Fen Mapping for the Dixie National Forest

COLORADO NATURAL HERITAGE PROGRAM

December 2018

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 Dixie National Forest covers 1.7 million acres the Upper Colorado River, Lower Colorado River, and Escalante Desert Basins in southwest Utah. Wetlands within the Dixie National Forest provide important ecological services to both the Forest 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 Dixie National Forest 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 Dixie National Forest.

Potential fens in the Dixie National Forest 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 884 potential fen locations (all confidence levels), covering 2,281 acres or less than 1% of the total land area. This total included 62 ***likely fens***, 237 ***possible fens***, and 585 ***low confidence fens.*** The average fen polygon was 2.58 acres, but individual fen polygons ranged from 88 acres to less than an acre.

Fen distribution was analyzed by elevation, bedrock geology, Land Type Association, and watershed. The vast majority of mapped potential fens occurred between 8,000 to 11,000 feet. This elevation range contained 90% of all potential fen locations and 70% of likely fen locations. Two watersheds in particular have higher numbers of likely fens: Upper North Creek and the Headwaters of Boulder Creek both had 10 mapped likely fens.

This report and associated dataset provides the Dixie National Forest with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing Dixie National Forest 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

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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, Dee Malone, Sarah Marshall, and Kristin Schroder. 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 Dixie National Forest (Dixie National Forest) covers 1.7 million acres within the Upper Colorado River, Lower Colorado River, and Escalante Desert Basins in southwest Utah and spans a broad elevation range from 2,800 to 11,322 ft. Several types of wetlands occur within the Dixie National Forest. Snowfall in the mountains percolates through shallow mountain soils and creates wet meadows, riparian shrublands, and organic soil wetlands known as fens. These wetland habitats provide important ecological services to both Dixie National Forest 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. In advance of the biological assessment, biologists at the Dixie National Forest 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 Dixie National Forest. This project builds upon CNHP's previous projects mapping fens on the White River National Forest (Malone et al. 2011), Rio Grande National Forest (Smith et al. 2016), Ashley National Forest (Smith & Lemly 2017a), Manti-La Sal National Forest (Smith & Lemly 2017b), Salmon Challis National Forest (Smith et al. 2017) and the Bridger-Teton National Forest (Smith & Lemly 2018).

[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 Dixie National Forest, which is administered as four discontinuous units located in southwest Utah (Figure 1). Dixie National Forest includes portions of Garfield, Washing, Iron, Kane, Wayne and Piute counties. The largest municipalities near the study area are St. George, Cedar City, Washington, and Hurricane, Utah. Dixie National Forest straddles the divide between the Great Basin and the Colorado River Basin. Elevation in the study area ranges from 2,800 ft. (850 m) to 11,322 ft. (3,451 m) and the mean elevation is 8,984 ft. (2,738 m). The Pine Valley Ranger District is the lowest elevation area in the Forest and the Escalante Ranger District contains Boulder Mountain which is the highest timbered plateau in North America. The Forest is located in close proximity to Capitol Reef, Bryce Canyon, and Zion National Parks, as well as Cedar Breaks and Grand Staircase-Escalante National Monuments.

The Dixie National Forest straddles three different HUC6 river basins: the Upper Colorado-Dirty Devil (HUC6: 140700), the Lower Colorado-Lake Mead (HUC6:150100), and the Escalante Desert-Sevier Lake Basin (HUC6: 160300) (Figure 2). The headwaters of the Sevier River flow northward out of the Cedar City and Powell Ranger Districts into the Great Basin. The Virgin River collects water from the Pine River Ranger District as it flows southwest away from the study area.

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 Land Type Associations referenced in this report are draft versions that did not have the LTA Group applied yet, so the final version of this dataset may be different than what is described in this report. The most common grouped Land Type Association in the Dixie National Forest is the Pine Valley (28% of study area) (Figure 3). The next most common Land Type Associations are the Aquarius Plateau (24%), Markagunt Plateau (23%) and Sevier Plateau (12%).

2.3 Geology

The most common geology in the fen mapping study area is metamorphic or igneous with a dominantly silicic composition, which covers 43% of the study area (Figure 4). The next most common geology is sandstone (23% of study area). Quaternary age younger alluvium (16%) and shale (8%) are also common.

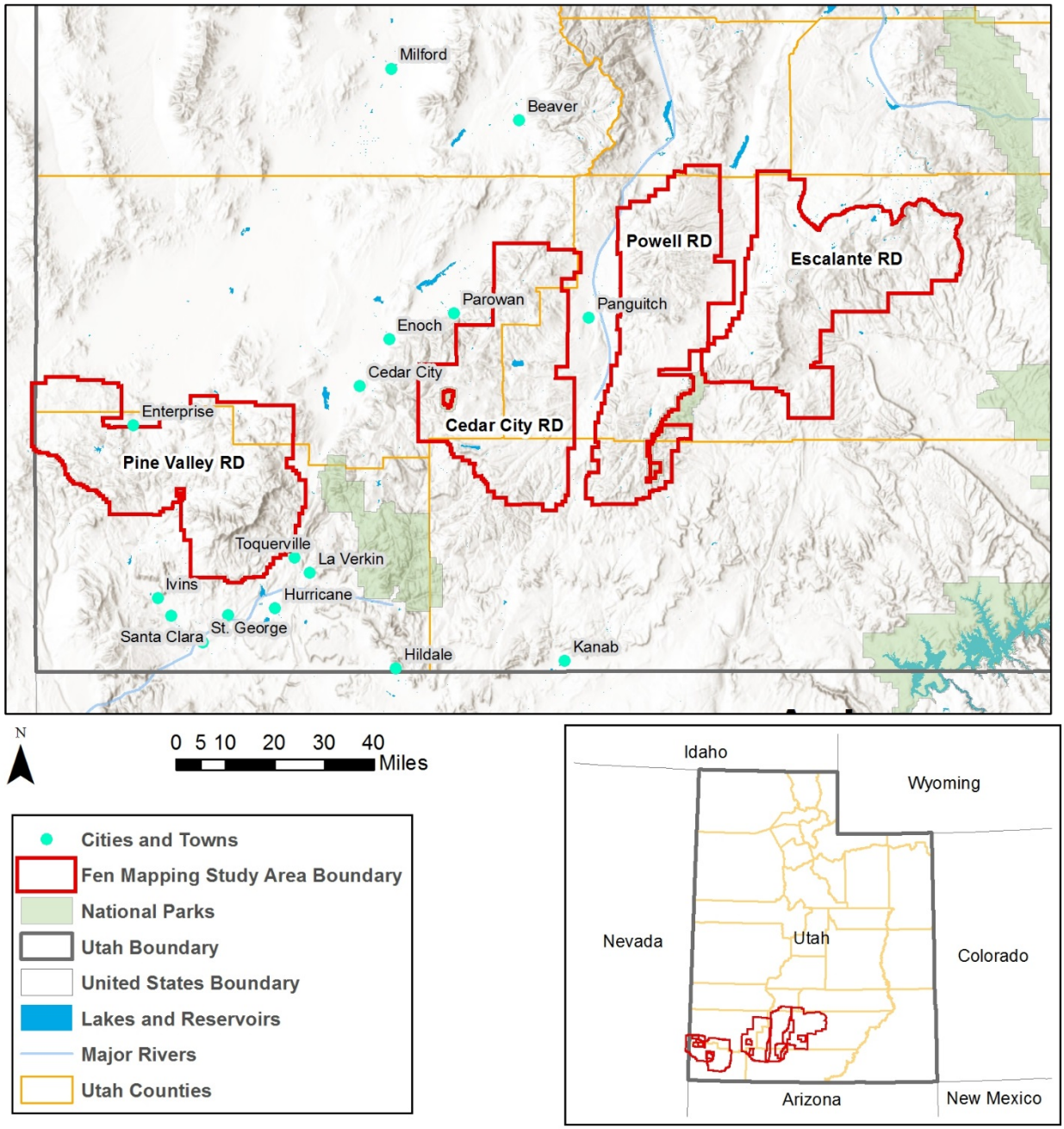

Figure 1. Location of the Dixie National Forest (fen mapping study area) within Utah.

