Fen Survey Report
Feather River District
Plumas National Forest

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INTRODUCTION

The Sierra Nevada Framework has identified riparian and other water-dependent habitats as places of interest and concern on National Forest land, due to their uniqueness and vulnerability to disturbance. Fens are one type of wetland habitat, and the Plumas National Forest initiated surveys in 2003 to identify, characterize and map the fens on the Feather River district of that Forest. The survey was conducted by Jim and Catie Bishop between July and October in both 2003 and 2004.

Fens are unique and important in the following ways:

- They contain a higher diversity, and a much higher diversity per area, of plant species than the surrounding forest
- They lack invasive non-native plant species.
- The fen imposes a varied habitat structure that supports a higher diversity of wildlife than is found in the adjacent forest.
- Fens are relatively rare on the landscape and may represent examples of higher-latitude ecosystems.

Further studies in the fens will be able to give us insights into important areas such as:

- Some of the fens may have begun to form at the end of the last ice age, and studying peat cores will help us understand the climatic history of the area through time.
- Pollen cores will enable us to know about changing plant community composition and abundance.
- Isotope studies of the water in the fen could reveal when that water fell as rain, and how long it has been traveling underground. This will give us insight into the hydrologic framework that has formed and maintains the fens.
- Plant and water chemistry studies will show us how vegetation, especially mosses, interacts with water chemistry and influences nutrient availability.
- Studies of outside influences, such as cattle grazing and human impact, will show us how to better manage these unique wetlands.

There are three currently accepted criteria for defining a fen. First of all it must be a continuously wet area that dries only minimally or not at all during the year. The continuous wetness encourages the formation of peat. Peat is incompletely decayed vegetation, the decay being retarded by saturated, oxygen-deficient conditions. The second criteria for a wetland to be a fen is a peat depth of 40 centimeters or greater. Peat forms exceedingly slowly and deep peat layers indicate a stable environment lasting perhaps several thousand years. The peat builds up under the current year's vegetation, whose roots are contained within the peat layer. So the third

criteria is that the vegetation in a fen receives essentially all of its mineral nutrients from ground water, as it is not rooted in mineral soil. The fens have wetter and drier areas, as well as various depths of peat. So, not every square foot is technically a fen. However, in this report, the entire open area is referred to as the fen opening.

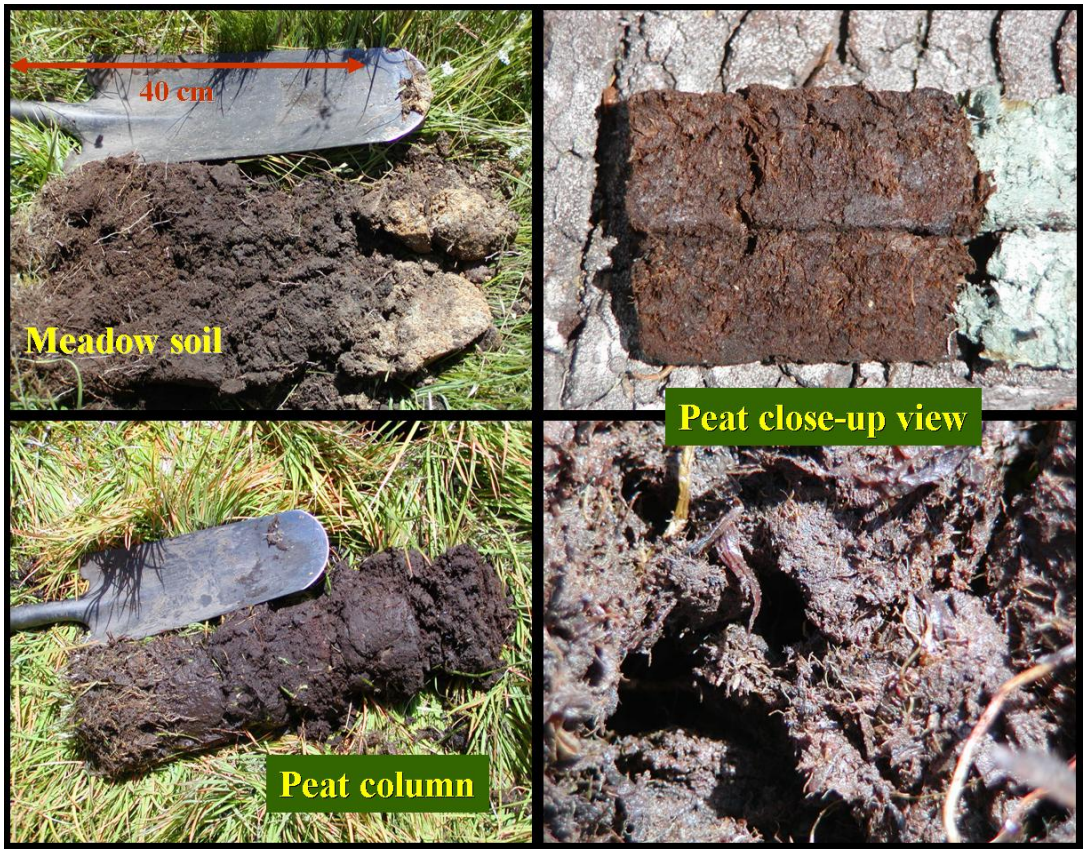


Figure 1. Peat, undecomposed vegetation, is an inherent feature of fens. Shown here are examples of peat, a peat column representing the peat profile under Narthecium, and a meadow soil for comparison. Gray clay, a common substrate below the peat, shows in the upper right photo.

REGIONAL SETTING

An overview of the climate, geology, elevation, geography, and vegetation of the fens surveyed portrays their natural setting. The climate in which these fens exist reflects the typical Mediterranean pattern that dominates in California. There is a predictably hot and dry summer period and an unpredictably wet winter period. The heaviest rains fall during the winter months, with only occasional summer thunderstorms, that deliver little if any water. Precipitation totals about 75 to 80 inches annually. All of the fens so far surveyed have been between 5000 and 7000 feet in elevation, and so have a short growing season and are buried in snow all winter. The fens are underlain by rock which included silicic, intermediate, basic and ultramafic types (Table 1; Figure 3). While fens can have different water sources, all of ours were spring-fed, or a combination of spring-fed and ponded water. All of our fens occurred on gentle slopes or gentler portions of moderately steep slopes. All sites were in openings of the red or white fir vegetation

alliance, while the fen itself was considered sedge alliance and fen habitat, after the convention of the Manual of California Vegetation.

Figure 2. Typical fens and surroundings. The bordering shrub zone can be broad, narrow, or non-existent, but usually is a transitional band between the fen opening and the forest, and is made up of water-dependent shrubs. Lower left photo shows a change in flora at the far, dry end (white flowers). Fens ranged from tenths of an acre to several acres in size.

Table 1. Substrate rock type and corresponding geochemical affinity of the substrate are shown for all of the fens. Question marks indicate two fens where the rock type was unclear due to difficulty locating the fen on the available geological map.

Associated fens	Rock type	Geochemical affinity
Fens 11-009, 011, 012, 015 (?)	serpentinite & peridotite	ultramafic
Fen 11-010 (?)	meta-gabbro and hornblendite	mafic
Fens 11-001, 004, 007, 008	meta-andesite	intermediate
Fens 11-002, 003, 005, 013, 014	meta-dacite	intermediate-silicic
Fen 11-006	meta-rhyolite	silicic
Fen 11-016, 017, 018	undifferentiated meta-volcanics	intermediate to silicic

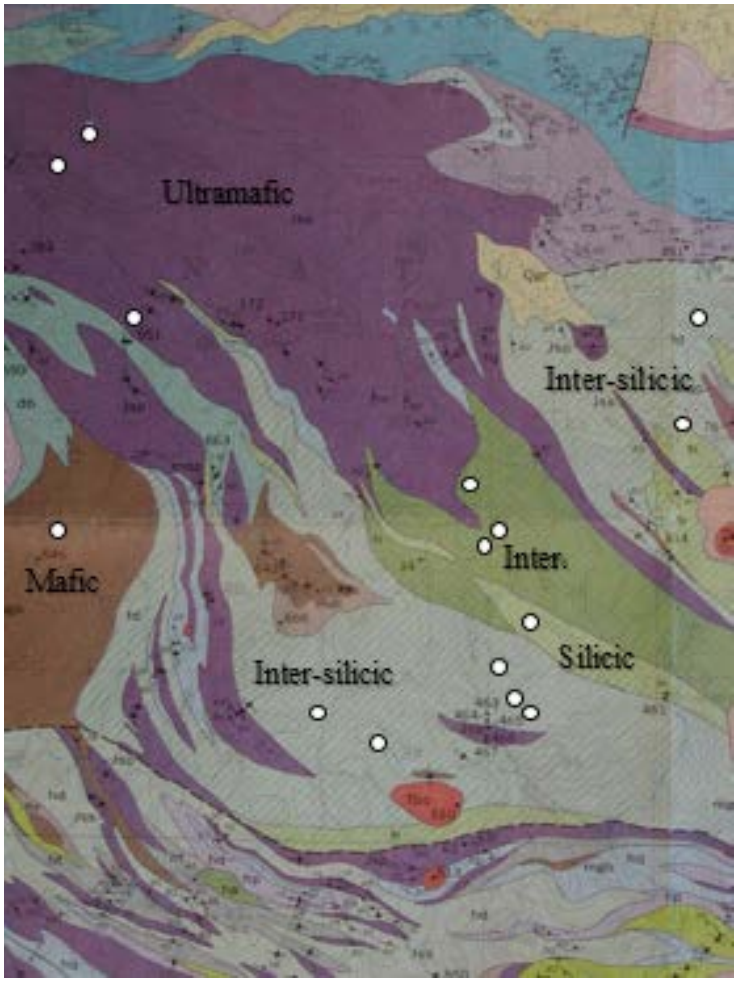


Figure 3. Geological setting. The central concentration of fens is shown on a section of Bucks Lake Quadrangle geological map. Geochemical affinity of the substrates ranged from ultramafic to silicic.

