limestone or dolomite (Cooper 1996; Johnson & Steingraeber 2003). Given the variety of sedimentary formations with the ANF, it is possible that many fens in the Forest may be rich or extreme rich fens with uncommon plant species. Several plant species, many of which are rare in the state of Utah, have been identified within mapped potential fens from past surveys (Kate Dwire, *personal communication*) (Table 9). Even more may exist in the newly mapped fens.

Previous studies of wetland condition in other high elevation forests have found that high elevation wetlands were generally in excellent to good condition (Lemly 2012). Human stressors were observed in some fen wetlands while mapping fens on the ANF, such as off-roading vehicle trails, foot trails or impoundments, and those observations were captured in the "Notes" field of the GIS dataset accompanying this report. However most potential fens in ANF showed little sign of human disturbance, particularly at higher elevations.

Table 9. Plant species found in fens within Ashley National Forest.

Species Name	*Utah State Rank*
Carex aquatilis	SNR/SU
Carex buxbaumii	SNR/SU
Carex lasiocarpa	S1
Carex limosa	S3
Carex livida	S1
Carex magellanica	SNR/SU
Carex saxatilis	SNR/SU
Eleocharis quinqueflora	SNR/SU
Potentilla palustris	S1

In total, 8,614 potential fens were mapped throughout the ANF, of which 4,019 were most likely to be fens. The number and acreage of mapped potential fens is less than for saturated polygons mapped by the National Wetland Inventory. While NWI polygons were an excellent starting point for identifying fens, this project showed that delineating new polygons specifically for fens produced a more accurate and precise accounting of fen number and acreage. We see this as a model for future fen mapping efforts in the state and for the U.S. Forest Service. In addition to this hand drawn fen map, we are also providing the forest with an enhanced version of original NWI data with a "Fen Potential" attribute that highlights areas of significant overlaps between wetlands mapped as saturated or aquatic bed in NWI and the fen mapping. This additional dataset may be useful in modeling efforts, but should not be used for precise fen locations or acreage summaries.

This report and associated dataset provide the ANF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing ANF biological assessment required by the 2012 Forest Planning Rule, but can also be used to establish buffers around fens for individual management actions, such as timber sales, grazing allotments, and trail maintenance. Wherever possible, the Forest 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.

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APPENDIX A: LIKELY FENS BY HUC12 WATERSHED, SORTED BY FEN DENSITY

HUC 12 Code	HUC 12 Name	Watershed Acres	Likely Fen Count	Likely Fen Acres	Fen Density (Fen Acres/ Watershed Acres)
140600031101	Shale Creek-North Fork Uinta River	37062	205	1322	3.57%
140600020101	Twin Lakes	19600	145	667	3.40%
140600031202	East Fork Whiterocks River	31094	240	1054	3.39%
140600020201	South Fork Ashley Creek	15072	375	486	3.22%
140600031201	West Fork Whiterocks River	15448	96	424	2.75%
140600030702	Milk Creek-Yellowstone Creek	15319	151	361	2.35%
140600030602	Oweep Creek	15360	116	326	2.12%
140600030601	Ottoson Creek-Lake Fork Creek	16192	220	314	1.94%
140401060601	Upper Sheep Creek	18652	267	343	1.84%
140600030303	West Fork Rock Creek	19348	236	346	1.79%
140600030301	Fall Creek-Rock Creek	18431	251	319	1.73%
140600030701	Garfield Creek	11673	98	195	1.67%
140401060603	Middle Sheep Creek	19243	266	300	1.56%
140600030302	East Fork Rock Creek	11720	122	181	1.55%
140401060701	Beaver Creek	13123	86	203	1.54%
140600020202	North Fork Ashley Creek	19555	180	279	1.43%
140600031102	Atwood Creek-Uinta River	35697	113	422	1.18%
140600030704	Swift Creek	18140	78	209	1.15%
140600020501	Upper Little Brush Creek	13454	14	110	0.82%
140600020103	Dry Fork-North Fork	10119	46	78	0.77%
140600020103	Dry Fork-North Fork	10119	46	78	0.77%
140600020102	Dry Fork-Twin Creek	10793	95	80	0.74%
140600030604	Brown Duck Creek-Lake Fork River	24822	78	158	0.64%
140600030603	East Basin Creek-Lake Fork River	15406	48	97	0.63%
140600030703	Swasey Lakes-Yellowstone Creek	17844	27	95	0.53%
140600020401	Upper Big Brush Creek	14869	13	74	0.50%
140600020204	Ashley Gorge	13917	85	68	0.49%
140401060702	Upper Carter Creek	16773	102	79	0.47%

140600020104	Brownie Creek	12603	57	56	0.45%
140600031104	Pole Creek	21990	14	69	0.31%
140600030901	West Fork Dry Gulch Creek	11456	19	34	0.30%
140600031203	Paradise Creek-Whiterocks River	21714	21	64	0.29%
140600020203	Black Canyon	12385	41	21	0.17%
140600030903	Headwaters Dry Gulch Creek	19206	14	30	0.16%
140600030305	Cabin Creek-Rock Creek	21719	33	26	0.12%
140600030106	Hades Creek-Duchesne River	18278	20	22	0.12%
140401060704	Lower Carter Creek	25048	5	29	0.12%
140600030304	South Fork Rock Creek	10359	6	11	0.11%
140600031103	Clover Creek-Uinta River	31883	11	35	0.11%
140600031402	Hominy Creek-Farm Creek	21443	13	13	0.06%
140600030605	Petty Creek-Lake Fork River	31940	1	2	0.01%
140600030705	Crystal Creek-Yellowstone River	26198	5	1	0.01%
140600040803	Lake Canyon	27020	1	1	0.01%
140600030104	East Fork-Duchesne River	15454	1	0	0.00%
140600030107	Swift Creek-Duchesne River	12872	3	0	0.00%
140600030201	Blind Stream	11120	1	0	0.00%