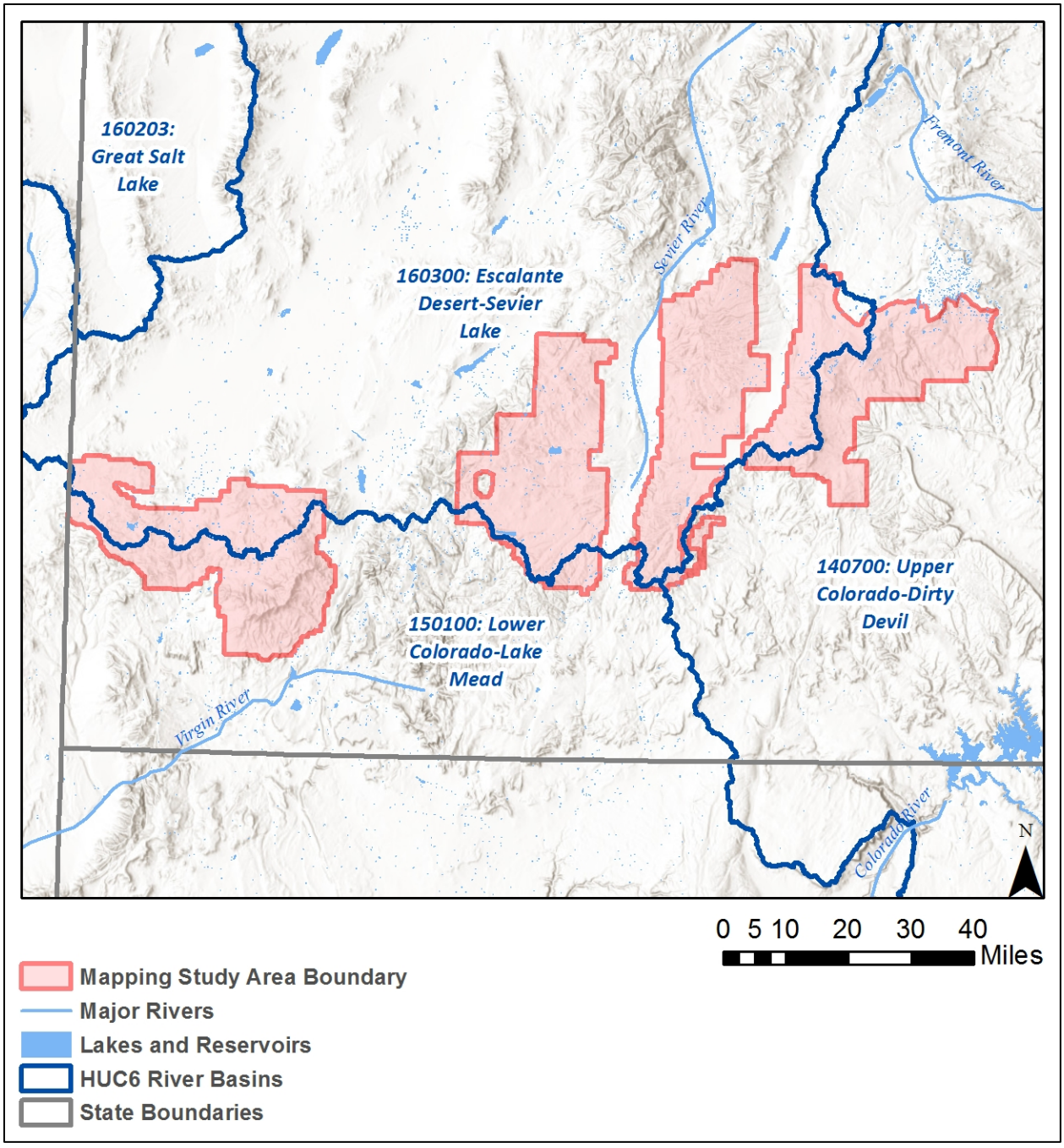

Figure 2. HUC6 river basins and major waterways in the fen mapping study area.

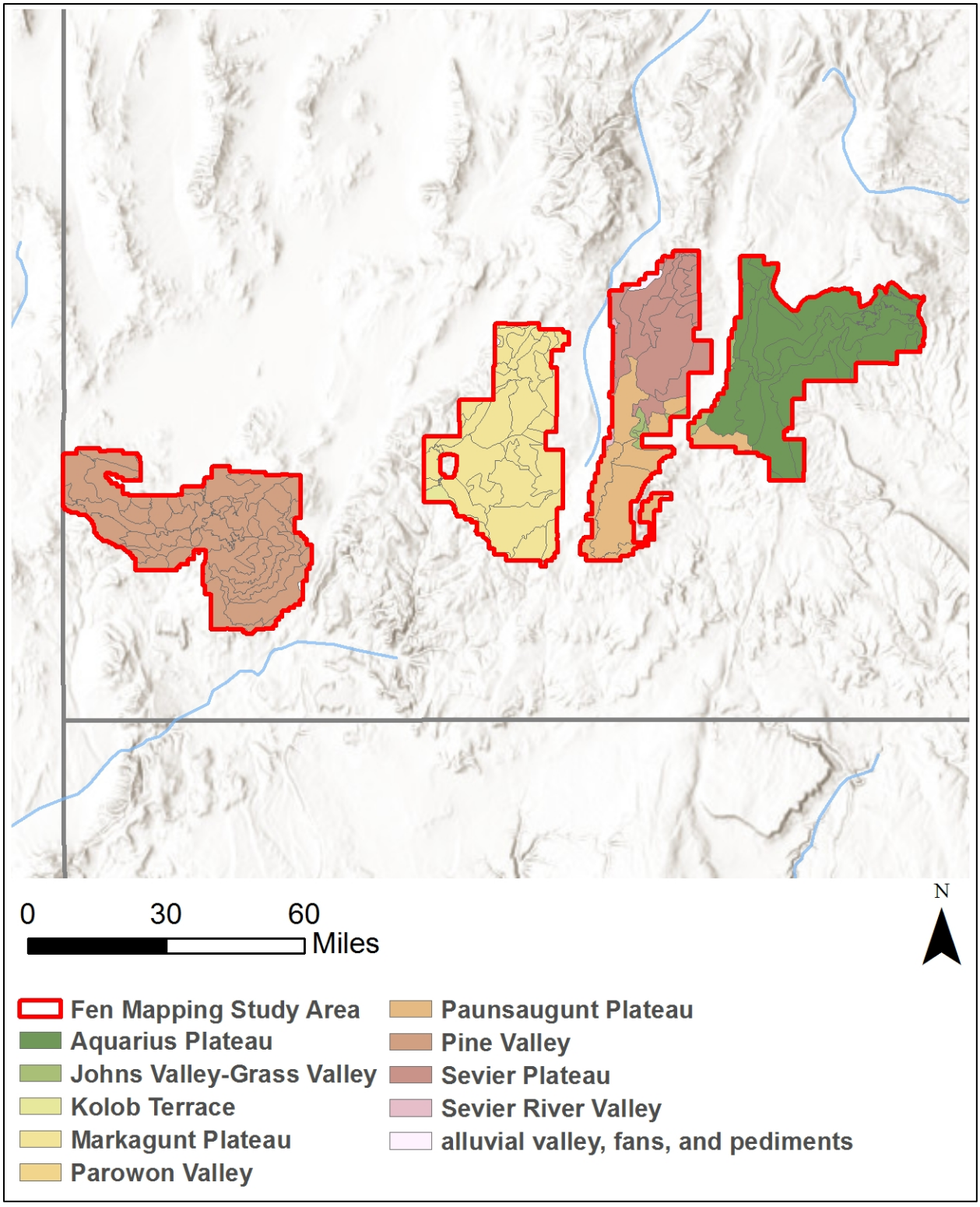

Figure 3. Grouped Land Type Associations of the fen mapping study area.