The topographic position of the fens was quite consistent among them. The upland zones in the study area are of relatively gentle slope and modest relief. The flanking slopes of incised canyons below the upland are steep. The fens tend to occur in small drainages in the uplands, near the broad ridgetops, and not at all on the steep canyon slopes. Some occur on benches below main ridges. Two fens occupy shallow, wet basins at the foot of the steep north slope of Red Mountain,

SCOPE AND METHODOLOGY

The scope of this project was to identify, characterize and map as many fens as we could during the latter half of the 2003 and 2004 field season. Our survey covered about 180,000 acres. Two strategies were used to locate possible fens: 1. Occurrence records for *Drosera rotundifolia*; 2. Photo reconnaissance. We visited 40-50 sites and found 20 of them to fit our working definition of a fen as outlined above. There are 20 numbered fens, two of which are complexes that include 3&2 separate fens each. At each targeted site surface wetness was checked, and sample holes were dug to evaluate subsurface wetness and peat depth. We spent very little time in wet areas that we determined were not fens. The "non-qualifying" areas were usually meadows, sometimes with wet portions but often not saturated, and lacking sufficient peat depth.

In each fen Jim located one or more areas that were clearly water sources supplying the fen. These could often be recognized by their cold temperature (40-48 ^{o}F), having come directly from underground and not yet exposed to solar heating. Some springs arose underneath the vegetation in the fen opening and could not be directly sampled. The water temperature and pH were taken at each water source. Sample holes were dug at various locations out in the fen, with a narrow-bladed "sharpshooter" shovel or with a post hole digger, to a depth of 40 cm or more. A 1" diameter coring tool was used to extend the hole depth to 50cm. Soil and water temperature and pH were measured in sample holes at a depth typical of the rooting zone (15-20 cm). The peat profiles removed from the holes were examined and sometimes photographed. Saturation depth in some cores was determined by measuring from the ground surface to a level on the side of the hole where water appeared to be seeping out (Figure 4). Not all of the holes had obvious seeps, and some holes refilled from below. More extensive sampling and documentation was done on three selected fens (see section "Detailed Study of Selected Fens" pg. 14).

The basic accuracy of the pH meter is 0.1 pH unit. It was calibrated to a pH 7.0 standard each field day and was checked at the end of the day. Upon checking it would read pH 7.0 or 7.1. The thermometer was accurate to +/- 1 ^{o}F. A few fens initially surveyed in 2003 were partially re-sampled in 2004 for temperature and pH, to get a sense of how consistent the observations might be. All of the following reported average and maximum variations refer to the absolute value of the difference between an observation in 2004 and the corresponding 2003 observation. The temperatures of eight source-water samples varied an average of 1 ^{o}F and a maximum of 3 ^{o}F (for a poor source location). For ten root-saturation water samples the temperatures varied an average of 5 ^{o}F, and a maximum of 9 ^{o}F. The greater variability in near-surface water temperatures is expected, given the varying degrees of solar heating that influence it. The pH of six source-water samples varied an average of 0.15 pH units and a maximum of 0.4 pH units. And the pH of ten root-saturation water samples varied an average of 0.24 pH units, with a maximum variation of 0.5 pH units. The variation in all pH observations tended to be more in

the negative direction (2004 values lower in pH than in 2003) which may indicate that part of the variation was due to instrument responsiveness or drift.

At each sample hole the following routine measurements were made (Figure 4):

- slope (by clinometer) and aspect
- soil temperature (at 15-20 cm depth; typical of the root zone)
- temperature and pH of the root-zone-saturating water (by allowing a hole about 20 cm deep to refill)
- peat depth (where peat depth exceeded 50 cm, the maximum depth was not determined)
- water saturation depth (in 2003 the saturation depth was assumed to be "0" if the ground was "saturated", but in expanding our work in 2004, it was measured from the surface to visible seepage on the wall of the hole)

A GPS location and the above data were entered into a data dictionary for transfer to the GIS layer, and were recorded the old fashioned way in a field notebook. The fen opening perimeter was mapped using GPS. A sketch was made of the fen, its notable features, and source and sample locations.

Catie conducted the plant surveys. An attempt was made to identify all flowering plants in the fen opening and all border plants deemed to be wetland-dependent. Special interest plants were actively looked for (Plant lists are in Appendix A). In the case of bryophytes, samples were collected and submitted for expert identification (see bryophyte plant list, Appendix A).

All supplementary information was recorded on a Wetland/Fen Survey Record form, and those records are included in this report in Appendix B. The vegetation series (now known as "alliance") of the fen opening and the vegetation alliance of the surrounding forest was identified using the Manual of California Vegetation. The soil type of the surrounding forest was also recorded on the wetland forms. For most of the fens only a day was devoted to data gathering, and inevitably there were plants that were missed (second visits at several fens allowed more complete plant lists). Along with plant species data, the fen botanical features were described in a qualitative way. For examples, bordering shrub zones were described, and any drier or wetter portions of the fen were noted.

Figure 4. Survey methodology. A sample hole was dug and allowed to fill with water from the upper 10 to 20 cm, water typical of the rooting zone of the fen plants. Temperature and pH of that water were measured, as was soil temperature at 15 to 20 cm depth. As many plants as possible were identified in the fen opening and the adjacent, wetland-dependent shrub zone. Peat depth was measured, to at least 40 cm depth.

SUMMARY OF GENERAL FEN CHARACTERISTICS

Physical Characteristics

The observed physical features of the fens are tabulated in the individual Wetland/Fen Survey Records and summarized in Table 2. [Note: Fen 11-020 is identified as Fen 11-003.3 on the Wetland Survey Records] The pH data are summarized on Table 2 and Figure 5; the slope/aspect distributions are displayed on Figure 7.

The pH of source water and fen water was looked at as a function of geochemical affinity of the substrate rock. Source water pH was consistently in the mid-6 range for all rock types (except in the ultramafic rocks Fens 11-009, 11-011, 11-012, where at 7.6 it was markedly more alkaline), and averaged 6.5. Fen-saturating water pH had lost the imprint of its source pH and the average for all fens was 5.9, approximately 0.6 pH units more acidic than source water (presumably by

increased dissolved CO_2 and organic acids). Source water averaged 47°F, soil temperature (at 15 to 20 cm depth) averaged 57.5 °F, and root-zone-saturating waters averaged 59.8 °F.

Table 2. For each fen are shown the average values of all observations of pH and temperature (°F) made in that fen. Aspect and slope refer to the overall orientation of the fen.

FEN NAME AND #	FEN SOIL TEMP	FEN H2O TEMP.	FEN pH	SOURCE H2O TEMP	SOURCE pH	ASPECT	SLOPE%
FIRST FEN 11-001	no data	61.0	6.1	44.0	6.2	SE	10
GREENS FLAT 11-002	67.0	72.0	5.7	48.5	6.0	SE	4
CHINA GULCH 11-003.1	58.5	67.5	5.8	48.5	6.5	NW	8
CHINA GULCH 11-003.2	61.0	69.0	5.7	49.0	6.4	NW	10
TINY FEN 11-004	60.5	67.5	5.9	49.5	6.2	SE	10
LONG FEN 11-005	55.0	52.5	5.8	45.0	6.5	SW	12
TERRACE FEN 11-006	58.0	61.0	5.9	42.0	6.4	SSW	9
GUEST FEN 11-007	54.0	58.5	6.0	46.0	6.9	SE	8
BARELY FEN 11-008	62.0	61.0	5.8	48.0	6.4	W	5
COW FEN 11-009	57.0	51.0	6.4	44.0	5.9	WNW	7
SURPRISE FEN 11-010	59.0	no data	no data	61.0 (?)	6.4	S	2
ROGERS FEN 11-011	52.0	52.0	6.3	46.5	9.0	SE	3
GRIZZLEY FEN 11-012	49.0	45.0	6.4	46.5	7.2	N	2
LUCKY FEN 11-013	54.0	58.0	6.2	51.0	6.7	S	10
BLUEBERRY FEN 11-014	61.0	66.0	5.3	52.0	6.2	NE	4
LINNEA FEN 11-015	61.0	61.0	6.0	49.0	6.4	S	16
VACA FEN 11-016	58.0	59.0	5.8	46.0	6.3	SE	5
LOTUS FEN 11-017	57.0	58.0	6.0	46.0	6.2	SW	10
DALY COW CAMP 11-018	56.0	57.0	5.9	41.0	6.2	E	8
HIGH BENCH FEN 11-019	53.0	58.0	5.5	41.0	6.6	NW	4

FEN NAME AND #	FEN SOIL TEMP	FEN H2O TEMP.	FEN pH	SOURCE H2O TEMP	SOURCE pH	ASPECT	SLOPE%
BEAVER 11-020	57.0	62.0	6.0	49.5	6.6	SE	2
AVERAGE OF ALL FENS	57.5	59.8	5.9	47.3	6.5		7

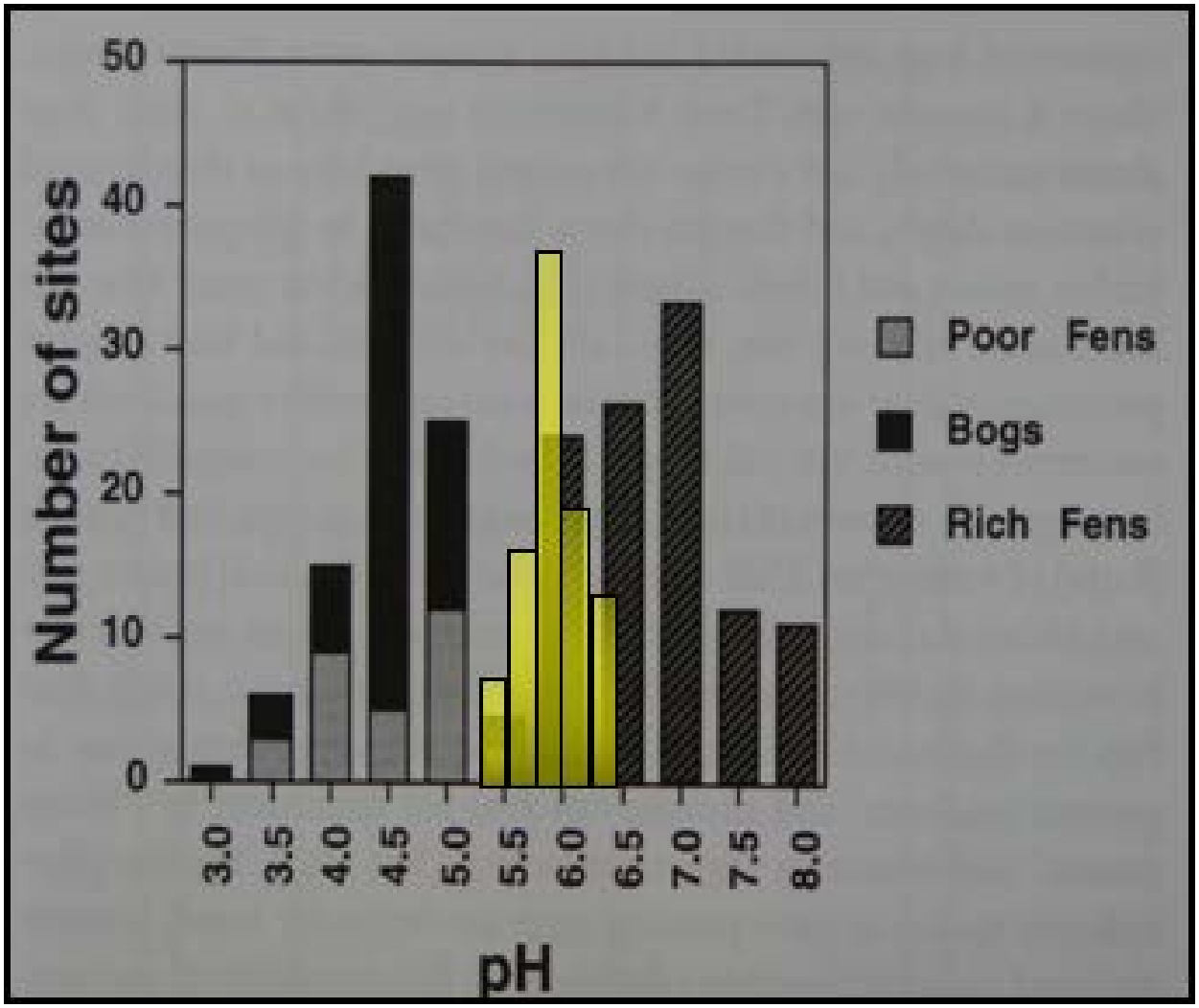
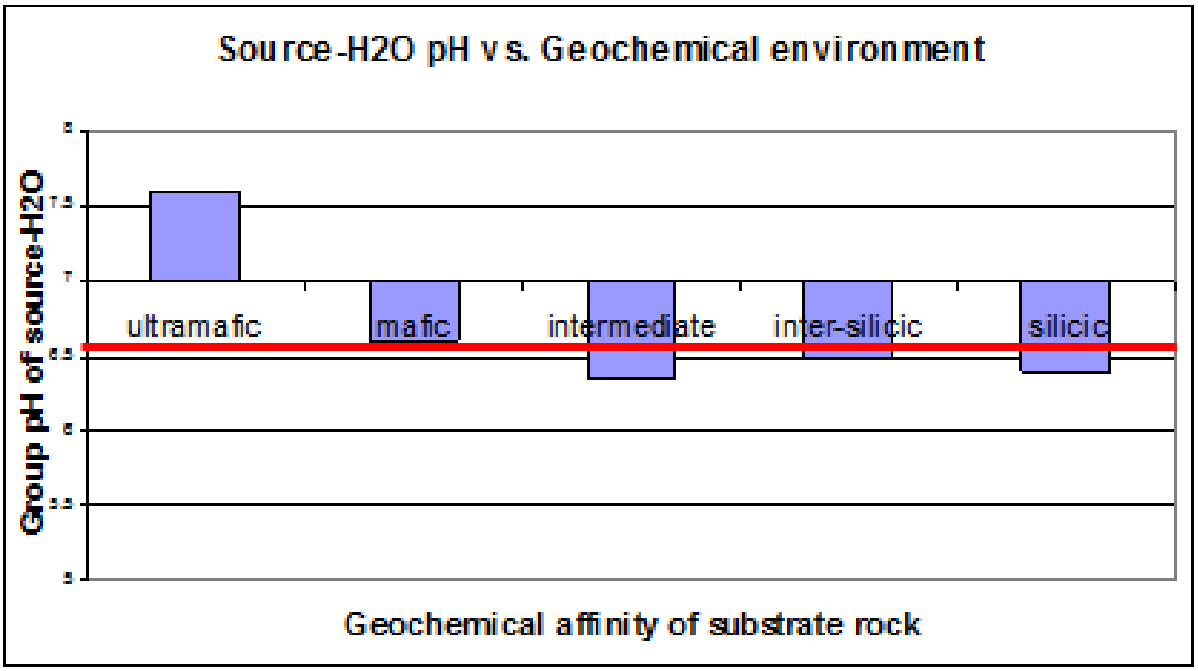


Figure 5. Distribution of fens as a function of pH for 100 western Canadian continental fens (Shaw and Goffinet, 2000) shown in gray. The pH distribution of fens in this report is shown superimposed in yellow. These fens cluster slightly to the alkaline side of the pronounced minimum in the bimodal distribution of Canadian fens.