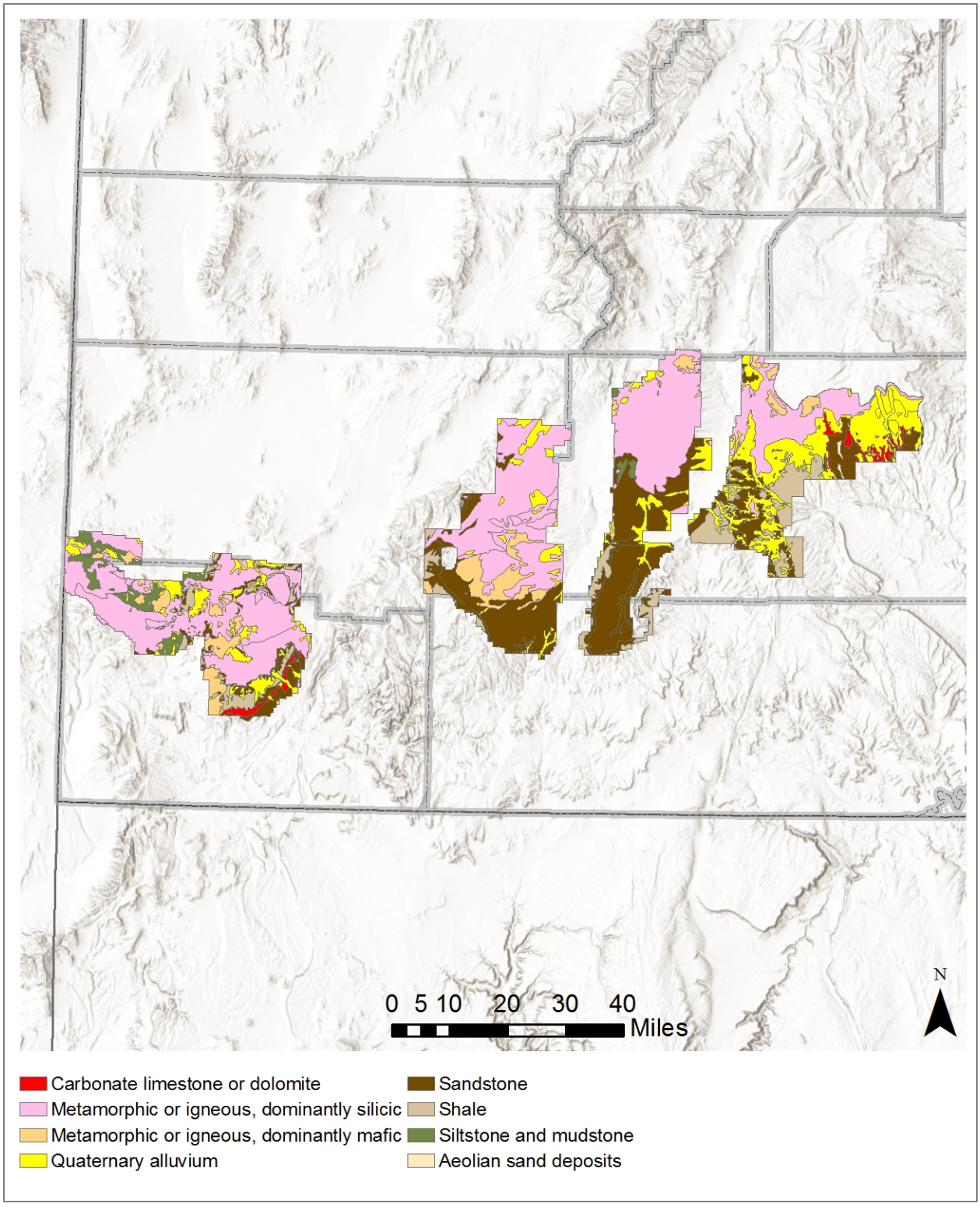

Figure 4. Geology within the fen mapping study area.

3.0 Fen Mapping Methods

Potential fens in the Dixie National Forest were identified by analyzing digital aerial photography and topographic maps. True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2009, 2011 and 2014 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 can be 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.

Potential fen polygons were hand-drawn in ArcGIS 10.4 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 Dixie National Forest 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 1). 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 1. Description of potential fen confidence levels.

Confidence	*Description*
5	***Likely fen.*** Strong photo signature of fen vegetation, fen hydrology, and good landscape position. All likely fens should contain peat of 40cm or more throughout the entire area of the mapped feature.
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. Possible fens may or may not have the required peat depth of 40cm, but may have patchy or thin peat throughout.
1	***Low confidence fen.*** At least one fen indicator present, but weak. Low confidence fens are consistently saturated areas that do not show peat signatures in the aerial photography, but may contain fen or peat.

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

4.0 RESULTS

4.1 Potential Fen Mapping Acreage

The final map of potential fens contained 884 potential fen locations (all confidence levels), covering 2,281 acres or 0.1% of the total land area (Table 2; Figures 5 and 6). This total included 62 likely ***fens*** (confidence level = 5), 237 ***possible fens***, and 585 ***low confidence fens.*** On average the likely fens were considerably larger in size than the possible or low confidence fens (3.23 acres vs. 2.24 or 2.65 acres), resulting in 193 acres of likely fens, 538 acres of possible fens, and 1,549 acres of low confidence fens. The size of individual potential fens ranged from over 88 acres to 0.02 acres. The two largest mapped likely fens are shown in Figures 7 and 8.

Table 2. Potential fen counts and acreage, by confidence levels.

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	62	193	3.23
3 – Possible Fen	237	538	2.27
1 – Low Confidence Fen	585	1,549	2.65
TOTAL	**884**	**2,281**	2,58

Original NWI mapping for the Dixie National Forest contained 1,738 acres with a "B" (saturated) hydrologic regime, including 1,395 acres of herbaceous wetlands (PEMB and PEMBb) and 344 acres of shrub wetlands (PSSB and PSSBb) (Table 3). 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 44% of those acres (770 acres), while the remaining 53% were determined to not be potential fens. Finally, 529 acres not mapped as saturated by NWI were mapped as potential fens.

Polygons mapped as saturated herbaceous in NWI made up a far greater share of the potential fens (50% of the fen/NWI overlap) than polygons mapped as saturated shrubs (9%). This ratio was relatively similar to the ratio of all saturated herbaceous vs. shrub acres in NWI and indicates that the fens in Dixie National Forest are far more likely to be herbaceous dominated. However, this should be confirmed in the field, as many fen shrubs are short stature and may have been missed by NWI.

The sections that follow (4.2 through 4.5) break down the fen mapping by elevation range, bedrock geology, Land Type Association, and HUC12 watershed. The last section summarizes observations made by the fen mappers during the mapping process, including potential floating mat fens.

Table 3. 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*		
PEMB	729	376	186	86	648	1,377
PEMBb	10	2	6	--	8	18
PSSB	220	83	28	1	111	332
PSSBb	9	1	3	--	3	12
Total Saturated NWI Acres	**968**	**461**	**222**	**87**	**770**	**1,738**
Other NWI Code	4,778	350	108	70	529	5,307
Total NWI Acres	**5,746**	**811**	**324**	**165**	**1,300**	**7,045**
Not Mapped by NWI	n/a	738	207	35	981	n/a
Grand Total		**1549**	**538**	**193**	**2,281**	