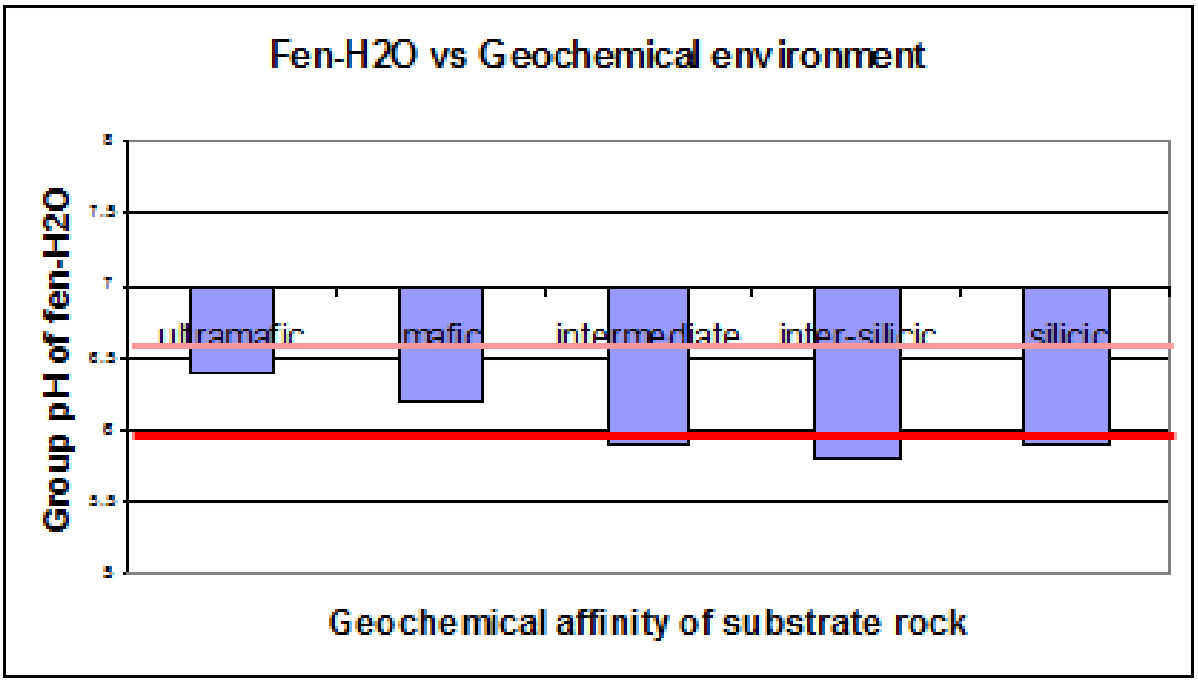


Figure 6. pH of source water and fen water (root-saturation zone) as a function of geochemical affinity of the substrate rock. Red lines indicate (approximately) the average for all fens, and the thinner pink line represents the source-water average. Except the alkaline source water in ultramafic settings, the source water is uniformly slightly acidic. The initial alkalinity of ultramafic source water is lost when it moves out into the fen, and all fens are slightly acidic, with fen water pH averaging 0.6 pH units less than the source water average pH. Mafic observations shown here are based on minimal observations due to the lack of fens on that substrate.

The topographic position of all but two of the fens would be termed “slope” position, with fens 11-011 and 11-012 being of a combined basin and slope type (see glossary for definition of terms, Appendix C). Slopes are primarily in the 3% to 12% range, and the majority of the aspects were distributed evenly between SE through SW to NW, probably reflecting the predominant regional slope to the SW. Except for the basin portions of those two fens, the fens were all of the “hanging” hydrogeomorphic type (on a slope and constantly watered by springs and seeps). The fens were typically convex in longitudinal profile, some markedly so. A few were of fairly uniform slope. The fens ranged in size from tenths of an acre to a few acres.

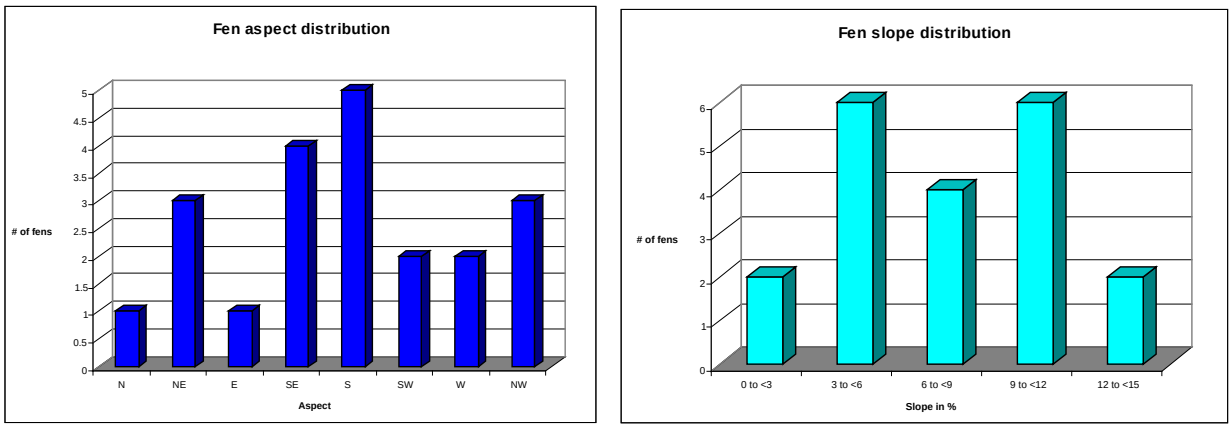


Figure 7. Summary of overall slope and aspect. Aspects were distributed mostly from SE through SW to NW, probably reflecting the regional SW slope. Slopes fell largely between 3% and 12%.

Botanical Characteristics

The fen opening contains both large and small-scale habitat variations, and even though there was some overlap, all had their special suite of plants. (Figures 8 & 12). Springs arising under the vegetation of the fen fed spring mounds which were raised above their surroundings (discussed in the section on fen biotopography). There were raised berms, areas of shallow pools, and areas with a mixture of low-growing plants. There were also “islands” of drier ground within the fen opening containing low shrubs and sometimes stunted trees. Although more studies are needed to quantify the differences, all variations seem to be related to water flow and perhaps water/soil temperature.

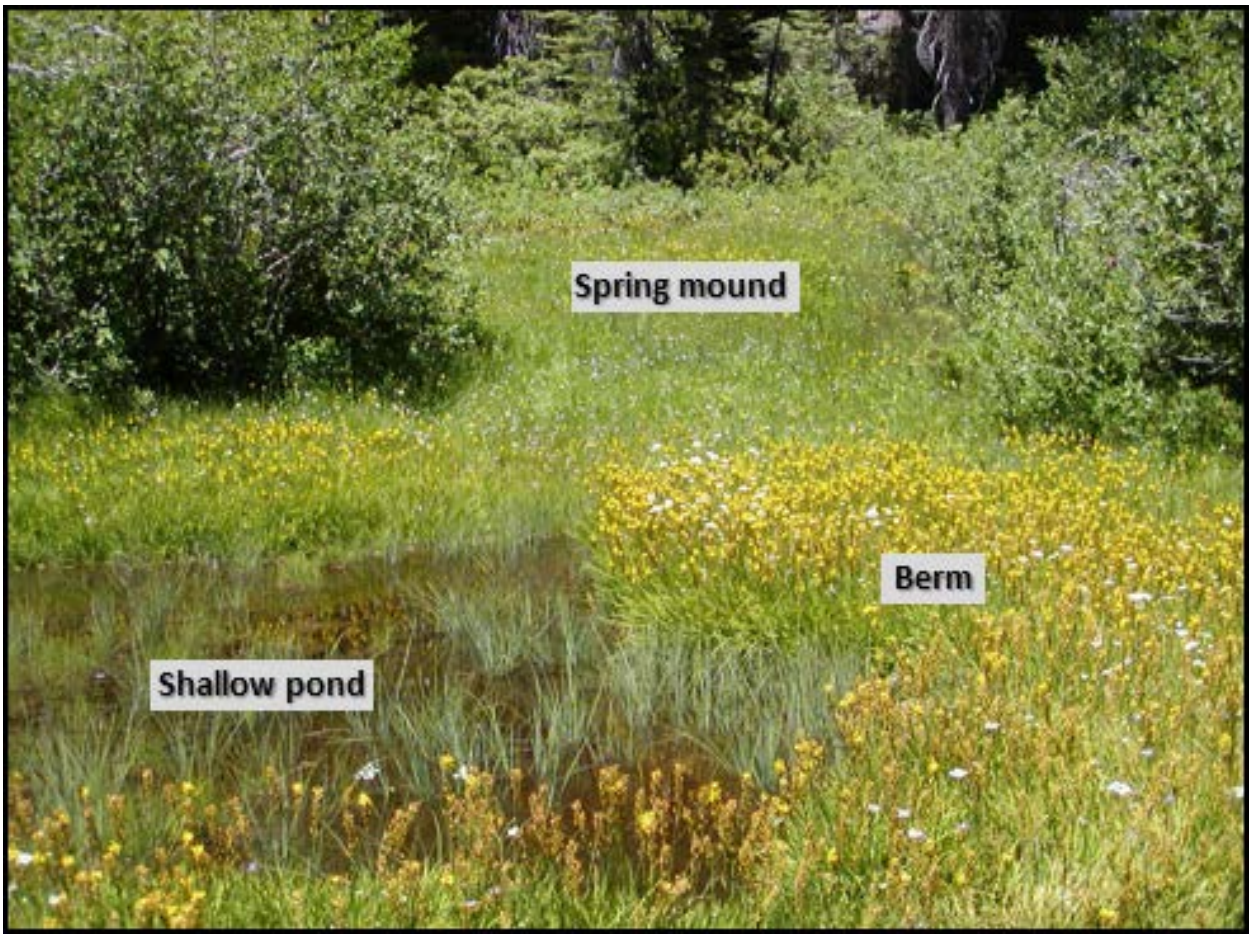


Figure 8. Features that are typical of the variation within fens in vegetation type, microtopography, and wetness. The spring mound and low berm are dominated by Narthecium californicum, and the shallow pond is sparsely vegetated mostly with Eleocharis.

Figure 9. An overview of typical fen plants. Variation in plant zonation of the fen offered the tiny Sundew (Drosera rotundifolia) and the low-growing bryophytes a refuge from the clump-forming and more vigorously growing Bog-Asphodel (Narthecium californicum) and the widespread tall Carex species.