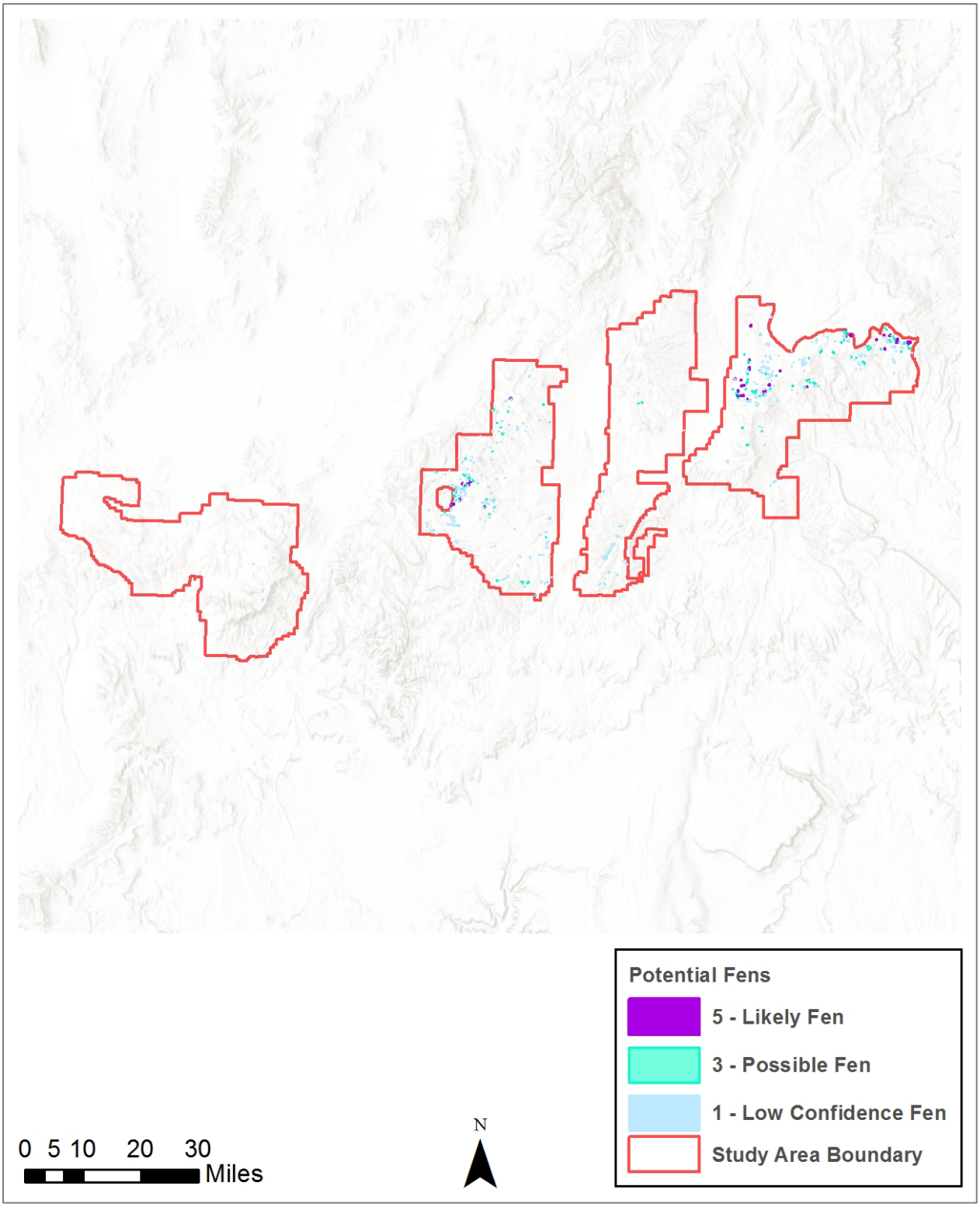

Figure 5. All potential fens within the fen mapping study area.

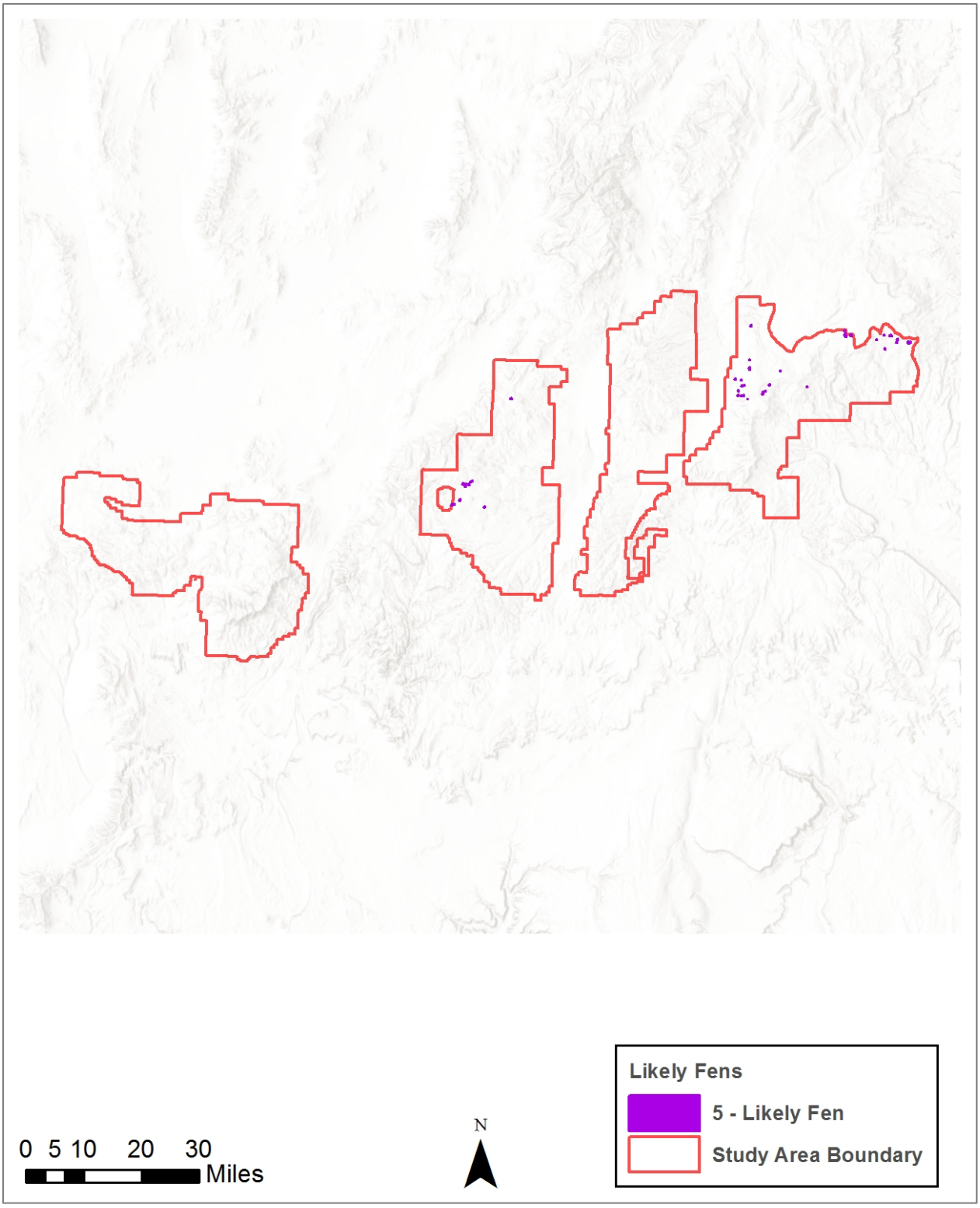

Figure 6. Likely fens (confidence rating = 5) within the fen mapping study area.

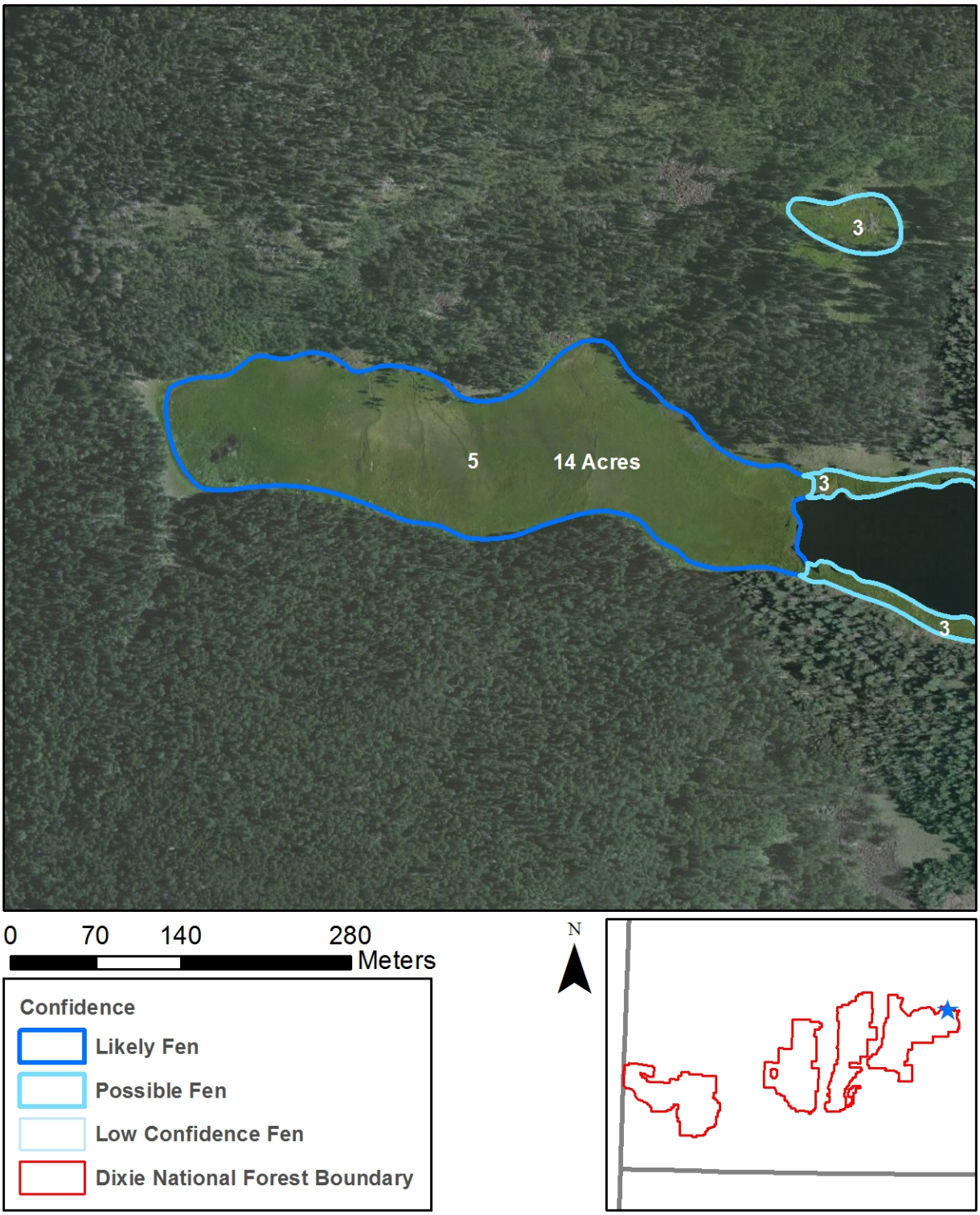

Figure 7. Largest mapped likely fen, 14 acres within one polygon. This fen is located along the East Fork of Boulder Creek, in Garfield County.

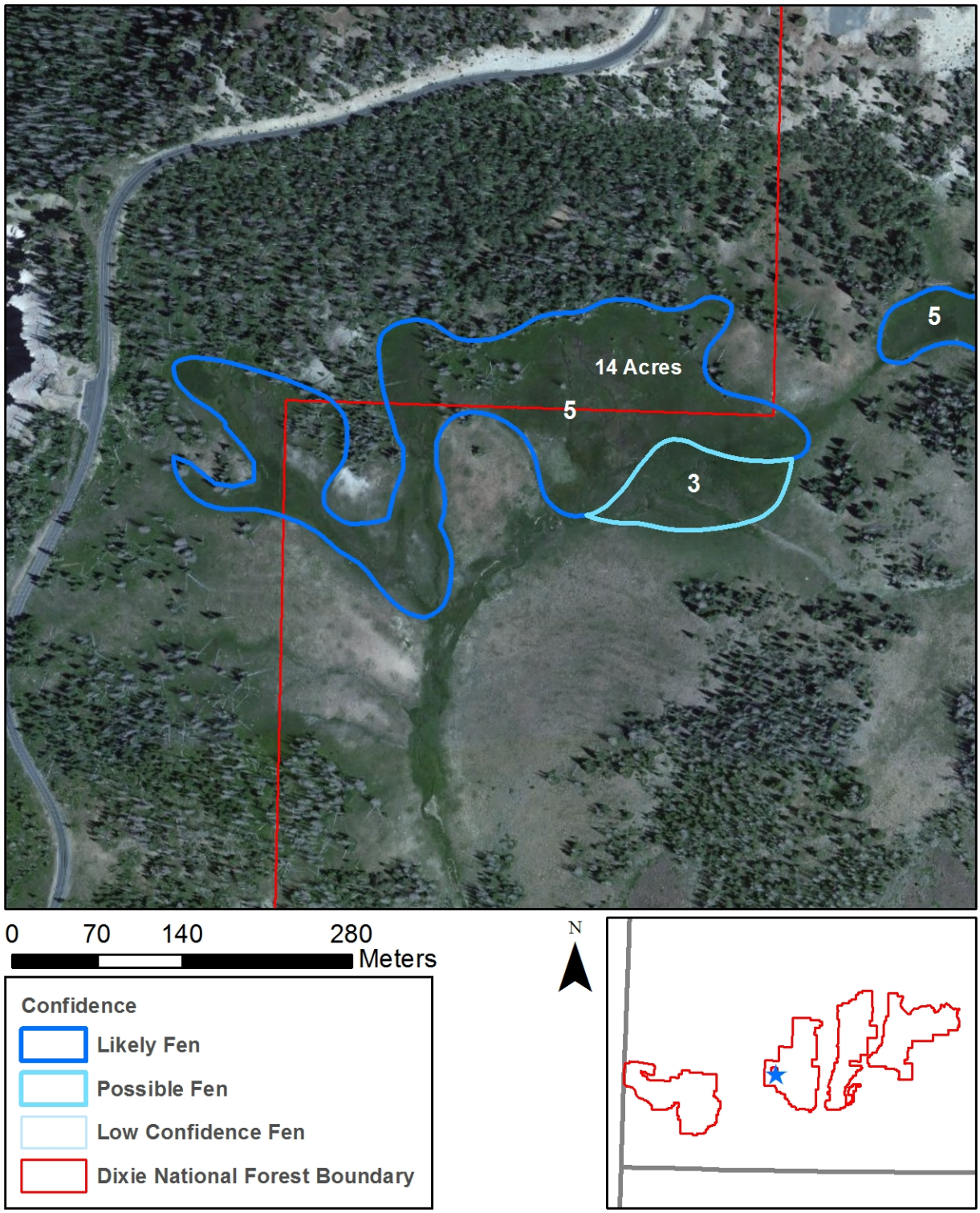

Figure 8. Second largest mapped likely fen, 14 acres within one polygon. This fen is located in the headwaters of Long Valley Creek, in Iron County.

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. Springs are also am important water source for fens in more arid regions and can occur across a wider elevation range.

Of all potential fens, 386 polygons (893 acres) were mapped between 9,000 and 10,000 feet, which represents 44% of potential fen locations and 39% of potential fen acres (Table 4; Figure 9). Of the 62 total likely fens mapped, 35 polygons (56%) and 5,345 acres (47%) were located between 9,000 and 10,000 feet (Table 5; Figures 10 and 11). This is the zone of maximum fen formation for the Dixie National Forest.

The elevation bands of 8,000 to 9,000 feet and 10,000 to 11,000 feet also contain many potential and likely fens. Between 8,000 to 9,000 feet, there were 167 mapped potential fens (502acres), which represent 19% of potential fen locations and 22% of potential fen acres. In addition, there were 4 likely fens (12 acres), which represent 6% of likely fen locations and 6% of likely fen acres. Between 10,000 to 11,000 feet, there were 241 mapped potential fens (15 acres), which represent 27% of potential fen locations and less than 1% of potential fen acres, and 5 likely fens (94 acres), which represent 8% of likely fen locations and 4% of likely fen acres. The likely fens mapped between 8,000 to 9,000 feet were much larger on average (3.0 acres) than the likely fens mapped between 10,000 to 11,000 feet (1.4).

These three elevation bands combined (8,000 to 11,000 feet) contain 90% of potential fen locations (62% of acres) and 70% of likely fen locations (56% of acres).

Table 4. 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*
< 7,000	23	57	--	--
> 7,000 – 8,000	67	254	1	12
> 8,000 – 9,000	167	502	4	12
> 9,000 – 10,000	386	893	35	94
> 10,000	241	15	5	7
Total	**884**	**2,281**	**62**	**193**