The shrubs also partitioned the border in a predictable way. For example on the wetter sites, where they occurred together, *Spiraea douglasii* would be closest to the fen proper and *Alnus incana var. tenuifolia* would be in the next zone out. In the drier border areas, *Ledum glandulosum* (Labrador tea) would be closest to the fen and *Leucothoe davisiae* (Sierra laurel) would be outward of that (Figure 10).

It has been noted from other regions that wetlands contain a high number of endemic plant species. We found one peatland-endemic, *Sphagnum* moss, and one near-endemic, *Narthecium californicum* (bog-asphodel). Another interesting plant whose occurrence was tightly correlated with the fens was *Drosera rotundifolia* (Sundew).

Sphagnum moss is an interesting bryophyte found in only a couple of the wet areas we investigated so far on the Plumas Forest. It requires a sufficiently low pH to colonize an area, but once it becomes established, it lowers the pH in its vicinity even more. *Sphagnum* was found at two locations on the Feather River District: Blueberry Fen 11-014; and a small but very wet spring-fed basin that lacked a peat layer. The pH of root-saturating water near *Sphagnum* did not

exceed 5.2, and in the greatest *Sphagnum* concentrations was 4.9 (the lowest pH we have observed). It has been hypothesized that the tendency of *Sphagnum* to lower the pH of its environment once it becomes established might account for the lack of fen pH values in the pH minimum around 5.5 (Figure 5).

Bog-Asphodel sits atop the deepest peat found in the fens, often occupying spring mounds (spring flow supporting greater vegetative growth and peat accumulation resulting in a mound) or berms. It was found in all the fens surveyed and only once in a non-fen wet meadow, and then only on the wettest sites. The Sundew is an insectivorous plant that grows in very saturated substrates and is on the Plumas National Forest Special Interest plant list. Although it has been found in small numbers in wet areas not strictly considered fens (primarily because of their lack of 40 cm of peat), it is found in large numbers in the undisturbed fens we surveyed. The sundew is an obligate hydrophyte and can only maintain itself in a consistently wet habitat.

Very importantly, we found no non-native plants in the fen opening. This was not something we looked for, but something we became increasingly aware of. In contrast, surveys done in other habitats in the local area almost always discover some non-native species.

The encroachment of conifers into the fens was minimal. The only tree species we found trying to colonize drier spots was the lodgepole pine. However the trees were always stunted and appeared not to live very long in that habitat, as there were many small, dead trees. Possibly that indicates episodic drier periods where the trees gain a foothold, followed by saturated conditions which kill them.

Figure 10. Shrub border plants. In the border zone around the fen the plants were arranged in zones evidently related to water availability, alder and Spiraea (not shown) tending to be in the wetter border areas and Sierra laurel and Labrador tea in the drier border areas.

Fen "Biotopography"

Topographic features of fen openings (Figure 11) with relief of order decimeters were apparently due to biological processes such as the differential growth and accumulation of vegetation, and mountain beaver pools. Springs were sometimes visible, generally near fen edges, but occasionally out in the fen. Springs also emerged from the ground beneath the fen vegetation nourishing greater plant productivity and creating spring mounds. Some long berms observed may have formed over a line of springs emerging from a fracture zone. One spring-fed basin within Fen 11-007 was covered with a floating mat of vegetation.

Another type of vegetation berm was noted surrounding small pools, apparently forming the very impoundment for the pool (tending to be elongate along contour). An especially notable example was seen in Fen 11-006, where an alternating series of elongate pools and berms, lying along the contour, covered one section of the fen. A possible mechanism for their formation might involve a higher productivity and peat accumulation over/near water sources, causing it to

form a low ridge, which in turn helps to impound the pool. The peat column underlying the pools is typically less solid and less competent than under the berms, and would tend to settle under an incipient basin therefore helping to deepen or maintain the pool. A larger scale possible example of such an impounding berm is the Fen 11-012.2 (on the NE side of Grizzly Lake). These interesting biotopographic features certainly deserve more study to explain their origins.

Figure 11. Fen "biotopography". Biotopographic features: 1. "spring mounds", where spring flow supports greater vegetative growth and accumulation resulting in a mound; 2. Small elongate ponds impounded behind elongate low berms formed by vegetation create a "terrace" biotopography. 3. Hot-tub sized pools were evidently created and maintained by mountain beavers, and fens would typically have one or two. The pools were often the only open water available in the area, and are utilized by many other animals and invertebrates.

DETAILED STUDY OF SELECTED FENS

As our work progressed we realized that there were important relationships between major plant type, the characteristic peat profile, and their position in the hydrologic regime. To help us define and understand those relationships more detailed studies were conducted for fens 11-001, 002, and 005. Also, anomalies within peat profiles were observed in two other fens.Within the fen opening are recognizable plant zones, each characterized by a dominant vegetation type. Those major plant zones are described below. Sketch maps (Figure 13) of the major plant zones were made. The maps are representative of the essential patterns and distribution of each plant zone, but they are of limited precision. A peat/soil profile was excavated to at least 50 cm depth within each zone, and temperatures were taken within the profile. The objective was to portray the patterns of vegetation and their characteristic peat profiles, and to evaluate the plant zones as a function of hydrologic position.

Plant Zones

The major plant zones:

Narthecium dominated—at least 90% *Narthecium californicum* (a tall, densely-clumping grass-like plant in the lily family) with minor *Perideridia parishii ssp latifolia , Oreostema alpigenum*; and various *Carex* species. It lacks mosses and other small-stature plants

Shallow pool—vegetation coverage is low, less than 20% (mostly water and mud); vegetation is predominantly *Eleocharis pauciflora* (a spike rush with sparse above-ground biomass, but dense, matted roots)

Forb dominated—more heterogeneous than the *Narthecium* and shallow pool zones; co-dominant suite of plants includes mosses, *Mimulus primuloides, Hypericum anagaloides, Drosera rotundifolia*; occasional plants include *Tofieldia occidentalis, Gentianopsis simplex,* and low-growing *Carex* and grasses

Meadow—not saturated in summer, although saturated in the spring; common plants include *Perideridia parishii ssp. latifolia, Juncus nevadensis, Danthonia californica var americana,* and *Trifolium longipes.*

In addition to the major zones defined above there were patches and small stands of distinctive vegetation, which are noted approximately on the sketch maps. Those additional plant zones include a tall *Carex* dominated type (actually a significant plant zone in some fens that will be looked at in greater detail next year but not fully deliniated here), *Pinus contorta ssp murrayana, Vaccinium uliginosum,* and *Kalmia polifolia*.

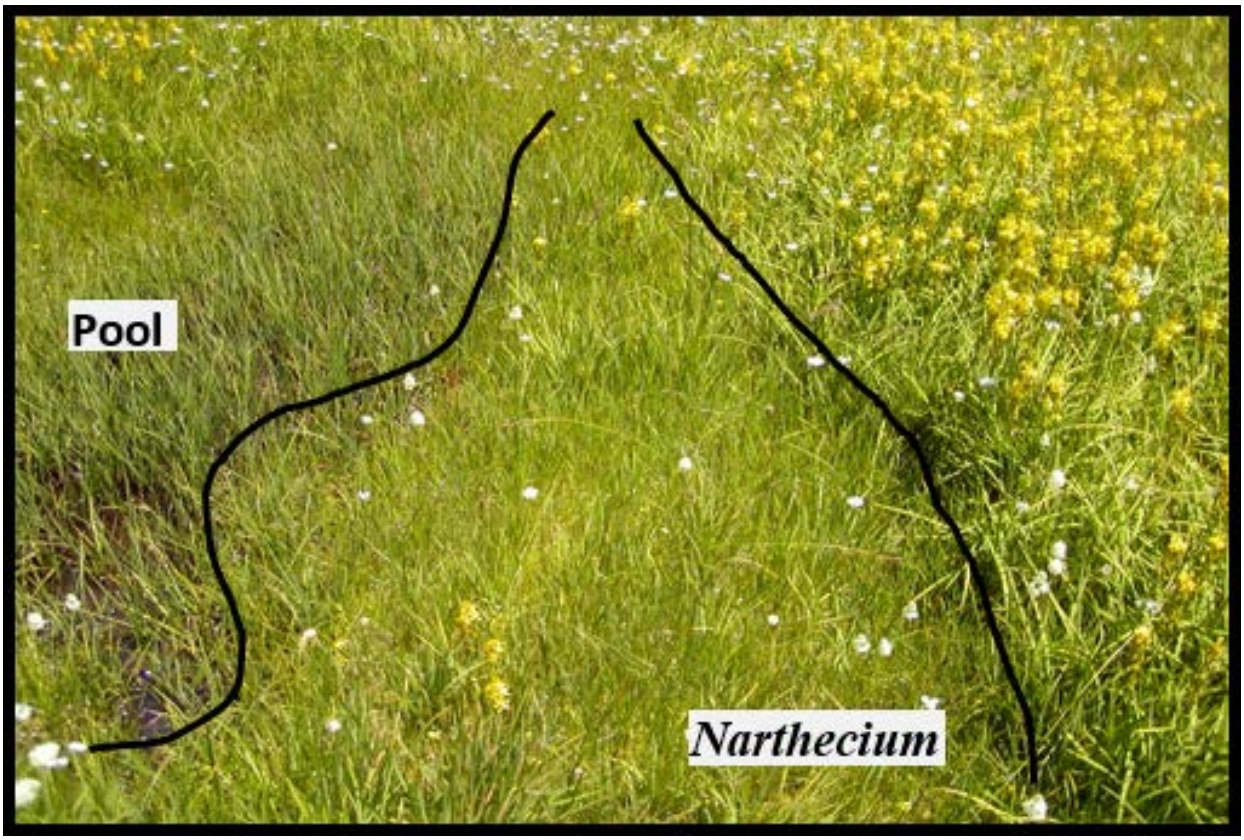


Figure 12. Major plant zones were highly correlated with degree of wetness and also with profile temperature. As seen above, Eleocharis dominates in standing water, Forbs on intermediate sites, and Narthecium tended to occupy hummocks and mounds.