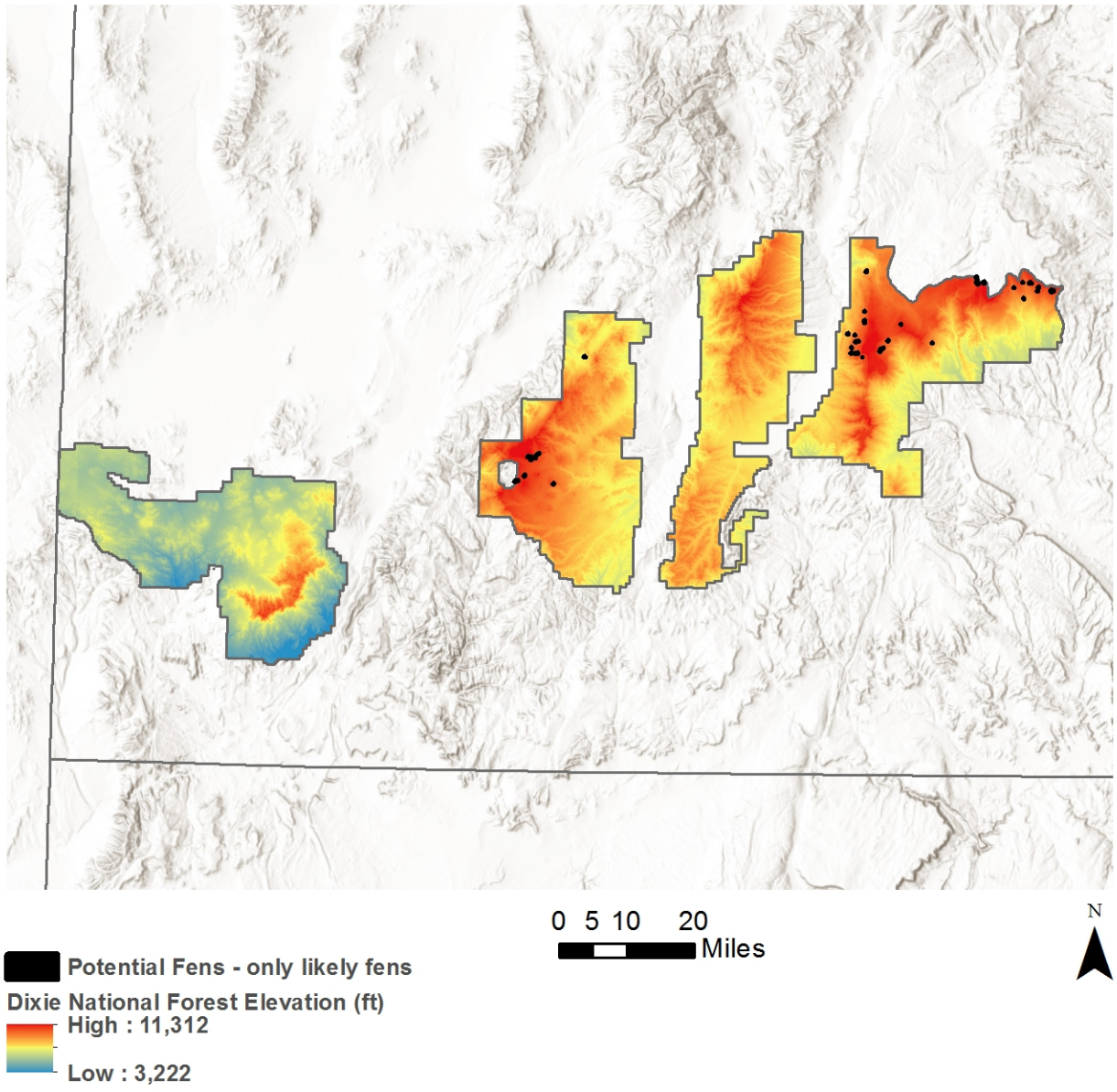

Figure 9. Likely fens (confidence rating = 5) and elevation within the fen mapping study area.

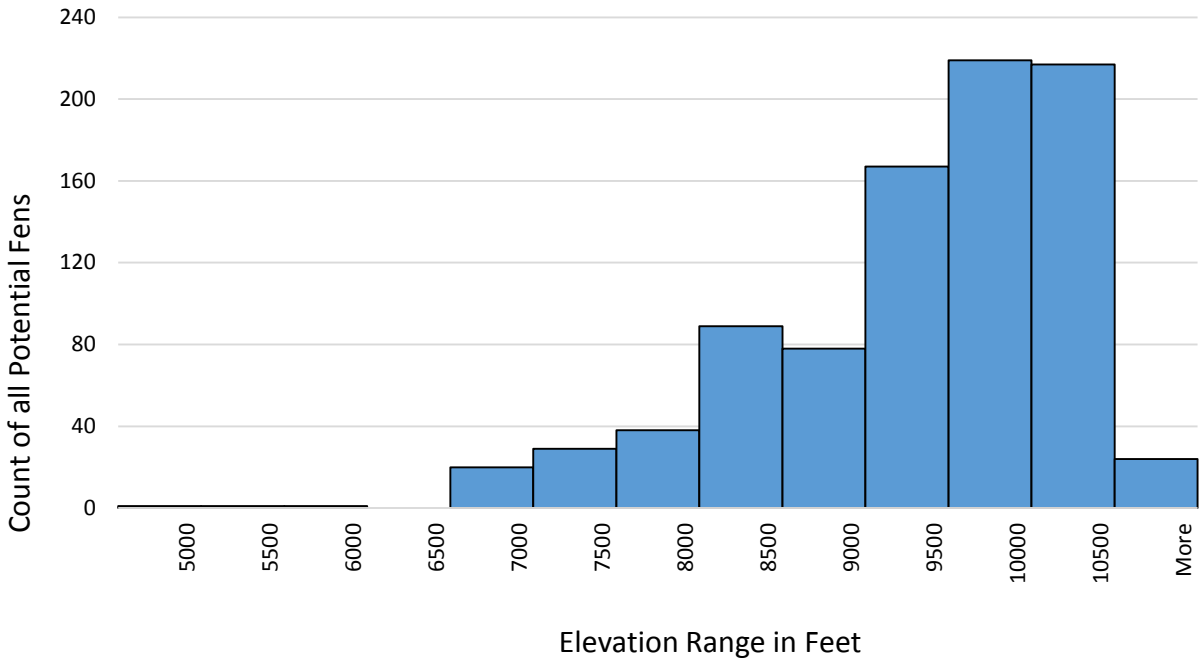

Figure 10. Histogram of all potential fens by elevation within the fen mapping study area.

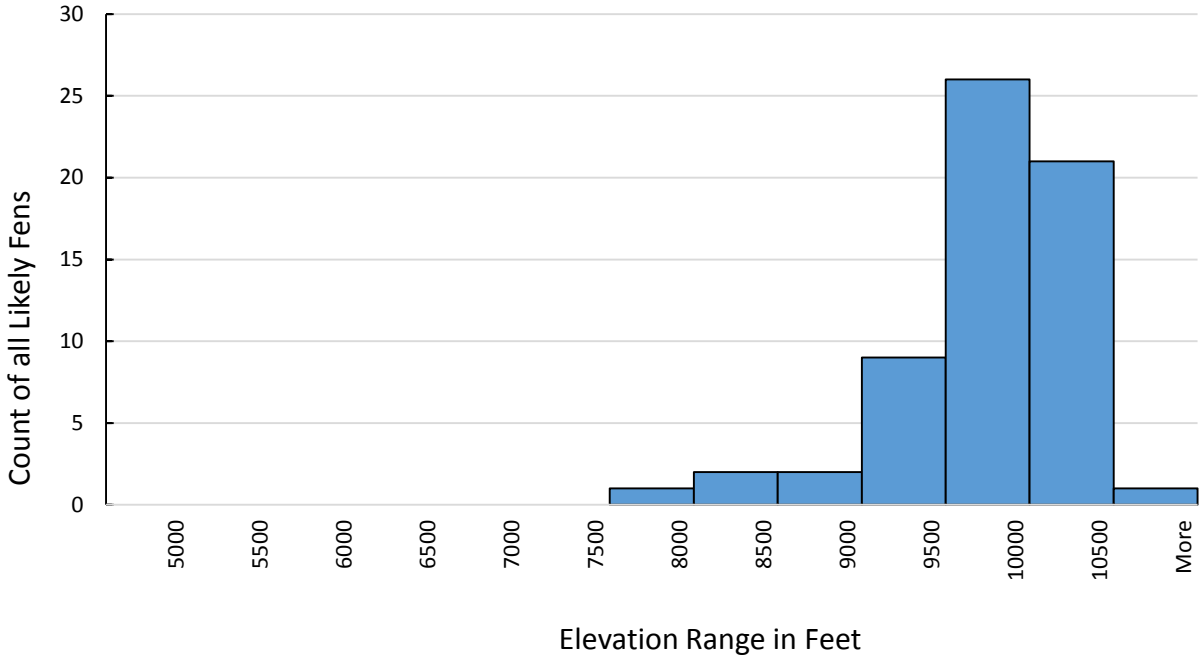

Figure 11. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

The most common geologic substrate under potential fens in Dixie National Forest was metamorphic or igneous with dominantly silicic composition, which underlies 414 mapped potential fens (911 acres). The most common geologic substrate under likely fens in Dixie National Forest was Quaternary age younger alluvium, which underlies 43 mapped likely fens (124 acres) (Table 5). While alluvium represents the dominant substrate in only 15% of the Forest, 35% of all potential fens and 69% 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 22% of the Dixie National Forest and 15% of all potential fens (135 locations) and 5% of likely fens (3 locations).