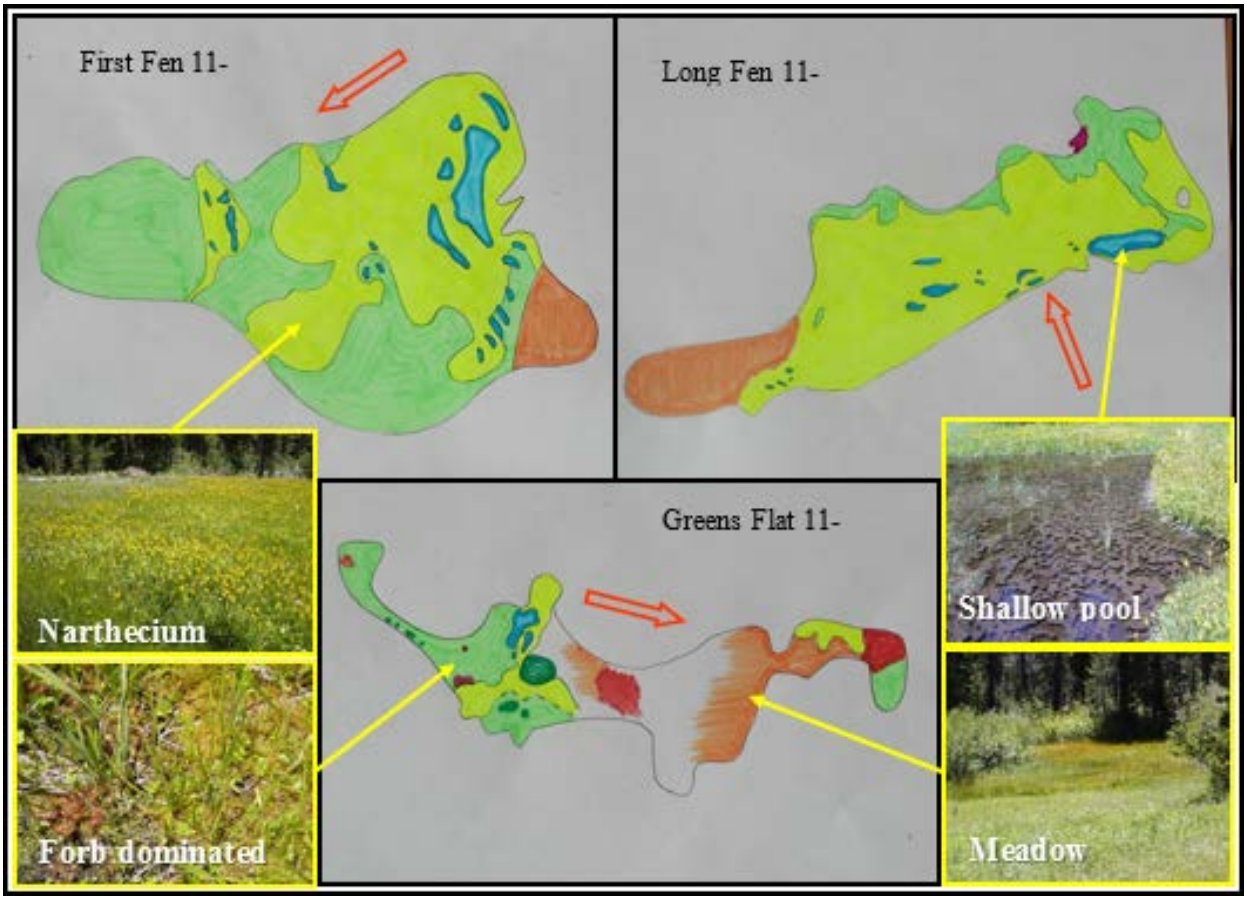


Figure 13. Maps show the distribution of 4 major plant zones, as identified by the photo insets. Also shown are Carex-dominated areas (red-orange), Vaccinium uliginosum (purple), and tree clusters (dark green). Color coding of plant zones is the same on all maps. Red arrows indicate the overall downslope direction and the general direction of water movement.

Peat/Soil Profiles and Hydrologic Position

A peat sample hole was dug with a post-hole digger in each major plant zone. The "core" was extracted, examined, and photographed/described. Under *Narthecium* the peat was deep (>50cm), competent and resilient, and nearly homogeneous in the vertical. Under the pools the peat was also deep (>50cm), but was less competent and predominantly of smaller particles, often fairly soft. The pool profiles tended to have 3 strata, from top to bottom: densely fibrous root zone, thick-slurry-like layer, and firmer peat. There was minimal peat under the forb-dominated zones, and those profiles had a large soil component. Typically at a depth of 20-25 cm in forb-dominated zones the root/soil zone gave way to dark organic-rich clay, and at about 30-35 cm depth was light gray clay. In the meadow zone there was no peat, just a normal soil over clay at about 30 cm (Figure 1).

Temperatures were taken within each sample hole (except in meadow zones, as they were not saturated) at several points, from 10 cm below the bottom to 10 cm below the ground surface. Those temperatures fell within a 2 ^{o}F range within a given sample hole (Table 3). Because water infuses the profile, the temperatures are taken to be indicative of the water temperature within

that profile, and are called the "profile temperature". Source waters are invariably the coldest in the fen (averaging 45 ^{o}F in these 3 fens), the water having recently come from the subsurface. As water resides on the surface or in the upper peat/soil zones it is warmed. Therefore, the temperature generally increases with time as water moves away the source. The profile temperature provides an indication of "hydrologic distance" from the source, that is, the position of the profile in the flow from source springs, into the peat layer, and eventually out and leaving the fen. In order from coolest to warmest (Figure 14) the plant zones were *Narthecium* (50 ^{o}F), pool (54 ^{o}F), and forb-dominated (58 ^{o}F), suggesting general water flow from *Narthecium* zones, to pool zones, to forb-dominated zones. *Narthecium* likely sits directly on the subsurface springs in many cases.

Saturation level (distance below the surface) and seepage rate (evidenced by time required to fill the hole) were also observed for each profile (Table 3). Saturation levels in *Narthecium* ranged from 3 to 7 cm, but in spite of the saturation the water flow was minimal and refill rates were slow (an hour or more). *Narthecium* tends to retain water well and to retard the movement of subsurface water, thereby providing resistance to the dispersal of water discharged from the spring sources. In the pool zones saturation level ranged from 2 to 5 cm, and seepage rate was fast, filling the hole in minutes (note that the pools had dried down and the holes were not being filled with surface water). The forb-dominated zones were usually not saturated above the 10cm level, and had very low seepage rates. The exception was in Long Fen in which the profile was saturated and the hole refilled rapidly from a source just above the clay layer. Despite their lack of peat and subsurface saturation, forb-dominated areas are often wet on the surface.

Table 3. Saturation level (cm below surface), refill rate (fast =>minutes; medium=>10s of minutes; slow=> hour or more) as a measure of permeability, and temperatures of the column at the indicated depths.