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

Geology	*Acres of Geologic Substrate Within Dixie*[1]	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Metamorphic or igneous with dominantly silicic composition	733,422	414	911	15	53
Sandstone	390,282	135	643	3	14
Quaternary age younger alluvium	268,103	307	600	43	124
Shale	133,588	15	26	--	--
Metamorphic or igneous with dominantly mafic composition	108,949	10	97	1	1
Siltstone and mudstone	42,635	1	1	--	--
Quaternary age older alluvium	11,150	2	2	---	---
		884	**2,281**	**62**	**193**

[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 Dixie National Forest.

4.4 Mapped Potential Fens by Land Type Association

Land Type Associations (LTA) combine location, geology, and dominant vegetation and are defined by each Forest. The Aquarius Plateau covers nearly a quarter of the Dixie National Forest (24%), and this LTA contains the majority of both potential and likely fen locations in Dixie National Forest. The Aquarius Plateau contains 437 mapped potential fens (1,022 acres) and 47 likely fens (140 acres) (Table 6). This represents 49% of potential fen locations and 76% of likely fen locations.

The Markagunt Plateau, which covers 23% of the Forest, contains 385 mapped potential fens (898 acres) and 14 likely fens (59 acres). This represents 44% of potential fen locations and 23% of likely fen locations. The Sevier Plateau also contains one likely fen location.

Table 6. Potential and likely fens by Land Type Association within the fen mapping study area.

Land Type Association Map Unit Name	*Acres within Dixie National Forest*[1]	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Aquarius Plateau	451,801	437	1,022	47	140
Markagunt Plateau	250,522	385	898	14	52
Paunsaugunt Plateau	304,822	32	322	--	--
Kolob Terrace	93,225	11	15	--	--
Pine Valley	169,601	10	17	--	--
Sevier Plateau	18,327	9	7	1	1
		884	**2,281**	**62**	**193**

[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 Dixie National Forest.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC12 watersheds revealed interesting patterns. Five watersheds in particular had significant numbers of likely fens (Figure 12). Upper North Creek (HUC12: 140700050103) had 10 likely fens, which covered 0.04% of the landscape in this watershed. Headwaters Boulder Creek (HUC12: 140700050206) also had 10 likely fens, covering 0.08% of the landscape. Upper Mammoth Creek (HUC12: 160300010201) had 8 likely fens, representing 0.13% of the landscape. Upper Pine Creek (HUC12: 140700050105) had 7 likely fens representing 0.09% of the basin. See Appendix A for the full HUC12 watershed and likely fens table.

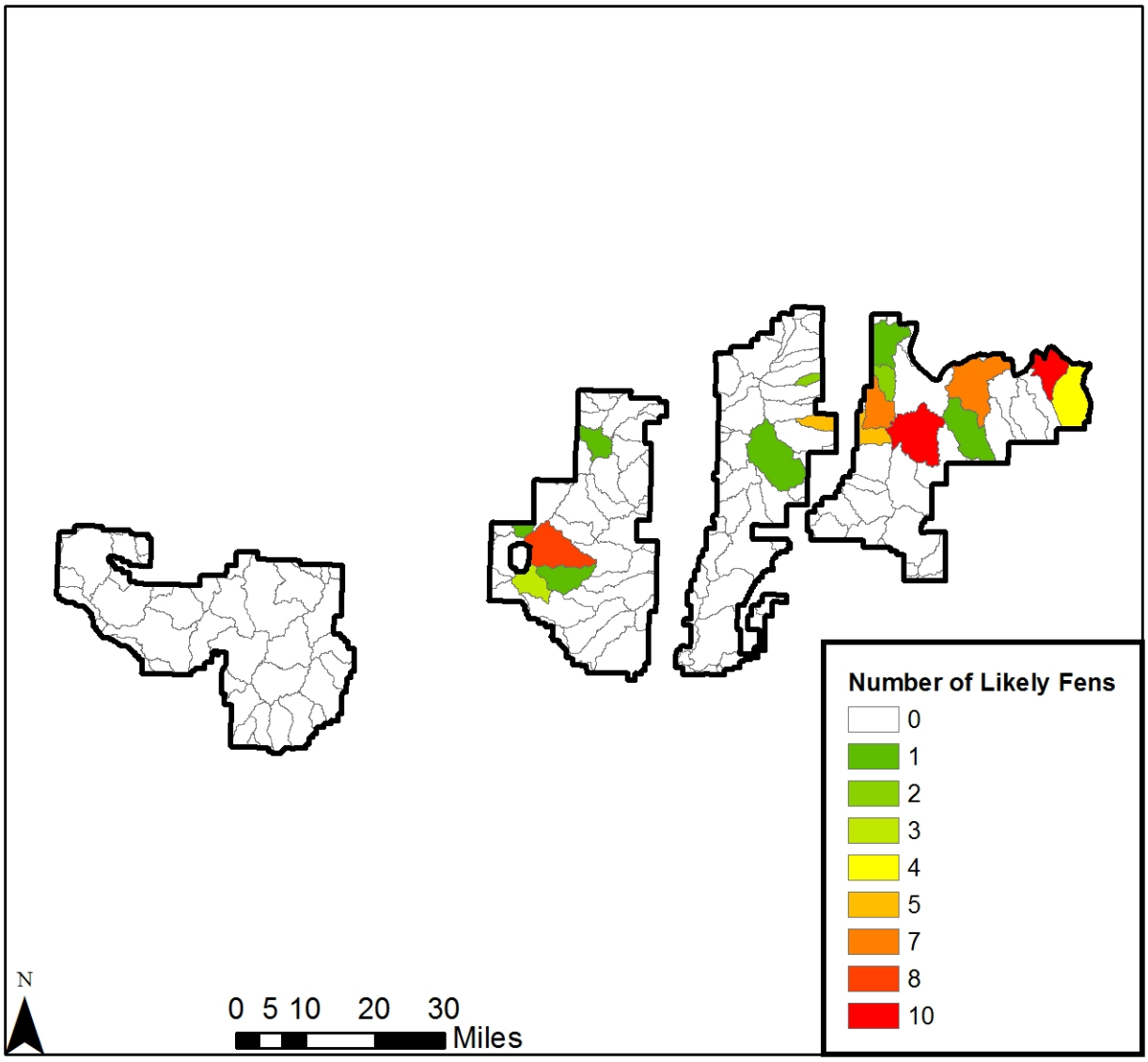

Figure 12. Likely fens by HUC12 watershed within the fen mapping study area.

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 7), 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 may occur in Dixie National Forest (Kate Dwire, *personal communications*). Sixteen potential fens (164 acres) and four likely fens (15 acres) were identified as potential floating mat fens. See Figure 13 for the largest example of a mapped likely fen with a floating mat component.

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. One hundred and thirty four potential fens and nine likely fens were observed in proximity to springs. See Figure 14 for an example of a mapped likely fen associated with multiple mapped 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. Seven potential fens (136 acres) showed some evidence of beaver influence.

Table 7. 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*
Spring	134	302	9	32
Possible Floating Mat	16	164	4	15
Beaver Influence	7	136	--	--
Total	**157**	**602**	**13**	**47**