Fen	Plant Zone	Saturation Level (cm)	Refill	^{o}F (50cm)	^{o}F (30cm)	^{o}F (20cm)	^{o}F (10cm)
First Fen 11-001	*Narthecium*	6-7	slow	51	51	51	52
Greens Flat 11-002	*Narthecium*	3	slow	48	48	49	49
Long Fen 11-005	Narthecium	6-7	slow	48	51	-	51
First Fen 11-001	Pool	5	fast	-	54	54	55
Greens Flat 11-002	Pool	2	med-fast	50	52	52	52

Fen	Plant Zone	Saturation Level (cm)	Refill	ºF (50cm)	ºF (30cm)	ºF (20cm)	ºF (10cm)
Long Fen 11-005	Pool	2	fast	58	58	-	-
First Fen 11-001	Forb-dominated	12-14	slow	57	59	58	59
Greens Flat 11-002	Forb-dominated	unsaturated	none	-	54	53	52
Long Fen 11-005	Forb-dominated	1	medium	61	61	-	66
Long Fen 11-005	Meadow	unsaturated	none	56	-	-	-

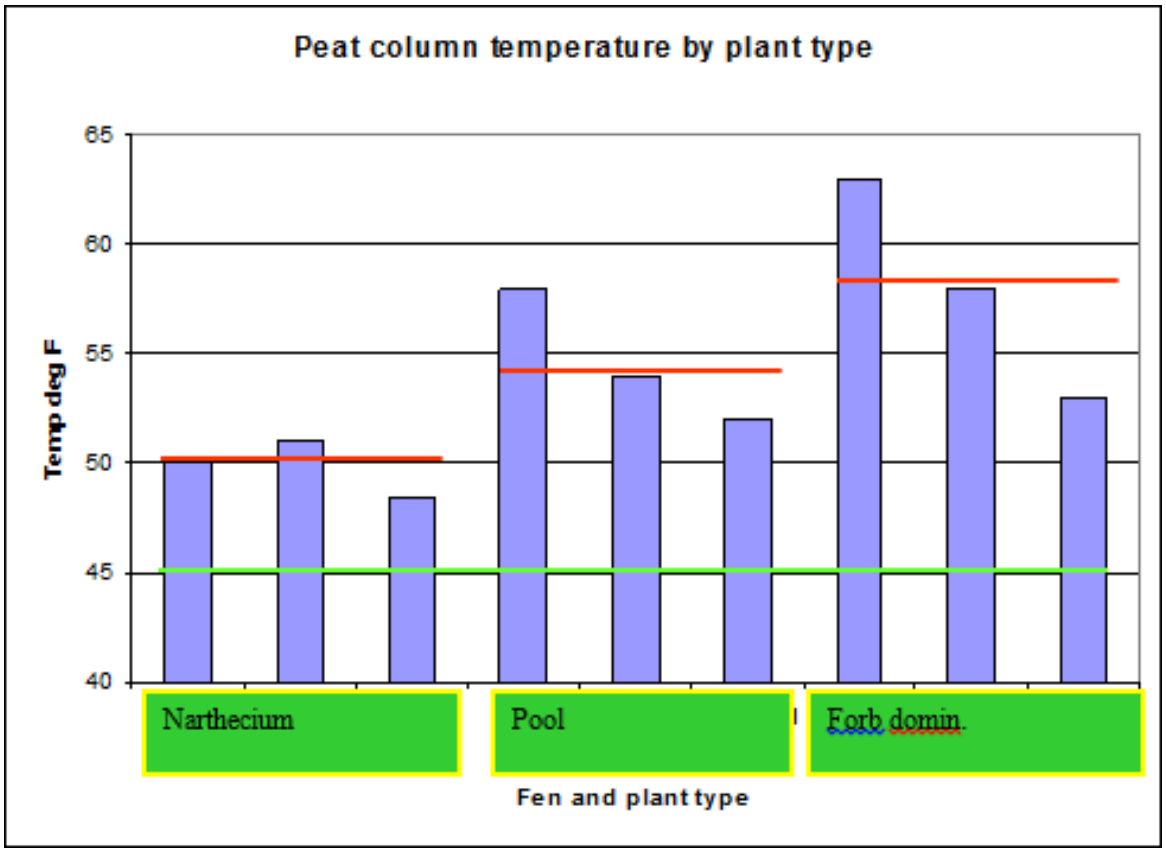


Figure 14. Profile temperature (average for the profile) in each fen. grouped by plant zone. Green line indicates source temperature for the fens, red lines indicate the average profile temperature for each plant zone. Temperatures increase from source to Narthecium, to Pool, to Forb-dominated zones, suggesting the order of each zone within the hydrologic flow.

Interesting Features in Peat Profiles

The peat profiles in a given plant zone were very similar from one fen to the next, and usually did not contain any anomalous features. However, several unusual features were observed, and are described here, features that hint at events that interrupt the steady accumulation of peat in the relatively stable fen ecosystem (Figure 15). In two profiles there were layers of clay with gravel clasts, and in other profiles occasional isolated gravel clasts. In one case clay occupied the layer at a depth of 25-30 cm and in the other case at 35-40 cm. Below the clay layer was more peat. In Fen 11-017 profile samples revealed a buried but still-green layer of moss at 10-15 cm depth, and at the same level an anchored root crown still in place in its substrate. Above the moss and root crown was more peat surmounted by a surface layer of moss. At 35 cm depth in a *Narthecium* profile were chunks of charcoal in and near a thin, discontinuous, clay-rich layer. Such unusual features are yet-to-be-read evidence of transient events in the life of the fen.

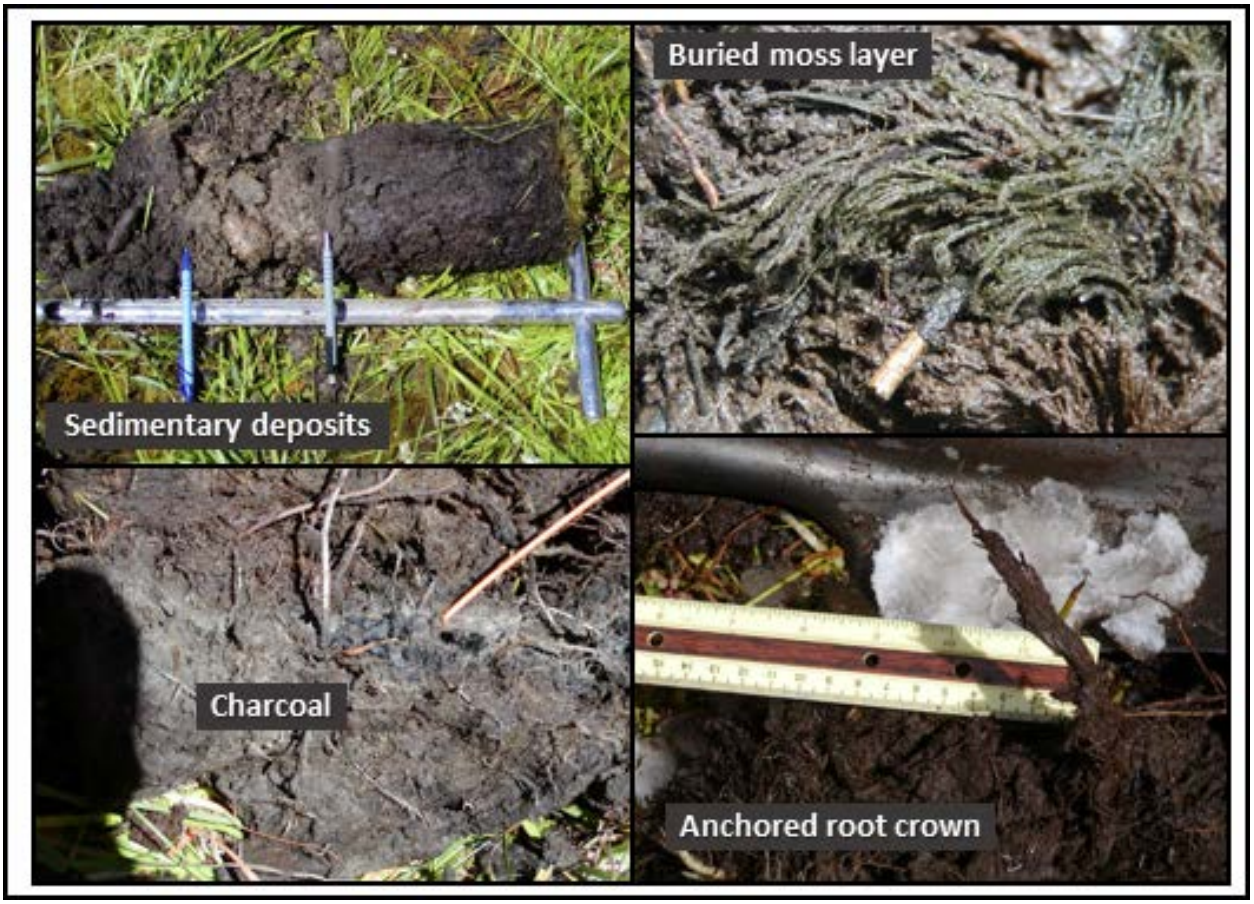


Figure 15. Peat-profile special features include: buried clay layers with gravel clasts (representing an influx of water-laid sediment); barely-altered moss and a rooted plant (representing a living-plant surface overtopped by other growth and peat); charcoal pieces within and near a thin, discontinuous clay layer. In all cases there is peat above and below the anomalous stratum. Soil corer is 50cm long, tip to handle.

DISCUSSION AND CONCLUSIONS

Some generalizations can be drawn from our reconnaissance regarding the likely habitat for fens on the Feather River District of the Plumas National Forest. They tend to occur on the lower-relief uplands that form the highest ridges in this area, where annual precipitation is approximately 75 to 80 inches and winter snows are deep. The substrate rock is crystalline and not porous, leading to most of the subsurface flow being concentrated in fractures. Where steady springs emerge on modest slopes they nourish vegetation growth, and in the saturated conditions the retarded decay of the vegetation results in peat accumulating. An equilibrium is established wherein the water flow maintains the fen, and the vegetation blanket retains the water. There is a balance between inflow and drainage, and altering either could damage the fen.