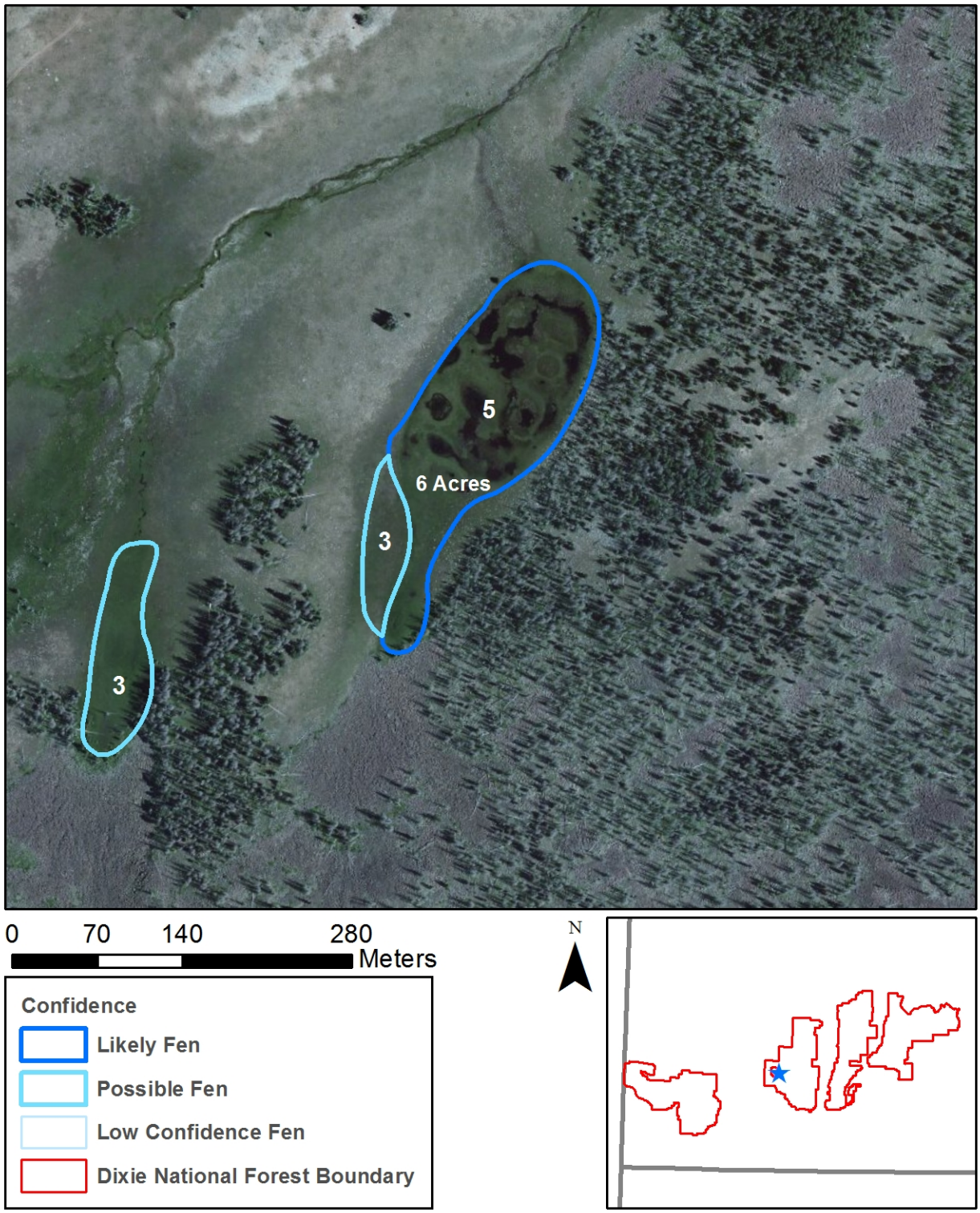

Figure 13. Possible floating mat fen located west of Hancock Peak, in Iron County.

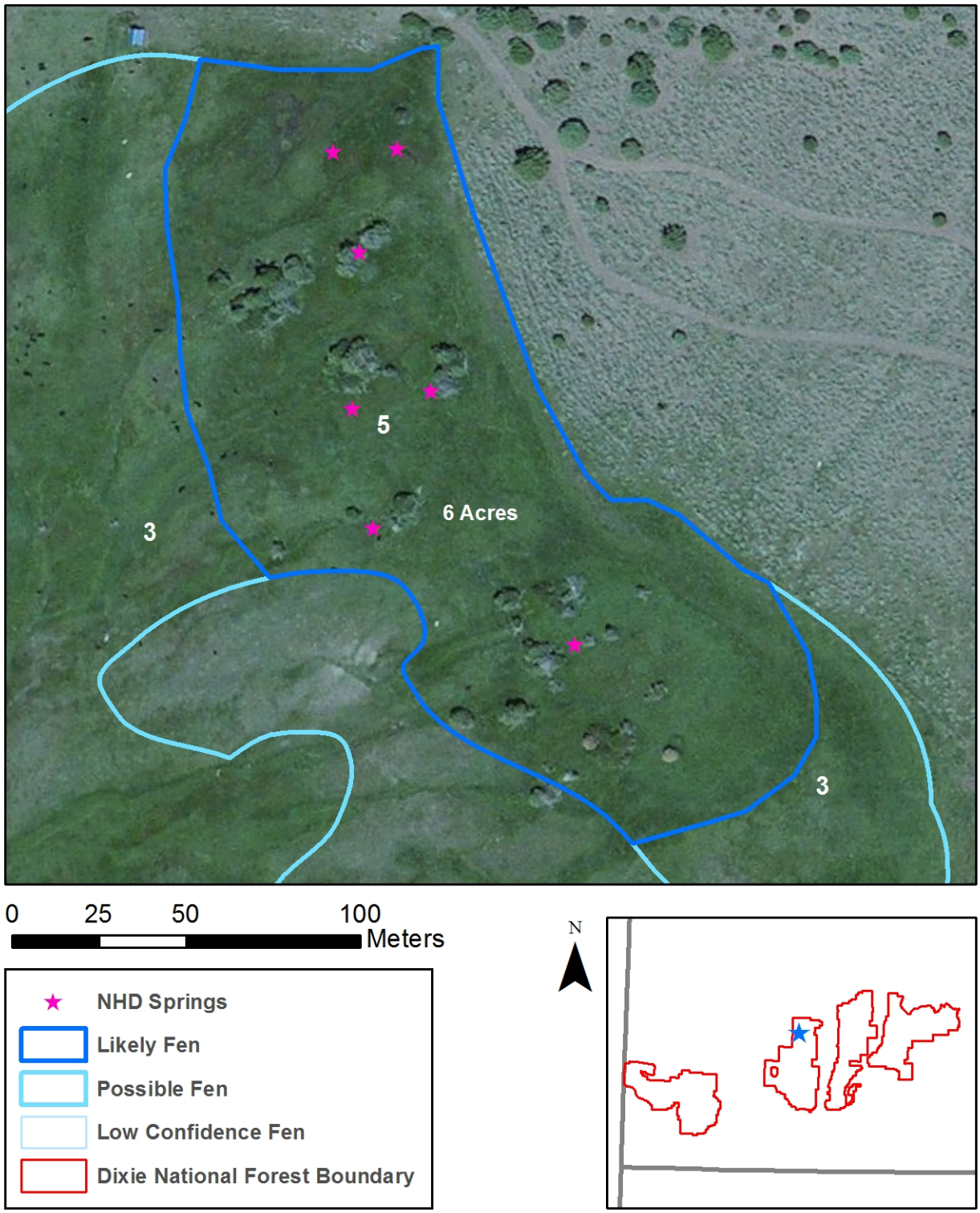

Figure 14: Likely fen associated with multiple springs located northeast of Mortensen Canyon, in Iron County.

5.0 DISCUSSION

The Dixie National Forest contains a relatively small number of potential fen wetlands, covering up to 884 acres across its jurisdiction. Most of the landforms in Dixie National Forest are not conducive to fen formation, with the notable exception of landforms on the Aquarius Plateau. While the potential fen resource represents only a very small portion of the entire landscape, these fen wetlands are an irreplaceable resource for the Forest and the citizens of Utah. Fens throughout the West 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).

In total, 884 potential fens were mapped throughout the Dixie National Forest, of which 62 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. Analysis of the potential fen data showed clear patterns in fen distribution within the Dixie National Forest. There was a strong elevation gradient, with 90% of potential fens falling between 8,000 and 11,000 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 Dixie National Forest, including the Upper North Creek and the Headwaters of Boulder Creek. These areas should be actively conserved.

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 Dixie National Forest, such as impoundments, and those observations were captured in the “Notes” field of the GIS dataset accompanying this report. However most potential fens in Dixie National Forest showed little sign of human disturbance, particularly at higher elevations.

This report and associated dataset provide the Dixie National Forest with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing Dixie National Forest 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)*
160300020409	North Creek	17,129	7	26	0.15%
160300010201	Upper Mammoth Creek	25,912	8	34	0.13%
140700050105	Upper Pine Creek	33,051	7	29	0.09%
160300010101	Midway Valley-Midway Creek	11,209	3	9	0.08%
140700050206	Headwaters Boulder Creek	33,998	10	28	0.08%
160300060108	Little Creek	14,550	1	5	0.08%
140700050207	Deer Creek	30,767	4	19	0.06%
160300020412	Pacer Lake	21,800	2	9	0.04%
140700050103	Upper North Creek	29,613	10	12	0.04%
160300020503	Antimony Creek	21,860	1	7	0.03%
160300020405	Ranch Creek-Sevier River	24,289	5	7	0.03%
160300010202	Tommy Creek	14,242	1	2	0.02%
160300060201	Dry Lakes Creek	14,211	1	1	0.01%
140700050106	Lower Pine Creek	29,608	1	2	0.01%
160300020306	Hunt Creek	34,008	1	1	<0.01%