The spring-derived source waters tend to be of nearly neutral pH, average 6.5, except somewhat alkaline on ultramafic substrates. Regardless of the geochemistry of the substrate, the waters saturating the fens are all slightly acidic, average pH 5.9. Source waters usually have temperatures in the 40s ^{o}F, average 47°F.

Some plants, while they may not be strict "fen endemics", at least showed an occurrence strongly correlated with fens. Such fen plants include *Drosera rotundifolia* and *Narthecium californicum*. They were found in each of the fens studied, and where they did occur outside of fens it was in very wet portions of meadows that were not fens primarily in lacking 40 cm of peat, but may have had sufficient peat to effectively contain the root zone. Very notable was the lack of any non-native plants in the fens.

Because of the continuous wetness and extreme age of the fens, plants and animals which require these stable conditions have colonized and maintain the stable fen ecosystem. We hope to date some of our fens in the future; other fens in the Sierra Nevada have been dated to between 4000 and 8500 years old (personal communication, Sagehen Field Station staff). In almost all of the fens we surveyed we have seen evidence of mountain beavers. These animals live in burrows in drier banks surrounding the fens, but excavate deeper channels and maintain small areas of open water. These openings are used by other wildlife (such as frogs for nurseries), and are often the only open water in the area. The shrub-dominated fen border provides good cover, diversity of structure, and is utilized by higher densities of wildlife, than in either the fen opening or the surrounding forest. This survey does not include invertebrates, however the presence of tiny clams (0.5-2mm), hydra, worms, and other water dependent animals were observed under the dissecting microscope during plant identification.

Historically wetlands of all kinds have been drained for agriculture, road building and other uses, or polluted by agriculture or mining and logging runoff. This makes the remaining intact wetlands even rarer. And protecting the fens is important for reasons going beyond those associated with plant and wildlife habitat. These ecosystems have been stable for thousands of years and have been used as windows on the past climate of an area, as core samples can reveal the changes in plant types and abundances. It is well known that wetlands are excellent natural filters of water-born impurities.

During this survey we noticed that where cattle grazing was allowed it impacted the fens. It will take more study to quantify the effects, but cattle preferentially eat certain plants and

mechanically alter with their hoofs the stream and rivulet banks (in one case lowering the water table by their propensity to walk in a line through the fen, where the water then runs in a self-reinforcing cycle to drain more water). Another question to be investigated in the future is if, or how much, the "fertilization" of a fen by cattle changes the nutrient input, and therefore the species composition, of an ecosystem that is defined by the special circumstance of the separation of its root system, and therefore its nutrition source, from mineral soil.

Fens appear to be very unique, stable, and relatively pristine ecosystems. On the Plumas NF they occur on a wide variety of geologic substrates (a potentially important determinant of a fen's character) which is unique compared to the widespread granitic substrate found elsewhere in the Sierra. They merit further study for many reasons: to locate fens in new areas; to add quantitative plant-frequency data; to characterize the chemistry of their groundwater; to get some absolute ages; and to analyze the embedded paleoecological and climate records. They have much they can tell us, once we know how to read them, and should be protected from direct impacts and from any impacts to the hydrologic systems on which they depend.

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Appendix A - Plant Lists

Plants Listed by Vegetation Type

Not all plants are on this list, see master plant list for all plants and bryophytes. Some plants may be found in more than one zone.

Fen Proper

DICOTS * = special interest plant

Aster foliaceus var. parri

*Drosera rotundifolia**

Epilobium ciliatum ssp. glandulosum

Eriophorum criniger

Gentianopsis simplex

Hypericum anagaloides

Lotus oblongifolius

Madia bolanderi

Mimulus primuloides

Oreostema alpigenum

Parnassia californica

Pedicularis attollens

Perideridia parishii ssp. latifolia

Polygonum bistortoides

Potentilla palustris

Rumex sp.

Veronica americana

Viola macloskeyi

Monocots

Agrostis stolonifera

Calochortus nudus

Camassia quamash ssp. quamash

Carex aurea

Carex echinata

Carex lenticularis var. impressa

Carex luzulina var. luzulina

Carex utriculata

Danthonia californica var. americana

Deschampsia cespitosa ssp. cespitosa

Eleocharis pauciflora

Glyceria elata

Juncus balticus var. balticus

Juncus covillei var. obtusatus

Juncus nevadensis

Juncus oxymeris

Muhlenbergia minutissima

Narthecium californicum

Parnassia californica

Platanthera leucostachys

Platanthera sparsiflora

Scirpus microcarpus

Sisyrhinchium elmeri

Spiranthes porrifolia

Tofieldia occidentalis ssp. occidentalis

Triteleia hiacynthina

Fen Margin

Adiantum aleuticum

Allium validum

Athyrium filix-femina

Caltha leptosepala

Castilleja miniata ssp. miniata

Lilium pardalinum ssp. shastense

Mimulus guttaturs

Polystichum lemmonii

Prunella vulgaris

Rudbeckia occidentalis var. occidentalis

Senecio triangularis

Sidalcea oregana

Solidago canadenais ssp. elongata

Sphenosiadium capitulatum

Stachys ajugoides var. rigida

Trifolium longipes

Eleocharis acicularis var. bella

Under Bordering Shrubs

Aconitum columbianum ssp. columbianum

Adiantum aleuticum

Athyrium filix-femina

Botrichium multifidum

Boykinia major

Circaea alpina ssp. pacifica

Pyrola assarifolia

Bordering Shrubs

Alnus incana var. tenuifolia

Cornus sericea

Kalmia polifolia

Ledum glandulosum

Leucothoe davisiae

Rhamnus purshiana

Salix sp.

Spiraea densiflora

Spiraea douglasii

Vaccinium uliginosum

Fen Master Plant List

Dicots *=Special Interest Plant

Aconitum columbianum ssp. columbianum

Alnus incana var. tenuifolia

Aster foliaceus var. parryi

Botrichium multifidum

Boykinia major

Caltha leptosepala

Castilleja miniata ssp. miniata

Cornus stolonifera

*Drosera rotundifolia **

Epilobium ciliatum ssp. glandulosum

Eriophorum criniger

Gentianopsis simplex

Helenium bigelovii

Heracleum lanatum

Hipurus vulgaris

Hypericum anagaloides

Kalmia polifolia

Ledum glandulosum

Leucothoe davisiae

Lotus oblongifolius var. oblongifolius

Madia bolanderi

Menyanthes trifoliata

Mimulus guttatus

Mimulus primuloides

Myriophyllum sibiricum

Nuphar lutea ssp. Polysepala

Oreostema alpigenum

Parnassia californica

Pedicularis attollens

Perideridia parishii ssp. latifolia

Polygonum bistortoides

Potentilla palustris

Prunella vulgaris

Rhamnus purshiana

Rudbeckia occidentalis var. occidentalis

Salix sp.

Senecio triangularis

Sidalcea oregana

Sisyrhinchium elmeri

Solidago canadensis ssp. elongata

Sorbus scopulina var. cascadensis

Sphenosiadium capitulatum

Spiraea densiflora

Spiraea douglasii

Stachys ajugoides var. rigida

Trifolium longipes

Vaccinium uliginosum

Veratrum californicum

Veronica Americana

Monocots

Agrostis stolonifera

Allium validum

Camassia quamash ssp. quamash

Carex aurea

Carex echinata

Carex lenticularis var. impressa (aquatilis)

Carex luzulina var. luzulina

Danthonia californica var. americana

Deschampsia cespitosa ssp. cespitosa

Eleocharis acicularis var. bella

Eleocharis pauciflora

Glyceria elata

Juncus balticus var. balticus

Juncus covillei var. obtusatus

Juncus nevadensis

Juncus oxymeris

Lilium pardalinum ssp. shastense

Listera convallarioides

Muhlenbergia minutissima

Narthecium californicum

Platanthera leucostachys

Platanthera sparsiflora

Scirpus microcarpus

Sisyrinchium elmeri

Spiranthes porrifolia

Tofieldia occidentalis ssp. occidentalis

Triteleia hyacinthina

Ferns

Adiantum aleuticum

Athyrium filix-femina

Equisetum arvense

Equisetum laevigatum

Polystichum lemmonii

Pteridium aquilinum var. pubescens

Trees

Abies concolor

Abies magnifica

Calocedrus decurrens

Pinus contorta ssp. murrayana

Pinus jefreyi

Pinus lambertiana

Pinus monticola

Populus tremuloides

Mosses, Liverworts, and Horsetails

Bryophytes with the exception of Sphagnum were determined by David Toren and Collin Dillingham. The *Sphagnum subsecundum* was determined by Dr. Joannes A. Janssens, Lambda-Max Ecological Research Minneapolis MN.

Aulacomnium palustre

Bryum pallens

Bryum pseudotriquetrum

Bryum turbinatum

Bryum weigelii

Campylium polygamum

Cephalozia pleniceps

Drepanocladus aduncus

Drepanocladus polycarpos

Equisetum arvense

Lepidodictyum humile

Marchantia polymorpha

Palustriella commutata

Philonotis caespitosa

Philonotis montana

Philonotis tomentella

Plagiomnium medium

Pohlia camptotrachela

Rhizomnium pseudopunctatum

Sphagnum subsecundum